MEDINFO 2019: Health and Wellbeing e-Networks for All
L. Ohno-Machado and B. Séroussi (Eds.)

doi:10.3233/SHTI190286

The Digitization of the ICU: An Evaluation of Usability and Hospital-Wide Acceptability

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Abstract

This paper explores the impact of an electronic medication management system (EMMS) on users in an intensive care unit using the Unified Theory and Use of Technology constructs. It also explores the impact of having a consistent EMMS hospital wide, as it is the first Australian hospital to implement the same EMMS hospital wide. The research model was evaluated using survey data from 100 nurses, doctors and pharmacists both within the ICU and externally, to assess the usability and acceptability of the system. Results showed that performance expectancy, effort expectancy, social influence and facilitating condition all correlate with overall user satisfaction. Overall, teams external to the ICU are in strong favor of its implementation whist user acceptance from within the ICU itself is poor.

Keywords:

Electronic Health Records, Intensive Care Units, Medication Systems

Introduction

The Intensive Care unit (ICU) is a complex environment that requires healthcare providers to balance competing tasks and responsibilities in their care for patients. Caring for complex patients requires communication and coordination of multiple healthcare team members and changes in work routines could affect their ability to provide safe, high-quality care. The ICU team consists of a range of staff including nurses, doctors and pharmacists. It involves coordinated patient management by internal intensivists and doctors, as well as external teams to the ICU such as surgeons, infectious diseases specialists, anesthetists, geriatricians and several others. All members require ease of communication, visibility of the medication charts and changes to medication regimens.

The patient record remains the principal instrument for ensuring continuity of care. The ICU is a data-rich environment and there is discordance between the mass of data and the capacity of paper-based documentation, which can lead to major defects in information processing [1]. There are many barriers to efficiency using a paper-based documentation system. Traditionally, on admission to, and discharge from, the ICU, a patient's paper-chart would be ceased, and a new chart would be written up by the ICU doctor. Transcription errors on admission to and from the ICU, as well as illegible handwriting [2,3], time spent on manual data entry [4], low quality of, and frequency of, medication errors [5] are just a few of the challenges that can result in inefficient workflow, medication errors and poor productivity [6]. Electronic medication management systems (EMMS) aim to improve work processes for all end users by presenting medication information that can be easily accessed during a patient's hospital stay.

However, EMMS that are unable to support clinical work-flow efficacy [7] can generate unintentional consequences that can harm patients [8]. Unintended consequences resulting in errors have been variously labeled 'system-related', 'technology-induced,' and 'computer-related' [9,10]. A frequent subgroup is system-related errors arising from the use and functionality of an EMMS which would be unlikely or unable to occur in paper-based medication ordering systems [10]. These are typically caused by the inability of the EMMS to match healthcare work patterns and settings, creating user acceptance barriers. It is therefore necessary to evaluate the claim that an EMMS will enhance the quality of patient care and increase documentation efficiency.

A Case Study

In Australia, the NSW state government eHealth Strategy for 2016–2026 is to develop a digitally-enabled and integrated health system delivering patient-centered health experiences and quality health outcomes [11]. A key component of this strategy is the roll-out of a commercial electronic medication management system referred to locally as- 'eMeds' (Millennium®, current code level 2015.01.25, Cerner Corporation, Kansas City, MO) to replace paper medication charts in general wards in 178 NSW state hospitals. eMeds is a physician order entry system. Prescribing using eMeds involves selecting items from a drop-down menu of predefined order sentences triggered on drug selection. When selecting a medication, it includes order sentences which contain details of the drug, strength, dose, and form, with the option to edit details in the order sentence. All orders are subjected to series of checks including drug allergies and interactions. EMeds is incorporated into the patient electronic medical record which contains all other aspects of patient care such as pathology, imagining etc.

In NSW hospitals, eMeds is being rolled out to general wards, whilst the ICUs are generally implementing an alternate commercial EMMS, known as the electronic record of intensive care or 'eRIC' (MetaVision ICU, iMDsoft®, Tel Aviv, Israel) or are remaining paper-based. This is creating hybrid or dual prescribing system environments. Studies have shown stakeholders believe this practice to have negative impacts on communication, with some users reporting missing patient information [12]. To ensure crucial patient information was not missed, it was proposed that eMeds EMMS be implemented in a 13-bed general ICU of a tertiary hospital in NSW, Australia, to align with the general wards which include surgical, acute and aged care wards. Prior to its implementation the remainder of the 750-bed general hospital had already been using this system for 3 years while the ICU during that time was out of scope, using the paper National Inpatient Medication Chart (NIMC) [13]. Across NSW there are 81 public hospital ICUs [14], 15[11] of these have implemented the alternative eRIC system [15] in the ICU and eMeds throughout the remainder of their hospital. This is one of the first hospitals in Australia to implement the eMeds EMMS system in the ICU, creating a consistent prescribing system across its facility. However, unlike the remainder of the hospital that is using computerized physician order entry (CPOE) and electronic clinical documentation across all aspects of care, the ICU are only using CPOE for medications and diagnostics tests. Additionally, some orders, such as continuous infusions and blood products, remained on a large-format daily ICU flowsheet at the request of the ICU medical staff.

This provided a unique opportunity to evaluate the impact of this EMMS in the ICU setting, as well as the effect of having the same system facility wide. Despite the coordinated care required amongst teams within and external to the ICU, most studies have focused primarily on a single group rather than the impact across all teams involved in the medication management process. Our research goal is to apply an existing technology acceptance model to evaluate the usability and acceptability of nurses, doctors and pharmacists within the hospital.

Methods

We chose a formative evaluation for this study. This paper focused on the results of a survey that was part of a larger case-based mixed-methods approach, as recent review of evaluation of health care IT recommends methodological pluralism, including both qualitative and quantitative methods [16].

Participants

The evaluators focused on the three main clinical groups (nurses, doctors and pharmacists) in both the ICU and the remainder of the general hospital. Usability evaluation studies need to provide a comprehensive image of usability by focusing on more than one single end-user perspective[17]. The survey link was sent to 70 ICU nurses, 15 ICU doctors and 2 ICU pharmacists. The possible maximum of non-ICU staff was difficult to obtain due to the nature of rotating shifts between nurses and doctors for a single patient's hospital admission. Staff were anonymous and of mixed age, gender, experience and seniority. These groups were chosen as they are central to the operation of the EMMS. Staff external to the ICU were included to determine the hospital wide effect of transitioning from a hybrid prescribing hospital environment of paper-based and an EMMS to a homogenous one. It also allowed for the comparison of the impact on teams involved in the direct use of the system with those on the receiving end of patients transitioning in and out of the ICU. Staff completing the survey were expected to have worked in the ICU and other relevant wards three months prior and during the implementation of eMeds in the ICU.

Survey Design

The survey was developed by the project team and based on the Unified Theory on Acceptance and Use of Technology (UTAUT) to evaluate the acceptance and use of eMeds. The UTAUT [18], was chosen as the framework for the development of the survey as it has been widely applied and empirically tested to investigate factors that could influence individuals to adopt and use technology in various environments [19].

UTAUT integrates eight theories on technology adoption and provides a comprehensive view of the factors related to users' adoption behavior [20]. The main UTAUT constructs are [18]:

- Performance expectancy (PE): ''The degree to which an individual believes that using the system will help him or her attain gains in job performance.''
- Effort expectancy (EE): "The degree of ease associated with the use of the system."
- Facilitating conditions (FC): ''the degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system."
- Social influence (SI): "the degree to which an individual perceives that important others believe he or she should use the new system."

According to the UTAUT, PE, EE and SI are theorized to influence behavioral intention to use a technology, while behavioral intention and FC determine technology use [20]. The UTAUT does not specify the methods or parameters to be used, as it is a case by case basis. In this paper we report on the survey outcomes designed against the UTUAT framework.

The survey used a 7-point Likert scale (1 – strongly disagree; 7 – strongly agree). It consisted of 69 questions capturing a range of user feedback questions, however this paper focuses only on data from 33 questions relevant to the UTAUT framework. The survey also had two open ended questions that asked, '*why do you think eMeds in the ICU is or isn't sustainable?*' and *'general comments regarding eMeds'*. Surveys sent to the ICU and non-ICU staff were identical, except for the questions under the effort expectancy construct. Effort expectancy between ICU and non-ICU were not compared directly as the questions under this construct were not in both surveys. Due to the nature of the questions, i.e. *'I find it easy to get the eMEDs system to do what I want it to do,'* which is not specific to the impact of eMeds in the ICU on non-ICU wards, they were removed from the non-ICU staff survey. The surveys were pilot tested on four participants. The phrasing and selection of question involved a methodological trade-off between following established standards and adapting these to adequately fit the case at hand.

Survey Distribution

Three months after the implementation of eMeds in the ICU, the survey was distributed to ICU nurses, doctors and pharmacists. One hundred ICU staff were emailed an online survey link or given physical copies. The second survey was sent to the nurses, doctors and pharmacists on the wards that ICU patients are commonly transferred to. Two reminder emails were sent out within 1-month after the initial email. Non-ICU staff completing this survey were expected to have been involved in the care of a patient transferred from the ICU. Participants were provided a coffee voucher upon survey completion.

Analysis

Data from the survey was collected and stored using a Research Electronic Data Capture Tool (REDCap), 8.3.1 (Vanderbilt University, Nashville). It was subsequently analyzed for descriptive, correlation and Cronbach's alpha statistics using the Statistical Package for the Social Sciences 22 (SPSS) (IBM Corp. Released 2016, Version 24.0. Armonk, NY: IBM Corp).

Results

A total of 100 surveys were received. Table 1 gives the response rates for the individual wards and professions.

Overall User Satisfaction

In technology-acceptance research, factors that may influence people's acceptance of systems are typically correlated with (self-reported) usage of systems. Because use of this system was mandatory, the items included in this study were correlated with user's overall assessment of the system. We first examined the user's general satisfaction with the EMMS by examining responses to the survey item, 'overall, I am satisfied with the way of working with eMeds.' Overall, ICU doctors were dissatisfied, (mean = 1.78, SD =1.72) particularly in comparison to non-ICU doctors (mean = 5.71, SD =1.14). Similarly, ICU pharmacists were less satisfied than non-ICU pharmacists (mean = 3.00, SD=1.41 and mean = 5.22, SD= 1.20 respectively) and ICU nurses less than non-ICU nurses (mean = 4.83, SD= 1.37 and 5.72, SD = 1.49 respectively. Of the 6 groups, non-ICU nurses were found to be the most satisfied. When examining the correlation between overall satisfaction and the UTAUT constructs, overall satisfaction was significantly correlated with all four constructs ($p < 0.01$). Overall satisfaction was positively moderately correlated with performance expectancy ($r= 0.499$), facilitating condition ($r= 0.455$) and effort expectancy (ICU, $r= 0.361$, non-ICU, $r=0.463$). It was most strongly correlated with social influence ($r= 0.510$). Suggesting that all 4 constructs play a role in the overall assessment of the system.

Table 1 – Survey Response Rates

	ICU staff	Non-ICU Staff
Profession	Respondents N, (response rate %)	Respondents * (N)
Doctors		
Senior doctors	5, (45%)	3
Junior doctors	4, (80%)	5
Unspecified	0, (0%)	7
Nurses	29, (41%)	36
Pharmacists	2, (100%)	9
Total:	40, (45%)	60

**Unable to obtain response rate % as the possible maximum of non-ICU staff was difficult to obtain due to the nature of rotating shifts between nurses and doctors for a single patient's hospital admission.*

The UTAUT Constructs Reliability

Cronbach's alpha was calculated for each of the constructs and found to be, for performance expectancy, $\alpha= 0.94$ consisting of 3 items, for facilitating condition, $\alpha= 0.93$ consisting of 3 items and for social influence, $\alpha= 0.89$ which consisted of 2 items. For the ICU staff survey, the effort expectancy construct consisted of 3 items with $\alpha= 0.91$. All the alpha values are above the recommended threshold of 0.7 [21] . The reliability of all 4 constructs are deemed satisfactory.

Performance Expectancy (PE)

The non-ICUs overall assessment of performance was satisfaction with the system compared to ICU staff, with a mean difference of -1.70 ($p<0.001$) (Table 2). Statistically significant mean differences between groups within the ICU were unable to be calculated due to the small sample size of individual professions. Of the three groups examined within the ICU, doctors perceived the system as supporting them the least in attaining gains in their job performance (Table 3). However, perception of performance expectancy varied across the three ICU groups. ICU nurses and pharmacists were slightly in favor of the EMMS increasing their job performance, with an average mean response rate of more than 4. Interestingly, all professional groups external to the ICU staff, rated performance expectancy higher than ICU groups and all groups perceived the EMMS useful to some degree in achieving a greater job performance. The highest mean response was from the nurses (mean = 5.81, SD= 1.58), followed closely by the doctors (mean = 5.60, SD= 1.60) and pharmacists (mean = 5.44, SD= 1.13).

Effort Expectancy (EE)

Overall, the ICU staff were neutral in their view on the degree of ease associated with the system (mean = 4.28, SD= 1.71). However, when broken down to the individual groups, table 3 shows that ICU doctors did not believe there was a degree of ease associated with use of the system (mean= 2.0, SD= 1.58). Similarly, to the trend in PE, ICU nurses and pharmacists (table 3) believed there to be a degree of ease associated with the system, with an average mean response rate of more than 4. Externally to the ICU, mean response to the question, 'the features of the eMEDs system meet the needs of my work tasks,' was favourable and had a mean value of 5.33 (1.69) and were positively supported by all three groups (Table 3).

Facilitating Condition (FC)

Unlike the other two constructs, there was consistency in the perception of FC across all groups both within and external to the ICU. Table 2 shows that both the ICU and non-ICU wards believed the hospital provided them with the required implementation and ongoing support for the system. All sub-groups both internal and external to the ICU had a mean average of more than 4. When comparing which group felt they had the most support, of all the groups Table 3 shows that both the ICU and non-ICU pharmacists agreed that the support was greatest. Nursing groups internal and external to the ICU rankings were the next followed closely by externals doctors and internal ICU doctors. The impact of hospital support is consistent across all three groups internal and external to the ICU.

Table 2 – Comparison of the Overall Mean for Each Construct of ICU and Non-ICU staff

	ICU Mean (sd), N	Non-ICU Mean (sd) N= 60 (All items)	Mean difference
PE	4.00 (1.66) N= 40	5.70 (1.51)	-1.70 (t_{78}= 5.08 , P <0.01)
EE	4.28 (1.71) N= 40	5.0 (1.65)	*
FC	5.16 (1.39) N= 37	5.73 (1.54)	-0.56 (t_{81} =1.69, P <0.10)
SI	4.35 (1.73) N= 37	5.73 (1.59)	-1.374 (t_{73} = 3.93, P < 0.01)

** Unable to compare means of EE as questions under the constructs differed between ICU and non-ICU ward. The N varies between each construct for ICU staff due to removal of non-response data. Missing data occurred throughout the survey, but did not exceed 10%.*

Social Influence (SI)

Both the ICU and non-ICU collectively perceived their seniors and colleagues as being in favor of the implementation of the EMMS in the ICU. The mean average of both the ICU and non-ICU group was more than 4 (Table 2). This suggests that department heads have provided managerial support throughout the implementation of the system. However, when broken down to individual group levels, Table 3 shows that the greatest managerial support was held by nurses within and externally to the ICU. Alternatively, whilst overall the ICU believed their seniors to be in support of the system, Table 3 shows that the ICU doctors alone had a contrasting view (mean = 2.44, SD= 1.67)

Across all 4 constructs, Table 2 shows that for the ICU staff, there were overall lower means and higher variations across all 4 constructs. However, non-ICU staff have higher means and lower variability across constructs, indicating there is greater consistency in the support for EMMS from external groups to the ICU, whilst there is less support and greater variability in opinion amongst groups within the ICU.

Table 3 – Comparison of mean responses of individual groups for ICU and non-ICU staff under the four UTAUT constructs.

	ICU STAFF mean (sd)			NON-ICU STAFF mean (sd)		
	Nurses	Doctors N=9	Pharmacists N= 2	Nurses N= 36	Doctors N= 15	Pharmacists N= 9
PE	4.59 (1.30) N=29	2.0 (1.32)	4.50 (0.7)	5.81 (1.58)	5.60 (1.60)	5.44 (1.13)
EE**	4.89 (1.08) N= 29	2.0 (1.58)	5.5 (0.71)	5.69 (1.53)	4.80 (1.90)	4.78 (1.79)
FC	5.31 (1.32) N= 26	4.44 (1.42)	6.50 (0.71)	5.75 (1.80)	5.50 (0.97)	5.89 (1.51)
SI	5.00 (1.30) N=26	2.44 (1.67)	4.50 (0.71)	5.94 (1.56)	5.90 (1.85)	4.78 (1.09)

*** Effort expectancy between ICU groups and NON-ICU groups not directly comparable due to the difference in which asked between each group due to the nature of the questions and their relevance to the ward. The N varies between each construct for ICU nurses due to the removal of non-response data. Missing data occurred throughout the survey, however this did not exceed 10%*

Comments Section

The survey responses to the open-end questions for ICU staff were more commonly negatively swayed. The most common responses given by ICU-doctors focused on the increased time it takes to prescribe medication and the negative impact it has on workflow. Similarly, all three ICU groups commented that whilst eMeds is appropriate for a general ward, this benefit did not extend to the fast-paced ICU environment. Across the three groups within the ICU, nurses had the most positive comments, outlining that it improved workflow and transition of care. Groups external to the ICU also commented that having eMeds within the ICU positively impacted on their own workflow and the transition of care of patients.

Discussion

The first major objective of the introduction of eMeds in the ICU was to optimize workflow and workload. Usability is an intrinsic characteristic of a technology that impacts end-users' interaction with the technology; it leads to higher work efficiency in case of good usability, but in case of poor usability it may also slow down user performance, decrease users' satisfaction, and expose users to use errors [17].

This study reveals a clear difference in overall satisfaction between ICU and non-ICU staff. The ICU believed the eMeds EMMS not to be an appropriate fit for their setting. Task Technology Fit (TTF) focuses on the degree to which systems characteristics match user task needs [12]. Studies have suggested that in the absence of customized interfaces and tailored workflow support, the fit between the information entry and review needs of doctors, and the features offered by EMMS is likely to differ [22]. Previous studies show that the system and its users should be studied together and considered, as both are vital for implementation in order for the process of system adoption to be met with less resistance [23]. As revealed in the comments, the ICU staff believe the EMMS is appropriate for general wards but does not align with the ICU workflow. Suggesting that an EMMS fit for the general hospital, does not necessarily transcend to the ICU setting.

An EMMS should facilitate the aggregation and synthesis of multiple data elements for physicians [22]. Traditional paper-charts involves the extraction of data from various sources, over several pages in the file, and then collate the information. An EMR system, in contrast, makes such data easy to retrieve and, review [22]. As the ICU has continued to adopt the hybrid method of CPOE and paper documentation as well as selected medications, this scattered display of information and various sources continues. Thereby potentially impacting the perception of the benefits of an EMMS by the ICU staff.

General wards external to the ICU are at the stage of optimization of the system to align with workflow, thereby have overcome initial user resistance issues that may arise during the shakedown phase and may have facilitated use. Whereas, currently within the ICU there are continued efforts being employed to make improvements. It is currently unknown if these issues would remain after 6-12 months of using the system in ICU. Evidence suggests that it may take up to 2 years post-implementation until the unit returns to complete stability [24]. The greater satisfaction of ICU pharmacists in comparison to doctors could also explain this as ICU pharmacists were using this same system in the rest of the hospital prior to its implementation in the ICU, whilst the other two groups (doctors and nurses) were not.

Similar to previous studies, these results confirm that groups of professionals react differently when EMMS are implemented, making it difficult to implement a one-EMMS-fits-all across professions and departments. The finding that within the ICU, doctors were least satisfied compared to the nurses and pharmacists in areas related to PE and EE could be attributed to doctors being responsible for the entering of information into the EMMS. Physicians are at the frontline and perform not only knowledge work, such as making decisions and crafting treatment regimen based on patient information, but also data entry. Accordingly, the influence of EMRs on different groups may differ if the technology provides disparate impacts with respect to information review versus information entry [22]. Previous studies found that a low level of usability plays an important role in unsatisfactory implementation of an EMMS which led to disruptions of workflows and accordingly negative impacts on job performance [25,26]. A literature review that looked at the impact of a critical care information system on time spent documenting by nurses and physicians revealed 25% of studies found an increase in time spent charting, 42% found no difference, and 33% of studies reported a decrease [25]. The benefits in effort are more likely reaped by those downstream who are not required to manually enter data.

The study also showed that users put a stronger emphasis on PE and EE, rather than facilitating condition or social influence . This could be attributed to its use being mandatory and had hospital management support. Resulting in the necessary resources and support for its successful implementation. This study also aimed to determine the effect of having the same EMMS hospital-wide rather than the popular dual prescribing environments. It was assumed that introduction of eMeds would favor workflow, workload and be beneficial hospital-wide. The results showed that whilst the general wards perceived having eMeds in the ICU as supporting them in their productivity, and effort, the ICU itself did not believe the system supported their work environment. This is the first Australian study that investigates the user perception from all three key groups within the ICU involved in the use of eMeds. It is also the first to explore the benefits of having the same EMMS facility wide. A key outcome is that external ICU users believe it to create a safer workflow and eases the patient transition throughout the hospital. The significant difference in impact on performance expectancy and effort expectancy between groups within and externally to the ICU could be attributed to the benefits associated with the electronic environment such as remote access and transparency of the patient medical journey.

Limitations

This paper focuses on the quantitative results of a survey which was part of a larger case-based mixed-methods approach. Concepts and results found from the survey will be triangulated with qualitative and medication safety data. Furthermore, the 45% response rate from ICU staff, the difference in sample size between ICU and non-ICU staff and within sub-groups calls for caution when interpreting the results.

Conclusions

This study aimed to determine the acceptance and usability of an EMMS system in the ICU setting, and the impact of having a homogenous EMMS hospital wide. It found that performance expectancy, effort expectancy, facilitating condition and social influence were all moderately correlated with user's overall satisfaction with the EMMS. It demonstrated that implementation entailed changes in work processes which were challenging for all ICU groups. Whilst user acceptance from within the ICU itself is poor, teams external to the ICU were in strong favor of its implementation. As this is part of a mixed-method case study design which includes triangulation of data, further investigations are being made into the core user-resistance concepts through qualitative evaluation methods.

Acknowledgements

Acknowledgements to the Sydney Local Health District Health Informatics Scholarship for the funding and ethics approval (approval number: LNR/18/CRGH/92) to complete the study.

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