MEDINFO 2017: Precision Healthcare through Informatics
A.V. Gundlapalli et al. (Eds.)

doi:10.3233/978-1-61499-830-3-743

User Centred Design and Nosocomials in Surgical ICUs: A Mobile Application for Peer Monitoring and Training in Hand Hygiene

Nadish Kariyawasam[a], Ming Chao Wong[a], Paul Turner[a]

[a] eHealth Services Research Group, University of Tasmania, Tasmania, Australia

Abstract

Nosocomial infections are a global public health risk. In low and middle-income countries the problem is acute with very high infection rates commonly contributing to poor patient outcomes including mortality. Organisational, cultural, and individual factors have been identified in these high rates, with poor hand hygiene compliance amongst clinicians a major risk factor. New approaches to achieving clinician behaviour change are required. User-centred approaches have proven effective to engage and support changes in clinician behaviours through the use of electronic tools. This paper reports on the experience of co-designing and implementing a mobile application with clinicians to enhance hand hygiene compliance. The peer monitoring and training supported by the application aims to directly contribute to evidence on reductions in infection rates in two surgical ICUs in Sri Lanka.

Keywords:
Mobile Applications; Cross Infection

Introduction

Nosocomial infections are a major public health concern throughout the world. Nosocomial infections contribute to elongation of hospital stay, long-term or permanent disability and death [1]. Each year health systems spend a considerable amount of resources, including high-end antibiotics, health professional work time, and hospital space to treat the consequences of nosocomial infections [2].

Previous research has already identified multiple factors contributing to differential rates of nosocomial infections in different clinical contexts. These include:

- Improper antibiotic usage and increasing antibiotic resistance;
- Congested and crowded healthcare facilities;
- Ineffective medical device cleaning and/or contamination during usage;
- Poor hand hygiene compliance amongst clinicians.

Numerous interventions have been implemented to reduce nosocomial infections with varying degrees of effectiveness. Infection rates, however, continue to be a significant burden on hospitals and patients, especially in lower and middle-income countries. Nosocomial infection rates in these countries continue to remain around 10 to 20 cases per 100 hospital admissions [3]. Sri Lanka, a 'low' middle-income country, continues to exhibit relatively higher rates of nosocomial infections in the cases/100 admissions scale. Explanation of these higher rates forms part of the investigation, however, previous anecdotal evidences appear to be intimately related to organisational and cultural factors. It is also evident that within intensive care units (ICUs) where patients are more immobile and more immunocompromised, infection rates tend to be highest [4]. As a result, this research has focused on exploring mechanisms to contribute to reducing infection rates in Sri Lankan Surgical Intensive Care Units (SICUs).

Information technology in health care, (*eHealth*) has already opened up opportunities to increase health care safety and quality [5]. eHealth is also already extensively used to improve various situations associated with hospital-acquired morbidities. These include improving patient handover [6], reduce medical and medication errors [7], antimicrobial stewardship [8], electronic surveillance of nosocomial infections [9], and post-operative monitoring [10]. However, inadequate usage, over usage, and inappropriate usage of eHealth can also contribute unintended negative consequences. These include contributing to safety risks through technology-induced errors and medication errors [11].

In optimising the development, implementation, and impact of eHealth, human factors engineering and user centred design (UCD) approaches have been used extensively to ensure technology user attributes, needs and work contexts are adequately understood and addressed as part of information technology development life cycle [12,13]. In healthcare, UCD has contributed to emergence of eHealth systems that are versatile, user-friendly, safe and dependable and that integrate more seamlessly into clinical work environments [14,15].

This paper reports on the experience of co-designing and implementing a mobile application with ICU clinicians developed utilising user centred design with the aim of contributing to improving hand hygiene compliance in two hospital surgical ICUs in Sri Lanka. The peer monitoring and training supported by the mobile application aims to directly contribute to evidence on reductions nosocomial infection rates.

Methodology

Project Overview

This research involved using a multi-centred and multi-phased approach [16].

Phase one involved establishment of baseline quantitative nosocomial infection data across six surgical intensive care units in six Sri Lankan hospitals. Information from patient records were entered into an online data collection form that comprised data pertaining to demographic information, separation diagnosis, antibiotic usage, clinical interventions performed, culture reports as well as any other significant clinical findings indicative of infections.

In phase two, several observation sessions were carried out in two surgical intensive care units. During these sessions, hand hygiene compliance behaviours of unit staff were observed according to the 'five movements' of hand hygiene [17,18]. The observations were recorded using the World Health Organization, hand hygiene monitoring observation form. Semi-structured interviews and focus group discussions were carried out to determine staff attitudes and perceptions towards hand hygiene compliance and perceptions of nosocomial infection rates and 'best practice' for infection rate reduction. Staff were invited to consider whether they felt the current situation in their ICU should be changed and if so, what measures they would recommend to improve the situation. Staff were generally very supportive of trying to reduce infection rates and recommended the need for measures that would target improved hand hygiene compliance. Following further user-led discussions the idea of intermittent peer monitoring and iterative training in hand hygiene compliance was agreed and interest shown in how an eHealth system could be developed and deployed to support this desired behavioural change.

A mobile application was developed using rapid prototyping and iterative design with staff, based on their requirements and evolving feedback. The developed application was implemented in two surgical intensive care units as part of the commencement of phase three of the research methodology. The developed mobile application was implemented over a four month period in both ICUs. Alongside data collected by the application itself, data pertaining to behavioural and attitudinal changes associated with its implementation were also collected at the start of the second and fourth month of the application's implementation. Post-implementation observations and interviews/focus groups were conducted to explore perceptions around improvements in hygiene compliance rates, staff attitudes and perceptions towards hand hygiene compliance. The overall impact on compliance rates and perceptional and attitudinal changes will be compared against baseline data on completion of six months after application's implementation.

Phase four will involve further collection of patient record data pertaining to demographic, diagnosis, antibiotic usage; interventions performed, culture reports, and other clinical findings indicative of infections to contribute to baseline comparisons about the nature, type, and severity of nosocomial infections.

Utilising UCD in a mobile application for peer monitoring and training on hand hygiene to improve compliance

The design of the mobile application was an iterative process that involved co-design with, decision-making by and guidance from intensive care unit staff, hospital infection control staff, hospital administrators and microbiologists. At the initial stage of the research, users identified nosocomial infections as a major reason for the worsening of patient conditions while being treated. Then they identified leading causes of nosocomial infections including poor hand hygiene compliance. Hand hygiene was ultimately identified as one of the major contributing factors. Staff further anticipated that proper intervention could significantly improve hand hygiene compliance. eHealth was identified as a potentially useful tool in the intervention. Staff suggested changes to the current 'Hand hygiene compliance observation form' and advocated incorporating this form into a more user-friendly and accurate mobile application for ease of access and use in the ICU environment and with staff workflow. A small tablet computer that could be easily cleaned with soft wipes was selected.

Development and Implementation of the Application

The mobile application was actually coded up using an agile development approach combined with iterative user feedback [19].

The application was based on the WHO hand hygiene compliance observation form but modified to accommodate local user needs and contexts of use. The iterative prototyping and user testing led to changing the app several times to reduce the 'number of clicks' and to improve the ease of 'repeated data entry'. The application collected hand hygiene compliance data during each peer monitoring session in each ICU and allowed time, staff member category, gender, and compliance with 'five movements of hand hygiene' to be easily and quickly recorded. This data was locally saved in the mobile device and synchronised to online system when connected to the internet.

Figure 1 shows the registration page of the developed application. New users registered their credentials while revisiting users can use their saved credentials to access the application.

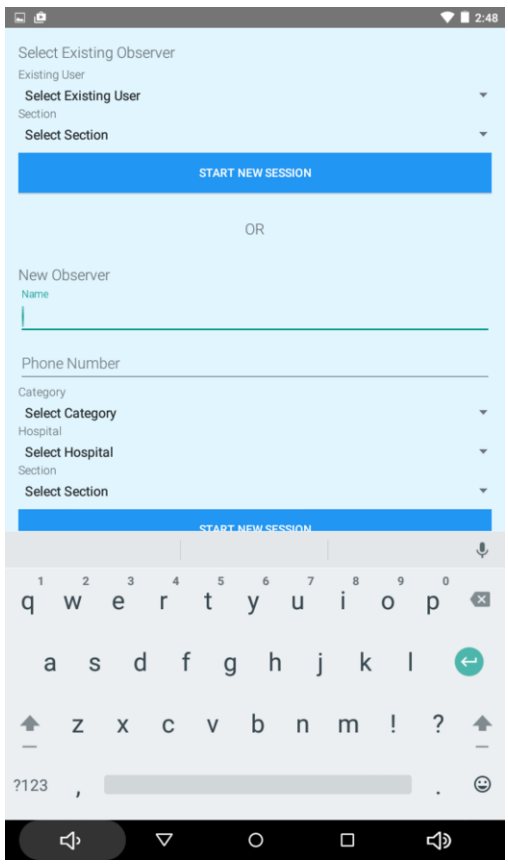

Figure 1 – Registration screen of mobile application

Figure 2 shows the hand hygiene compliance monitoring screen of the application. Users can monitor up to four staff members at any given time. After multiple usability testing, the application was implemented in two surgical ICUs in two hospitals in Sri Lanka. The application is currently being used mainly by nursing staff to monitor fellow nurses and other staff. Unlike most of the other monitoring methods where one person is always the observer and the others are always observed, in this instance observer/observed iterate their roles as part of the training component around enhancing hand hygiene compliance. The staff were keen to ensure a supportive, learning and collaborative implementation rather than a more punitive, error-checking approach. Therefore, every participant who conducts observations will also at some other time themselves be monitored for compliance.

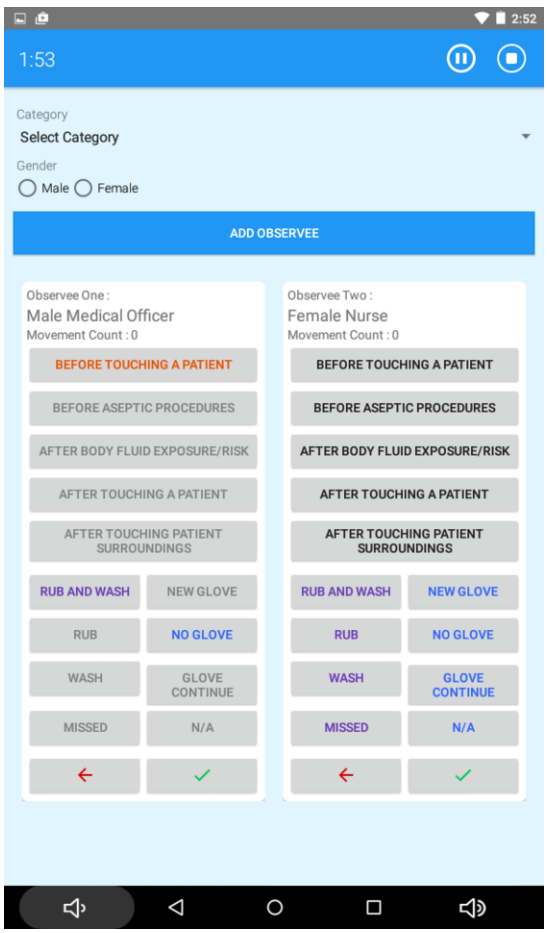

Figure 2 – Hand hygiene compliance data collection screen of the mobile application

During the initial phase of implementation, a decision was made to not provide any feedback on the observational findings. However, feedback is provided during the later part of the implementation to enable researchers to assess the impact of feedback on behavioural change. It is hoped this will contribute to enabling subsequent application roll-out to other hospital sites.

Results

Preliminary results of the research prior to provision of feedback are shown in tables 1-3. According to table 1, 12% of patients who were admitted to the SICUs had at least one positive culture report during their stay in the SICU or within 48 hours after leaving the SICU. However, regardless of the percentage of culture reports, 79% of patients who did not have any antibiotics prior to admission to SICU were started on antibiotics during their stay in SICU. Further, 60% of patients had signs, symptoms or investigations indicative of infections.

Table 2 demonstrates hand hygiene compliance rates observed by peers amongst a few categories of participant clinicians during the observations conducted prior to the provision of feedback. Based on these observations, nurses had a compliance rate of 42% while medical consultants and officers had a compliance rate of just above 20%. However, none of the electrocardiogram (ECG) technicians who visited SICU during observation sessions cleaned their hands.

Table 1– Percentage of patients with signs, symptoms, investigations and interventions indicative of nosocomial infections

Signs, Symptoms, Investigations, and Interventions	**%**
% of patients with a positive culture	12%
% of patients who were not on antibiotics at admission to ICU but started on antibiotics after admission	79%
% of patients with signs/ symptoms or investigations indicative of infections	60%

Table 2– Peer monitored hand hygiene compliance rates during first four months of implementation according to the service category

Service Category	**Compliance rate**
Medical Consultants	25%
Medical Officers	21%
Nurses	42%
Physiotherapists	31%
Radiographers	30%
ECG Technicians	00%

As reported in table 3, hand hygiene compliance rates are lowest during morning busy hours of 8 am to 12 noon closely followed by 12 noon to 4 pm. During the night-time hand hygiene compliance rates are relatively high with the highest rates reported during the hours of 8 pm and 12 midnight.

Table 3– Compliance rates during various times of the day

Hours of the day	**Compliance rate**
00 – 04	45%
04 – 08	49%
08 – 12	27%
12 – 16	28%
16 – 20	35%
20 – 24	50%

This research is currently in progress, and therefore the final outcomes are still unknown. However, several inferences can already be drawn from the available preliminary data:

1. Nosocomial infection rates appear to be high. However, when established filters are used to determine nosocomial infection rates using CDC guidelines the real infection rates found seems to be significantly lower than currently projected rates.
2. These discrepancies are mainly due to incomplete retrospective data hindering establishment of diagnoses.
3. Hand hygiene compliance is between 20% to 45% among health professionals. Compliance is comparatively high among Nurses while very low among ECG Technicians. Female professionals appear to comply better than males.
4. Out of five movements of hand hygiene, staff appear to be complying with proper hand hygiene measures with movement two and three (i.e., before aseptic procedures and after touching bodily fluids) but are least compliant with hand hygiene measures after movement five (i.e., after touching patients' surroundings).
5. Compliance rates are comparatively better during the night than when the ICU is busy during the daytime.
6. Almost all health care staff interviewed want an improvement in the situation to have better hand hygiene compliance and lower nosocomial infections. However, there seem to be huge differences in the level of commitment to change from individual to individual.
7. There is a marked difference between what health professionals perceive they are doing and their actual behaviour. Self-awareness of poor hand hygiene compliance seems to be lacking among most health professionals.
8. After implementation of the application, self-awareness of poor hand hygiene compliance has improved. Further, month to month hand hygiene compliance data appears to be on a positive trend.
9. Surgical Intensive Care Units staff seem to be more vigilant regarding potential introduction of infections from outside sources such as visiting staff and relatives of patients.

Discussion

This research is still in progress but provides a clear example of the benefit of utilising a user centred approach to ensure strong adoption and use of eHealth in a sustainable and inclusive manner. The UCD approach facilitated users to take more ownership of the application and contributed to improved awareness and support for the intervention. However, preliminary results have yet to indicate any marked improvement in compliance. Although quantitative analysis of how the changes and intervention have impacted on reducing nosocomial infections is yet to be done.

Further, this approach and ultimately the developed application help in supporting peer to peer mentoring among the health care workers, that is markedly different from Sri Lankan work culture which still exhibits significant hierarchy. This monitoring method may prove to be more beneficial in inculcating self-awareness of the issue. Moreover, it is hoped the approach will assist in supporting sustained behavioural change compared to routine hand hygiene monitoring strategies assigned to infection control staff. Critically, it may be that the application enables a move away from an 'examination' approach to one that stimulates genuine and sustained behavioural change where participants can support one another to improve overall compliance.

In peer to peer observations, inculcating behavioural change happens in two ways. Firstly, staff tend to be more aware of complying when being observed. Then while they observe others, they identify how frequent compliance errors are and learn from others' mistakes and try to avoid them while they are at work. Regular feedbacks give the staff re-enforcement about good hand hygiene practice.

Together, this intervention may prove holistically to raise awareness of the existence of the problem, and provide staff with practical re-enforcement to improving behaviour.

Challenges around Nosocomials and Baseline Data

Pre-interventional hospital records are being analysed to provide a statistical baseline on nosocomial infection rates. In analysing these records it was initially found that relatively low nosocomial infection rates were recorded. However, this is primarily due to inability to formally establish genuine nosocomial infections due to the following reasons:

- Non-availability of appropriate culture reports conclusively validating the nature of any infection
- Poor recording of appropriate signs, symptoms, and investigations in the patient record that hinders ability to establish infections
- Non-availability of pre-infection reports inhibiting ability to definitively differentiate nosocomial infections from other types of infections
- Irrational antibiotic usage that inhibits use of some of the criteria conventionally deployed for formally establishing nosocomial infections

Given these limitations, the research team developed with a micro-biologist some criteria that could be used to get an indication of infection rates. In this context, a concept "Signs, Symptoms and Investigations Indicative of Nosocomial Infections (SSIINI)" was developed and utilised. The following criteria were used to consider a patient as having SSIINI:

1. No sign, symptom or investigation finding indicative of infections before admission to SICU or during first 48 hours at the SICU.
2. No record of antibiotic usage up to the first 48 hours at SICU.
3. A positive sign, symptom or investigation indicative of an infection first recorded at least 48 hours after admission to SICU.
4. Patients with signs, symptoms or investigations indicative of infections before spending 48 hours in the SICU or patients who have received antibiotics before spending 48 hours in the SICU (unless just one dose) were excluded from the analysis.
5. Patients who have spent less than 48 hours in SICU were also excluded from the analysis.

Limitations of research scope and scale

Quantitative analysis involving just six hospitals may not generate statistically significant data for generalisation of the results to all surgical ICUs. However, it is anticipated that any trends associated with the intervention may be used to predict the outcome of similar interventions in other locations.

This research is also being carried out as part of the doctoral thesis, i.e. this primarily involves one researcher. Therefore, there were some limitations in terms of finance, time, and trained personnel to conduct a larger and more comprehensive research investigation. However, adopting a multi-centred approach has contributed in excluding the possibility of any recorded outcomes caused purely by chance.

Conclusion

This research is contributing to efforts to reduce nosocomial infection rates. Using a UCD in co-designing a mobile application has led to strong and sustained adoption and use of an application perceived as user-friendly and efficient. It is anticipated that the research will also enhance understanding of how peer assisted monitoring can be used in inculcating behavioural change. Though final outcomes of the research are still unknown, preliminary insights show important steps towards change in user behaviour associated with this eHealth intervention. A future research paper will discuss the quantitative outcomes of the research and overall impact of the research in contributing to improved hand hygiene compliance and its relationship to overall reductions in nosocomial (SSIINI) infections.

Acknowledgements

Authors wish to thank Ministry of Health Sri Lanka and all Administrative, Surgical Intensive Care Unit, Microbiology, Record Room and Infection Control staff for their participation assistance and guidance.

References

[1] World Health Organization, Report on the Burden of Endemic Health Care-Associated Infection Worldwide, In, World Health Organization, Geneva, Switzerland, 2011.

[2] E. Zimlichman, D. Henderson, O. Tamir, C. Franz, P. Song, C.K. Yamin, C. Keohane, C.R. Denham, and D.W. Bates, Health care–associated infections: a meta-analysis of costs and financial impact on the US health care system, *JAMA Intern Med* **173**(22) (2013), 2039-2046.

[3] M. Meric, N. Baykara, S. Aksoy, I.O. Kol, G. Yilmaz, N. Beyazit, B. Mete, and H. Vahaboglu, Epidemiology and risk factors of intensive care unit-acquired infections: a prospective multicentre cohort study in a middle-income country, *Singapore Med J* **53**(4) (2012), 260-263.

[4] A. Haddadi, M. Lemdani, and H. Hubert, Incidence, dependent and independent risk factors associated to nosocomial infections and to the mortality at the intensive care unit of the Timone University hospital, *Eur Sci J* **9**(18) (2013), 168-181.

[5] D.W. Bates and A.A. Gawande, Improving safety with information technology, *N Engl J Med* **348**(25) (2003), 2526-2534.

[6] M.C. Wong, E. Cummings, and P. Turner, User-centered design in clinical handover: exploring post-implementation outcomes for clinicians, *Stud Health Technol Inform*, **192** (2013), 253-257.

[7] D.W. Bates, Using information technology to reduce rates of medication errors in hospitals, *BMJ* **320**(7237) (2000), 788-791.

[8] J.C. McGregor and J.P. Furuno, Optimizing research methods used for the evaluation of antimicrobial stewardship programs, *Clin Infect Dis* **59** (Suppl 3) (2014), S185-192.

[9] J.S. de Bruin, W. Seeling, and C. Schuh, Data use and effectiveness in electronic surveillance of healthcare associated infections in the 21st century: a systematic review, *J Am Med Inform Assoc* **21**(5) (2014), 942-951.

[10] B. Debono, P. Bousquet, P. Sabatier, J.Y. Plas, J.P. Lescure, and O. Hamel, Postoperative monitoring with a mobile application after ambulatory lumbar discectomy: an effective tool for spine surgeons, *Eur Spine J* **25**(11) (2016), 3536-3542.

[11] S. Redwood, A. Rajakumar, J. Hodson, and J.J. Coleman, Does the implementation of an electronic prescribing system create unintended medication errors? A study of the sociotechnical context through the analysis of reported medication incidents, *BMC Med Inform Decis Mak* **11**(1) (2011), 29.

[12] M.C. Beuscart-Zéphir, E. Borycki, P. Carayon, M.W.M. Jaspers and S. Pelayo, Evolution of human factors research and studies of health information technologies: the role of patient safety, *Yearb Med Inform* **8**(1) (2013), 67-77.

[13] G. Declerck, and X. Aimé, Why Medical Informatics (still) Needs Cognitive and Social Sciences, *Yearb Med Inform* **8**(1) (2013), 86-92.

[14] O. Frykholm, M. Flink, M. Lindblad, and M. Ekstedt, User-centered design of integrated eHealth to improve patients' activation in transitional care, *Int J Integr Care* **16**(6) (2016), A338.

[15] J. Chan, K.G. Shojania, A.C. Easty, and E.E. Etchells, Does user-centred design affect the efficiency, usability and safety of CPOE order sets?, *J Am Med Inform Assoc* **18**(3) (2011), 276-281.

[16] N. Kariyawasam, M.C. Wong, P. Mahipala, and P. Turner, Reducing Nosocomial Infections: A User-centered Approach to Developing an eHealth system for Sri Lankan ICUs, In *Driving Quality in Informatics: Fulfilling the Promise* **208** (2015), 200-204.

[17] H. Sax, B. Allegranzi, I. Uckay, E. Larson, J. Boyce, and D. Pittet, 'My five moments for hand hygiene': a user-centred design approach to understand, train, monitor and report hand hygiene, *J Hosp Infect* **67**(1) (2007), 9-21.

[18] World Health Organization., *WHO guidelines on hand hygiene in health care : first global patient safety challenge : clean care is safer care*, World Health Organization, Patient Safety, Geneva, Switzerland, 2009.

[19] K. Kautz, Investigating the design process: participatory design in agile software development, *Information Technology & People* **24**(3) (2011), 217-235.

Address for correspondence

Dr Nadish Kariyawasam
Nadish.Kariyawasam@utas.edu.au