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Research Article

Designing devices to communicate effectively with intensive care nurses to prevent pressure injuries: A qualitative study

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ABSTRACT

Objectives: The aim of this research was to identify "what" key design elements of a device for detecting hospital acquired pressure injuries should do and "how" these elements should function. The goal of the resulting design was to prompt intensive care unit nurses to intervene appropriately to reduce the incidence/severity of pressure injuries, while minimizing workflow disruptions.

Methods: A mixed method study was performed in an intensive care unit, which included shadowing, interviewing, surveying and conducting focus groups with individuals knowledgeable about pressure injuries and related patient care. This study focused on identifying and prioritizing the needs/wants of nurses regarding devices aimed at detecting hospital acquired pressure injuries. These needs were then used as the foundation for designing key elements of such a device.

Findings: Intensive care nurses indicated that a device for the early detection of pressure injuries should communicate information as real-time summaries about the severity of a skin issue in an easy-to-understand manner and provide reminders for them to take action when needed without unnecessarily interrupting their workflow.

Conclusion: The findings regarding nurses' needs will be useful for the future development of technologies/devices that help reduce the incidence/severity of hospital acquired pressure injuries. In turn, nurses may be more likely to use such a device to enhance patient care.

Implications for clinical practice

- By participating in shadowing, interviews, surveys, and/or focus groups, nurses can share their needs to help inform both "what" key design elements of a medical device should do and "how" these elements should function.
- Nurses prefer that information is communicated through real-time summaries about the severity of an issue in an easy-to-understand manner and reminders are provided for them to take action when needed without unnecessarily interrupting their workflow.
- When nurses' needs are used as the foundation for designing the key elements of a new device, nurses may be more likely to adopt and use the device because the device would fit into their current workflow.

Introduction

While largely preventable, world-wide pressure injury prevalence in adults is 26.6% (Labeau et al., 2021); hence, pressure injuries continue to be a major problem in health care (Edsberg et al., 2014, Gaspar et al., 2019). In addition to being extremely painful, expensive to treat, and potentially fatal due to the risk of serious infection (Berlowitz et al., 2014), the occurrence of hospital acquired pressure injuries (HAPIs)

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reduces clinical institutions' healthcare quality ratings and exposes them to substantial financial losses from non-reimbursable treatment costs and lawsuits for wrongful injury or death (EPUAP/NPIAP/PPPIA, 2019). For example, the annual cost of HAPIs are estimated at up to USD $26.8 billion in the U.S. (Padula and Delarmente, 2019), GBP£502-578 million in the UK (Guest et al., 2020), and AUS$983 million in Australia (Team et al., 2020).

Given their underlying pathophysiology and patients' likelihood to be immobile, pressure injuries are especially common in intensive care units (ICUs) (Coyer et al., 2017). The standard for clinicians to identify early signs of skin damage is using risk assessment tools, including the Braden scale (Bergstrom et al., 1987, Braden and Maklebust, 2005), Waterlow scale (Waterlow, 1985, Waterlow, 2005), and Norton scale (Norton et al., 1962, Goldstone and Goldstone, 1982). Though visual skin assessment can identify subdermal tissue damage, it cannot prevent it (Gefen and Gershon, 2018); to this end, periodic repositioning of patients is recommended (Gillespie et al., 2020). However, nurses often report not repositioning patients regularly due to heavy workloads, staff shortages, and lack of training/knowledge (Mirshekari et al., 2017, Etafa et al., 2018, Coyer et al., 2019, Khojastehfar et al., 2020, Bergman et al., 2021, Hu et al., 2021).

In addition to active repositioning strategies, pressure injury prevention is often aided by devices such as support surfaces (e.g., mattress replacement or overlays), prophylactic/foam dressings, and positioning devices (Alves et al., 2019, Gaspar et al., 2019). Additional prevention efforts involve implementing care bundles (Tayyib et al., 2016, Richardson et al., 2017, Anderson, 2018), but to be most effective, bundle elements must be delivered continuously, as a cluster, and through collaboration between multiple healthcare practitioners from different disciplines (Zuo and Meng, 2015). Reminders at the point of care, such as on-screen reminders about a patient's risk of developing pressure injuries, were also found to be effective in reducing their incidence (Sebastián-Viana et al., 2016, Arditi et al., 2017, Gunningberg et al., 2018).

A newly developed, promising strategy in support of pressure injury management is the use of medical device technology. Currently, the only U.S. Food and Drug Administration authorized pressure injury management tool is a sub-epidermal moisture scanner, which has been shown to reduce the incidence of pressure injuries by 80% or more (Bryant et al., 2021, Nightingale and Musa, 2021). Additional research has explored the use of wireless, fabric-based pressure sensor arrays (Chung et al., 2013) and conductive fiber sensors that measure pressure and sweat volume (Tsuda et al., 2020). There is also research investigating the effect of prolonged pressure on sacral tissue using a wearable, non-invasive skin patch based on near-infrared spectroscopy that is able to monitor alterations in superficial and deep tissues alike in real-time (Day and Pollonini, 2020).

While such technologies may help reduce the incidence/severity of pressure injuries, developing acceptance for the use of such devices among clinicians is a major issue (West, 2020), particularly in the ICU where nurses' workloads are significant (Mohammadi et al., 2015, Hoogendoorn et al., 2021). To help address issues related to the adoption of medical devices, this research utilized a mixed methods study (Creswell and Plano Clark, 2018) to investigate "what" key design elements of a device for detecting HAPIs should do and "how" these elements should function to achieve the ultimate goal of prompting ICU nurses to intervene appropriately to reduce the incidence/severity of pressure injuries, while minimizing workflow disruptions. The findings of this research are of interest for the future commercial development of HAPI detection devices.

Methods

Under the umbrella of a mixed methods study (Creswell and Plano Clark, 2018), this investigation utilized the Design for Six Sigma (DFSS) methodology, which is a systematic approach for building robustness and high performance into the design of products and processes (Yang, 2005, Hasenkamp, 2010, de Mast et al., 2011, Pyzdek and Keller, 2014). Following this approach, both qualitative and quantitative data were collected. As shown in Fig. 1, the needs/wants of ICU nurses were identified through consented shadowing and interviews, and this information was then prioritized through a survey. The sub-set of the most important needs was used to guide the design of how a device for detecting HAPIs should communicate actionable patient information to ICU nurses. This involved brainstorming sessions to develop design

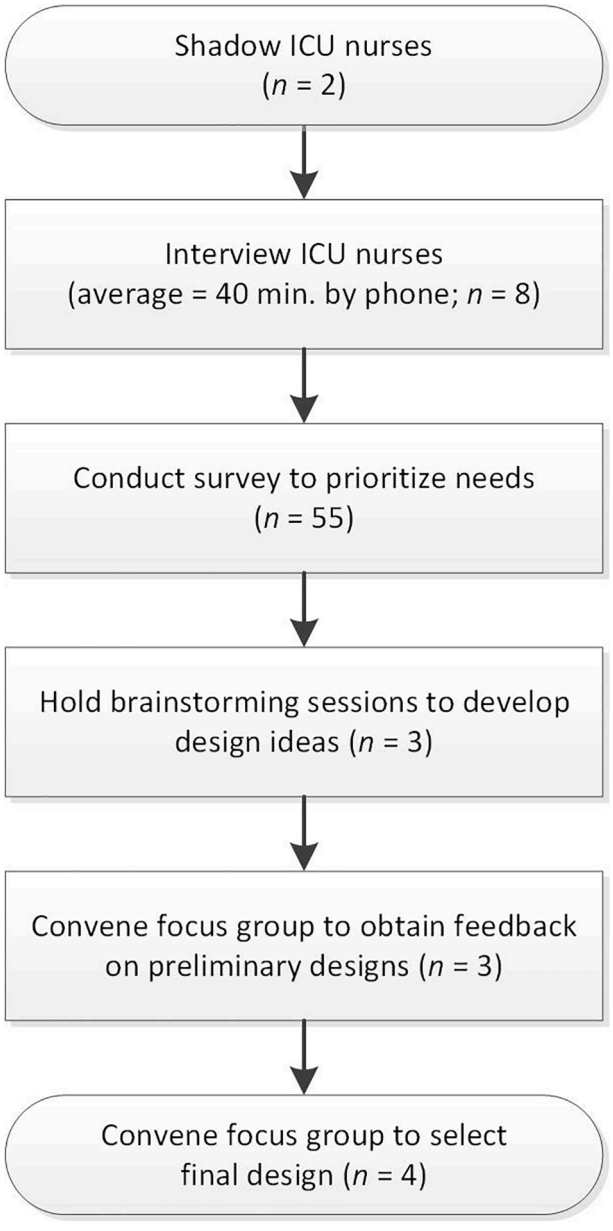

Fig. 1. Steps utilized following the DFSS approach.

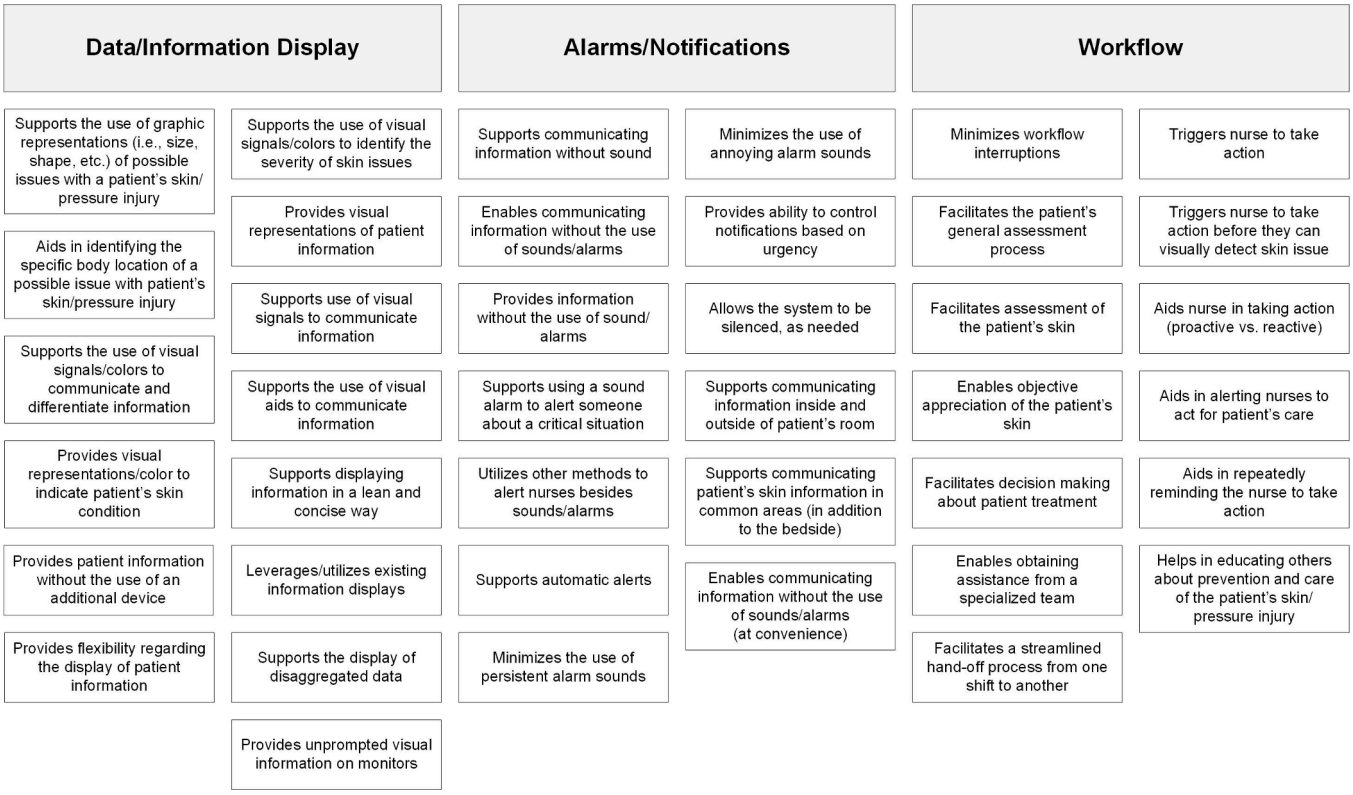

Fig. 2. Excerpt of translated needs of ICU nurses based on interview responses.

ideas; then feedback obtained from focus groups was used to refine and select the final design.

Setting and sample

Research participants consisted of individuals within the nursing profession knowledgeable about pressure injuries and related patient care, such as ICU nurses, wound, ostomy, and continence (WOC) nurses, ICU nurse managers, etc., including men and women aged 18–64 across all races. Anyone not knowledgeable about pressure injuries and related patient care, based on their work experience, was excluded from this study. Some of the same participants took part in multiple data collection procedures (i.e., shadowing, interviews, etc.). Other participants took part in only one data collection procedure. All data collection procedures were facilitated by the researchers.

A list of more than 25 individuals from Houston area medical institutions that participated in a prior, related study (part of the National Science Foundation's Innovation Corps program) was utilized to solicit participants. Two medical institutions in the Houston area agreed to participate in this study. These institutions provided contacts for shadowing, interview, survey, brainstorming, and focus group opportunities.

Ethical Statement

This study was approved by the Institutional Review Board (STUDY00001764), known as the Committee for the Protection of Human Subjects, at the university where this research was performed. Consent was obtained from all research subjects prior to their participation in this study, and all work was carried out within the ethical standards set forth in the Helsinki Declaration.

Data collection and analysis

Shadowing and interviews

One ICU nurse from each of the two participating institutions was shadowed for one 12-hour shift. Researchers observed the work performed by the ICU nurses and took notes regarding the activities in their typical workday. Separately, interviews were conducted with ICU nurses to identify their needs regarding how a device for detecting HAPIs should communicate actionable patient information to them. Invitations to participate in interviews were sent to 17 ICU nurses, of which eight agreed to participate (47% response rate). On average, interviews took 40 min and were conducted via phone prior to or following a nurse's shift (i.e., off duty time).

During interviews, nurses were asked how they would use early detection of HAPI information, what they liked/disliked about current communication methods, and what suggestions they had to improve the communication of actionable patient information. Data collection ended once interviews reached saturation (i.e., further interviews led to very few, if any, new responses). Interview responses were translated into need statements that described "what" key elements of a device for detecting HAPIs should do, not "how" it should operate. Translation of interview responses into needs statements paid particular attention to preserving the original meaning/sentiment of the ideas expressed by interviewees.

Prioritization survey

The most frequently occurring need statements from ICU nurses' interview responses were included in a prioritization survey, which asked respondents to indicate, using a 5-point scale, how important each statement was when considered as a feature or attribute of a device for detecting HAPIs. This survey was administered to 70 participants, of which 55 completed the survey (79% response rate). Survey results were analyzed using descriptive statistics and need statements that received a median score of 5, indicating that at least 50% of respondents rated the item as critical, were identified as the top-rated needs.

Brainstorming and focus groups

To obtain ideas regarding how to fulfill the top-rated needs identified through the survey, notes taken when shadowing ICU nurses and responses to the last interview question were mined. Literature was also searched to identify approaches used in other industries (i.e., telecommunications, energy, oil and gas, etc.) to communicate system monitoring information to employees. Additionally, brainstorming sessions were held with three participants who were asked to think of possible ways for a device to communicate early detection HAPI information to ICU nurses that addressed one or more of the top-rated needs.

Preliminary design ideas obtained to this point were organized into affinity groups and unique design options were created by combining various features from different groups. To obtain feedback regarding these designs, a focus group consisting of three participants was held. Following detailed descriptions regarding each option, focus group participants were asked what they liked/disliked about each design option and what features they would add/remove for each option. This feedback was used to combine and revise aspects of the preliminary design options to create more detailed designs.

To select the final design, an additional focus group was held. Following comprehensive descriptions regarding the detailed design options, four participants were asked to evaluate each design in terms of how well it fulfilled the selection criteria (i.e., top-rated needs/features). For each criterion, participants individually rated each design option using a 3-point scale. Scores were calculated by summing ratings down each column, and grand totals were calculated by summing participants' scores for each design. The option with the highest total was identified as the final design.

Findings

An excerpt of ICU nurses' responses from interviews and corresponding translated need statements is shown in Table 1. The translation of interview responses resulted in 66 unique need statements, an excerpt of which is shown in Fig. 2. Examples of need statements include "supports the use of visual signals/colors to communicate and differentiate information," "aids in repeatedly reminding the nurse to take action," and "reduces the chance of nurses developing alarm fatigue."

As shown in Fig. 3, the survey to prioritize ICU nurses' needs included 18 statements reflecting the most frequently occurring need statements based on interview responses. Analysis of survey responses indicated six needs (denoted in gray in Fig. 3) had a median score of 5 indicating that at least 50% of respondents rated the item as critical. The top-rated needs included communicating information about a patient's skin condition 1) at-a-glance (quickly, all in one place), 2) in real-time, 3) with minimal workflow interruption, 4) in an easy to understand, straightforward manner, 5) to trigger/remind nurses to take action, and 6) to identify the severity of the issue.

Fig. 4 depicts the 38 preliminary design ideas obtained from all sources. Combining ideas from different affinity groups resulted in the development of six unique design options. Using the feedback obtained from focus groups regarding preliminary design options, two detailed designs were created. Based on the evaluation of each detailed design against the selection criteria, which is shown in Table 2, design "Alpha" (described in the following section) was identified as the best option.

An example of one of the six unique preliminary design options, "Option A," is denoted by bold boxes in Fig. 4. This design includes displaying pressure injury information on existing monitors at the bedside and in the corridor. That is, this information would be displayed in a separate area/box on the monitors using brief text and large font that will be color-coded to indicate the severity of the patient's skin issue (i.e., green – normal, yellow – abnormal/warning, red – critical). Additionally, the border of the area/box on the display will be color-coded (to match text) and flash to indicate warnings/critical situations, and a timer will indicate how long these situations have been present. Once the issue is resolved/pressure is reduced, notifications will automatically be dismissed (i.e., displays return to green with the timer no longer displayed).

In addition to the features included in "Option A," the best option, design "Alpha," includes features that will be integrated with a facility's electronic medical record (EMR). All data collected from the HAPI

Table 1
Example responses and interpreted needs from interviews with ICU nurses.

Question	Response	Translated Need Statement
How will you (ICU nurses) use actionable patient information about the early detection of pressure injuries?	Depending on the severity of the skin issue, the nurse decides what to do.	Provides information about severity of skin issue. Triggers nurse to take action.
What do you like about current communication methods?	Nurses can see patient information at-a-glance on monitors.	Provides patient information at-a-glance.
	Using color coding helps easily identify the patient's condition.	Supports the use of visual signals/colors to identify the severity of skin issues.
What do you dislike about current communication methods?	Too many alarms and beeping can cause alarm fatigue for nurses.	Utilizes other methods to alert nurses instead of sounds/alarms. Reduces the chance of nurses developing alarm fatigue.
Suggestions for how to improve communication of actionable patient information?	It is okay if the device produces a sound, but not in a way that is too annoying or persistent.	Minimizes use of annoying alarm sounds. Minimizes use of persistent alarm sounds.

Instructions: Please indicate how important the communication related features of a device to communicate actionable patient information about the early detection of pressure injuries to nurses listed below are to you, using the following scale:

1. Feature is undesirable. I would not consider a device with this feature.
2. Feature is not important, but I would not mind having it.
3. Feature would be nice to have but is not necessary.
4. Feature is highly desirable, but I would consider a device without it.
5. Feature is critical. I would not consider a device without this feature.

Rating	Feature
	Communicating information about a patient's skin condition:
_____	1. With ability to control notifications/alarms
_____	2. Using visual signals/colors
_____	3. At-a-glance (quickly, all in one place)
_____	4. In real-time
_____	5. With minimal workflow interruption
_____	6. Without using sounds/alarms
_____	7. In an easy to understand, straightforward manner
_____	8. Using a customizable display
_____	9. With minimal use of sounds/alarms
_____	10. Using existing devices (systems, monitors, etc.)
_____	11. Using graphical representations (location, size, shape, etc.)
_____	12. To facilitate follow-up
_____	13. To trigger/remind nurses to take action
_____	14. To identify the severity of the issue
_____	15. To facilitate decision making about patient treatment
	Use information about a patient's skin condition to:
_____	16. Enable trend analysis
_____	17. Facilitate documentation
_____	18. Generate reports

Fig. 3. Users' needs' prioritization survey (with features denoted in gray that had a median score of 5 indicating that at least 50% of respondents rated the item as critical).

detection device will be stored in the EMR. When ICU nurses log-in to a patient's EMR, they will see a body avatar (available in both posterior and anterior views) with color-coded indicators that represent the location of the devices on the patient and severity of the patient's skin condition (using green, yellow, and red color-coding). As needed, clicking an indicator will allow ICU nurses or others to see a visual representation of skin pressure information as a simple line/trend graph, two or three-dimensional contour map, and/or a time-based animated graphic like a weather radar display, for example.

Pop-up windows will also be used in the EMR to signal warnings/critical situations that correspond to changes in color-coded displays on the patient's bedside monitor. Pop-up windows will include a timer to indicate how long the alert has been active and provide options to snooze or dismiss the alert or request help. For accountability and later review, all actions in the EMR will be recorded, such as the number of times an alert is snoozed. Snooze length options, as well as total number of snoozes allowed, will be configured based on the policies/practices of the facility in which the HAPI detection device is being implemented. Finally, selecting "request help" will send a notification to the nurse station to alert others that help is needed in a specific patient's room.

Discussion

One might argue that the findings of this research are somewhat obvious and could have been developed without this type of study (Sligo et al., 2017). However, this investigation provides information that confirms the critical needs/wants of ICU nurses that should be considered when designing devices that ICU nurses will use (Holden and Karsh, 2010), such as for detecting HAPIs. Unlike prior research that collected feedback from ICU nurses only when testing a new device (Gunningberg et al., 2018), this study utilized information about ICU nurses' needs as the foundation for designing key elements of a device so that the device would fit into the current nursing workflow (Waterson et al., 2013). For example, the design developed through this research utilizes visual signals (e.g., color-coded/flashing displays, pop-up windows) to indicate warnings/critical situations instead of audible alarms, which addresses

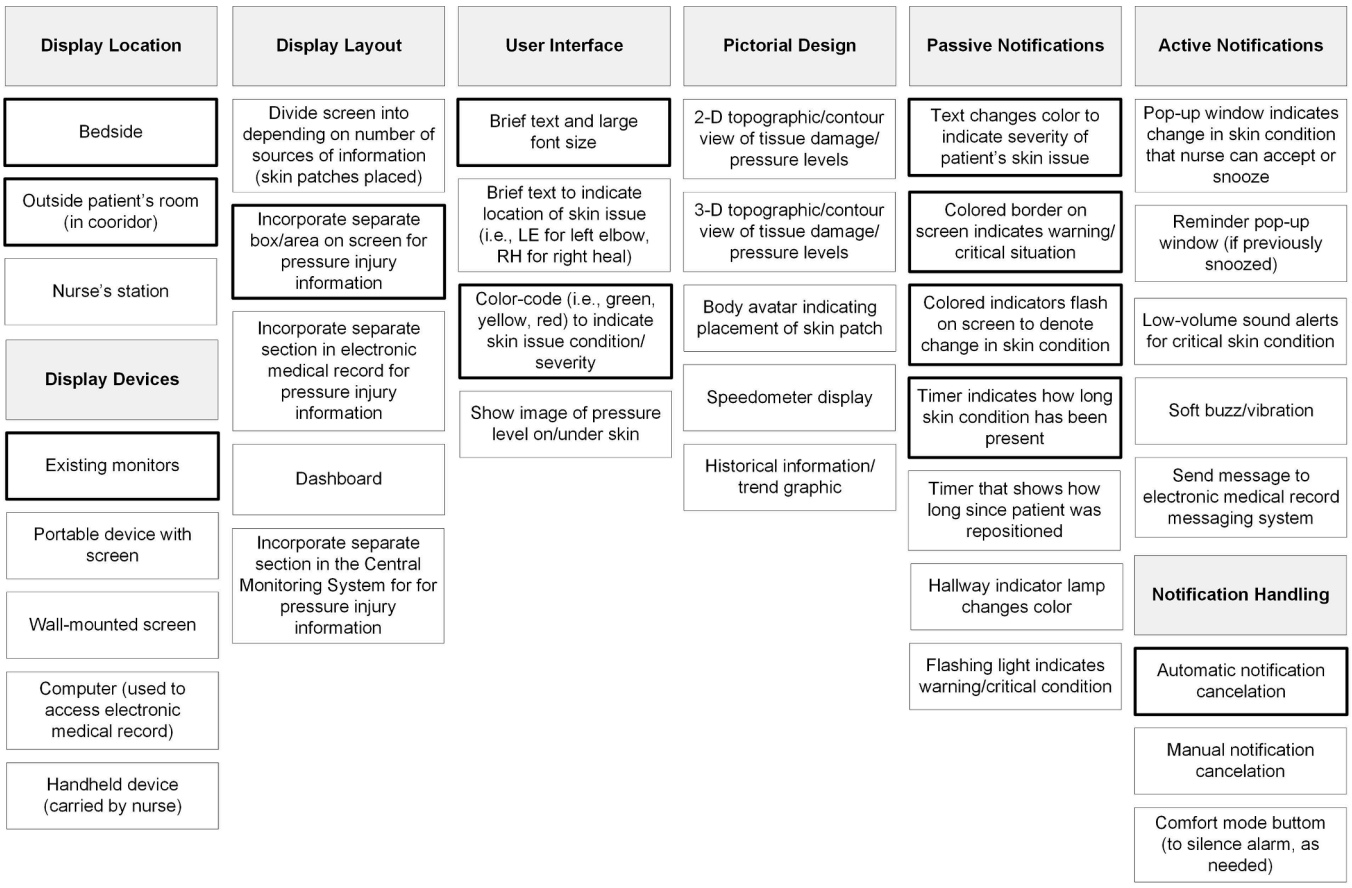

Fig. 4. Preliminary Design Ideas (with example of one design option denoted by bold boxes).

Table 2
Evaluation of detailed design options (with selected design option denoted in gray).

Selection Criteria (top-rated needs/features)	Design Alpha				Design Beta			
	P1	P2	P3	P4	P1	P2	P3	P4
Information is communicated at-a-glance (quickly, all in one place)	3	3	3	3	1	1	2	3
Information is communicated in real-time	2	2	3	3	2	2	3	3
Information is easy to understand/straightforward	3	3	3	3	1	1	3	3
Triggers/reminds nurses to take action	2	2	3	3	2	1	2	2
Aids in identifying the severity of a patient's skin condition	2	2	2	2	2	2	2	2
Facilitates decision making about the patient's treatment for issues related to their skin condition	3	2	2	2	2	2	2	2
Score	15	14	16	16	10	9	14	15
Grand Total	61				48			

P – Participant; Scale: 1 – Does not fulfill criteria; 2 – Fulfills criteria; 3 – Exceeds expectations for criteria.

P – Participant; Scale: 1 – Does not fulfill criteria; 2 – Fulfills criteria; 3 – Exceeds expectations for criteria.

issues with alarm fatigue (Cho et al., 2016). It also capitalizes on teamwork within ICUs (Donovan et al., 2018) by providing a way for nurses to request help from others, as needed.

Limitations

Limitations of this research include that data were collected from subjects working at just two Houston area medical institutions, and aspects of this study relied on small sample sizes for interviews, focus groups, etc. While this research strived to reach saturation with respect to data collection efforts, larger sample sizes and/or the inclusion of subjects from additional facilities may have led to different results; hence, the findings of this study may not be generalizable to all healthcare settings, especially given that this research focused on the ICU environment.

Conclusion

The literature describes many technologies being investigated to help prevent the incidence/severity of HAPIs (Scafide et al., 2020). In support of this, the findings regarding ICU nurses' needs identified through this research will be useful for the development of such devices. For example, to support the adoption of new medical devices in clinical settings, in addition to the device providing meaningful information, developers also need to establish ways for the devices to communicate actionable patient information to clinicians. No matter how well the device works, if the information it provides is not presented in an intuitive way and/or is not integrated within their current workflow, clinicians are not likely to use it (Holden and Karsh, 2010, Waterson et al., 2013). To address this issue, this research used the needs of ICU nurses as the foundation for designing key elements of a device to detect HAPIs, which fits into the current nursing workflow.

CRediT authorship contribution statement

Jamison V. Kovach: Methodology, Formal analysis, Investigation, Writing – original draft, Visualization, Project administration. **Luca Pollonini:** Conceptualization, Resources, Writing – review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Alves, P., Black, J.M., Gefen, A., Kottner, J., Santamaria, N., 2019. Meeting report: Addressing risk factors with evidence-based technologies for the prevention and treatment of pressure injuries in different healthcare settings. Wounds Int. 10 (3), 76–81.

Anderson, M. (2018). Universal pressure ulcer prevention bundle with WOC nurse support: A pressure injury prevention journey. Pressure Injury, Diabetes and Negative Pressure Wound Therapy. Recent Clinical Techniques, Results, and Research in Wounds. S. M. and L. M. Switzerland, Springer: 31-41.

Arditi, C., Rège-Walther, M., Durieux, P., Burnand, B., 2017. Computer-generated reminders delivered on paper to healthcare professionals: Effects on professional practice and healthcare outcomes. Cochrane Database Syst. Rev. (7).

Bergman, L., Falk, A.C., Wolf, A., Larsson, I.M., 2021. Registered nurses' experiences of working in the intensive care unit during the COVID-19 pandemic. Nurs. Crit. Care 26 (6), 467–475.

Bergstrom, N., Braden, B.J., Laguzza, A., Holman, V., 1987. The Braden Scale for predicting pressure sore risk. Nurs. Res. 36 (4), 205–210.

Berlowitz, D., Lukas, C., Parker, V., Niederhauser, A., Silver, J., Logan, C., Ayello, E.A., Zulkowski, K., 2014. Preventing Pressure Ulcers in Hospitals - A Toolkit for Improving Quality of Care. Agency for Healthcare Research and Quality, Rockville, MD.

Braden, B.J., Maklebust, J., 2005. Preventing Pressure Ulcers with the Braden Scale: An update on this easy-to-use tool that assesses a patient's risk. Am. J. Nurs. 105 (6), 70–72.

Bryant, R.A., Moore, Z.E.H., Iyer, V., 2021. Clinical profile of the SEM Scanner—Modernizing pressure injury care pathways using Sub-Epidermal Moisture (SEM) scanning. Expert Rev. Med. Devices 18 (9), 833–847.

Cho, O.M., Kim, H., Lee, Y.W., Cho, I., 2016. Clinical alarms in intensive care units: Perceived obstacles of alarm management and alarm fatigue in nurses. Healthc. Inf. Res. 22 (1), 46–53.

Chung, P., Rowe, A., Etemadi, M., Lee, H., Roy, S., 2013. Fabric-based pressure sensor array for decubitus ulcer monitoring. 2013 35th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), Osaka, Japan. IEEE.

Coyer, F., Cook, J.-L., Doubrovsky, A., Campbell, J., Vann, A., McNamara, G., 2019. Understanding contextual barriers and enablers to pressure injury prevention practice in an Australian intensive care unit: An exploratory study. Austr. Crit. Care 32 (2), 122–130.

Coyer, F., Miles, S., Gosley, S., Fulbrook, P., Sketcher-Baker, K., Cook, J.-L., Whitmore, J., 2017. Pressure injury prevalence in intensive care versus non-intensive care patients: A state-wide comparison. Austr. Crit. Care 30 (5), 244–250.

Creswell, J.W., Plano Clark, V.L., 2018. Designing and Conducting Mixed Methods Research. SAGE Publications.

Day, B., Pollonini, L., 2020. A wearable diffuse optical tomography patch for investigating pressure injuries. Optical Tomography and Spectroscopy, Fort Lauderdale, FL, USA. Optical Society of America.

de Mast, J., Diepstraten, G., Does, R.J.M.M., 2011. Design for Six Sigma: Method and application. Qual. Eng. 23 (2), 204–211.

Donovan, A.L., Aldrich, J.M., Gross, A.K., Barchas, D.M., Thornton, K.C., Schell-Chaple, H.M., Gropper, M.A., Lipshutz, A.K.M., 2018. Interprofessional care and teamwork in the ICU. Crit. Care Med. 46 (6), 980–990.

Edsberg, L.E., Langemo, D., Baharestani, M.M., Posthauer, M.E., Goldberg, M., 2014. Unavoidable pressure injury: State of the science and consensus outcomes. J. Wound Ostomy Cont. Nurs. 41 (4), 313–334.

EPUAP/NPIAP/PPPIA (2019). Prevention and treatment of pressure ulcers/injuries: Clinical practice guide. E. Haesler, European Pressure Ulcer Advisory Panel, National Pressure Injury Advisory Panel and Pan Pacific Pressure Injury Alliance.

Etafa, W., Argaw, Z., Gemechu, E., Melese, B., 2018. Nurses' attitude and perceived barriers to pressure ulcer prevention. BMC Nurs. 17 (1), 1–8.

Gaspar, S., Peralta, M., Marques, A., Budri, A., Gaspar de Matos, M., 2019. Effectiveness on hospital-acquired pressure ulcers prevention: A systematic review. Int. Wound J. 16 (5), 1087–1102.

Gefen, A., Gershon, S., 2018. An observational, prospective cohort pilot study to compare the use of subepidermal moisture measurements versus ultrasound and visual skin assessments for early detection of pressure injury. Ostomy/Wound Manage. 64 (9), 12–27.

Gillespie, B.M., Walker, R.M., Latimer, S.L., Thalib, L., Whitty, J.A., McInnes, E., Chaboyer, W.P., 2020. Repositioning for pressure injury prevention in adults. Cochrane Database of Syst. Rev. (6).

Goldstone, L.A., Goldstone, J., 1982. The Norton score: An early warning of pressure sores? J. Adv. Nurs. 7 (5), 419–426.

Guest, J.F., Fuller, G.W., Vowden, P., 2020. Cohort study evaluating the burden of wounds to the UK's National Health Service in 2017/2018: Update from 2012/2013. BMJ Open 10 (12), e045253.

Gunningberg, L., Bååth, C., Sving, E., 2018. Staff's perceptions of a pressure mapping system to prevent pressure injuries in a hospital ward: A qualitative study. J. Nurs. Manag. 26 (2), 140–147.

Hasenkamp, T., 2010. Engineering Design for Six Sigma-a systematic approach. Qual. Reliab. Eng. Int. 26 (4), 317–324.

Holden, R.J., Karsh, B.-T., 2010. The technology acceptance model: Its past and its future in health care. J. Biomed. Inform. 43 (1), 159–172.

Hoogendoorn, M.E., Brinkman, S., Bosman, R.J., Haringman, J., de Keizer, N.F., Spijkstra, J.J., 2021. The impact of COVID-19 on nursing workload and planning of nursing staff on the Intensive Care: A prospective descriptive multicenter study. Int. J. Nurs. Stud. 121, 104005.

Hu, L., Sae-Sia, W., Kitrungrote, L., 2021. Intensive care nurses' knowledge, attitude, and practice of pressure injury prevention in China: A cross-sectional study. Risk Manage. Healthc. Policy 14, 4257–4267.

Khojastehfar, S., Ghezeljeh, T.N., Haghani, S., 2020. Factors related to knowledge, attitude, and practice of nurses in intensive care unit in the area of pressure ulcer prevention: A multicenter study. J. Tissue Viab. 29 (2), 76–81.

Labeau, S.O., Afonso, E., Benbenishty, J., Blackwood, B., Boulanger, C., Brett, S.J., Calvino-Gunther, S., Chaboyer, W., Coyer, F., Deschepper, M., François, G., Honore, P.M., Jankovic, R., Khanna, A.K., Llaurado-Serra, M., Lin, F., Rose, L., Rubulotta, F., Saager, L., Williams, G., Blot, S.I., 2021. Prevalence, associated factors and outcomes of pressure injuries in adult intensive care unit patients: the DecubICUs study. Intensive Care Med. 47 (2), 160–169.

Mirshekari, L., Tirgari, B., Forouzi, M.A., 2017. Intensive care unit nurses' perceived barriers towards pressure ulcer prevention in South East Iran. J. Wound Care 26 (3), 145–151.

Mohammadi, M., Mazloumi, A., Kazemi, Z., Zeraati, H., 2015. Evaluation of mental workload among ICU ward's nurses. Health Promot. Perspect. 5 (4), 280.

Nightingale, P., Musa, L., 2021. Evaluating the impact on hospital acquired pressure injury/ulcer incidence in a United Kingdom NHS Acute Trust from use of sub-epidermal scanning technology. J. Clin. Nurs. 30 (17–18), 2708–2717.

Norton, D., Exton-Smith, A.N., McLaren, R., 1962. An Investigation of Geriatric Nursing Problems in Hospital. UK, National Corporation for the Care of Old People, London.

Padula, W.V., Delarmente, B.A., 2019. The national cost of hospital-acquired pressure injuries in the United States. Int. Wound J. 16 (3), 634–640.

Pyzdek, T., Keller, P.A., 2014. The Six Sigma Handbook: A Complete Guide for Green Nelts, Black Belts, and Managers at All Levels. McGraw-Hill Professional, New York.

Richardson, A., Peart, J., Wright, S.E., McCullagh, I.J., 2017. Reducing the incidence of pressure ulcers in critical care units: A 4-year quality improvement. Int. J. Qual. Health Care 93 (3), 1–7.

Scafide, K.N., Narayan, M.C., Arundel, L., 2020. Bedside technologies to enhance the early detection of pressure injuries: A systematic review. J. Wound Ostomy Continence Nurs. 47 (2), 128–136.

Sebastián-Viana, T., Losa-Iglesias, M., González-Ruiz, J.M., Lema-Lorenzo, I., Nunez-Crespo, F.J., Fuentes, P.S., 2016. Reduction in the incidence of pressure ulcers upon implementation of a reminder system for health-care providers. Appl. Nurs. Res. 29, 107–112.

Sligo, J., Gauld, R., Roberts, V., Villa, L., 2017. A literature review for large-scale health information system project planning, implementation and evaluation. Int. J. Med. Inf. 97 (1), 86–97.
Tayyib, N., Coyer, F., Lewis, P.A., 2016. Implementing a pressure ulcer prevention bundle in an adult intensive care. Intensive Crit. Care Nurs. 37, 27–36.
Team, V., Tuck, M., Reeves, J., Way, M., Enticott, J., Evans, S., Weller, C.D., 2020. Pressure injury data in Australian acute care settings: A comparison of three data sets. Int. Wound J. 17 (3), 578–586.
Tsuda, Y., Odagaki, M., Kondo, Y., 2020. Development of a sensor with a conductive textile for detecting decubitus ulcers. IEEJ Trans. Electr. Electron. Eng. 15 (7), 1065–1069.
Waterlow, J., 2005. From costly treatment to cost-effective prevention: Using Waterlow. Br. J. Community Nurs. 10 (Sup3), S25–S30.
Waterlow, J.A., 1985. A risk assessment card. Nurs. Times 81, 51–55.
Waterson, P., Hoonakker, P.L., Carayon, P., 2013. Special issue on human factors and the implementation of health information technology (HIT): comparing approaches across nations. Int. J. Med. Inf. 82 (5), 277–280.
West, J., 2020. Design in healthcare: The challenge of translation. Design for Health 4 (2), 252–269.
Yang, Y., 2005. Design for Six Sigma for Service. McGraw-Hill, New York.
Zuo, X.-L., Meng, F.-J., 2015. A care bundle for pressure ulcer treatment in intensive care units. Int. J. Nurs. Sci. 2 (4), 340–347.