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An electronic handoff tool to facilitate transfer of care from anesthesia to nursing in intensive care units

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Abstract

Checklists are commonly used to structure the communication process between anesthesia nursing healthcare providers during the transfer of care, or handoff, of a patient after surgery. However, intraoperative information is often recalled from memory leading to omission of critical data or incomplete information exchange during the patient handoff. We describe the implementation of an electronic anesthesia information transfer tool (T2) for use in the handover of intubated patients to the intensive care unit. A pilot observational study auditing handovers against a pre-existing checklist was performed to evaluate information reporting and attendee participation. There was a modest improvement in information reporting on part of the anesthesia provider, as well as team discussions regarding the current hemodynamic status of the patient. While T2 was well-received, further evaluation of the tool in different handover settings can clarify its potential for decreasing adverse communication-related events.

Keywords

checklists, handoff tool, post-operative communication, transfer of care

Introduction

The patient handoff or transfer-of-care is a contemporaneous, interactive process of passing patient-specific information from one caregiver to another to ensure continuity and safety of patient care. It is well recognized that the transfer-of-care is a point of vulnerability where valuable patient information can be distorted and omitted.[1,2] The Joint Commission has reported that communication breakdowns were the leading cause of reported sentinel events between 1995 and 2006. Similar studies have estimated that errors in communication at handoff or transfer of care may be implicated in as many as 80 percent of serious medical errors.[3–5] To this end, multiple regulatory

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agencies have called for quality improvement measures to standardize handover processes and quickly identify handoff-related errors.

The post-operative transfer-of-care involves members of the anesthesia and surgery care teams providing a verbal report of the intraoperative patient course to the recovery room or intensive care unit (ICU) healthcare teams. However, the transfer-of-care occurs while there are competing clinical demands on attention, including the exchange of monitors, infusions, and their intravenous line attachments. A plethora of studies in the literature have identified a variety of problems associated with transfer-of-care, such as incomplete or inaccurate information exchange,[2,6,7] unstandardized (or absent) tools to guide the order of the handover,[8,9] interruptions, and lack of anticipatory guidance for subsequent care.[10]

Use of standardized checklists to help structure the verbal communication process between the transferring operating room (OR) team and the receiving ICU team has been studied before.[8–12] However, a checklist simply provides a structure for communication and in itself does not guarantee accurate and complete exchange of information during handoff. During handoff, providers are often forced to recall from memory information related to critical elements of clinical care. This process can be problematic due to incorrect or incomplete recollection of information. The problem is particularly serious during post-operative handoff because a surgical episode generates a large volume of critical data and multiple providers often care for patient during surgery. Hence, there is a critical need to have an information transfer tool in the context of a pre-existing handover checklist to facilitate handoff. Such a tool could summarize and present critical information such that clinical events and data need not be recalled from memory. The use of such a tool to supplement a handoff checklist has not been explored before. In this article, we describe the development and use of a novel electronic anesthetic information transfer tool (T2) for use in the transfer of intubated patients to the ICU. We also performed a pilot comparison of reported transfer-of-care information items with and without using T2 tool, utilizing a pre-existing OR-to-ICU checklist as a guide for comparison. Additionally, we also performed a usability survey to gauge user acceptance of the tool.

Methods

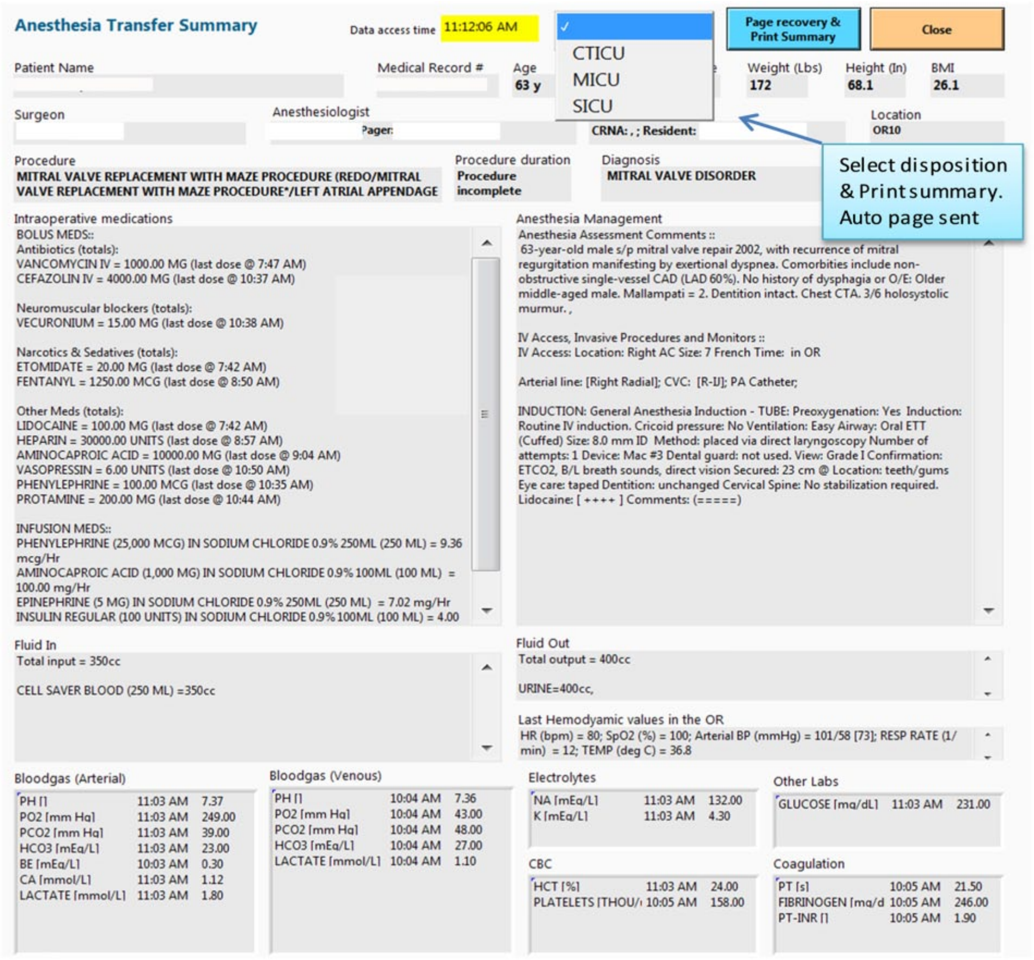
Study setting

This study was performed in an academic medical center from 27 October–12 December 2014. It was deemed exempt by our Institutional Review Board as a quality improvement project.

Electronic transfer tool (T2)

Our institution uses an anesthesia information management system (AIMS) (Merge AIMS; Hartland, WI, USA) to document anesthesia care in the ORs. To enhance the functionality of this system, we developed a decision-support software—Smart Anesthesia Manager (SAM). SAM acquires near real-time data from AIMS to provide real-time feedback and guidance to anesthesia providers on clinical care, billing, and compliance aspects.[13] For this study, we enhanced SAM by adding an informatics tool (transfer tool; T2) to facilitate handoff. The first component of T2 is an automatically generated transfer report that summarizes the anesthesia and surgery episodes into a concise and printable sheet. The second component is a communication module that notifies the recovery team of patient transport from the OR to recovery.

Content categories for the transfer tool (Figure 1) were derived from a review of previously studied tools in the literature[2,6,7,10] and is comprised of the following main sections:



Anesthesia Transfer Summary

Data access time 11:12:06 AM

Patient Name

Medical Record #

Age 63 y

Weight (Lbs) 172

Height (In) 68.1

BMI 26.1

Surgeon

Anesthesiologist

Pager:

CRNA: , ; Resident:

Location OR10

Select disposition & Print summary. Auto page sent

Procedure
MITRAL VALVE REPLACEMENT WITH MAZE PROCEDURE (REDO/MITRAL VALVE REPLACEMENT WITH MAZE PROCEDURE*/LEFT ATRIAL APPENDAGE

Procedure duration
Procedure incomplete

Diagnosis
MITRAL VALVE DISORDER

Intraoperative medications

BOLUS MEDS::
Antibiotics (totals):
VANCOMYCIN IV = 1000.00 MG (last dose @ 7:47 AM)
CEFAZOLIN IV = 4000.00 MG (last dose @ 10:37 AM)

Neuromuscular blockers (totals):
VECURONIUM = 15.00 MG (last dose @ 10:38 AM)

Narcotics & Sedatives (totals):
ETOMIDATE = 20.00 MG (last dose @ 7:42 AM)
FENTANYL = 1250.00 MCG (last dose @ 8:50 AM)

Other Meds (totals):
LIDOCAINE = 100.00 MG (last dose @ 7:42 AM)
HEPARIN = 30000.00 UNITS (last dose @ 8:57 AM)
AMINOCAPROIC ACID = 10000.00 MG (last dose @ 9:04 AM)
VASOPRESSIN = 6.00 UNITS (last dose @ 10:50 AM)
PHENYLEPHRINE = 100.00 MCG (last dose @ 10:35 AM)
PROTAMINE = 200.00 MG (last dose @ 10:44 AM)

INFUSION MEDS::
PHENYLEPHRINE (25,000 MCG) IN SODIUM CHLORIDE 0.9% 250ML (250 ML) = 9.36 mcg/Hr
AMINOCAPROIC ACID (1,000 MG) IN SODIUM CHLORIDE 0.9% 100ML (100 ML) = 100.00 mg/Hr
EPINEPHRINE (5 MG) IN SODIUM CHLORIDE 0.9% 250ML (250 ML) = 7.02 mg/Hr
INSULIN REGULAR (100 UNITS) IN SODIUM CHLORIDE 0.9% 100ML (100 ML) = 4.00

Anesthesia Management

Anesthesia Assessment Comments ::
63-year-old male s/p mitral valve repair 2002, with recurrence of mitral regurgitation manifesting by exertional dyspnea. Comorbities include non-obstructive single-vessel CAD (LAD 60%). No history of dysphagia or O/E: Older middle-aged male. Mallampati = 2. Dentition intact. Chest CTA. 3/6 holosystolic murmur. ,

IV Access, Invasive Procedures and Monitors ::
IV Access: Location: Right AC Size: 7 French Time: in OR

Arterial line: [Right Radial]; CVC: [R-IJ]; PA Catheter;

INDUCTION: General Anesthesia Induction - TUBE: Preoxygenation: Yes Induction: Routine IV induction. Cricoid pressure: No Ventilation: Easy Airway: Oral ETT (Cuffed) Size: 8.0 mm ID Method: placed via direct laryngoscopy Number of attempts: 1 Device: Mac #3 Dental guard: not used. View: Grade I Confirmation: ETCO2, B/L breath sounds, direct vision Secured: 23 cm @ Location: teeth/gums Eye care: taped Dentition: unchanged Cervical Spine: No stabilization required. Lidocaine: [++++] Comments: (=====)

Fluid In
Total input = 350cc

CELL SAVER BLOOD (250 ML) =350cc

Fluid Out
Total output = 400cc

URINE=400cc,

Last Hemodyamic values in the OR
HR (bpm) = 80; SpO2 (%) = 100; Arterial BP (mmHg) = 101/58 [73]; RESP RATE (1/min) = 12; TEMP (deg C) = 36.8

Bloodgas (Arterial)

PH []	11:03 AM	7.37
PO2 [mm Hg]	11:03 AM	249.00
PCO2 [mm Hg]	11:03 AM	39.00
HCO3 [mEq/L]	11:03 AM	23.00
BE [mEq/L]	10:03 AM	0.30
CA [mmol/L]	11:03 AM	1.12
LACTATE [mmol/L]	11:03 AM	1.80

Bloodgas (Venous)

PH []	10:04 AM	7.36
PO2 [mm Hg]	10:04 AM	43.00
PCO2 [mm Hg]	10:04 AM	48.00
HCO3 [mEq/L]	10:04 AM	27.00
LACTATE [mmol/L]	10:04 AM	1.10

Electrolytes

NA [mEq/L]	11:03 AM	132.00
K [mEq/L]	11:03 AM	4.30

CBC

HCT [%]	11:03 AM	24.00
PLATELETS [THOU/	10:05 AM	158.00

Other Labs

GLUCOSE [mg/dL]	11:03 AM	231.00

Coagulation

PT [s]	10:05 AM	21.50
FIBRINOGEN [mg/d	10:05 AM	246.00
PT-INR []	10:05 AM	1.90

Figure 1. Electronic transfer tool (T2).

1. *Patient/provider information.* This section contains patient identifiers and demographics, American Society of Anesthesiologists (ASA) physical status, primary procedure and diagnosis, procedure duration, and anesthesia and surgery staff, and their contact information;
2. *Anesthetic Information.* Pertinent medical history and concerns noted by the anesthesia providers, intravenous and invasive line sites, airway management, regional blocks, and case-specific events such as cardiopulmonary bypass and emergence from anesthesia;
3. *Medications.* Total dose and time of last dose of bolus medications. Infusion medications and the latest infusion rate;
4. *Labs.* Categorized lab results during the intraoperative phase;
5. *Vitals.* The last set of hemodynamic parameters captured from the patient monitor.

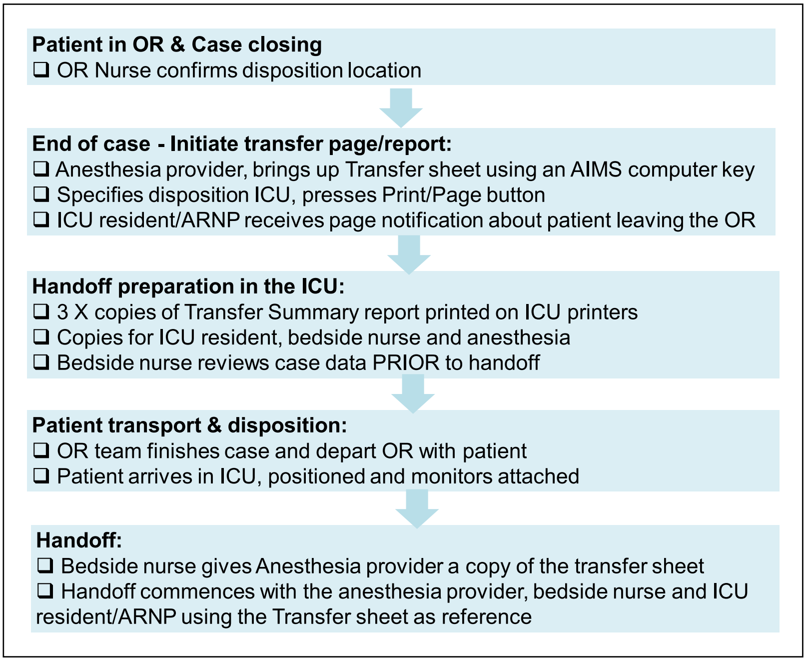
The transfer tool, T2, which embeds the transfer summary report can be evoked on an AIMS computer using a pre-assigned hot key on the keyboard. The report can be printed in designated recovery area printers using the "Print" button. The communication component is also embedded into T2, whereby a text message is sent to a designated recovery pager when the transfer summary report is printed.

Workflow integration

For this study, we piloted T2 to facilitate transfer of care of intubated surgery patients in an ICU for the cardiothoracic service (cardiothoracic intensive care unit (CTICU)) and other surgical services (surgical intensive care unit (SICU)). A flowchart describing the integration of T2 into the anesthesia and nursing workflow is shown in Figure 2. When the anesthesia provider is preparing to exit the OR with the patient, he/she evokes T2 on the OR AIMS computer with a simple keystroke. The anesthesia provider selects a disposition location from a drop-down menu and presses the "Print and Page Recovery" button. This initiates a text page to the ICU team resident, informing him/her about the imminent arrival of the patient. Concurrently, three copies of the transfer report are printed in two ICU printers. The ICU resident, bedside nurse, and anesthesia provider use the three copies during the handoff process. The ICU resident and an assigned nursing staff member bring copies of the transfer report to the patient's bedside prior to patient arrival. Upon reaching the recovery bed, the OR team deposits patient in the ICU bed and initiates postoperative verbal handover process. During the handoff process, the anesthesia, ICU, and nursing providers use the transfer report as reference to communicate the relevant anesthesia and surgery information to the recovery team. Our ICUs use a visual checklist for the handoff process (Appendix Figure 4). The use of this checklist was continued during the pilot evaluation of T2.

Education and activation of T2

A series of steps were undertaken over a 4-week period to educate all perioperative practitioners about the OR-to-ICU handoff protocol. Multiple methods and venues were used, including presentations at staff meetings and grand rounds, nursing in-services at shift changes, cognitive aids (workflow posters posted near anesthesia workstations), and informative emails. The educational steps emphasized the key points of the transfer report, initiation of the communication page, and collection of the printed transfer report. In addition, it was also emphasized that the providers continue to use the existing handoff checklist, with the new transfer report being used as a reference document. Subsequently, the T2 feature in SAM was activated for ICU patient transfers.



Patient in OR & Case closing

☐ OR Nurse confirms disposition location

End of case - Initiate transfer page/report:

☐ Anesthesia provider, brings up Transfer sheet using an AIMS computer key

☐ Specifies disposition ICU, presses Print/Page button

☐ ICU resident/ARNP receives page notification about patient leaving the OR

Handoff preparation in the ICU:

☐ 3 X copies of Transfer Summary report printed on ICU printers

☐ Copies for ICU resident, bedside nurse and anesthesia

☐ Bedside nurse reviews case data PRIOR to handoff

Patient transport & disposition:

☐ OR team finishes case and depart OR with patient

☐ Patient arrives in ICU, positioned and monitors attached

Handoff:

☐ Bedside nurse gives Anesthesia provider a copy of the transfer sheet

☐ Handoff commences with the anesthesia provider, bedside nurse and ICU resident/ARNP using the Transfer sheet as reference

Figure 2. Transfer template (T2) workflow integration.

Data collection—audits

Two independent observers (medical students) were recruited and trained to observe the handoff in the ICU. Potential cases to be audited were identified from the OR schedule on the days when the observers were available. A structured observer audit form (Appendix Figure 5) was created to evaluate handover metrics. The metrics were derived from the data categories listed in existing handoff checklist. The observers completed the audit form for handoffs during both the pre-intervention period when T2 was not used and the post-intervention period when T2 was used.

Data collection—survey

A single two-item survey regarding frequency of use and helpfulness of T2 was separately distributed to all anesthesia providers, surgery residents, and attending physicians, as well as all ICU personnel engaging in the ICU transfer-of-care for patients during the time period of 1 July 2015 through 1 August 2015. E-mail distribution was utilized for all anesthesia and surgery personnel through program coordinators, while CTICU and SICU nurse administrators conducted paper distribution of the same survey. Survey results were tallied in August 2015. The 2-question survey was posed to obtain a subjective measure of comfort and satisfaction of using T2 by the end-user.

Statistical analysis

Handoff metrics were compared during the pre- and post-intervention periods. To test for statistical significance, we used a 2-sample t-test and Mann–Whitney U test, as applicable, for continuous variables and Fisher's exact test for categorical variables. A p-value of <0.05 was

Table 1. Patient demographics, disposition, service attendees, and handoff durations.

	Control, N = 12	Intervention, N = 14	p-value
Patient demographics			
Age (years)	61 ± 19	61 ± 16	1.000
Gender			
Male	6 (37.5%)	10 (62.5%)	0.421
Female	6 (60.0%)	4 (40.0%)	
Service attendees			
Anesthesia	12 (100.0%)	14 (100.0%)	1.000
Surgery	12 (100.0%)	14 (100.0%)	1.000
ICU bedside nurse	12 (100.0%)	13 (92.9%)	1.000
RN calls to demand attendance of any member? (# of audits)	2 (16.7%)	2 (14.3%)	1.000
All attendees stay until end of handover? (# of audits)	7 (58.3%)	8 (57.1%)	1.000
Handoff durations			
Time to start handoff (min) (range)	4.5 ± 2.6 (1–11)	6.0 ± 3.0 (1–12)	0.189
Handoff duration (min) (range)	11.7 ± 4.5 (7–23)	14.8 ± 4.8 (5–26)	0.101

RN: registered nurse.

considered statistically significant. Data were analyzed with SPSS software (Version 19.0, IBM Corp., Armonk, NY, USA).

Results

A total of 26 handoffs, 12 during pre-intervention (no T2 used) and 14 during post-intervention (T2 used) were observed. Patient demographics, location of ICU disposition, presence of service attendees during handoff, and handoff durations are presented in Table 1. Although most parameters were similar, there were a greater proportion of CTICU patients represented in the study during the post-implementation phase.

Comparison of critical elements communicated during handoff is shown in Table 2. There was a moderate improvement in the discussion of the intraoperative anesthetic plan, medications, blood products (or lack thereof), and intraoperative laboratory results with the post-implementation group. A similar increase in reporting airway concerns, antibiotic administration, and fluid losses (i.e. urine output and blood loss) was observed when using the T2 tool. Also, there was a greater proportion of handovers including a discussion about the current patient status, including hemodynamics and current infusions, in the post-implementation audit cohort. With the exception of the wound management plan (for which the discussion is typically led by the surgery team), the reporting rates for all items pertaining to current patient status were greater than 50 percent when using the T2 tool.

Table 2 also presents the conclusion summary and interruptions during handoff. During the post-implementation phase, all 14 audited handoffs (100%) contained a verbal acknowledgment of opportunities for questions, which represents a slight increase from the pre-implementation period when only 9 handoffs had this opportunity. There was no significant difference in the proportion of handoffs that included a clear intraoperative summary (by either the surgeon or anesthesiologist). The number of interruptions (as observed by the auditors) was also similar between the two study periods.

Table 2. Comparison of critical elements communicated during handoff in control and intervention cases.

	Control, N = 12	Intervention, N = 14	p-value
Key elements			
Patient identifiers	11 (91.7%)	14 (100.0%)	0.462
Procedure/diagnosis	12 (100.0%)	14 (100.0%)	1.000
Anesthesia course			
Airway concerns	9 (75.0%)	12 (85.7%)	0.635
Anesthetic type	7 (58.3%)	14 (100.0%)	0.012
Medications	8 (66.7%)	14 (100.0%)	0.033
Blood products	6 (50.0%)	14 (100.0%)	0.004
Fluids	7 (58.3%)	14 (100.0%)	0.012
Antibiotics	9 (75.0%)	13 (92.9%)	0.306
Paralytics last dose	6 (50.0%)	12 (85.7%)	0.090
Estimated blood loss (EBL)	3 (25.0%)	9 (64.3%)	0.062
Urine output (UOP)	4 (33.3%)	11 (78.6%)	0.045
Significant labs	6 (50.0%)	13 (92.9%)	0.026
Patient status			
Hemodynamics	7 (58.3%)	14 (100.0%)	0.012
Infusions	6 (50.0%)	12 (85.7%)	0.090
Available blood products/T&C status	3 (25.0%)	8 (57.1%)	0.130
Pain management	6 (50.0%)	10 (71.4%)	0.422
Wound management	3 (25.0%)	4 (28.6%)	1.000
Discharge plan	5 (41.7%)	7 (50.0%)	0.713
Call triggers	1 (8.3%)	2 (14.3%)	1.000
Conclusions and summary			
Opportunities for questions	9 (75.0%)	14 (100.0%)	0.085
Summary at end of handoff	1 (8.3%)	3 (21.4%)	0.598
Interruptions/side bars (range)	4.6 ± 2.3 (1–9)	5.7 ± 5.3 (1–22)	0.480

Table 3 presents the patient care roles for respondents to the three-item survey. Data are grouped by service category (anesthesia, surgery, and ICU) as well as specific job titles. At 6 months post-implementation, the T2 was utilized at least once by 79 of 162 respondents (49%). A significantly greater proportion of anesthesiologists reported use of the T2 compared to the remainder of the cohort (68% vs 41.5%; $p = < 0.05$). The "Resident" role, with respect to both the anesthesia and ICU care teams, reported the highest frequency use of the T2 template (Figure 3(a)). The "ICU Nurse" role was associated with the largest number of survey responses (N = 43). However, only 20 respondents (47%) reported using the T2, while 10 respondents (23%) were not familiar with the tool at all.

The vast majority of users who reported using the T2 at least once also rated the tool as being at least "somewhat helpful" (77 of 79 users; 97.5%) (Figure 3(b)). All but one respondent with the "ICU Nurse" job title found the T2 to be "very helpful" (19 of 20 users; 95.0%).

Discussion

The transfer of patient care between the OR and recovery teams at the end of surgery is an important juncture where critical and relevant information should be communicated for continued safe care of the patient. With the traditional paper anesthesia record, the anesthesia team had a reference

Table 3. Primary patient care roles during OR-ICU transfer-of-care (survey 1 July 2015 through 1 August 2015).

Specialty/role	N	Not familiar	No	Yes
Anesthesiology	44	4 (9.1)	10 (22.7)	30 (68.2)
Advanced care practitioner	1	1 (100)		
Attending Physician	15	1 (6.7)	6 (40.0)	8 (53.3)
Resident	28	2 (7.1)	4 (14.3)	22 (78.6)
Critical care/ICU	92	28 (30.4)	26 (28.3)	38 (41.3)
Advanced care practitioner	1			1 (100.0)
Attending physician	12	3 (25.0)	6 (50.0)	3 (25.0)
Fellow	13	4 (30.8)	1 (7.7)	8 (61.5)
Nurse	43	10 (23.3)	13 (30.2)	20 (46.5)
Resident	4		1 (25.0)	3 (75.0)
Respiratory therapist	19	11 (57.9)	5 (26.3)	3 (15.8)
Surgery	26	10 (38.5)	5 (19.2)	11 (42.3)
Attending physician	8	2 (25.0)	4 (50.0)	2 (25.0)
Resident	18	8 (44.4)	1 (5.6)	9 (50.0)
All specialties	162	42 (25.9)	41 (25.3)	79 (48.8)

document in hand when transferring patient to the nursing team in recovery. Furthermore, the finalized paper record is kept in the patient's chart at the end of the case, which meant that the recovery nurses and other clinicians had a reference clinical record on intraoperative course for subsequent care. However, paper anesthesia records can be incomplete and illegible and have been largely replaced by electronic AIMS. Moreover, AIMS data often remain digitized in electronic databases not readily available to the OR and nursing teams at the time of handoff. This is particularly true when the anesthesia and nursing electronic medical records (EMRs) are not integrated. In our institution, we utilize an AIMS that is not integrated with the hospital-wide EMR used for nursing documentation in the recovery areas. Furthermore, the AIMS itself does not have a tool to facilitate handoff. For these reasons, as a quality improvement initiative, we developed a handoff tool to assist with patient handoff.

Our pilot investigation reveals that the overall quality of handoff, in terms of information exchange, was improved when using the T2 tool in conjunction with the pre-existing checklist. The quantitative improvements were mostly observed in reporting of elements related to anesthesia course and patient status. Specifically, the data elements that were presented in the transfer summary report were communicated more often when using T2. In addition, there was a trend toward improved communication of other elements related to handoff as well, although the difference did not reach statistical significance. The use of a handoff checklist throughout the evaluation period may have resulted in an overall improvement in the quality of handoff.[10,11,14] Although the checklist was used for both control (no use of T2) and intervention (use of T2), it is unclear whether the differential improvements seen during the intervention period can be solely attributed to T2. Likely, the combination of using T2 with the handoff checklist contributed to improved handoff.

Observation of handoff using the T2 tool highlighted several qualitative improvements. The numerical data (e.g. medication and fluid totals) clearly presented in the T2 printout allowed more time and focus to be spent on other aspects of the handoff. The T2 tool changed the dynamics of the handover process by shifting time and attention from the receiving members documenting

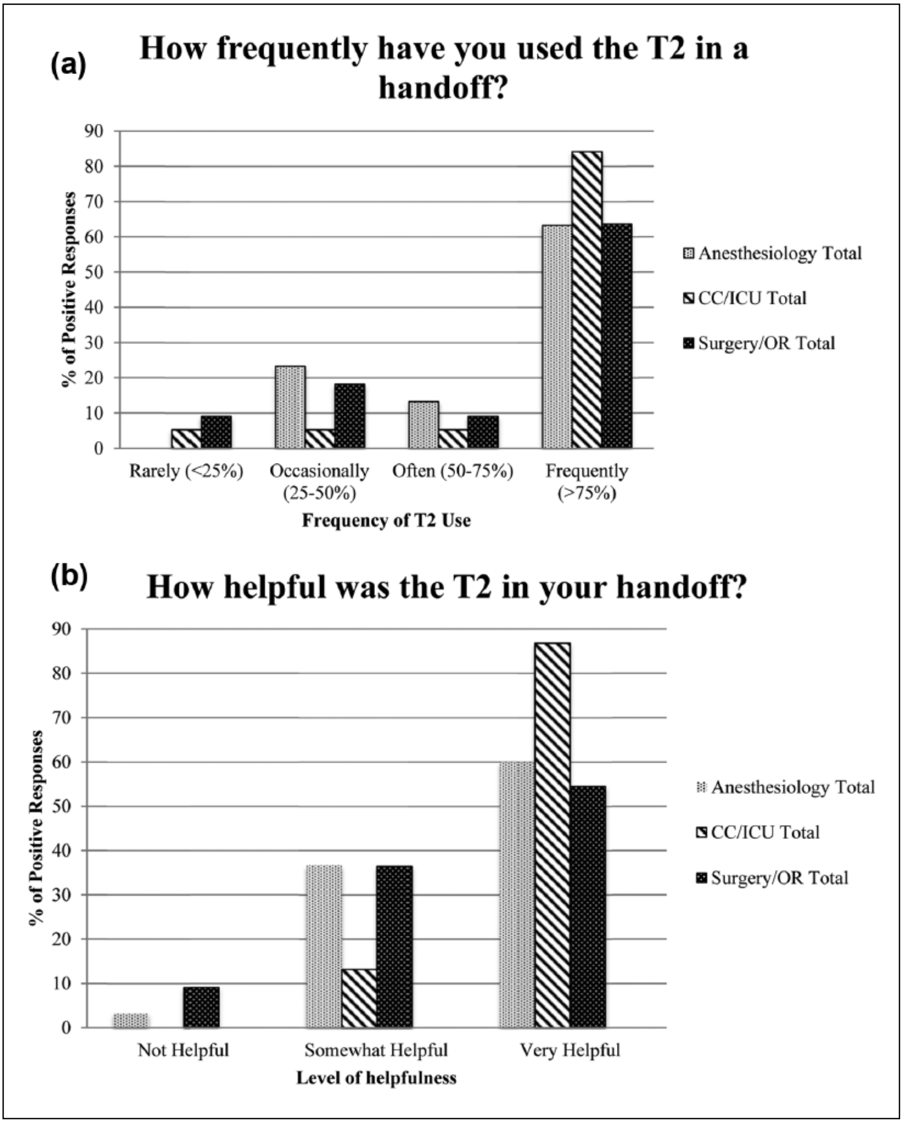


Figure 3. (a) and (b) Survey responses (1 July 2015 through 1 August 2015) (N = 162).

numerical details to the presenting team discussing the continuity of care for the patient (including anticipated complications and discharge, additional imaging/testing needed, etc.). This made the best use of time for the surgical/anesthesia staff as they could refer most questions regarding numerical details to the T2 printout. In addition, during the handoff process, both the anesthesia and nursing staff had copies of the T2 printout. Although the anesthesia provider initiated the transfer of information going through the handoff checklist while referencing the T2 printout, the receiving nursing staff also used the T2 printout as reference, verifying the received information. This process of concurrent communication and verification contributed to a better information exchange. Finally, having multiple participants with different roles using copies of the T2 printout allowed shared review and discussion of critical information. This encouraged a team approach and engagement of all parties during the handoff process diminishing communication barriers placed by role and seniority of different care personnel.

Improved information retention could be an indirect etiology of improved patient care. As the healthcare provider tasked with delivering or receiving a handover becomes more comfortable with the sequence of reporting (i.e. the purpose of the checklist) and their ability to report the correct information with high fidelity (i.e. the purpose of the T2), they will have more time to clarify information regarding the pre- or intraoperative care of the patient being transferred to the ICU. Questions posed will be focused on specialty-specific items not covered in a generic checklist (with concurrent decreased redundancies of information already reported) as well as the ultimate plan for the patient (i.e. a greater emphasis on the plan and relevant alerts for a patient). There is increased engagement of the handover team members that accompanies better information retention and reporting using the T2–checklist combination. Our outgoing hypothesis is that this greater engagement will improve anticipatory guidance by helping to decrease communication-related errors such as drug errors and improving care delivery by improved timeliness of time-sensitive tasks (labs, medications) in the immediate post-operative period.

Adoption and integration of T2 into the nursing workflow over the study period were fairly smooth, and both the ICU and OR teams generally welcomed the use of the tool. However, we initially encountered some practical challenges. At first, we printed only one copy of the summary report, which was reviewed by the ICU resident prior to patient arrival in the ICU and then used by the anesthesia team during handoff. However, feedback from the anesthesia, nursing, and ICU teams highlighted the need for multiple copies of the summary report, so that each group has a reference document during the verbal handoff. While a majority of anesthesia providers reported using the T2, a lower proportion of ICU nurses responded positively. We subsequently programmed T2 to print copies of the summary report in multiple printers, so that each of the anesthesia provider, bedside nurse, and ICU resident has a copy of the summary report. A second challenge was encouraging the anesthesia provider to remember all the steps in initiating the T2 (display on screen, setting physical disposition (CTICU vs SICU), and pressing “PRINT” button). In several cases, failure of one or more of these individual steps led to the failure of the transfer report to print at the destination. As a remedial step, we integrated T2 to be automatically launched when the provider presses the button in AIMS to document transport to recovery, thus unifying the processes associated with setting the physical location, paging the ICU team, and printing the transfer report. Transport to recovery is a routine documentation step that anesthesia provider performs in AIMS just as the patient leaves the OR.

Currently, the summary report of T2 comprises only information from the intraoperative phase. Future enhancements would include reporting preoperative information such as patient medical and medication history, allergies, and preoperative lab results. Another useful enhancement would be to present the summary report in a format similar to the handoff checklist which will allow the handoff teams to navigate the checklist while reviewing the corresponding data. A third enhancement would be to eliminate the printout of the summary report and instead have the data displayed on mobile platforms (mobile computers, electronic tables, and encrypted smartphones) during the handoff process.

Although our outcome measures were focused on handover accuracy and quality metrics, a larger-scale study is necessary to evaluate the effect of T2 on adverse communication-related events and hospital quality-of-care metrics. This objective may be approached by extending the use of the T2 to the recovery room setting, which is frequented by a larger number of post-operative patients. Bittner et al.[15] demonstrated an association between improved handover scores and a decreased length of stay in the recovery room. In spite of possible improvements that can be made to T2, it still provides a helpful reference for anesthetic management information for the delivering and receiving healthcare teams during the transfer-of-care.

Conclusion

In summary, we developed a transfer tool that summarizes and presents pertinent information on anesthetic management to be used concurrently with a checklist during ICU handoff after surgery. This tool obviated the need for information to be recalled from memory, thus minimizing the risk of omission of critical data and incorrect exchange of information during handoff. A workflow that utilizes multiple copies of the transfer summary printout encouraged concurrent communication and verification of information and a team participation of surgical, anesthesia, and nursing personnel during the handoff process.

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Declaration of conflicting interests

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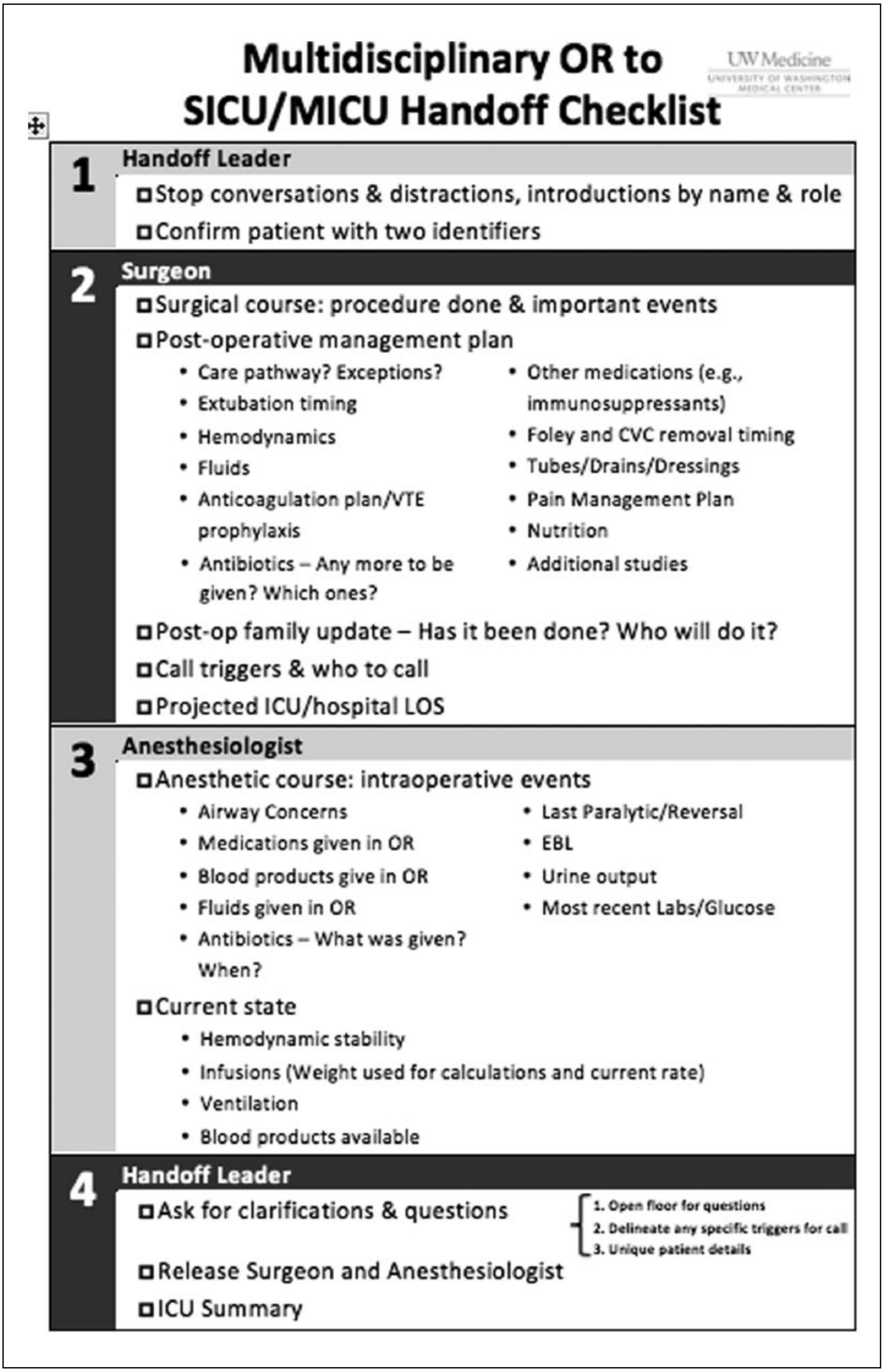
Appendix 1



Multidisciplinary OR to SICU/MICU Handoff Checklist

UW Medicine
UNIVERSITY OF WASHINGTON MEDICAL CENTER

1 Handoff Leader

☐ Stop conversations & distractions, introductions by name & role

☐ Confirm patient with two identifiers

2 Surgeon

☐ Surgical course: procedure done & important events

☐ Post-operative management plan

- Care pathway? Exceptions?
- Extubation timing
- Hemodynamics
- Fluids
- Anticoagulation plan/VTE prophylaxis
- Antibiotics – Any more to be given? Which ones?
- Other medications (e.g., immunosuppressants)
- Foley and CVC removal timing
- Tubes/Drains/Dressings
- Pain Management Plan
- Nutrition
- Additional studies

☐ Post-op family update – Has it been done? Who will do it?

☐ Call triggers & who to call

☐ Projected ICU/hospital LOS

3 Anesthesiologist

☐ Anesthetic course: intraoperative events

- Airway Concerns
- Medications given in OR
- Blood products give in OR
- Fluids given in OR
- Antibiotics – What was given? When?
- Last Paralytic/Reversal
- EBL
- Urine output
- Most recent Labs/Glucose

☐ Current state

- Hemodynamic stability
- Infusions (Weight used for calculations and current rate)
- Ventilation
- Blood products available

4 Handoff Leader

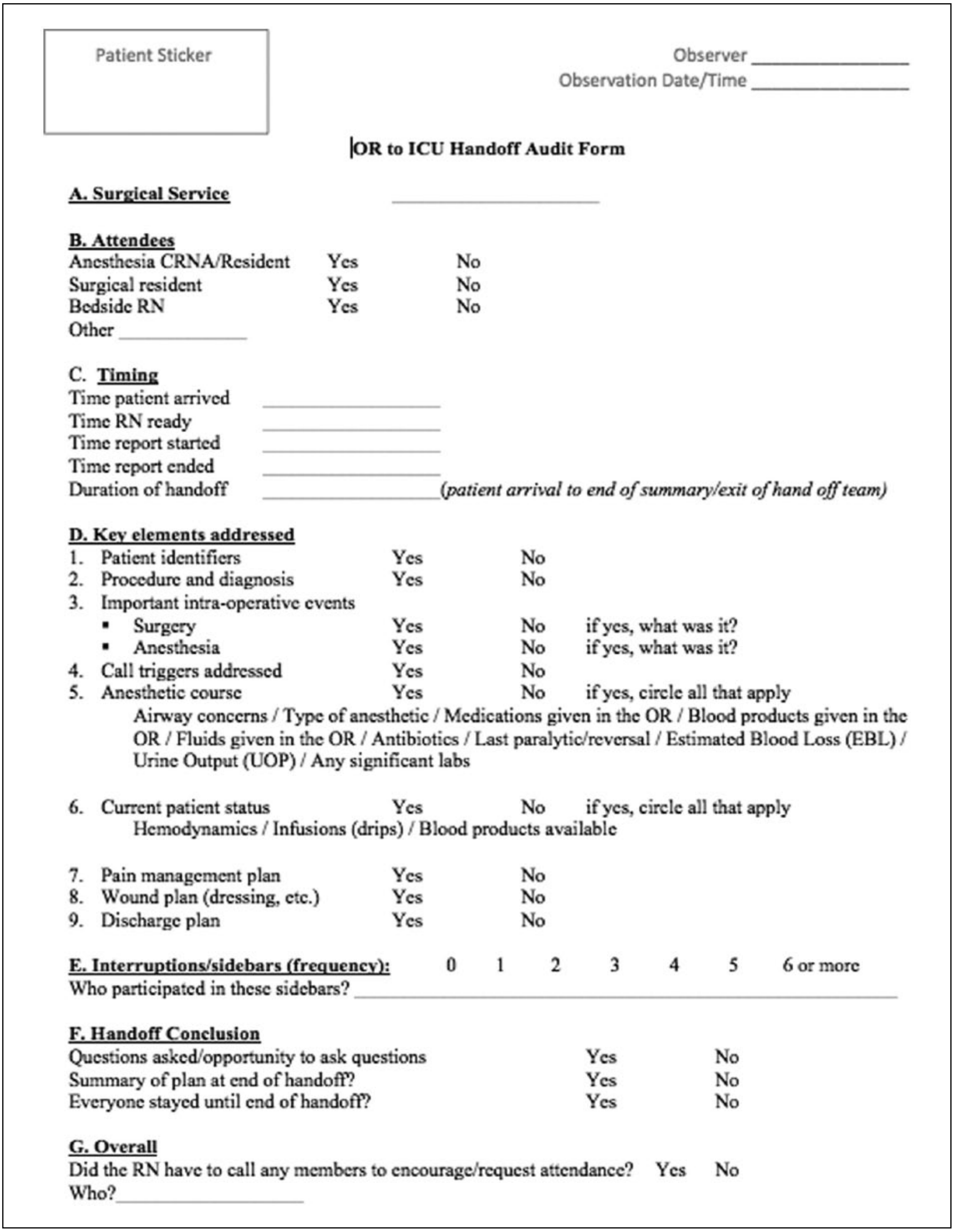
☐ Ask for clarifications & questions

1. Open floor for questions
2. Delineate any specific triggers for call
3. Unique patient details

☐ Release Surgeon and Anesthesiologist

☐ ICU Summary

Figure 4. OR-to-ICU transfer-of-Care checklist (pre-existing).



Patient Sticker

Observer ________________
Observation Date/Time ________________

OR to ICU Handoff Audit Form

A. Surgical Service ____________________

B. Attendees
Anesthesia CRNA/Resident Yes No
Surgical resident Yes No
Bedside RN Yes No
Other ____________

C. **Timing**
Time patient arrived ________________
Time RN ready ________________
Time report started ________________
Time report ended ________________
Duration of handoff ________________*(patient arrival to end of summary/exit of hand off team)*

D. Key elements addressed
1. Patient identifiers Yes No
2. Procedure and diagnosis Yes No
3. Important intra-operative events
    - Surgery Yes No if yes, what was it?
    - Anesthesia Yes No if yes, what was it?
4. Call triggers addressed Yes No
5. Anesthetic course Yes No if yes, circle all that apply
    Airway concerns / Type of anesthetic / Medications given in the OR / Blood products given in the OR / Fluids given in the OR / Antibiotics / Last paralytic/reversal / Estimated Blood Loss (EBL) / Urine Output (UOP) / Any significant labs

6. Current patient status Yes No if yes, circle all that apply
    Hemodynamics / Infusions (drips) / Blood products available

7. Pain management plan Yes No
8. Wound plan (dressing, etc.) Yes No
9. Discharge plan Yes No

E. Interruptions/sidebars (frequency): 0 1 2 3 4 5 6 or more
Who participated in these sidebars? ____

F. Handoff Conclusion
Questions asked/opportunity to ask questions Yes No
Summary of plan at end of handoff? Yes No
Everyone stayed until end of handoff? Yes No

G. Overall
Did the RN have to call any members to encourage/request attendance? Yes No
Who?________________

Figure 5. OR-to-ICU handover audit form.

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Expertise in French health forums

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Abstract

More and more health websites hire medical experts (physicians, medical students, experienced volunteers, etc.) and indicate explicitly their medical role in order to notify that they provide high-quality answers. However, medical experts may participate in forum discussions even when their role is not officially indicated. Detecting posts written by medical experts facilitates the quick access to posts that have more chances of being correct and informative. The main objective of this work is to learn classification models that can be used to detect posts written by medical experts in any health forum discussions. Two French health forums have been used to discover the best features and methods for this text categorization task. The obtained results confirm that models learned on appropriate websites may be used efficiently on other websites (more than 98% of F1-measure has been obtained using a Random Forest classifier). A study of misclassified posts highlights the participation of medical experts in forum discussions even if their role is not explicitly indicated.

Keywords

author-profiling, health forums, medical expertise, text categorization

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Introduction

Health forums are increasingly visited by both sick and healthy users when they want to get help and information related to their health.[1] According to a study conducted by the Health On the Net (HON; www.healthonnet.org) foundation, 50 percent of e-patients use online health forums to acquire medical information. However, these forums are not limited to patients. More and more frequently, a significant number of medical experts are involved in online discussions.[2] Indeed, some medical websites hire health experts (physicians, medical students, volunteers, etc.) and indicate explicitly their role. Others visit health forums unofficially and answer the patient's questions without a special indication about their expertise. Being experts, they are able to clearly explain the problems, the symptoms, to correct false affirmations, and to give precise and trustworthy answers. Furthermore, patients may acquire expertise through their own experience with a particular disease. After recovery, many of them go back to online forums in order to share their experience and help other patients. The aim of this study is to distinguish between posts written by medical experts (health practitioner or experienced patients) and by non-expert users.

Identifying expert posts may have many useful applications. For example, highlighting these posts facilitates the identification of best answers that are more likely to be trustworthy and informative. Furthermore, expert posts detection can help forum administrators to find new potential moderators who have enough expertise to answer the forum questions and moderate the discussions. Finally, this information allows studying the expertise evolution of the forum users over time. The main objective of our study is to use posts from websites, in which the medical roles are indicated, in order to build efficient classification models that can predict the potential expertise in other health forums. We intend to tackle the question through the analysis of the posts content. The proposed method uses supervised machine-learning algorithms in order to perform text categorization. Similar methods have been developed for the author-profiling tasks PAN[3–5] in order to identify the age, gender, and personality traits of a text author. In fact, companies are increasingly interested in discovering these characteristics about users who liked or disliked their products based on web blog posts.[5,6] Similarly, health organizations can extract valuable knowledge from expert and non-expert posts written on health forums.[7] They may study and use this knowledge in order to improve their practice (treatments, medications, etc.).

Many features can be exploited in order to perform author-profiling from text posts.[8] Here, we focus on those that can be efficient for medical expertise categorization. Tapi-Nzali et al.[9] mentioned that medical experts and patients use different vocabularies. Patients write more about symptoms and about themselves: I have a headache, etc., while experts should write more about treatments and about the non-experts: you should pass a mammography test, etc. Therefore, a bag of words configuration is considered. Rangel and Rosso[10] studied the impact of emotions and sentiments in author-profiling (age and gender). They proposed an emotion graph to model the way people use the language and the emotions when writing. They obtained, respectively, the first and the second best results for age and gender on the Spanish partition of PAN 2013 corpus. Grabar et al.[11] compared documents written by medical doctors and researchers (clinical reports and scientific literature) with the patient discourse (discussions from health forums). They observed differences in the use of descriptors like uncertainty markers, non-lexical (smileys, repeated punctuations, etc.) and lexical emotional markers, and medical terms related to disorders, medications, and procedures. In this work, these features are considered along with further annotations and preprocessing in order to evaluate the most representative components of a forum post that allow to perform efficiently medical expertise categorization.

The rest of the article is organized as follows. Section "Materials and methods" introduces the studied corpora and details of the proposed method. Section "Experiments" presents the obtained results, and section “Discussions” discusses them. Finally, section “Conclusion and prospects” concludes and gives our main prospects.

Materials and methods

This section discusses the used corpora and the proposed methods, which are based on supervised machine-learning. Indeed, these methods are known to perform well when trained on appropriate annotated datasets. In our case, many online forums indicate explicitly the medical expertise of their users, which provides good and inexpensive annotated datasets.

Corpora

Two French corpora have been collected from two health forums as described below.

AlloDocteurs.fr is a French health forum covering a large number of topics related to health such as alcoholism, pregnancy, and sexuality. A total of 16,000 messages posted from June 2009 to November 2013 have been collected. The forum contains both expert and non-expert users. Medical experts include professional physicians and medical students. Even if their number is limited (16 medical experts over more than 6000 registered users), their participation in the forum exchanges is important. Indeed, they posted more than 3000 posts among the 16,000.

MaSanteNet.com is an online ask-the-doctor service that allows users to submit one or more questions to two doctors. The range of topics covered is also large. Users can ask questions on more than 20 different topics such as nutrition, dermatology, and pregnancy. More than 12,000 messages posted from January 2011 to March 2014 have been collected from this website. All the questions published on the website have answers. Therefore, the collected posts are equitably divided between patients’ questions and doctors’ answers.

Cleaning

Once the two corpora are collected, a cleaning step is applied to improve their quality. First, quotes present inside some posts are filtered out. Indeed, some medical experts quote the questions before answering them, which may introduce non-expert statements into posts of health professionals. All additional pieces of text, such as author signatures and date of the last modification, are removed. Finally, posts with less than 10 characters (blank posts or very short posts such as “yes”) are considered as irrelevant and also removed since they do not convey enough information. Figure 1 presents the number of posts and words in the obtained datasets. On the one hand, it appears that the first corpus has fewer posts than the second one: approximately 4400 posts for AlloDocteurs and approximately 12,000 posts for MaSanteNet. On the other hand, it appears that in both datasets, posts written by non-experts are longer than those written by medical experts.

Preprocessing

Texts from social media have several linguistic peculiarities that may influence the classification performance.[12] Therefore, the following preprocessing steps are applied:

Slang. Some abbreviations are frequently used in social media. They are replaced by the corresponding standard text (e.g. “lol” is replaced by “lot of laugh”).

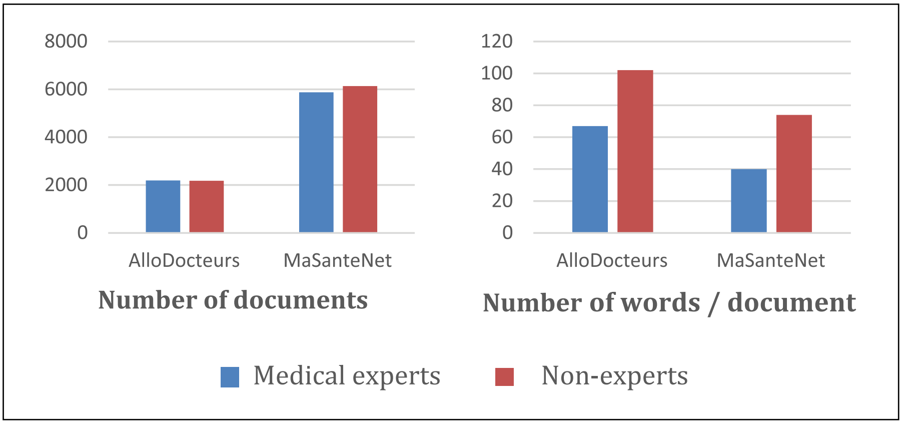

Figure 1. Number of documents and the average number of words per document in each corpus.

User tags. User tags are identified in our corpora and replaced by the word “tag” (e.g. “@Diana …” becomes “tag …”).

Hyperlinks and emails. Hypertext links are replaced by the word “link” and email addresses are replaced by the word “mail.”

Pseudonyms. The medical expert pseudonyms, previously extracted from each website, are used to replace all their apparitions inside the posts by the word “fdoctor.” Similarly, pseudonyms of non-experts are extracted and used for their replacement by the word “fpatient.”

Lowercasing and spelling correction. All words are lowercased and processed with the spell checker Aspell (www.aspell.net, accessed 26 February 2016). The default Aspell French dictionary is expanded with all the pseudonyms and all the medical words extracted from our corpora. The medical terms are obtained after an annotation step as described below.

Annotations

In order to categorize the discourse of medical experts and the discourse of non-experts, the descriptors proposed in Grabar et al.[11] have been annotated using the Ogmios platform.[13] This annotation step allows us to include them easily as features in the classification step.

Medical concepts. Terms belonging to three semantic types (diseases, treatments, and procedures) are detected using the following medical resources: the Systematized Nomenclature of Human and Veterinary Medicine (www.ihtsdo.org/snomed-ct, accessed 26 February 2016), the Thériaque database (www.theriaque.org, accessed 26 February 2016), the Unified Medical Language System (www.nlm.nih.gov/research/umls, accessed 26 February 2016), and the list of authorized medication that can be marketed in France.

Emotions. A French emotion lexicon made by the authors[14] is used to annotate adjectives, verbs, and nouns conveying seven types of emotions (joy, trust, sadness, anger, fear, disgust, and surprise). The lexicon contains about 14,000 emotional terms. In addition, some non-lexical expressions of

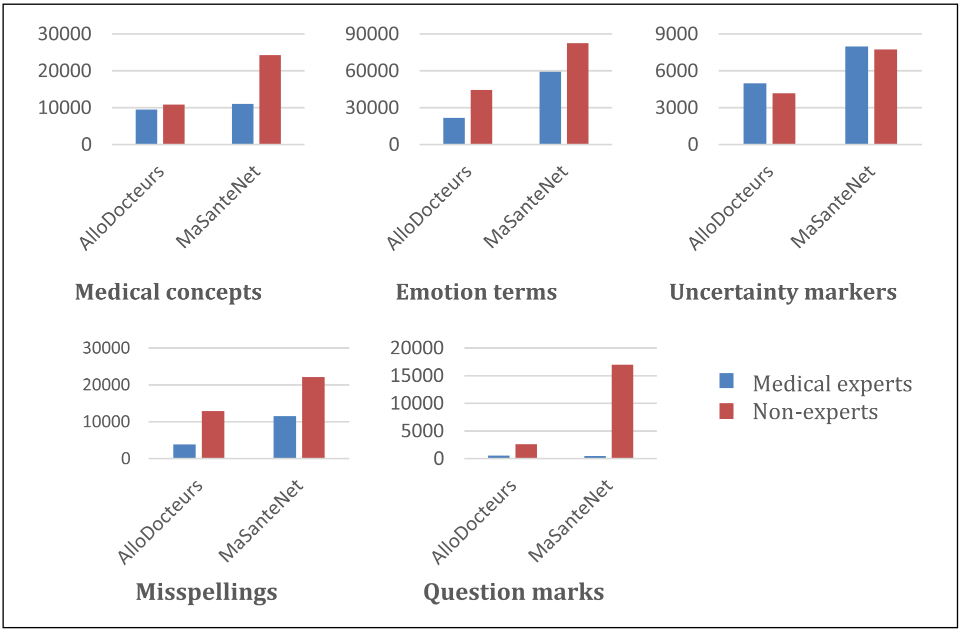

Figure 2. Number of medical concepts, emotion terms, uncertainty markers, misspellings, and question marks in each corpus.

emotions, such as repeated letters, repeated punctuation signs, smileys, slang, and capital letters, are detected and annotated with specifically designed regular expressions.

Uncertainty. A set of uncertainty words[11] is used to annotate verbs, nouns, adjectives, and even adverbs conveying uncertainty meaning (e.g. to seem, possible, and probably). Three levels of uncertainty are considered: weak, medium, and strong.

Classification

Features. In addition to the features based on the annotation step, the number of misspellings and question marks are included in the categorization. Figure 2 shows the number of medical concepts, emotions terms, uncertainty markers, misspellings, and question marks in each benchmark. It appears that non-experts use more medical concepts and emotion terms, ask much more questions, and do more spelling mistakes, while medical experts use slightly more uncertainty markers (usually to make an uncertain diagnosis). Therefore, 15 attributes representing these descriptors are included in our classification task (medical concepts: three attributes, emotion terms: seven attributes, uncertainty markers: three attributes, questions: one attribute, and misspellings: one attribute). For each attribute, we compute the number of occurrences normalized by the corresponding post length. The length of each post corresponds to the number of words it contains. We call these attributes as "Dictionary-Based Features."

Moreover, a bag of words representation is considered. Words that appear at least two times in the training sets are included. Each word is represented by his normalized number of occurrences (number of occurrences divided by the corresponding post length). In the next section, we evaluate all these features on the classification performances.

Table 1. Weighted F-scores obtained with 10-fold cross validation on AlloDocteurs.

Feature group	SVM SMO	J48	Random Forest	JRip
Bag of words	92	90.6	92.1	89.7
Dictionary-based markers	71.6	73	74	75
Bag of words + dictionary-based markers	92.7	90.7	92.7	90.3

SVM SMO: support vector machines–sequential minimal optimization.

Feature selection. Feature subset selection is applied to select the most discriminant features: those that frequently appear in only one category of posts. Therefore, the selected features should characterize one category of users. The information gain method is used as a filter to select attributes in each experiment.

Classifiers. The Weka data-mining platform[15] is used to learn the classification models. We tested the following models that have been reported in the literature as efficient for text categorization:[16] support vector machines–sequential minimal optimization (SVM SMO), decision trees (J48 and Random Forest), and rule-based models (JRip). Since feature selection does not remove redundant attributes, models that assume the independency of the features (such as Naïve Bayes) are not adapted. The Weka default configuration is used for each classification model.

Evaluation metric. Weighted F1-scores are used to evaluate the classification performances of different combinations of features and algorithms. F1-score is computed as the harmonic mean of the precision and the recall of a given class. Weighted F-score is the mean of all class F-scores weighted by the proportion of elements in each class. For a balanced dataset, chance will produce a weighted F-score of 0.5 that can be considered as a baseline for evaluating our results.

Experiments

In this section, the conducted experiments and the obtained results are described.

Cross validation

First, 10-fold cross validation has been performed on each dataset separately. K-fold cross validation is a validation technique that randomly partitions the dataset into k equal size subsets. A single subset is used for testing, while the remaining $k-1$ subsets are used as training set. This process is repeated k times so that each of the k subsets is used as a testing set exactly once. The features construction, selection, and classification models are learned on the training subset of each fold. Moreover, the same training and testing sets are used to learn and test our four classification models in each fold.

Tables 1 and 2 show that on both datasets, bag of words induce high weighted F1-measures. They obtain more than 0.90 on AlloDocteurs and perfect classification F1-measures[1] on MaSanteNet. However, the dictionary-based markers induce lower weighted F1-measures: between 0.70 and 0.75 on AlloDocteurs and between 0.55 and 0.60 on MaSanteNet. Regarding the classification models, SVM SMO and Random Forest obtained the highest F1-measures on MaSanteNet. Finally, the use of the dictionary-based features along with the bag of words configuration does not change the results (the obtained F1-measures are almost the same as those obtained only with bag of words). The presented results may indicate that our models are

Table 2. Weighted F-scores obtained with 10-fold cross validation on MaSanteNet.

Feature group	SVM SMO	J48	Random Forest	JRip
Bag of words	100	100	100	100
Dictionary-based markers	88.9	91.6	93.6	92
Bag of words + dictionary-based markers	100	100	100	100

SVM SMO: support vector machines–sequential minimal optimization.

Table 3. Weighted F-scores obtained with AlloDocteurs as training set and MaSanteNet as testing set.

Feature group	SVM SMO	J48	Random Forest	JRip
Bag of words	96.6	97.7	98	96.9
Dictionary-based markers	57	62.1	69.6	69.6
Bag of words + dictionary-based markers	96	97.3	98.2	96.6

SVM SMO: support vector machines–sequential minimal optimization.

Table 4. Weighted F-scores obtained with AlloDocteurs as training set and MaSanteNet as testing set.

Feature group	SVM SMO	J48	Random Forest	JRip
Bag of words	37.3	33.3	46.3	33.3
Dictionary-based markers	57.1	52.9	53.2	55.3
Bag of words + dictionary-based markers	37.5	33.3	43.7	33.3

SVM SMO: support vector machines–sequential minimal optimization.

dependent on the forum used for learning. Therefore, we evaluate the genericity of the models learned on each forum and test them on the other forum.

Training and testing on different datasets

In this study, we assume that models learned on specific forums can be used efficiently on other forums. In order to evaluate this claim, two more experiments are conducted. In each experiment, features and classification models are constructed and learned on one dataset and tested on the other dataset.

Table 3 shows that models learned on AlloDocteurs obtain significantly high F1-measures. The bag of words used alone or with the dictionary-based features induces more than 0.95 weighted F1-measures when tested on MaSanteNet. Once again, Random Forest obtains the highest F1-measure. The dictionary-based features induce F1-measures between 0.55 and 0.70. These results show that the models learned on AlloDocteurs remain highly efficient when applied on MaSanteNet. However, Table 4 shows that the classification models learned on MaSanteNet obtain low F1-measures. The weighted F1-measures of the bag of words features used alone or with the dictionary-based features drop significantly when tested on AlloDocteurs (between 0.35 and 0.55). The weighted F1-measures obtained by the dictionary-based features drop slightly when tested on AlloDocteurs (between 0.50 and 0.60). SVM SMO induces the highest F1-measure using these features. Finally, we can conclude that the bag of words models learned on MaSanteNet are extremely context dependent, which makes this forum inappropriate for training generic models.

Discussions

In this section, we discuss the obtained results and describe a manual error analysis step.

Results interpretation

Despite the high F1-measures obtained with cross validations on both datasets, the models learned on AlloDocteurs remain efficient when applied on MaSanteNet. However, those learned on MaSanteNet gave lower F1-measures when applied on AlloDocteurs. These results can be explained by the fact that the first website is a health forum, in which 16 medical experts participate in the forum discussions. They post messages in any thread where their expertise is needed, which make the discourse of the medical experts more extensive and diversified. Therefore, models learned on this forum may cover topics and medical discourse may also be found on MaSanteNet. However, MaSanteNet is a limited health forum (an ask-the-doctor service) in which only two medical experts answer the questions. There are no long discussions since each thread contains only one question and one answer. The answers are formed following the same pattern, which makes the discourse of the medical experts specific to this website. For this reason, MaSanteNet appears to be less suitable for learning classification models that can be used on other forums.

Using emotions, uncertainty markers, and medical concepts, Grabar et al.[11] obtained F1-measures between 0.91 and 0.95 when classifying forum posts produced by patients and clinical reports produced by medical experts. Our study shows the limits of using these markers in categorizing the patients' discourse and the medical experts' discourse when the text documents are of the same nature (forum posts). Our results suggest to use bag of words features, which are the most adapted to perform such categorization. This result confirms those obtained in the author-profiling challenge PAN,[5] where the best systems used content-based features (bag of words, words n-grams, TF-IDF n-grams, etc.).

Error analysis

An error analysis of the 10-fold cross validation applied on AlloDocteurs has been performed. In each fold, four classification algorithms have been trained on 90 percent of the data using all the features (bag of words and dictionary-based markers) and tested on the remaining 10 percent. If at least three algorithms agree to classify a post to the wrong category (with respect to the role given on the website), the post is to be studied manually. Therefore, this study included 164 posts among which 107 were written by patients but classified as medical experts and 57 which were written by medical experts but classified as patients.

On the one hand, the manual analysis of the 107 posts classified as medical experts allowed us to find new users having medical expertise but not indicated as such on the website. They may be either medical physicians (e.g. "… many similar cases come to see us in the hospital …") or only users who had the same experience before (e.g. "… the pain will disappear in few days, my mother had the same surgery …"). These users posted 79 messages among the 107, which confirms that medical experts may participate in the discussions even if their role is not explicitly indicated. In this case, only 47 posts have been considered as misclassified. On the other hand, the manual analysis of the 57 posts that has been written by medical experts and classified as patients showed that medical experts may have the same discourse as patients (e.g. they may ask questions). This observation highlights that even medical experts may lack expertise in a particular topic or need precision on the patient's condition.

Conclusion and prospects

In this article, we presented a supervised learning approach designed to distinguish posts written by medical experts and by patients in French online health forums. The performed experiments show very high F-scores with bag of words features. Moreover, they confirm that models learned on appropriate forums where many medical experts participate in various discussions can be applied on other websites with satisfactory results. Finally, analyzing the misclassified posts allowed us to find out that medical experts may write posts in online health forums even if their medical role is not indicated on the website. The study of the misclassified posts also shows that the expertise of a user may change according to the discussed topic.

As future work, a temporal dimension may be included to highlight the evolution of the author's expertise over time. Indeed, users may develop expertise especially in the case of chronic diseases. A study of a French forum on breast cancer (www.cancerdusein.org/forum, accessed 23 March 2016) shows that the discourse of patients changes according to the evolution of the disease and treatments.[17] Some of them start as information consumers and progressively acquire the status of information providers. Usually, for many of them, once they recover from the disease, they want to go back online to share their knowledge and experience with other patients. This observation also stands for technical and programming forums (www.stackoverflow.com/help/whats-reputation, accessed 23 March 2016), where a programmer begins as non-experienced and gradually acquire expertise. A temporal dimension may be easily included to this method in order to highlight those changes.

Another interesting research issue to detect expert users instead of expert posts consists of mining the answers received by a given user in the forum. We are working on another textual content-based method that analyzes the posts addressed to a user instead of the posts written by him.[18] Natural language processing methods may be used to detect the trust expressed in these answers. This trust may be inferred by searching agreement, disagreement, and thanking expressions. The first step is to identify the recipient(s) of each post. Then, the posts addressed to each user must be evaluated to detect trust expressions. Finally, the expertise of the user may be computed by measuring the number of positive and negative replies.

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The European Union's Ambient and Assisted Living Joint Programme: An evaluation of its impact on population health and well-being

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Abstract

The Ambient Assisted Living Joint Programme, instituted in 2008 by the European Union, aimed to create better living conditions for older adults through the funding of information and communications technology projects. This review aimed to uncover what can be learned from the Ambient Assisted Living Joint Programme by determining (1) the target populations served, (2) technology-based interventions used and (3) effects on health and well-being outcomes. Information from the Ambient Assisted Living catalogue, project websites and deliverables and from papers in PubMed and EMBASE was reviewed. Overall, 152 projects from the first six rounds of funding were identified. Sensors, computers, phones, tablets and televisions were used for various purposes, that is, monitoring, feedback, coaching, reminders and communication. In total, 12 projects reported evaluating health and well-being outcomes; however, these evaluations demonstrated poor methodological quality. Only three projects reported exact values. For all other projects, published evidence on the effect of these projects on health and well-being outcomes was not available.

Keywords

ageing, Ambient Assisted Living, healthy ageing, information communication technology, review, technology

Introduction

The European Union (EU) has predicted that more than 20 percent of Europeans will be aged 65 years or older by 2025,[1] and the increase in the ageing population is expected to have far-reaching consequences in all European member states.[2] Promotion of healthy ageing has been identified as a

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key objective by the EU.[3] While healthy ageing remains inadequately defined,[4] it has been considered a means for optimizing opportunities for physical, social and mental health and enabling individuals to take an active part in society without discrimination and enjoy independence and a good quality of life. Additionally, promoting healthy ageing means taking a holistic approach that takes into consideration the multifaceted aspects of life.[5]

While the majority of older adults have been found to report good health,[6] the prevalence of chronic conditions and disability nonetheless increases with age.[7,8] Indeed, older adults more often experience frailty, functional dependency, loneliness and isolation, cognitive impairment, falls, dizziness, syncope and urinary incontinence.[9,10] Adequate management of these common conditions necessitates detection, prevention and early intervention.

The main challenge associated with promoting healthy ageing is supporting quality of care in the context of restricted budgets and limited informal and professional care availability. Here, the use of technology, and specifically information and communications technology (ICT), could offer solutions. ICT points to the integration of telecommunication solutions (e.g. telephone lines and wireless signals), computers and middleware, storage and audio-visual systems to enable users to access, store, transmit and manipulate information.[11] Given the constraints of and high demands on professional healthcare, ICT can increase the efficiency of or offer alternatives to professional care. However, ICT has not yet been frequently used in gerontology and geriatrics.

The use of technology in relation to ageing has recently proliferated following the establishment of the AAL JP by the EU. The AAL JP was initiated in 2008 with the objective of creating better living conditions for older adults and strengthening industrial opportunities in Europe by funding ICT projects.[12] Ambient and Assisted Living (AAL) may refer to heterogeneous applications of technologies, products and services ranging from simple devices (e.g. medication dispensers and sensors) to networked homes and complex interactive systems.[13] AAL provides a digital environment that supports autonomous living at home, self-confidence, mobility, health, functional capability and healthy lifestyles and prevents social isolation, enhances security, supports caregivers and increases the efficiency and productivity of resources. A Cochrane review published in 2008 identified a significant volume of the literature on the use of smart technologies within the healthcare setting but did not identify any studies that evaluated the effect of these technologies on person-centred health and well-being outcomes, measures of health or social care requirements or professional performance.[14]

Because the Cochrane review did not identify any studies assessing effectiveness outcomes in the published literature, we screened the projects funded by the AAL JP under the purview of the EU beginning in 2008. We aimed to uncover (1) the target populations of current AAL initiatives, (2) the type and commercial availability of the developed technology-based interventions and (3) the effects that have been demonstrated on health and well-being outcomes. The overall aim of this article was therefore to provide a person-centred health and well-being perspective on AAL.

Methods

The catalogue of AAL projects was reviewed,[15] which includes the abstracts of all AAL projects funded within the first six calls of the EU programme, including their contact, consortium and funding details and project websites. Two more recent calls have been issued (in 2014 and 2015); however, projects funded through these calls were excluded, as most of the information for these projects is not yet publicly available. All project abstracts and the websites of all projects were reviewed. If a project website was not available, the project page on the AAL website was reviewed (http://www.aal-europe.eu/our-projects/). All public webpages, reports and papers related to one or more of the AAL JP programmes were reviewed. In addition, the website, http://deliverables.

aal-europe.eu/, which contains links to the published deliverables of the AAL JP projects was reviewed, and all available deliverables were scanned for relevant content. The names and acronyms of the AAL projects were entered into PubMed and EMBASE to retrieve published papers. Similarly, Google was searched for commercially available products originating directly from AAL JP projects. Lastly, two public intellectual property rights (IPR) databases (i.e. Espacenet Patent Search and the United States Patent and Trademark Office (USPTO) Patent Full-Text and Image Database) were searched using project acronyms and company and company representative names. Project coordinators were contacted when clarification was needed.

For each project, a standardized summary was drafted containing the following information: contact details, aim of the project, target population, sampling strategy, project methodology, technologies used for intervention purposes, results related to the effect of the intervention on health and well-being outcomes and project outputs (commercial products, intellectual property). Project data were analysed thematically to summarize their aims and the target populations and uses of ICT within the AAL JP. Projects were first screened to determine whether they reported health and well-being outcomes. Next, both reviewers (B.V.G. and T.v.A.) reached consensus on which outcomes reflected health and well-being, and data were collected on the study methodology (i.e. sampling strategy, sample size, methodology (qualitative or quantitative evaluation)) and characteristics of the study design (i.e. group allocation, follow-up periods and measurement of outcomes). In all cases, the health and well-being outcomes of these projects were summarized by a second reviewer. As all studies on health and well-being outcomes used comparative quantitative approaches, nine criteria (i.e. randomized allocation, allocation concealment, groups similar at baseline, eligibility criteria specified, outcome assessors blinded, care provider blinded, subjects blinded, variability of primary outcomes and intention-to-treat analysis) were assessed to determine their methodological quality.[16]

All searches, data abstraction, data appraisal and analyses were performed by one reviewer, with discussion with another reviewer in cases of doubt or unclear reporting of results. Additionally, the main findings, their interpretation and conclusions were reviewed and discussed by both authors.

Results

Projects within the Ambient and Assisted Living Joint Programme

In total, the AAL JP fostered 152 projects funded through six calls for innovative projects in support of healthy ageing.[15] The six calls have focused on (1) prevention and management of chronic conditions in older adults, (2) advancement of social interaction in older adults, (3) advancement of independence and participation in the 'self-serve-society' in older adults, (4) advancement of mobility in older adults, (5) solutions for (self-) management of daily life activities in the home in older adults and (6) solutions for supporting the occupational life of older adults. The development of ICT-based services for and solutions to age-associated problems was a central component of every project.

Target populations

Overall, community-dwelling older adults were the end-users of interest. Many studies included relatively younger patients; 11 projects sampled data from individuals aged 50 years or younger, 55 projects included individuals younger than 65 years old and 70 projects included individuals younger than 70 years old. In 23 projects, the oldest participants were aged 70 years or older; 13 projects included individuals aged 80 years or older and only 2 projects included adults over the age of 90 years. Seven projects reported the mean age of their participants, and the mean ages of

Table 1. Target populations.

Target population	Number of studies
Older adults living at home	68
Caregivers of older adults	19
Cognitively impaired older adults	17
Working or retired adults	15
Older adults with mobility problems and increased fall risk	10
Adults suffering from comorbidity and chronic health problems	8
Sensory impaired older adults	7
Adults with functional impairment or impaired strength	5
Nursing home residents	1
Socially isolated older adults	1
Producers of health technology	1
Total	152

Data are reported thematically. Not all projects were limited to one target group, some served multiple populations.

participants in these studies were 61, 62, 65, 74, 71, 51 and 82 years. Many projects also included (informal) caregivers as either primary or secondary users. General populations of older adults living at home were targeted in 68 projects, and (informal) caregivers were included by 19 projects. Only one project focused on nursing home residents. Other projects focused on specific populations of individuals living at home (see Table 1). These projects targeted working older adults or retired individuals from a labour perspective (n = 15), individuals with specific geriatric problems or conditions (n = 40) and individuals with chronic health problems (n = 8). Finally, one project aimed to support producers of AAL technology.

Technologies and purposes

As a result of the six AAL JP calls, various technologies were utilized for different purposes (Table 2). Sensors were frequently used, often in combination with other technologies and with various purposes. Sensor technology was always used for the purposes of monitoring and measurement and most often used for the measurement of vital signs or other physical parameters (n = 26), measurement of activity level (n = 15) and detecting emergency situations (n = 12). Sensor technology was used less frequently for monitoring medication intake (n = 3), locating and/or tracking individuals (n = 5) and detecting care needs (n = 3). Personal computers (PCs), phones, tablets and televisions often facilitated various intervention components. These technological devices were most often used to facilitate communication and interaction (n = 56) through video, audio, text, social media and networks, interactive games, virtual worlds and forums to support social inclusion, connectedness and telemonitoring. These telecommunication means were also employed for coaching or education purposes (n = 32); giving feedback on activity (n = 11); sending reminders for activities of daily living, medication intake or exercise (n = 23); monitoring or assessing older adults and supporting them during emergency situations or with care needs (n = 30) and service provision such as information related to news, social events, activities, trip planning, shopping assistance or health planning (n = 27). Finally, these technologies were also used for outdoor orientation, navigation and mobility (n = 24) and exercise (n = 2). Other ICT applications that were used to a lesser extent were smart kitchens (n = 1), electric power wheelchairs (n = 1), e-stockings (n = 1), assistive

Table 2. Technology-based interventions.

Technology	Purpose								
	Feedback	Monitor, measure	Coaching, education	Reminders	Social interaction	Services	Orientation	Exercise	Other
Sensors		69							
Personal computer	3	7	19	5	15	8			
(Smart) Phone	3	11		7	4	7	24		1
Tablet	4	5	6	4	11	5		1	1
Television (with set-top box)		3	1	6	13	4		1	2
Web-based platform	1		5		11				
Game platform								4	
Robot		1			2				
Other		3	1	1		3	2	5	4

Projects were not limited to one technology or one purpose. Some projects were therefore reported in multiple categories of technology and purpose.

exoskeletons (n=1), AXO-suits (n=1), ambient lighting (n=1), all terrain walker frames (n=1), intelligent loudspeakers (n=1), white canes (n=1), hearing implants (n=1), wall displays (n=1) and smart gloves (n=1). Some differences were noted with respect to the main purpose of these ICT solutions, for example, phones were more frequently used for outdoor orientation and navigation (n=24) and monitoring the status and activities of relatives (n=11). A PC, however, was more frequently used for coaching and education purposes than were other technologies (n=19).

Project outputs: commercial products and intellectual property

A total of 62 projects reported developing a business model and marketing strategy. Of these projects, four (the RGS, M3W: the RGS, M3M, T-Break Osteolink and Dalia projects) made their product available to the public, and three (the Inclusion Society, I'CityForAll and T&Tnet projects) publicly reported registration of an IPR.

The RGS project developed a virtual reality–based system for stroke rehabilitation and, based on this project, founded a spin-off company named Eodyne. Eodyne offers a rehabilitation gaming system that can be used at home or in the clinic for recovery of motor and cognitive function after brain damage.[17] The Maintaining and Measuring Mental Wellness (M3W) project developed an online tool with computer games to measure mental changes and support mental wellness in an online community.[18] An account can be created on the M3W project website for free. The T-Break Osteolink project developed an online osteoporosis community to address the educational and support needs of osteoporosis patients in Europe and Australia. An account can be created on the T-Break Osteolink project website for free.[19] The Dalia project developed a personal virtual assistant for communicating with family and friends, maintaining a calendar and diary writing, emergency calls and falls detection, medication reminders and health state tracking.[20] The Virtask company has made this virtual care assistant, called 'Anne', available as a commercial product.[21]

The Inclusion Society project developed a service system platform that connected users with friends, family and healthcare providers to support self-management of health and well-being, and, based on this project, developed a spin-off company named 'WellTogether' who would own the IPR (but no further information is available).[22] The I'CityForAll project developed audio systems to improve community mobility in hearing impaired adults and filed a patent for these systems.[23]

Table 3. Methodological quality.

Quality appraisal	Randomized allocation	Allocation concealed	Groups similar at baseline	Eligibility criteria specified	Outcomes assessors blinded	Care provider blinded	Subjects blinded	Variability of primary outcomes	Intention to treat analysis
Agnes[25]	+	?	?	–	?	?	–	+	?
Aladdin[26]	+	?	–	+	?	?	–	+	?
RGS[27]	–	?	?	–	?	?	–	–	?
Rosetta[28]	–	–	–	+	?	–	–	+	?
Confidence[29]	–	NA	NA	–	?	?	–	+	?
GAMEUP[30]	+	?	?	+	?	?	?	?	?

Quality appraisal. '+': criteria was met; '–': criteria was not met as stated by the authors; '?': authors did not report adequate enough details to score the criteria; NA: not applicable as the design did not include a control group.

The T&Tnet project developed a personalized context-based multimodal journey planning app and reported sharing the intellectual property rights within its published strategies.[24]

Evaluation methodology and outcomes

A user-centred design was utilized by all the AAL JP projects. Generally, the performance of an end-user requirement analysis provided support for the development of ICT-based services. These services were then validated during lab-tests or field-tests, employing survey analyses of usability and acceptability. Specific sampling strategies were generally not reported, but a small sample of volunteers usually piloted the ICT within the projects.

A total of 12 projects reported aiming to evaluate the effects of AAL solutions on health and well-being outcomes. All of these projects used quantitative comparative designs, and qualitative evaluations of health and well-being outcomes were not described. By 1 June 2016, six of these projects had not yet reported results (four of the six projects were ongoing during the first half of 2016, while the other two projects were completed on 1 March 2011 and 1 March 2013).

Six projects (Agnes, Aladdin, RGS, Rosetta, Confidence and GAMEUP) reported results for the health and well-being outcomes assessed using a comparative design. Three projects used randomized controlled trials (RCTs); two projects used non-RCTs and one project used a single group pre-post comparison. These six projects included modest numbers of subjects (between 30 and 60) in their evaluations; however, their methodological quality was questionable (Table 3). Study reports often provided unclear descriptions of several aspects of the studies including blinding of outcome assessors, baseline equivalence of study groups and eligibility criteria for participants. Information on the specific outcomes of these projects is provided in Table 4.

Agnes included 55 older adult volunteers in an RCT and evaluated improvements in cognition and well-being using validated screening instruments at 1-year follow-up.[25] The intervention used in-home sensing technology to collect information on the emotional status, living situation and activity of older adults and facilitate social inclusion with their family and friends. For this project, a web-based social network was developed using input gathered from a smart watch, mobile phone, web cam, tangible device and ambient display. One year after the start of the intervention, no effect was observed on cognition, mood, functional performance or overall well-being when comparing the post-test scores between the intervention and control groups. Only the 'affection' well-being subscale demonstrated significant improvement.

Aladdin included 60 participants with known (mild to moderate) cognitive impairments and their caregivers in a multicentre RCT. The project aimed to reduce caregiver burden and distress

Table 4. Effectiveness of AAL solutions on health and well-being outcomes.

Project	Sample	Design	Intervention	Outcome	Endpoint (time)	Effects		p-value
						Mean IG (SD)	Mean CG (SD)	
Agnes[25]	55 volunteers included; 41 volunteers (65–85 years) completed study; IG = 25; CG = 15	RCT	Web-based social network; individual ICT use training; smart watch, mobile phone, web cam, tangible device, ambient display	Change in cognitive functioning	1 year	+0.56 (no SD)	+0.26 (no SD)	>0.05
				Change in depressive symptoms	1 year	−0.68 (no SD)	+0.36 (no SD)	>0.05
				Change in activities of daily living	1 year	'no difference'	'no difference'	>0.05
				Change in well-being	1 year	not reported	not reported	>0.05
Aladdin[26]	Carers of 60 hospital outpatients living at home with known cognitive impairment; IG = 30; CG = 30	RCT	Informative computer platforms Education about dementia Forum to share experiences Questionnaires on own health	Carer burden	3 months	35.6 (15.8)	27.6 (11.6)	0.03
					6 months	39.7 (23.1)	30.6 (17.6)	0.19
				Carer distress score	3 months	6.2 (4.8)	4.0 (4.2)	0.12
					6 months	6.8 (4.3)	3.2 (2.3)	0.01
				Carer depression	3 and 6 months	not reported	not reported	–
				Carer health related quality of life	3 months	0.6 (0.3)	0.72 (0.2)	0.36
					6 months	0.8 (0.1)	0.62 (0.2)	0.05
				Carer quality of life VAS score	3 months	57.60 (30.2)	72.90 (18.5)	0.36
					6 months	58.7 (36.8)	59.0 (27.2)	0.99
				Carer quality of life	3 months	74.4 (8.1)	77.8 (11.3)	0.19
					6 months	75.3 (8.5)	77.8 (12.0)	0.56
				Patient dementia severity	3 and 6 months	'worse scores'	'better scores'	<0.05
				Neuropsychiatric symptoms	3 and 6 months	'worse scores'	'better scores'	<0.05
RGS[27]	40 stroke patients	n-RCT	Virtual rehabilitation gaming system at home; perform training tasks 2–3 days, 5 days a week	Change in arm and hand function	3 weeks	'improved more'	'improved less'	<0.05
					12 weeks	'no difference'	'improved less'	>0.05
				Balance, sensation, functioning	3 and 12 weeks	'no difference'	'no difference'	>0.05
				Depression	3 and 12 weeks	'no difference'	'no difference'	>0.05
Rosetta[28]	42 persons with mild cognitive impairment/ dementia and 32 informal carers	n-RCT	Integrated system including: video home terminal and mobile device to support memory, social contact, recreation and safety; early detection software to detect significant changes in daily functioning; surveillance system for detecting emergency situations	Perceived autonomy	0.5–8 months	35.8 (8.8)	36.3 (8.8)	0.88
				Quality of life:	0.5–8 months			
				Self-assessed		36.1 (6.9)	34.4 (3.4)	0.62
				Carer-assessed		30.3 (6.7)	30.1 (3.9)	0.37
				Caregiver competence	0.5–8 months	4.13 (1.5)	5.13 (0.8)	0.11
				Delay of nursing home admission	0.5–8 months	3 admissions	3 admissions	–
				Care needs of older adults:	0.5–8 months			
				Met self-assessed		7.1 (3)	6.9 (3.5)	0.65
				Met carer-assessed		8.3 (5.1)	6.0 (5.4)	0.42
				Unmet self-assessed		2.1 (2.2)	1.2 (1.6)	0.83
				Unmet carer-assessed		2.1 (0.6)	1.2 (0.5)	0.79

(Continued)

Table 4. (Continued)

Project	Sample	Design	Intervention	Outcome	Endpoint (time)	Effects		p-value
						Mean IG (SD)	Mean CG (SD)	
Confidence[29]	41 older adults, no or mild cognitive impairment	Pre-post	Location-augmented voice; video and tracking service; mobile care	Quality of life	2 weeks	six had higher scores, six had lower scores	NA	–
GameUP[30]	30 older adults (>65 years) training prescribed, walk > 20 m	RCT	Three mini-exercise games training mobility, strength and balance	Balance	2 weeks	‘no difference’	‘no difference’	–
				Falls efficacy	2 weeks	unclear	unclear	–
				Mobility		not reported	not reported	–

IG: intervention group; CG: control group; SD: standard deviation; RCT: randomized controlled trial; n-RCT: non-randomized controlled trial with parallel groups; ICT: information and communications technology; VAS: visual analogue scale; NA = not applicable.

Agnes: outcomes assessed 1 year after the start of the intervention. Values reported represent the post-intervention difference between the intervention and control group. Cognitive functioning measured using Mini-Mental State Examination: mean (SD) (range: 0–30). Depressive symptoms measured using Geriatric Depression Scale: mean (SD) (range: 0–15). Activities of daily living measured using Barthel Index: mean (SD) (range: 0–100). Well-being measured using SPF-IL scale based on Social Production Function theory to assess subjective well-being: mean (SD) (range: 0–12).

Aladdin: outcomes assessed at 3 and 6 months. Values reported represent post-intervention difference between groups. Carer burden measured using Zarit Burden Interview: mean (SD) (range: 0–88). Carer distress score measured using Neuropsychiatric Inventory, carer distress mean score (SD). Depression measured using Beck Depression Inventory: mean (SD) (range: 0–63) and Zung Depression Self Rating Scale: mean (SD) (range: 20–80). Quality of life measured using EuroQol: mean (SD) (range: 0–1), VAS score: mean (SD) (range: 0–100) and Quality of Life Scale: mean (SD) (range: 16–112).

GAMEUP: no results have been reported. The intensity of the performed self-training is based on the frequency and duration of individual training sessions during 10 working days. Self-perceived fall efficacy is measured using the German and Spanish version of the Fall Efficacy Scale-International version. Mobility is measured using the Berg Balance Scale. Stability is measured using a tri-axial accelerometer.

RGS: outcomes were assessed at 3 and 12 weeks, but no exact values are reported. Functional ability of arm and hand was measured using the Chedoke Arm and Hand Inventory. Motor function, balance, sensation and joint functioning were assessed using the Fugl-Meyer Assessment. Depression was measured using the Hamilton scale.

Rosetta: outcomes assessed directly after trial phase, with variable duration (average or 4 months, range: from 0.5 to 8 months). Perceived autonomy was self-assessed by persons with mild cognitive impairment or dementia, using newly composed scale (range: not given) based on items from Mastery Scale and World Health Organization Quality of Life (WHOQOL)-100. Quality of life was self- and caregiver-assessed using Quality of Life in Alzheimer Disease Scale (range: 13–52). Caregiver Competence was measured with Short Sense of Competence Questionnaire (SSCQ; range: 7–35). Delay of nursing home admission was assessed by registering nursing home admissions for study participants. Care needs were measured using the Camberwell Assessment of Need for the Elderly, thus assessing both met and unmet needs and using both self-assessments and caregiver assessments.

Confidence: Quality of life assessed with five-point scale, after self-defining quality of life by participants.

and improve caregivers' quality of life with assessment at 3 and 6 months using validated screening instruments.[26] Sensors monitored the daily activities of the older adults and assessed psychiatric and behavioural symptoms. PCs were used to administer questionnaires, to provide support, information and education and to share experiences. Health-related quality of life of informal caregivers improved significantly more in the intervention group as compared to the control group over a 6-month period, but other assessments of quality of life showed no differences between the intervention and control groups. The distress score in caregivers at 3 months' follow-up was higher in the intervention than control group, but this difference could be related to the higher distress scores identified at baseline. Among participants with mild to moderate cognitive impairment, individuals in the intervention group suffered from more severe dementia and neuropsychiatric symptoms at 3 and 6 months than did individuals in the control group; however, the differences identified at follow-up between the two groups resembled baseline differences.

RGS reported conducting a non-RCT including 40 stroke patients to evaluate the effects of virtual rehabilitation gaming at home.[27] Stroke patients in both groups were asked to perform a 20-min training task two to three times a day, 5 days a week. The intervention group played the RGS project's virtual games, whereas the control group was asked to stack and unstack plastic cups. The study report provided p-values for statistical tests only, which indicated no differences in any outcomes at 12 months. At 3 months' follow-up, the study results indicated 'more improvement' in arm and hand function in the intervention group but no differences in other study outcomes.

Rosetta evaluated an integrated ICT system for older adults with mild cognitive impairment or dementia.[28] The system included a video home terminal, mobile device to support memory, social contact and recreation and software to detect changes in daily patterns or emergency situations. The non-RCT performed to evaluate the effects of this intervention included 42 older adults and 32 informal caregivers. The study evaluated perceived autonomy, care needs, quality of life and time to nursing home admission in older adults and competence in caregivers but did not detect any differences between study groups.

Confidence included 41 older adults with or without mild cognitive impairment in a single group pre-post study.[29] The Confidence project set out to provide a mobility safeguarding service for older adults that included a location-augmented voice and video-channel, tracking service and mobile care service. The quality of life in older adults was assessed at baseline and after 2 weeks of using the mobility service. Statistical testing results were not provided, but the study report indicated a lack of pre-post differences in quality of life; out of the 12 participants with a changed quality of life, 6 reported improvement and 6 reported deterioration.

GAMEUP utilized an RCT including 30 individuals older than 65 years of age and able to walk independently for over 20 m to determine post-intervention effects on balance, mobility and perceived falls efficacy.[30] Participants used a Kinect®-based system to play three mini-exercise games, and improvements in the aforementioned outcomes were evaluated. The available study report did not provide exact numbers or estimates but reported no differences in balance between the intervention and control groups and provided an unclear description of the effect of the intervention on falls efficacy. Outcomes for mobility were not reported.

Discussion

The AAL JP was instituted to foster 'the emergence of innovative ICT-based products, services and systems for ageing well at home, in the community, and at work'.[12] With the original programme running from 2008 to 2013 and covering a budget of 600 million Euros, the AAL JP resulted in a total of 152 projects aimed to support healthy ageing.[15,31]

The ICT solutions funded by the AAL JP were selected for their potential to support independent living among older adults by facilitating health monitoring, coaching and education, feedback, reminders, activity and social interaction through the use of technology. While many projects aimed to develop a marketable product, only two projects met this objective (a spin-off company was established in both cases). Indeed, other reviewers have also concluded that few devices and standards were tested and applied beyond the pilot study level.[32] The observed lack of, or delay in, offering marketable products as a result of these projects is in accordance with the results of a recent systematic review on the development of robots for supporting independent living.[33] The review identified 107 robot development projects, of which only six were commercially available. The authors concluded that there is a large discrepancy between what robots were claimed to be capable of doing and what was demonstrated in publications, suggesting that it will be a long time before a robot will really be able to enhance independent living in older adults.

The AAL JP was created with the aim of 'increasing the quality of life, autonomy, participation in social life, skills and employability of older adults, and reducing the costs of health and social care'.[12] However, only 12 (out of 152) projects reported aiming to evaluate the effect of these AAL solutions on health and well-being outcomes. Of these studies, only six reported the results of these evaluations and only three reported exact comparative values. The overall quality of these studies was very low (both in design and sampling methods), and sample sizes were small, thus limiting their internal, external and statistical conclusion validity.

While innovative ideas are proposed, their values must be ultimately demonstrated by improving outcomes relevant to older adults and using prospective controlled studies. Others have suggested that health technology assessment should focus on process measures rather than outcomes.[34] We believe that both are needed, as changes in processes can affect outcomes, but complex interactions with context determinants can result in non-linear relationships.[35,36] It would be incorrect to assume that changes in processes will automatically affect the desired outcomes. First, the theoretical assumptions underpinning the changes in the process might not be valid (i.e. theory failure). Second, a novelty effect may initially produce change, but this change may not be maintained over time (i.e. implementation failure). As a result, the value and impact of AAL technology can only be considered in relation to the longitudinal outcomes associated with its use in answer to the following question: Does the technology produce the hypothesized change and lead to the desired effect, and is this effect sustained over time?

While we highlighted the importance of outcome assessment, other key dimensions of quality should be considered in evaluations. Solutions should (1) be tailored to individual needs, (2) recognize a natural decline in health and progressing disability, (3) be continuously co-created and (4) be embedded in social networks based on service integration and (5) learn and improve.[37] valuation of AAL solutions can, therefore, not be restricted to quantitative outcome evaluations but should also incorporate in-depth qualitative evaluations that address the following question: How did a unique individual experience the value of AAL solutions in relation to their personal life values, needs, challenges and context? However, no such evaluations were identified in the AAL JP projects.

Based on the results of this study, we recommend AAL projects to consider the following. First, ICT should be considered as a facilitator of health and well-being interventions but not their main driver.[38] Theory- and evidence-based behavioural strategies should inform the use of technology for health and well-being purposes. Second, ICT should not be considered a standalone solution. While self-management aims to increase individuals' involvement and control over their own lives, professional involvement is still needed for teaching new skills, instilling confidence, providing self-management tools and assessing problems and accomplishments.[39,40] Third, ICT solutions should be designed to fit into everyday life to be used to their full effect,[14] and should, therefore, require minimal effort and be relevant, as indicated by the perception of the user. Indeed, the solution should fit a personal need.[37] Furthermore, ICT solutions should be designed to support long-term usefulness and fidelity to their designed use, as abandonment of the solution is a major threat to its effectiveness. Fourth, designing ICT solutions to fit current care, health and well-being initiatives, services, processes and structures could help facilitate their uptake. Primary care professionals, for example, have a central role in supporting self-management in individuals[39,40] and have been considered key to the success of telehealth.[41] Fifth, AAL projects should demonstrate their effectiveness in order to facilitate implementation within the healthcare setting and convince healthcare professionals to use the designed solutions.[42] Sixth, ICT solutions should be designed to accommodate what matters most to individuals with assisted living needs (i.e. social connectedness, mobility and autonomy).[43] Overall, AAL solutions should be considered a complex intervention for which the UK Medical Research Council framework for the development and evaluation of complex interventions could be used.[35]

Considering the perspectives of the AAL JP and other published studies, the value of ICT for healthy ageing and independent living in general and AAL specifically remains to be determined. However, three studies funded by the AAL JP are ongoing and may still prove their effectiveness towards promoting healthy ageing and independent living. Protection of intellectual property may also explain why information regarding the effectiveness of these interventions was unavailable, as companies may not want to publish key information regarding their studies and results; however, it should be noted that very few studies set out to study effectiveness. Furthermore, the search strategy employed in our review was limited to projects funded by the AAL JP in the EU, and although our results are in line with other reviews and a database search of abstracts in PubMed and EMBASE, other AAL solutions may exist that have proven to be effective in the improvement of health and well-being outcomes. This review only considered outputs related to population health and well-being. However, while an evaluation of the user-centred design process leading to project outputs might also prove to be a useful exercise, such an assessment was outside the scope of this study.

Finally, the results of this review could be considered very disappointing. So far, an investment of 600 million Euros in 152 projects has led to two marketable products and no evidence indicating superior health and well-being outcomes in older adults. However, it should be noted that the vast majority of these projects ran for 3–4 years and were initiated with the development of new or partly new ICT solutions. The AAL JP probably encouraged its project consortia to promise marketable solutions and demonstrate benefits, but it could be questioned if these objectives were realistic. In this light, the AAL programme's goals could be revisited with the objective of increasing realism and specifying priorities. A more realistic end goal might either be proof of concept or starting from proof of concept and aiming for impact evaluation. Nonetheless, the EU should be clear on what is expected from project outputs.

Conclusion

A discrepancy between project aims and outputs was identified, as the majority of projects focused on product development but have not yet demonstrated a significant impact on healthy ageing and independent living in terms of the products available on the market or beneficial outcomes in older adults. This discrepancy reflects a lack of clear objectives provided by the AAL JP and a lack of standards for developing, evaluating and implementing health technology in general. When developing technology, products should be co-created and driven by end-users instead of technology-driven, which appears to be the current standard. A particular concern is the maintenance of technology use over time and how the technology fits the dynamic needs of an older adult progressing through the course of life. When evaluating technology, several perspectives should be considered including both quantitative effects and qualitative user information, and long-term use should be monitored. Ultimately, the value of the AAL JP, in specific, and health technology, in general, will be determined by the benefits associated with older adults' health technology use in everyday life. However, this information is not yet available.

Author contribution

Both authors conceived the study, designed the search methodology and performed the literature search and analysed the data. Both authors drafted and revised the paper. The second author supervised this research.

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Computer-based self-help therapy: A qualitative analysis of attrition

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Abstract

The impact of computer-based cognitive-behavioral self-help therapy programs is limited by high attrition. This study explored reactions to computer-based cognitive-behavioral self-help therapy use among individuals not completing a full treatment course. Individuals receiving outpatient substance use disorder treatment at a Veterans Health Administration clinic who enrolled in a study implementing a computer-based cognitive-behavioral self-help therapy for insomnia, but subsequently dropped out prior to completion, were interviewed. Reactions to use and reasons for attrition were explored through thematic analysis of interviews. Among barriers to use, themes of competing demands, personal attributes, the computer-based format of computer-based cognitive-behavioral self-help therapies, and negative experiences with the specific program used were identified. Among facilitators of use, themes of personal support, the computer-based cognitive-behavioral self-help therapy format, and personal attributes were identified. Recommendations for future implementation efforts to include additional person-to-person contact during computer-based cognitive-behavioral self-help therapy participation were made. These themes may be employed to develop strategies for computer-based cognitive-behavioral self-help therapy implementation in order to maximize program engagement and completion.

Keywords

cognitive-behavioral therapy, computer-based therapy, health information technology, Internet, Veterans

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Introduction

Computer-based cognitive-behavioral self-help therapies (cCBTs) are self-guided programs delivered over a computer or the Internet and focused on improving knowledge, awareness, or behavior change.[1] Participants use these therapies at a pace and in a setting of their choosing and can be provided varying levels of guidance or support during participation. Numerous evidence-based mental health–oriented cCBTs have shown efficacy for the treatment of multiple disorders including depression, anxiety, substance use, and insomnia, the disorder targeted in this study.[2–4] The potential benefits of cCBTs include convenience, reduced travel barriers, provision of treatment for people who cannot come to a clinic during business hours, and reduced stigma associated with mental healthcare.[5,6] The programs may also increase self-care and health-system productivity.[7–9]

A major issue with regard to the effectiveness and successful dissemination of these treatment programs is attrition, defined as non-completion of the course of treatment for a given program.[10] In large trials and reviews of cCBT use, attrition can commonly range up to 50 percent, and even 99 percent in programs where personal support is not provided.[11,12] In a recent pragmatic feasibility trial of a cCBT for insomnia implemented among Veterans in outpatient care, 57 percent did not complete the program.[13] In comparison, attrition from large trials of face-to-face cognitive-behavioral therapy (CBT) for insomnia ranges from 10 to 20 percent.[14–16] Attrition is one of a number of factors which determine the effectiveness of such programs and is likely vital as studies have shown that program completion is associated with improved clinical outcomes.[17]

Prior research on reasons for attrition from cCBTs has involved analysis of data from clinical trials either in the form of structured follow-up surveys or the qualitative analysis of participant interviews. This literature is associated primarily with programs for the treatment of depression or anxiety; few studies have evaluated cCBT engagement or attrition for individuals in substance use or insomnia treatment. There is evidence that the most important facilitator of engagement and completion is the provision of support or guidance to individuals as they participate.[11] Support has been provided in the form of face-to-face, telephone, or messaging interactions and is thought to encourage engagement and completion, as well as improve outcomes.[18,19] Secondary factors associated with attrition can be loosely grouped into "patient-" and "treatment"-related categories as Johansson et al.[20] have discussed in one of the only analyses of interviews specifically with individuals who dropped out of cCBT treatment. Patient-associated factors include low computer literacy, competing demands on participant time or energy, symptom improvement prior to completion, and the potential negative consequences of improvement.[11,20–24] Treatment-associated factors include difficulty with Internet/computer access, problems with specific program content (e.g. too boring or too demanding), and technology fatigue.[11,20,21]

Limiting attrition will be important to improving cCBT effectiveness and dissemination in outpatient care. Therefore, a better understanding of the reasons for attrition is needed in order to support program engagement and completion. This study was undertaken to validate findings from previous qualitative and quantitative studies on attrition from cCBTs in a unique population: Veterans in outpatient Veteran Health Administration (VHA) substance abuse care. The study employed semi-structured interviews to explore personal reactions to using a cCBT for insomnia.

Methods

Study design

The feasibility of implementing a cCBT for insomnia in a VHA outpatient clinic for substance use treatment was tested in an open trial with 51 participants and has been described previously.[13] The cCBT, RESTORE™, is a six-session, Internet-based, self-administered program consisting of therapeutic components common to other face-to-face and self-help CBTs for insomnia. The RESTORE program has shown efficacy in a randomized and controlled trial.[25] In our prior study, RESTORE was implemented using a strategy consisting of face-to-face provider and patient education sessions, on-site Internet access, and clinician telephone support.[13] The program and implementation strategy were usability tested in two individuals prior to the start of the trial. Participants who chose to stop using the program prior to completing all sessions were asked to participate in a one-on-one interview with research personnel during their follow-up contact session.

Sample

Participants were English speaking with chronic insomnia and no evidence of sleep apnea, restless leg syndrome, recent psychiatric instability, or concurrent treatment with buprenorphine, methadone, or CBT for insomnia. Of 29 individuals who did not complete the program, 12 (41%) agreed to an interview. Participants provided informed consent in accordance with protocols approved by the institutional review boards of the VA Connecticut Healthcare System and Yale University School of Medicine.

Data gathering

The principal investigator (E.D.A.H.) conducted and audio recorded interviews in a quiet private area of the clinic. Interviews were semi-structured using an interview guide that introduced the purpose of the study and allowed for exploration of topics, such as reasons for attrition and recommendations for future efforts. Interviews lasted between 30 min and 1 h.

Data analysis

Interviews were transcribed verbatim to obtain a final set of data for analysis. Thematic Analysis, a foundational approach in the analysis of in-depth interviews, was used to analyze interview content and included a five-step process used by the first four authors: (1) familiarization with transcribed data; (2) generation of initial codes (short grammatical phases labeling data segments from interviewee statements); (3) collating codes into potential themes; (4) reviewing, discussing, and modifying themes in relation to coded extracts; and (5) developing a typology of and defining themes.[26] To facilitate in-depth analysis and decrease travel burden, the first four authors divided into two teams to perform an initial analysis and coding of interview content (phases 1, 2, 3 above) by randomly dividing the interviews into two groups. Phases 4 and 5 used a group process involving all authors to develop consensus. Discrepancies were resolved through discussion with final adjudication by the first author. Codes within themes were then reviewed using the entire data set to identify examples and counter-factuals.

Results

On average, the sample of Veterans interviewed consisted of middle-aged males with a high school education. An equal proportion reported being White or another race/ethnicity, and most reported at least one psychiatric disorder. The sample completing interviews did not differ statistically from those not interviewed by socio-demographic characteristics or reported psychiatric diagnoses (Table 1).

Table 1. Socio-demographic characteristics of individuals interviewed among those not completing a cCBT for insomnia.

Variable	Total sample of Veterans not completing the cCBT (n = 29)	Veterans interviewed (n = 12, 41.4%)	Test statistic[a]	*p*-value
Age, mean (SD)	52 (12.0)	49 (12.3)	1.90	0.18
Gender (male), n (%)	25 (86.2)	10 (83.3)	0.14	0.71
Race/ethnicity, n (%)				
White	19 (65.5)	6 (50.0)	2.18	0.14
Other	10 (34.5)	6 (50.0)		
Education, n (%)			0.47	0.49
High school graduate and less	10 (34.5)	5 (41.7)		
Partial college and more	19 (65.5)	7 (58.3)		
Any psychiatric disorder, n (%)	25 (86.2)	10 (83.3)	0.14	0.71

cCBT: computer-based cognitive-behavioral self-help therapy; SD: standard deviation.

[a] Between-group comparisons were tested with chi-square for categorical variables and analysis of variance for continuous variables.

After the analysis of interviews, personal reactions to using a cCBT for insomnia were organized into three groups: barriers to completion, facilitators of engagement, and participant suggestions for future implementation efforts.

Barriers to completion

Barriers to completion were noted in all interviews, with four identified sub-themes: competing demands from other activities, characteristics of individual participants, aspects of the computer-based format, and negative experiences with the specific program.

Competing demands. Competing demands were the most commonly cited barriers, found in 11 interviews (92%). Interviewees described spending significant time and effort on the performance of or motivation to perform activities other than those related to the cCBT. A prominent competing demand (n = 7, 58%) was difficulty prioritizing the program among activities related to other health problems. The high number of medical and mental health appointments as well as time spent attending to other health difficulties were described as direct competitors with cCBT completion (the direct effect of psychiatric and medical symptomatology is discussed in a later section). One Veteran said, "I got these appointments that they [the VHA] are bombarding me with … so there's a lot of stuff I gotta do …" Many participants (n = 6, 50%) said their simultaneous enrollment in college courses interfered with cCBT program completion, even though some said they had thought, prior to engagement, that the cCBT would dovetail nicely with coursework: "I started school right at the same time and way overloaded myself; took on way more than I could handle first time back in school in fourteen years." A meaningful portion (25%) were also struggling to meet basic needs such as paying bills and obtaining stable housing and talked about the negative impact of these demands on program completion: "I mean, you gotta make sure you have what you need in order to even begin to think about something else."

Attributes of the individual. Participants talked about personal traits, characteristics, or symptoms that contributed to difficulty completing the program. In nine interviews (75%), cognitive symptoms including difficulty concentrating, forgetfulness, and distractibility, as well as anxiety, were noted. Anxiety symptoms were described either as having no antecedent cause or as associated with other factors related to discontinuation, such as competing demands from other activities: "I won't be able to concentrate and actually take in what I'm doing. I get easily distracted and I just can't feel comfortable enough to get the full benefit." In three interviews, medical disorders, such as acutely elevated blood sugar or chronic pain, interfered with concentration and the ability to attend to the program. "I could sit down, but I have to get up. I have to get up so that my legs actually don't freeze up on me." In addition, several participant statements revealed a general lack of receptivity to new treatment options or ideas related to their care: "But me, I'm not as sharp as I used to be. I'm not as receptive as I used to be for learning new things." Alternatively, several non-completers said, in effect, "I'll try anything." perhaps suggesting that they agreed to participate in the program without an adequate understanding of the commitment or work needed for completion. A similar attitude of "I'll try anything for the good of Veterans" was described by other individuals and is discussed below as a facilitator to engagement.

Aspects of the computer-based format. Participants identified features of the computer-based format of cCBTs and their lack of familiarity with computer technology as barriers to program completion. Eight participants (67%) mentioned stress related to a lack of experience with, or ability to use, computers or the Internet as reasons for non-completion: "… I didn't know how to turn it on. That's one of my things that puts me in a tense or anxious situation. So I try to eliminate that." Related to the stress associated with low technology literacy were additional negative feelings toward computers such as fear or distrust associated with prior experience with them, noted by seven participants (58%): "I hated it. They [Army] make you sit at the computer for three hours at a time and do stuff, and do some stupid thing on line that doesn't even matter." Seven participants (58%) said that limited access to a computer with an Internet connection in a safe, private, space was a barrier to engagement and completion. Several in this group noted that they had recently lost a previously stable source of Internet or computer resources:

> … at the time I started the study my personal computer crapped the bed and that left me to either have to come to the VA or go to a library or public facility or something like that … I could have put more effort into going to the library but like I just don't feel comfortable in a public place to do stuff like that.

Negative experiences with the program. This theme related to characteristics of the specific program used, RESTORE, separate from the computer-based format. Most participants cited one main negative experience with the program, while also echoing other common complaints. The four most common complaints describing negative experiences are shown in Table 2.

Facilitators of engagement

Almost all individuals who did not complete the program and were interviewed, n = 11 (92%), also noted themes that facilitated engagement in the program, such as clinician support, attributes of the individual, and characteristics of the computer-based format.

Staff support. Part of the strategy used to implement the program involved a clinician educating participants during an initial session, supplemented by weekly follow-up phone contact. Eight participants (67%) said this support was helpful, by encouraging them to engage, providing technical help, or simply knowing help was available if needed: "I was probably getting a little lost in my

Table 2. Negative experiences with the specific program.

Negative experience	Description	Frequency, n (%)	Example
Time Consuming	Interviewees did not feel the program was designed to be efficiently used	9 (75)	"It's definitely not for the type of person that's very busy … It's not like something you can do on the run, it's something that you have to actually pencil in on your schedule."
Boredom	Other terms used: "monotone" and "long-winded"	5 (41)	"It's like watching one of them old TV shows where you having this boring professor sitting in this dark room … That was just so dead looking that it's like eww; I don't want to watch this."
Lack of Individualization	The program did not address the underlying specific cause of their insomnia	5 (41)	"My sleep pattern kinda didn't fit the categories … There's no room for individuality or difference from the program and so it's like only having two columns to check republican or democrat."
Lecture-Based Pedagogy	Lecture-based approach was not appealing, especially in the context of schoolwork with a similar format	4 (33)	"After I was going to school … and I'm listening to these lectures and all of that, last thing I wanted to do was go home and listen to somebody else."

own situation. By you checking up on me, it kind of brought my attention back to me thinking more, getting more personalized with this study." In addition, two participants spoke of helpful support from family members.

Attributes of the individual. Seven participants (58%) mentioned a variety of personal characteristics that facilitated enrollment in the program. Two characteristics stood out—the willingness of participants to try anything they believed might help improve their symptoms and a sense of duty or public service: "My thought at the beginning of the program was maybe it will be beneficial to myself as well as others. If I can do it, I'll do it … Basically, I'll try anything for the benefit of future veterans." This sense of duty and public service differed from the "I'll try anything" attitude described as a barrier, because it focused on service to others and was described as a reason why individuals signed up to participate in the research project.

Aspects of the computer-based format. Seven individuals (58%) noted specific aspects of the computer-based format that facilitated engagement, such as the privacy it provided, the convenience of 24/7 access to treatment, and the opportunity to proceed at one's own pace: "You could have more time to think about stuff before you put it in there. Because you're doing it on your own instead of sitting in front of someone getting asked questions."

Suggestions for future implementation efforts

At the end of each interview, Veterans were asked "Do you have any suggestions on how the use of this program [cCBT] could be improved?" Six individuals (50%) indicated a desire for increased personal interactions in the form of face-to-face support, stating that these interactions would increase motivation and provide a format for trouble shooting problems and getting questions answered. Several participants also suggested the addition of a face-to-face peer support group of individuals using the program as a way to facilitate this support:

> It [a support group with other participants] maybe a "meet and greet." You know, to feed off of each other … I wouldn't want to do the group all the time … even once a month …. You might think of something while talking to them, "Yeah, that's how I felt," and bounce ideas off each other.

Discussion

Although there is strong evidence for the efficacy of many cCBTs for common mental health conditions, attrition is one of the factors that limits program effectiveness in clinical practice.[12] To develop strategies for implementing cCBTs that support program completion and limit attrition, a better understanding of the reasons for attrition from cCBTs must be developed, especially among Veterans in outpatient care where this work has yet to be completed. This study explored personal reactions to using a cCBT for insomnia among Veterans in substance abuse treatment. The most important barriers to program completion were patient factors such as competing demands for participants' time, attention, and energy, followed by personal attributes such as anxiety about technology and low technology literacy. Participants also identified face-to-face support from clinicians and other Veterans as facilitators of engagement and recommendations for future implementation efforts.

The scant data available on reasons for attrition from cCBTs come primarily from participant assessments during controlled clinical trials and interviews with individuals who have completed their respective programs.[21,22,24,27] A recent similar qualitative study in individuals who did not complete a program for generalized anxiety by Johansson et al.[20] helpfully divided reasons for non-adherence into patient- and treatment-related factors. Patient factors may be the most influential as they appear to be most widely shared among studies, the most important of which are competing demands from other activities and low computer literacy in some participants. Competing demands (alternatively described as "life factors,"[20] feeling "overwhelmed,"[24] and "motivation" in the face of other demands),[11] especially with participants' other medical care and educational activities as identified here, are some of the most important barriers in this as well as other studies.[21] However, treatment factors such as characteristics of the specific program, especially its ability to hold the participants attention, and aspects of the computer-based format, such as the need for reliable Internet or computer access, are also important factors in attrition revealed in a number of other studies.[11,20]

Other barriers identified here have not been noted in previous studies such as physical illness. The theme of physical illness is closely associated with the competing demand of medical care and may have been more pronounced in this study because VA patients are generally older and have more medical comorbidities than members of the general population.[28] However, it is notable that while technology access and literacy were cited as barriers and are thought to be common among the elderly, the barrier of competing demands appeared to outweigh these considerations.

Another key finding of this study was a group of themes facilitating engagement in this group of participants who actually did not complete the program. This finding suggests that the changes in the strategy used to implement cCBTs may encourage increased engagement and completion. Many of the facilitators and suggestions revealed here have been emphasized in other studies, such as the relative freedom from scheduling and travel barriers associated with face-to-face therapy as well as the anonymity cCBTs provide.[21,24]

Themes identified in this study will be helpful in developing a comprehensive strategy to support the implementation of cCBTs in VHA outpatient care by reducing identified barriers and strengthening facilitators. As observed in a recent large-scale effectiveness trial of cCBTs for depression in the United Kingdom, a lack of engagement and completion is associated with a lack of program effectiveness.[12] Primary among participant's suggestions for future implementation was the need for users to have direct contact with individuals while participating in the program.[11,19,20] This study has led our group to define a cCBT implementation strategy, which includes training a clinical intermediary, other than the referring provider, who will provide face-to-face and other modalities of support and education to patients throughout their engagement with the program. We also recommend provider and staff facilitation and education to encourage referral, as well as stepped-care for those requiring additional treatment.[29]

There are several characteristics of this study that make it unique within the cCBT attrition literature. As discussed above, this is one of the only studies utilizing interviews with individuals who dropped out of a cCBT program.[20] Although the literature on cCBT programs for the treatment of insomnia is growing, this is the only work in this group which specifically addresses attrition through the analysis of participant interviews. Likewise, this is the only cCBT study in the substance abuse treatment setting to address attrition and insomnia treatment. Prior work in this area has primarily focused on alcohol and tobacco use.[30,31] Findings from these studies in conjunction with this study and its unique sample suggest that barriers and facilitators of cCBT use may not be disorder specific but hinge more on factors related to the cCBT platform and an individual's response to the platform.

Primary limitations of this study concern the sample: individuals in VHA outpatient substance use treatment who did not complete a cCBT for insomnia. The group interviewed consists of Veterans, who are characteristically older with more medical and psychiatric comorbidities compared to the general population and receive care within a unique, integrated, and nationwide healthcare system. Their experience may differ from those who are non-VHA service users, or receive treatment in non-specialty care settings. Moreover, only 41 percent of participants not completing the cCBT volunteered to be interviewed, potentially introducing a selection bias, as their views may be different than those not interviewed. In addition, the process of interviews, which were completed by the researcher conducting the trial, may have affected responses and the topics discussed. Therefore, the results cannot be regarded as representative for all individuals who receive computer-based self-help treatment, especially those who completed the program. However, the immediate goal of this work was to identify an initial and general set of barriers, facilitators, and user suggestions on which to base the content of an implementation strategy for cCBTs in VHA outpatient care. Therefore, the selection of this sample was appropriate in this context. An additional limitation is that successful implementation of cCBTs hinge on barriers and facilitators identified by providers and administrators, who also play key roles in such efforts, and institutional factors that may either support or compromise the successful implementation of cCBT programs.[32] Efforts are currently underway to uncover such factors.

Limiting attrition from cCBTs will be a key factor in realizing their effectiveness and successful dissemination in outpatient care. This study uncovered barriers to cCBT completion such as competing demands on Veteran time and limited technology literacy, as well as facilitators of cCBT engagement and suggestions for future implementation, such as face-to-face support from clinicians and other Veterans. This information will be used to develop robust implementation strategies to foster increased engagement in and completion of these programs with the goal of increasing access to evidence-based mental healthcare.

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SAGE

A clinical decision support tool to assist with the interpretation of the 12-lead electrocardiogram

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Abstract

This article reports the design and testing of a novel interactive method, abbreviated to ANALYSE (systemAtic aNALYsiS of Electrocardiography) to assist interpretation of 12-lead electrocardiogram. 15 participants interpreted a total of 150 12-lead electrocardiogram recordings randomly using a standard and this novel (ANALYSE) reporting format. The overall aggregated mean score attained using the standard format was 53% (range = 38–82%, standard deviation = 12). Conversely, the overall aggregated mean score attained using ANALYSE format was 75% (range = 55%–93%, standard deviation = 9). A total of 14/15 participants consistently scored higher when interpreting electrocardiograms using the ANALYSE format (range = 10% -45%). A significant difference between the aggregated marks scored using the ANALYSE format and the standard format was calculated (Wilcoxon Z Score = −3.2374 (df = 14), $p < 0.01$). This study demonstrates the clinical utility of a novel method (ANALYSE) to assist the learning of electrocardiogram interpretation and its association with enhanced diagnostic performance in novices.

Keywords

decision support systems, electrocardiography, teaching

Background

The recording of 12-lead electrocardiograms (ECGs) is one of the most useful and commonly performed medical procedures. ECGs are used in diagnosis, risk-stratification management decision-making and assessment in response to therapy.[1] Interpretation of the 12-lead ECG involves analysing several waveforms (P, QRS, ST and T waves) which permits the detection of abnormalities that affect normal electrical conduction.[2] The interpretation of 12-lead ECG recordings is complex and clinically challenging. Appropriate interpretation can be difficult to achieve with misinterpretation resulting in patient fatality.[3] Despite its widespread use, several studies have highlighted deficiencies in ECG interpretation skills among health professionals.[2,4–10]

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In the last few years, decision support systems (DSS) in medicine are being increasingly configured as an innovative mechanism for providing health professionals with clinical knowledge and patient-related information.[11] DSS are designed to assist health professionals with decision-making tasks that reduce the likelihood of errors and improve care quality.[12] DSS knowledge base, ranging from guidelines of best practices for managing patients with specific disease states to new medical knowledge from clinical research, is the key element surrounding this supporting process.[12] Indeed, a recent review of the topic reported that DSS improved practitioner performance in 40 per cent of diagnostic systems and 62 per cent of disease management systems.[13]

This article reports the design and testing of a novel ECG interpretation teaching tool systemAtic aNALYsiS of Electrocardiography (ANALYSE) Smart Form (Figure 1). As a proof of concept, the smart form was evaluated with a group of 15 healthcare science practitioner (HCSP) students studying an introductory module of electrocardiography over a period of one teaching term (12 weeks). All students were recently educated to second year undergraduate university level in a medical-related discipline as a part of their university undergraduate degree course. HCSP's within the United Kingdom have expertise in applied scientific techniques within cardiac physiology and work in a healthcare setting with a clearly defined technologically based role in the delivery and technical reporting of quality assured tests, investigations and interventions for patients.[14] The aim of this research was to evaluate the diagnostic accuracy of learners against a standard curriculum using the ANALYSE Smart Form compared to a traditional reporting format for 12-lead ECG interpretation (Figure 2).

Material and methods

Model design

To develop a standardised format for ECG interpretation, we identified the possible ECG metrics that will incrementally lead to an eventual diagnosis. The use of an analytic framework, described as lists of key variables to be sequentially considered, involved careful scrutiny of a systematic review of published literature.[15–22] An interactive Smart Form learning tool labelled ANALYSE was devised using a Microsoft Word 2010 template populated with content controls (Figure 1). This tool incorporates a systematic process of analysis with the major objective to achieve precise and accurate interpretation by applying various deductive approa ches.[15–22] ECG interpreters are required to examine the tracing to evaluate heart rate, rhythm, cardiac axis, signs of chamber hypertrophy, signs of ischaemia and measure electrocardiographic conduction intervals in an organised fashion. ANALYSE incorporates a number of features to collect this data and assimilate it into a comprehensive format. ECG interval measurement prompts (Figure 3) request the interpreter to measure the different ECG segments and intervals which relate directly to phases of cardiac conduction (Figure 4). Limits have been set on these from which to diagnose deviations from normality and are presented in convenient drop-down menu statements (Figure 5). Interpreters can also type freely onto the smart form using free text annotations (Figure 6).

Study design. Participants (n = 15, 5 male and 10 female, 19–31 years old) were recruited and required to interpret five ECGs (Table 1) using the ANALYSE approach (Figure 1) and again to interpret the same five ECGs using a standard ECG reporting format[11] (Figure 2) in two separate sessions. As a result, a total of 150 ECG interpretations were collected (75 interpretations using the standard approach and 75 interpretations using the devised ANALYSE method). Marks were

Main underlying rhythm: Choose an item.	**Regular rhythm heart rate calculation:** No. of small squares: 1500/ OR No. of large squares: 300/	**Irregular rhythm heart rate calculation:** No. of R waves in 6 secs of ECG = Click here to enter text. x 10:
PR interval measurement: Click here to enter text.seconds Choose an item.	**P wave morphology comment:** Choose an item. Choose an item. Choose an item. Choose an item. Choose an item.	
QRS Axis: Most Equiphasic Lead :Choose an item. **Perpendicular Lead**: Choose an item. **Axis measurement**: Choose an item. **QRS Axis measurement**: Click here to enter text.degrees	**QT interval measurement**:Click here to enter text.seconds **RR interval measurement**:Click here to enter text.seconds **Bazett's formula QTC = QT / RR interval (in secs)**: **QTc measurement**: Choose an item.	
QRS duration measurement: Click here to enter text.seconds Choose an item. **QRS morphology**: Choose an item. Choose an item. Choose an item.	**Ventricular Hypertrophy measurement**: **R wave amplitude Lead V1**: Click here to enter text.mV **S wave amplitude Lead V6**: Click here to enter text.mV **Total**:Click here to enter text.mV **R wave amplitude Lead V6**: Click here to enter text.mV **S wave amplitude Lead V1**: Click here to enter text.mV **Total:**Click here to enter text.mV **Ventricular Hypertrophy measurement:** Choose an item.	
ST segment measurement: Click here to enter text.mm **Evidence of** Choose an item.	**Leads with ST changes**: Click here to enter text.	
T wave morphology comment: Choose an item. Choose an item. Choose an item.	**Any other significant findings**: Choose an item. Choose an item. Choose an item.	
Conclusion:		

Figure 1. ECG interpretation interactive Smart Form learning tool: ANALYSE (systemAtic aNALYsiS of Electrocardiography).

Heart Rate:	
Comment on P Wave Morphology:	
PR Interval measurement:	
Rhythm Interpretation:	
QRS axis measurement:	
QRS Duration measurement: **QRS Morphology interpretation:**	
QT interval measurement: **QTc Interval measurement:**	
Evidence Of Hypertrophy (Measurement as per Sokolow/Lyon Criteria ONLY):	
Comment on T Wave/Any abnormalities:	
Any other clinically significant findings:	
Complete summary/Diagnosis:	

Figure 2. Society for Cardiological Science and Technology (SCST) standard ECG report form.[11]

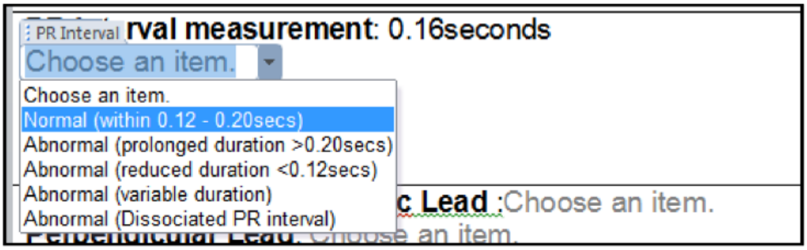
PR interval measurement: Click here to enter text. seconds

Choose an item.

Figure 3. Screen capture shots to illustrate the working of ANALYSE, specifically free text annotation of data.

awarded for accuracy of ECG analysis and interpretation. Scores were then compared for each format and sequence used (Table 2). Ethical approval for this study was granted from the ethics board of the Institute of Nursing and Health Research Centre at Ulster University.

Recruitment. Students enrolled on module ECG interpretation within the Healthcare Science degree programme (Module Coordinator: Cathal Breen) were invited to partake in the study. The principal learning outcome for this module is 12-lead ECG interpretation in accordance with the national UK curriculum so an appropriate study cohort could be assured.[23] Recruitment to this study was advertised on student notice boards using posters. Students who volunteered sent an email to the module coordinator. An information sheet and a consent form were sent to the student following their initial communication.

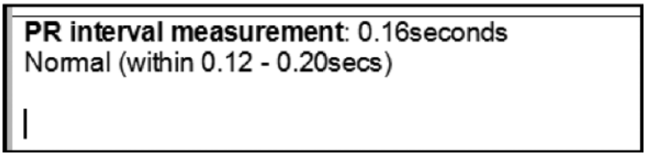


PR Interval rval measurement: 0.16seconds
Choose an item.

Choose an item.
Normal (within 0.12 - 0.20secs)
Abnormal (prolonged duration >0.20secs)
Abnormal (reduced duration <0.12secs)
Abnormal (variable duration)
Abnormal (Dissociated PR interval)

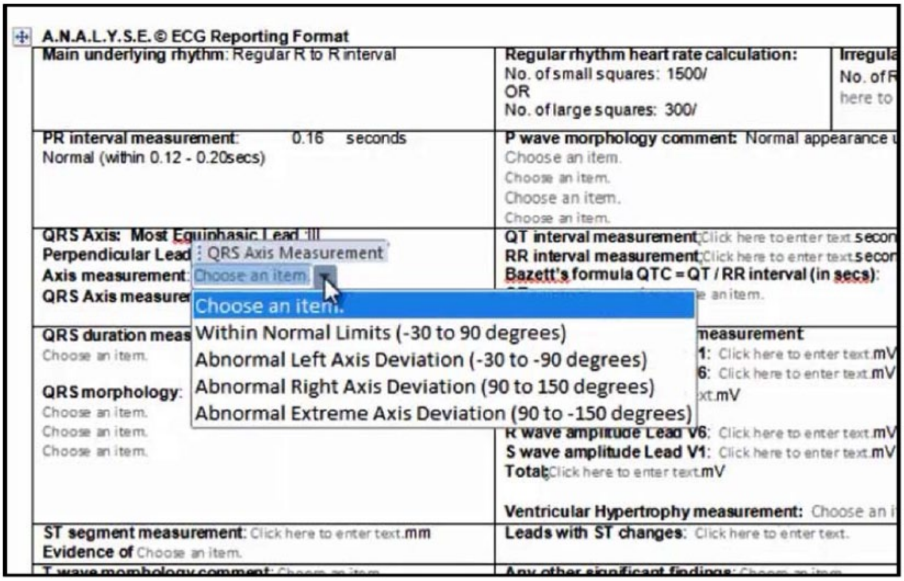
c Lead :Choose an item.
Perpendicular Lead: Choose an item.

Figure 4. Screen capture shots to illustrate the working of ANALYSE, specifically drop-down box use with normal range data.



PR interval measurement: 0.16seconds
Normal (within 0.12 - 0.20secs)

Figure 5. Screen capture shots to illustrate the working of ANALYSE.



A.N.A.L.Y.S.E.© ECG Reporting Format

Main underlying rhythm: Regular R to R interval

Regular rhythm heart rate calculation:
No. of small squares: 1500/
OR
No. of large squares: 300/

Irregula
No. of R
here to

PR interval measurement: 0.16 seconds
Normal (within 0.12 - 0.20secs)

P wave morphology comment: Normal appearance
Choose an item.
Choose an item.
Choose an item.
Choose an item.

QRS Axis: Most Equiphasic Lead III
Perpendicular Lead
Axis measurement: Choose an item.
QRS Axis measure

QRS Axis Measurement
Choose an item.
Within Normal Limits (-30 to 90 degrees)
Abnormal Left Axis Deviation (-30 to -90 degrees)
Abnormal Right Axis Deviation (90 to 150 degrees)
Abnormal Extreme Axis Deviation (90 to -150 degrees)

QT interval measurement: Click here to enter text. secon
RR interval measurement: Click here to enter text. secon
Bazett's formula QTC = QT / RR interval (in secs):
e an item.

QRS duration meas
Choose an item.

QRS morphology:
Choose an item.
Choose an item.
Choose an item.

measurement
1: Click here to enter text. mV
6: Click here to enter text. mV
xt. mV
R wave amplitude Lead V6: Click here to enter text. mV
S wave amplitude Lead V1: Click here to enter text. mV
Total: Click here to enter text. mV

Ventricular Hypertrophy measurement: Choose an i

ST segment measurement: Click here to enter text. mm
Evidence of Choose an item.

Leads with ST changes: Click here to enter text.

T wave morphology comment: Choose an item.

Any other significant findings: Choose an item.

Figure 6. Screen capture shots to illustrate the drop down answer prompts of ANALYSE.

Trial design. A cross-over randomised controlled trial (RCT) experimental design was used for this study. All participants attended a clinical skills laboratory to demonstrate their ECG interpretation competence. Participants were randomised in advance into groups (A or B) by having their names drawn from an envelope to determine the sequence of ECG interpretation format they would use (i.e. for the cross-over RCT). Group A (n = 8) initially used the ANALYSE format to interpret the

Table 1. The dominant features of the five 12-lead ECG recordings used with this study (as deducted through Figure 7).

ECG tracing	Diagnosis
ECG1	Normal sinus rhythm, voltage criteria for left atrial enlargement.
ECG2	Normal sinus rhythm, voltage criteria for left ventricular hypertrophy with associated T-wave flattening. Left axis deviation.
ECG3	Normal sinus rhythm, delta wave, shortened PR interval, broad QRS complex duration and ST/T-wave displacement correlate to pre-excitation syndrome (e.g. Wolff–Parkinson–White Syndrome).
ECG4	Atrial flutter with a fast ventricular response.
ECG5	Normal sinus rhythm, voltage criteria to suggest left atrial enlargement, one isolated premature ventricular contraction.

ECG: electrocardiogram.

Table 2. Aggregated marks attained using the ANALYSE format when compared to the standard ECG reporting format.[11]

Participant ID	Order of ECG analysis		Marks (%)	Marks (%)	▲
	First ECG reporting format	Second ECG reporting format	Standard report format	ANALYSE report format	Difference between formats
1	Standard	ANALYSE	41	73	32
2	Standard	ANALYSE	82	93	11
3	Standard	ANALYSE	66	55	−11
4	ANALYSE	Standard	48	75	27
5	Standard	ANALYSE	42	83	41
6	Standard	ANALYSE	49	62	13
7	Standard	ANALYSE	67	78	11
8	ANALYSE	Standard	64	78	14
9	ANALYSE	Standard	43	72	30
10	ANALYSE	Standard	57	78	20
11	ANALYSE	Standard	55	65	10
12	Standard	ANALYSE	58	85	27
13	ANALYSE	Standard	41	86	45
14	Standard	ANALYSE	38	75	36
15	ANALYSE	Standard	46	72	26
Mean			53	75	22
Median			49	75	26
IQR			19	9	19
SD			12	9	14

ANALYSE: systemAtic aNALYsiS of Electrocardiography; ECG: electrocardiogram; IQR: interquartile range; SD: standard deviation.

Hypothesis testing comparing marks from the two formats: Wilcoxon Z Score = −3.2374 (df = 14, $p < 0.05$) and Cohen's effect size value ($d = 1.47$).

ECGs and later used the standard ECG reporting format. Group B ($n = 7$) initially used the standard ECG reporting format to interpret the ECGs followed by the ANALYSE format. All students completed a questionnaire reporting their experience of the ANALYSE format to interpret the ECGs.

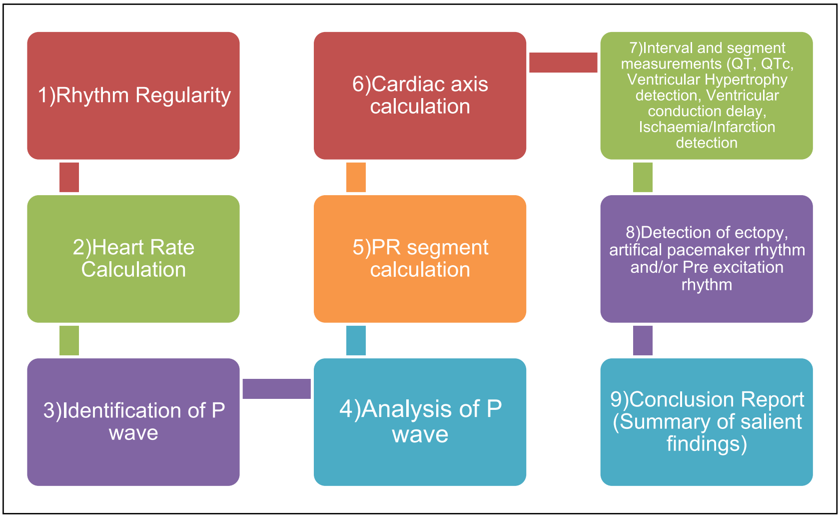


Figure 7. A flowchart to illustrate the work flow of ANALYSE smart form (refer to Table 1).

ECG interpretation. During the experiment, each participant was asked to visually inspect, determine measurements and document their interpretation of each of the ECG tracings using one of the two separate analysing formats (i.e. the standard form or the ANALYSE form). As aforementioned, the ANALYSE reporting format consisted of an interactive smart form which prompted the learner to complete a systematic ECG analysis. The ANALYSE tool provides decision support in the form of an aid memoir for critical parameters used when visually inspecting ECGs. Key analytical criteria (Figure 1) adopted from a range of published literature required the learner to input correct ECG interval measurements, align their interpretation to these values and provide descriptions of their visual inspection of the waveform morphologies to determine a complete analysis of the ECG tracing (Figure 7). For comparison, learners were asked to use an alternative traditional reporting format devised from the aligned professional body in the United Kingdom, the Society for Cardiological Science and Technology (SCST)[24] (Figure 2). The ECGs incorporated within this study were chosen based on the inclusion and illustration of precise electrical abnormalities in a unique or combined format aligning to the curriculum[23] and learning content delivered in a given week of the training period (1–4 weeks) and were consensually agreed appropriate by the teaching faculty who has expertise in clinical education and electrophysiology. All ECGs in this study were displayed electronically on a desktop PC and represented a sample of cardiac conditions (Table 1). A marking scheme for each ECG was devised by a panel of experts via consensual agreement focusing on accuracy of interval measurements, explanation of diagnosis and use of ECG terminology.

Data collection

Quantitative data from the ECG interpretations were in the form of marks, which were statistically analysed and compared. Statistics were generated and calculated using Microsoft Excel. Correlations were calculated using Cohen's effect size (d values), and statistical significance testing was calculated using student's t-test or Wilcoxon matched pairs test where appropriate with a significance value of $p < 0.05$. Statistics are presented in mean and median formats with standard deviation (SD), degrees of freedom (df) and/or interquartile ranges (IQRs). Experiential feedback data from each participant's experience in using the ANALYSE reporting format were collected

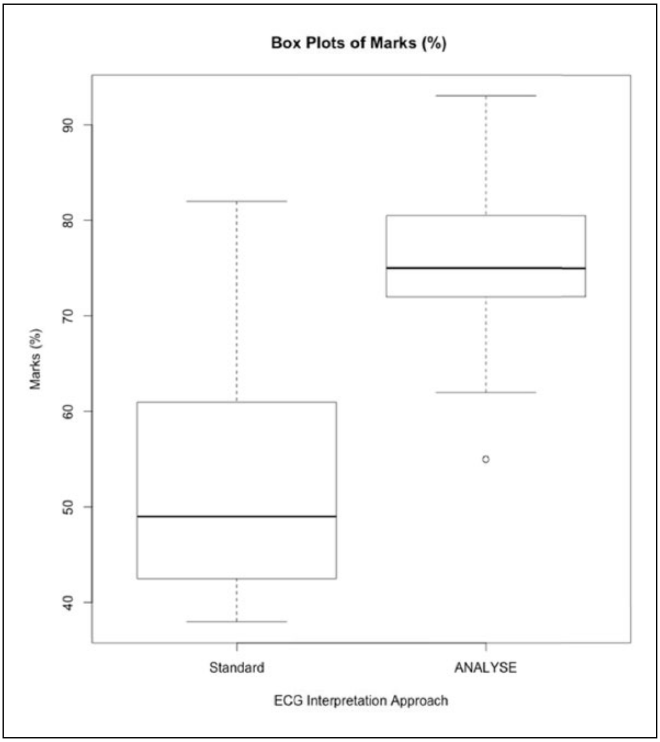


Figure 8. Box plots depicting the distribution of marks when using each of the ECG reporting formats.

using a questionnaire. A total of 10 questions which incorporated Likert scales and comment boxes were disseminated following completion of the study.

Results

ECG findings

Performance data were calculated after each trial was completed (ANALYSE findings vs traditional). Marks were awarded based on how exactly answers correlated to those outlined within the score sheet (Supplementary Appendix 1). The overall aggregated mark attained using the ANALYSE format was 75 per cent (range = 55%–93%, SD = 9) and the overall aggregated mark attained using the standard format was 53 per cent (range = 38%–82%, SD = 12). A total of 14/15 participants consistently scored higher when interpreting ECGs using the ANALYSE format (range = 10%–45%). One participant scored lower using this format (−11%). A significant difference between the aggregated marks scored using the ANALYSE format and the standard format was calculated (Wilcoxon Z Score = −3.2374 (df = 14, $p < 0.05$) (Table 2). Figure 8 depicts box plots that illustrate the significant impact the ANALYSE tool has on ECG interpretation across the entire distribution.

Survey findings

The usefulness of the ANALYSE format was highly rated (mean = 9, median = 9, SD = 1), participants commented that ANALYSE was a faster and efficient ECG reporting mechanism that assisted in clarifying their answers and supporting their decisions particularly when they were uncertain. Participants rated the drop-down menu option most favourably (n = 15, 100%) stating that this feature is what enabled them to rapidly interpret the ECG (n = 12, 75%) and to do so more accurately (n = 9, 56%). Participants stated that using the ANALYSE format would improve their competence in learning ECG interpretation (n = 15, 100%). Decision-making is faster because the correct ranges of normality are available and really help with interpretation and the acquisition of this practical skill. All participants agreed that the ANALYSE format should be adopted into the curriculum of this topic (n = 15, 100%). Prior to completing the interpretation, participants rated their ability to interpret an ECG as low (median = 4, SD = 1) stating that they felt not knowledgeable enough at this stage of their learning, they lacked confidence in performing this skill and that they identified a lack of independent study (n = 5). No significant improvement in their confidence performing this skill on completion was reported (median = 5, SD = 2) although participants testified that the experience identified what gaps they had in their understanding and that ANALYSE assisted with identifying what a learner needs to know to achieve competency of this skill.

Discussion

Traditional teaching practices of ECG interpretation are didactical and they primarily focus on memorising diagnostic criteria and morphological patterns of ECG rhythms.[7] Memorising abstract signals, such as the shape of the complexes seen in ECGs, and associating them with disease processes has its limitations; thus, teaching ECG interpretation remains a challenge for educators.[4]

The cardiological knowledge that is needed for interpreting ECG patterns can be categorised as morphological waveform knowledge of ECG tracings and the physiological event knowledge of the cardiac conduction system.[1] Accurate medical image interpretation is the culmination of a two-stage process that incorporates both the perceptual skills (they must be able to search the image and detect the abnormality) and the decision skills of the reader (once the abnormality is focused upon, readers must interpret it). Learning is accomplished by the repeated implementation of a skill which can be applied to every ECG tracing over and over again until fluency is achieved.[1] In this study, the Smart Form ANALYSE supported learner's ECG interpretation ability by increasing the documentation of information acquired and improving compliance of relevant diagnostic terminology necessary to fully interpret an ECG. Like some DSS that use disease-specific templates, the Smart Form ANALYSE organises clinical data in a focused manner to facilitate decision-making and also highlights and 'requests' information related to ECG abnormalities.[11–13]

The curriculum for teaching ECG interpretation varies across learning establishments with the incorporation of indigenous protocols and techniques. In addition, different interpreters adopt various analytical techniques and nomenclature.

While it may be simplistic, the Smart Form ANALYSE may help educators to eventually develop more effective training in ECG interpretation to expedite the learning process in novices.

Limitations

This study design is a proof of concept and preliminary testing study investigating ANALYSE as a learning tool of ECG interpretation. A limitation of this study was the small number of participants sampled. This reflected the recruitment of participants enrolled on module ECG interpretation within the Healthcare Science degree programme (participation rate = 93.7%). This cohort offered a uniform sample to study as they possessed similar academic knowledge and clinical practical experience of the 12-lead ECG interpretation.

ECG tracings illustrating structural and/or rhythmical disturbances and abnormalities were incorporated for interpretation omitting ECG tracing of myocardial infarction. Testing to detect several ECG manifestations is a primary learning outcome of this module so that a participant can demonstrate advanced appraisal of clinical presentations. Due to the clinical relevance of this pathology and the consequence for patient management, future studies should incorporate ECG tracings of myocardial infarction.

Conclusion

The findings of this study demonstrate the clinical utility of a simple teaching Smart Form ANALYSE for the 12-lead ECG interpretation and its association with enhanced diagnostic performance in learners. Future studies involving larger numbers of subjects, from which the findings of this study will inform of the sample size calculation, and the incorporation of a broader range of ECG tracings are recommended.

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Clinical relevance

The purpose of the Smart Form ANALYSE was to support learners with ECG interpretation by increasing the documentation of information acquired and improving compliance of relevant diagnostic terminology necessary to fully interpret an ECG. The Smart Form ANALYSE is primarily a documentation tool and has many features including the ability to add, edit and delete structured ECG information. While it may be simplistic, the Smart Form ANALYSE may help educators to eventually develop more effective training in ECG interpretation to expedite the learning process in novices.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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Graphical timeline software for inpatient medication review

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Abstract

MedHistory is a web-based software module that graphically displays medication usage (y-axis) against time (x-axis). We set out to examine whether MedHistory would improve clinician's interactions with the medical record system. The authors invited house-officers at our institution to complete a survey about inpatient medication administration before and after using MedHistory. Detailed logs were also kept for 1 year after the study period. Compared to the pre-intervention survey, the post-intervention survey found that reviewing medication history was easier (pre: 13.2% vs post: 32.4%, $p = .008$), that medication review now fit within resident workflow (38.9% vs 75.7%, $p < .001$), and that there was increased satisfaction with the electronic health records software (2.6% vs 29.7%, $p = .002$). Additionally, determining the timing (29% vs 50.1%, $p = .045$) and dosing history (21.1% vs. 43.2%, $p = .036$) of inpatient medication administration was easier with MedHistory. Anti-infective agents and drugs requiring frequent adjustments were the most commonly reviewed. A graphical timeline of inpatient medications (MedHistory) was met with favorable response across multiple areas, including efficiency, speed, safety, and workflow.

Keywords

data visualization, electronic medical records, medication administration

Background

Medication administration is an essential part of inpatient medical care, yet remains an important source of iatrogenic adverse events.[1] Multiple strategies employ information technology to minimize inpatient medication adverse events, including electronic health records (EHR), computerized physician order entry, clinical decision support systems, alerts, barcodes, and electronic medication administration records, with variable effect.[2–7] Adverse events related to inpatient medication administration persist, despite the wide-scale use of information systems related to inpatient medication administration.[8,9]

The usability of these systems, particularly the speed, efficiency, and design, is increasingly recognized as important in determining their efficacy, as is the visualization of the resultant data

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generated.[10,11] In 2012, an American Medical Informatics Association (AMIA) task force called for standardization of certain components of EHRs to improve accessibility, usability, and interoperability.[12] Many systems are still not optimized to display and process the large amounts of data presented in an inpatient clinical setting.[12,13] In addition, these systems are often built without usability in mind, which may limit the benefit to clinicians.[14] Graphical displays assimilate large quantities of data into succinct, visually appealing charts.[15,16] For inpatient medication administration, graphical tools could allow the clinician to quickly visualize the timing, name, and dosages of a patient's medication history.

Objectives

We postulated that software designed to graphically present inpatient medication administration history would improve clinician's interactions with the medical record system and allow for easier access to data, ultimately improving efficiency and satisfaction. By creating this software, and subsequently surveying medical residents at our institution before and after using the software, we sought to address these questions. In addition, following the study (when the software was subsequently made generally available), we kept detailed records of usage patterns to identify patterns and trends in the data sought and used by clinicians.

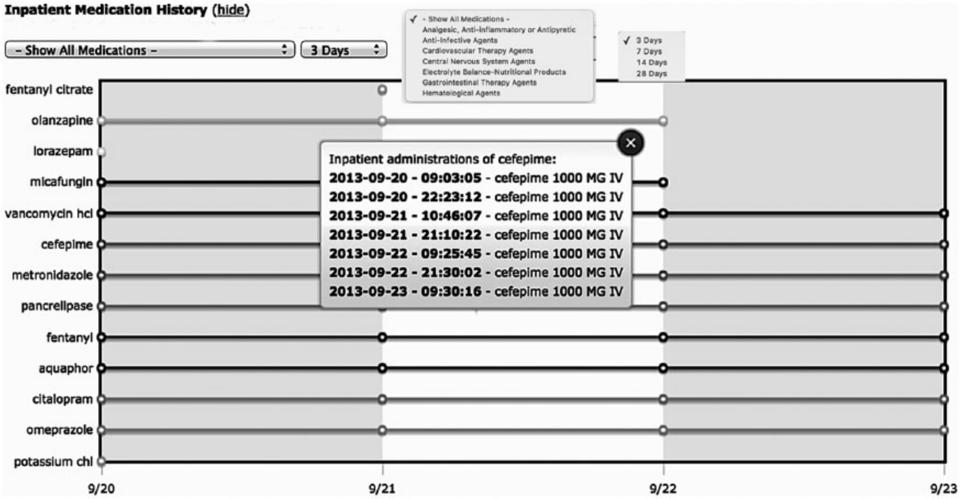
Methods

MedHistory

MedHistory (MH) is an inpatient medication review tool that we created to improve physician review of inpatient medication administration. MH graphically displays medications (y-axis) against time (x-axis), allowing clinicians the ability to quickly assess medication administration history. By default, the graph presents a simple view indicating which medications were administered, but does not specify timing or dose. However, MH is interactive, easily allowing granular data display. For example, clinicians can click on a specific medication name to display specific dosing and timing. In addition, the graph can be filtered by time or medication class (Figure 1). MH is embedded within the existing sign-out and rounding tool (a proprietary web-based solution) previously used by all residents, as well as most clinical fellows and attending staff at our institution.[17] Recognizing a need for improved medication review, MH was custom-built by the authors over several months prior to study initiation. Beta-testing was done by a small group of clinical volunteers not involved in the study. MH is a web-based tool, largely built with JavaScript/HTML, specifically jQuery (https://jquery.com) and Flot (http://www.flotcharts.org). It was designed for desktop computers, and also works on tablets and mobile devices.

Study design

Prior to release of the software, all internal medicine residents (n = 189) at our institution (a large, 1000+ bed quaternary care medical center) were invited to complete an optional survey on current practices, limitations, and opinions related to inpatient medication review. A link to the survey was sent via email. After ascertaining current post-graduate year, the questions focused on current practices with respect to inpatient medication review: for example, what specific software they used currently, the settings in which individuals reviewed inpatient medications (cross cover, discharge planning, etc.), challenges they faced in reviewing these medications, and specific classes of medications for which they felt detailed medication review was particularly important. Finally, the last



Inpatient administrations of cefepime:
2013-09-20 - 09:03:05 - cefepime 1000 MG IV
2013-09-20 - 22:23:12 - cefepime 1000 MG IV
2013-09-21 - 10:46:07 - cefepime 1000 MG IV
2013-09-21 - 21:10:22 - cefepime 1000 MG IV
2013-09-22 - 09:25:45 - cefepime 1000 MG IV
2013-09-22 - 21:30:02 - cefepime 1000 MG IV
2013-09-23 - 09:30:16 - cefepime 1000 MG IV

Figure 1. MedHistory shows medications plotted against time (in days). The graph is interactive, allowing clinicians to click for more granular information, for example, specific medication dosages and timing.

five questions asked residents to rate a series of subjective statements using a Likert scale that assessed satisfaction with existing tools (e.g. “Efficiently reviewing medication administration history is easy” and “I am satisfied with current methods of reviewing medication administration”). The survey was administered at the end of the academic year, so all respondents had at least 11 months of experience with the current Electronic Medical Record (EMR).

Residents who completed the initial survey were granted access to MH and given a brief overview and instructions on usage. Clinical setting was not restricted, and residents could use MH in a variety of settings (intensive care unit (ICU), general wards, consult service, etc.). After 2 weeks, a reminder email with instructions on usage was sent to those with access to MH. After 5 weeks of usage, the residents who completed the initial survey were invited via email to complete a second survey. The follow-up survey was identical to the initial questionnaire, with the addition of four statements the residents were asked to rate using a Likert scale (e.g. “the graphing tool made viewing medication history easier” and “the graphing tool made discharge planning safer”). The residents were instructed to answer these last questions only if they had used MH.

At the end of the study, MH was made generally available to all clinicians at our institution and at a sister institution. We kept detailed, blinded, de-identified usage logs during a 12-month post-study period. We tracked patterns of usage, including time of day and week, specific medication classes, and specific medications viewed, as well as role (attending, fellow, resident, etc.) of the users.

Analysis

Baseline comparisons between the initial survey group and those who completed the survey and indicated they had used MH were done using Pearson’s chi-square test. The pre- and post-usage questions, graded using a Likert scale as described above, were compared with the Wilcoxon signed-rank test. Questions answered only by those who used MH were tabulated as well.

Table 1. Baseline characteristics and comparisons of initial survey respondents with MedHistory (MH) users.

Characteristics	Completed initial survey (n = 101)	Completed post-survey and used MH (n = 38)	p-value
Post-graduate year			
1	37 (36.6%)	12 (31.6%)	
2	33 (32.7%)	17 (44.7%)	
3	29 (28.7%)	9 (23.7%)	
4 or greater	2 (1.98%)	0 (0%)	
			.18
In the hospital, I review a patient's inpatient medication history			
Cross cover	72 (71.3%)	30 (79%)	0.19
Discharge planning	77 (76.2%)	32 (84.2%)	0.14
Day-to-day management	99 (98.0%)	38 (100%)	0.27
Consultant	34 (33.7%)	14 (36.8%)	0.60
Challenges of reviewing inpatient medication administration history			
Accuracy	24 (23.8%)	10 (26.3%)	0.64
Availability	31 (30.7%)	13 (34.2%)	0.55
Data presentation	86 (85.2%)	33 (86.8%)	0.71
Speed of accessing data	87 (86.1%)	35 (92.1%)	0.18

Questions were asked in the pre-intervention survey only. Comparisons were made and p-values calculated using chi-square test.

Study data were collected and managed using REDCap electronic data capture tools hosted at our institution.[18] Statistical analyses were performed using Stata software, version 12.0 (StataCorp, College Station, TX) and R (R Core Team, 2016; https://www.R-project.org). The Partners HealthCare Human Research Committee determined the study to be exempt from review.

Results

Invitation emails were sent to 189 people, and 101 filled out the pre-usage survey. The survey respondents represented all four post-graduate years. A total of 48 residents opted to fill out the post-usage survey, 38 of whom indicated they had used MH. Initial resident respondents (n = 101) indicated that they reviewed inpatient medications for a variety of purposes, including cross cover (72/101, 71.2%), discharge planning (77/101, 76.2%), day-to-day management (99/101, 98%), and as consultants (34/101, 33.6%). Initial respondents also indicated several challenges to inpatient medication review, including accuracy (24/101, 23.8%), availability (31/101, 30.7%), data presentation (86/101, 85.2%), and speed (87/101, 86.1%). There were no significant differences between individuals who completed only the initial survey and those who used MH and completed the follow-up survey (Table 1).

MH was generally met with positive response, with most individuals answering "agree" or "strongly agree" to survey questions using a Likert scale. Of the 38 residents who completed both surveys and indicated they used MH, the vast majority (31/38, 81.5%) felt the tool made viewing medication history easier, 78.9 percent (30/38) indicated it saved them time, and 50 percent (19/38) felt it made discharge planning safer (Figure 2, "agree" or "strongly agree"). Compared to the pre-intervention survey, the post-intervention survey found that reviewing medication history was

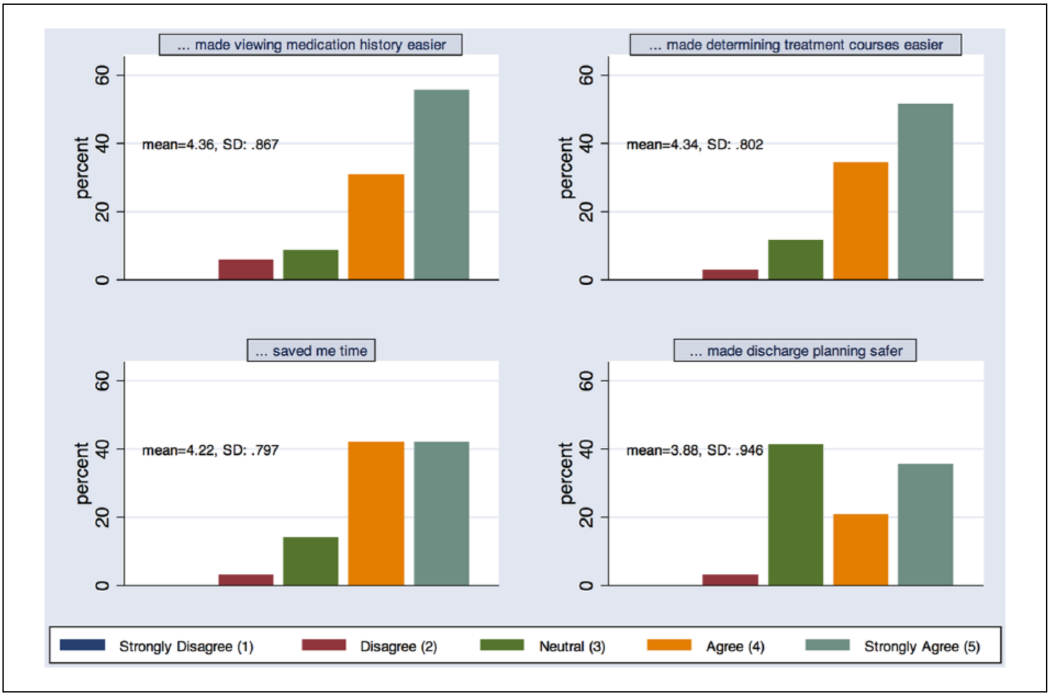


Figure 2. Post-intervention survey results. For all four questions, MH was met with favorable response.

easier (pre: 13.2% vs post: 32.4%, z = −2.65, p < .01), that medication review now fit within resident workflow (38.9% vs 75.7%, z = −3.89, p < .001), and that there was increased satisfaction with the EHR software (2.6% vs 29.7%, z = −3.09, p < .01). Additionally, determining the timing (29% vs 50.1%, z = −2.00, p < .05) and dosing history (21.1% vs 43.2%, z = −2.10, p < .05) of inpatient medication administration was easier with MH (Figure 3).

Patterns of usage were tracked for 12 months following the end of the study period through detailed log collection. Study authors and beta-testers were specifically removed from the log data that were analyzed. Anti-infective agents were the most widely used drug class filter (67%, n = 12,037; Table 2). In addition, 3 of the top 10 medications viewed over the 12 months of analysis were antibiotics (vancomycin, cefepime, and ceftriaxone). Other medications commonly viewed were medications requiring frequent dose adjustments (furosemide and metoprolol) or medications requiring adjustments based on laboratory values (potassium, warfarin, heparin, and insulin) (Table 2). Finally, residents and medical students tend to use MH the most, though fellows and attendings also used MH.

Discussion

We have shown that implementation of a graphical timeline-based method of displaying inpatient medication history ("MedHistory") subjectively improved medication review—more than 80 percent of residents indicated improvements in time spent on medication review and ease of viewing medication administration. In addition, comparing pre- and post-intervention surveys, significant improvements were noted in ease of use, as well as subjective workflow benefit, specifically around medication review.

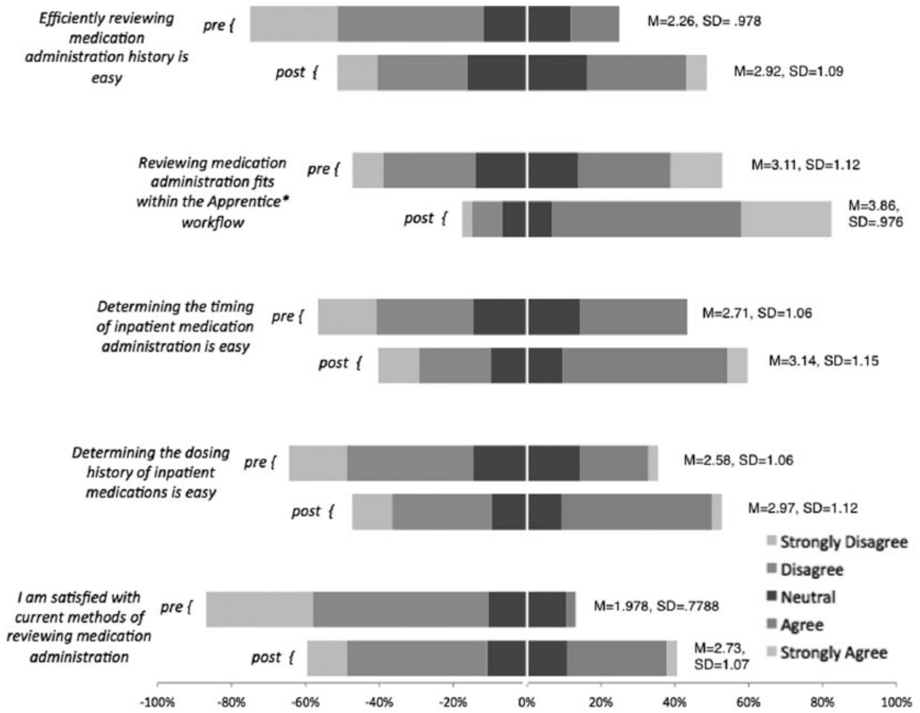


Figure 3. Comparison of pre and post-intervention survey questions. All five questions were asked on a Likert scale (“strongly disagree” → “strongly agree”). Each stacked bar represents percent responses for that question, with pre- and post-intervention questions paired for comparison.

MH did not require instructions or training for clinicians to use—our only active intervention was a reminder email halfway through the study period. Usage of MH relied on the intuitive nature of the graph, a critical part of understanding visualizations of patient data. These visualizations can subsequently support complex tasks, like a detailed patient medication history.[19] MH also emphasized time, an essential part of visualizations.[20] As clinicians are exposed to increasing quantities of patient data in the hospital, improved methods of processing and visualizing this data are critical to clinician workflow and patient safety. Medication administration, an essential part of inpatient medical care, is an ideal focus for these kinds of interventions.

Usage patterns in the 12 months following the study period revealed several important insights. First, our data point to several medications that users sought more detailed information about. These medications (e.g. vancomycin, furosemide, cefepime, and potassium) are ripe targets for clinical decision support at the point of electronic ordering. Traditional representation of medication dosing (name, dose, route, and frequency) may not be adequate to fully represent the clinical significance of these medications. Anti-infective agents as a class were particularly heavily utilized (10 of the top 25 medications, 67% overall) which emphasizes not only their importance in inpatient medicine but also the number of clinical events potentially associated with this class of medications (drug rash, drug fever, acute interstitial nephritis, etc.) where exact timing and dosing is important. MH facilitates a more comprehensive medication history that is challenging to replicate using traditional tools, particularly at our institution. Prior to initiation of MH, medication review was electronic and based on commercial modules in conjunction with in-house modules; however, it was text-based,

Table 2. Most frequent medications, drug class distribution, and the number of users by role/position for the 12 months following the study period when MH was widely available.

Medication	Views	Users
Vancomycin	294	97
Cefepime	120	46
Furosemide	106	46
Heparin	54	39
Metoprolol	52	34
Ceftriaxone	51	24
Insulin	49	41
Ciprofloxacin	48	30
Hydromorphone	47	31
Levofloxacin	46	29
Prednisone	45	29
Warfarin	43	27
Metronidazole	42	27
Potassium	40	32
Lorazepam	40	24
Acyclovir	37	21
Dexamethasone	30	14
Hydrocortisone	28	14
Enoxaparin	26	17
Acetaminophen	25	22
Ceftazidime	25	12
Oxycodone	25	15
Imipenem	23	11
Linezolid	22	11
Methylprednisolone	20	15

Usage by drug class

Drug class	Percent total
Hematologic agents	6.8
Anti-infective agents	67.0
Cardiovascular therapy agents	7.9
Analgesic, anti-inflammatory, anti-pyretic	7.0
Central nervous system agents	4.4
Electrolyte balance, nutritional products	3.0
Gastrointestinal therapy agents	2.8

Users by role/position

Role	Users	Percent total
Medical student	40	16.39
Resident	148	60.66
Fellow	29	11.89
Physician's assistant	3	1.23
Attending	24	9.84
Total	244	

The top 25 medications viewed (of over 500) are shown.

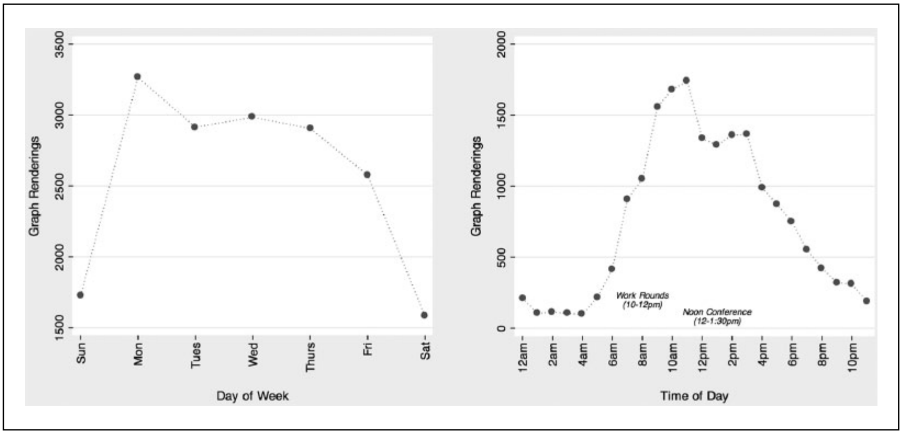


Figure 4. MH viewing patterns by day of week and time of day.

slow to load, and could only display 5–10 medications at once. The prior solution had a time-series representation, but it had similar limitations—only 5–10 medications could be viewed at once, it was slow to load, and had extraneous information, for example, all medication orders were listed as separate entries, so one medication could be listed many times if the dosing had changed.

Finally, usage patterns reflected the workflow of an academic medical center. The majority of users were residents and medical students (those closest to medication ordering and adjustments), but also included consultants and more senior clinicians. Usage peaked on Mondays and was particularly high in the late-morning, perhaps reflecting the importance of MH in work rounds but also discharge planning (Figure 4).

Strengths of our study included the fact that the study group consisted of residents from all post-graduate years, so represented different stages of clinical training. In addition, MH was integrated in the current rounding and sign-out tool that all house-staff use, so did not require separate installation or configuration. Our study design allowed for qualitative, immediate feedback on a new intervention; none of the study group had been exposed to MH until the study period.

Our study also has several important limitations. Because our study group was using MH for the first time, it is possible that the efficacy of the intervention was limited by a learning curve. Efficiency and comfort with the software would be expected to improve over time. In addition, our study data were largely qualitative. Though residents indicated subjective improvement across multiple measures, we did not objectively assess improvements in time or efficiency. Our response rate was also modest, with only 38 out of 189 possible residents using MH and completing both surveys (though this rate is similar to other studies of residents in general[21,22]). Although we found no significant difference between respondents who completed only the initial survey and those who completed both surveys, both groups could still represent those biased toward new technology and clinical improvements. Finally, our study subjects included only medical residents—we did not survey non-residents.

Conclusion

In conclusion, a graphical timeline to display inpatient medications was met with favorable response across multiple areas, including efficiency, speed, safety, and workflow. This approach has the potential to improve clinician review of medication administration and other forms of clinical data for which timing and duration are relevant. Future studies could objectively measure the impact of these systems on patient safety and clinician efficiency.

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Extended use of electronic health records by primary care physicians: Does the electronic health record artefact matter?

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Abstract

The deployment of electronic health record systems is deemed to play a decisive role in the transformations currently being implemented in primary care medical practices. This study aims to characterize electronic health record systems from the perspective of family physicians. To achieve this goal, we conducted a survey of physicians practising in private clinics located in Quebec, Canada. We used valid responses from 331 respondents who were found to be representative of the larger population. Data provided by the physicians using the top three electronic health record software products were analysed in order to obtain statistically adequate sub-sample sizes. Significant differences were observed among the three products with regard to their functional capability. The extent to which each of the electronic health record functionalities are used by physicians also varied significantly. Our results confirm that the electronic health record artefact 'does matter', its clinical functionalities explaining why certain physicians make more extended use of their system than others.

Keywords

clinical decision-making, electronic health record artefact, electronic health records, health care service innovation and IT, primary care

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Introduction

The deployment and use of information technology (IT) artefacts play a critical role in the profound changes occurring in health care systems around the world. Among these artefacts, electronic health record (EHR) systems are designed to support the core activities of primary care physicians and other health care professionals in medical practices and ambulatory care settings. EHR systems aim to support patient-centred care, the coordination of such care, and the exchange of clinical information to improve quality of care.[1,2]

Despite the potential benefits associated with these systems, problems remain with regard to achieving extensive and mindful use by primary care physicians.[3–5] This may be due to a lack of awareness, as a significant gap has been identified between the functionalities presently offered in EHR systems and those actually being used by physicians.[6] It may also be due to software vendors, medical associations, and health care authorities that emphasize the automational impacts of EHR solutions,[7] seeking to implement the 'paperless' primary care practice[8] at the expense of the informational and transformational impacts that would lead to the 'smart' medical practice.[9]

While previous research has suggested than less-than-optimal use of the EHR artefact might be related to a lack of awareness of functionality or insufficient emphasis on the transformational potential of this type of system, we propose a third explanation which focuses on the differences among EHR artefacts with regard to their functional capabilities. As a fact, functional differences exist between the various EHR software products available on the market,[10] despite the creation by governments in recent years of EHR software certification and adoption incentive programs,[5] brought about by the push for more meaningful EHR use in the United States[11] or more extended use in countries with national health care systems such as the United Kingdom and Canada.[12,13] Since EHR systems are not all created equal by software vendors,[14,15] it becomes relevant and important to ask whether such differences in terms of system functionalities influence usage by primary care physicians.

In light of the above, this study aims to conceptualize the EHR artefact, and to do so in a comprehensive and multi-faceted manner in order to place it at the theoretical and empirical core of the medical informatics field.[16] Since EHR systems are highly contextualized due to their mission-critical nature,[5] we intend to generate empirically valid and useful findings on how these systems are characterized as IT artefacts from the perspective of their main users, that is, primary care physicians. To this end, we seek to answer the following research questions: What are the differences between the various commercial EHR solutions in terms of ease of use and context of use? What are the differences between EHR artefacts in terms of the clinical, communication, and administrative functionalities that are available to primary care physicians? And, most importantly, do these differences explain the extent of EHR use by family physicians?

Background

This study emanates from a body of work that has sought to define and characterize the IT artefact for Information Systems (IS) research purposes, focusing on its nature as a software application.[17] From this perspective, EHR systems are considered as software packages developed and commercialized by software vendors, whose design attributes are meant to support medical practices.[18] In conceptualizing and theorizing EHRs as an IT artefact, the ultimate aim is to better understand the extent of fit between the design of an EHR system and both the practice's processes and a physician's main tasks.[19]

The fundamental differences between system designers and users were initially ascertained by researchers investigating business software design in general.[20] Users have been found to use software in ways not anticipated by designers,[21] to differ from designers in their satisfaction with design methodologies,[22] and to behave differently from what was expected by the designers when

Table 1. Two complementary research perspectives on the EHR artefact.

	EHR designers' perspective (e.g. EHRsoft1, EHRsoft2, EHRsoft3)[a]	EHR users' perspective (e.g. primary care physicians)
EHR research focus	Theoretical EHR artefact (technological capability)	Empirical EHR artefact (functional capability)
EHR research variables	Technical features of the EHR artefact	Functionalities of the EHR artefact mobilized by its use
Basis for understanding the EHR artefact	Influence of the EHR artefact and its technical features	Influence of the EHR artefact and the functionalities mobilized by its use Influence of context of use on the EHR artefact and its functionalities
Implications for EHR research and practice	Limited understanding of the role of the EHR artefact in situ, that is, in primary care settings Faster obsolescence of practical implications	Improved understanding of the role played by the EHR artefact More opportunities for practical improvements to the EHR artefact and its use in primary care settings

EHR: electronic health record.

[a]Aliases of three major EHR solutions in use in primary care medical practices in Quebec, Canada.

they access business Web sites.[23] Similar discrepancies have also been identified between developers' and users' appraisals of the technology-task fit of health IT artefacts such as PACS (picture archiving and communication systems) and EHR systems.[24,25]

The user's perspective differs from the software designer's perspective. The former is in the presence of an empirical – as opposed to a theoretical – artefact whose conceptualization is founded upon a functional configuration, that is, the functionalities of the EHR system actually being used; whether such a configuration has been designed by the software developer or has emerged from the user's adaptations. Table 1 synthesizes the two research perspectives on the EHR artefact in terms of the research focus, the research variables, the basis for understanding the EHR artefact, and the implications for EHR research and practice.[26]

The user's perspective focuses on the *why* of the EHR artefact's existence, on the *needs* of users (including how they change over time), and on *how* they can use and adapt this artefact in a complex and dynamic social context.[27] Implications for practice are thus centred on the artefact's usefulness, that is, on the functional evolution (customization) of the EHR artefact, made in collaboration with the artefact's vendor, in order to optimize its use by primary care physicians.[28,29] In our previous work,[6] we reviewed the relevant literature[30–34] to identify the functionalities required by EHR artefacts to fulfil their purpose in primary care settings. These functionalities were then classified along three dimensions: clinical, communication, and administrative.

Figure 1 presents the formative model of the EHR artefact that emerged from our previous study.[6] By characterizing an IT artefact in this way, we seek to represent the user's perspective as founded on the functionalities actually used.[35] More precisely, the EHR artefact construct is operationalized through the three functional dimensions identified above, each dimension capturing a different aspect of the construct, and the combination of the three defining the construct. Hence, the EHR artefact is modelled as a formative construct in light of its composite and multidimensional nature.[36]

Method

We employed a Web-based survey to collect data for our research questions. We approached the 4845 members of the Quebec Federation of General Practitioners (QFGP), in the province of

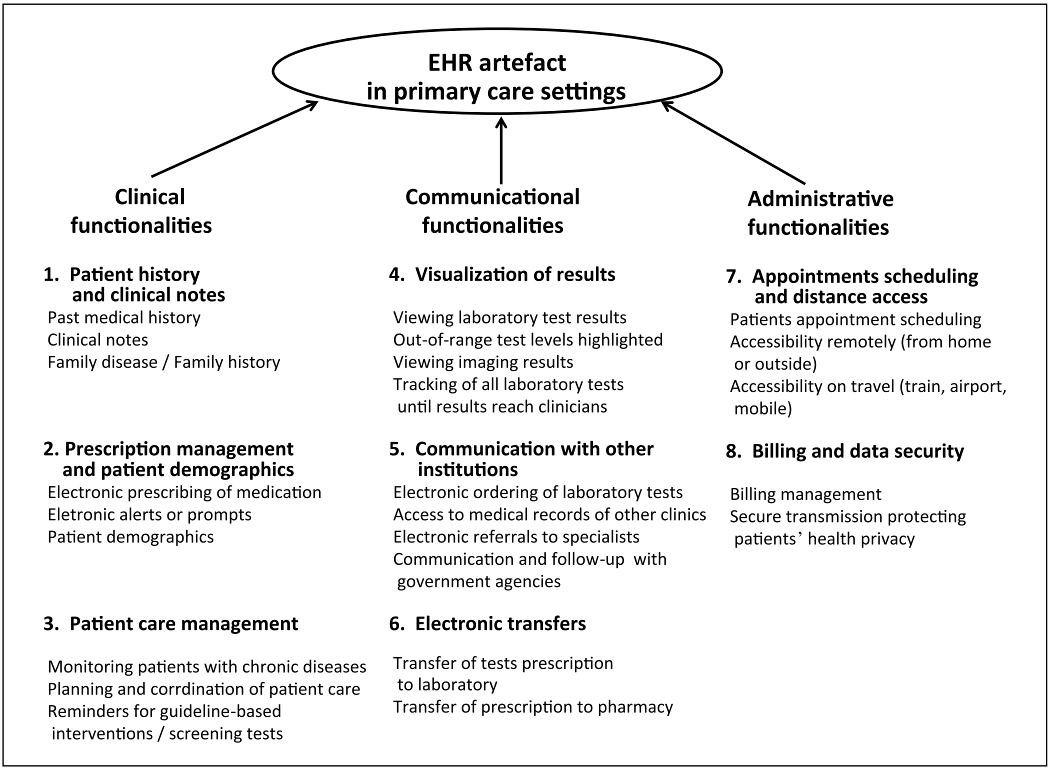

Figure 1. Formative model of the EHR artefact as used in primary care settings.
Source: Adapted from Raymond et al.[6]

Quebec, Canada, who could be reached by email. Valid responses were obtained from 780 family physicians. While the survey's 16 per cent response rate appears satisfactory, the potential for response bias was assessed by comparing the 156 late respondents (i.e. those who answered after receiving a reminder sent 1 week after the initial invitation to participate) with the 624 early respondents. As no statistically significant difference was found between these two sets of respondents on all attributes, response bias was deemed unlikely.[37] The sample was also confirmed to be statistically representative of the target population, that is, the QFGP's members, in terms of age, gender, and years of professional experience.

While the survey initially targeted two different types of physicians – those working in medical practices with and without EHR systems – only the responses from the 331 physicians who were actually using EHR systems are of interest here. Using an initial list of 24 EHR system functionalities (see Figure 1), we asked our respondents to indicate whether each functionality was available (or not) in their EHR system, and if available, whether they actually used it (or not). We also asked them to indicate their level of satisfaction with each of these functionalities using a 5-point scale (1: very dissatisfied, 5: very satisfied). The EHR artefact's ease of use, that is, the extent to which the respondent perceived its use to be free of effort, was measured with an instrument borrowed from the Commonwealth Fund's international survey of primary care physicians,[38] composed of eight 5-point scales (1: unable to use, 2: difficult, 3: neutral, 4: easy, 5: very easy to use). We confirmed its reliability (Cronbach's $\alpha = 0.81$). Note that this measure is bi-dimensional,[6] as two items indicate ease of use in patient management (e.g. 'List of all medications taken by an individual patient') and six items indicate ease of use in communicating with care providers (e.g. 'List of patients vulnerable or not vulnerable to specific diagnoses/disease cohorts').

The context of use of the EHR artefact was ascertained by asking respondents to indicate the length of their experience (in years) as a family physician and as a user of EHR systems, as well as the size and EHR experience of the medical practice in which they worked (number of physicians and number of years since the first EHR implementation, respectively). Finally, given the nature of the initial research questions, the collected data were interpreted through analysis of variance (ANOVA) and analysis of covariance (ANCOVA), as well as through regression analyses.

Results

Out of the 331 primary care physicians who used an EHR artefact, 48 per cent were women. As for their age, 38 per cent were in their 50s, 28 per cent in their 40s, and 19 per cent in their 30s. They had an average of 22 years' experience in the medical profession, with a minimum of 2 and a maximum of 45. They also had an average of 4 years' experience using their clinic's EHR system, with 56 per cent of the sampled physicians having 3 years of experience or less. Moreover, 167 physicians (50.5%) indicated using EHRsoft1's EHR software product, 66 (20%) used EHRsoft2's product, 48 (14.5%) used EHRsoft3's product, while the 50 other physicians (15%) used a variety of other EHR software products. Note that all EHR vendor names in this study are aliases. Since answering our research questions requires making comparisons of the functional configuration of the EHR artefacts deployed in primary care settings, we analysed only the data provided by the physicians using the three main vendors' EHR software products (n = 281) in order to obtain statistically adequate sub-sample sizes.

Given our study's main objective and the ensuing formative model of the EHR artefact (Figure 1), our first analytical task is to describe and characterize this artefact from the family physician's perspective. Concerning our first research question, the results presented in Table 2 indicate one significant difference in the contexts of use of the three EHR artefacts: the 167 physicians using EHRsoft1's software product had significantly less experience using their EHR (3 years on average) than the 66 physicians using EHRsoft2's product (5 years) and the 48 physicians using EHRsoft3's product (6 years). This may be related to the fact that EHRsoft1 penetrated Quebec's EHR market relatively recently when compared to the other two vendors. Furthermore, the medical practices that implemented EHRsoft1's product had significantly more organizational experience with EHR systems (2 years on average) than those that implemented EHRsoft3's product. Another noteworthy result is that all three EHR artefacts were characterized similarly in terms of ease of use, that is, all were perceived by their respective users to be equally difficult to use (2 on average, on a scale of 1–5), with regard to both patients and other care providers. This last finding clearly raises questions about the design quality of the EHR artefacts' human–system interfaces, despite the fact that all three have been certified by Quebec's health care authorities and Canada Health Infoway.

Table 3 presents the differences observed between the three EHR artefacts in terms of their functional capabilities, that is, the perceived availability of clinical, communication, and administrative functionalities, using our formative model of the EHR artefact as a benchmark. We first note that in the eyes of primary care physicians, EHRsoft1's software product clearly dominates the other two solutions in terms of the availability of clinical functionalities. For instance, 66 per cent of EHRsoft2's users reported that the 'patient care management' functionality is available in their EHR system, as opposed to 37 and 56 per cent of EHRsoft2's and EHRsoft3's users, respectively. All three artefacts are rather similar in terms of the perceived availability of communication functionalities, except for greater availability of the 'communication with other institutions' functionality in the EHRsoft1 software product (45%, vs 20% and 18% for the other two). Finally, EHRsoft3's

Table 2. Characterization of the EHR artefact's context and perceived ease of use.

	EHR artefact developer/vendor			ANOVA F
	EHRsoft1 mean ($n = 167$)	EHRsoft2 mean ($n = 66$)	EHRsoft3 mean ($n = 48$)	
Organizational context of use				
EHR experience of the practice (years)	16.0^{a}	14.5^{a,b}	14.0^{b}	7.2***
Size of the practice (no. of physicians)	12	11	12	0.5
Individual context of use				
EHR experience of the user (years)	2.9^{b}	5.3^{a}	6.0^{a}	21.4***
Primary care experience of the user (years)	21	22	24	1.3
Perceived ease of use of the EHR artefact				
In patient management	2.8	2.5	2.9	2.5
In coordinating care with other care providers	1.7	1.8	2.0	1.4

EHR: electronic health record; ANOVA: analysis of variance.

[a,b]Within a given row, different indices indicate a significant difference ($p < 0.05$) between two means on the basis of Tamhane's T2 (post hoc) test.

***$p < 0.001$.

software product is found to be inferior in terms of the perceived availability of administrative functionalities and especially with regard to the 'appointment scheduling/remote access' functionality (65% vs 89% and 86% for the other two). Note that these differences remain significant when controlling for the primary care physician's EHR experience and primary care experience, as well as for the EHR artefact's perceived ease of use.

Next, we validated the preceding characterization of the EHR artefact from the user's perspective, having ascertained that such a characterization is both relevant and useful to health IT theory and practice. To this end, we examined the relationship between the artefact's design and its use in a primary care context. Our aim was to determine whether characterizing an EHR artefact from the user's perspective can help us to predict and explain the nature and extent of its use and eventually assist in the design of EHR artefacts.

In response to our second research question, the nature of EHR use was defined through the three basic purposes for which it is assumed that primary care physicians use these systems: for clinical, communication, and administrative purposes. The extent of this use can range from none at all to full extended use of all available functionalities. The results presented in Table 4 clearly indicate that there are significant differences between the three EHR artefacts in terms of the extent of their use by physicians. More specifically, users of the EHR system developed by EHRsoft1 were found to use significantly more clinical functionalities than users of either the EHRsoft2 or the EHRsoft3 software products. For instance, physicians in the EHRsoft1 group make use of 65 per cent of the clinical functionalities they perceive to be available in their EHR system, as opposed to 44 per cent for the EHRsoft2 group. Moreover, physicians using EHRsoft2's product use a greater number of communication functionalities than those in the EHRsoft3 group (38% vs 27% of the functionalities perceived as available). Once again these differences remain significant independent of the physicians' EHR experience, primary care experience, and perceptions of the ease with which their system can be used.

To further explore the differences identified above, the physicians' satisfaction with their system's clinical, communication, and administrative functionalities was compared among the three

Table 3. Differences between EHR artefacts with regard to their functional capabilities.

Primary care physicians as users of an EHR artefact	EHR artefact developer/vendor			ANOVA F	ANCOVA F¶
	EHRsoft1 mean (n = 167)	EHRsoft2 mean (n = 66)	EHRsoft3 mean (n = 48)		
Perceived availability of EHR functionalities[d]					
Clinical functionalities					
Patient history/clinical notes	0.98[a]	0.64[c]	0.84[b]	46.8***	38.9***
Prescription management/ patient demographics	0.91[a]	0.73[b]	0.88[a]	16.0***	15.7***
Patient care management	0.66[a]	0.37[b]	0.56[a,b]	12.8***	8.7***
Communication functionalities					
Visualization of results	0.64	0.70	0.65	1.2	0.6
Communication with other institutions	0.45[a]	0.20[b]	0.18[b]	26.7***	11.9***
Electronic transfers	0.3	0.28	0.31	0.1	0.0
Administrative functionalities					
Appointment scheduling/ remote access	0.89[a]	0.86[a]	0.65[b]	20.9***	15.4***
Billing and data security	0.82[a]	0.72[a,b]	0.61[b]	8.5***	8.1***

EHR: electronic health record; ANOVA: analysis of variance; ANCOVA: analysis of covariance.

[a,b,c] Within a given row, different indices indicate a significant difference ($p < 0.05$) between two means on the basis of Tamhane's T2 (post hoc) test.

[d] No. of EHR functionalities available/total no. of EHR functionalities.

¶With covariates: EHR experience and size of the practice, EHR experience and primary care experience of the user, and perceived ease of use.

***$p < 0.001$.

Table 4. Differences between EHR artefacts with regard to their use by primary care physicians.

Primary care physicians as users of an EHR artefact	EHR artefact developer/vendor			ANOVA F	ANCOVA F¶
	EHRsoft1 mean (n = 167)	EHRsoft2 mean (n = 66)	EHRsoft3 mean (n = 48)		
Use of EHR functionalities[d]					
Use of clinical functionalities	0.65[a]	0.44[b]	0.52[b]	22.3***	17.6***
Use of communication functionalities	0.35[a,b]	0.38[a]	0.27[b]	3.0	2.0
Use of administrative functionalities	0.82	0.79	0.76	0.8	1.0

EHR: electronic health record; ANOVA: analysis of variance; ANCOVA: analysis of covariance.

[a,b,c] Within a given row, different indices indicate a significant difference ($p < 0.05$) between two means on the basis of Tamhane's T2 (post hoc) test.

[d] No. of EHR functionalities used/no. of EHR functionalities perceived as available.

¶With covariates: EHR experience and SIZE of the practice, EHR experience and primary care experience of the user, and perceived ease of use.

***$p < 0.001$.

Table 5. Differences between EHR artefacts with regard to user satisfaction.

Primary care physicians as users of an EHR artefact	EHR artefact developer/vendor			ANOVA F	ANCOVA F¶
	EHRsoft1 mean (n = 167)	EHRsoft2 mean (n = 66)	EHRsoft3 mean (n = 48)		
User satisfaction with EHR functionalities[a]					
Satisfaction with clinical functionalities	3.7	3.6	3.8	0.8	1.5
Satisfaction with communication functionalities	3.8	3.9	3.7	0.5	2.4
Satisfaction with administrative functionalities	4.2	4.2	4.1	0.3	1.2

EHR: electronic health record; ANOVA: analysis of variance; ANCOVA: analysis of covariance.

[a] 1: very dissatisfied, 2: dissatisfied, 3: neither dissatisfied nor satisfied, 4: satisfied, 5: very satisfied.

¶With covariates: EHR experience and size of the practice, EHR experience and primary care experience of the user, and perceived ease of use.

All F-tests were non-significant ($p > 0.05$).

EHR artefacts. As shown in Table 5, no significant differences were found in this regard; users were equally satisfied, on average, with all three EHR software products. Considering that physicians using EHRsoft1's product made more extensive use of their system's clinical functionalities (compared to the other two groups) and that all respondents were equally satisfied with their EHR systems, we posit that more attention needs to be paid to the EHR artefact's functional capability and physicians' behaviours – rather than attitudes – towards EHR systems if clinical performance is to be enhanced by implementing this technology in primary care settings.[6]

With regard to our third research question, the relationship between the EHR artefact as designed (by EHRsoft1, EHRsoft2, and EHRsoft3) and the EHR artefact as used (by primary care physicians) was ascertained through multiple regression analyses, as shown in Table 6. The independent variables were the EHR artefact group memberships, that is, two binary or dummy variables (1: yes, 0: no) indicating whether the physician was using EHRsoft1's or EHRsoft2's product, with EHRsoft3's user group as a constant term (i.e. the base EHR artefact category against which the other two categories were assessed) in the regression equation. The dependent variables were the three indicators of EHR use: the extent to which clinical, communication, and administrative functionalities are utilized. Two regression models were tested for each dependent variable, the first (Model 1) included only the EHR artefact group membership variables, whereas the second (Model 2) also included the control variables.

The regression results for Model 1 show that EHRsoft1's system is significantly associated with higher levels of clinical use by primary care physicians and that EHRsoft2's system is significantly associated with higher levels of use of communication functionalities. Unsurprisingly, an EHR system's ease of use is a significant predictor of clinical, communication, and administrative use when the control variables are factored into the regression equation (Model 2), increasing the percentage of explained variance from 14.3 to 49.8 per cent, from 2.2 to 29.3 per cent, and from 0.7 to 25.2 per cent, respectively. It is also important to note that the effect size of the EHR artefact when used by physicians is 'medium' in clinical terms ($f^2 = 0.167$), 'small' in communication terms, and nonexistent in administrative terms.[39]

In sum, these findings confirm the theoretical importance and practical relevance of characterizing the functional design of an EHR artefact in terms of both the different types of functionalities (administrative, communicational, clinical) and the different number of functionalities of each type that are made available to users. In such terms, the more comprehensive the commercial

Table 6. Regression analysis of the EHR artefacts with regard to their use by primary care physicians.

Dependent variable (n = 281)	Use of clinical functionalities		Use of communication functionalities		Use of administrative functionalities	
Independent variables	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
	T-coefficient		T-coefficient		T-coefficient	
EHR artefact developers/vendors						
EHRsoft3 (constant term)	16.3***	2.3*	7.4***	2.3*	17.6***	4.0***
EHRsoft1 (binary variable)	3.6***	3.5***	2.1*	1.3	1.3	1.3
EHRsoft2 (binary variable)	−2.0*	−1.2	2.4*	2.2*	0.5	0.3
Control variables						
EHR experience of the practice		−0.2		−1.9		0
Size of the practice		0.9		0.2		−1.3
EHR experience of the user		0.3		0.3		1.4
Primary care experience of the user		0.0		0.6		−2.3*
Perceived ease of use						
In patient management		3.8***		3.0**		1.2
In coordinating care with other care providers		1.3		0.6		1.1
F	3.1***	9.0***	3.1*	2.6*	1.0	21.8
R^2	0.143	0.498	0.022	0.293	0.007	0.252
Cohen's f^2	0.167	0.992	0.022	0.414	0.007	0.337

EHR: electronic health record.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

EHR solution provided by a vendor, the more extended will be its use by primary care physicians. More precisely, our results indicate that the functional design of an EHR artefact does matter in that it explains extended use in two ways. First and foremost, the greater availability of clinical functionalities explains why certain physicians use their EHR system more extensively because such functionalities would better support or 'fit' their main medical tasks than administrative or communicational functionalities.[24] Second, EHR systems that are more comprehensive within any of the three functionality categories are also used more extensively because physicians would perceive such systems to have more usefulness as more administrative, communicational, or clinical tasks would be supported.[6]

Discussion

Starting with a tridimensional formative model of the EHR artefact, we developed an approach that characterizes this artefact in the context of its use by primary care physicians. In contrast to previous studies, our approach focuses on the use of the EHR in its material form (i.e. concrete EHR functionalities) rather than its conceptual form (i.e. collective idea found in a community discourse).[40] Thus, as its main contribution to the medical informatics literature, this study enriches our knowledge of the true nature and usage of EHR systems in primary care settings.

In terms of research implications, the conceptual approach adopted in this study expands the basis for comparing EHR artefacts in terms of their core capabilities, structuring this comparison process and rendering it more transparent. Furthermore, it allows for greater control of EHR artefact variables in relational analyses, including the influence of specific primary care contextual factors on the EHR artefact and its use, such that our approach can be combined with existing health IT research models designed to study IT artefacts in context by adapting and applying previously validated models focused on the ease of use, usefulness, and success of such artefacts.[38] Finally, by characterizing and documenting the EHR artefact from the physician's perspective, researchers can avoid the conceptual disconnect that can occur when one attempts to link a theoretical artefact (the EHR as designed) to observed use (the EHR as used).[26]

From a practical standpoint, our main goal was to determine whether characterizing an EHR artefact from the user's perspective can help us to explain the nature and extent of its use, that is, the type (administrative vs communicational vs clinical) and number of EHR functionalities used by primary care physicians, and eventually assist in the design of such artefacts. For one thing, our findings reveal that all three EHR artefacts were perceived by their respective users to be rather difficult to use, despite the fact that all three have been certified by health care authorities. This clearly raises questions about the design quality of the EHR artefacts' human–system interfaces and, hence, reinforces the role and importance of user involvement.[41] Furthermore, our study can guide the evaluation and improvement of existing EHR artefacts and serve in the development of benchmarks to guide physicians and other health care professionals as they select, deploy, and use such artefacts. If the development of an EHR system is to be consistent with its intended function, and if its usefulness is to be maintained in response to changing user requirements and usage contexts, EHR designers' knowledge should be subordinated to users' knowledge. Again, this implies that constant exchange between users and designers is critical for health IT artefacts such as EHRs, whose clinical value depends upon the quality of their fit with the tasks of physicians, nurses, and other professionals working in primary care settings.

Conclusion

This study revealed significant differences among three EHR artefacts with regard to their functional capabilities, that is, the provision of various clinical, communication, and administrative functionalities by their vendor. We were also able to observe that primary care physicians differed significantly in terms of the extent to which they made use of each functionality available in their EHR system. But most importantly, our results further confirm that the EHR artefact indeed matters to primary care physicians, as we found that the functional design characteristics of commercial EHR solutions, and especially their clinical functionalities, play a significant role in the extent to which physicians use EHRs in this context.

While the distinction between the 'conceptual' and the 'material' EHR artefact represents a key contribution of this study, we did not keep track of the actual functionalities that were available in each of the EHR solutions in use at the time of the survey. We therefore acknowledge that the lack of such a portrait represents a major limitation of our work. In this line of thought, we then recommend that future studies assess whether the perceived availability of EHR functionalities (by physicians) differs from the actual availability of these same functionalities (as embedded in the EHR software solutions). Future research should also help EHR vendors design systems that are aligned with the specific needs and requirements of primary care physicians. To this end, a classification framework is an indispensable tool for the study of EHR systems as well as the study of health IT in general. In response to calls made to adequately identify health IT artefacts in terms of their design, deployment, and use, a clear and precise characterization of EHR systems is even more important, given the great diversity of such systems brought about by the rapid changes in the IT and network infrastructures that enable them. Of particular interest for future research are the influence that can be exerted by EHR use, through feedback, and context of use, on the EHR artefact's functional configuration (customization, emergence of new functionalities to preserve usefulness), that is, the process by which the artefact is assimilated by physicians, nurses, and other allied professionals.

Declaration of Conflicting Interests

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Electronic health record use among cancer patients: Insights from the Health Information National Trends Survey

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Abstract
Over 90% of US hospitals provide patients with access to e-copy of their health records, but the utilization of electronic health records by the US consumers remains low. Guided by the comprehensive information-seeking model, this study used data from the National Cancer Institute's Health Information National Trends Survey 4 (Cycle 4) and examined the factors that explain the level of electronic health record use by cancer patients. Consistent with the model, individual information-seeking factors and perceptions of security and utility were associated with the frequency of electronic health record access. Specifically, higher income, prior online information seeking, interest in accessing health information online, and normative beliefs were predictive of electronic health record access. Conversely, poorer general health status and lack of health care provider encouragement to use electronic health records were associated with lower utilization rates. The current findings provide theory-based evidence that contributes to the understanding of the explanatory factors of electronic health record use and suggest future directions for research and practice.

Keywords
electronic health records, information behavior, meaningful use

Introduction

Health information technology and health communication strategies are recognized as key tools to improve population health outcomes and achieve health equity.[1] Mapping out the progress toward these goals, the US national health objectives include the increase in the number of people who use electronic health records (EHR), feel capable finding information online, and use the Internet to communicate with their health providers.[1] In parallel with setting the goals for EHR use, a national program was created to provide incentives for the adoption and meaningful use of EHR systems by health providers and consumers.[2] The earlier aims of the incentive program supported by the

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Centers for Medicaid and Medicare Services have focused on creating data capturing infrastructure (Stage 1) and advancing clinical processes (Stage 2). Now approaching Stage 3, the meaningful use incentive program looks for further development of EHR into a tool for the improvement of health outcomes and health self-management.

Access to health information can lead to greater patient empowerment and better health outcomes.[3] Over 90% of US hospitals support online patient portals that provide patients with access to e-copy of their health records that contain laboratory test results, list upcoming appointments, provide summaries of past visits, and allow patients send messages to health care providers.[4] A sizable body of research looked at the uptake of technology for health communication and information seeking. The use of EHR creates opportunities for patient support and empowerment in complex medical situations,[5] such as cancer treatment. In the provision of care for cancer patients (i.e. those with the history of cancer diagnosis), EHR can be used to serve as quality control measures for discovering missed diagnosis opportunities,[6] create and implement comprehensive cancer survivorship care plans,[7] and provide a channel for education, communication, and information seeking for cancer patients.[3] Provision of and access to cancer-related information play a role in the support of effective coping with cancer and improved understanding of cancer disease management.[8] Despite its positive effects, health information can also lead to increased uncertainty about health status, recognition of the complexity of illness management, or diminished hope for a desired but unlikely health outcome.[9] Consequently, information behaviors can range from engaged information seeking to intentional information avoidance.[10] Dissemination of reliable information about prevention and treatment can also support uncertainty management associated with cancer diagnosis and recurrence.[11] EHR and patient portals are tools for information dissemination that afford patient empowerment, and their use can serve as its indicator. Patient empowerment can be defined as a greater participation of patients in health decision-making and self-management activities.[5] Going beyond deficit-model education approaches and support of treatment adherence, EHR can empower patients through personalization of information (e.g. by providing patients with convenient access to their test results and relevant health management and disease prevention tips).[12] It also supports collaborative communication enabling patient sharing of pertinent health information and active participation in the process of health management. However, despite the possible benefits and availability of EHR, only 27% of US health consumers regularly use this technology.[13] The lack of understanding of patient information-seeking behavior presents a significant barrier for the successful engagement of patients with the technology and its continued use.[14]

The factors that explain information behavior and the use of different health information channels have been conceptualized within the framework of the comprehensive model of information seeking (CISM).[10,15] The original conceptualization of CISM assessed individual and channel factors of information-seeking behaviors from communication with health care providers. CISM predicts that individuals' predispositions to search for health information are influenced by demographics, direct experience, salience, and beliefs. Individual factors act as antecedents to information content and channel preferences. Prior research has found that demographic factors, such as age, sex, race, education, and income level, are associated with health information seeking, and disparities in access to information can contribute to the digital divide.[16] Although the number of Americans, including minorities, who access the Internet for health information continues to grow, some disparities associated with low socio-economic status are still prevalent.[17] Besides the demographic factors, prior experience with and general orientation toward online health information have been identified as precursors of EHR use.[17] Finally, health information behavior can be affected by the beliefs about access efficacy and cultural norms related to the desirability and necessity of the access to health information.[15]

This article acknowledges the role of social factors and showed that channel factors should not be viewed in isolation but rather they should include social interaction. This means that the information management process as it relates to information seeking and repeat use of an information source is a social process. Such social information management allows formulating a proposition that information seeking is affected by both channel factors and social information management factors. CISM has been used in context of different online health information channels that present and passively distribute information, like online webpages. The first hypothesis, therefore, extends the application of CISM-defined individual factors for information seeking to predict the use of EHR:

> *H1*. The level of EHR use among cancer patients is associated with the individual information behavior factors of demographics, prior experience, salience, and access efficacy beliefs.

The second group of factors identified by CISM is associated with the characteristics and perceived utility of access to a particular information carrier. Characteristics of access refer to the trust toward the information source,[18] which in the context of electronic transmission of information and EHR use has also been associated with the perceptions of information security.[19] The perceived value of accessing health information has been positively associated with patient-reported health status.[20] Carrier factors account for channel accessibility as well as information needs and preferences of health consumers.[11] Information needs of cancer patients have been shown to depend on the stage of cancer,[15] as well as their overall health status, which in turn determine the utility of an information carrier to a health consumer. Research on the information behaviors among cancer patients showed more broad and active information seeking among those in earlier stages of cancer and focused on direct communication with a health provider and limited additional information seeking by those with more progressed cancers.[10] Therefore, the second hypothesis extends prior research on the characteristics and utility of access to and use of EHR:

> *H2*. The level of EHR use among cancer patients is associated with the EHR access factors of perceived information security and utility.

Methods

Source of data

The data came from the National Cancer Institute's Health Information National Trends Survey (HINTS) 4, Cycle 4, which was collected via mail surveys ($N = 3677$) between July and November 2014 (National Cancer Institute, 2015). As with previous surveys, the sample included those who have had a cancer diagnosis (n = 542) and those who have not. Information seeking can vary greatly between those who have been diagnosed with cancer and those who have not;[10] therefore, only responses from participants who identified themselves as cancer patients were included.

Variables and measurement

Guided by CISM, individual information behavior factors included demographics, prior experience, salience, and access efficacy beliefs. Demographic variables included age, sex, race, income, and level of education. Direct experience was assessed with two questions that asked about the respondents' use of email or apps to exchange medical information with a health care professional in the past 12 months. Salience and applicability of access to EHR were assessed with nine items that measured how interested participants were in exchanging information about appointment reminders, tips, medical reminders, lab/test results, diagnostic information, vital signs, lifestyle behaviors, symptoms, and digital images/videos with a health care provider electronically. The scale showed high reliability ($\alpha = 0.94$). Finally, beliefs about the norm of EHR access were measured with responses to the statement, "You should be able to get to your own medical information electronically."

Access factors included perceived security and utility of EHR use. Following the original conceptualization, the characteristics of information source were operationalized as the extent to which EHR is considered a secure source of information. Therefore, security perceptions toward EHR use were assessed by one question that asked whether respondents were concerned about the security of their medical information when it is sent electronically from one health care provider to another. In addition, because communication with health care providers can influence online health information seeking, the question asking whether a health care provider has offered access to EHR was included in the analysis to assess its impact on the utilization of EHR as a source of health information. Finally, CISM conceptualized utility of EHR to depend on the health status. Therefore, self-reported health status variable was included in the model.

EHR use behavior, the dependent variable, was measured by one question, "How many times did you access your personal health information online through a secure website or app in the past 12 months?"

Analytic procedures

A hierarchical regression was used to test the hypotheses. Individual information behavior factors were entered in the first block of the model and EHR use factors were entered in the second block of the model. Also, because the hypotheses focused on testing a previously developed model, weights for population-level estimates were not used.[18,21] Results are reported as unstandardized coefficients with 95% confidence intervals.

Results

The level of EHR use was expected to be associated with the personal factors (H1) of demographics (age, sex, race, education, and income), prior experience, salience (interest in accessing health information electronically), and EHR access beliefs. H1 was supported, $R^2 = 0.28$, $F(7, 439) = 24.66$, $p < 0.001$, and, as shown in Table 1, individual information behavior factors explained significant amounts of variance in the current use of EHR. Among demographic variables, higher income level was associated with more frequent use of EHR ($b = 0.03$, standard error (SE) = 0.02, 95% confidence interval (CI) = 0.001–0.06), but none of the other variables were significant predictors. Also, as predicted, prior experience ($b = 0.95$, $SE = 0.11$, 95% CI = 0.72–1.17), salience, ($b = 0.14$, $SE = 0.05$, 95% CI = 0.05–0.23), and access beliefs ($b = 0.14$, $SE = 0.07$, 95% CI = 0.01–0.28) were found to be significant predictors.

The level of EHR use was also expected to be associated with the access factors of perceived security characteristics and utility of EHR (H2). This prediction was supported, and access factors have shown significant variance in EHR use, $\Delta R^2 = 0.12$, $F(3, 436) = 29.87$, $p < 0.001$. Specifically, general health status was a significant negative predictor of EHR use ($b = -0.09$, $SE = 0.04$, 95% CI = −0.17 to −0.01), and low health status rate was associated with less frequent EHR use. Furthermore, health provider encouragement for the use of EHR was a strong positive predictor ($b = 0.79$, $SE = 0.09$, 95% CI = 0.61 to 0.95). Although the perception of the safety of electronic health information sharing did not reach significance, its p value ($p = 0.09$), signals that health consumers could have concerns related to the protections of their health information.

Table 1. Regression of EHR use on personal information behavior and EHR access factors.

Predictor	*b* (*SE*)	95% CI
Block 1: Personal information behavior factors	$R^2 = 0.28^{**}$; $F(7, 439) = 24.66$	
Age	−0.004 (0.02)	−0.01 to 0.002
Sex (male = 0, female = 1)	0.06 (0.10)	−0.13 to 0.24
Race (White = 0, non-White = 1)	−0.19 (0.12)	−0.42 to 0.05
Education	−0.05 (0.03)	−0.07 to 0.04
Income	0.03* (0.02)	0.001 to 0.06
Salience	0.14** (0.05)	0.05 to 0.24
Prior experience	0.95** (0.11)	0.73 to 1.17
Beliefs	0.14* (0.07)	0.01 to 0.28
Block 2: EHR access factors	$\Delta R^2 = 0.12^{**}$; $F(3, 436) = 29.87$	
EMR security perceptions	−0.10 (0.06)	−0.21 to 0.02
EMR use recommendation	0.79** (0.09)	0.62 to 0.96
Overall health	−0.09* (0.04)	−0.17 to −0.01

EHR: electronic health records; CI: confidence interval; SE: standard error.
$^{*}p < 0.05$; $^{**}p < 0.001$.

Discussion

This study looked at the use of EHR reported by cancer patients who participated in the HINTS. Guided by the CISM,[10,15] this article identified the factors that explain the use and barriers to greater adoption of EHR among health consumers. The results of this study showed that CISM is an applicable theoretical framework for the analysis of EHR use among cancer patients. The results of this study showed that CISM is an applicable theoretical framework for the analysis of EHR use among cancer patients. As predicted by CISM, salience of health information use online, prior experience using online health information, and beliefs about the importance of access to EHR serve as explanatory antecedent factors for EHR use.

This study has several notable findings. First, only income approached significance among the demographic factors. Although higher level of income was identified as a demographic predictor of EHR use, other factors that were previously associated with the digital divide, such as gender and age,[18] were not significant predictors of EHR use among cancer patients. Information-seeking behavior is dependent on patient characteristics,[22] and income emerges as a factor that acts as an antecedent for EHR use across the age and race groups of cancer patients and has been continuously identified as a significant predictor.[8] These findings correlate with other research that showed that the use of technology for access to health information is no longer dividing across the racial line, but the findings related to other demographic variables bring in new evidence that the use of health information technology (IT) is becoming widespread.[16,23]

Next, the importance of salience as a predictor of EHR use and high reliability of the scale used to measure it indicates that health consumers could be involved in health information exchange in a number of ways. Health behavior tips and lifestyle behaviors were among the types of health information types that were sought after by cancer patients. These information types are key in providing cancer education, and EHR could be used as a rich source of information exchange between health care providers and patients.[22,24] While this study focused on cancer patients, future studies could assess the promise of EHR to provide cancer prevention and screening.

The findings also showed that channel and utility characteristic explain the use of EHR, and those who rated their health lower are less likely to access the information. This study has two theoretical implications related to the continued development of CISM as a conceptual framework. First, previous applications of CISM have looked at cross-sectional situations of information seeking, when a particular need for health information is either satisfied or not satisfied through information seeking depending on the personal and information carrier factors.[25] However, both personal and carrier factors affect continued use of technology for health information uptake.[14] This study extends the application of CISM to explain the differences in frequent repeat use of an information carrier channel. As a proposition, it could be stated that personal and information carrier factors are predictive of the initial and continued use of a health information channel. The second theoretical contribution made by this article is related to the application of CISM to an interactive information behavior. Previous applications have focused on non-interactive information seeking and the dimension of an information behavior that ranges from information seeking to avoidance.[25,26] Applied to the EHR, which afford two-way communication, this study extended the use of CISM and showed that previously identified personal and information carrier factors form a stable predictive model. This finding could be formulated as a proposition that personal and information carrier factors are predictive of the use of information channels that afford interactive, two-way communication between patients and health care providers.

Applied to the practice of communication in health-related contexts and the support of greater adoption of EHR by patients, this study allows to provide two recommendations. First, the use of EHR is strongly associated with provider recommendation for its use. Health practices could capitalize on this finding by distributing instructions for EHR sign-on and its features in the office and with a personal message from a health provider. Similarly, focused campaigns that could include nursing staff, physicians, and their extenders could result in an increased uptake of EHR. However, these actions could lead to unexpected negative results if health care providers themselves do not hold positive attitudes toward the use of EHR. Receiving information about EHR use from health care providers was found to be the strongest predictor of EHR use. Future studies could assess whether reminders during office visits or targeted education campaigns through posters or brochures distributed in clinics could encourage greater utilization of EHR. Although provider attitudes toward the use of EHR might not predict their own EHR use,[27] consideration and caution should be exercised to account for the possible effect of provider attitudes on patient intentions to adopt and regularly use EHR.

Theoretical and practical implications of this study could be further explored in future research studies. First, as some consumers choose to avoid health information associated with cancer[25] and become overwhelmed by it,[28] future studies could assess whether EHR could be used to tailor the information based on patients' preferences and be used as a mechanism to build patients' self-efficacy and skills for information seeking. Second, active and interactive engagement with health information has been linked to more effective information management skills. The active styles of EHR screen sharing have been linked to greater patient engagement, while the passive styles have predictably resulted in lesser engagement.[29] Similar research is necessary to assess the effects of health care provider communication styles on the continuance and frequency of use of EHR by patients. Finally, future research should look at the qualitative properties of EHR use. Specific to the information needs of cancer patients, future studies could evaluate the patterns of use related to the diagnosis and office visits, the utility of sharing educational and health literacy information through EHR, and feasibility of collecting patient-reported outcomes.

Conclusion

The use of EHR can provide patients with access to health information, facilitate health self-management, and improve the quality of preventive health care. While personal beliefs in the importance of EHR use and experience looking for information online predict EHR use, encouragement from health care providers can further facilitate the rate of EHR adoption by health information consumers. Furthermore, EHR could also serve as a channel for the dissemination of health promotion and disease prevention information allowing tailoring of information to account for the needs of cancer patients with different health status. Existing theoretical frameworks, like the CISM, can inform the effective use of EHR as a channel for patient–provider communication that provides reliable and personally relevant health information within a secure environment.

Declaration of conflicting interests

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Patients are doing it for themselves: A survey on disease-specific knowledge acquisition among people with Parkinson's disease in Sweden

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Abstract

Effective self-management is key to living well with Parkinson's disease and one important aspect is disease-specific knowledge. This article explores how people with Parkinson's disease in Sweden (1) acquire disease-specific knowledge and (2) use Parkinson's disease–related healthcare. Data were collected through an online survey, which had 346 respondents (16–87 years old, median age: 68 years, 51% male; time since diagnosis: 0–31 years, median time: 7 years). Our results show that disease-specific knowledge is mainly found online, especially for women with Parkinson's disease and people with Parkinson's disease of working age, that most people with Parkinson's disease in Sweden see their neurologist for 1 h or less per year and only one in two people with Parkinson's disease has regular contact with other Parkinson's disease–related healthcare professionals. We also find that people with Parkinson's disease reporting higher levels of specific knowledge also are more likely to be satisfied with the amount of time they get with their neurologist, regardless of the amount of time.

Keywords

disease-specific knowledge, health information seeking, online survey, Parkinson, self-management

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Introduction

Parkinson's disease (PD) is a chronic neurodegenerative disease resulting in motor and non-motor symptoms causing significant burdens on individual patients and family members, as well as on healthcare and society.[1] PD is extremely individual in nature and the range and fluctuations of symptoms often require complex medication regimens.[2] The prevalence increases with age; median age of onset is 60 years although 10 per cent of people with Parkinson's disease (PwP) are younger than 45.[1,3] The number of PwP in Sweden is about 22,000.[4] Worldwide, the number of PwP is predicted to double between the years 2005 and 2030.[5]

Healthcare has historically dealt with caring for acute injuries and illnesses where healthcare professionals were experts and patients passive recipients of care.[6] Chronic conditions, however, require a very different model for healthcare, one that is based more on patients' self-management and patient education.[7,8]

When in need of health-related or medical information, people with chronic diseases turn to different sources. In a study from the United States,[9] the following percentages were reported: health professionals: 93 per cent, friend or family member: 60 per cent, books or similar: 56 per cent, Internet: 44 per cent, insurance provider: 38 per cent, and other sources: 6 per cent. Although many studies explore patients' online information-seeking behaviour,[10–13] we have not found any similar studies looking at other sources too for other countries, including Sweden, or for PwP.

Internet access has accelerated the search for information and resources, and patients with chronic diseases actively use the Internet to search disease-related information outside of healthcare. For example, in the United States, 51 per cent of adults living with chronic conditions go online to find health-related information.[9] Another US study reports that about half of the population with chronic conditions would appreciate guidance when searching for health information online.[14] A survey study from Japan[15] demonstrated a lower use of Internet for health purposes; 23.4 per cent used a computer to acquire health information and 6 per cent used cell phones. We have not been able to find any similar study for a Swedish population but we know that Internet use in Sweden is high; in 2015, in total, 91 per cent of the population were online with slightly higher use (>95%) for ages 8–55 years.[16] There are, however, differences in use of the Internet across the population; a different study shows that among those 65 and older, being male, high education, not living alone, not being cognitively impaired, being younger within the studied population and urban living correlated significantly with higher Internet use.[17]

Specifically in PD, effective self-management is crucial to successfully managing the disease and includes knowledge about the disease, medications and side effects, monitoring of symptoms, finding reliable sources of information and knowing when to take action.[18–20] A large majority of PwP want to be active in health-related decisions and to have access to correct and relevant information.[21–23] Online tools and services are frequently used among people with chronic diseases and have also been observed in PD.[24–26] A US study shows that PwP often have access to and feel comfortable using computers, mobile phones and the Internet.[27]

The concept of health literacy has emerged as a way of describing, measuring and improving patient education. It was originally defined as 'the degree to which individuals have the capacity to obtain, process and understand basic health information and services needed to make appropriate health decisions'.[28] With the increasing use of online services, eHealth literacy has been developed. There are a number of different definitions of eHealth literacy and one of the most frequently used is 'the ability to seek, find, understand and appraise health information from electronic sources and apply knowledge gained to addressing or solving a health problem'.[29] It seems that health and eHealth literacy in the context of PD are under-researched concepts. A search using search terms 'health literacy' OR 'ehealth literacy' AND 'Parkinson*' in several databases (PubMed, Web of Science and CINAHL) revealed only three studies, two of which were abstracts for conference posters and the third, a pilot study. One of the conference abstracts determined the readability of letters sent from clinics to PwP and states that there might be a discrepancy between PwP's self-rated understanding and the actual readability.[30] The other one reports a study of health literacy in 121 PwP using two brief assessments and concluded that low health literacy is common in the investigated population and is likely to be even more prevalent in a general population of PwP.[31] The pilot study reports a prospective study of the functional health literacy of 44 men with PD and concludes that contrary to existing literature, PwP can be expected to preserve health literacy.[32]

Rather than to study the full concept of health literacy, we wanted to study one specific aspect, namely, acquisition of disease-specific knowledge. This has previously been studied in the context of chronic disease,[9,15] but we have not been able to find any previous studies of this aspect specifically for PD. In this article, we use the term disease-specific knowledge as meaning all knowledge relating to PD, including but not limited to knowledge about symptoms, medication and other treatments, side effects, disease management and healthcare provision. This is relevant because raising the level of disease-specific knowledge among PwP has been found to increase health-related quality of life.[33,34] A recent study in China assessed the knowledge of PD among PwP and noted a great need for improvement in key areas such as disease management and awareness of medication side effects.[35]

Since health professionals and healthcare are traditionally the main sources of validated disease-specific knowledge,[36] it is worth looking at time that is available to provide this knowledge. In the United States, PwP have appointments with their neurologist three to four times a year;[37] in Italy, one to three times,[38] and in Sweden, once a year.[4] This indicates a discrepancy between the availability and significance of healthcare as a source of disease-specific knowledge.

We investigated two research questions:

- How do PwP in Sweden
    - Acquire disease-specific knowledge?
    - Use PD-specific healthcare?

Methods

Data were collected from PwP in Sweden by means of a survey developed in a step-wise process. The survey (in Swedish) was designed and distributed using the online tool Typeform.[39]

General information about the survey (purpose of the study, investigator, instructions for responding) was included and questions were kept short and focussed to reduce the risk of respondents abandoning the survey before completion.[40] The survey questions are listed in Table 3 of Appendix 1 and include questions on background (gender, year of birth, place of living and education level), year of diagnosis and the importance, level and main source of disease-specific knowledge. There were also questions on how much time is spent in healthcare every year (neurologist and other healthcare professionals), as well as an assessment of time sufficiency. Response options were numerical, categorical or free text. When asked about their opinion, respondents were given a five-point Likert scale to choose from, where the middle option signified a neutral opinion.

The survey was first tested on a smaller pilot group with PD, four participants (50% women) with varying ages (49–67 years) and time since diagnosis (6–13 years), in a fully functional online form. Some minor text edits were made before distributing more broadly using the online tool. To maximise the number of responses, the web link to the survey was distributed to PwP in Sweden via email to patient organisations and patient groups, as well as social media and personal networks. No incentives were offered for responding. The survey was made available as soon as it was ready and data collection was terminated when the number of new responses tapered off. It was online for 4 weeks (7 March–4 April 2015), after which the results were downloaded and analysed.

Table 1. Respondent characteristics.

Respondent characteristics	Number of respondents	Interval	Median	
Age	346	16–87 years	68 years	51% male
Time since diagnosis	335	0–31 years	7 years	
Education level				
Compulsory school (<9 years)	74 (21%)			
Upper secondary school (9–12 years)	93 (27%)			
University (>12 years)	179 (52%)			

Only respondents living in Sweden were included in the analysis and duplicate answers were excluded. Age and time since diagnosis were calculated from year of birth and year of diagnosis. Categorical and numerical variables were analysed with an interactive calculation tool[41] using the χ^2 test with statistical significance defined at $p < .05$.

This study is exempted from ethical approval by the regional ethical review board in Stockholm (according to decision 2015/1572-31/4).

Results

Background data

The survey had 346 valid responses, 11 of which did not give year of diagnosis, and 48 per cent of the unique visitors completed the survey. The age (Table 1 and Figure 1) and gender (Table 1 and Figure 2) distributions are consistent with what would be expected in a population with PD and representative for Swedish PwP compared to a study by Lökk et al.[4] There is one 16-year-old respondent, who is unusually young for PD but rare forms have been reported with juvenile onset.[42]

Our respondents are relatively well educated (Table 1), 52 per cent have completed more than 12 years of education, which is more than the general population in Sweden, where 30–35 per cent of the population are reported to have studied for 12 years or more.[43]

Disease-specific knowledge

Results regarding self-reported importance, level and main source of disease-specific knowledge are presented in Table 2. In total, 91 per cent of the respondents considered knowledge about PD important (4 or 5 on the Likert scale for *Importance of knowledge*) and 55 per cent reported to have been able to acquire the knowledge they need (4 or 5 on the Likert scale for *Level of knowledge*). When asked which is their main source of disease-specific knowledge, 36 per cent responded that they had found the information themselves online, 29 per cent from patient organisations and similar, and 25 per cent from healthcare.

People with different education levels could be expected to report different levels and sources of knowledge; however, chi-square analyses of our respondents showed that neither level ($p = .58$) nor source of knowledge ($p = .18$) are significantly associated with education level. Furthermore, age, gender or time since diagnosis could be expected to influence level and source of knowledge. We have chosen to use the definition of 'older adults' from the Swedish National Board for Health and Welfare[44] (65 years). For 'time since diagnosis, we use the median value (7 years) for separating into two groups. We found that the self-reported level of knowledge is not significantly associated with age ($p = .41$), gender ($p = .64$) or time since diagnosis ($p = .41$). Similarly, the self-reported main source of knowledge is not significantly associated with time since diagnosis ($p = .18$).

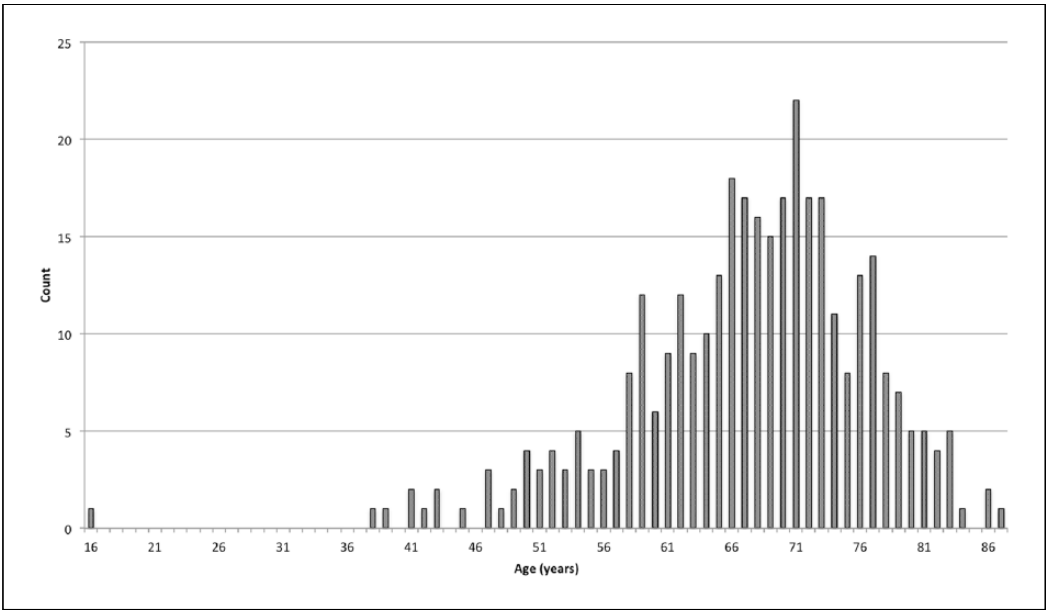

Figure 1. Age distribution of the respondents.

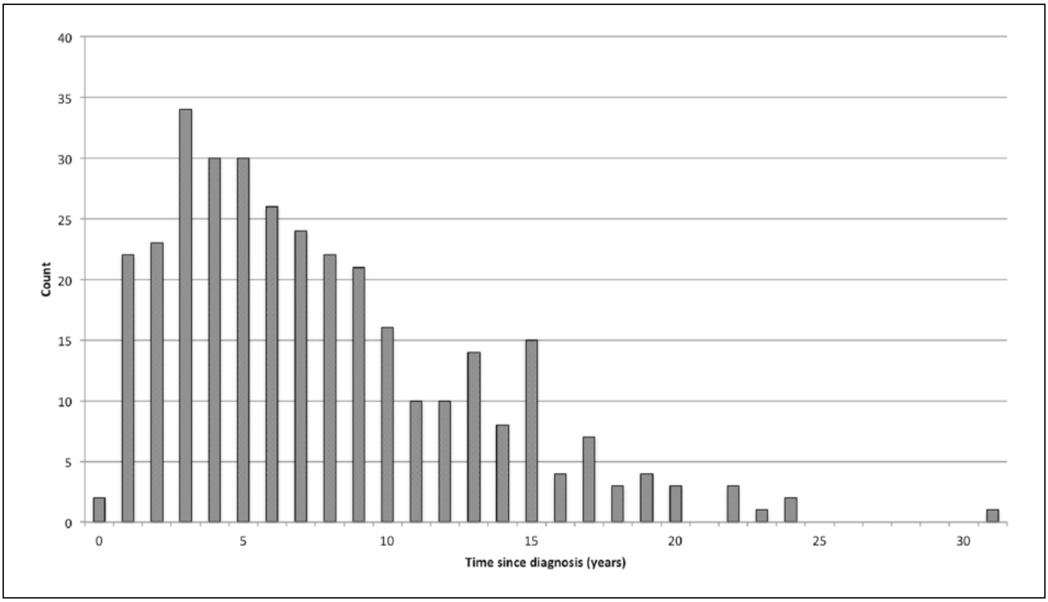

Figure 2. Time since diagnosis for the respondents.

Analyses show, however, that significantly different main sources of knowledge are reported depending on age ($\chi^2 = 13.6$, df = 3, $p = .003$) and gender ($\chi^2 = 9.62$, df = 3, $p = .022$). Online information is the most important main source of disease-specific knowledge for PwP under 65 years of age, whereas the group 65 and older more often report patient organisations as their main source

Table 2. Importance, level and source of knowledge.

Importance of knowledge	1	2	3	4	5	Total
How important is knowledge about your disease to you? (1 = unimportant, 5 = very important)	0 0%	9 3%	22 6%	53 15%	262 76%	346 100%
Level of knowledge	1	2	3	4	5	Total
Have you been able to acquire the knowledge you need about your disease? (1 = not at all, 5 = absolutely)	17 5%	35 10%	103 30%	121 35%	70 20%	346 100%
Source of knowledge						
Which of these is your main source of knowledge about your disease? Pick one.						
Information I have found myself online	123	36%				
Information from patient organisations, etc.	100	29%				
Information from healthcare	87	25%				
Information from other patients	18	5%				
Information from family, relatives and friends	9	3%				
Other sources	9	3%				
Total	346	100%				

(Figure 3). It is worth noting that the 31 per cent of the group 65 and older who report Internet as their main source of disease-specific knowledge is still a relatively high number. Men and women also report significantly different sources (Figure 4); women more often find their information online. To enable the use of chi-square testing for analysing source of knowledge, the response options '*other patients*', '*family, relatives and friends*' and '*other sources*' were merged.

Time in healthcare

When it comes to time spent in healthcare (Table 4 of Appendix 1), 35 per cent visited their neurologist once and 38 per cent twice during 2014. Three visits were made by 10 per cent of the respondents and 9 per cent had four visits or more. This means that 8 per cent (n = 29) of our respondents did not see a neurologist at all during the year. As for the length of visits, 14 per cent met with their neurologist for up to 15 min, 48 per cent between 15 and 30 min, 23 per cent for 30–45 min and 14 per cent for an hour or more per visit. We calculated the total yearly time with the neurologist from number of visits and time per visit. In total, 60 per cent (n = 206) saw their neurologist for up to an hour during the year (Figure 5; Table 4 of Appendix 1).

When asked if they considered the time they have with their neurologist to be sufficient, 35 per cent of the respondents said no (1 or 2 on the Likert scale), 43 per cent said yes (4 or 5 on the Likert scale) and 22 per cent were neutral (3 on the Likert scale) (Table 4 of Appendix 1). As expected, there is a significant association between spending more time per year with your neurologist and being satisfied with the amount of time spent ($\chi^2 = 16.8$, df = 4, $p = .002$).

On the question about regular contact with other healthcare professionals, 47 per cent (n = 161) reported that they had met with a nurse, speech therapist, physiotherapist or similar during 2014 (Table 5 of Appendix 1). About one-third of the people with no time with their neurologist (9 out of 29) reported that they had regular contact with other healthcare professionals, for example, nurse, physiotherapist or speech therapist. Of these, one person had 10–20 h and the remaining eight had up to 5 h during the year.

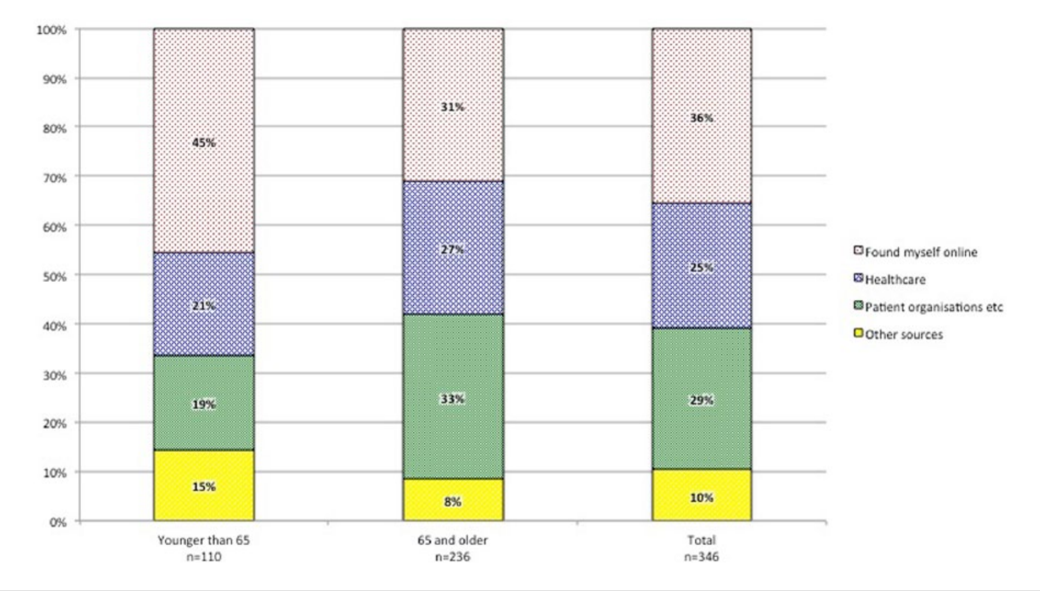

Figure 3. Self-reported primary source of disease-specific knowledge for different age groups.

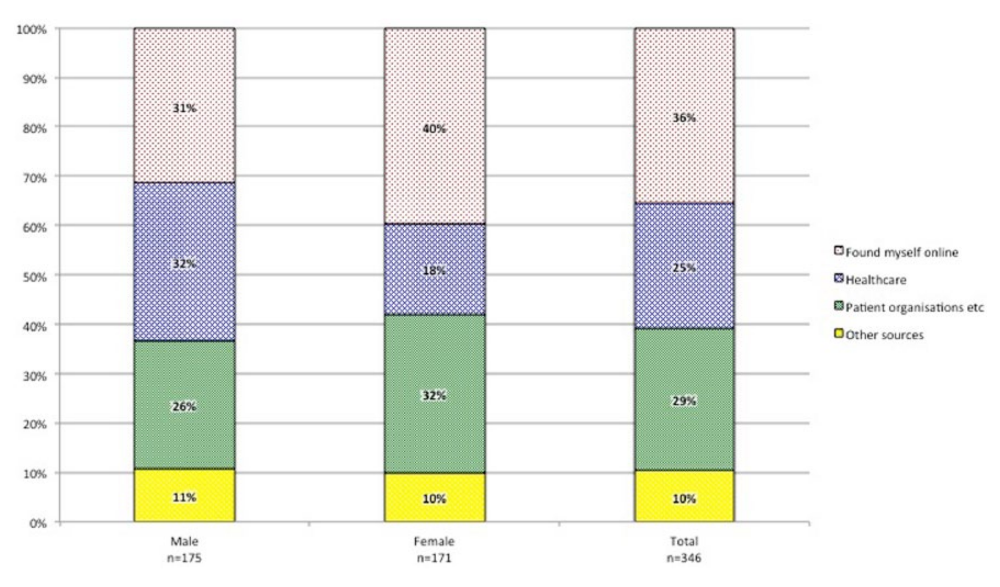

Figure 4. Self-reported primary source of disease-specific knowledge for different genders.

One could expect that people who spend more time with their neurologist per year would report higher levels of disease-specific knowledge and also more often report healthcare as their main source of knowledge. Chi-square analyses show, however, that yearly time with neurologist is not significantly associated with level (p = .43) or main source of knowledge (p = .15).

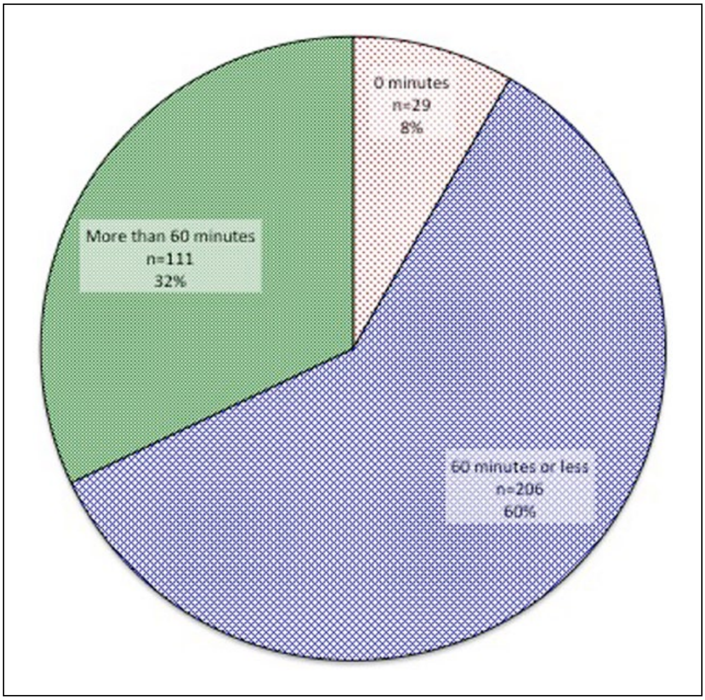

Figure 5. Total time with neurologist in 2014.

A person's gender, level of education or age could be expected to have an effect on their expectations on and satisfaction with healthcare. Furthermore, that the time since diagnosis might influence how much contact with the neurologist is perceived as needed. Analyses of our data show, however, that PwP's satisfaction with the time they get with their neurologist is not significantly associated with age ($p=.17$), gender ($p=.63$), time since diagnosis ($p=.44$) or education level ($p=.83$).

Furthermore, we also found a significant association between self-reported level of knowledge and satisfaction with the time with the neurologist every year ($\chi^2=30.1$, df= 4, $p<.001$). This means that PwP reporting a higher level of knowledge were more likely to be satisfied with the time they had with their neurologist, regardless of how short or long that time was.

Discussion

The aim of this study was to explore how PwP in Sweden acquire disease-specific knowledge and to investigate the use of PD-related healthcare in Sweden. The results from our survey indicate that Swedish PwP mainly acquire their disease-specific knowledge online and that the Internet is an even more important source of information for women with PD, as well as PwP under 65 years of age. We also see that most PwP in Sweden see their neurologist for 1 h or less per year. In the following sections, the results and methods will be discussed in more detail.

Discussion of results

It is hardly a surprising finding that the Internet is an important source of knowledge for PwP considering the increasing online presence of patients across all diseases. Age and gender seem to have a significant influence on the main source of knowledge, influence that appears independent from time since diagnosis, education level or time spent with neurologist per year. The fact that our data show that women to a higher degree find their information online could be seen as contradicting earlier research that suggests that men in Sweden are more online than women[17] but could also be seen as an indication that even though women are less online than men, they mainly find their disease-specific knowledge online.

Should the fact that people find their disease-specific information online be perceived as a problem? Not necessarily, because although it is important to acknowledge that it can be difficult finding correct and relevant information online, Internet does enable patients to more effectively manage their health and healthcare.[45] 'Internet-informed' patients influence the patient–provider relationship and contribute to making healthcare more patient-centered while healthcare professionals can overestimate the risks of online health information.[46,47] Results from a study among American patients with chronic conditions showed that a majority, 94 per cent, reported that they had not been harmed by health information they found online.[9] It is, however, important to note that Internet use can be an issue for PwP. Excessive use of Internet may be a sign of impulse control dysfunction, a known side effects of PD medications.[48,49]

The effects of PD can also have an influence on our results. With the progression of the disease, for example, hand function may be affected, presenting as impaired fine motor skills and/or severe tremor. This could result in reduced ability to use keyboard, computer mouse or touch screens, hence making it more difficult to respond to online surveys.

The quality and accessibility of the information provided online can potentially be an issue. Indeed, the quality of information found can be difficult to assess for PwP. Misinformation can be both deliberate with the purpose to promote a specific product or cause and unintended mistakes. Both of these can be problematic and should be explored further. When it comes to readability, a study of PD information websites in English aimed towards PwP showed that the majority of the sites studied did not comply with readability guidelines.[50] Whether or not this is the case for Swedish websites with information on PD is not known, and based on the survey results, we cannot know which sites the respondents use to gather information, nor if our respondents defined 'the knowledge you need' in the same way or regarded the information they found as being credible, reliable and helpful. In accordance with existing research, we also cannot know in what way the information given is perceived and understood.[8]

Would it not be better if healthcare took a larger responsibility in educating patients? There may of course be a role here for healthcare professionals to involve PwP more in their treatment and care, and according to a Dutch study, PwP expect healthcare to provide relevant information, tailored to the individual's needs.[22] However, as is reflected in a different study, advances in medicine and time constraints in healthcare make it hard for healthcare professionals to keep up with new knowledge and patients' needs and expectations, which often leaves patients feeling frustrated with the information provided.[45] The study even suggests that patients who are more Internet-savvy than their providers often feel better able to find the health-related information they need by themselves online.[45] As we can see from our results, most PwP have 60 min or less with healthcare annually, leaving little room for continuous information provision or patients' questions. In combination with the high Internet use in Sweden, even among the older population, it could be assumed that Swedish PwP might sometimes be able to find the information they need more easily than their healthcare providers.

It is also important to note that there is a difference between information and knowledge. Healthcare professionals might feel confident that they provide the right information at the right time but, for time constraints or other reasons, they are not able to ensure that the information is properly received and transformed into knowledge by the individual. The perception of what kind of information is relevant at different times and stages of the disease might also vary between healthcare and PwP, and even between PwPs. This makes it, of course, very difficult for healthcare professionals to provide information relevant to each PwP at every occasion. Furthermore, we would argue that different sources might provide different types of information. It might be feasible to think that certain types of information would be best if given by healthcare, whereas other kinds might be best found elsewhere, a topic that would need further exploration in the future.

We also see the fact that PwP find their information online as part of the on-going shift from patients being passive recipients of care to active participants who have the possibility to be experts in managing their own disease and situation.[23] Considering the complexity of the disease and treatments, we believe it is unreasonable to expect the limited time PwP have in healthcare to be sufficient to adequately address all the relevant issues. We therefore propose that other avenues for supporting the acquisition of disease-specific knowledge for PwP are explored. Our data show that also fellow patients, in the form of patient organisations and similar, are important sources of disease-specific knowledge. We propose to combine the power of the Internet with the force of patients to complement the current information provision by healthcare. By utilising the networking powers of online communities and online learning, we believe that some of the pressure on healthcare can be alleviated. This is developed further in 'Future work' below.

Discussion of methods

Choosing an online survey as a data collection method has its own advantages and limitations. Although online surveys are a fast and efficient way to collect data,[40] they bias the results in favour of people who are already active online and probably use Internet as a knowledge source. Our respondents are more educated than the Swedish population in general and a higher level of education has been shown to significantly predict the use of Internet for health purposes.[45] This means that our results might overestimate the proportion of people who mainly find their information online. However, since Sweden, in general, has a very high use of Internet, the overestimate is likely to be minor.

Respondents were asked to self-assess their level of disease-specific knowledge and relate it to the knowledge they considered themselves needing. They were also asked to self-report the frequency and length of healthcare visits. Relying on self-assessments and recall gives rise to uncertainties in the responses.

Despite the weaknesses described above, our results contribute to new knowledge in an under-explored research field and they point towards a development where the importance in online sources for patients' knowledge acquisition increases.

Our survey collected responses from about 1.5 per cent of all PwP in Sweden and when comparing with a study reporting age and gender distribution in that population,[4] our population seems reasonably representative, with some lack of responses in the higher age groups.

Future work

As far as the authors know, this is the first study exploring acquisition of disease-specific knowledge by PwP. Our questions were not detailed but rather general. Future research should focus on exploring the satisfaction of PwP with online information, investigating whether different sources provide different kind of information and individualising the knowledge type, form and delivery to patient needs and preferences. Exploring ways to objectively assess PwP disease-specific knowledge is another future research focus, as well as looking at potential methods for ensuring the quality of online health information, to avoid inappropriate guidelines and recommendations. In a subsequent next step, the results from the proposed work, an online service for implementing these ideas could be developed.

Conclusion

PwP in Sweden mainly find their disease-specific information online, especially so for women and people in working age. At the same time, healthcare has a very limited possibility to provide disease-specific information since the majority of PwP see their neurologist for 1 h or less per year. Moreover, only 1 out of 2 has contact with other PD-specific healthcare professionals. Given the overburdened healthcare system, it would be worth exploring other ways of guiding patients to relevant and accurate health information, such as education programmes and peer support networks delivered by patient organisations or other entities independently from healthcare. The timing, content and delivery mode of PD-specific knowledge need to be addressed in future research.

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Appendix 1

Table 3. Survey questions and response options.

Question	Reply options
Gender?	M/F
Year of birth?	Numeric
County council of residence?	Dropdown of all Swedish county councils
Highest completed education?	Compulsory school (<9 years)
	Upper secondary school (9–12 years)
	University (>12 years)
Year of diagnosis?	Numeric
How important is knowledge about your disease to you?	Scale from 1 to 5 where 1 = unimportant, 5 = very important
Which of these is your main source of knowledge about your disease? Pick one.	Healthcare
	Patient organisations and similar
	Found myself online
	Other patients
	Family, relatives and friends
	Other sources
Have you been able to acquire the knowledge you need about your disease?	Scale from 1 to 5 where 1 = not at all, 5 = absolutely
How many times did you see your neurologist during 2014?	None
	Once
	Twice
	Three times
	Four times or more
	I do not have a neurologist
Non-mandatory comment about visits to the neurologist	Free text
How long is each visit on average? Pick the time closest to the actual time.	About 15 min
	About 30 min
	About 45 min
	An hour or more
Do you also have regular contacts with other healthcare professionals, for example, nurse, speech therapist, physical therapist, social worker?	Yes
	No
	I do not know
Total time spent in healthcare for PD during 2014 (neurologist visits excluded)	Up to 5 h
	Between 5 and 10 h
	Between 10 and 20 h
	More than 20 h
Non-mandatory comment about your other healthcare contacts	Free text
Do you think your time with the neurologist is sufficient?	Scale from 1 to 5 where 1 = not at all, 5 = absolutely
Non-mandatory comment about the time spent with the neurologist	Free text

Table 4. Time with neurologist.

Number of visits							
How many times did you see your neurologist during 2014?	None	Once	Twice	Three times	Four times or more	I don't have a neurologist	Total
	25	120	133	34	30	4	346
	7%	35%	38%	10%	9%	1%	100%
Length per visit							
How long is each visit on average?	About 15 min	15–30 min	30–45 min	1 h or more			Total
	50	165	81	50			346
	14%	48%	23%	14%			100%
Total time							
Total time with neurologist in 2014	0 min	15–60 min	61–120 min	>120			Total
	29	206	92	19			346
	8%	60%	27%	5%			100%
Time sufficiency							
Do you think your time with the neurologist is sufficient? (1 = not at all, 5 = absolutely)	1	2	3	4	5		Total
	67	55	76	72	76		346
	19%	16%	22%	21%	22%		100%

Table 5. Total time spent in healthcare for PD.

Total time spent in healthcare for PD during 2014 (neurologist visits excluded)	Count
<5 h	70
5–10 h	18
10–20 h	26
>20 h	47
Total	161

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Mapping a Careflow Network to assess the connectedness of Connected Health

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Abstract

Connected Health is an emerging and rapidly developing field which has the potential to transform healthcare service systems by increasing its safety, quality and overall efficiency. From a healthcare perspective, process improvement models have mainly focused on the static workflow viewpoint. The objective of this article is to study and model the dynamic nature of healthcare delivery, allowing us to identify where potential issues exist within the service system and to examine how Connected Health technological solutions may support service efficiencies. We explore the application of social network analysis (SNA) as a modelling technique which captures the dynamic nature of a healthcare service. We demonstrate how it can be used to map the `Careflow Network' and guide Connected Health innovators to examine specific opportunities within the healthcare service. Our results indicate that healthcare technology must be correctly identified and implemented within the Careflow Network to enjoy improvements in service delivery. Oftentimes, prior to making the transformation to Connected Health, researchers use various modelling techniques that fail to identify where Connected Health innovation is best placed in a healthcare service network. Using SNA allows us to develop an understanding of the current operation of healthcare system within which they can effect change. It is important to identify and model the resource exchanges to ensure that the quality and safety of care are enhanced, efficiencies are increased and the overall healthcare service system is improved. We have shown that dynamic models allow us to study the exchange of resources. These are often intertwined within a socio-technical context in an informal manner and not accounted for in static models, yet capture a truer insight on the operations of a Careflow Network.

Keywords

Careflow Network, collaborative work practices and information technology, Connected Health, healthcare service innovation and information technology, information technology design and development methodologies, modelling healthcare services, organisational change and information technology, social network analysis

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Introduction

The world around us is changing dramatically through the use of technology, both hardware and software. It is not unusual in many of our everyday environments to use smart phones, Internet, mobile technology, integrated software systems and ubiquitous computing. This has resulted in systematic changes in how people undertake everyday activities. Within a healthcare context, the growth of health technology, digital media and mobile devices has contributed towards technology-enabled care.[1] Data are now exchanged across personal and professional technology platforms, for example, via smartphones apps, biosensing wearables or healthcare monitors.[2] As these can provide real-time healthcare information, they can ultimately facilitate improved healthcare quality outcomes.[3] This has given rise to the emergence of Connected Health (CH) – a new socio-technical model for healthcare management which exploits the use of information technology (IT) for clinical or wellness decision-making tasks.[4] CH software innovation contributes towards the coverage and quality of healthcare services, improved health outcomes, reduced costs and improved quality of care (QoC).

Research question

Our research has indicated that in order to improve a healthcare service, we must successfully model the network in which the service operates. This allows us to assess where improvements may be made and examine whether improvements actually occurred due to innovation enabled by IT. Failing to do so can hamper efforts to clearly align healthcare needs and software development. Within a healthcare context, this is often overlooked and has not been addressed. Thus, to address this gap, we formulate the following research question: *How can we model the connectedness of a Careflow Network to identify potential service bottlenecks and opportunities for Connected Health solutions?* This article addresses this question using social network analysis (SNA). We describe how it presents significant potential to model Careflow Networks and how it supplements other existing modelling techniques.

Research methods

Literature review. We conducted an exploratory literature review to examine the concept of a healthcare system and careflow systems. For example, the objective of this exploratory research was to gather preliminary information to support the definition of the problem in modelling healthcare systems and to suggest how SNA can offer a suitable approach to capture the dynamic nature of Careflow Networks. Within the literature review process, we identified that there is a need to model the dynamic interaction within a healthcare service, for example, the exchange of healthcare resources between actors. We explored current modelling techniques and network properties within the Careflow Network, and our resulting thesis is that *Social Network Analysis (SNA) is a suitable tool to model a Careflow Network.*

Case study. To illustrate our thesis, we present a hypothetical scenario within a case study as a particular instance within a Careflow Network. We provide a scenario and describe how the interactions within the Careflow Network can be easily replicated in a real-work context. Our objective here is simply to demonstrate the potential of employing SNA to model the connectedness of a Careflow Network and to identify potential service bottlenecks and opportunities for CH solutions.

Careflow systems

There are ample sources of literature which explain how clinical guidelines describe the activities of a medical team in a comprehensive manner for the purpose of defining best practice for patient

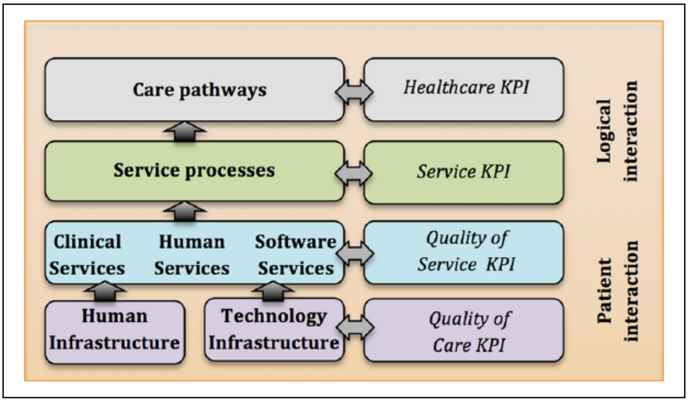

Figure 1. Key layers of a Careflow Network.

management. Within clinical guideline literature, the concept of 'careflow' largely focuses on behavioural aspects of medical practice with increasing attention on possible IT-enabled support solutions.[5–8] These are often referred to as 'careflow systems' which implement workflow concepts in the clinical domain.[6] Workflow involves the coordinated execution of multiple tasks performed by different agents to handle the delivery of a healthcare service as effectively and efficiently as possible. Thus, workflow defines, executes and automates specific processes where tasks, information or documents are passed from one participant to another for action, according to a set of procedural rules.[9] These rules are often based on the presumption, represented in healthcare guidelines, of how healthcare professionals formally interact with one another. However, there is an obvious lack of a service boundary due to the complex nature of a healthcare system.[10] In addition, to date, there are few efforts which map the real-world dynamics of healthcare services to truly capture the interactions (formal and informal) of healthcare actors and to identify (a) how connected actors are and (b) identifying where technology is best placed within the Careflow Network to alleviate healthcare bottlenecks.

Careflow Network

We define a Careflow Network as the interaction within a healthcare service structure that facilitates the exchange of resources and competencies between actors through defined care pathways in order to achieve quality and safe patient outcomes (Figure 1). Building on careflow systems literature, we introduce the concept of a Careflow Network to emphasise the need to map the interactions which sustain the provision of healthcare services before we can attempt to provide effective IT solutions. The difference between careflow systems and Careflow Network is that Careflow Networks shed light on the real-world interactions which exchange healthcare resources (e.g. information, medicines or support) rather than simply focusing on the formalised workflow approach to identify where linear process execution could be supported through IT. The Careflow Network approach goes beyond the 'traditional' view of healthcare, where a patient interacts with a clinician only. We consider all meaningful dynamic interactions, some of which will be supported by technology and some that often goes undocumented on a day-to-day basis. Thus, we need to introduce applicable modelling techniques to capture these healthcare dynamics.

Figure 1 illustrates the key layers of a Careflow Network which are linked to different performance measures or key performance indicators (KPIs). The Careflow Network comprises the following:

1. *Care pathways*. The main tools used to manage healthcare quality concerning the standardisation of care processes. This layer focuses on the clinical services of other layers and describes clinical practice. It also establishes healthcare KPIs to assess the overall healthcare service performance.
2. *Service processes*. Deliver valuable capacities for action to a particular client/patient. This layer also focuses on the logical interactions of other layers and identifies service KPIs to indicate where strengths and opportunities exist to enhance the overall service.
3. *Clinical services*. Provides services relating to the medical treatment that are provided to patients to treat a medical problem. This layer focuses on the patient interactions from a clinical, human and software service perspective to assess quality of service (QoS) KPIs.
4. *Human services*. Provides an interdisciplinary approach to meeting healthcare needs through an applied knowledge base, focusing on prevention as well as treatment of healthcare conditions to improving the overall quality of healthcare service through various skills. It sheds more insights on how these services contribute towards QoS KPIs.
5. *Software services*. Executes services guided by a set of related software functionalities that can be reused for different purposes to support practice and policies. It supports other related services to enhance the QoS KPIs.
6. *Human service infrastructure*. Defines the social service structure of a healthcare network which is sustained by social networks to deliver a healthcare service. It provides some insight on how various health-related and non-health-related services contributes towards QoC KPIs.
7. *Software service infrastructure*. Focuses on the business rules of the healthcare environment, for example, a service-oriented infrastructure to support the enterprise, the application architecture and the infrastructure via a pool of resources (web servers, application servers, database servers, servers, storage instances). It explores both strengths and opportunities on how these services contribute towards QoC KPIs.

Defining KPIs ensures that performance across each layer directly impacts on the other layers. This ultimately supports the provision of care through defined care pathways, for example, QoC, quality of experience (QoE), process performance, service performance and healthcare performance. Of particular interest is the connectedness between the various layers and how the healthcare stakeholders interact to sustain a healthcare service. We contend that the human service infrastructure layer offers us a very important insight into this and argue that there is a need to understand the human infrastructure before we can design software solutions within a healthcare context to support the connectedness of healthcare services.

Applicable modelling techniques

Through the concept of the Careflow Network, we capture healthcare dynamics and build on the characteristics of modelling techniques such as workflow, resource flow, clinical pathways, social networks and careflow management systems which can assess healthcare environments:

- *Workflow*. A defined pattern of activity enabled by the systematic organisation of resources into processes that is, defined, executed, registered and controlled processes.[11] However, as identified by Krogstie[12] (p. 65), the problem is not formality in workflow modelling, but the lack of interaction whereby ‘a model must be formally complete to prevent ambiguity and deadlock from paralysing the process’. Within a healthcare context, this does not capture the nature of healthcare systems.

Table 1. Overview of modelling techniques.

Modelling technique	Description
Stakeholder diagrams	Illustrate how stakeholders are hierarchically structured, for example, a hospital's department structure, similar to organisation charts
Information diagrams	Illustrates the hierarchical structure of documents or information, for example, healthcare standards
Process content diagrams	Represent a hierarchical list of activities, for example, health consultation representation and decision-making
Flowcharts	Describe the sequence of activities, for example, mapping a client registration process
Swim lane activity diagrams	Indicates the sequence of activities with a clear role definition by arranging activities according to responsibilities, for example, a understanding roles and responsibilities for a specific healthcare process
State transition diagrams	Defines the way in which a system's behaviour changes over time by showing, for example, understanding a process in a patient-centred way on a discharge process
Communication diagrams	Indicates how information/material interactions occur between various healthcare stakeholders
Data flow diagrams	Demonstrates how information is processed and where information is stored, for example, within a clinical diagnosis
Resource flow view	Documents the major activities of a process, and the primary sequence in which they are performed through the production and consuming of artefacts.

Source: Adapted from Jun et al.[18]

- *Resource flow.* Links among and within organisations which define the environment as a network flow of resources (i.e. valued activity, service or commodity) over a specific period of time.[13] This is largely used in organisational studies to capture the main formal resources considered, that is, money, information and support.[14] Based on this insight, we are reminded of the three main patterns of information flow identified by Galaskiewicz and Marsden:[15] symmetry in which bidirectional information flow within a channel; exchange in which bidirectionality is supported through the use of different channels; and multiplexity in which information flows unidirectionally in multiple channels. Within a healthcare context, communication is multifaceted which can be guided by formal healthcare guidelines and exchanged through informal networks of healthcare professionals.
- *Clinical pathway*. A standardised multidisciplinary plan of care which executes care processes within a specific timeframe which reduces the variability in clinical practice and improves outcomes.[16]
- *Social network*. A social structure comprising a set of social actors (e.g. people or healthcare institutions) and a set of the dyadic ties (or interactions) between these actors.[17]
- *Careflow management systems*. A system which defines, creates and manages the execution of careflows to improve performance in delivering to administer, support and monitor the execution of healthcare services through the use of software according to a process definition.[7]

At a more simplistic level, Jun et al.[18] provides an overview of some of the key healthcare modelling techniques (Table 1). Healthcare requires dynamic interactions between a patient and healthcare professionals (i.e. careflow) throughout the patient's journey that is supported through various resources being exchanged within a network. This exchange process is of particular interest if we are to truly understand and capture the provision of care within a Careflow Network.

The connectedness of healthcare services

A key concept a Careflow Network builds on the 'connectedness' of technological enabled solutions to provide various healthcare services.[19] Given that there is a growing interest in examining how IT is used within such networks,[20,21] Careflow Networks will play a critical role in sustaining evolving partnerships between all healthcare service system stakeholders.[22,23] To truly assess the impact of technology, we must identify suitable techniques to model Careflow Networks within existing healthcare systems. A healthcare system may be described as the organisation of people, institutions and resources that deliver healthcare services to meet the health needs of society. Thus, healthcare comprises of an extremely diverse group of people who interact with one another to deliver a service.[24] These include the following:

- Patients with a known condition;
- Patients at risk of various healthcare conditions;
- Family members or friends concerned about patient wellbeing;
- Persons interested in their personal wellness;
- Informal carers who comprise of family members and neighbours providing voluntary care;
- Formal carers such as homecare assistants who provide care as part of their profession;
- Clinicians in the community such as public health nurses, general practitioners (GPs), social workers, physiotherapists;
- Clinicians within the hospital setting such as specialist consultants, nurses, radiographers.
- Healthcare (non-clinical) support services including, for example, administration, suppliers, buildings and maintenance.

In addition, when we refer to services, a service may be described as the end product of human assemblage, knowledge, innovation, interaction and consumption.[25] Within a healthcare context, people also interact with non-human elements to facilitate healthcare provision services which include medical devices (e.g. X-ray machines or cardiographs) and information sources (e.g. patient records or NICE standards (https://www.nice.org.uk/standards-and-indicators)). The interactions that exist between socio-material elements (humans and non-humans) may be described as the relational infrastructure,[17] whereby collaboration between actors supports the exchange of resources and competencies, for example, healthcare information.[26] To uncover the dynamics of the relational infrastructure, the connectivity of various stakeholders within the health management system can reveal insights on the healthcare system.[27] For example, it can inform us how the healthcare network is structured, who or what are the most influential/powerful stakeholders,[27] what is the resource flow and where are the service bottlenecks.[24] Understanding and analysing the relational infrastructure can present opportunities of where technology could potentially optimise healthcare service operations to support a healthcare ecosystem. Thus, while there are some existing modelling techniques which apply to certain context, their application to examine the relational structure of a Careflow Network is inadequate. Rather than just focusing on technical flows, the shifting socio-material assemblages of service dynamics should also be presented. What is interesting here is the idea that one can map the, what is often considered 'invisible',[28,29] relational infrastructure to visualise the exchange of resources and patterns of interactions[17,28], and explain that there needs to be increased efforts to 'delayer organisations and reduce functional boundaries, coordination increasingly occurs through networks of informal relations rather than channels

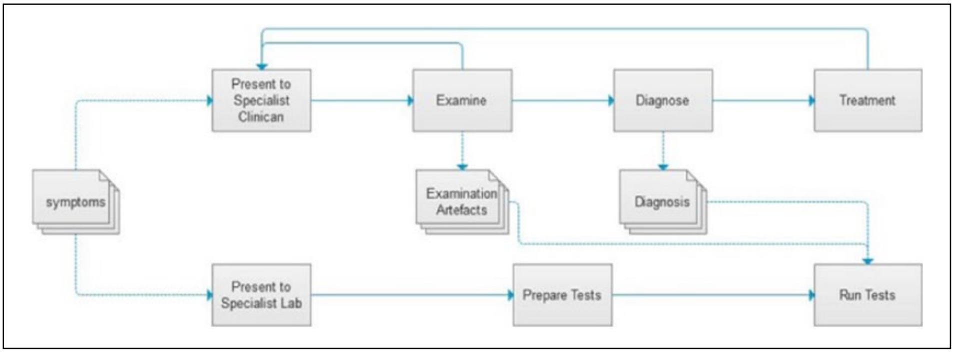

Figure 2. Resource flow model.

tightly prescribed by formal reporting structures or detailed work processes' (p. 25).[28] We explore this within a Careflow Network context in our research question.

Key findings and analysis

Our literature review on modelling techniques indicated how various representations of a real-world system are used to address a specific question. To understand, for example, information flows and network elements, service networks are typically viewed through process models. However, these often fail to capture the real-world dynamic nature of services exchanging resources and competencies and often remain an underexplored and 'invisible' infrastructure.[30]

Taking one of the above techniques (outlined in section 'Applicable modelling techniques'), for example, resource flow model (Figure 2), we can learn how the static modelling techniques fail capture the dynamic nature of healthcare. Undoubtedly, the resource flow view[31] indicates how a nominal sequence of activities is involved in the treatment of a set of symptoms: the patient presents himself to a specialist clinician, an examination is undertaken and after which a diagnosis is made followed by a course of treatment. However, detail in healthcare is of vital importance to quality and safety, yet models such as the resource flow model 'does not seek to capture every detail and nuance of a knowledge-intensive process. (p. 44).[31] Of course, a model cannot capture 'everything', but we will demonstrate how our Careflow Network approach is more effective in capturing healthcare dynamics. Thus, to truly optimise healthcare operations, we must move beyond the resource flow approach and introduce methods which complement and capture interactions within a dynamic healthcare environment.[21] This will ultimately inform us on 'how' and 'where' healthcare solutions can better support healthcare innovation, clinical practice and patient engagement.[4]

It has been claimed that organisational managers have ignored the 'dynamic characteristics of networks and the ways that dynamic qualities of networks affect organisations' flexibility and change' (p. 133).[29] This is also witnessed in healthcare, that is, how care is delivered[32] and how networks hinder the adoption of healthcare change.[33] This has unavoidably led to organisations such as hospitals failing to capture the true operations of their service networks performance (e.g. behavioural, functional, compositional and structural) and the overall contributory value of service linkages (i.e. relational structures).

Principles of a social network

SNA is the study of social relations among a set of actors,[34] for example, people, groups, organisations or computers. The nodes within the network represent the people and groups under

Table 2. General principles of a network.

Characteristic	Description
Structure	A collection of nodes (e.g. healthcare professionals) and links that have a distinct format or topology which suggests that function follows form for example, specific healthcare departments
Emergence	Network properties are emergent as a consequence of a dynamic network achieving stability, for example, improving the provision of a healthcare service
Dynamism	Dynamic behaviour is often the result of emergence or a series of small evolutionary steps leading to a fixed-point final state of the healthcare system, for example, discharge of a patient after treatment
Autonomy	A network formed by the autonomous and spontaneous action of interdependent nodes that come together (link), rather than central control or central planning, for example, emergency service operations
Bottom-up evolution	Networks grow from the bottom or local level up to the top or global level. They can be designed and implemented from the top down, for example, nursing care within a specific department supporting specific care needs
Topology	The network architecture or properties that emerges over time as a consequence of distributed – and often subtle – forces or autonomous behaviours of its nodes, for example, healthcare routines and norms within practice
Power	The power of a node is proportional to its degree (number of links connecting to the network), influence (link values), and betweenness or closeness; the power of a network is proportional to the number and strengths of its nodes and links, for example, healthcare department managers
Stability	The degree to which a network pattern changes over time, for example, introducing healthcare technology to improve service efficiencies

Source: Adapted from Carroll.[17]

investigation, while the links demonstrate the relationships or flows between the nodes. Thus, SNA offers a specific approach and set of techniques that supports the study of resource exchanges (e.g. information) among actors.[17] There is a large body of literature which suggests that SNA presents a unique method to model and monitor the interactions and potentially contributory value of actors within a service network such as healthcare,[17,30,34–41] all of which direct our attention to the need to understand the principles of a network before we can begin to understand and/or improve the network under investigation. These network principles offer us a lens to view healthcare service operations that is, viewing Careflow Networks as a network of interconnecting elements that sustain a specific structure, bound by various interactions to deliver a healthcare service (Table 2).

Why SNA? A social network is a set of actors (or nodes) that supports some form of relationship (or edges, or ties) with another node.[28] In a Careflow Network, these actors include stakeholders such as patients, carers, GP, physiotherapists, healthcare administration, community carers, formal/informal carers and social carers. Therefore, to exploit the potential of SNA, it is important to define what actors comprise the network and to develop an understanding of the Careflow Network under investigation. This provides a comprehensive and rigorous description of a pattern of social relationships to support our analysis.[17] Often, it is difficult to fully appreciate how connected a social network is within a specific population,[28,29] but there are a number of techniques to support us identify the ‘boundaries’ of a specific network and to define the social network. From this, we can begin to identify emerging patterns of social structure. This is particularly important to enable us to visualise Careflow Network patterns or graphs and offers us a suitable approach to illustrate the connectedness of a healthcare service system, identify inefficiencies and explore opportunities to integrate technological innovation. Using formal methods to represent a social network is achieved through mathematical software applications to analyse the network data and derive structural analysis. From a clinical, technology, social science and business perspective, the results from such analysis present us with the structures of a Careflow Network. SNA can provide answers towards descriptive and exploratory research questions to provide empirical findings regarding the networks structures. Visualising healthcare interactions has the potential to offer us a real insight on how a healthcare service truly operates as opposed to how it 'ought' to work. To achieve this, SNA can assist us in examining the relational structures of a Careflow Network environment, providing us with a lens to examine the socio-technical entities. SNA software is vital to support the visualisation and relational descriptions of the Careflow Network. This approach also complements what Spohrer and Maglio[42] describe as the importance of implementing new modelling methods in modern service environments and the intertwining complexity and dynamic configuration of people, knowledge, activities, interactions and intentions that creates and delivers value. We explain the motivation of this through the potential application of SNA to Careflow Networks.

The connectedness of Careflow Networks

A dynamic healthcare environment involves various stakeholders at different organisational levels, yet many of the modelling techniques to map healthcare behaviour provide a rather static view of healthcare systems.[43] Careflow Networks reproduce and embody the complex interplay of professional, healthcare, technical, economic and political factors. Thus, the involvement of multiple factors in healthcare systems has made IT-based healthcare systems expensive, competitive and complex.[44] The deployment of different programming languages, platforms and data management standards has led to restrictions in flawless exchange, integration and reuse of information across different systems.[44] Therefore, modelling healthcare and its dynamics is a critical first step to understand the healthcare environment and its behaviour. Building on our Careflow Network concept, we revisit[38] and examine the network concepts and network properties as summarised in Table 3. These are also considered fundamental to Careflow Network dynamics.

SNA can be employed as a technique to graphically represent and visualise service relational structures. More importantly, SNA is an approach and set of techniques which can assist in to study the exchange of resources and competencies. The nature of the links considers the strength and qualitative nature of the relation between two or more actors or nodes. The structural characteristics examine the overall pattern of relationships between the actors, for example, clustering, network density and special nodes on the network are all structural characteristics. Watts and Strogatz[45] report that real-world networks are neither completely ordered nor completely random, but rather exhibit properties of both. In addition, they claim that the structure of a network can have dramatic implications for the collective dynamics of a system, whose connectivity the network represents, and that large changes in dynamic behaviour could be driven by even subtle modifications to the network structure. Therefore, the orchestration of structural relations (emergent property of the connection, for example, the exchange process) or attributes (intrinsic characteristics, for example, value of an exchange) become a central factor to analyse a network's structural properties. This complements what one might describe as the connectedness of Careflow Networks which contributes towards delivering healthcare services. The properties of a network listed in Table 3 provide us with a new vocabulary to develop Careflow Network metrics, for example, the intensity of links, the structural size of the network, the stability of a network, the key actors who act as a bridge within a network. Gathering this information requires a specific methodology, which can be

Table 3. Social network analysis concepts and network properties.

Property	Description
Transactional content	Four types of exchanges 1. Expression of effect (e.g. initiate a care pathway) 2. Influence attempt (e.g. negotiating patient admission) 3. Exchange of information (e.g. patient diagnosis) 4. Exchange of goods and services (e.g. payment for care)
Nature of links	
1. Intensity	The strength of the relations between individuals (e.g. quality of care)
2. Reciprocity	The degree to which a relation is commonly perceived and agreed on by all parties to the relation (i.e. the degree of symmetry)
3. Clarity of expression	The degree to which every pair of individuals has clearly defined expectations about each other's behaviour in the relation, that is, they agree about appropriate behaviour between one another (e.g. expectation of quality of care)
4. Multiplexity	The degree to which pairs of individuals are linked by multiple relations. Multiple roles of each member (e.g. patient, radiologist, consultant, etc.) and identifies how individuals are linked by multiple roles (the more roles, the stronger the link)
Structural characteristics	
1. Size	The number of individuals participating in the network (i.e. Careflow Network)
2. Density (connectedness)	The number of actual links in the network as a ratio of the number of possible links
3. Clustering	The number of dense regions in the network (i.e. network positioning or structural holes)
4. Openness	The number of actual external links of a social unit as a ratio of the number possible external links
5. Stability	The degree to which a network pattern changes over time (e.g. the evolution of healthcare change)
6. Reachability	The average number of links between any two individuals in the network
7. Centrality	The degree to which relations are guided by the formal hierarchy
8. Star	The service with the highest number of nominations (e.g. quality of healthcare delivery)
9. Liaison	A service which is not a member of a cluster but links two or more clusters
10. Bridge	A service which is a member of multiple clusters in the network (i.e. a linking pin)
11. Gatekeeper	A star who also links the social unit with external domains (i.e. knowledge diffusion)
12. Isolate	A service which has uncoupled from the network

Source: Adapted from Tichy et al.[38]

executed across the healthcare community within a specific context and identify key factors that influence the Careflow Network dynamics.

Scenario: examining Careflow Network operations

A Careflow Network may comprise of hundreds or thousands of actors including home, family, friends, community, hospital, healthcare professional and social care. Therefore, defining the network and its boundary will influence the data gathering process. In this section, we demonstrate how SNA can be used to model the Careflow Network.

Through this hypothetical scenario, we examine one set of actors within a socio-matrix, which are linked through various relationships at a specific period of time. Table 4 provides the simple view of a traditional healthcare service which captures the healthcare professional's interactions in order to deliver quality care for a patient, Noel, a 60-year old who has broken his leg. When he engages in the clinical pathway, he interacts with a number of actors. Initially, *Julie*, his GP, performs a diagnosis and informs him that he must undergo an X-ray. To do so, he must visit the hospital and interact with various healthcare professionals (listed as follows):

- *John*, the porter, for assistance, for example, provision of a wheelchair;
- *Mary*, the receptionist, to sign healthcare documents and ensure insurance coverage is adequate;
- *Joe*, the consultant, who diagnoses the specific injury and prescribes the treatment plan;
- *Susan*, the student doctor, who refers Noel to a radiologist to identify the extent of the breakage;
- *Pat*, the radiologist, who conducts the X-ray on Noel;
- *Susan*, the doctor who places a plaster cast on Noel's leg;
- *Sean*, the physiotherapist, who instructs Noel on various rehabilitation procedures and exercises;
- *Frank*, the homecare provider, who checks in on Noel every week to check on his progress;
- *Julie*, the GP who re-examines Noels progress and recovery once every month for 3 months.

Capturing this interaction among the actors provides us with a map of the Careflow Network. To do so, we used UCINET (https://sites.google.com/site/ucinetsoftware/home) to map the Careflow Network. Figure 3 represents the actors and their interactions with other healthcare staff in order to successfully complete a specific process (the arrows illustrate the direction of the relationship).

Discussion on the Careflow Network. Through the hypothetical scenario, we examine one set of actors which are linked through various relationships at a specific period of time which provides a socio-matrix. Table 4 provides the simple view of a traditional healthcare service which captures the healthcare professional's interactions in order to deliver quality care for a patient (i.e. *Noel*). While this is a small sample to demonstrate the use of SNA, it is important to examine the service network by reaching a sufficient sample size which can be achieved through a survey tool. The survey should capture background information to profile participants, examine with whom a person must interact with to complete a process within the service, explore people's attitudes or opinions of service operations and identify ideas for change. To support the analysis, it is also a good idea to interview respondents to learn more about the actual relationship between actors. Within a healthcare context, we may examine who is involved with admission, post-admission and discharge of a patient. For demonstration purposes, we merge the traditional healthcare service (T) and Connected Health (C) within Table 4 to highlight the changes in each context, that is, the impact of CH solutions on the Careflow Network. It is worth noting that traditionally, the GP was considered a gatekeeper of healthcare services[46,47] within a community context and directed patients to specific services or consultants depending on the nature of the patient's condition presented to the GP.[48] For the purpose of this study, the CH solution is a technical solution that is envisaged to empower patients to be directly assessed by a doctor (Susan) and then referred to the

Table 4. Example of a simple socio-matrix demonstrating the impact of a Connected Health (C) solution on the Traditional Healthcare system (T).

Context	Noel (patient)		John (porter)		Mary (receptionist)		Joe (consultant)		Susan (doctor)		Pat (radiologist)		Sean (physiotherapy)		Frank (homecare)		Julie (GP)	
	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C	T	C
Noel (patient)	✗	✗	✓	✗	✓	✗	✓	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓	✗
John (porter)	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	✗	✗	✗	✓	✗	✗	✗
Mary (receptionist)	✓	✗	✓	✗	✗	✗	✓	✗	✓	✗	✗	✗	✓	✗	✗	✗	✗	✗
Joe (consultant)	✓	✓	✗	✗	✓	✗	✗	✗	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗
Susan (doctor)	✓	✗	✗	✗	✓	✗	✓	✗	✗	✗	✓	✓	✗	✗	✓	✗	✗	✗
Pat (radiologist)	✓	✓	✗	✗	✗	✗	✓	✓	✓	✗	✗	✗	✓	✗	✗	✗	✗	✗
Sean (physiotherapy)	✓	✓	✗	✗	✗	✗	✓	✗	✓	✗	✓	✓	✗	✗	✓	✗	✓	✗
Frank (homecare)	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	✓	✗	✗	✓	✗
Julie (GP)	✓	✗	✗	✗	✗	✗	✓	✗	✗	✗	✗	✗	✗	✗	✓	✗	✗	✗

GP: general practitioner.
✓: interaction; ✗: no interaction.

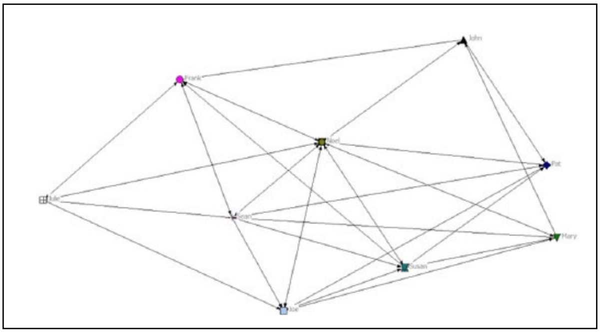

Figure 3. Mapping a traditional Careflow Network.

most suitable service within the Careflow Network. This eliminates the need for a GP (Julie) to interact initially with the patient and then refer a patient to the doctor and later onto a consultant. This can be achieved via an online consultation process with Susan rather than having to go through the traditional face-to-face visit with the GP service and thereby streamlining the healthcare process. However, the focus of this article is to highlight the need modelling techniques such as SNA to generate new insights and analysis to trigger questions on the process flow and process efficiency of a Careflow Network.

The interactions/links within the network are represented using arrows. The SNA offers a clear view of the service operations and provides an overview of the interactions. Mapping the network provides us with an opportunity to visualise the complexity and identify potentially service bottlenecks by investigating social structures. From here, we can begin to identify the network size through the number of actors (nodes) in a Careflow Network. Then, we can assess the density of the network which measures the proportion of all possible ties that are actually present. The density informs about us the efficiency in which information or resources diffuse among the nodes, that is, the more nodes that receive information from multiple others, the network may be described as not 'efficient'. This may be also as a result of the reachability within a network, that is, average number of links between any two individuals in the network. The reachability informs us whether two actors are connected through either direct or indirect pathways. Such insights can support us in managing or redesigning a care pathway and we can begin to explore efficient ways to deliver healthcare. For example, we can use geodesic distance. This examines the number of relations in the shortest possible path from one actor to another and suggests the most efficient connection between two actors. We could experiment with the inclusion of technology as an additional actor, thus investigating the potential contribution and impact of CH innovation (Figure 4).

Our preliminary findings suggest that CH innovation brings about improved healthcare efficiency since the CH solution reduces the density of the Careflow Network, that is, the number of ties which suggest that resources such as information may be received in a more efficient manner. For example, introducing an online appointments system could remove the need for the receptionist and perhaps the porter within this Careflow Network. However, each of these connections can be of different nature. One cannot simply argue that the geodesic distance indicates how two different actors can closely communicate or share information. Patients may value the interaction with homecare staff and have built up a holistic healthcare relationship with them, whereas the consultant may be very disease-focused. This requires further research such as the adoption of ethnography methods and design thinking techniques[4] in order to fully understand the weighting or contribution each actor has on the delivery of care.

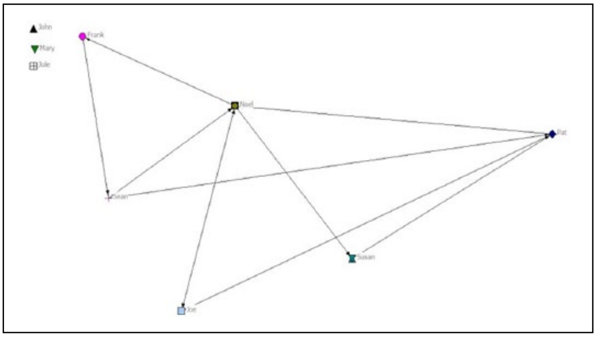

Figure 4. Mapping a Careflow Network with integration of a Connected Health solution.

When ties are directed, we can calculate the total number of ties sent (out-degree) and ties received (in-degree). The out-degree is typically used to examine the influence. The in-degree may be used to assess the popularity of another node which may represent a QoS, that is, expertise of a doctor. However, the degree centrality does not take into account indirect ties which an actor has. Closeness centrality emphasises the distance of an actor to all others in the network. The degree centrality measures local position, while closeness centrality measures global position. Closeness is indefinite for disconnected nodes and is meaningful only for a connected network. The more dependency placed on a particular actor through various connections (e.g. Joe the consultant), the more powerful the actor becomes within the network.

From a CH perspective, removing some administrative and support actors while introducing a patient platform software solution removes tasks such as porter assistance, reception administration and homecare instruction while offering a more healthcare-focused solution. Such a solution could enable the patient to book an appointment online, locate the consultant's practice within a hospital building, avail of online support and physiotherapy rehabilitation instructions. Online GP/consultant meetings may also be arranged to achieve greater healthcare efficiencies and community-based care. With the use of SNA, for example, we begin to learn how density represents the proportion of possible relationships in a network that are actually present. A sparsely connected network has fewer links to nodes within the network. By contrast, densely connected networks indicate a more evenly distributed network. However, we may argue that sparsely connected networks offer more patient-centric opportunities, adding greater connectivity to patient care. In addition, the average degree of a node indicates the number of edges connected to it which suggests that the CH solution(s) may offer more efficient and direct solutions to service users. A measure called betweenness centrality is the extent to which an actor falls on the geodesic paths between other pairs of actors in the network. For example, the betweenness measures of Sean's position post-implementation of the CH solution has decreased compared to the pre-implementation position as there is now less interaction and demand on his service since he can offer a physiotherapy solution online. While removing the need for direct interaction between Noel (patient) and Sean (physiotherapist) via a home-based exercise prescription service and e-learning tool, the evidence base provides both Noel and Sean with a rich insight of Noel's progress. Adopting such measures and applying them as Careflow Network metrics may enable us to explore the causes of such bottlenecks and examine the potential of applying healthcare technology solutions to enhance the health service efficiency. For example, through introducing new pathway measures, we can calculate total network cohesion. We can compare these measures to determine the impact of CH innovation on a specific network. This type of activity also demonstrates the value of SNA to map a Careflow Network. For example, we visually identify the

Table 5. Impact of Connected Health innovation of density of Careflow Network.

	Density	No. of ties	Standard dev.	Average degree
Traditional Healthcare Network	0.542	39	0.498	4.333
Connected Health Network	0.153	11	0.360	1.222
Explanation	Reduced number of links within the Careflow Network potentially creating greater efficiencies	Reduced ties within the Careflow Network suggesting faster transfer of information	Reduced mean density of the Careflow Network which could streamline the transfer of healthcare resources	Reduced average number of edges connected to node within the Careflow Network leading to improved efficiencies

impact of a CH solution (a patient platform that offers a self-service check-in tool and physiotherapy interactive e-learning tool) on the overall Careflow Network.

Adopting SNA for Careflow Network metrics. A further requirement for efficient modelling is that metrics are provided, and within the Careflow Network, the key focus must be on delivering quality information to support the delivery of quality care. The nature of Careflow Networks is changing rapidly due to the integration of CH innovation. For our scenario, Table 5 presents the density measure using SNA. When comparing two populations (i.e. traditional healthcare and CH) we can identify how many actors are connected in one network and may not be connected to another ('isolates'). For example, John, Mary and Julie are removed from the Careflow Network (Figure 4, top left of image). We can conclude that, based on interactions, the operations are now very different in the two populations. Measuring the density gives us an index of the degree of dyadic connection in a network. This is important to demonstrate the level of interaction and the resources exchanged between actors. It also highlights the potential service bottleneck and the importance an actor plays within the Careflow Network. Measuring the ties among actors with various values, for example, strengths, closeness, probabilities, density is usually defined as the sum of the values of all ties divided by the number of possible ties. That is, with valued data, density is usually defined as the average strength of ties across all possible ties.

The characteristics of the Careflow Network can provide researchers with the ability to introduce new metrics into CH to support decision-making and derive improved healthcare analytics. Such an approach can provide us with a visual aid to map a healthcare network to understand 'what the current situation is' and how tasks are 'really done' rather than high-level workflow charts which offer us little insights on the dynamic nature of a healthcare environment. From a Careflow Network perspective, for example, using SNA we can begin to examine how network science measures inform us of Careflow Network behaviour. The SNA technique will provide other measures such as degree of centrality, closeness and betweenness (see Table 3), which may also be employed to assess healthcare service operations and structure. Thus, they will support us in determining the impact of IT to improve operations and/or service structure.

Adopting SNA to model Careflow Networks

Based on this initial exploratory research, we have identified the suitability of applying SNA to map and measure Careflow Networks and develop thorough insights on the connectedness of a

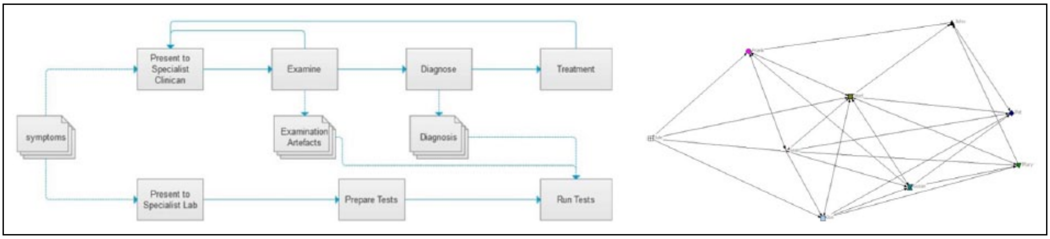

Figure 5. Complementary models: Resource flow and SNA view of care pathway.

healthcare service system. SNA offers a unique approach to model the exchange of various resources to provide a healthcare service. Through its inherent inclusion of resource flow dynamics, SNA can successfully supplement traditional methods of modelling care pathways. It will be useful in providing rich insights on how a health service operates and where the introduction of CH technological innovation may enhance various activities, such as decision-making, within the pathway.

Figure 5 illustrates how different modelling techniques can complement each other when examining care pathways. The resource flow view[31] indicates how a nominal sequence of activities involved in the treatment of a set of symptoms: the patient presents himself to a specialist clinician, an examination is undertaken and after which a diagnosis is made followed by a course of treatment. However, this does not reflect the dynamic nature of healthcare delivery and the level of interaction (formal and informal) that is executed to deliver a particular healthcare service. SNA provides such insights. Implementing a combination of both approaches may also offer a dual lens (or multiple layers) on how Careflow Networks may be modelled in terms of the standardisation of resources and the dynamics of actor interaction.

Discussion and conclusion

We set out to describe the impact of which CH is having a rapidly developing field that has the potential to transform healthcare service systems by increasing its safety, quality and overall efficiency. However, as part of our research developments, we identified a significant gap to employ suitable models and modelling techniques to capture the dynamic nature of CH. To address this gap, we study and model the dynamic nature of healthcare delivery. This allowed us to identify where issues exist within the service system and to examine how CH technological solutions may support service efficiencies. This study is important for a number of reasons. First, healthcare is a complex service and is increasingly reliant on accurate and timely data and networking. GPs and specialist consult with patients, healthcare teams develop and execute treatment plans, pharmacists review and fill prescriptions, and patients' research and communicate with peers and it is important to uncover the dynamic interaction within a healthcare system. Second, the Careflow Network is introduced to demonstrate how vast the healthcare system is and relies on numerous actors to interact and provide a healthcare service in many forms. Therefore, a third key contribution of this work includes the application of SNA as a technique to map and explore how we can begin to improve the efficiency of this network with connected technologies with a view to improve healthcare outcomes and quality of life, while reducing costs. Our research supports the need to reconsider how we can design healthcare systems and operationalise Careflow Networks. Specifically, we challenge the need to reconsider how we view a GP as a healthcare service gatekeeper[46,47] within a community healthcare context. We support Greenfield et al.[48] analysis on the need to rethink primary care's gatekeeper role. We suggest that CH solutions can empower patients to self-manage their healthcare while reducing the need for interactions with specific Careflow Network actors. In so doing, this can improve the effectiveness and efficiency of delivering care.

The Careflow Network is a first attempt to develop an understanding as to what the actual network is, who participates, what is its structure, how is formal and informal work undertaken within the network, where are the inefficiencies across the healthcare system exists. Ultimately, this can also influence decisions on whether care pathways can be redesigned. Technology can also be included in this analysis. Networked devices and healthcare are already improving QoC. This article has presented a discussion on the suitability of SNA to model Careflow Networks and demonstrated this through the case study. It also provided both a technique and a vocabulary to inform healthcare managers and entrepreneurs how the delivery of healthcare could be potentially improved. SNA allowed us to establish insights through our hypothetical scenario and examine led us to new research ideas which we describe in section 'Future research'.

Study limitations

This section offers a discussion on the limitations of this overall study. For example, considering the novelty of this work and the research gap identified by the authors, the literature review was a challenge to identify suitable sources to support our work. However, separating the literature into CH/E-health, healthcare systems and SNA, to identify the gap allowed the authors to argue the need to explore the benefit of this work using a hypothetical scenario. While another limitation of this research is that the case study employs a hypothetical Careflow Network scenario, we also explain that this can be carried out in a real-world context by adopting the same technique using SNA. This will also form part of our future research. In fact, the hypothetical scenario became a key asset to demonstrate the promise of applying SNA to map the Careflow Network and connectedness of CH. To successfully conduct a real-world case study, ethical considerations may present some additional limitations particularly regarding the need to track actors' interactions within a healthcare system. However, if one can incentivise research participants while upholding ethical, privacy and data protection policies, such a study could be presented as a means to improve a healthcare system and alleviate the burden on healthcare professionals' day-to-day interactions. While the behaviour of any unit of analysis of a person, group or organisation such as a Careflow Network, it can influence the outcome of interactions of the entity. However, while we accept this as a limitation of a case study, we are focused on the technique used to model the interactions and not the behaviour that influences such interactions. Thus, we use the hypothetical scenario to demonstrate how SNA can be employed to map such interactions with a view to identify bottlenecks and uncover how or where CH innovation may be best placed within a Careflow Network.

Future research

As part of our future research, we will model healthcare environments to include the connectedness of various Careflow Networks in various settings including hospitals and homecare. In addition, we will also continue to explore how SNA can be combined with other modelling techniques such as resource flow and value stream mapping, thereby offering a multi-layered view of Careflow Networks. Identifying a suitable tool such as a staff identification key-fob which captures human interactions may prove to be a very useful way to gather a large dataset within a Careflow Network. Ethical approval will be a critical element to employ such research methodologies. We recognise that SNA does have some limitations. For example, additional information is required to capture the weight or importance of a node in a complex health setting rather than merely focusing on the number of connections. We also need to understand how weights may be assigned to the importance of healthcare actors and the influence they have in the provision of safe and quality care services, for example, from a patient experience perspective. We can expand on the Careflow Network categories (transactional, nature of links and structural characteristics) to elaborate on the SNA. These will allow us to establish service metrics (Carroll et al. 2012) that inform us on how various factors are influenced by social behaviour, service structures and decision-making. Table 5 offers an insight on what may be achieved by employing SNA concepts and properties as Careflow Network metrics. Further research must be carried out to expand on establishing metrics that can stem from Table 3 (listing key concepts and network properties). Ultimately, this will allow us to recognise where CH innovation may optimise the impact of healthcare delivery.[21,49] Combined with other modelling techniques, we consider that SNA is a suitable modelling technique for the assessment of the impact of healthcare innovations on Careflow Networks.

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Accessing care summaries at point-of-care: Implementation of mobile devices for personal carers in aged care

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Abstract

Continued development of mobile technology now allows access to information at the point-of-care. This study was conducted to evaluate the use of one such tool on a mobile device, from the carer perspective. Caregivers across 12 aged-care facilities were supplied mobile devices to access a Picture Care Plan (PCP), a specific tool designed around the role of the personal carer. An anonymous questionnaire was subsequently completed by 85 carers with questions relating to participants' experience. Perceived helpfulness of the PCP at the point-of-care was high (87%). A significant number of participants believed the use of the PCP increased resident safety and quality of care (76%). Practical components related to the carrying of the device, network speed and the requirement to maintain communication with senior members of staff to ascertain updates were also expressed by participants. Findings suggest that staff are receptive to adoption of mobile devices to access care directives at the point-of-care and that the technology is useful.

Keywords

adoption, aged care, long-term care, mobile technology, user perceptions

Introduction

Continued development of mobile technology has seen the integration of mobile devices, software and operating systems into the healthcare sector. Access to information at the point-of-care to increase accuracy and efficiency has been a primary driving factor.[1,2] Particularly for the aged-care

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sector, the pressure to increase efficiency and quality of care in the face of limited resources has led to increased focus on mobile technologies to provide a cost-effective method of providing greater information access regarding resident care needs.[3] Increasing integration and acceptance of mobile device–accessed documentation systems in aged care has the potential to dramatically increase access to resident care directives for not only nurses and allied health professionals but also for personal carers completing routine care tailored to the individual.

Continued development and successful integration of such software and technology is especially poignant considering that current evidence suggests that accessibility of appropriate resident information is still lacking in the aged-care sector. One study reported that only 38.5 per cent of participating staff across four Australian residential aged-care homes (RACH; including managers, registered nurses (RNs), enrolled nurses (ENs) and personal carers (PCs)) always had access to resident information at point-of-care.[4] There is significant potential for mobile devices to dramatically increase this figure. However, several barriers to successful integration exist, including reluctance of staff to use mobile devices at point-of-care due to fear of being alienated from residents, fear of a foreign tool or due to inadequate fit of the operating system to meet work requirements and individual preferences.[1] Adoption of mobile technology across the aged-care sector is variable.[3]

In addition to variability in integration of mobile technology and health management software, work intensity for RACH nurses is increasing. Trends indicate that supply projections will not keep pace with predicted demand for future resident placements. Australian data reveal that aged-care nurses are increasingly required to supervise more residents as well as more staff, raising concerns over the continued quality of care provision.[5] The changing landscape of the RACH workforce in Australia has seen increases in PC numbers, with PCs (also termed as assistants in nursing (AINs)) constituting 68 per cent of the RACH workforce in 2012, while RNs and ENs constituted only 15 and 12 per cent, respectively.[6] Specific to addressing concerns over the continued quality and continuity of care is the use of handheld mobile devices to access resident data at point-of-care.

Currently, research has primarily focused on the use of mobile devices by RNs or other medical practitioners; however, day-to-day care of residents in RACHs is primarily provided by PCs. These carers are actively involved in the daily lives of residents with approximately 45 per cent of their time, not including indirect care and preparation, spent directly interacting with residents, completing tasks, such as personal hygiene, toileting, mobility, medication, nutrition, assessment and oral communication.[7] PCs engage with residents, spending an estimated 2 h per shift in oral communication with residents, often concurrently with care activities.[7] Although care has traditionally been seen as task oriented,[8] there has been a greater emphasis on a person-centred approach in recent years. PCs are therefore integral to the personal well-being of residents and are significant to the functioning of aged-care homes. Research must focus not only on health management systems as experienced by RN, ENs and other health practitioners but also on the experience of PCs involved in providing direct care for the resident. The potential of health management systems designed around the role of the PC and integrated into care are yet to be thoroughly explored.

Methods

Sites

A total of 12 RACH, located in Queensland, Australia, operated by the same not-for-profit organisation participated in the study. The large long-standing RACH provider had implemented a new documentation system, yet to be appraised from the PC/AIN perspective.

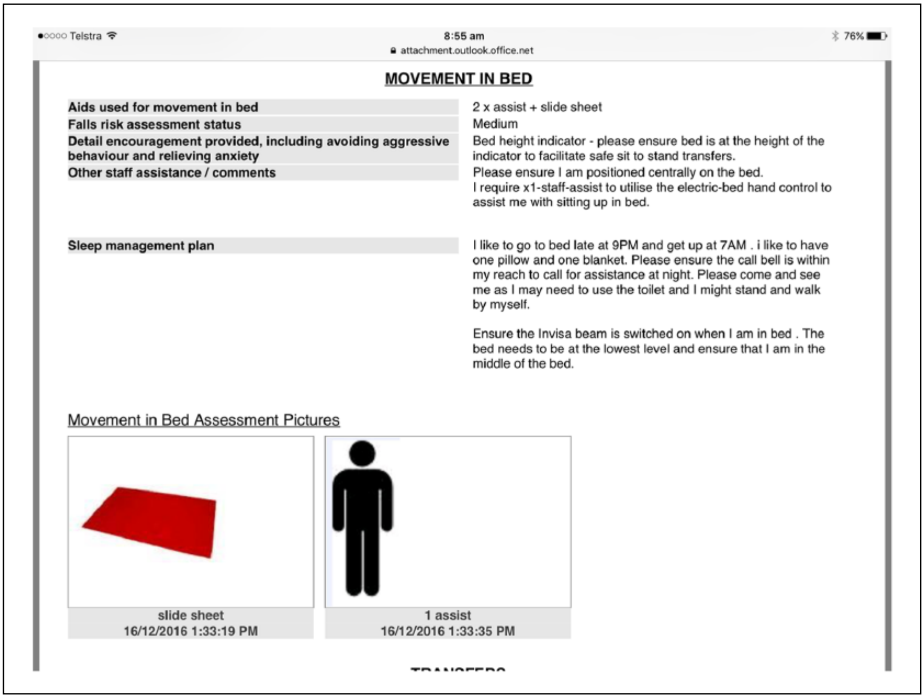
Documentation system

Leecare Solutions, Leecare Platinum 5.0 Care, Lifestyle, and Management software had been initiated at each of the sites over a 2-year period. Go live dates ranged from 2 December 2013 to 15 June 2015 earning the participating RACH provider the 2015 Best Implementation of the year ITAC (Information Technology in Aged Care) award for organisations with a budget of over $30 million per year. The Leecare software utilised was developed specially to meet the needs of the Aged an Community Care industry, with access to resident information at point-of-care of particular focus, '… specifically engineered for advanced touch screen interface devices such as Apple and Android tablets, this solution provides users with an application that is completely device and location independent'.[9] The primary aim of the software was to provide efficient access for healthcare professionals, PCs and other relevant aged-care workers to accurate resident information within a simple and easy-to-use interface. The software allows users to navigate within the programme within two clicks or two touches, in the case of mobile devices, and was designed to be adaptable to specific organisational needs. The Leecare software implemented at the participating sites continues to undergo development alongside the organization's own clinical support team in consultation with facility managers and aged-care employees.

Included in the programme is the application, a *Picture Care Plan* (PCP), developed specifically to aid carers to complete daily-care activities required by the individual resident. The tool aims to provide clear summarised information, accompanied by relevant illustrations, to be accessed immediately prior to providing care or at the bedside. Sections are broken into safety, movement in bed, transfers, mobility, hygiene, toileting, meals/drinks, skin care, oral/dental, communication and pain management, as well as a brief life history. Text is limited to provide only care directives. Pictures typically represent aids/tools necessary for the care of the resident and are included as appropriate in each section. Examples of typical images include the following: support, transfer and mobility aids, hygiene, skin care and incontinence products, hearing aids/glasses, chairs, beds and commodes, which are to be used for that individual resident. PCP is accessed on Samsung Galaxy Tab 3 7.0″ provided by the organisation for PCs/AINs to utilise as part of their normal work practices. Tablet dimensions are as follows: 188 × 111.1 × 9.9 mm^3 and weight: 306 g. For example screenshots of the PCP displayed on the device, please refer Figures 1 to 4. Please note these examples are for a fictional resident.

Participants and process

A total of 85 PCs/AINs were recruited across the 12 sites constituting an overall participation rate of 14.4 per cent (n = 589). Study design targeted specifically day-shift workers, bringing the participation rate of relevant workers to 24.1 per cent (n = 353). Research indicates that response rate for aged-care workers in Australia is approximately 39.8–44 per cent completing similar studies;[10,11] however, research has also shown that AINs are less likely to respond to surveys than RNs or ENs in aged care.[4] Very few studies have targeted or included PCs. Participation was anonymous. As part of the rollout of Leecare across the homes, all PCs/AINs received 3 h in-house training on the use of Leecare as relevant to their role. These employees then received 1 week of onsite support during rollout of the software. Staff who started after the rollout received the same training and were then supported by colleagues on site. PCs/AINs were expected to carry the dedicated mobile devices (tablets) supplied by each site for the purposes of carrying out work-related duties. Specifically, PCs/AINs were expected to carry and use the mobile device to access the PCP application located in Leecare Platinum v5.0, which displayed concise, summarised data specific to the care of each resident.



MOVEMENT IN BED

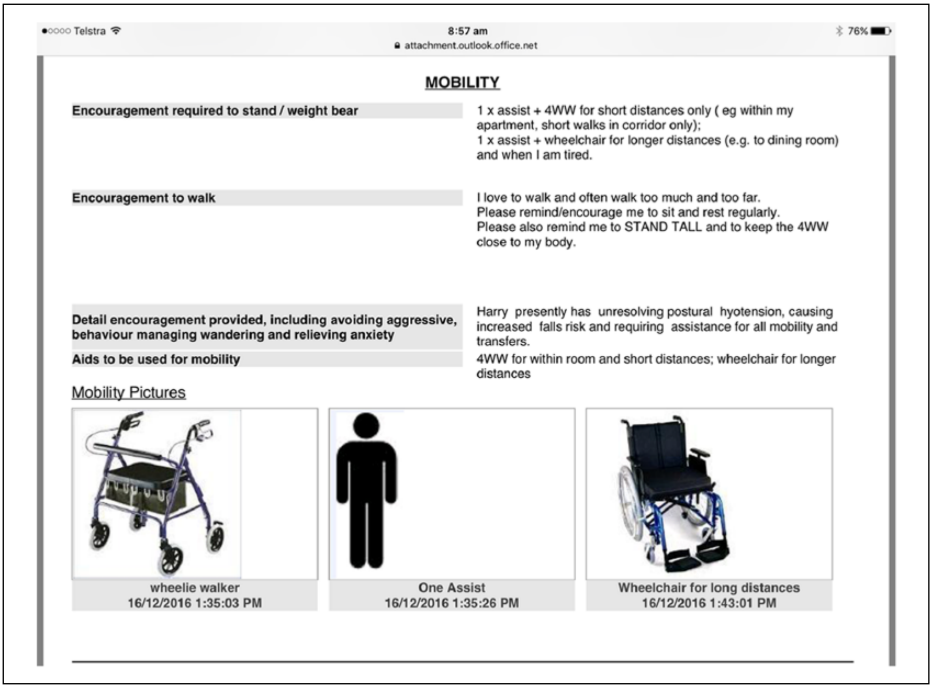
Aids used for movement in bed	2 x assist + slide sheet
Falls risk assessment status	Medium
Detail encouragement provided, including avoiding aggressive behaviour and relieving anxiety	Bed height indicator - please ensure bed is at the height of the indicator to facilitate safe sit to stand transfers.
Other staff assistance / comments	Please ensure I am positioned centrally on the bed. I require x1-staff-assist to utilise the electric-bed hand control to assist me with sitting up in bed.
Sleep management plan	I like to go to bed late at 9PM and get up at 7AM . i like to have one pillow and one blanket. Please ensure the call bell is within my reach to call for assistance at night. Please come and see me as I may need to use the toilet and I might stand and walk by myself. Ensure the Invisa beam is switched on when I am in bed . The bed needs to be at the lowest level and ensure that I am in the middle of the bed.

Movement in Bed Assessment Pictures

slide sheet
16/12/2016 1:33:19 PM

1 assist
16/12/2016 1:33:35 PM

Figure 1. PCP screenshot: movement in Bed.



MOBILITY

Encouragement required to stand / weight bear	1 x assist + 4WW for short distances only (eg within my apartment, short walks in corridor only); 1 x assist + wheelchair for longer distances (e.g. to dining room) and when I am tired.
Encouragement to walk	I love to walk and often walk too much and too far. Please remind/encourage me to sit and rest regularly. Please also remind me to STAND TALL and to keep the 4WW close to my body.
Detail encouragement provided, including avoiding aggressive, behaviour managing wandering and relieving anxiety	Harry presently has unresolving postural hyotension, causing increased falls risk and requiring assistance for all mobility and transfers.
Aids to be used for mobility	4WW for within room and short distances; wheelchair for longer distances

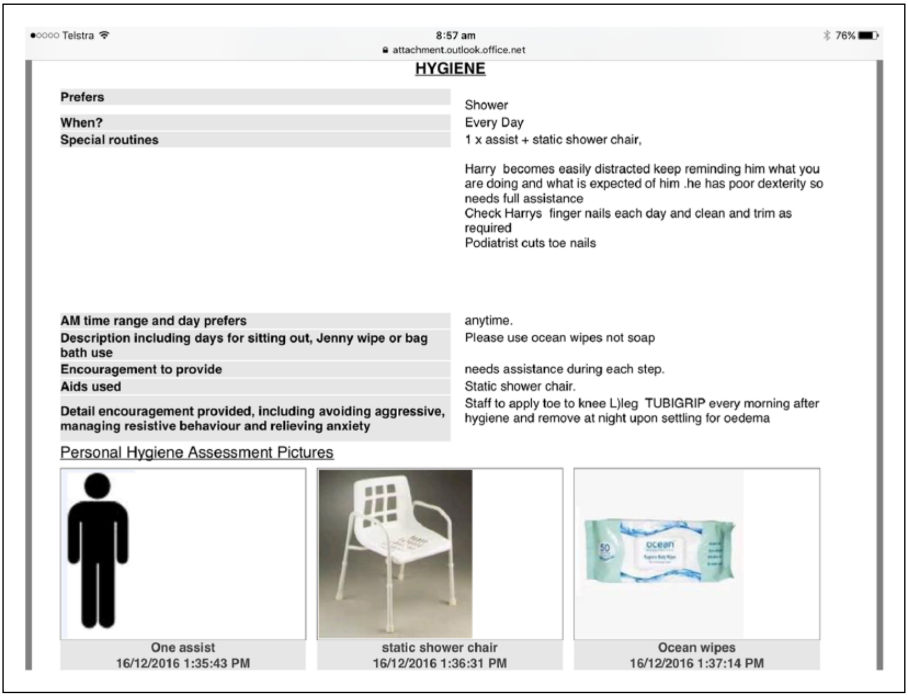
Mobility Pictures

wheelie walker
16/12/2016 1:35:03 PM

One Assist
16/12/2016 1:35:26 PM

Wheelchair for long distances
16/12/2016 1:43:01 PM

Figure 2. PCP screenshot: mobility.



HYGIENE

Prefers	Shower
When?	Every Day
Special routines	1 x assist + static shower chair, Harry becomes easily distracted keep reminding him what you are doing and what is expected of him .he has poor dexterity so needs full assistance Check Harrys finger nails each day and clean and trim as required Podiatrist cuts toe nails
AM time range and day prefers	anytime.
Description including days for sitting out, Jenny wipe or bag bath use	Please use ocean wipes not soap
Encouragement to provide	needs assistance during each step.
Aids used	Static shower chair.
Detail encouragement provided, including avoiding aggressive, managing resistive behaviour and relieving anxiety	Staff to apply toe to knee L)leg TUBIGRIP every morning after hygiene and remove at night upon settling for oedema

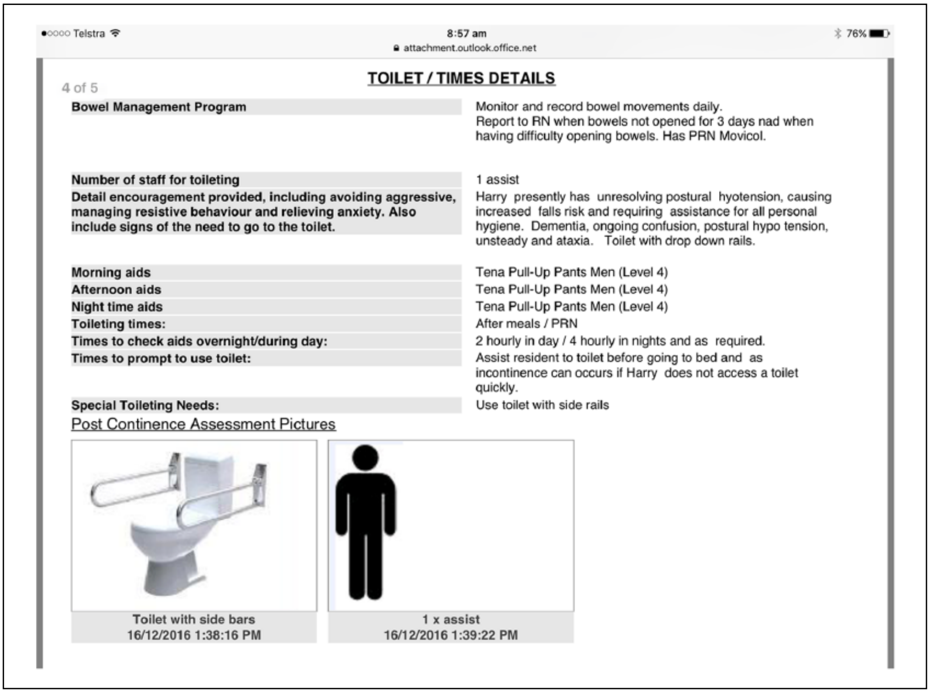
Personal Hygiene Assessment Pictures

One assist
16/12/2016 1:35:43 PM

static shower chair
16/12/2016 1:36:31 PM

Ocean wipes
16/12/2016 1:37:14 PM

Figure 3. PCP screenshot: hygiene.



TOILET / TIMES DETAILS

Bowel Management Program	Monitor and record bowel movements daily. Report to RN when bowels not opened for 3 days nad when having difficulty opening bowels. Has PRN Movicol.
Number of staff for toileting	1 assist
Detail encouragement provided, including avoiding aggressive, managing resistive behaviour and relieving anxiety. Also include signs of the need to go to the toilet.	Harry presently has unresolving postural hyotension, causing increased falls risk and requiring assistance for all personal hygiene. Dementia, ongoing confusion, postural hypo tension, unsteady and ataxia. Toilet with drop down rails.
Morning aids	Tena Pull-Up Pants Men (Level 4)
Afternoon aids	Tena Pull-Up Pants Men (Level 4)
Night time aids	Tena Pull-Up Pants Men (Level 4)
Toileting times:	After meals / PRN
Times to check aids overnight/during day:	2 hourly in day / 4 hourly in nights and as required.
Times to prompt to use toilet:	Assist resident to toilet before going to bed and as incontinence can occurs if Harry does not access a toilet quickly.
Special Toileting Needs:	Use toilet with side rails

Post Continence Assessment Pictures

Toilet with side bars
16/12/2016 1:38:16 PM

1 x assist
16/12/2016 1:39:22 PM

Figure 4. PCP screenshot: toiletting.

Questionnaire

The questionnaire developed for this study was based specifically on the needs of the organisation. Questions were designed and selected based on pre-existing research,[12,13] current knowledge of organisational structure and software implementation of participatory sites. The questionnaire included demographic characteristics and questions relating to participants' own experience of mobile device use, specifically including the use of the PCP, that had been recently implemented across all homes (Supplementary Material 1). Questions relating to the current use of mobile devices and the PCP as part of normal working practices consisted of a five-point Likert response, ranging from *never* to *always* and were developed to measure usefulness, time-saving ability, training, ease of use and information content of both the mobile device and PCP, at a level appropriate for the English literacy of PCs. These factors have been shown to be useful when assessing feedback from nurses and nursing students.[10] Three questions relating to participant's own reflections on the use of a PCP to increase resident safety, quality of care and staff confidence were included with a five-point Likert response, ranging from *strongly disagree* to *strongly agree*, adapted from Johansson et al.[12,13] Qualitative questions were also included to provide an opportunity for the staff participants to provide rich insightful data to compliment the quantitative feedback addressing their suggestions for possible improvements and limitations of mobile device use and the associated tool. Nearly, one-third of PCs/AINs came from non-English speaking backgrounds, according to human resources. Challenges around English language literacy were limited by keeping the wording of the survey questions to an appropriate level and by conducting the surveys using an interview style: reading the questions aloud for participants, while providing a written copy for them to read through, and transcribing their responses verbatim.

Data analysis

Descriptive statistics (frequencies and mode) were applied and data analysis was conducted using SPSS v 22. Examples of quotations received in response to qualitative questions were used to complement and highlight the results and are presented in text.

Ethics

Ethical approval was received by the UnitingCare Queensland Human Research Ethics Committee in conjunction with approval from the organisation's own Research Awareness Group.

Results

As seen in Table 1, participants (n = 85) typically consisted of female PCs/AINs aged between 25 and 64 years, with a peak in workplace constituents between 35 and 54 years (55%). Of the participant cohort, 89 per cent held a certificate III in Aged Care or higher in line with current industry practice[6] and 86 per cent reported home use of mobile technology. (*Note*: Graduates at the Certificate III level have theoretical and practical knowledge and skills for work and/or further learning, which is roughly equivalent to a National Vocational Qualification-Level 2 (NVQ 2)/ General National Vocational Qualification (GNVQ) Intermediate in the United Kingdom.[14])

Results from the questionnaire revealed that 60 per cent of participants reported consistent use of the mobile device when providing care, with a further 15 per cent reporting they sometimes used the device (Table 2). In all, 75 per cent of participants reported that the device was helpful most of the time. Similarly, 73 per cent found it time-saving and 81 per cent found it easy to use. Illustrations

Table 1. Demographics.

Characteristics	n (%)[a]
Age (years)	
18–24	4 (4)
25–34	16 (19)
35–44	24 (28)
45–54	23 (27)
55–64	16 (19)
65 or older	1 (1)
Missing	1 (1)
Gender	
Female	76 (89)
Male	8 (9)
Prefer not to answer	1 (1)
Certificate III in Aged Care	
Yes	76 (89)
No	8 (9)
Missing	1 (1)
Home use of mobile device	
Yes	73 (86)
No	11 (13)
Missing	1 (1)

[a] Percentages have been rounded down (0.1–0.4) or up (0.5–0.9).

were reported to be particularly helpful (85%). Satisfaction with training was high. However, there was no consistency in responses in terms of accessing resident information by other means, for example, desktop computers.

Qualitative findings

Comments and questions throughout the survey revealed common themes among respondents with regard to the limitations of utilising the mobile device during care. The number one concern of staff was the weight of the device, with some staff reporting that the tablet was heavy and cumbersome pulling down on their utility belt/shoulder bag. This practical component deterred some staff from using the device while carrying out care duties, 'to carry the tablet and the phone together when we are providing care for the residents is a bit uncomfortable, the bags provided to us cannot fit both devices'. The tablet weighs 306 g. Some staff also highlighted the need to log into the device due to inactivity several times during a shift as time-consuming and suggested logging in and out only once per shift as a time-saving measure. The current system requires staff to re-enter their password after 20 min of inactivity. This is a security setting to ensure that if a device is accidently left on resident, data are protected. Some staff reported that device and wifi speed as issue and citing time constraints as a deterring factor when utilising the device. Limitations of the device and system expressed by staff predominately surrounded, heaviness, log in times and speed.

In addition to these comments, staff also made suggestions for future improvements. These included the following: wall mounting the devices in the hallways to allow quick access as staff pass to negate having to carry the device and to ensure battery life, more pictures to be included,

Table 2. Mobile device and PCP use among PCs/AINs (n = 85).

PCP use at point-of-care	Never, n (%)[a]	Rarely, n (%)[a]	Sometimes, n (%)[a]	Often, n (%)[a]	Always, n (%)[a]	Mode	Missing, n (%)[a]
Utilisation	9 (11)	6 (7)	13 (15)	9 (11)	42 (49)	5	6 (7)
Helpfulness	3 (4)	4 (5)	10 (12)	26 (31)	37 (44)	5	5 (6)
Time saving	6 (7)	4 (5)	9 (11)	17 (20)	45 (53)	5	4 (5)
Ease of use	0 (0)	3 (4)	9 (11)	19 (22)	50 (59)	5	4 (5)
Necessary information	0 (0)	0 (0)	8 (9)	29 (34)	42 (49)	5	6 (7)
Other access to resident information	15 (18)	10 (12)	19 (22)	14 (17)	20 (24)	5	7 (8)
Illustration helpfulness	0 (0)	0 (0)	7 (8)	22 (26)	50 (59)	5	6 (7)
Training	No, n (%)[a]	Yes, n (%)[a]	Missing, n (%)[a]				
Training for mobile device (general)	6 (7)	73 (86)	6 (7)				
Training for Leecare including PCP	5 (6)	74 (87)	6 (7)				
Quality of care	Strongly disagree, n (%)[a]	Disagree, n (%)[a]	Neither agree nor disagree, n (%)[a]	Agree, n (%)[a]	Strongly agree, n (%)[a]	Mode	Missing, n (%)[a]
Use of the PCP on the mobile device might help to increase resident safety	7 (8)	2 (2)	8 (9)	32 (38)	32 (38)	4/5	4 (5)
Use of the PCP on the mobile device might help to increase the quality of care	7 (8)	2 (2)	6 (7)	30 (35)	35 (41)	5	5 (6)
Use of the PCP on the mobile device gives me a higher degree of confidence in my work	8 (9)	3 (4)	8 (9)	30 (35)	29 (34)	4	7 (8)

PCP: Picture Care Plan; PC: personal carer; AIN: assistant in nursing.
Mode from the five-point Likert scales.
[a] Percentages have been rounded down (0.1–0.4) or up (0.5–0.9).

and having the option to call up only specific items in the PCP, that are needed in that instance. Other useful device applications, such as alerts to be included for 2-h repositioning and for two-person assists were also suggested. Suggestions provided insight into what PCs/AINs believed would be useful in their current work format.

When asked how they, the PCs/AINs, determined that the PCP was updated, the need to confer with the RN or clinical nurse consultant (CNC) at the start of each shift was expressed. PCs/AINs were not able to update changes directly into the PCP, having to verbally report any changes or observations to senior staff members for documentation. The carers cannot update a care plan as this requires a review by RNs and allied health professionals. A care plan guides and provides specific detail of the care that specific resident needs. To determine whether there were any changes to resident care needs confirmation of any changes at handover was necessitated due to the lag time in updating the PCP. One PC/AIN highlighted the importance of communication between staff members of differing positions:

> Better communication between RN's/CN's and PC's in regards to changes and updates in the PCP. Perhaps more comprehensive and frequent staff messages regarding the change/editing of the PCP. It is difficult for the PC to just 'know' what residents have had changes to their PCP, so in this regards I feel like it is extremely important for the lines of communication to be open between all staff when dealing with this.

Despite ongoing technological developments and solutions, communication between staff members at all levels of an aged-care home remains significant to the functionality of the team.

Discussion

Utilisation of PCP at the point-of-care was reported by the staff participants to be easy to use and helpful with most participants employing the technology at least some of the time. Previous findings had indicated that caregivers in long-term care facilities were highly receptive to the use of mobile devices to access residents' information.[15,16] Information from this study further supports that aged-care workers are open and receptive to the integration of new technologies and systems to provide a convenient manner to access resident information. Relevant illustrations accompanying care directives were perceived to be helpful. As one-third of all aged-care staff are from culturally and linguistically diverse backgrounds, with PCs comprising 74.4 per cent of this demographic,[6] pictures may aid in comprehension. Moreover, a significant number of participants believed that the use of the PCP increased resident safety and quality of care, in addition to increasing confidence in their work.

The demographics of the study cohort revealed that 86 per cent of PCs/AINs currently used mobile device technology outside of work, which reflects current trends.[17] Older members of the workforce also readily accepted and used mobile devices in and out of work. In all, 40 per cent of the participating PCs/AINs were aged 45 years or older, reflective of the Australian RACH workforce.[6] This is significant as user age and background knowledge impact user behaviour of electronic devices, with background knowledge shown to influence trial-and-error behaviour and frustration levels.[18] Findings from this study may suggest that home use of similar devices, training and clinical support may positively influence mobile device adoption while undertaking care duties. Computer skills, perceived usefulness and perceived ease of use, all positively influence behavioural intention to use IT applications in long-term care.[16] In total, 86–87 per cent of this study's participants believed that they received adequate training on the mobile device and PCP, respectively, and perceived usefulness and ease of use were high.

However, barriers to successful integration and consistent utilisation were evident. Personal factors, physical design, software inefficiencies, security and speed of wireless transmission and fear of breaking the device have previously been identified as possible barriers to mobile device adoption in healthcare.[19] In this study, physical design was reported to be particularly problematic. The weight and current method of transporting the device in the custom belt holder or shoulder bag of the Samsung Galaxy Tab 3 7.0″ (306 g) was reported to be cumbersome, echoing a finding from a previous study into the integration of mobile devices in an Australian aged-care facility.[3] The study reported that handheld devices were problematic when carers required the use of both hands to perform manual tasks in the care of their residents.[3] Other factors including device speed and personal preferences for desktop computers and desire to maintain engagement with the resident were also expressed.

Individual characteristics influence perceived fit and ultimate utilisation of the device.[1] Organisational environment may help to reduce the impact of these barriers through physical modifications, adaptations to the software interface and content, and through continued support and encouragement of PCs/AINs utilising the PCP on the mobile device. It has been recommended by Aged and Community Services Australia (ACSA) that industry and government support the implementation and uptake of technological initiatives through support of change management strategies and training.[20] Fostering of positive attitudes towards such technology change and resilience among staff may help to increase uptake of new technological solutions in the workplace.

Communication between staff was also highlighted as an important component of receiving up-to-date information. Data from this study suggest that point-of-care access to information does not impact the need to seek out information by other means. The PCP did not replace the need for carers to confer with senior staff members, in relation to resident changes occurring immediately prior. Practices surrounding communication and care plan updates can be streamlined. Notifications of upcoming reviews would allow PCs/AINs to know which residents were likely to have changes to their PCP and therefore to know to check the PCP prior for changes. Implementation of a communication book detailing observations made by PCs/AINs during their shift, along with current verbal reporting, may also assist communication and help to initiate resident care plan reviews as necessary. A collaborative approach to reviews between not only qualified nurses and allied health professionals but also carers with knowledge of the resident at the coalface may be of benefit not only to residents but also to workplace cohesion. PCs/AINs may contribute further value to the workplace.

Limitations

Limitations included staff participation rates and the absence of an appropriate validated tool. Although participation was open to all PCs/AINs, staff participation rates are typically low, approximately 25 per cent based on previous research at the participating sites. In this study, 20 per cent of PCs participated. Factors affecting participation were availability of staff, with care activities taking priority, and shift work. Nightshift and weekend shift workers were under-represented. Generalisability may also be limited, without the use of a validated instrument. There was no appropriate tool to determine the useability of software tools for carers in aged care. The survey had to be based on practical components of the integration of the PCP, as well as audience readability, influenced by participants' education level and English literacy. Practical limitations highlighted may provide some insight into the challenges of successfully implementing research in a mostly under-represented group in the healthcare literature.

Future directions

Following consultation with PCs/AINs, revision of the current PCP has and is being undertaken. Senior management in conjunction with clinical support provided by internal business and support services are conducting a review of the efficacy and user-friendliness of the current system with changes to be made based on PCs/AINs preferences, scope of practice and organisational policy. Trialling of some aspects of Leecare as an app on the devices is also being conducted at present with the intention to also add the PCP to the app to increase functionality of the tablet and increase the speed of accessing the information. Future integration of a resident preference-based care planning tool within the application may also fall within scope of the PC duties. The use of mobile technology to help elicit resident preferences by nurses and encourage shared decision-making has previously been shown to improve patient-centred care for elderly patients.[21] Ongoing evolution of the software in line with staff requirements is to be continued to improve utilisation and maintain best practice.

More broadly, ongoing critical evaluation of new mobile devices and tailored software products are required. With the continual emergence of new software packages and technological devices' usability and effectiveness need to be critically reviewed. As much as technological advancements may seem to enhance accuracy and efficiency, the system still relies upon communication between different members of a team. Up-to-date recording of residents' care needs relies upon a sufficient system for assessment of the resident, communication and appropriate documentation. As it is outside scope for PCs/AINs to update a residents' care plan independently, a system needs to be in place to ensure efficient communication and reporting of any changes in the residents' needs are yet to be addressed.

Conclusion

Continued integration of mobile devices and health management systems into aged-care homes has the potential to increase accuracy and efficiency. Provision of technological solutions designed around the role of the PC is particularly important given that PCs constitute the greatest proportion of aged-care staff and their direct role with the resident. Currently, there is little research into adoption and usefulness of point-of-care information systems around PCs in an aged-care setting. This study aimed to evaluate, from the carer perspective, a mobile tool to assist in the daily-care activities of residents to provide a basis for future developmental changes. Findings suggest that staff are receptive to adoption of mobile devices to access care directives at point-of-care and that the technology is useful. However, barriers pertaining to physical characteristics of the device, speed and staff communication were noted. Evolution of the PCP will continue alongside critical evaluation to provide a successful means of delivering resident information in a manner that supports PCs/AINs to fulfil their role as PC.

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Author contribution

R.E.B. conceived and contributed to study design, data collection, analysis and interpretation, drafting of article and final approval of the version submitted. A.G. contributed to conception of study design, revision of article and final approval of the version submitted. S.M. provided necessary background information for the design of the study and interpretation, and contributed to revision of article and final approval of the version submitted. J.A.W. contributed to conception and design of study, aided in data interpretation, revision of article and final approval of the version submitted.

Declaration of conflicting interests

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Interprofessional education and social interaction: The use of automated external defibrillators in team-based basic life support

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Abstract

Automated external defibrillators are pervasive computing devices designed for the treatment and management of acute sudden cardiac arrest. This study aims to explain users' actual use behavior in teams formed by different professions taken after a short time span of interaction with automated external defibrillator. Before the intervention, all the participants were certified with the American Heart Association Basic Life Support for healthcare providers. A statistically significant difference was revealed in mean individual automated external defibrillator technical skills between uniprofessional and interprofessional groups. The technical automated external defibrillator team scores were greater for groups with interprofessional than for those with uniprofessional education. The nontechnical automated external defibrillator skills of interprofessional and uniprofessional teams revealed differences in advantage of interprofessional teams. Students positively accept automated external defibrillators if well-defined and validated training opportunities to use them expertly are available. Uniprofessional teams were successfully supported by their members and, thereby, used automated external defibrillator effectively. Furthermore, the interprofessional approach resulted in as much effective teamwork as the uniprofessional approach.

Keywords

automated external defibrillator, basic life support, interprofessional education, technology acceptance

Introduction

In order to reduce costs and increase safety, quality, and sustainability, healthcare authorities continuously integrate new healthcare technologies into existing systems. The application of pervasive computing technologies to healthcare ensures its availability to all irrespective of place and time.[1]

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Sometimes, these efforts result in problems in the dissemination and acceptance of technologies, especially where healthcare workers are unable to use the products, devices, or guidelines as designed by the manufacturers.[2] Currently, healthcare providers face different issues when using the numerous new technologies available on the market. Therefore, organizations are currently acting to incorporate these technologies into the daily routines of users, provide necessary support and facilitation for integration, and create necessary time and training opportunities.

Healthcare can be defined as a collaborative patient-centered practice. In order to play an active role in ensuring patient care and making associated decisions, healthcare providers must communicate with each other and organize themselves; they must respect each other's contributions, as well.[3,4] The existing literature strongly suggests that interprofessional learning associated with interprofessional work is effective.[5,6] Interprofessional education (IPE) is an effective teaching method that develops effective collaboration among healthcare practitioners.[5] It proposes to educate healthcare providers from different professions together in a supportive environment so that they gain necessary skills to practice together throughout their careers. As concepts like patient safety and rights became prominent,[7] it became difficult to perform learning activities in real environments. Current approaches to the professional competence development of students emphasize controlled experiences of rare and risky situations, learning from mistakes, reflection, and multiple sets of feedback. Using simulation techniques, it is possible to build lifelike, supervised, and safe environments that allow learners to develop significant learning experiences and educators to evaluate the quality and competency of learning outcomes.[8,9]

Sudden cardiac arrest (SCA) is a worldwide public health problem that may result in death in the absence of timely and correct intervention. For the survival of SCA cases, early defibrillation and effective chest compression are critical.[10] Research shows that unless caregivers are ready, willing, and motivated, they will not start an initial intervention for a patient having a cardiac arrest.[11] Although the individual resuscitation attempts of healthcare providers are vital for the patient, multiple providers working in concert, sharing tasks and acting simultaneously, are much more useful. Automated external defibrillators (AEDs) sense cardiac arrests, give feedback, and provide cardiopulmonary resuscitation (CPR) instructions to the rescuer. The use of AEDs by basic life support (BLS) providers improves the quality of CPR.

The International Liaison Committee on Resuscitation (ILCOR) offers AEDs for SCA treatment and management.[10] This has resulted in the adoption and dissemination of innovative medical technologies in CPR practices. The American Heart Association (AHA) BLS training is a certification program that recognizes the use of AEDs as a basic skill and focuses on the importance of teamwork. Although ILCOR recommends the use of AEDs, they are not widely used in all CPR training programs to date. The use of this new technology in an interprofessional healthcare setting is inevitable; however, studies focusing on the adaptation and integration of this globally used technology are not sufficient. Moreover, direct performance measurements are limited in the social influence studies investigating health professional's behaviors and intentions; they are mostly based on self-reported data. Current studies reveal that team characteristics and team-directed strategies influence technology acceptance via perceived support from peers or coworkers. This study discusses how social interaction influences a healthcare professional's decision to use an AED in an emergency.

Background

BLS with AED

BLS is the principal practice followed in treating SCA cases. The adult BLS chain of survival includes early diagnosis of SCA; early access to emergency response systems; early, high-quality CPR; and, if necessary, early defibrillation. An AED is a pervasive computing device[12] designed for the treatment and management of acute SCA. An AED guides its user through the stages of administering CPR, monitors the patient's heart rate, and diagnoses the condition and administers a shock automatically, if necessary.[13] The AED training device is preferred by educators because it provides monitoring and evaluation of the task and the entire learning process.[14]

Technology acceptance and implementation

Introducing users to a new medical technology does not automatically lead to the realization of expected benefits. The main problem with the introduction of innovations is that caregivers do not automatically use them as intended by the developers.[15] Even though many innovations have the potential to improve the quality of healthcare significantly, their implementation can be delayed due to the resistance offered by some caregivers. In order to predict the determinants of caregivers' adoption and use of new technologies, technology acceptance models (TAMs) were developed. The main assumption of TAMs is that behavioral intention is a valid predictor of actual use. There are four prominent models (TAM1, TAM2, TAM3, and Unified Theory of Acceptance and Use of Technology (UTAUT)) and two frameworks (theoretical and implementation) related to TAMs.

Often, TAM1 is used to explain the acceptance and use of computerized technologies.[16] It has two external variables that determine the attitude toward technology usage (A): the users' confidence that technology will improve their performance is "the perceived usefulness (U)," and their confidence that using the technology in daily work will demand extra effort is "the ease of use (E)." TAM2 preserves the basic structure of TAM1; however, the attitude toward using the technology is extracted from the model, and predictors of "perceived usefulness" and "intention to use" are detailed under social influence.[17] TAM3 is the advanced version of TAM2.[18] Similar to TAM2, perceived usefulness is the strongest predictor of behavioral intention. Image perception using innovation will enhance users' status in the social system, and experience is an important moderating variable in the contexts of information technology (IT) adoption. UTAUT formulates the core determinants of performance and effort expectancy, social influence, and facilitating behavioral conditions to use IT.[19]

Venkatesh and Bala[18] developed a theoretical framework presenting the determinants of TAM belief structures using the variables produced by all the TAM studies (Figure 1). In this framework, the core model of TAM2 is used; furthermore, in this model, the perceived ease of use directly influences perceived usefulness. Individual differences, system characteristics, and social influence direct and shape the perception of IT. Facilitating conditions represent the organizational support that facilitates the use of an IT. Fleuren et al.[20] developed an implementation framework that explained the relationship and interaction among an innovation's determinants, strategy, and process.

The successful introduction of a new technology makes it easier for a user to use and accept it. Effective implementation processes can enhance the adoption and use of IT by employees.[21] This study aims to explain the actual usage behavior of users in teams comprising different professions, which is determined after a short time span of interaction with an AED. Therefore, this study includes both the TAM theoretical[18] and implementation[20] frameworks (Figure 2).

Methods

The study was designed to investigate how uniprofessional and IPE methods influence the adoption and use of AEDs by students (Figure 3). Recent studies emphasize that innovation processes, strategy, and determinants influence technology acceptance.[2,19,20] Therefore, we followed the TAM theoretical framework and developed certification and matching processes to bring the determinants and variables under control, consolidate differences, and ensure that members are equally distributed among the groups.

The learning domain BLS and subdomain AED skills existed in the professional competency definitions of all participants. The differences in expertise and experience among the

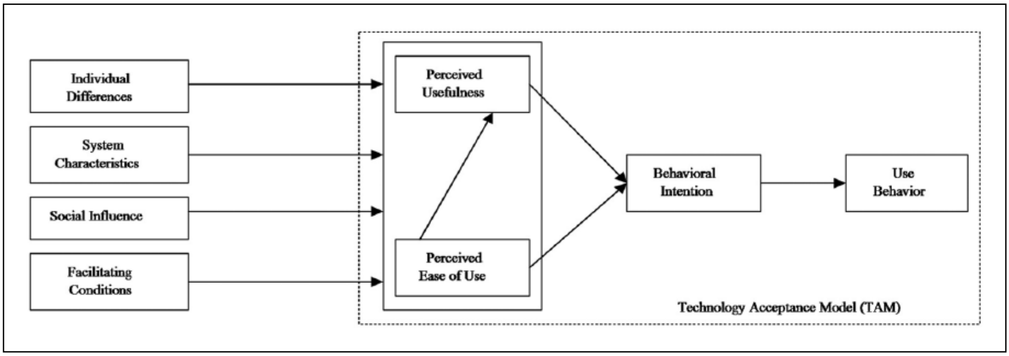

Figure 1. TAM Theoretical framework.[18]

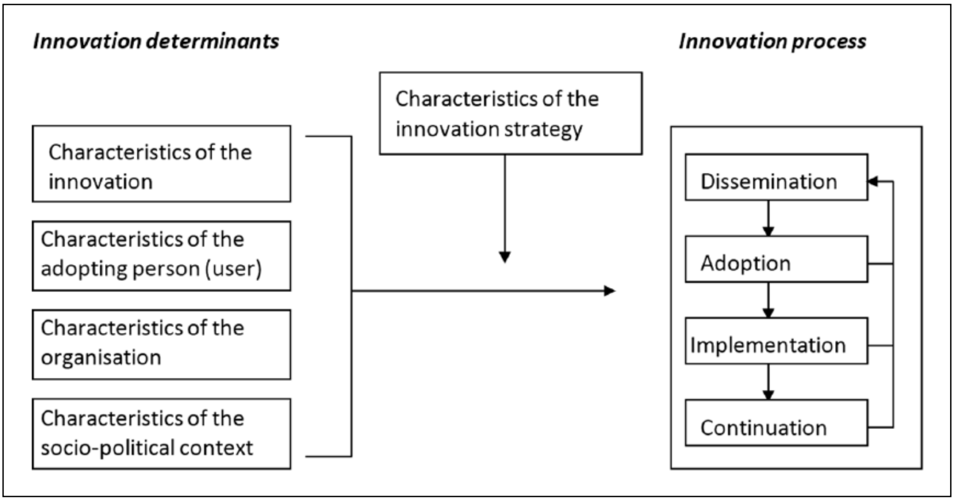

Figure 2. Framework represents the innovation process and related categories of determinants.[20]

subjects were equalized using the AHA BLS certification. In order to build balanced, distributed groups, individual differences, gender, profession, and knowledge were considered. The purpose of building balanced groups was to equalize the parameters as dynamic influences—except the sociopolitical context and social influence—for both groups and explain the differences using the method. Table 1 shows the innovation determinants, processes, and strategy that are in line with the implementation framework of this study. Students were assigned to the groups based on their CPR knowledge, and individual BLS with AED performance scores were used at the end of the certification stage.

Participants

In this study, 72 fourth-year medicine, third-year nursing, and second-year first and emergency aid program students from Hacettepe University participated during the 2013–2014 academic year. A free AHA BLS certification was offered to these students. A conformity consent, dated 24 July 2013 was granted by the Non-interventional Clinical Trials Ethics Council of Hacettepe

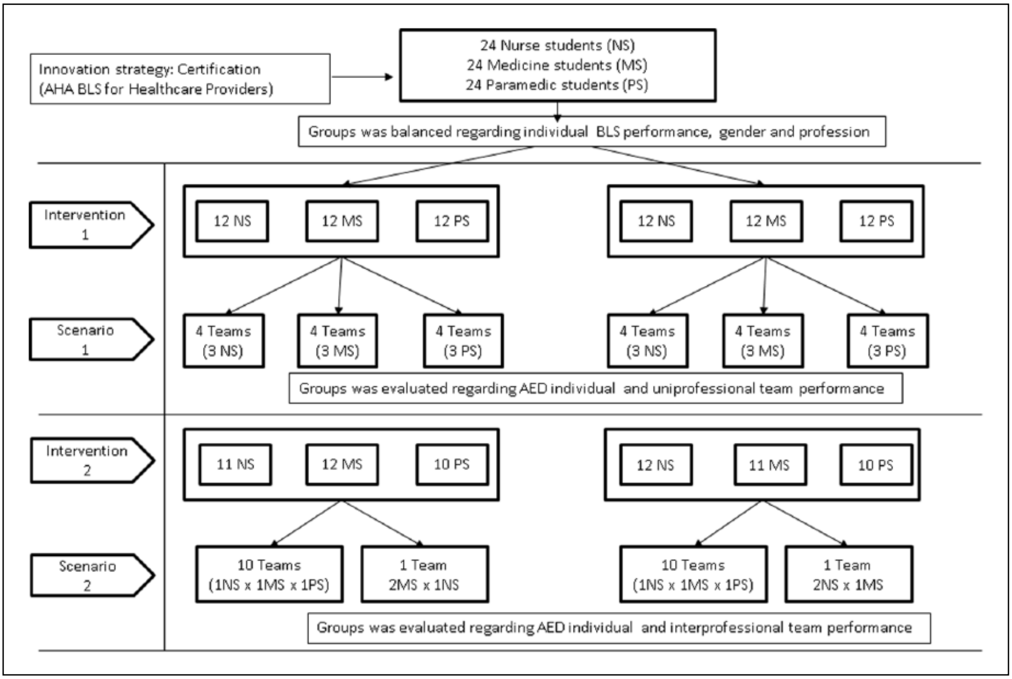

Figure 3. Flowchart for overall research design.

University. Among the participants, male students comprised the minority, and 21 of the nursing, 70 of the medicine, and 14 of the paramedic students were female.

Assessment instruments and devices

Quantitative data were derived from video analyses of CPR performances to examine the changes in individual and team-level technical AED skills, and qualitative data were collected to define the effects of the collaborative practices on nontechnical AED skills.

Technical AED skills form for individual and team evaluation. In this study, a technical AED skill evaluation form preserving the basic structure of the AHA BLS with AED skill testing sheet was developed. An evaluation set examining the participants' general ability to follow AED instructions and manage situations was used to assess their technical AED skills at the end of each scenario. Recorded videos were used for detailed evaluation. Using the technical AED skill evaluation checklist, a team could score a maximum of 42 points and individuals up to 45 points (Table 2).

Nontechnical AED skills form for individual and team evaluation. In this study, a thematic observation form preserving the basic categories of the Team Emergency Assessment Measure (TEAM)[22] was developed for the evaluation of nontechnical AED skills. An evaluation set examining the participants' abilities such as effective communication, adaptability to changing situations, situation awareness, and supportive behavior was used to assess their technical AED skills at the end of each scenario. We used the Resusci Anne manikin with SkillReporter, manufactured by Laerdal, and Life-Point AED training defibrillator, manufactured by METsis Medikal.

Table 1. The determinants, process, and strategy of innovation.

Innovation determinants	Innovation process
Characteristics of innovation strategy (coaching, video- and practice-based instruction, mastery learning)	Dissemination stage Every student is introduced to the innovation (AHA BLS certification)
Characteristics of the sociopolitical context Interprofessional–uniprofessional	Adoption stage The student develops a positive intention to use the innovation (certification feedback)
Characteristics of the adopting person Healthcare provider student Nurse, medicine, paramedic	Implementation stage The student has the opportunity to use the innovation in daily practice and gain experience (Scenario 1)
Characteristics of the innovation Pervasive health technology AEDs are used to manage and guide the treatment of SCA	Continuation stage The student works with the innovation and, soon, its use becomes routine (Scenario 2)
Characteristics of the innovation strategy Coaching, video- and simulation-based instruction, gaining mastery	

AHA BLS: American Heart Association Basic Life Support; AED: automated external defibrillator; SCA: sudden cardiac arrest.

BLS team performance scenarios 1 and 2

In the first performance scenario, a BLS team comprising three students from the same professional group performed BLS for 10 min on the patient in need of support. The second scenario mainly differed from the first one in that the team comprised students from different professional groups.

In this study, each professional group was represented by 24 students. In both scenarios 1 and 2, practice rescue teams comprised three students. The participants formed uniprofessional and interprofessional teams for scenarios 1 and 2, respectively (Figure 4).

There were differences in the BLS education programs of the students involved in the study. In order to evaluate the effects of educational intervention impartially, study groups were shaped according to similar BLS competency and professional maturity. Therefore, a 1-day AHA BLS provider training was planned and delivered to enable the students to master BLS skills. Experiment and control groups were built according to the initial CPR knowledge and individual BLS performance assessments and evaluations of students. After each learning intervention, the evaluation of students took place in different scenarios. The study groups were evaluated in terms of individual and team technical and nontechnical AED performances.

Results

BLS with AED performance for the first scenario

The technical AED skills of teams. The median AED performance scores of the experimental and control groups were 38 and 39, respectively. There was no significant statistical effect of the differences in method on the AED performances of the teams comprising participants of the same profession (Mann–Whitney U = 46.500, p = 0.352).

Individual technical AED skills within teams. A two-way analysis of variance (ANOVA) was conducted to examine the effects of profession and method on individual AED performance. The technical AED score averages of the experimental and control groups were $\bar{x} = 42.27$ and $\bar{x} = 42.49$,

Table 2. Basic AED skill evaluation checklist.

1. Bring the AED to the scene.
2. Take position at the appropriate side of the manikin.
3. Open the AED's cover.
4. Switch on the AED.
5. Place pads appropriately on the bare chest of the manikin, as shown on it.
6. Plug the connector to the AED.
7. Verbally warn everyone not to touch the manikin because the AED is analyzing the rhythm.
8. If the device is shock advised, check for safety prior to pressing the button for defibrillation.
9. Verbally clear the area and clear oneself.
10. Press the button for shock delivered.
11. Deliver shock within 90 ss.
12. When instructed, start CPR.
13. Check responsiveness at the end of the 2-min CPR period.
14. Switch roles while the AED is analyzing the rhythm.
15. Follow the visual and voice prompts of the AED

AED: automated external defibrillator; CPR: cardiopulmonary resuscitation.

respectively; moreover, the difference between these two groups was not significant (F (1, 60) = 0.092, p = 0.762).

BLS with AED performance for the second scenario

The technical AED skills of teams. The Mann–Whitney test indicated that the technical AED scores were greater for groups with interprofessional (median = 36) than uniprofessional (median = 31) education (U = 12.000, p = 0.001, r = 0.68).

Individual technical AED skills within teams. A two-way ANOVA was conducted to examine the effects of profession and method on individual AED performance. The technical AED score averages of the experimental and control groups were $\bar{x} = 33.33'$ and $\bar{x} = 26.24$, respectively; furthermore, there was a statistically significant difference in mean individual technical AED performances between the experimental and control groups (F (1, 60) = 32.608, $p < 0.01$, $\eta_p^2 = 0.352$).

Evaluation of nontechnical AED skills

The nontechnical AED skills of participants were evaluated using the thematic observation form derived from TEAM.[21] Students did not hesitate to use the AED; furthermore, they did not face any difficulty in demonstrating AED competence in an environment in which their team members were present. It is thought that IPE overcomes the professional differences of team members, which is believed to cause underperformance in teams. With the IPE group, problems recognized by team members are corrected either by the members themselves or through feedback. Team members share respiratory and heartbeat recovery information, and the performer rotates according to the analysis warning of the AED. The situational awareness of interprofessional teams was higher compared to the control group.

Within teams, the team members had to be appropriately assigned specific duties and tasks. This requirement was covered by the IPE teams. They properly assessed airway, breathing, and compression (ABC) when a shock was not recommended. IPE teams shared more supportive and task-related (touch or not) feedbacks. They gave appropriate warnings to the

Figure 4. Interprofessional BLS team performing CPR with AED.

interprofessional group and voiced feedbacks loudly with much more self-confidence. Furthermore, IPE teams took turns working and relaxing.

Discussion

Uniprofessional design

The differences in individual AED performances of students explained by profession were not significant. Similarly, educational methods did not cause any differences in individual and team AED performance scores. Considering the students' expertise in using AEDs, pre-BLS certification can be stated as the appropriate strategy for introducing AEDs.[2,20]

Interprofessional design

The individual AED performance differences of students explained by profession were not significant; however, differences in educational methods resulted in differences in individual and team AED performance scores. The findings of the study indicate that collaborative learning has a positive effect on the IPE group. In this group, the IPE method improved the individual and team AED performance scores of team members, even when they were from different professions. This result is consistent with the findings of Mäkinen et al. They observed that nurses hesitated to use AEDs in emergency situations, even though the previous training and the availability of equipment.[23] In our study, nurses gained confidence to start CPR after the IPE intervention, which made the difference on it. Wilkes et al.[24] stated that specific organizational, cultural, and teamwork factors significantly affected the use of new health technology. They defined the key operational and cultural barriers as lack of trust, poorly defined leadership, and lack of communication policies. Lapkin et al.[25] measured subjective norms of students, which explained how healthcare provider perceived the opinions of other health professionals, patients, and family member in relation to medication safety and collaborative practice. Their results showed that health professional students appeared to place less value on the contribution and perceptions of others regarding medication safety. Their suggestions for the solution were education on role reversal, team-building activities, and feedback mechanisms to share concerns.

According to the research conducted in this field, the sociopolitical context is an important determinant of innovation acceptance and its influence either suppresses or enhances technology usage behaviors.[2,19,20] According to Pynoo et al.,[21] physicians perceive that their social environment encourages the use of technology; in contrast, Liu et al.[26] report that social influence is not important for therapists' acceptance of new technologies for rehabilitation if their usage is not mandatory. Furthermore, Casey and Wilson-Evered[27] suggest that trust may mediate the effects of technology acceptance constructs.

Conclusion

Although BLS performed by lone rescuers is effective in the treatment of SCA, patient outputs are much more positive when BLS is carried out by a team.[11] Social influence within the team affects practitioners' decision regarding the use of AEDs and individual and team AED performances.

It is observed that teams comprising individuals from the same profession tend to communicate positively, give feedback, and behave supportively. The supportive activities performed by team members may help a practitioner in effectively using a new technology. Furthermore, IPE approaches help to remove professional barriers and the perception of competition.

In this study, all participants displayed mastery of AED techniques. It is thought that audio and visual guidance reduces the cognitive load of students in complicated situations. Hence, audio and visual performance support systems can be used in learning environments to strengthen the students' ability to make sense of their learning and connect with their professional performances.

Individual difference variables such as personality and demographics can influence an individual's perception of the usefulness of a technology.[19] In this study, female students constitute the majority of participants. Although the groups' gender distribution was balanced, one should consider this limitation when evaluating the findings.

This study has a pre-implementation value for the acceptance of AED technology in Turkey because the use of AEDs was recognized officially and added as an option to the valid national first aid course in 2016. This study is expected to contribute to the reduction of initial resistance of workers and students to newly introduced technology and help them perceive realistically the features of the technology and understand how the technology can support them in their daily work.

Author's Note

The data in this study were collected as part of a larger dissertation study.[28]

Declaration of conflicting interests

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Design, functionality, and validity of the SWInCaRe, a web-based application used to administer cancer registry records

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Abstract

We described the design of a web-based application (the Software Integrated Cancer Registry—SWInCaRe) used to administer data in a cancer registry and tested its validity and usability. A sample of 11,680 records was considered to compare the manual and automatic procedures. Sensibility and specificity, the Health IT Usability Evaluation Scale, and a cost-efficiency analysis were tested. Several data sources were used to build data packages through text-mining and record linkage algorithms. The automatic procedure showed small yet measurable improvements in both data linkage process and cancer cases estimation. Users perceived the application as useful to improve the time of coding and difficulty of the process: both time and cost-analysis were in favor of the automatic procedure. The web-based application resulted in a useful tool for the cancer registry, but some improvements are necessary to overcome limitations observed and to further automatize the process.

Keywords

cancer case coding, cancer registry, record linkage, software, text-mining

Introduction

Cancer is among the leading cause of mortality affecting almost 15 million individuals and accounting for more than 8 million deaths worldwide.[1] In this scenario, information systems are needed to evaluate epidemiological parameters on cancer at population level, as well as to collect more detailed data on patients' demographic characteristics and clinical parameters potentially useful for in-depth studies on the relevant topic. Cancer registries have been established in several regions to collect information about new cases of cancer and to produce statistics about incidence, prevalence, survival, and mortality.[2] The process of identification and coding of cancer cases represents

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the main challenge to establish a cancer registry. Manual identification and coding is time consuming, money costing, and accuracy and validity of the process cannot be guaranteed.

Record linkage is a widely used process to link records derived by separate databases.[3,4] With the diffusion of large electronic health databases, the requirement for automated systems of record linkage has increased dramatically over the last decades.[5] Moreover, from a technical and financial point of view, the cross-link of multiple sources makes almost impossible the use of human resources to manually work on such prohibitively large data. Record linkage is a key component of cancer registries because case identification depends on the integrated information from various sources. The territorial distribution of the population requires a decentralization of the operators that triggers critical issues concerning the synchronization of the data collected and processed in the different areas. Moreover, the security management is challenged by the distribution of the databases through the territory and by the need to transmit data to the main servers. Once the cancer cases are identified, data must be coded according to the international coding rules before being analyzed and compared with other cancer registries data. Procedures of record linkage, tests for quality checks, and storage and control procedures of cancer cases are commonly used.[6,7] Software applications used for the management of data entry exist and their use has been widely validated.[8] However, record linkage associated with semi-automatic and automatic processing of incidence cancer cases strongly depend on the data source and ad hoc software build to optimize the workflow are highly demanded. Thus, the aim of this study was to describe methodology adopted to set up a web-based platform used in a regional cancer registry in Italy to collect and administer data on cancer cases and to describe its functionalities.

Methods

The following factors were considered to achieve a comprehensive description of the web-based platform:

- Design and functionality;
- Data quality (comparison of human (manual) *versus* software (automatic) procedure);
- Software usability;
- Cost-efficiency analysis;
- Random observation of system stability.

Setting

The cancer registry of Catania-Messina-Siracusa-Enna covers a population of approximately 2,300,000 inhabitants distributed across four main cities and a number of minor towns in the Eastern area of Sicily, Italy. The area involves a total of 207 municipalities and 79 main public hospitals.

Data sources

Data sources were the following:

- *Patient identification fiscal code* (FC), an univocal code determined through an algorithm using a person's name and his or her date and place of birth;
- *Regional identification registry* ("Nuova Anagrafica Regionale"—NAR), a regional database of all registered individuals living in the region (Sicily);

- *Hospital discharge record* (HDR), a form with an identification and information on type of procedures performed (including primary disease) provided at the moment of discharge from any Italian hospital. Only oncologic HDR are provided to the cancer registry, representing the main source of information for all cancers. All cases coded using the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) are provided to the cancer registry;
- *Pathology record* (PR), available from suspect malignancy that undergoes biopsy or surgery to remove cells or tissues for examination under a microscope. The PRs provide necessary information such as topography and morphology as well as additional information, including the TNM stadium, tumor size, margins, vascular invasion, and lymph node status. These records allow to include patients who were assessed or treated in both hospital and outpatient setting (eventually not admitted at hospital nor diagnosed in primary hospitalization, such as screening program patients);
- *Mortality registry* ("Registri Nominativi delle Cause di Morte"—RENCAM), which are databases managed by the Health Local Authority keeping track of mortality of the population through and providing information on the cause of death according to the ICD-9;
- *Disease-specific exemption database*, which collect information on patients diagnosed of cancer by a specialist (oncologist) and provided documentation of their condition to Health Local Authority in order to obtain universal health insurance for medicaments and procedures;
- *Medical record* (MR), exceptionally required (case-sensitive) when no other source is available and is necessary to identify information relative to the case (either regarding clinical information or date of occurrence);
- *Other sources* include pharmaceutical prescriptions (File F) and diagnostic procedures (File P) related to oncological diseases.

Hardware and software characteristics

The web-based application that we created (the Software Integrated Cancer Registry—SWInCaRe) allows the storage of all oncological information provided either via a direct connection to the hospital servers or by data entry of individual information provided by the Regional Epidemiological Department in digital form. An SQL-server database and a programming language (Asp Dot Net) were used to store the data. To ensure the safety of access, we introduced 128-bit identification keys for the operators. Identification keys are renewed periodically (annually). According to the regulations for sensitive data in the health sector, HL7 languages are used for the connection to the main servers of the hospital associated with the cancer registry.

As information often relies on scanned paper/pdf files, text-mining algorithms were used if the available input databases were contained in text fields. Algorithms were designed in SQL-server. The procedure of text recognition was standardized first by definition of keywords in the database and then extraction of the information of interest through string searches.

Data of interest

According to the International Agency for Research on Cancer (IARC) guidelines, the basic information necessary to register a cancer case includes date of incidence, topography (anatomic site), and morphology. Anatomic codes are determined by the cancer sites origin, while the morphological codes are determined by the tissues and cells characterizing the cancer type, the levels of cancer differentiation, and the behaviors of tumor biology. Further European initiatives (i.e. high-resolution studies of the EUROCARE project) require additional detailed information from MRs on representative samples of population-based cancer cases in order to conduct studies on clinical features of cancer patients.

Study sample

To test the quality of data collected, manual and automatic procedures were compared. A sample data from the province of Catania registered between 2003 and 2005 was considered for this study. Due to the high number of records, we selected only the surnames with the "C" letter (representing the most significant alphabetical group) including a total number of 11,680 records.

Human operators

The participating staff members consisted of six medical doctors who were provided the records to be examined and one information technology (IT) operator who worked on the web-based platform. The six medical doctors independently reviewed the records assigned to define incident, prevalent, and benign cases and resolved the existing discordances between the manual and the automatic procedures using the platform after a 1-week training; we considered this last procedure (automatic + manual check) as the gold standard to identify the best available estimate of the total number of cancer cases in this study.

Software usability

To evaluate the application usability, an Italian translation of the Health IT Usability Evaluation Scale was used.[9] The 20-item questionnaire is based on a 5-point Likert scale ranging from strongly disagree to strongly agree on four main domains: quality of work life, perceived usefulness, perceived ease to use, and user control. The score could range from 0 to 100, with score higher than 80 indicating high usability. The questionnaire was administered to the six medical doctors after use of the web-based platform.

Cost-efficiency analysis

Regarding the monetary comparison of the human resources needed for the operation compared with the software usage, we determined material and personnel costs in both cases. To assess the length of operations, completion time of the procedures (both manual and automatic) was taken from system log files. The costs of material acquisition and maintenance as well as personnel expenditures were collected through the administrative offices of the cancer registry. The calculation is based on the assumption that basic IT infrastructure, like printers and WiFi, already existed. Moreover, we did not include the costs for the operative system (such as various versions of Microsoft Windows) because it was used also for other tasks and in both procedures. To determine the personnel expenditures, we averaged hourly costs for healthcare/scientific assistant, taking into account a 25-Euro/h-threshold. We further calculated the cost-per-case by dividing the total costs for the number of cases found.

Statistical analysis

Continuous variables are presented as means and standard deviations (SDs) and categorical variables as frequencies and percentages. Specificity and sensibility were calculated for the manual

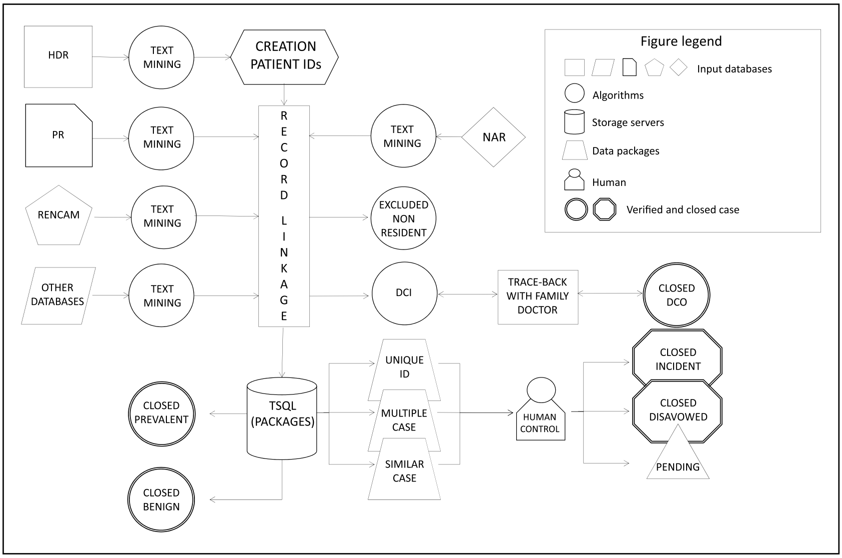

Figure 1. The Software Integrated Cancer Registry (SWInCaRe) implementation scheme.
DCI: death certificate initiated; DCO: death certificate only; HDR: hospital discharge record; NAR: regional identification registry; PR: pathology record; RENCAM: mortality registry; T-SQL: Transact–Structured Query Language.

and automatic procedures compared. All data were analyzed with Microsoft Excel (Microsoft, Washington, USA).

Results

Record linkage and case coding

The information collected is processed by the software according to the record linkage algorithms that allow to create potential univocal packages (Figure 1). A text-mining algorithm creates patients ID starting from the FC or from full name text, date of birth, and place of residence contained in data sources. Once the ID is created, all related information retrieved from any other available source related to the ID are matched to create univocal “data packages” stored in the database. A second algorithm searches for similarities between packages created through checking of identification components, such as name, surname, day, month, year of birth, and FC. The algorithm recognizes similarities as follows: (1) same name and surname without one letter or inverted, (2) same FC without last letter, and (3) inverted day and month of birth. If ID similarities refer to the same tumor, the algorithm merges the records; if ID similarities refer to different cancers potentially on the same patient, it creates a “multiple case”; if similarities are not sufficient to merge the records, it suggests the case as “similar,” leaving to the human operator the choice whether to unify the records or not. IDs are automatically matched with the NAR and non-resident patients are excluded from the database automatically.

Besides the patient ID, the software automatically recognizes and provides a temporary topographic and morphologic diagnosis for all potential cases through the text-mining algorithm that recognize keywords from text of the HDR, PR, and RENCAM. The software encodes tumor anatomical codes automatically identifying from ICD-9. The morphological coding is relative to the biological behavior of the tumor, including malignant cancers, in situ cancers, benign, and uncertain behavior cancers. Other morphological characteristics that the software recognize and register include the level of differentiation (such as undifferentiated, low, middle, and high differentiated), the types of tissues from which the tumor originated (such as epithelium, mesenchyme, lymph, hematopoietic, and nerve), and the type of cells from which the tumor originated (such as squamous, gland, basal, and transitional cells in the epithelial tissues).

The algorithm sets as primary potential data of incidence the oldest date provided by the HDR. Once the case is created, the operator can review all the information gathered in order to decide whether they are enough to close it. The case can be tagged as follows: (1) "verified incident," if diagnosis occurred over the period of observation; (2) "verified prevalent," if the diagnosis occurred previously, generally overlapping with previous closed cases; (3) "disavowed," whether the diagnosis was of benign cancer or not tumor disease. If the minimum dataset necessary to close a case is reached (including date of incidence, morphology, and topography), the case can be saved as verified and stored as incident; otherwise, the case can be saved as "pending" for further information.

Human versus software procedure

Six operators were asked to review the 11,680 records (including HDR, RENCAM, PR) in order to define incident, prevalent, and disavowed cases, including merging potentially overlapping cases, multiple cases (several cancer sites in the same patient), and check for actual residency in the area associated with the cancer registry during the period of diagnosis (Table 1). The process required 8 h and led to the identification of 4267 potential univocal packages. The record linkage was manually performed by linking the ID retrieved with all sources available for clinical information (HDR, PRs, etc.). The process took a total of 620 h for all operators and led to the identification of 2713 incident malignancies, 879 benign cases (disavowed), and 675 prevalent cases. In all, 152 were multiple cases. The same sample was tested with the automatic procedure of the software. The processing time was about 3 min. The system identified 4169 unique packages (Table 1). The record linkage with the sources and the creation of the cases took about 7 h. A total of 2696 malign incident cases, 869 benign, 604 prevalent cases, and 4 non-residents were excluded cases. The same number of multiple cases was retrieved.

Both procedures were reviewed by the six operators that manually validated the cases created, reducing to a total of 2561 incident cases (including 862 benign, 604 prevalent cases, and 4 non-residents). The discordant cases identified through the manual procedure were due to human error in identification of same patients (mistakes in univocal packages retrieved). The discordant cases identified through the automatic procedure were due to mismatch between data sources ID information (incorrect names and surnames, FCs, birth dates, derived by human data entry). However, part of such mistakes were identified by the algorithm as "similar cases" and left to the human review (data not shown).

Software usability

The graphical user interface was kept simple and consistent throughout the entire application. The landing page provides several search fields in order to allow to retrieve cases by name/surname, FC, and case characteristics (year of diagnosis, topography, morphology, mortality, and status (to be verified, verified, pending); Figure 2). Once entered a case, the application interface is designed to provide all mandatory information to close a case (according to IARC guidelines) always visible (Figure 2) and a further drop down menu to provide additional information required for high-definition studies (Figure 2). A list of all data collectable and respective source is shown in Table 2.

Table 1. Manual and automatic procedures to identify cases from a sample of 11,680 total records (including hospital discharge records, pathology records, and death certificates).

	Human (manual) procedure	Software (automatic) procedure	Confirmed (automatic + manual review)	Human procedure		Software procedure	
				Sensitivity	Specificity	Sensitivity	Specificity
Univocal packages, n (%)[a]	4267	4169	4185	94.5%	97.0%	96.6%	98.1%
Incident malignant cases, n (%)[b]	2713	2696	2561	92.7%	88.5%	93.3%	89.4%
Multiple incident cases, n (%)[b]	152	152	152	100%	100%	100%	100%
Incident benign cases, n (%)[b]	879	869	862	98.0%	99.4%	99.2%	99.8%
Prevalent cases, n (%)[b]	675	604	604	82.2%	94.7%	100%	100%
Non-resident patients, n (%)[b]	–	4	4	NA	NA	100%	100%

NA: not applicable.

[a] Total number refers to the total hospital discharge records examined.

[b] Total number refers to univocal packages retrieved.

Data Nascita: XXXXX
Comune nascita: XXXXX
Residenza: XXXXX
Stato: In vita alla data XXXXX
Caso: Da Verificare
Medico: XXXXX

ICDO3T C18.9 - COLON, NAS
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Differenziazione . non definibile
BaseDiagnosi X: provvisoria
DataDiagnosi

Figure 2. Basic interface of the SWInCaRe.

Eye-catching icon-buttons also allow to request additional data sources (including MRs, pathology reports, or contact of general practitioner of the patient) in case needed.

The evaluation of the completed Health IT Usability Evaluation Scale questionnaires showed an overall score of 90 (2.6 SD) out of a maximum of 100, indicating high usability of the product. The single evaluation of all questions can be found in Table 3. Among those statements reaching higher scores, those mainly related to quality of work life showed complete agreement among users. In contrast, those items related to ease to use showed slightly lower scores, suggesting that the

Table 2. Variable domains collected through the SWInCaRe.

Variable domains	Input database	Notes
Personal data		
Sex, age, residence, date of birth	HDR, PR, File F, File P	Automatic
Identification codes		
Patient identification number		Auto-created
Tumor characteristics		
Incidence date, ICDO3 topography, ICDO3 morphology	HDR, PR, RENCAM	Automatic
Laterality, dimension, TNM Stage, grade, diagnosis source, positive lymph nodes, total lymph nodes analyzed	PR, MR (occasional), family doctor (occasional)	Manual
Gleason score, grade, resection margin (for prostate cancer)	PR	Automatic
Receptor status, hercept test, cerb2, vascular invasion, resection margin, sentinel lymph node (for breast cancer)	PR, MR (occasional), family doctor (occasional)	Manual
Clark, Breslow, sentinel lymph node (for melanoma cancer)	PR, MR (occasional), family doctor (occasional)	Manual
Dukes, Aslter Coller (for colorectal cancer)	PR, MR (occasional), family doctor (occasional)	Manual
Grade, resection margin (for skin cancer)	PR	Automatic
Chemotherapy, radiotherapy, surgery	HDR, MR, File F, File T	Automatic (except from clinical records)
Follow-up		
Date of follow-up	HDR, MR (occasional), family doctor (occasional), RENCAM	Automatic (except from clinical records)

SWInCaRe: Software Integrated Cancer Registry; File F: pharmaceutical prescriptions; File P: diagnostic procedures; HDR: hospital discharge records; MR: medical records; PR: pathology records; RENCAM: mortality registry.

learning curve may be longer than expected. Finally, the interviewed agreed that the web platform helped them more likely to code faster than more correctly.

Monetary analysis

A total of 620 h for six operators were needed for the identification of potential univocal packages (8 h) and potential cases (612 h) through the manual procedure: the total amount of pay-per-hour would correspond to 15,500 Euros and about 4 Euros per case. The automatic procedure required 8 h of work for one operator and two servers for data storage for a total of 250 Euros and about 5 Euro Cents per case.

System stability

We found no particular instabilities of the automatic system. However, being the system web-based, we observed some slowdowns in occasion of some troubles occurring at the central Internet connection provider, which caused long loading periods and, in some cases, even system crashes. In occurrence of session crash, information imputed by the operator were lost if not saved previously.

Table 3. Modified version of the Health IT Usability Evaluation Scale adapted to test the SWInCaRe usability.

Questions	Scores, mean (SD)
Quality of work life	
1. I think SWInCaRe has been a positive addition to coding procedures	5.0 (0.0)
2. I think SWInCaRe has been a positive addition to our organization	5.0 (0.0)
3. SWInCaRe is an important part of our coding process	5.0 (0.0)
Perceived usefulness	
1. Using SWInCaRe makes it easier to code	5.0 (0.0)
2. Using SWInCaRe enables me to code more quickly	5.0 (0.0)
3. Using SWInCaRe makes it more likely that I will code correctly	1.6 (0.8)
4. Using SWInCaRe is useful for coding	5.0 (0.0)
5. I think SWInCaRe presents a more equitable process for coding	5.0 (0.0)
6. I am satisfied with SWInCaRe for coding	4.3 (0.8)
7. I code in a timely manner because of SWInCaRe	5.0 (0.0)
8. Using SWInCaRe increases number of coded cases	5.0 (0.0)
9. I am able to access information to code whenever I use SWInCaRe	4.6 (0.5)
Perceived ease of use	
1. I am comfortable with my ability to use SWInCaRe	4.5 (0.5)
2. Learning to operate SWInCaRe is easy for me	4.5 (0.5)
3. It is easy for me to become skillful at using SWInCaRe	4.0 (0.0)
4. I find SWInCaRe easy to use	3.3 (0.5)
5. I can always remember how to log on to and use SWInCaRe	5.0 (0.0)
User control	
1. SWInCaRe gives error messages that clearly tell me how to fix problems	4.0 (0.0)
2. Whenever I make a mistake using SWInCaRe, I recover easily and quickly	3.3 (0.5)
3. The information (such as online help, on-screen messages, and other documentation) provided with SWInCaRe is clear	5.0 (0.0)
Total score	90.0 (2.6)

SWInCaRe: Software Integrated Cancer Registry; SD: standard deviation.

Discussion

The aim of this study was to describe the rationale behind the creation of a web-based platform able to administer data for a cancer registry and validate its functionality and usability. We reported an optimal performance of the algorithms as well as a good usability of the platform. Some limitations have, however, emerged and commented.

Linking HDRs with other registries data has emerged as a major source of gaining diagnosis and treatment procedure information related to cancer.[10] The process of designing and testing of the web platform required the work of several specialists providing individual expertise on the topic: epidemiologists provided support to design the functionalities needed to collect crucial information to identify the cases and to share the data with international bodies; clinicians, pathologists, and oncologists identified clinical core information to be added to minimum standard data collected; and IT experts, necessary to program the platform as well as to manage data input and databases.[11] We used external information through linkage with several data sources and algorithms able to identify univocal data packages (in most cases completion of topography and morphology) that can be validated by the human operator in order to identify and close a case.

The main advantage of using several data sources is that increase the algorithm capacity to identify the patients ID as well as to allow more complete and precise information recorded about the individuals of interest.[4] The main limitation for the application relied on local issues related to inaccuracy of the sources due to typo or transcription errors regarding the ID information. The errors encountered may regard incompleteness or omission of second names/surnames and errors of the FCs. Another limitation depended on the PRs, which are still manually registered (thus subjective of typo errors) and significantly missing of important information necessary for the identification of the patient and record linkage process (i.e. missing date and place of birth). However, errors were overcome by manual check of cases, leading to a proper functioning of the entire system with a minimum manual work on the automated procedure provided by the algorithms.

The automatic procedure showed small yet measurable improvements in both data linkage process and estimating cancer cases. However, the main goal of the application was to reduce the time of coding, rather than the quality itself. Commercial and ad hoc programmed software for data linkage are commonly used in cancer registries.[12,13] In epidemiological studies, false-positive linkages result in underestimation of true rates, whereas false-negative linkages result in overestimating rates. As small errors in record linkage (5%) can yield a significant error in estimating true rates, both procedures tested require further control by human operators.[14] However, the web-based application is designed to aid human operator to code cancer cases rather than automatically code and close the cases. The application usability has been tested showing high scores especially on the work quality and usefulness. Regarding the latter, users did not perceive the application as useful to improve the quality of coded data, despite our analysis showed a more accurate coding through the automatic procedure than the manual ones. However, the time analysis and the easiness to code were obviously in favor of the automatic procedure. A potential contributor to the usability may be the web-based solution, which did not require installation of the program and increased usability through access from any device.

The results of this study should be considered in light of some limitations. As mentioned before, the accuracy of the record linkage performed by the application depend on the quality of the information included in the database, which in our geographical area of application are subject to lack of digitalization, lack of barcode IDs, and typo mistakes. Moreover, the core of the information is based on the HDRs, which are administrative data collected to inform payment and billing operations, rather than clinical care. Thus, using them for clinical purposes requires some degree of inference and is yet not sufficient to provide full information for the minimum dataset as well as for additional inquiries (for instance, register cancer recurrence). Another limitation that should be taken into consideration with text-mining is that the algorithms are not univocal but must be continuously updated on the basis of the information that should be retrieved by the text, which can be presented in various ways if not included within a template form (for instance, pathologist can use different sentences when describing the variables extracted from the pathologic anatomy records). Lack of a unique person identifier within the country does not permit to overcome the problems related to record linkage and all data privacy concern.

In conclusions, the use of our web-based application on administrative databases to build patients registries offers great opportunities to enhance cancer-related research through the study of large numbers of patients. These resources can help us better understand cancer treatment outcomes, quality of care, resource utilization, and clinical management. Finally, further record linkage with other administrative databases on diseases that can be tracked (i.e. diabetes) would amplify the utility of software related to cancer registries and provide insights on cross-link between diseases at population level.

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Information and communication technology and the future of healthcare: Results of a multi-scenario Delphi survey

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Abstract

Technological advances toward consumer-specific expectations require a sustained commitment and coordination across policy- and decision-makers. The present scenario-based study aimed at identifying prevailing perceptions regarding telehealth applications among Austrian healthcare experts. During a two-round online Delphi survey, panelists rated perceived benefits, obstacles, innovativeness, desirability, and estimated implementation date of 10 telehealth scenarios. Panelists (n = 73, 74% males) perceived that the implementation of telehealth scenarios could especially improve patients' knowledge, quality of social healthcare, and living standard. In contrast, the three top-ranked obstacles were costs, technical prerequisites, and data security. Survey participants rated innovativeness of the presented future scenarios as quite high, whereas perceived desirability was moderate. Overall, ratings suggested precautious attitudes toward technological innovations. The survey findings suggest building taskforces and enhancing communication between healthcare stakeholders to proactively shape the future of telehealth in Austria.

Keywords

Austria, data security and confidentiality, mobile health, pervasive technologies, telecare

Introduction

Given latest demographic changes and steadily increasing expenditures for high-quality healthcare, telehealth is crucial to tackle bottlenecks in healthcare provision.[1] Although the current life expectancy trends are favorable, two societal factors are colliding in aging societies worldwide. First, due to the baby boom aging wave, the prevalence of chronic health conditions presupposing long-term medical care increases significantly. Second, aging baby

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boomers among health personnel imply an upcoming shortage of physicians and nursing staff.[2] For the United States, Sargen and co-workers[3] anticipated an imbalance of about 20 percent between demand and domestic allocation of medical workforce in 2025. These future societal trends are prognosticated to cause logistics and supply chain problems, especially in rural communities.[4]

The vision of bridging spatial distances between doctors and patients via telephone, Internet, and video to address the increasingly aging population and age-related disabilities and diseases has already been accomplished decades ago.[5] As a far-reaching effect of the digital revolution, telehealth concepts referring to the delivery of healthcare services at a distance using information and communication technology (ICT) are inevitable innovations for modern healthcare provision. Designing ICT-based solutions for medical purposes constitutes an emerging field of activity for medical informatics and related scientific disciplines.[6]

If end users accomplish basic communicative and technological skills, telehealth could tremendously support and facilitate patient empowerment and care on multilayered levels of communication, health promotion, and health monitoring.[7] ICT-mediated integration of complex diagnoses with customized preventive medicine and lifestyle suggestions considerably improve patients' knowledge and compliance, and thus therapeutic success.[8] According to Huh et al.,[9] self-monitoring of health parameters in non-clinical settings exerted lasting effects on consumers' self-responsibility enhancing doctor–patient relationship as well as physical and mental health. Related studies found that ICT-based home care models for myocardial infarction as well as knee replacement rehabilitation positively affect health and well-being.[10,11] Hence, increasing patient self-care reduces institutionalization, hospitalization, duplicative testing, and mortality rates.[1]

In the rapidly growing ICT and telehealth sector, allocating adequate resources of personnel, financial, and know-how is central for equitably providing high-quality healthcare.[12] However, authoritative healthcare stakeholders own a vested interest in influencing political decision-making processes. We consider that recent liberalization and privatization efforts in telecommunication and network industries in Austria warrant exploring prevailing opinions regarding telehealth applications.

Thus, the current survey studied perceptions among a panel consisting of medical professionals (MP), patient advocates (PA), and administrative personnel (AP). In an anonymous, biphasic online Delphi process, these experts evaluated 10 prospective scenarios regarding perceived obstacles, benefits, innovativeness, desirability, and expected implementation date. The scenarios described possible outcomes of societal and IT development processes categorized into the three main topics (1) doctor–patient communication, (2) health promotion, and (3) pervasive health monitoring.[13–15] Regarding doctor–patient communication, we assumed that telehealth influences the traditional relationship and face-to-face interaction between MP and their patients.[7,16] Furthermore, we assumed that sustainable health promotion and disease prevention require empowered, self-reliant consumers. Based on consumer-centred doctor–patient communication and health promotion, we assumed that pervasive health monitoring via mobile sensors offers cost-effective health management.[17–20]

To meet the complexity of the multi-scenario-based approach, our analysis followed a stepwise procedure, picturing the collected data on the micro-, meso-, and macro level, respectively.[13–15] Interpretation of single scenarios structured around the three main topics yielded in-depth scenario-specific information on a micro level. Focusing on one of the specific central topics investigated topic-specific assumptions on a meso level. Ultimately, interpreting summarized multi-scenario results compiled gathered data on a macro level. This article focused on the macro level, reporting the consolidated and group-specific findings of the Delphi survey.

Methods

Telehealth scenarios

The Delphi survey was conducted in 2010 in accordance with the principles laid down in the Declaration of Helsinki. Ten scenarios illustrated implementation of software and monitoring solutions in the foreseeable future, spanning from quite likely to more innovative descriptions.[21–24] We identified the key research fields: ICT-based doctor–patient communication (scenarios 1 and 2), health promotion (scenarios 3–8), and pervasive health monitoring (scenarios 9 and 10). These scenarios were scenario 1: cooperation, scenario 2: communication, scenario 3: compliance, scenario 4: education, scenario 5: cancer risk, scenario 6: insurance rates, scenario 7: activities, scenario 8: prevention, scenario 9: monitoring, and scenario 10: motivation. Table 1 provides an overview of these scenarios and the related literature.

The Delphi survey process

The online Delphi survey questionnaire in German language consisted of two autonomous sections.[13–15] The first part assessed socio-demographic characteristics. The second part evaluated each of the 10 scenarios in ascending order using the corresponding fixed questionnaire items for benefits, obstacles, degree of innovation, desirability, and implementation date.

Two multiple-answer-questions assessed relevant benefits (six factors) and obstacles (nine factors) for implementation of telehealth solutions. Choices for benefits were as follows: quality of social healthcare, living standard, patients' knowledge, funding of social healthcare, doctor–patient relationship, and no improvement. Choices for obstacles were as follows: cost/funding, acceptance by MP, acceptance by PA, acceptance by AP, data security/privacy, technical prerequisites, regulations/standards, influence of stakeholders, and no obstacles.

Furthermore, we evaluated innovativeness, that is, the degree of innovation, of the respective scenario by a 5-point Likert scale ranging from *not innovative* (=1) to *very innovative* (=4) as well as the non-response type choice "not applicable." Subsequently, we dichotomized innovativeness to obtain low (i.e. not innovative, barely innovative, not applicable) and high innovativeness (i.e. somewhat innovative, very innovative). Next, the survey participants stated scenario desirability (desirable/not desirable). Ultimately, we asked the experts to indicate the time horizon of scenario implementation in Austria on a horizontal time line spanning the years 2010–2030.

After pilot-testing, we used SoSci Survey, a software package for scientific surveys, to conduct the Delphi survey.[45] A sample of Austrian experts working for national healthcare providers and health maintenance organizations were eligible for survey participation. The experts were approached via personalized e-mail invitation letters and pre-assigned to the corresponding group membership representing MP, PA, or AP. We selected these three groups due to their known role as key experts in telehealth-related decision-making and implementation processes.[46] Written informed consent was obtained prior to participation in the survey.

For round 1, we distributed a link to the online questionnaire and instructions by e-mail. For round 2, PHP program code and Microsoft Excel charting templates presented the summarized group responses along with individual ratings gathered in the preceding cycle. We invited the panel members to utilize this feedback loop to eventually adapt their previous ratings.

Statistical data analysis

Collected data were statistically evaluated using Excel spread sheet (Microsoft, Seattle, WA, USA) and SPSS version 21.0 (SPSS Inc., Chicago, IL, USA). We assessed frequency of participants

Table 1. Telehealth scenarios covering ICT-based (1) doctor–patient communication, (2) health promotion, and (3) pervasive health monitoring.

Scenario	Description	Author/s (publication date)^{reference}
(1) Doctor–patient communication		
Scenario 1: cooperation	Patient empowerment with new information and communication technologies has replaced the traditional asymmetric doctor–patient relationship with a cooperative partnership.	Bissell et al. (2004)[25] Chaudhry et al. (2006)[26]
Scenario 2: communication	Cyber medicine, which is the use of the Internet to provide medical services, leads to a more effective doctor–patient communication.	Feliciani (2004)[5] Weiner (2012)[27]
(2) Health promotion		
Scenario 3: compliance	Personalized information and communication technologies remind patient of punctual intake of prescribed medicine, resulting in higher compliance and thus better therapeutic outcome.	Alpay et al. (2009)[12] Dunbar et al. (2003)[28] MacLaughlin et al. (2005)[29] Pirnejad et al. (2006)[30]
Scenario 4: education	Scientific, interactive multimedia is broadly accepted and intensively used for public health education and preventive medicine.	Bouwman et al. (2005)[31] Chaikoolvatana et al. (2009)[32]
Scenario 5: cancer risk	Target group-specific, information and communication technology–assisted preventive medicine is widely used to reduce the individual cancer risk.	Parham et al. (2010)[33] Ryhanen et al. (2010)[34] Treacy and Mayer (2000)[35]
Scenario 6: insurance rates	Funding of health insurances is deregulated, and insurance rates depend on individual information and communication technology–tracked lifestyle choices.	Ornish (2009)[36] Wu et al. (2011)[1]
Scenario 7: activities	Target group-specific tourist and recreational activities for patients with similar socioeconomic and medical background are a common population-based health promotion effort.	Giles-Corti et al. (2009)[37] Guillen et al. (2009)[11]
Scenario 8: prevention	Web-based communication tools assist handicapped or elderly people by providing information for primary and secondary health prevention.	Guillen et al. (2009)[11] Hettinga et al. (2009)[38]
(3) Pervasive health monitoring		
Scenario 9: monitoring	Patients use intelligent, non-invasive sensing, and monitoring systems to collect vital signs in a home care setting.	Lee et al. (2009)[39] Lin et al. (2008)[40]
Scenario 10: motivation	Wearable sensor systems constantly collect real-life data and associated persuasive information and communication technologies provide personalized interventions motivating for beneficial health behavior.	Fjeldsoe et al. (2009)[41] Haux et al. (2008)[6] Blanson Henkemans et al. (2009)[42] Patrick et al. (2009)[43] Slootmaker et al. (2010)[44]

endorsing benefits and obstacles per scenario and group-specific frequencies of perceived benefits, obstacles, degree of innovation, desirability, and estimated date of implementation of telehealth scenarios in Austria. For providing consolidated survey data on the 10 scenarios (macro-level analysis), we built a summarized multi-scenario score of scenario- and group-specific means. To further investigate inter-group differences, we conducted Kruskal–Wallis tests for nonparametric statistics on group size-weighted data.[47]

Results

In total, 73 participants (74% males; mean age 43.9 years, standard deviation [SD] 9.4 years) fully completed both Delphi cycles. Whereas the subgroups did not differ regarding average age, survey participation rate of males compared to those of females was higher in the subgroup of AP (86%) and MP (84%), and slightly lower among PA (48%). During the biphasic Delphi survey, the panelists evaluated each of the 10 prospective scenarios. As shown in Table 2, the three top-ranked benefits were quality of social healthcare (overall mean 50%), highest in scenario 3 (81%), patients' knowledge (overall mean 47%), highest in scenarios 1 and 4 (both 69%), and living standard (overall mean 45%), highest in scenario 8 (80%). Scenario 6 (26%) was highest ranked regarding "no improvement." Compared to benefits, obstacles reached higher ratings consistently. Financial investment was seen as the top priority factor (overall mean 61%), highest in scenario 9 (85%). Acceptance by PA (overall mean 44%), highest in scenario 6 (74%), ranked second and data security/privacy (overall mean 40%) ranked third and highest in scenario 9 (67%).

Table 3 depicts group-specific ratings, revealing that MP consistently picked fewer beneficial factors, "no improvement" more often (22% vs overall mean 16%), and "no obstacles" less often (5% vs 6%) compared to the other groups. Furthermore, regarding group self-assessment, the second ranked factor acceptance by PA yielded lowest agreement among PA (37% vs 42%) and the fourth ranked factor acceptance by MP received lowest agreement among MP (31% vs 37%). Reversely, the seventh ranked factor acceptance by AP attained highest agreement among AP (19% vs 12%).

Participants perceived high innovation degree for all scenarios (overall mean 72%), with highest agreement for scenario 1 (88%), whereas low innovativeness (28%) was most prominent in scenario 6 (41%). Regarding desirability, 71% of participants perceived the scenarios as being desirable with highest agreement in scenario 3 (88%). Accordingly, 29% of panelists rated low overall desirability with the lowest rank for scenario 10 (62%). The year 2019 was the median expected scenario implementation date with the furthest away year (all: 2020) for scenarios 2, 6, 9, and 10.

Furthermore, we investigated group-specific survey response frequencies and differences (Table 4). Kruskal–Wallis tests revealed statistically significant overall group size-weighted, inter-group differences for benefits (mean 2.2 ± SD 1.3, $p = 0.003$), obstacles (2.4 ± 1.2, $p = 0.010$), as well as desirability (71%, $p < 0.001$). MP scored lowest in the categories benefits (1.8 ± 1.3) and desirability (0.6 ± 0.2), whereas PA scored lowest in obstacles (2.2 ± 1.2) compared to the other stakeholder groups. MP scored highest in these two domains compared to the other experts (innovativeness: 3.1 ± 0.9, date estimates: 2019.3 ± 2.8). Nevertheless, we did not find statistically significant differences for innovativeness (overall 3.0 ± 0.9) and date estimates (overall 2019 ± 3.0), all: p = n.s.

Discussion

It is evident that on-going technological achievements impact all levels of healthcare. Given the complexity of today's healthcare environments, successful telehealth adoption presents multidimensional and inter-professional challenges, depending explicitly on human-related, social, and institutional factors. Apparently, diverse interest groups emphasize different aspects depending on the organizational system they belong.[25,48] To assess multidisciplinary perspectives, this study's Delphi panel consisted of experts serving as representatives of the medical professional, patient, as well as administration perception.[13,14]

In our survey, experts anticipated that quality of social healthcare, patients' knowledge, and living standard as the top-ranked factors could eventually profit from future telehealth scenarios. Finding these qualities among the top three benefits could represent a change in paradigm, resulting

Table 2. Overall mean as well as scenario-specific ranking of perceived benefits and obstacles for implementation of telehealth scenarios in Austria.

Factors[a]		Scenarios (%)[b]									
Rank	Overall mean (1–10)	1	2	3	4	5	6	7	8	9	10
1. Benefits											
1	Quality of social healthcare										
	50.7	64.7	44.1	80.8	43.1	70.8	33.6	44.1	46.7	43.6	35.6
2	Patients' knowledge										
	48.6	69.6	47.8	46.2	70.1	52.0	27.6	42.0	37.7	44.0	48.8
3	Living standard										
	46.4	17.0	19.1	56.3	50.5	54.7	26.1	77.6	79.8	45.1	38.2
4	Funding of social healthcare										
	34.6	28.7	29.7	43.6	34.6	44.1	72.9	25.5	22.4	24.9	19.7
5	Doctor–patient relationship										
	32.6	81.4	59.5	43.6	23.4	34.6	6.9	9.6	10.7	37.7	18.6
6	No improvement										
	16.2	2.2	20.3	6.4	11.2	9.1	26.6	15.0	9.1	21.4	40.5
2. Obstacles											
1	Cost, funding										
	61.4	53.7	56.8	58.0	45.3	67.5	25.0	70.8	73.4	85.1	78.1
2	Acceptance by PA										
	42.3	19.2	43.6	59.5	33.5	46.9	77.6	25.6	25.0	58.0	33.7
3	Data security, data privacy										
	39.8	62.3	56.9	34.6	4.8	42.7	50.1	10.7	11.2	66.0	59.0
4	Acceptance by MP										
	36.8	76.5	65.4	27.1	41.9	22.9	25.5	8.0	13.3	40.5	47.3
5	Technical prerequisites										
	31.2	27.6	38.3	44.7	17.1	24.5	6.9	4.2	9.0	73.4	66.5
6	Regulations, standards										
	21.7	19.7	20.2	20.2	14.4	22.4	32.5	9.6	11.2	30.4	36.6
7	Acceptance by AP										
	12.1	8.5	8.5	1.6	9.0	8.0	28.2	16.5	14.9	13.3	12.8
8	Influence of stakeholders										
	8.5	18.6	11.7	6.9	5.3	4.2	27.6	2.2	2.2	3.2	2.7
9	No obstacles										
	6.2	1.1	2.7	1.6	19.2	7.4	1.6	15.4	11.2	1.1	1.1

PA: patient advocates; MP: medical professionals; AP: administrative personnel.

[a] (1) Which factors are improved by wide acceptance of the specific scenario in Austria? (2) Which factors hamper the implementation of the specific scenario in Austria? (All: % of participants endorsing benefits and obstacles per scenario.)

[b] Scenario 1: cooperation; scenario 2: communication; scenario 3: compliance; scenario 4: education; scenario 5: cancer risk; scenario 6: insurance rates; scenario 7: activities; scenario 8: prevention; scenario 9: monitoring; scenario 10: motivation.

in improved health services along with end users' empowerment, autonomy, and self-assertion.[1,7] These results are in accordance with Haux et al.,[6] who suggested that quality of healthcare delivery significantly benefits from interactive, long-distance counseling and pervasive health monitoring applications.

Table 3. Perceived benefits, obstacles, degree of innovation, desirability, and estimated date of implementation of telehealth scenarios in Austria, stratified by expert groups.

Factor[a]	Expert groups			Total
	MP	PA	AP	
N	31	21	21	73
1. Benefits (%)				
Quality of social healthcare	46.5	51.0	54.8	50.7
Living standard	35.5	55.2	48.6	46.4
Patients' knowledge	35.8	55.7	54.3	48.6
Funding of social healthcare	31.0	31.0	41.9	34.6
Doctor–patient relationship	29.7	31.0	37.1	32.6
No improvement	22.3	11.0	15.2	16.2
Mean[b]	35.7	44.8	47.3	42.6
2. Obstacles (%)				
Cost, funding	57.4	61.0	65.7	61.4
Acceptance of PA	45.8	36.7	44.3	42.3
Data security, data privacy	44.2	30.5	44.8	39.8
Acceptance of MP	31.0	32.9	46.7	36.8
Technical prerequisites	31.3	37.1	25.2	31.2
Regulations, standards	26.1	17.6	21.4	21.7
Acceptance of AP	12.6	5.2	18.6	12.1
Influence of stakeholders	8.7	4.8	11.9	8.5
No obstacles	4.8	7.1	6.7	6.2
Mean[c]	32.1	28.2	34.8	31.7
3. Innovation (%)				
High	75.8	71.0	68.1	71.6
Low	24.2	29.0	31.9	28.4
4. Desirability (%)				
Desirable	61.3	79.5	77.6	72.8
Not desirable	38.7	20.5	22.4	27.2
5. Date (years)				
Mean	2019	2019	2019	2019
Median	2019	2019	2019	2019

MP: medical professionals; PA: patient advocates; AP: administrative personnel.

[a] (1) Which factors are improved by wide acceptance of the specific scenario in Austria? (%); (2) Which factors hamper the implementation of the specific scenario in Austria? (%); (3) In your opinion, how innovative is this scenario for Austria? (%); (4) In your opinion, is this scenario desirable for Austria? (%); (5) In your opinion, when will the scenario be widely accepted in Austria? (years).

[b] Without "No improvement."

[c] Without "No obstacles."

Expected costs, acceptance by PA, and data protection were among the most relevant obstacles for the nationwide adoption of innovative health technologies. Other important obstacles included acceptance by MP and technical prerequisites. Given scarcity of funding, every resource spent on health promotion has opportunity costs in other economy sectors. Hence, we suggest that the aforementioned rating reflected a shift toward consumer-centric healthcare using existing resources (e.g. privately owned smartphones) without overstraining the available capacities.

Table 4. Group size-weighted, inter-group comparisons of perceived benefits, obstacles, degree of innovation, desirability, and estimated date of implementation of telehealth scenarios in Austria.

Factor[a]	Expert groups			Total
	MP	PA	AP	
1. Benefits				
Mean	1.8	2.3	2.4	2.2
SD	1.3	1.2	1.4	1.3
p				0.003*
2. Obstacles				
Mean	2.5	2.2	2.5	2.4
SD	1.3	1.2	1.2	1.2
p				0.010*
3. Innovation				
Mean	3.1	2.9	2.9	3.0
SD	0.9	0.9	0.9	0.9
p				0.338
4. Desirability				
Mean	0.6	0.8	0.8	0.7
SD	0.2	0.1	0.1	0.2
p				0.0001**
5. Date				
Mean	2019.3	2019.2	2018.6	2019.0
SD	2.8	2.9	3.5	3.0
p				0.139

MP: medical professionals; PA: patient advocate; AP: administrative personnel; SD: standard deviation.

[a] 1. Which factors are improved by wide acceptance of the specific scenario in Austria? (mean, SD); 2. Which factors hamper the implementation of the specific scenario in Austria? (mean, SD); 3. In your opinion, how innovative is this scenario for Austria? (degree of innovation, 1–4 points); 4. In your opinion, is this scenario desirable for Austria? (0 = *not desirable*, 1 = *desirable*; mean, SD,); 5. In your opinion, when will the scenario be widely accepted in Austria? (in years: mean, SD).

Kruskal–Wallis test: $^{*}p < 0.05$; $^{**}p < 0.001$.

Concerns about IT security are increasingly advancing, as shown by other surveys,[26,27,49] and quantified by the share of spending budget for achieving acceptable levels of security and ensuring system resistance to security compromises.[27] Data privacy measures include confidentiality and privacy aspects, but also safekeeping of data manipulation. Data security awareness of staff members could minimize risks of IT breaches and security vulnerability. Effective technical prerequisites require organizational and personnel measures to ensure privacy and security of sensitive patient data. Ultimately, the patients' trust in the fact that doctors ensure all conceivable aspects of privacy constitutes an extremely valuable asset for everyday doctor–patient relationships.[49,50]

Our findings on external assessment and self-assessment of acceptance suggested that PA and MP undermatched the level of how other interest groups perceived their halting attitudes in telehealth implementation. Contrarily, AP were more likely to be self-confident regarding their respective positive attitudes.

The multifarious, fragmented internal structures of health organizations have been claimed responsible for slower IT integration and adoption in the healthcare sector compared to other branches.[48] We assessed estimates of time frames for scenario implementation to seize the prevailing temporal expectations among experts involved in respective decision-making. The ratings pointed toward a date approximately 10 years ahead of the year 2010 when this study was conducted, a surprisingly long time period considering that the scenario-based telehealth solutions were already conceived by then. These findings on quite reluctant temporal estimates might provoke experts to reframe priorities of doctor–patient communication, health promotion, and pervasive health monitoring applications.

Inter-group comparison regarding desirability revealed that PA and AP perceived more scenarios as desirable compared to MP. This finding confirms the notion that MP might be more critical about telehealth and related technological applications.[48] As a possible explanation, the perceived undermining power of profoundly embedded professional constructs of doctor–patient interactions could hamper acceptance of telehealth among physicians' health culture, age, and gender independently.[31,32,51] However, according to Anderson,[52] general practitioners perceive that ICT applications could increase patient empowerment and reduce expenses. Respective "soft" obstacles include insufficient IT knowledge, privacy, and legal concerns, whereas high initial costs and lack of financial support are seen as "hard" barriers.[53]

As physicians' intention to telehealth use is vital for national-scale implementation, highlighting the expected telehealth merits could increase technology adoption.[32,34] Akesson et al.[36] reported that telehealth users felt more empowered and better informed about their health status. Also, these consumers did not perceive ICT utilization, absence of face-to-face consultations, and privacy issues as obstacles. In their review article on mobile apps used in health behavior interventions, Payne et al.[37] proposed good acceptance of mobile apps to assist individuals in modifying their health habits, though identifying a lack of best practice evidence. Health-related technologies might be more difficult to adopt especially for the elderly or neglected strata of the population such as mental healthcare consumers, requiring particular consideration regarding their training, support, and specific personal needs.[38,54]

Smartphone apps offer a huge range of health- and fitness-related applications for preventive, curative, as well as recreational purposes.[55] Given nearly ubiquitous Internet access nowadays, identification of individual preferences and health information needs of consumers is a prerequisite for effective telehealth solutions.[11,56] Along with empowerment of end users and improved collaboration of healthcare stakeholders, governmental strategies for adequate funding and performance incentives are required to implement future costumer-tailored telehealth services.

Austria started a nationwide test run of a shared electronic health record (EHR) system in 2015.[57] Through this new electronic health management tool, laboratory and radiology reports, hospital discharge letters, and a patient medication history called eMedication will be electronically available. Although the concept of this new electronic health management tool is well-founded, the expected organizational and procedural challenges dramatically decreased acceptance by MP. This skepticism and resistance to adopt the EHR delayed its implementation several years. Our Delphi survey adds to the body of knowledge in the research field so far missing insight into Austrian experts' perception of future health-related ICT solutions. Additionally, we introduced 10 future scenarios and developed an online questionnaire for collecting data of a two-round online Delphi survey.

Strengthens and limitations

A strength of the study was the large study population consisting of experts (n = 73) in high-ranking positions in the Austrian healthcare sector from all nine Austrian provinces. We conducted the survey over two rounds to maintain robust feedback and to minimize high attrition rates inherent in multiple feedback rounds. The survey results could be used to validate evolving demands of modern healthcare systems including target group-specific user acceptance. The consolidated results synthesized the expert opinions and corresponding inter-group comparisons. As such, the insights gained in this study could help to more comprehensively evaluate the complex interplay between consumers, health practitioners, and policy makers. Further research could adjust the survey to on-going technological advances and refine our findings using cross-sectional, quasi-experimental, and mixed method approaches, subsequent focus groups, and consensus conferences.[58]

The results of the study should be considered within the context of study design and associated limitations. Noteworthy, the data have been gathered in 2010, and more recent societal as well as technological developments should be taken into account when referring to our findings. Panelists were not able to unerringly predict prospect technical developments in a Delphi survey setting. However, their opinions could be of interest due to their influence as key decision-makers shaping the future of Austrian telehealth. The scenarios were intended to strongly link to the currently existing concerns of policy makers addressing the key question of where to place resources in telehealth implementation processes. The telehealth scenarios were not intended to formulate ideal, best-case, or worst-case scenarios. Nevertheless, findings from this survey might represent a conceptual basis for increasing mutual understanding and activating critical examination of current practices.

Conclusion

As both human and organizational factors affect successful telehealth adoption, this study suggests potential targets for facilitating mutual policy- and decision-making processes. Measures should be taken to increase respective public knowledge and skills. The findings of this Delphi survey recommend increasing awareness on interest group-specific needs regarding future healthcare by establishing close cooperation, networking, communication, and practice sharing among competent authorities. Telehealth stakeholders should feel obliged to focus on transparent and rigorous quality and safety assurance procedures. To avoid health inequalities in aging societies, these stakeholders should address the digital divide that refers to unequal telehealth access by disadvantaged populations typically affecting disabled and elderly people.

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Setting priorities for EU healthcare workforce IT skills competence improvement

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Abstract

A major challenge for healthcare quality improvement is the lack of IT skills and knowledge of healthcare workforce, as well as their ambivalent attitudes toward IT. This article identifies and prioritizes actions needed to improve the IT skills of healthcare workforce across the EU. A total of 46 experts, representing different fields of expertise in healthcare and geolocations, systematically listed and scored actions that would improve IT skills among healthcare workforce. The Child Health and Nutrition Research Initiative methodology was used for research priority-setting. The participants evaluated the actions using the following criteria: feasibility, effectiveness, deliverability, and maximum impact on IT skills improvement. The leading priority actions were related to appropriate training, integrating eHealth in curricula, involving

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healthcare workforce in the eHealth solution development, improving awareness of eHealth, and learning arrangement. As the different professionals' needs are prioritized, healthcare workforce should be actively and continuously included in the development of eHealth solutions.

Keywords
Child Health and Nutrition Research Initiative, healthcare workforce, IT skills competence, priority-setting, ehealth

Introduction

Healthcare systems throughout the world are endeavoring to rise to the challenges that result from aging population, prevalence of chronic conditions, rising life expectations, and multi-morbidity.[1–3] The traditional healthcare delivery is unsustainable and is increasingly recognized that integrated care can significantly improve the quality and continuity of services.[4] With the focus on creating more efficient and cost-effective care, eHealth is seen as one of the key solutions. An EU report indicated that eHealth has the potential to be the third pillar in the health market, along with pharmaceuticals and medical devices.[5] The 2010 EU Citizenship Report underlined the role of eHealth in facilitating cross border healthcare.[6] Its focus is to advance and create new models for delivering better quality, more efficient healthcare services, and not to replace traditional ways of care delivery, such as face-to-face consultations.

According to the EU project "Chain of Trust," which analyzed the experience of 6704 patients and health professionals who used eHealth, two most prominent topics were the confidence in health IT and health professionals' skills.[7] Traditional curricula commonly do not equip healthcare workforce even with the basic health IT skills. Identifying approaches for achieving high proficiency in eHealth healthcare workforce including those working in public health, and allied professionals, is a key to healthcare transformation.

The need to improve the eHealth/IT competences of healthcare workforce has been frequently emphasized by policymakers at an international level. One of the projects aiming to identify healthcare workforce IT skills needs is the CAMEI project.[8–10] It is a collaboration between the United States and Europe, which was initiated by the Memorandum of Understanding on Cooperation Surrounding Health-Related Communications and Technologies.[11] Other studies focus on some specific areas or workforce groups.[12–15] In this study, we use the World Health Organization (WHO) definition of healthcare workforce as "*all people engaged in action whose primary intent is to enhance health*."[16] The eHealth/health IT skills are defined as "*any competence and knowledge deficiencies among all staff in healthcare delivery, management, administration and support to ensure universal application of ICT solutions in health services*."[17]

To our knowledge, this is the first study that used a systematic approach in setting priorities for the IT skills competence development among healthcare workforce. A bottom-up approach, with collaboration between experts from diverse backgrounds in healthcare is the way to ensure the health IT skill issues faced by healthcare workforce be addressed appropriately. The objective of this study was to identify and prioritize the actions needed to develop the IT skills competence among healthcare workforce

Methods

The study was approved by the Bioethics Committee of the Medical School of the Aristotle University of Thessaloniki, Greece (approval no. 94/26-06-2014). Relevant information about the study was presented to the participants when asking for their consent of participation. The information covered the standard domains of identifying the researchers, the study purpose and procedures, confidentiality, and how to contact the researchers with any questions or to obtain study results. The way to use the participants' response was also informed, as well as their impact on the results. Their response to the questionnaire indicated their understanding and willingness to participate in the study. Due to the various geographical locations of participants, the information was sent via emails.

Our research is about collecting basic and non-sensitive information. No harm is made to the participants. The collected data can only be used for research purposes and are stored accordingly to social science research guidelines. All the participants were not given any information about the data obtained from one another. All the data were analyzed anonymously. No comparison was made from one participant's opinion to another. Taking into account the collected data, it was presented as it was without altering it to satisfy certain predictions. The participants in this study did not receive and were not promised any forms of compensation in return.

The Child Health and Nutrition Research Initiative (CHNRI) methodology for priority-setting was used to assist prioritizing actions in this study.[18] The process uses a systematic and transparent approach to assemble and analyze a wide spectrum of collective actions from an array of healthcare experts. Prioritization criteria relevant to the topic were used to score and rank the actions. The CHNRI methodology has been used previously to identify research gaps and resource priorities in areas such as birth asphyxia and mental health, and it is increasingly being used by policy-makers, large donors, and international organizations.[18–20] Figure 1 illustrates the four stages of CHNRI methodology.

Stage 1: define the context and criteria

Defining the context is a critical part of the CHNRI process as priority scores for many actions may strongly depend on the context in which the process takes place. The context for this study was specified as follows:

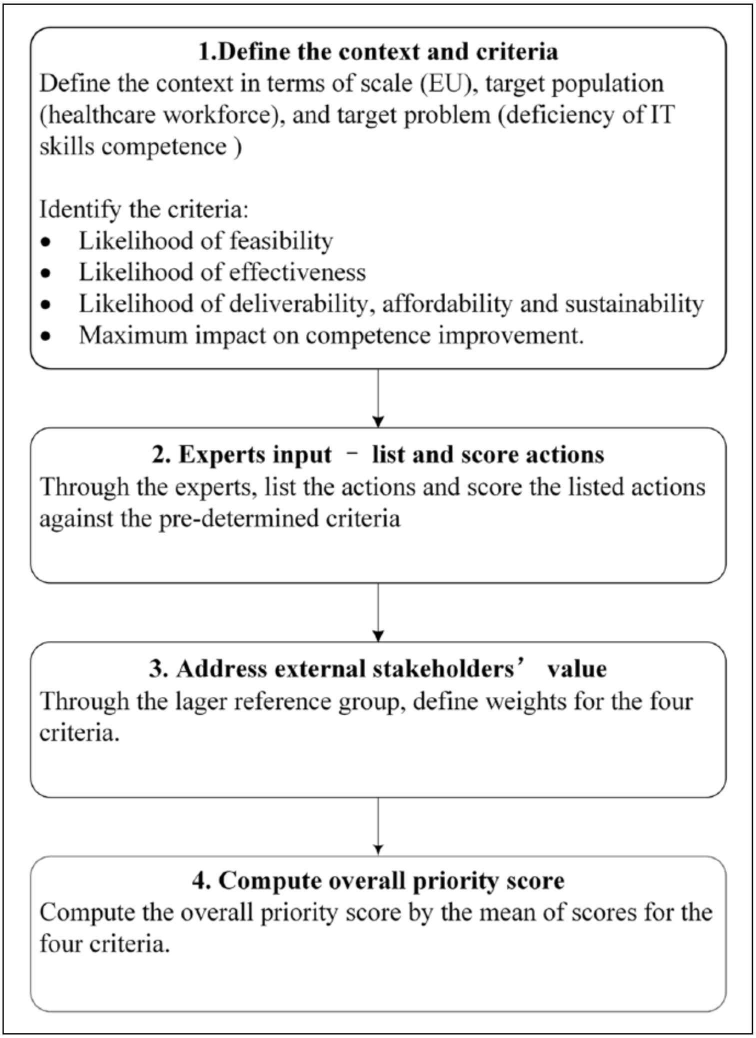
- Scale of the study: EU;
- Problem: deficiency of IT skills competence;
- Target population: healthcare workforce;

Based on CHNRI's conceptual framework,[18] four scoring criteria were identified: (1) feasibility; (2) effectiveness; (3) deliverability, affordability, and sustainability; and (4) maximum potential impact on competence improvement.

Stage 2: experts input—listing and scoring actions

A total of 46 leading experts, representing different expertise and geographical locations, were invited to participate on the basis of their record in eHealth or their membership in an international health organization, which mainly include the following:

- American Health Information Management Association (AHIMA)
- Computer-Based Medical Systems Committee (CBMS)
- Standing Committee of European Doctors (CPME)
- European Association of Hospital Pharmacists (EAHP)
- European Federation for Medical Informatics (EFMI)
- European Federation of Nurses Association (EFN)
- Healthcare Information and Management Systems Society (HIMSS)
- International Medical Informatics Association (IMIA)
- Joint Information Systems Committee (JISC)



1.Define the context and criteria

Define the context in terms of scale (EU), target population (healthcare workforce), and target problem (deficiency of IT skills competence)

Identify the criteria:

- Likelihood of feasibility
- Likelihood of effectiveness
- Likelihood of deliverability, affordability and sustainability
- Maximum impact on competence improvement.

2. Experts input – list and score actions

Through the experts, list the actions and score the listed actions against the pre-determined criteria

3. Address external stakeholders' value

Through the lager reference group, define weights for the four criteria.

4. Compute overall priority score

Compute the overall priority score by the mean of scores for the four criteria.

Figure 1. CHNRI methodology process.

- Medical Informatics Europe Committee (MIE)
- Health Level Seven International (HL7)
- openEHR initiative stakeholders

A total of 29 experts from 14 countries participated in the study listing actions via web survey in March 2015, whereas 34 experts from 19 countries scored actions via web survey from April to May 2015. There was an overlap of 17 experts who were involved in both processes, as shown in Figure 2. In the listing process, experts proposed actions that they thought were important to improve IT skills competence among healthcare workforce. The experts were from 14 countries, including the United States, the United Kingdom, Finland, Norway, Iceland, Switzerland, Denmark, German, Spain, Czech Republic, Ireland, Austria, Belgium, and the Netherlands. Among 29 experts, 10 percent were academics or researchers only, about 69 percent were academics or researchers and belonged to a non-governmental organization (NGO), and 21 percent were from

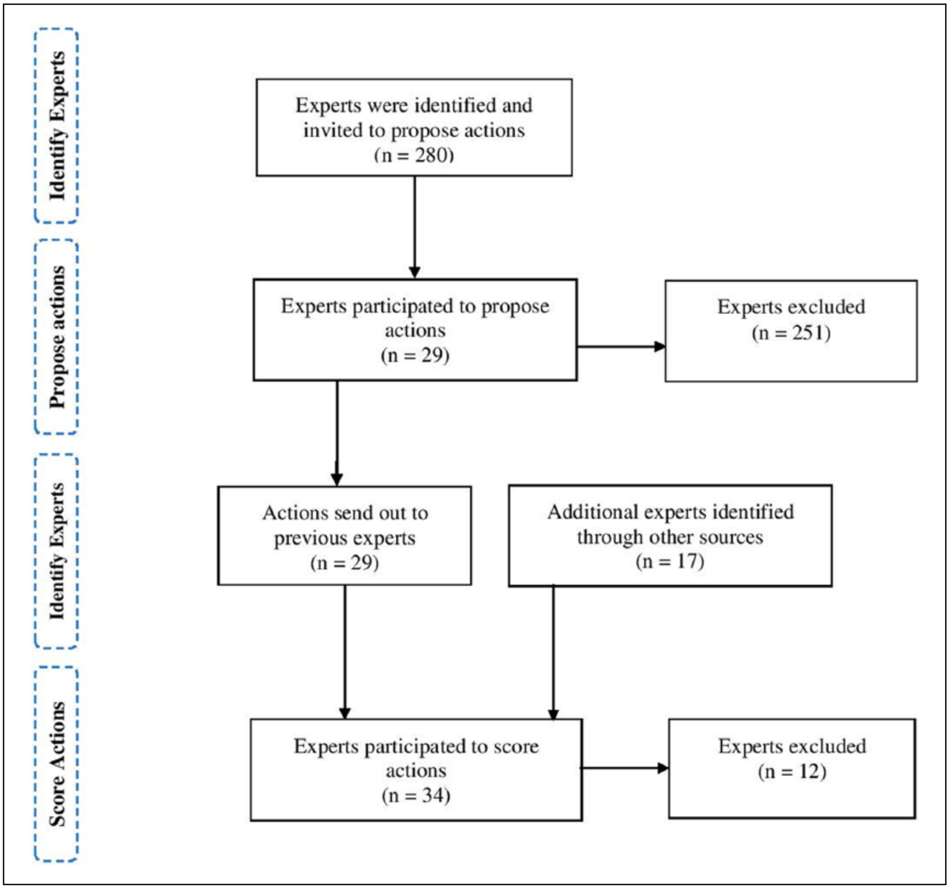


Figure 2. Experts' recruitment process.

NGO only. The process was open-ended and all the proposed ideas from each of the experts were collected independently. The list of actions was compressed to highlight important gaps, yet still represent the range of possibilities to improve IT skills. Then, the final list of actions was reviewed by the authors to ensure that they were framed correctly and comprehensively to allow scoring.

In the scoring process, experts evaluated the final list of actions independently according to the criteria as described in Stage 1. Every expert scored all four criteria, which limited potential impact of any single expert on overall scores. In this way, the listed actions received four "intermediate scores," ranging from 0 to 100 percent. These values represented a direct measure of the collective optimism of the experts. In addition to the 14 countries in the listing process, more experts from Sweden, Greece, Kosovo, Slovenia, and Bulgaria participated in the scoring process. Among 34 experts, 17 percent of them were academics or researchers only, about 59 percent were academics or researchers and belonged to a NGO, and 24 percent were from NGOs only.

Apart from EU countries, experts from the United States were also invited to participate in the study due to the collaboration between the European Commission and the United States in actively addressing the needs for skilled workforce.[11] This was also necessary to make sure that identifying approaches to develop IT skills competence involved a diverse group of experts (rather than isolate EU experts only).

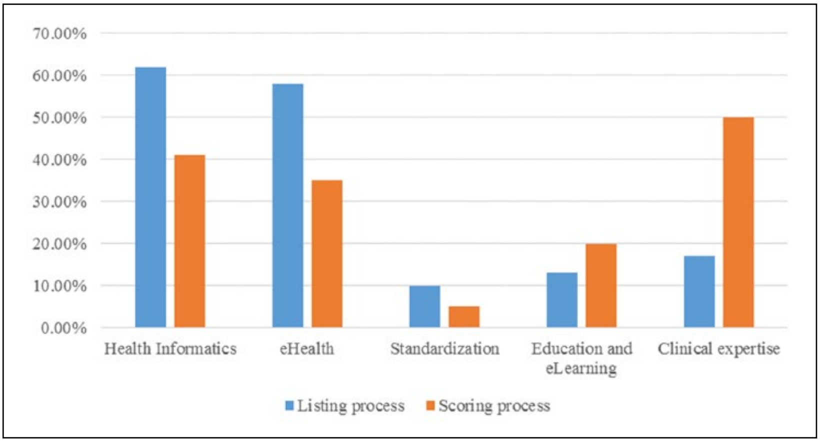


Figure 3. Experts' expertise information.

Figure 3 illustrates the expertise of participants in both listing and scoring processes, which mainly included the following:

- eHealth: EHR, telehealth, clinical decision support, healthcare information system, and health knowledge management;
- Health informatics: medical informatics, nursing informatics, and biomedical informatics;
- eLearning and education;
- Standardization: SNOMED CT and interoperability;
- Clinical expertise: medical doctor, nursing, and pharmacy.

A full list of experts with their expertise and affiliations are presented in Tables S1 and S2.

Stage 3: address external stakeholder's value

The CHNRI methodology ensures the involvement of stakeholders in the process regardless of their expertise. The term "stakeholders" refers to all individuals and/or groups who have an interest in the prioritization of health research, therefore will comprise a large and very heterogeneous group (e.g. expected recipients of the research, taxpayers, medical students, health workers, journalists and media, and political experts).[18] They lack expertise to directly decide research priorities, but they can still weigh the chosen priority-setting criteria based on values assigned by them.[21] In this study, it was decided that the external stakeholder's value will not be addressed and final rankings were based on the priority scores from the perspectives of experts.

Stage 4: compute priority scores and assign ranks

Each expert scored each action by answering one question per criterion. According to CHNRI framework,[18] the answers to each question are simply: "Yes" (1 point) or "No" (0 points). When the experts were sufficiently informed to answer the question, but can neither agree nor disagree, they were allowed to choose "Undecided" (0.5 points). Furthermore, when the experts did not feel they have enough knowledge to answer some questions, they chose "Unqualified to answer." Thus, the listed actions got a score for each of the four criteria. The overall scores were calculated as the mean of the scores for the four criteria according to the below formula

Table 1. Ten actions with greatest overall priority score.

Rank	Action	F	E	D	M	PS
1	Integrate health IT in curricula at both undergraduate and postgraduate levels	92.6	95.5	75.8	76.7	85.1
2	Ensure the competence for educators and train the trainer in eHealth IT skills	88.2	92.4	79.0	78.3	84.5
3	Raise awareness of the importance of eHealth	88.2	86.3	85.5	77.6	84.4
4	Inclusion of healthcare professionals in the development process of the ICT solutions (e.g. usability testing of software)	92.6	89.4	83.9	70.0	84.0
5	Training on patient-centered eHealth/health IT services for different professional groups	91.2	89.4	82.2	71.7	83.6
6	Training on role-specific and organization-specific IT skills for different professional groups	83.8	84.8	79.0	73.3	80.3
7	Exposure to relevant ICT solutions and medical technologies, and increase users' confidence in eHealth	88.2	81.8	77.4	73.3	80.2
8	Improve learning arrangements—facilities, methods, and equipment	81.2	87.5	65.0	76.7	77.6
9	Training on the development of processes and activities supported by IT solutions for different professional groups	77.9	80.3	74.2	70.0	75.6
10	Increase research in user acceptance of IT for healthcare workforce	85.2	81.8	69.3	63.8	75.1

F: feasible; E: effective; D: deliverable; M: maximum impact; PS: overall priority score.

$$\frac{(\text{Criterion 1 score})+(\text{Criterion 2 score})+(\text{Criterion 3 score})+(\text{Criterion 4 score})}{4}$$

Results

The full list of 23 actions and scores from each individual expert is presented in Table S3. The results exposed how actions can be prioritized depending on the criterion of feasibility, effectiveness, deliverability, and maximum potential impact on competence improvement.

Table 1 shows the 10 actions with greatest overall priority score. The action that achieved highest score was about integration of health information technology in curricula for healthcare workforce at different levels (85.1). In addition to that, other actions that focus on continuing training among healthcare workforce also obtained high scores. The action about ensuring the trainer competence was ranked second (84.5); training on patient-centered eHealth services was fifth (83.6); training on role-specific IT skills was sixth (80.3), and training on the development of processes and activities supported by IT solutions was tied ninth (75.6).

Two high-scoring actions were related to improve the workforce involvement: inclusion of healthcare workforce in the development process of eHealth (ranked 4th) and research in user acceptance (10th). High scores were also given to two related actions that identified education on eHealth, specifically for and improving awareness (3rd) and increasing confidence (7th).

Table 2 shows the 10 lowest-scoring actions. Concerns about feasibility were expressed for actions related to identification of IT skills competence needed at international level (ranked 16th, feasibility score: 74.2), evaluation of skills of existing and new staff, offer qualification procedure

Table 2. Ten actions with lowest overall priority score.

Rank	Action	F	E	D	M	PS
14	Introduce online training tools, for example, MOOC, as well as in-house training	83.3	73.4	66.7	66.7	72.5
15	Analyse the skills needed for jobs	81.2	77.2	67.7	55.0	70.4
16	Identification of IT skills competence needed at international level, allow recognition of competences beyond frontiers, and create competence framework	74.2	75.0	72.4	58.3	70.0
17	Help to recognize eHealth/health IT as a specialty	77.9	68.1	71.7	61.7	69.7
18	Guarantee the governance for education and training	82.3	72.7	53.2	56.7	66.2
19	Carry out regular audit/evaluate the skills of existing and new staff, and offer qualification procedure	73.5	74.2	53.2	56.7	64.4
20	Joint funding for generic training programs	66.7	68.2	55.0	61.7	62.9
21	Set up coordinating body to support availability of ICT in broad community of healthcare workers	58.8	59.1	53.3	55.0	56.6
22	Create and use registries	57.6	58.0	53.4	50.0	54.7
23	Improve training on potential healthcare workforce at high school level and undergraduate level	50.0	51.6	41.4	48.3	47.8

F: feasible; E: effective; D: deliverable; M: maximum impact; PS: overall priority score.

(19th, feasibility score: 73.5), and joint funding for training programs (20th, feasibility score: 66.7). For the effectiveness criteria, experts identified actions that introduce online training tools and in-house training for different healthcare workforce as less effective (14th, effectiveness score: 74.2). Other effective action was related to helping workforce recognize eHealth/health IT as a specialty (17th, effectiveness score: 68.1).

Several actions reached the bottom line because they had low scores in the likelihood that these actions could be deliverable, affordable, and sustainable taking into account the current resources. These actions included guaranteeing the governance for education and training (18th, deliverability score: 53.2), setting up coordinating organizations to support availability of ICT in broad community of healthcare workforce (21st, deliverability score: 53.3) and improving training on potential healthcare workforce (23rd, deliverability score: 41.4). Two actions that proposed to analyze the IT skills needed for jobs and create registries (15th and 22nd, maximum impact score: 55.0 and 50.0) received low-priority scores because they were perceived to have less impact on the improvement of IT skills competence.

To summarize, the action that proposed to integrate health IT in curricula was acknowledged as most feasible (92.6) and effective (95.5). Raising awareness of the importance of eHealth was considered to be most deliverable (85.5) while ensuring the competence for educators could mostly impact the IT skill improvement (78.3).

Discussion

Main findings

Prioritization mechanisms are necessary to facilitate the current demand for skilled healthcare workforce, particularly competence to support national eHealth work agendas.[14,15] The overall message of this prioritization study suggests that actions to improve IT skills competence among healthcare workforce in the EU should concentrate on improving workforce training, the inclusion of healthcare workforce in the development of eHealth solutions, raising awareness of eHealth, and improving learning arrangements. The results are generally in line with the recommendations from a recent eHealth Stakeholder Group report[22] that focused on eSkills and health workforce.

Of the top 10 actions, 5 were related to training among healthcare workforce, which reflects the significance of continuous training in IT skills development since the gap between current curriculum and eHealth.[23,24] The importance of training for healthcare workforce in the use of new technologies was also acknowledged in several studies, as well as a Green Paper on the EU health workforce.[14,25,26] Moreover, the results showed the great need of involving healthcare workforce in decisions on introducing eHealth, as well as in designing, testing, and deploying eHealth. Similar results were also demonstrated in another study; user involvement is perceived as crucial to ensuring acceptance in the long term.[7] Furthermore, improving learning arrangements was considered as an essential approach to improve the workforce IT skills. It has been identified by Fields[27] that being limited or with not enough access to technology was one of the top 10 challenges faced by healthcare workforce.

The 2012 Action Plan for the EU Health Workforce from the European Commission[28] outlined three priority areas of actions to promote a sustainable healthcare workforce: forecasting workforce needs and improving workforce planning methodologies, anticipating future skills' needs in the health professions, and sharing good practice on effective recruitment and retention of health professionals. However, the two actions related to identify the IT skills needed were not highly featured, despite being crucial for future workforce plan. These lower prioritizations were due to the concerns on the maximum impact on IT skill improvement.

Two exception actions addressed training issues: "introduce online training tools" and "training on potential workforce," which ranked low priorities. Although a recent systematic review of the effectiveness of online eLearning suggested that eLearning is possibly superior to traditional learning,[29] experts probably feel that the actions were not deliverable, affordable, and sustainable.

Scores for feasibility and effectiveness of the 23 actions were relatively higher than deliverability and had maximum impact. For instance, while the action "Guarantee the governance for education and training" scored 82.3 percent on feasibility, it scored poorly on deliverability (53.2%). This illustrates the fundamental characteristics of health system delivery across the EU. Similar to the EU, the healthcare delivery system in the United States is facing critical challenges as each unit in health industry operates independently and focuses on its own performance.[30]

Strengths and limitations

The main strength of the CHNRI methodology can be summarized as follows: (1) clearly defined context and key criteria that qualify some actions as a funding priority over the others, (2) transparent process for individual input and decision-making in priority-setting, (3) systematic way in scoring actions, thus limiting the influence of individual biases on the outcome, (4) prevent individuals from dominating the process, and (5) an intuitive quantitative outcome that is easy to justify and understand.

Still, the methodology is not free of some possible biases. Although the methodology attempts to involve a wide range of opinions from the participants, many good ideas may not have been included in the initial list of actions. The listing process ended up with open-end questions that may result in multilevel answers from experts. Although efforts were made to phrase the initial actions in a better way, the process was done only by the main authors and some phrased actions may be still confusing for experts. In addition, experts understanding in "IT skills competence" and "healthcare workforce" would be a bias on the outcomes.

Another concern over the CHNRI process is that the possible bias regarding the opinions of a very limited group of experts and the results from the choice of the experts. As the study was based on EU level, the participating experts in the study are only from 18 EU countries. The concept of "healthcare workforce" relates to a broad range of individuals with both clinical background and non-clinical background;[16] however, not every expertise was involved and balanced among experts. The number of individuals who possess enough experience, expertise, and knowledge on IT skills competence among healthcare workforce to evaluate the actions presented is rather limited.

Another bias could be the results from the scoring process. In order to improve the responsiveness of experts and decrease the burden of scores, a minor change was made to score the actions by answering one question per criteria rather than three questions according to the CHNRI guideline. It could affect the accuracy of results to some extent. As for the calculation of priority scores, the answers "yes" got 1 positive point, "no" got 0—no extra point, if it is "undecided," a positive grade (0.5) is still added to the achieved sum. Nevertheless, compared to other priority-setting methodologies mentioned above, the CHNRI approach is prominently featured in the special algorithm and limits the individuals' bias on the outcomes.

Validity

The fundamental principle of CHNRI methodology is "wisdom of crowds," which refers to the process of taking into account the collective opinion of a group of individuals rather than a single expert to answer a question.[31] It has been shown that the average of collective guesses is often better than any expert judgment. By giving each individual the equal right and opportunity to express their own judgment, the personal biases that each one brings to the process tend to negate and diminish, regardless of the participant selection. Following the CHNRI guideline, the same action was scored by a larger group multiple times that improves the degree of accuracy.

Future work

The results from this study present a first step toward identifying the priorities of actions needed to improve the IT skills competence among healthcare workforce. Further research that includes experts with more expertise in healthcare is essential to better characterize all actions that needed for adoption of health informatics technology among workforce. One of the interesting approaches is to incorporate opinions from wider public who are interested in priority-setting in health area but lack of expertise to list actions. In this way, the final priority score for each action will contain the input from both experts and the stakeholders.

The CHNRI methodology ensures transparency in scoring process; therefore, it offers the potential to expose the points of the greatest agreement and the greatest controversy among the experts.[20] In this case, in addition to the information on how each action fulfills with the chosen priority-setting criteria, information about the amount of agreement between the experts on each action could also be obtained. Since the study context and other components of the contexts may change over time, actions can be taken so that research portfolio will continuously be adjusted to the context and aim, including (1) adding further actions to the list, (2) adding additional criteria, and (3) re-scoring all actions in the redefined context.

Conclusion

The growth of new technology, new medical appliances, and diagnostic techniques is leading to new ways of healthcare delivery, which requires a new mix of skills including technical and e-skills. Improving the eHealth IT competences demands concrete actions at an international level. This exercise has led to a concerted EU effort led by a group of experts, all of whom have eHealth-related experience, identifying the priorities of actions needed to be taken for IT skills improvement. The findings are a clear call for attention to integration of eHealth in current curricula, training for both educators and healthcare workforce, raising awareness of the importance of eHealth and inclusion of workforce in the development of eHealth solutions.

This study first explored the actions needed to develop IT skills competence among healthcare workforce using CHNRI methodology and systematically ranked priority list for generating specific suggestions. It is definitely clear that more researches in this field are required in order to provide comprehensive understanding of actions needed to foster IT skills competence for healthcare workforce at different levels.

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Supplementary Material

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Evaluation of health information systems research in information systems research: A meta-analysis

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Abstract

Given the importance of the health-care industry and the promise of health information systems, researchers are encouraged to build on the shoulders of giants as the saying goes. The health information systems field has a unique opportunity to learn from and extend the work that has already been done by the highly correlated information systems field. As a result, this research article presents a past, present and future meta-analysis of health information systems research in information systems journals over the 2000–2015 time period. Our analysis reviewed 126 articles on a variety of topics related to health information systems research published in the "Senior Scholars" list of the top eight ranked information systems academic journals. Across the selected information systems academic journals, our findings compare research methodologies applied, health information systems topic areas investigated and research trends. Interesting results emerge in the range and evolution of health information systems research and opportunities for health information systems researchers and practitioners to consider moving forward.

Keywords

health information management, health information technology, health care, health-care information systems

Introduction

Developments in information technology (IT) and information systems (IS) fields are changing the health-care industry.[1] Health-care leaders, practitioners and researchers alike have been in search of ways to improve health-care delivery and health-care economics. IT and IS have been proposed

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as an essential piece to help solve the health-care puzzle. Specifically, even though the adoption of IT use in health care has traditionally lagged behind other industries and to date many practices have failed to adopt health-care information systems (HIS),[2] HIS is viewed as a key enabler for improving health-care quality and managing costs.[3,4] Significant increases in IT spending in recent years[5] has generated great interest in its effects on the health-care industry cost structure, health-care quality and patient privacy (e.g. the US Health Insurance Portability and Privacy Act). From a research perspective, IS researchers are uniquely positioned to assess how information can be captured, stored, processed and communicated to decision makers for better coordination of health care at both the individual and population levels. As a result of treating HIS as a subtopic area of the IS field, unique opportunities exist for HIS researchers and practitioners to learn and apply concepts previously studied in the IS field to HIS.

The field of IS, by design, applies IT to real-world, business-oriented problems. It seeks to use IT to improve effectiveness and efficiency. Clearly, health-care organizations have sought out the benefits and opportunities presented through technology developments.[6] As a result, the needs of the health-care industry and the ambitions of IS researchers coincide. Health-care organizations face multiple future hurdles that IS researchers are well equipped to study and have studied.[7,8] Prominent among these hurdles are applying IT to improve the quality of health-care processes and reduce medical errors; developing e-services to connect health-care stakeholders, including government, insurers, health-care administrators, clinical staff and patients; identifying obstacles to acceptance and continued use of HIS; adapting user-centered design principles to health-care settings; assessing financial and other organizational impacts of IT in health care; and managing HIS effectively.

In total, two related needs provide the motivation for this article. First, with the increased recognition and importance assigned to HIS, there is a need to review what has been done in the corresponding IS research area and share those findings with HIS professionals. Second, in order for HIS research to advance, from both an IS and HIS perspective, there is a need for researchers to periodically review methods used by researchers and provide insights to which methods have been and should be utilized in a given research field.[9] Historically, meta-analysis served as a valuable tool in determining where we have been and where we are headed as researchers.[10] As a result, this research study provides the opportunity for both IS and HIS researchers to review what has been done in the field and suggests future research efforts.

Before reviewing the literature, we need to highlight the importance of HIS, not only for academics but also for the society as a whole since health-care delivery has ramifications for us all. The stakes are high for health-care organizations to utilize HIS to improve health-care delivery. First, health-care spending is a topic that has received widespread attention. Health-care spending has been increasing exponentially. According to the Centers for Medicare and Medicaid Services[11] in 2015, US health care spending increased 5.8 percent to reach 3.2 trillion, or $9,990 per person. Additionally, health spending was at 17.8 percent of US gross domestic product (GDP). The United States has continued to outspend all other Organisation for Economic Co-operation and Development (OECD) countries by a wide margin, with spending on health per capita of US$8233, or 17.9 percent of GDP, compared to the overall OECD average of US$3268. Overall, health-care spending accounts for a substantial portion of GDP in many countries (e.g. 17.91% of American GDP; 10.1% of Japan GDP; Germany 11.3%, China, France 11.7%). In addition, the health-care industry faces major institutional and regulatory pressures that are different from other industries. Health-care organizations have to find ways to improve efficiency to drive down the cost of their services to remain financially viable. All nations, including developed and developing nations, are facing pressures to control costs but at the same time increase outcome quality and access to health care.

The importance of health care to individuals and governments and its growing costs to the economy have contributed to the emergence of health care as an important area of research for scholars in business and other disciplines.[12] HIS directly influences a diverse set of stakeholders, including patients, people working in the health care and IS industries, as well as nations or regions struggling to deliver efficient health care. From an academic perspective, evidence of the increased interest and significance of HIS is demonstrated by the proliferation of health-care tracks at IS conferences, special interest groups, the sheer number of research articles directly addressing HIS, along with entire special issues from top tier journals dedicated to the topic (*European Journal of Information Systems*, 2007; *Journal of the AIS*, 2011; and *Information Systems Research*, 2011). This increased interest confirmed in recent years has contributed to our interest in investigating and reflecting on what is known about HIS. Clearly, with the growing reliance and predicted growth in HIS, there is a significant need for HIS researchers to learn from past research, assess the present state of HIS research and plan future research directions to support the anticipated importance of HIS.

The maturity of the HIS field along with the increased number of publications dedicated to HIS in recent years contributed to our motivation to investigate and reflect on the HIS field. As a result of the growing academic, social and practitioner interest in the field of HIS, there is a significant need to do a comprehensive assessment of HIS research activities. Regardless of the stakeholder perspective considered, it can be argued that HIS is a noteworthy global phenomenon that demands researcher attention and a greater understanding. The article at hand seeks to meet this need by systematically reviewing and analyzing prior IS academic literature on HIS. Based on a review of top-ranked IS journals, we compile an exhaustive review of 126 publications focused solely on HIS during the 2000–2015 time period. This article seeks to answer questions such as "What research methods are commonly used to study HIS?" "What are the dominant topics addressed by HIS research?" and "What are trends in HIS research?" As a result, the goal of this article is to review the literature with the goal of identifying significant knowledge gaps and motivate researchers to aim to close the gaps. Thus, this research reviews extant literature and proposes an agenda for future research. The remainder of this article is organized as follows: The next section discusses our methods for collecting and analyzing HIS articles. Next, we discuss the results describing the research methodologies applied, subject matters addressed and HIS research trends. We conclude with discussions on implications and future research directions.

Method

Our approach to this analysis of HIS research conducted by IS researchers was to first review the IS literature. Specifically, our goals were to capture the trends associated with (1) the number and distribution of HIS articles published in the leading IS journals, (2) identify methodologies employed in HIS research, and (3) highlight the HIS research topics being published in IS journals. Cumbie et al.[13] provided a three-step method for meta-analysis including journal selection, article classification, and data assessment/synthesis. We adapted this method and followed a structured approach to conduct this meta-analysis. First, in order to limit the review to the most influential IS articles, the "Senior Scholars" basket of eight journals (see Table 1) was selected.[14] The Senior Scholars list encourages colleagues, deans and department chairs to treat the basket of eight as the top journals in the IS field. The list is limited to those in the "IS field" and omits both multidisciplinary and specialty areas. We searched through the 2000–2015 time frame and accumulated a pool of HIS articles from the leading IS journals using the ABI/INFORM database and associated journal websites. We searched the titles and abstracts of each of the eight journals using phrases such as "health care," "health," "health care," "EHR," "electronic health record," "patient" and "e-health" in order to cover the range of potential health-related topics.

Next, after all articles were identified and collected, we examined and categorized each article based on the research strategy applied. Each article was categorized based on the research

Table 1. Journals in study.

Journal title	Acronym
MIS Quarterly	*MISQ*
Information Systems Research	*ISR*
Journal of Management Information Systems	*JMIS*
Journal of Association of Information Systems	*JAIS*
Information Systems Journal	*ISJ*
Journal of Information Technology	*JIT*
European Journal of Information Systems	*EJIS*
Journal of Strategic Information Systems	*JSIS*

Table 2. Research strategies.

Research strategy	Description
Formal theory/literature reviews	Summarization of the literature in an area of research in order to conceptualize models for empirical testing.
Sample survey	The investigator tries to neutralize context by asking for behaviors that are unrelated to the context in which they are elicited.
Laboratory experiment	Participants are brought into an artificial setting, usually one that will not significantly impact the results.
Experimental simulation	A situation contrived by a researcher in which there is an attempt to retain some realism of context through use of simulated situations.
Field study: primary data	Investigates behavior in its natural setting. Involves collection of data by researchers.
Field study: secondary data	Involves studies that use secondary data (data collected by a person, agency or organization other than the researchers).
Field experiment	Collecting data in field setting but manipulating behavior variables.
Judgment task	Participants judge or rate behaviors. Sampling is systematic versus representative, and the setting is contrived.
Computer simulation	Involves artificial data creation or simulation of a process.

categories (see Table 2) presented in Scandura and Williams.[9] The nine research strategies included formal theory/literature reviews, sample survey, laboratory experiment, experimental simulations, field study (primary data), field study (secondary data), field experiment, judgment task and computer simulation. These research strategies are the most common approaches in the business discipline where IS sits.[9] In order to normalize the categorization process,[15] we performed a pilot on unused articles to discuss the results and refine the definitions.

Each research strategy (see Table 3) by design and definition is associated with certain trade-offs that researchers must make when designing a study. The trade-offs are inherent flaws that limit the conclusions that can be drawn from a particular research strategy. The trade-offs include the generalizability from the sample to the target population (external validity), precision in measurement and control of behavioral variables (internal and construct validity), and the issue of realism of context.[9]

Third, we classified the articles by research topic. In order to classify the articles by research topic, we held several brainstorming and discussion sessions. In the discussion sessions, our goal was to synthesize the literature and provide a better understanding of the current state of HIS research in traditional IS journals. Once the category definitions were established, we categorized only a few articles at a time to minimize coder fatigue and protect intercoder reliability.[15]

Table 3. Trade-offs of research strategies.

Research strategy	Strategy trade-offs		
	Degree of precision measurement	Degree of realism of context	Generalizability to target population
Formal theory/literature reviews	Low	Low	Maximizes
Sample survey	Low	Low	Maximizes
Laboratory experiment	Maximizes	Low	Low
Experimental simulation	Moderate	Moderate	Low
Field study: primary data	Low	Maximizes	Low
Field study: secondary data	Low	Maximizes	Low
Field experiment	Moderately high	Moderately high	Low
Judgment task	Moderately high	Low	Moderately high
Computer simulation	Low	Moderately high	Moderately high

Source: Scandura and Williams.[9]

Results

Our analysis resulted in a collection of 126 journal articles from the 2000–2015 time period. For a complete list of the articles, see Appendix 1. Based on the articles in our pool, we analyzed the articles based on year of publication, journal and research topic. Our findings from this study revealed that IS researchers are starting to provide some attention to HIS topics. Table 4 highlights the number of HIS articles by year across all journals included in the sample. We can see that with HIS issues becoming more important to IS researchers and practitioners that an increasing trend in the number of articles is a result. A spike in the number of articles in 2011 corresponds with passage of the Affordable Care Act in 2010 or the fact that this was near the first year of incentive payouts for meaningful use per the HITECH act of 2009. An encouraging sign is that in the last 2 years in our study 2014 and 2015, we see increased attention given by IS researchers to HIS topics.

Another area of investigation was to examine the degree to which articles from leading IS journals are focused on HIS topics. Our review revealed that HIS research in IS journals is steadily increasing but is not a dominant topic area for IS researchers. We calculated the percentage of HIS articles based on the total number of articles published in each journal over the 2000–2015 time period. As shown in Table 5, none of the top tier IS journals publish over 5 percent of their articles on HIS topic areas. It appears that the top tier IS journals do not devote a substantial amount in total to HIS research. The fact that top tier IS journals published between 1.30 and 4.72 percent of their publications on HIS topic areas should not be particularly alarming since IS is a broad field, but it does highlight opportunities for additional IS research focused on emerging HIS issues.

Analysis of research strategies in HIS research

Our categorization of the 126 articles into the research categories produced the following results (see Table 6). In total, 53 articles were classified as field study: primary data making it by far the most prevalent research strategy with 42.06 percent of all articles utilizing that research method. Field study: secondary data (24.60%), sample survey (13.49%) and formal theory/literature reviews (11.90%) were the only other categories garnering over 10 percent of the total. No articles were classified experimental simulation, and only one article each was classified as laboratory experiment and judgment task. Overall, the top three research strategies made up over 80 percent of all research strategies applied (field study: primary data, field study: secondary data and sample

Table 4. Number of HIS articles per year.

Year	No. of HIS articles
2000	3
2001	0
2002	0
2003	1
2004	5
2005	4
2006	4
2007	18
2008	4
2009	8
2010	7
2011	24
2012	9
2013	6
2014	16
2015	17
Total	126

HIS: health-care information systems.

Table 5. HIS articles as a percentage of total articles 2000–2015.

Journal name	HIS articles	Total articles	HIS % of total
MISQ	22	719	3.06
ISR	29	614	4.72
JMIS	12	707	1.70
JAIS	19	536	3.54
ISJ	8	419	1.91
JIT	6	463	1.30
EJIS	21	762	2.76
JSIS	9	480	1.88
Total	126	4700	2.68

HIS: health-care information systems.

survey). An analysis of the research strategies over the 2000–2015 time period demonstrates that field study: primary data, field study: secondary data, formal theory/literature reviews and sample survey were represented in almost every year of the selected time frame (see Table 7).

Our findings present inquiry into why these research strategies have dominated the IS research on HIS topics. The use of these research strategies may be explained by the fact that these research strategies tend to be more exploratory in nature and indicate the beginnings of a body of research.[9] Given the small percentage of articles dedicated to HIS topics, one could consider HIS research performed by IS researchers to be in its relative infancy. Other studies investigating a segment of IS research (business intelligence) found similar results when comparing research strategies applied in building a body of knowledge at the early stages.[16] Interestingly, our findings revealed a very low usage of experiments in HIS research. One of the reasons for such a low usage of

Table 6. HIS research category percentages.

Research category	Total	Category %
Formal theory/literature reviews	15	11.90
Sample survey	17	13.49
Laboratory experiment	1	0.79
Experimental simulation	0	0.00
Field study: primary data	53	42.06
Field study: secondary data	31	24.60
Field experiment	5	3.97
Judgment task	1	0.79
Computer simulation	3	2.38
Total	126	100

HIS: health-care information systems.

Table 7. Research strategy versus year.

Research category	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Formal theory/literature reviews	1	0	0	0	0	0	0	1	0	0	3	2	1	1	3	3
Sample survey	0	0	0	0	1	1	1	3	0	0	1	5	3	0	2	0
Laboratory experiment	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Experimental simulation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Field study: primary data	1	0	0	1	3	1	3	10	3	4	3	13	2	1	7	0
Field study: secondary data	1	0	0	0	1	1	0	3	1	3	0	4	3	3	3	9
Field experiment	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	4
Judgment task	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Computer simulation	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0
Total	3	0	0	1	5	4	4	18	4	7	7	24	9	6	16	17

experiments could be the sensitive data involved with many HIS studies. Based on our findings, it is apparent that numerous research opportunities to apply alternative research strategies are available to both IS and HIS researchers. HIS researchers are encouraged to broaden the usage of alternative research methodologies as the HIS field matures.

Analysis of research topic categories in HIS research

During our analysis, six relatively distinct research topic categories emerged (see Table 8). The health-care emerging technology and delivery category consists of research dedicated at investigating the implementation of the latest health-care technologies. The health-care performance (quality, cost and efficiency) category contains articles focused on evaluating health-care performance resulting from the application of HIS. The health-care coordination and acceptance category details the evaluation of HIS implementations from a stakeholder point of view. The data-driven health-care management category consists of research focused on how data analysis was applied to make changes to improve health-care operations, patient treatment and/or predictive medicine. The national health category reviews the role that HIS has played in improving national health systems. The health-care privacy, ethics and security category focuses on issues surrounding patient data from a privacy, ethical or security management concerns. These six topic categories provided a classification scheme for all of the 126 articles identified in our research pool. Based on our

Table 8. HIS topic categories.

Category	No. of articles
Health-care emerging technology and delivery	30
Health-care performance (quality, cost and efficiency)	35
Health-care coordination and acceptance	39
Data-driven health-care management	4
National health	7
Health-care privacy, ethics and security	11
Total	126

HIS: health-care information systems.

Table 9. HIS topic categories by year.

Topic area	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Health-care emerging technology and delivery	1	0	0	0	1	2	0	4	0	2	4	4	1	2	2	5
Health-care performance	2	0	0	0	2	0	1	0	1	3	0	8	5	1	5	7
Health-care coordination and acceptance	0	0	0	1	1	2	2	11	3	2	2	6	1	1	5	2
Data-driven health-care management	0	0	0	0	0	0	0	0	0	0	0	3	0	0	2	1
National health	0	0	0	0	1	0	0	1	0	1	0	1	0	0	2	1
Health-care privacy, ethics and security	0	0	0	0	0	0	1	2	0	0	1	2	2	2	0	1
Total	3	0	0	1	5	4	4	18	4	8	7	24	9	6	16	17

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classification, 39 articles were classified in the health-care coordination and acceptance category making it the most prevalent HIS category. A close second was the health-care performance (quality, cost and efficiency) category with 35 articles. This category was followed by the health-care emerging technology and delivery category with 30 articles. These results should not be overly surprising since technology and IS use, acceptance and performance have been traditional IS research areas. After those topic categories, we see a substantial drop-off with regard to the other research categories: health-care privacy, ethics and security (11), national health (7) and data-driven health-care management (4). These numbers help illustrate the amount of attention that IS journals have given to the various HIS research categories and identify areas where IS researchers can build on their experiences to extend into HIS topic areas in need.

An examination of the research topic categories over the years (see Table 9) reveals a few interesting results. We can see that in the early 2000–2005 time period that very little research was published on emerging health-care technologies and the acceptance of health technology. However, later in the final years of our study 2011–2015, we can see a growing emphasis by IS journals on the HIS topic areas of health-care performance, health-care coordination and acceptance and health-care emerging technology and delivery. The rationale for these findings could be driven by the fact that in the year 2000, we were in the infancy of modern HIS. With the passage of the Affordable Care Act in 2010, which placed a higher emphasis on utilizing technology in managing health data, and the HITECH act of 2009, which incentivized payouts for meaningful use, we can see a greater number of HIS articles focused on emerging technologies, acceptance and performance. IS researchers may be attempting to evaluate how the government directives are impacting the performance, delivery and acceptance of HIS now that HIS is highly encouraged across health-care agencies. HIS research published in the leading IS journals appear to be following industry's introduction and acceptance of HIS. One would expect that moving forward as HIS is widely implemented and accepted by industry that IS academics will shift research interests to security, national health and data-driven topic areas.

An analysis of HIS topic categories versus research strategies (see Table 10) reveals the research strategies applied in the IS journals on the various HIS topic areas. Overall, many of the research categories utilized the field study method with primary data collection as their research strategy. Specifically, health-care performance, health-care coordination and acceptance, national health and health-care privacy, ethics and security category areas all utilized field study with primary data collection as the research strategy applied for a large percentage of their publications. In particular, we see the health-care coordination and acceptance category utilizing field study with primary data collection for close to 70 percent of the articles published.

When looking across topic areas and research strategies, we see zero articles on experimental simulation and only one publication each applying laboratory experiments and judgment task. The rationale for these findings is as follows: First, the HIS topic areas themselves may not fit with experimental or judgment task research methods. Second, the researchers conducting the HIS research from an IS perspective are many times located in a business college where surveys are far more common and accepted in comparison to experimental studies or judgment tasks. Third, HIS in many cases involves private patient data. Organizations may not be open to having patients exposed to experimental studies or judgment tasks. These findings are not limitations but opportunities for future researchers to explore when selecting an appropriate research strategy for HIS topic areas.

Discussion

Given the importance of the health-care industry and the promise of HIS, researchers are encouraged to build on the shoulders of giants as the saying goes. The HIS field has a unique opportunity to build on and leverage the work that has already been done by the highly correlated IS field. HIS researchers are encouraged to review and build off of the findings published in the leading IS journals as presented in our article. Our findings discussed above provide a strong overview of what has been done in the IS field and identify areas for future areas for HIS research.

As our results demonstrate, there is an opportunity for researchers to continue to address important HIS questions by applying a variety of research strategies. Scandura and Williams[9] stated that looking at research strategies employed over time by triangulation in a given subject area can provide useful insights into how theories are developing. We encourage HIS researchers to review methodologies applied and search for gaps within the HIS area. Our results demonstrate that little triangulation has occurred during our selected time frame, which in itself offers multiple research opportunities. The absence of coordinated theory development causes the research in HIS to appear haphazard and unfocused. An opportunity exists to expand on the categories and research strategies applied through future research studies. We also see opportunities for IS researchers to contribute to the growing trend of data-driven health-care and security/privacy/ethics topic areas. Very few IS articles have addressed these topics, and the IS field can contribute significantly to these HIS topic areas. We hope that this research has laid the foundation for such efforts that will enhance the body of knowledge and theoretical progression relative to HIS.

A major contribution of this article is to show the trends of HIS coverage in the journals covered. Tables 4 and 5 illustrate how the topic of health care has received limited attention by IS scholars. Although recent years have seen an increase in coverage, this article shows that more coverage can clearly be done. While innovative technologies have been introduced to support

Table 10. HIS topic category versus research strategy.

Category	Formal theory/ literature reviews	Sample survey	Laboratory experiment	Experimental simulations	Field study (primary data)	Field study (secondary data)	Field experiment	Judgment task	Computer simulation	Total
Health-care emerging technology and delivery	9	6	1	0	5	7	1	0	1	30
Health-care performance	4	5	0	0	12	12	2	0	0	35
Health-care coordination and acceptance	0	4	0	0	27	7	1	0	0	39
Data-driven health-care management	1	0	0	0	1	0	1	0	1	4
National health	1	0	0	0	3	3	0	0	0	7
Health-care privacy, ethics and security	0	2	0	0	5	2	0	1	1	11
Total	15	17	1	0	52	18	5	1	3	126

HIS: health-care information systems.

health care, it does not appear that IS scholars have studied the context to the same extent it has expanded. The expansion of HIS has become a mandatory part of the industry's operation, and IS literature should be making a larger contribution.

As in all research articles, our article is not without limitations. The primary limitation of this study is that we did not review all journals in IS or the HIS field. Reviewing the entire spectrum of journals is virtually impossible and was not deemed the goal of this article. However, we did review a strong subset of the top IS journals to provide insight into the state of HIS research in the IS field. Our data are from those ranked as the top journals in the IS field and represent a sample of arguably the best practices in IS research that should be of value to HIS researchers. We encourage both HIS and IS researchers to consider our findings and embark on research to address the many HIS research opportunities.

Conclusion

In this study, we examined the overall HIS research strategies and topic areas published in leading IS academic journals over the 2000–2015 time period. HIS researchers are encouraged to build on our reported IS research findings. In this article, we provided a strong overview of HIS topics addressed by IS researchers and areas of research opportunities with regard to both topic and methodology for both HIS and IS researchers to consider. Overall, our analysis has shown that the study of HIS in top tier IS academic journals has steadily increased over the 2000–2015 time period, which is encouraging given the overreaching impact of health care. Overall, the HIS field continues to develop with technology innovations, and HIS researchers are in a unique position to leverage IS research findings. It is essential that future studies and discussions on HIS recognize and review the accumulated IS knowledge. In conclusion, our article has identified significant implications for researchers and provided a status report of HIS research published in the top IS journals. HIS is clearly a topic that will not disappear in the foreseeable future and is garnering increased attention across disciplines. Most importantly, our analysis clearly points to the need for further research on HIS, and we encourage both HIS and IS researchers to continue this work to improve worldwide health-care delivery.

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Appendix 1

Complete list of health-care information systems articles

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Exploring patients' perceptions of accessing electronic health records: Innovation in healthcare

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Abstract

The more widespread implementation of electronic health records has led to new ways of providing access to healthcare information, allowing patients to view their medical notes, test results, medicines and so on. In this article, we explore how patients perceive the possibility to access their electronic health record online and whether this influences patient involvement. The study includes interviews with nine patients and a survey answered by 56 patients. Our results show that patients perceive healthcare information to be more accessible and that electronic health record accessibility improves recall, understanding and patient involvement. However, to achieve the goal of involving patients as active decision-makers in their own treatment, electronic health records need to be fully available and test results, referrals and information on drug interactions need to be offered. As patient access to electronic health records spreads, it is important to gain a deeper understanding of how documentation practices can be changed to serve healthcare professionals and patients.

Keywords

ehealth, electronic health records, healthcare information, healthcare service innovation and IT, patient access

Introduction

Digital technology and digital platforms that support the distribution and exchange of information have enabled the digitalization of processes that were previously supported by analogue tools. Digitalization is also assumed to reduce communication costs and facilitate collaboration across

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traditional organizational boundaries.[1] Within the healthcare sector, the progress in digital technology and the growing amount of digital health information have led to a change in the delivery of healthcare information within and across organizations and between patients and professionals.[2] One example of the change from analogue to digital processes is the provision of patient access to electronic health records (EHRs). In the past, health records were reserved for healthcare professionals,[3] but the more widespread implementation of EHRs and patient portals has led to new ways of making healthcare information accessible to patients. Legal efforts such as the Federal Health Insurance Portability and Accountability Act of 1996 (HIPAA) and directives such as the eHealth Action Plan have opened up for these new patient services. Predecessors within the field include the OpenNotes Project in the United States[4–6] and the SUSTAIN project in Europe.[7] EHRs are now available online to patients, allowing them to access medical information concerning treatments, medicines, test results and so on.

The development within the area has been possible due to the increased implementation and renewal of existing services and innovation in both communication and interaction between patients and healthcare professionals. New services or renewal of existing services, which are put into practice, can be defined as service innovations. Research on innovation traces back almost a century,[8] but the term ‘innovation’ and how it is defined still varies. Traditionally, it is viewed as a novel combination of new and existing resources.[8] The Organisation for Economic Co-operation and Development (OECD)[9] describes innovation as a product (including service), process, marketing method, or organizational method that is put into practice. As for service innovation, it is argued that it is difficult to apply these four different types of outcomes, as services are both products and processes.[10] Service innovation has been defined as something novel that provides change and is put into practice and that offers value on several levels.[11] Although there is a need to study and understand the emergence of service innovations, that is, the innovation process,[10] it is equally important to understand the outcomes of such processes.[11,12] Therefore, we focus on patient outcomes of the use of a service innovation, patients’ online access to EHRs.

In this article, we present the results of an exploratory study on patients’ perceptions of accessing their EHR online and the resulting effects on patient involvement. The knowledge obtained can be used to design longitudinal studies to follow up and evaluate the effects of service innovations such as patient access to EHRs. Due to a significantly improved service and process,9 we define the new service, patient access to EHRs, as a service innovation. Patient involvement, in this article, refers to involvement in decision-making, that is, how patients increase their involvement in treatments decisions, changing the role of the patient from a passive patient to an informed and engaged consumer of services.[13]

Previous research

Previous research on the effects of providing patient access to health records and EHRs has been reported in both literature reviews and research studies. A review on patient access to health records performed in 2003 focused on the effects of facilitating patient access to health records. The review shows that prior research has mainly focused on three areas: the effects on patients, the patient–physician relationship and medical practice.[14] The effects on the patients include improvements in adherence, patient empowerment and patient education, for example, recall and understanding of medical information. In addition, there are modest improvements in patient–physician communication, although patients find parts of the medical information difficult to understand. Nonetheless, few patients find the information confusing or upsetting.[14]

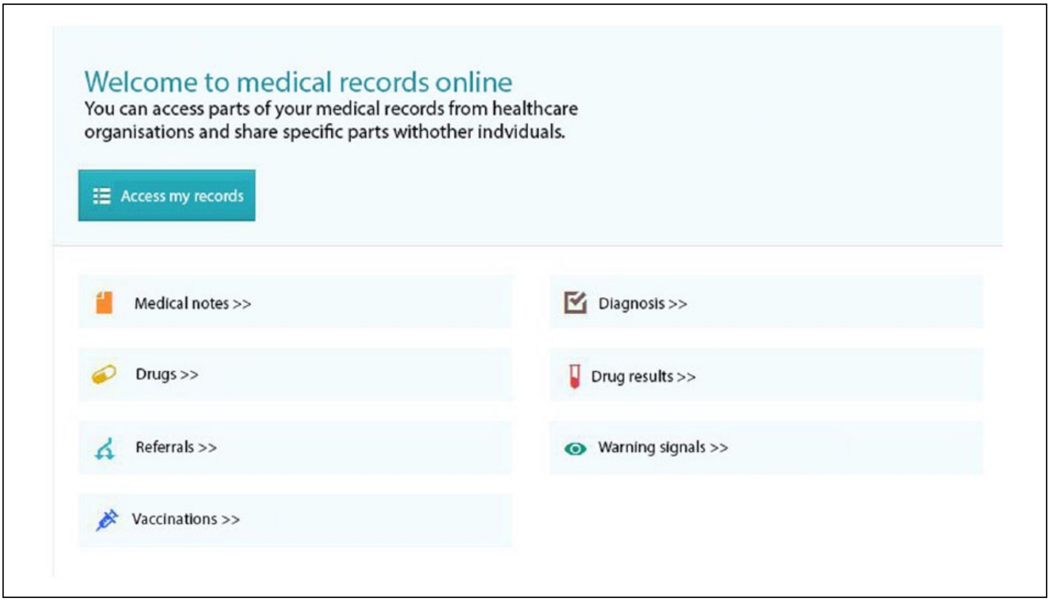
Similar issues have been found in more recent studies on the OpenNotes Project, which started in 2010 when 100 primary care physicians began digitally sharing notes with their patients. Studies on the OpenNotes Project report benefits such as increased adherence and compliance,[4,15] feeling more in control of one's care[4] and increased patient participation.[16] OpenNotes was shown to enhance patients' understanding and recall of health information,[4,16,17] improve trust and communication in the patient–physician relationship,[16,17] and increase patient-centredness.[17] Some patients reported privacy concerns, but few stated that the notes caused confusion, worry, or offense.[4] Vodicka et al.[18] assert that even if patients have concerns about privacy issues, the benefits of accessing health records seem to outweigh the perceived risks. In the end, patients have asked for more widespread access to EHRs.[17]

Patient access to EHRs in Sweden: from paper to online

In Sweden, EHRs in the primary care were developed in the 1990s. This development was possible due to the public financing of healthcare, which provided the regions the financial capacity needed to support the implementation of these systems in larger as well as smaller care centres.[19] This advancement was followed by the implementation of EHRs in hospitals,[20] which followed a similar pattern as countries like the United States, the United Kingdom and Denmark, in which the implementation was often driven by government initiatives.[21] It was not until 2010 that EHRs were fully implemented for professionals across the entire Swedish healthcare system, including primary care, hospitals and psychiatric care.[22] Prior to this, computer-based patient records had been implemented in local units and clinics to reduce costs and improve quality of patient care.[3,23] Since the 1980s, Swedish patients have had the right to request a printed copy of parts of their health record,[24,25] but with the expansion of EHRs discussions on online access to healthcare information started. In 2012, Uppsala County Council was the first healthcare provider in Sweden to implement online access to EHRs for all its patients.[20] In 2013, the Swedish Ministry of Health and Social Affairs presented a report that noted the need for a new patient legislation that sought to empower patients.[26] In the report, it is stated that patients need access to information to be empowered and to make health-related decisions. According to the report, it is assumed that a more informed patient will feel less anxious and more in control.[26] The report further asserts that the patient should have access to information about his or her healthcare status, different procedures, expected waiting time of healthcare, course of treatment, complications and follow-up care.[26]

Based on the report, Region Jönköping County decided to give all patients, age 18 years or older, online access to their EHRs.[27] The region decided on a 'big bang' approach towards the implementation of patient access to EHRs and provided limited information in the media to patients about the new opportunity. The service was implemented across all care units in February 2015 apart from the departments of Psychiatry and Habilitation. Information from the EHR is made accessible via a national platform for eHealth. The platform enables integration between services and information systems by standardizing and sharing information between different healthcare actors.[28] The possibility to access the EHR is optional, but all patients have the option to access the information through a secure log-in at the national patient portal 'Healthcare Guide 1177' (www.minavardkontakter.se). Patients log in to the portal with the same electronic ID that they use for banking and other government e-services (www.bankid.com).

Today, patients can access their EHR in real-time and see and read the information there, including medical notes, diagnoses and vaccinations. The information shown is dated back to 1 July 2014, while older medical notes can be requested and received on paper. Healthcare professionals have 14 days, after documentation of the event, to confirm and if needed correct the medical notes before they become accessible to the patient. However, after 14 days, all notes are made accessible regardless of whether they have been confirmed. Patients can decide to



Welcome to medical records online

You can access parts of your medical records from healthcare organisations and share specific parts withother indviduals.

Figure 1. Overview of the service. During the time of the study, medical notes, vaccinations and diagnoses were accessible to the patients.

share their EHR with other persons, and parents can access their children's EHR until they turn 13 years, due to national regulations. Patients are allowed to cancel their own access to the EHR at any time. Patients are not notified about new entries in the EHRs. The information included in the EHR is presented as an integrated record in which data are accessible chronologically, with every point of care organized by time and date.[29] An overview of the service is presented in Figure 1.

The expected effects of the service innovation include increased patient involvement, a better understanding of healthcare information and the ability for patients to be better prepared before an appointment.[30] Patient access to EHRs is also believed to enhance communication, patient safety and adherence and provides patients the opportunity to identify and correct errors.[31] During the time of the study, patients' online access to the EHR had been implemented for 14 months.

Methods

In the first step of the case study, before developing the survey to be distributed to patients in the Jönköping region, we reviewed the previous literature on patient perceptions of access to medical notes.[4,17,18,32–34] This review provided us with knowledge of how previous studies had been designed. In the second step, we conducted interviews with nine patients to identify the major perceived benefits and worries related to patients' online access to EHRs and to ensure that they were included in the survey.

The patients interviewed were recruited at the county hospital in the region and were later contacted by email to agree on a time to conduct the interview at the hospital. Four of the respondents were women and five were men, aged between 34 and 83 years, and all had accessed their EHR when the study was performed. During the interviews, the respondents were asked questions regarding the patients' use of the EHR service, the benefits and drawbacks of accessing the EHR, improvements in the patient–physician communication and suggestions for further functions to be added to the service. The interviews were recorded and subsequently transcribed verbatim. The first author reviewed the transcripts of the interviews and identified themes focusing on the benefits, risks and expectations of accessing the EHR. The interviews were analysed using inductive content analysis as presented by Graneheim and Lundman[35] which is a systematic way of describing and analysing verbal communication.[36] The themes were derived from the interviews by focusing on sentences or paragraphs that were related in content. These sentences were then shortened and labelled with a code. Finally, the codes were compared and unified into themes. The themes were transformed into survey questions, and items on patient characteristics were added to the survey. The survey was reviewed by five patients and was revised according to the feedback received.

The survey was distributed to patients at three different sites in the Region of Jönköping County, Sweden: a primary care unit, a cardiology outpatient clinic and a urology outpatient clinic. The care unit and outpatient clinics were selected for survey distribution to reach patients who were currently in contact with the healthcare system. The survey was paper-based and was given to patients by a medical secretary upon registration for their visit along with an accompanying letter that stated that participation was voluntary and anonymous. The patients were eligible for the study if they had accessed their EHR via the patient portal. The completed survey could be returned in a box at the reception or sent by mail to the researchers if the patients preferred to complete it at home. No employees at the Region of Jönköping County had access to the individual answers. The distribution of surveys lasted for 2 weeks in May 2016, and because it was anonymous, no reminders were sent. In total, 56 patients completed the survey (12 patients declined to take part in the study and 24 did not return the survey).

The survey included questions regarding the use of the service, attitudes towards the benefits and downsides of accessing the EHR and possible improvements to the services. For statements focusing on attitudes, we examined the results across a 5-level grade including 'agree', 'somewhat agree', 'neither agree nor disagree', 'somewhat disagree' and 'disagree'. The percentage of patients who agreed or disagreed to the statements was calculated for each question.

Results

The following section addresses the results from the survey. The results are presented according to the four sections that follow the structure of the survey: patients' perceived benefits of accessing the EHR, patient involvement, patients' worries and misunderstandings and possible improvements of the service.

The response rate for the survey was 61 per cent (n = 56), 70 per cent were men, ages ranged from 35 to 83 years and 68 per cent used the Internet several times a day (n = 53). Almost all the patients viewed patient access to the EHR as a good or very good initiative (94%, n = 56). None of the patients considered it to be a negative initiative. The respondents were asked to choose the words they considered most suitable to describe the service. To do this, they were able to select from 23 'positive' and 'negative' expressions (the list of alternatives is presented in Appendix 1) and were also able to list additional words. The respondents answered that they would almost exclusively use expressions that were positive in nature, with the most common terms being as follows: trustworthy service, time saving, a citizen's right and easily accessible information (for details, see Table 1).

Table 1. Expressions that the respondents would use to describe the service (n = 45).

Rank	Expressions	% (n)	Rank	Expressions	% (n)
1	Trustworthy service	70 (31)	8	Openness towards citizens	44 (20)
2	Time saving	64 (29)	9	Enables participation	44 (20)
3	A citizen's right	62 (28)	10	Enables responsibility	42 (19)
4	Easily accessible information	60 (27)	11	The patient can influence	33 (15)
5	Easy to navigate	51 (23)	12	Difficult to navigate	7 (3)
6	Secure information management	49 (22)	13	Undeveloped service	4 (2)
7	Rich with information	47 (21)	14	Creates misunderstandings	2 (1)

Benefits of accessing EHRs

To identify patients' perceived benefits of accessing the EHR, the respondents were asked to judge whether they agreed to five statements (Figure 2 and Appendix 2, Table 3 for details). Almost all patients stated that it was easier to access information (96%), to remember what was said during an appointment (90%) and 72 per cent stated that they were more or somewhat more prepared. The respondents expressed that the access to the EHR facilitated the understanding of what was documented, 72 per cent stated that it was easier to discuss what was being documented in the EHR and 80 per cent stated that it was easier to coordinate what was being documented.

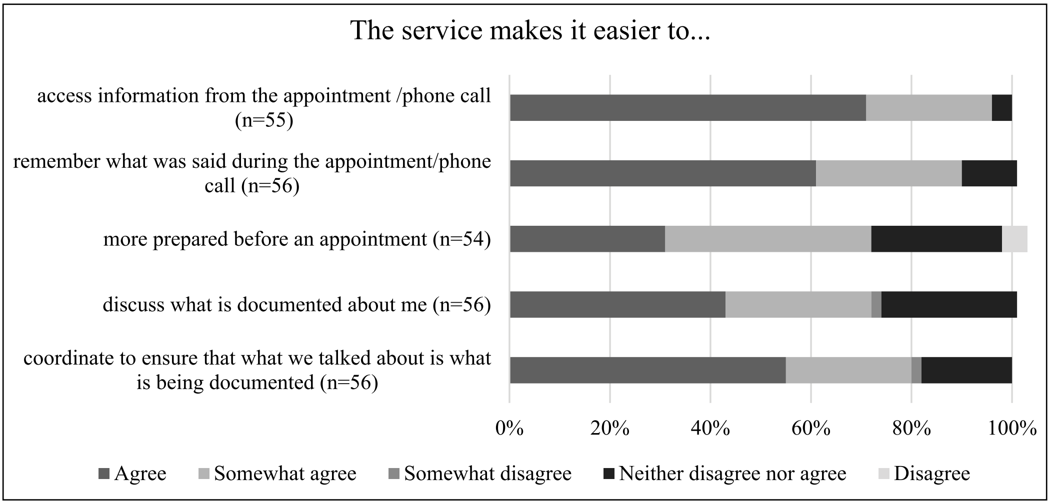


Figure 2. Patients' perceived benefits of accessing the EHR.

Patient involvement

The perceptions regarding patient involvement showed that 81 per cent agreed or somewhat agreed that the service made them more involved in their treatment, and 70 per cent stated that they were more likely to follow the advice given by healthcare professionals. In addition, 76 per cent agreed or somewhat agreed that the service made it easier to take responsibility for their care, while 62 per cent stated that it was easier to more actively affect their own care. Also, 89 per cent perceived it easier to understand what was said during the appointment and 82 per cent of the patients agreed or somewhat agreed that the service made it easier to talk to healthcare professionals about their situation (Figure 3 and Appendix 2, Table 4 for details).

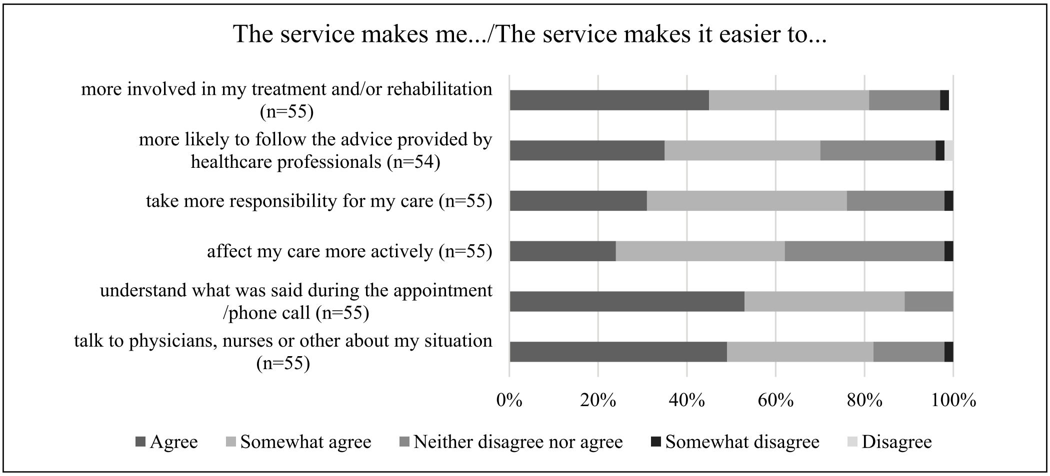


Figure 3. Patients' perceptions regarding patient involvement.

Worries and misunderstandings

None of the respondents tended to misunderstand the information in the EHR and 58 per cent somewhat disagreed or disagreed to the statement. Only 11 per cent and 9 per cent of the patients agreed or somewhat agreed that they became worried or upset about the information in the EHR (Figure 4, Appendix 2, Table 5 for details). In a follow-up question, 70 per cent of the respondents expressed that some of the information in the EHR was difficult to understand. This information included medical terms (61%) and abbreviations (32%).

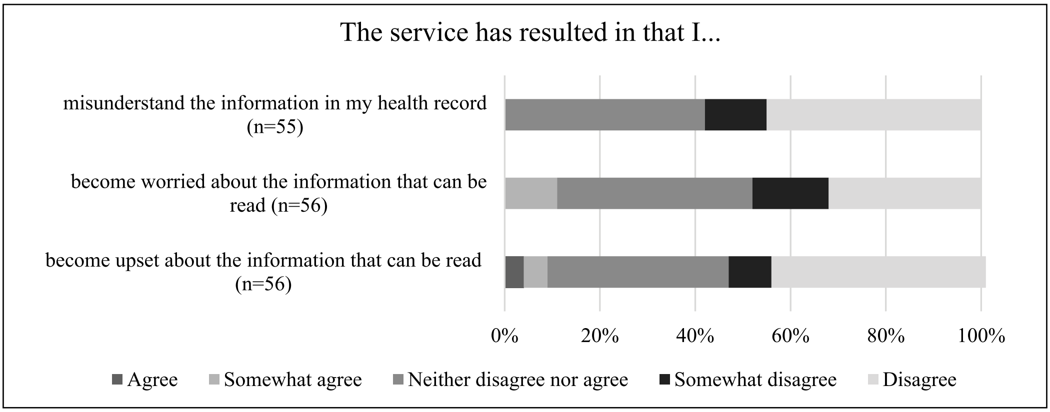


Figure 4. Patients' perceptions regarding worries and misunderstandings.

Improvements to the service

To determine the potentially valuable improvements to the EHR for patients, the respondents were asked to judge between seven predefined functionalities (presented in Table 2). They could also suggest other functionalities that were not listed. The top three preferred improvements of the service included information on test results (85%), access to referrals (61%) and information on the interactions between different drugs (46%).

Table 2. Assessment of proposed EHR functionalities.

Rank	Functionalities selected in the top three by the respondents (n = 46)	% (n)
1	Test results	85 (39)
2	Referrals	61 (28)
3	Interactions between different drugs	46 (21)
4	Medical records dated before 2014	35 (16)
5	Reminders about new information in the EHR by SMS or e-mail	22 (10)
6	The ability to report errors in the EHR	15 (7)
7	Information on when to update vaccinations	13 (6)

EHR: electronic health record.

Discussion

In this article, we focus on how patients perceive the ability to access their own EHR online and whether the service innovation influences patient involvement. Overall, the patients report patient access to EHRs to be a good initiative. The results show that the possibility to access the EHR increases information accessibility and improves patients' ability to understand and recall what was said during an appointment. These results are consistent with similar previous studies, with Delbanco et al.[4] identifying benefits such as a greater understanding of visits and improved recall of healthcare plans. Esch et al.[17] as well as Rexhepi et al.[37] also reported that patients used medical notes to refresh their memory and to confirm their understanding. The results also seem to show that patients' relationship with healthcare professionals is improved, as it is easier to talk about their health with healthcare professionals and to discuss and coordinate what is documented. One of the most important outcomes of this study is the fact that patients feel more involved in their treatment, which is one dimension of patient involvement.[13] Moreover, patients report that patient access to the EHR enhances responsibility-taking for their own care and adherence to healthcare professionals' advice. These outcomes are consistent with studies performed in projects like the OpenNotes project[4,17] and in a study on EHRs with veterans.[16]

Although there are previous reports on patient concerns regarding security and privacy in relation to EHRs,[18,38,39] the results show that the patients consider the service to be trustworthy and a secure way of managing health information. In our study, few patients reported being worried or upset about the information provided. However, the results show that even though patients do not misunderstand the information in the EHR, the majority find medical terms and abbreviations difficult to understand. EHRs were originally developed to increase quality of care and support practitioners and healthcare professionals.[3] The political aim of providing patient access to EHRs is to increase patient involvement. To achieve the goal to fully involve patients as active decision-makers in their own treatment, it will be necessary to study how documentation practices can be changed to serve healthcare professionals and patients.[39,13] The development of new documentation practices also needs to be complemented with the explanation of abbreviations and medical terms. This is consistent with previous research on service innovation, which argues that there is a need to not only offer new value propositions to the customer but also transform organizational practices, structures and roles.[40–43] This includes the roles of the employees as well as the service users.[41] It is important to stress that medical documentation still needs to be expressed in such a way that healthcare can be safely performed by professionals.

Among the top three functionalities that the respondents wanted to add to the EHR were information on test results and access to referrals. This is routine patient-specific information that is related to the medical notes that patients can access today. The patients also valued information on the interactions between different drugs. Although this is not a typical EHR function, it would clearly provide patients additional benefits and increase the value offered by the patient portal. These are novel findings compared to those reported by Hoerbst et al.,[38] for instance, who identified electronic vaccination records, online information on hospitals and the management of appointments and reminders as the most favoured functionalities of an EHR. Currently, Swedish citizens partly have access to these functionalities through the patient portal, and more individual and healthcare-related services have been requested. According to the classification proposed by Prey et al.,[44] personalized decision support, such as information on drug interactions, is a more complex type of service that enables patient engagement to a higher degree.

By providing patients with online access to their EHR, the Region Jönköping County expected patients to identify and notify the healthcare provider about the need to correct errors in the EHR.[31] However, our findings show no signs of any requests for amendments; the reason can be the lack of information on whether and how patients can request changes to their records. If management expects this type of innovation effect, additional information needs to be provided to the patients.[45]

Conclusion

Although patients are central to healthcare, information systems have traditionally been developed and implemented for professionals with the aim to improve quality and safety and not for patients.[3,46] Providing patients with online access to their health records presents a new situation. The results show that patients perceive their healthcare information to be more accessible and that the additional accessibility saves time, enhances recall and understanding and increases patient involvement. Hence, we argue that patient access to EHRs provides an improved service delivery and process.

Patients' online access to EHRs seems to be a step towards changing the role of the patient by enabling access to and providing patients with information that has previously been disclosed or less accessible. According to this study, patients expressed that the access to the EHR improves patient involvement and the patient–professional relationship. However, to change the role of the patient from a passive receiver to an active engaged patient, it is necessary to fully share medical records with patients and provide information on test results, the opportunity to monitor referrals and additional services such as information on drug interactions. As patient access to EHRs spreads, it is important to gain a deeper understanding of how the practice can adapt and change to better prepare and educate patients to enhance patient involvement.[13] Currently, there seems to be a need to find alternatives that support patients who do not have a medical background or sufficient knowledge to interpret medical information. A deeper examination of these aspects will be important, especially for specific patient groups such as psychiatric patients and patients with other native languages.

Although this study was limited by the relatively small sample, we believe that our results provide insight into an understudied area of providing patients access to their EHRs in a setting outside of the United States and the OpenNotes Project. Previous Swedish studies have, except for Rexhepi et al.,[37] mostly focused on the development and usability issues of this type of service,[47] the public debate,[48] privacy issues[49] and the attitudes of healthcare professionals.[50]

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Appendix 1

☐ Time saving
☐ Time consuming
☐ Easy to navigate
☐ Difficult to navigate
☐ Secure information management
☐ Insecure information management
☐ Openness towards citizens
☐ A trustworthy service
☐ An unreliable service
☐ A citizen's right
☐ An inappropriate investment
☐ Enables responsibility
☐ Bureaucratic
☐ A misprioritized investment
☐ Rich on information
☐ Enables participation
☐ Can be influenced by patients
☐ Undeveloped service
☐ Creates worries
☐ Creates misunderstandings
☐ Stressful
☐ Confuses the patient
☐ Easily accessible information

☐ Other ____________________
☐ Other ____________________
☐ Other ____________________

Appendix 2

Table 3. Patient perceptions of the benefits of accessing the EHR.

The service makes it easier to …	Agree % (n)	Somewhat agree % (n)	Neither agree nor disagree % (n)	Somewhat disagree % (n)	Disagree % (n)
Access information from the appointment/phone call (n = 55)	71 (39)	25 (14)	4 (2)	–	–
Remember what was said during the appointment/phone call (n = 56)	61 (34)	29 (16)	11 (6)	–	–
More prepared for an appointment (n = 54)	31 (17)	41 (22)	26 (14)	–	2 (1)
Discuss what is documented about me (n = 56)	43 (24)	29 (16)	27 (15)	2 (1)	–
Coordinate to ensure that what we talked about is what is being documented (n = 56)	55 (31)	25 (14)	18 (10)	2 (1)	–

Table 4. Patient perceptions regarding patient involvement.

The service makes me …	Agree % (n)	Somewhat agree % (n)	Neither agree nor disagree % (n)	Somewhat disagree % (n)	Disagree % (n)
More involved in my treatment and/or rehabilitation (n = 55)	45 (25)	36 (20)	16 (9)	2 (1)	–
More likely to follow the advice provided by healthcare professionals (n = 54)	35 (19)	35 (19)	26 (14)	2 (1)	2 (1)
The service makes it easier to …					
Take more responsibility for my care (n = 55)	31 (17)	45 (25)	22 (12)	2 (1)	–
Affect my care more actively (n = 55)	24 (13)	38 (21)	36 (20)	2 (1)	–
Understand what was said during the appointment/ phone call (n = 55)	53 (29)	36 (20)	11 (6)	–	–
Talk to physicians, nurses or other about my situation (n = 55)	49 (27)	33 (18)	16 (9)	2 (1)	–

Table 5. Patient perceptions regarding worries and misunderstandings.

The service has resulted in that I …	Agree % (n)	Somewhat agree % (n)	Neither agree nor disagree % (n)	Somewhat disagree % (n)	Disagree % (n)
Misunderstand the information in my health record (n = 55)	–	–	42 (23)	13 (7)	45 (25)
Become worried about the information that can be read (n = 56)	–	11 (6)	41 (23)	16 (9)	32 (18)
Become upset about the information that can be read (n = 56)	4 (2)	5 (3)	38 (21)	9 (5)	45 (25)

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Impact of a scribe program on patient throughput, physician productivity, and patient satisfaction in a community-based emergency department

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Abstract

Previous literature on the impact of scribe programs varies and has mostly been reported from academic institutions or other clinics. We report the implementation of the scribe program in the emergency room of a community hospital and its impact on patient throughput, physician productivity, and patient

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satisfaction. We performed a quasi-experimental, before-and-after study measuring patient throughput metrics, physician productivity, and patient satisfaction. The intervention measuring the scribe implementation was divided into pre- and post-implementation periods. Patient throughput metrics were (1) door-to-room time, (2) room-to-doc time, (3) door-to-doc time, (4) doc-to-disposition time, and (5) length of stay for discharged/admitted patients. Our secondary outcome was physician productivity, which was calculated by measuring total patients seen per hour and work relative value units per hour. Additionally, we calculated the time-motion analysis in minutes to measure the emergency department physician's efficiency by recording the following: (1) chart preparation, (2) chart review, (3) doctor–patient interaction, (4) physical examination, and (5) post-visit documentation. Finally, we measured patient satisfaction as provided by Press Ganey surveys. Data analysis was conducted in 12,721 patient encounters in the pre-scribe cohort, and 13,598 patient encounters in the post-scribe cohort. All the patient throughput metrics were statistically significant ($p < 0.0001$). The patients per hour increased from 2.3 ± 0.3 pre-scribe to 3.2 ± 0.6 post-scribe cohorts ($p < 0.001$). Total work relative value units per hour increased from 241(3.1 ± 1.5 per hour) pre-scribe cohort to 336 (5.2 ± 1.4 per hour) post-scribe cohort ($p < 0.001$). The pre-scribe patient satisfaction was high and remained high in the post-scribe cohort. There was a significant increase in the clinician providing satisfactory feedback from the pre-scribe (3.9 ± 0.3) to the post-scribe (4.7 ± 0.1) cohorts ($p < 0.01$). We describe a prospective trial of medical scribe use in the emergency department setting to improve patient throughput, physician productivity, and patient satisfaction. We illustrate that scribe use in community emergency department is feasible and results in improvement in all three metrics

Keywords

patient satisfaction, patient throughput, physician productivity, scribes

Introduction

The practice of emergency medicine (EM) has seen its fair share of growing pains and transitions throughout its advancement and ongoing development. One of the most important and historic transitions came back in 2006 when the Institute of Medicine recognized handwritten reports or notes to be detrimental to the standard of patient care. They identified that manual order entries, poor legibility, and nonstandard abbreviations lead to medical errors and as a result caused harm.[1,2] The offered solution was the advent of electronic health records (EHRs) and computerized physician order entry (CPOE)[3] to equip the fast-paced practice of EM with the necessary tools to deliver optimal patient care to its growing and aging patient population while minimizing/eliminating medical errors. However, the implementation of EHRs did not come without its fair share of criticism.[4–7] Previous literature illustrates 25–33 percent drop in physician productivity,[8,9] decreased patient satisfaction,[8,10] and physician concern over an increased amount of time doing computer tasks to go along with other concerns such as poor usability, time-consuming data entry, less time for face-to-face patient care, learning billable coding, and degradation of clinical documentation by trying to force it into structured fields.[8,11–13] To address some of these validated concerns, the industry of medical scribes has emerged nationally to reduce data-entry burden for clinicians, improve throughput efficiency, improve quality of patient care, and enhance revenue cycle. Even though community hospitals outnumber academic institutions,[14] most data on how the implementation of medical scribe services impacts EM come from academic institutions.[15,16] We conducted a prospective study in a community emergency department (ED) setting to illustrate the impact of medical scribes on patient throughput, physician productivity, and patient satisfaction.

Materials and methods

Study design

We performed an uncontrolled before-and-after study. This study was performed in accordance with national regulations and was deemed exempt from institutional review board approval for human subjects.

Study setting and population

This study was carried out from July 2015 through February 2016 at a suburban non-academic community ED, treating approximately 80,000 visits annually, which included both adults and pediatrics. The ED is an American College of Surgeons Level II Trauma Center. Providers seeing patients include physicians, nurse practitioners, and physician assistants. The study, however, only included data recorded on physicians. Other providers were not included in this study. There were no staff changes during the study period.

Study protocol

We measured the before-and-after metrics of patient throughput in the ED. The intervention measuring the scribe implementation was divided into pre- and post-implementation periods. The pre-implementation period started with baseline data collection for 90 days beginning 1 July 2015 through 30 September 2015. This was followed by a washout period of 2 months during which the scribe program was phased in and fully operational. The post-implementation data collection lasted for 90 days starting from 1 December 2015 to 28 February 2016.

Intervention

A scribe system operating company in the private sector implemented the program and provided ongoing program management. There were no financial arrangements between company and any of the authors. In the medical scribe system model, scribes mostly are college students or recent college graduates interested in medical science careers. They receive on-job training and are considered proficient after 20 shifts and skilled after 40 shifts. Depending on the numbers of physicians in the ED, there are 3–4 scribes available at all times. One assigned to each physician. All scribe charts are forwarded to the physician to review, amend, and sign.

Measures

ED throughput data were collected using quality assurance reports produced by the EHR system. The objective was to measure the effect of scribes on ED patient throughput as quantified by the changes between cohorts such as:

- Door-to-room time—time when patient arrives in ED to patient shifted into a room;
- Room-to-doc time—time when patient placed in a room to when an ED physician sign-up for the patient;
- Door-to-doc time—time patient arrives in ED to when an ED physician sign-up for a patient;
- Doc-to-disposition time—time ED physician sign-up for a patient to time the patient is discharged or admitted;
- Length of stay (LOS) for admitted/discharged patients in the before-and-after studies.

The metrics of physician productivity was calculated by measuring total patients seen per hour and work relative value units (wRVUs) per hour. The wRVUs is a measure of value used in the US Medicare reimbursement formula for physician services. The wRVUs depended on the level of service for each patient visit and was reviewed by coders who ensured that the documentation justified the level of service. Additionally, we calculated the time-motion analysis in minutes to measure the ED physician's efficiency by recording the following: (1) chart preparation, (2) chart review, (3) doctor–patient interaction, (4) physical exam, and (5) post-visit documentation (time it took to complete patient chart after examining the patient).

Patients completed a standard patient satisfaction survey in which they were asked to rate their ED visit and their satisfaction with the clinician as follows: (1) doctor carefully listened to your concerns, (2) provided satisfactory feedback to your questions, (3) doctor explained things in a way you can understand, (4) meticulousness of the examination, (5) doctors' instructions concerning follow-up care, and (6) was the doctor courteous. All patient responses were graded using a five-point Likert-type scale[17] with the following categories: excellent (5), very good (4), good (3), fair (2), and poor (1).

Data analysis

Patient throughput was analyzed using descriptive statistics because the generalizability and increased power afforded using means and the standard t-test to assess for significance outweighed the possible skewness of the data typical of administrative throughput research. However, the productivity measures, and patient satisfaction scores, were calculated and reported as mean ± standard deviation. p-values were calculated using unpaired t-tests. p-values <0.05 were considered significant. All data were derived from our IT data warehouse.

Results

Data analysis was conducted in 12,721 patient encounters in the pre-scribe cohort and 13,598 patient encounters in the post-scribe cohort. Given the large sample size in each cohort, all variations were statistically significant ($p < 0.0001$). There was a 2-min improvement in the time it took for an ED physician to sign-up for a patient once patient was placed in a room from the pre-scribe to the post-scribe cohort ($p < 0.0001$). After the scribe program was integrated, all patient throughput metrics improved. This improvement occurred despite additional 877 patient visits in the post-scribe cohort. Subsequently, the overall door-to-doc time improved from 61 min pre-scribe to 56 min post-scribe. Additionally, both door-to-room and doc-to-admit disposition times improved by 4 min ($p < 0.0001$) and 9 min ($p < 0.0001$), respectively. ED physician satisfaction increased 15 percent from pre- to post-scribe (Table 1).

A 24-h patient care was provided in pre- and post-scribe days. Physician productivity metrics are shown in Figure 1. Average direct wRVUs generated per patient in pre-scribe (2.57 ± 0.84) and post-scribe (2.74 ± 0.54) cohort were similar ($p = 0.88$). The patients per hour increased from 2.3 ± 0.3 pre-scribe to 3.2 ± 0.6 post-scribe cohorts ($p < 0.001$). Total wRVUs per hour increased from 241 (3.1 ± 1.5 per hour) pre-scribe cohort to 336 (5.2 ± 1.4 per hour) post-scribe cohort ($p < 0.001$). Table 2 illustrates the mean time spent performing various patient tasks. Figure 2 illustrates this data in a visual timeline. An average visit lasted 25.9 min in the pre-scribe cohort, and post-scribe visits averaged 23.2 min. Mean time required to complete a post-scribe visit (including documentation) was 31 percent shorter in duration than that seen in the pre-scribe cohort. Chart review and post-visit documentation times were all significantly lower (<0.01) in the post-scribe cohort. The time spent in direct patient interaction was twofold greater in the post-scribe cohort.

Table 1. Pre-scribe and post-scribe patient throughput measures.

	Pre-scribe (n = 12,721)	Post-scribe (n = 13,598)
Door-to-room (min)	41	37
Room-to-doc (min)	26	24
Door-to-doc (min)	61	56
Doc-to-admit dispo (min)	237	228
Length of stay—discharged patients (min)	303	287
Length of stay—admitted patients (min)	507	473
Emergency center satisfaction (percentile)	71%	74%
Emergency physician satisfaction (percentile)	66%	81%

Patient satisfaction data was collected for the six questions and is presented in Figure 3. The pre-scribe patient satisfaction was high and remained high in the post-scribe cohort. There was a significant increase in the clinician providing satisfactory feedback from the pre-scribe (3.9 ± 0.3) to the post-scribe (4.7 ± 0.1) cohort ($p < 0.01$).

Discussion

The use of medical scribes is gradually becoming prevalent in the contemporary healthcare environment as organizations search methods to improve clinician efficiency and productivity.[18–20] Traditionally, scribes assisted with documentation allowed clinicians to focus on billable services. In the current medical era—with the adoption of EHRs—the role of the medical scribe has developed and there is increased awareness about the impact scribes have on patient throughput.[19,21,22] Ample literature in various patient settings including the ED illustrates an increase in patient throughput after the implementation of medical scribes into the workflow.[14,23–26] In a pilot study with a total of 12,609 patients, Bastani et al.[14] describe that the time it took for patient to be seen and evaluated by a physician is 74 min pre-scribe and 61 min post-scribe, respectively, and the overall LOS significantly improved after the implementation of medical scribes. Our study, which included 13,598 patients, resonates with the findings of Bastani et al. We found that the overall door-to-doc time improved from 61 min pre-scribe to 56 min post-scribe. Additionally, both door-to-room and doc-to-admit disposition times improved by 4 min ($p < 0.0001$) and 9 min ($p < 0.0001$), respectively. These are important throughput metrics in a community-based ED where there are no residents to decrease the documentation burden which ultimately falls on the physicians which we suspect is one of the many causes of decreased patient throughput metrics. It is important to mention a counterargument by Heaton et al.,[27] who found that scribes failed to improve patient-specific throughput metrics in the first few months post-implementation in a tertiary academic ED with both an adult and pediatric ED. We feel this might be the result of having resident physicians carrying a large documentation workload given the academic settings of the study. Additionally, it would also be prudent to provide a time–motion analysis in between the pediatric and adult population along with patient acuity to understand the difference in the academic and the community setting.

In a retrospective study conducted in an academic setting, Arya et al.[21] concluded that ED physician's use of a medical scribe correlates with improved productivity as measured by wRVU/hour and patient/hour. Both of the metrics in this cohort were statistically significant ($p = 0.0011$ and $p = 0.0024$, respectively). Our results that are based out of a community ED resonate with these findings as the patients per hour increased from pre-scribe to post-scribe cohorts

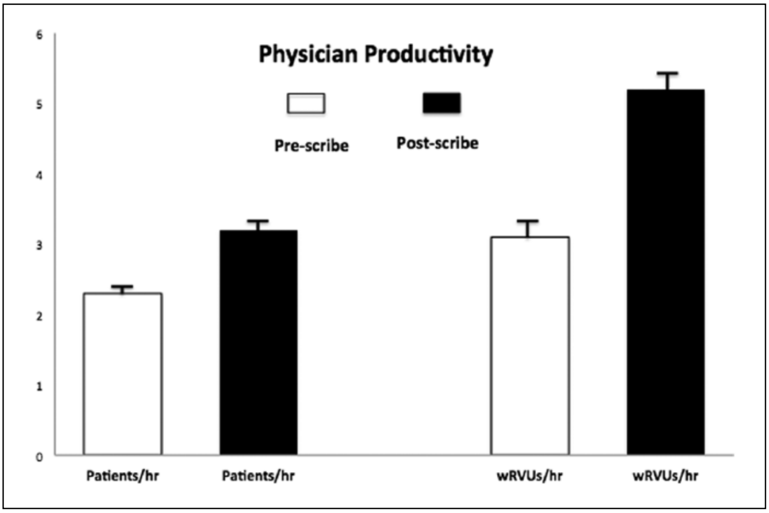

Figure 1. Productivity metrics in total patients seen per hour and total wRVUs generated per hour on pre- and post-scribe cohorts.

Table 2. Time–motion analysis of physician activities.

	Pre-scribe	Post-scribe	p-value
Chart prep	1.2 ± 0.3	0 ± 0	<0.01
Chart review	5 ± 1.9	7 ± 1.2	<0.01
Doctor–patient interaction	4 ± 0.57	7.8 ± 1.2	<0.01
Physical exam	1.2 ± 0.27	1.45 ± 0.44	0.53
Post-visit documentation	14 ± 3.1	7 ± 0.43	<0.01

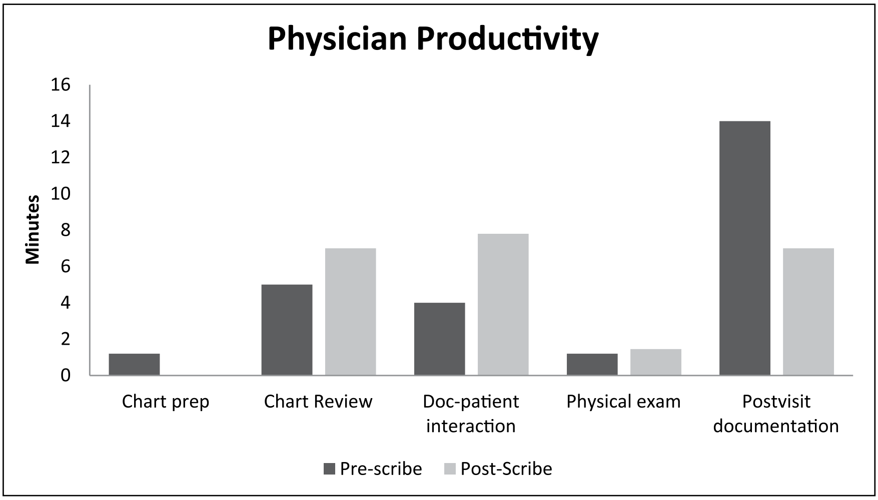

Figure 2. Time–motion analysis in pre- and post-scribe cohorts.

Figure 3. Patient satisfaction metrics as measured by questionnaire in pre- and post-scribe cohorts.

($p < 0.001$), and the total wRVUs/hour increased from pre-scribe cohort to post-scribe cohort ($p < 0.001$). An important mention here is that we try matching ED physicians with medical scribes of their choosing—if schedule permitting—to allow the physician more autonomy which literature shows improves the physician productivity and in return managerial financial bottom-line.[28,29] Scribes can also influence the physician's productivity by checking back with the physician, when lab or imaging results are back or when a patient bed is ready. This allows the physician to maintain a consistent workflow without jumping back and forth between patient charts. In a meta-analysis, Heaton et al. describe a small increase in the number of patients seen per hour when using scribes. While this may be correct, there are two important facts, which must not be overlooked. First, just as physicians take time to familiarize with and obtain optimal benefit from EHRs, the same transitions would apply with scribes. Second, in our cohort, we had a washout period of 2 months during which the scribe program was phased in and became fully operational. This allowed time to make adjustments and work on the logistics of optimal use of the scribe service.

Patient–doctor communication has an important effect on medication adherence, conflict resolution, patient satisfaction, and clinical outcomes. ED physicians have voiced concern over the use of an EHR, which results in fewer psychosocial discussions, less attention to the patient's agenda, a shift from a conversational to a blocked style of communication.[30] EHRs force ED physicians to spend more time documenting and less time with patients. This lack of interaction greatly affects patients' perception on the quality of their care and the overall experience. Using the medical scribe services, these issues can be addressed, and allow ED physicians to refocus on patient care. Previous literature states improved patient satisfaction using medical scribe services.[14,23,27,31] Our cohort showed that there was a significant increase in the clinician providing satisfactory feedback from the pre-scribe (3.9 ± 0.3) to the post-scribe (4.7 ± 0.1) cohort ($p < 0.01$). It should be duly noted that patient satisfaction in our cohort was high on both pre- and post-scribe days. Based on verbal and written feedback, vast majority of patients were either neutral or liked the scribe system. Few patients with previous ED visits gave verbal feedback to staff about having the ED physician's full attention and staying with them longer to address their concern.

Limitations

Our cohort has a few limitations. The pre- and post-scribe design of the cohort limits our capacity to make causal claims regarding the results. This is a common critique of cohorts where randomization is impractical. However, important steps were taken to limit the impact of any unforeseen factors to our results. We did not make any changes in our staffing models in both the pre- and post-scribe cohorts. We also eliminated any experimenter's bias by collecting the data from our data warehouse and blinding the ED staff to the study. Given the number of patient encounters in this cohort, we believe it has a good generalizability. Further research on tracking the success of the aforementioned metrics in the longer run is important to monitor any incline or decline in the metrics and measure various components which may be playing an important underlying role.

Conclusion

We describe a prospective trial of medical scribe use in the ED setting to improve patient throughput, physician productivity, and patient satisfaction. We illustrate that scribe use in community ED is feasible and results in improvement in all three metrics. Reaching optimal levels in all parameters ultimately helps improve patient care, the staff morale, and the administrative financial bottom-line.

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