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Pressure Injury Prevention for Complex Cardiovascular Patients in the Operating Room and Intensive Care Unit

A Quality Improvement Project

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ABSTRACT

PURPOSE: The purpose of our project was to examine the effect of an alternating pressure (AP) overlay on hospital-acquired pressure injury (HAPI) in high-risk cardiovascular surgical patients.

PARTICIPANTS AND SETTING: This quality improvement (QI) initiative was conducted in a core group of 8 cardiovascular operating room (OR) suites and 1 cardiovascular surgical critical intensive care unit (ICU) in a large Indiana-based academic hospital. The sample comprised adult patients who underwent complex cardiovascular surgical procedures and those in the cardiovascular surgical ICU with extracorporeal membrane oxygenation (ECMO), ventricular assistive device (VAD), and undergoing heart and/or lung transplant, or open chest procedures.

APPROACH: The AP overlay was placed on OR cardiovascular foam surfaces and on selected ICU support surfaces for patients who met inclusion criteria. We used a pre/postcomparative QI design to assess outcomes including OR-related HAPI rates, ICU aggregate unit HAPI data, related costs, and staff satisfaction during the 3-month project period.

OUTCOMES: Operating room-related HAPIs were reduced from 8/71 (11%) preintervention to 0/147 (0%) postintervention ($P = .008$), resulting in a cost avoidance of $323,048 and positive staff satisfaction (mean = 3.85; 1- to 4-point Likert scale). No adverse outcomes occurred. Although not significant, ICU HAPI rates decreased from 10 to 7 pre/postintervention ($P = .29$), demonstrating a 14% HAPI reduction with a cost avoidance of $121,143. The ICU incidence density decreased from 3.57 to 3.24; however, there was no decrease in ICU monthly unit prevalence. Critical care staff satisfaction was positive (mean = 2.95; 1- to 4-point Likert scale) with most staff members preferring the AP overlay to a fluid immersion surface. A cost savings of 48% (AP overlay vs fluid immersion rental) was identified in the ICU.

IMPLICATIONS FOR PRACTICE: We achieved fewer HAPIs and reduced costs and observed positive staff satisfaction, along with no adverse events with the use of the AP overlay. Further research is needed to determine the safety and efficacy of this device for this pressure injury prevention option for immobile patients in both the OR and the ICU.

KEY WORDS: Alternating air pressure overlay, Cardiovascular, Critical care, Hospital-acquired pressure injuries, Intensive care, Operation room, Pressure injury, Pressure ulcer, Prevention, Quality improvement.

INTRODUCTION

Prevention of hospital-acquired pressure injuries (HAPIs) is an important patient safety priority in healthcare settings because they have negative physical and financial implications. Mortality and length of stay for patients with pressure injuries are more than 2-fold higher than those for patients without pressure injuries; those with injuries experience a 30% likelihood of readmission within 30 days of discharge.[1] Despite decades of preventive efforts, HAPI is one of the only hospital-acquired conditions that has continued to increase since 2015.[2,3] Critically ill cardiovascular surgical patients are especially at risk due to their complex medical conditions and exposure to prolonged surgical procedures. These patients often

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exhibit poor tissue tolerance due to hypoperfusion, inadequate tissue oxygenation, nutrition, and prolonged immobility, in combination with long perioperative times.[1] Additional risk factors for development of an HAPI include advanced age, severity of illness, comorbid conditions including diabetes mellitus, sepsis, vascular disease, low arteriolar pressure, prolonged critical care stay, and use of vasopressor agents.[4,5] However, these risk factors do not sufficiently explain all of the risk in specialized groups of patients, specifically those in the intensive care unit (ICU) and those undergoing prolonged surgeries.

Research shows HAPI rates range from 2.8% to 53.4% among patients in critical care units compared to 2.0% to 8.3% among those in medical-surgical units; many are perioperative-related.[3,6] Pressure injuries occur 2 to 3 times more often in surgical patients, especially in the postsurgical critical care patient population, and have been attributed to the perioperative period.[1] Patients undergoing surgery are at an especially high risk for pressure injury development because they are immobile for long periods of time, on a relatively hard surface, and unable to reposition. In addition, patients experience a loss of sensation due to anesthesia, tissue perfusion deficits due to hypotension and administration of vasoactive medications, pressure from medical-related devices, and friction and/or shear.[7] Operating room (OR)–related HAPIs can be described as those occurring within 72 hours postsurgery and corresponding to the positioning used in surgery.[8] A systematic review by Chen and colleagues[4] reported the incidence of OR-related HAPIs to be as high as 57%, with a pooled incidence of 15%, and has increased during the previous 5 years. Many hospitals are now monitoring and tracking pressure injuries that may be associated with the OR and surgical procedures in order to identify new and effective preventive interventions for this population.

Due to the identification of a high number of OR-related HAPIs, up to 30%, in our large Midwestern academic health center and the complexity of the patient population, a team of ICU and surgical nurses within this organization explored new HAPI prevention strategies for both the OR and the cardiovascular ICU. A dynamic alternating pressure (AP) overlay was identified that offers a new and innovative HAPI prevention technology for complex surgical patients. The unique nodal design in this AP overlay provides low-profile intermittent tissue off-loading. This is accomplished by inflating and deflating multiple rows of air-filled geometric nodes dynamically in alternating sequence every 5 minutes. Two zones are controlled by the computerized device providing the alternating air fill of the nodes. The low-profile design of this overlay allows for micropressure relief and reduction of shear without appreciable movement in the surgical field (Figure 1).[9] The team of OR and ICU nurses chose a clinically pragmatic quality improvement (QI) strategy to explore the use of this AP overlay in the complex cardiovascular population.

The purpose of this QI project was to examine the effect of the AP overlay on HAPI prevention in high-risk cardiovascular surgical patients in both the OR and the ICU. The specific aims of the project were to: (1) examine the effect of the AP overlay to reduce OR-related HAPI rates in cardiovascular surgical patients having extended (≥10 hours) surgery; (2) examine the effect of the AP overlay to reduce HAPI incidence and prevalence in a cardiovascular ICU; (3) compare cost of the AP overlay to usual/standard care; (4) examine safety events related to the use of the AP overlay in the OR and the ICU; and (5) examine healthcare professionals' satisfaction when using an AP overlay in high-risk patients.

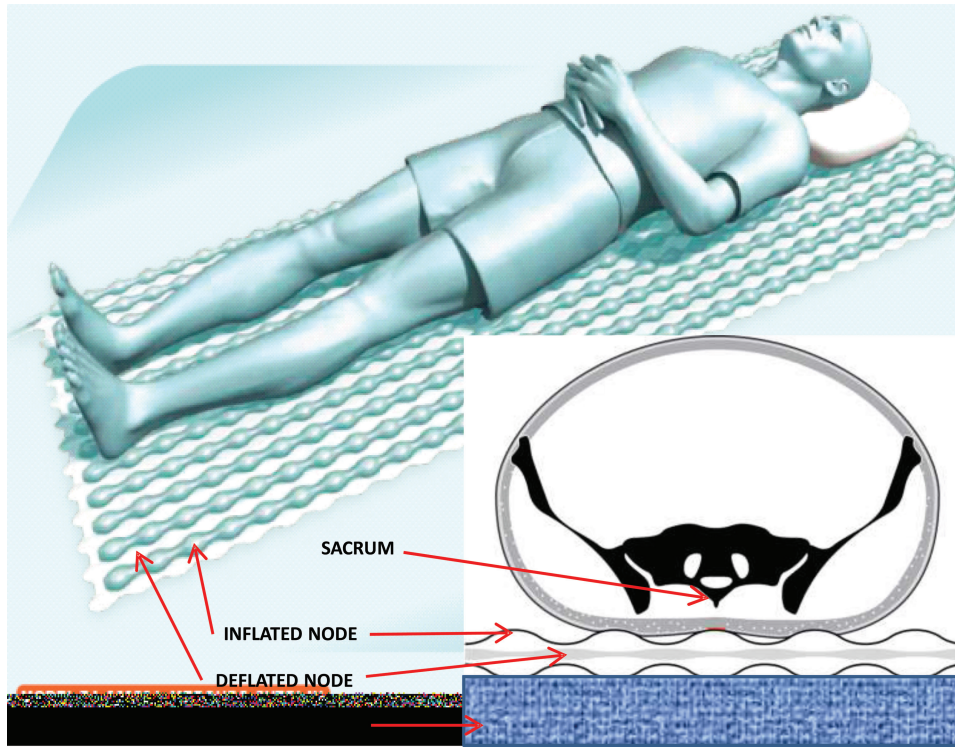

Figure 1. Alternating pressure overlay with pressure points.

APPROACH

Using the SQUIRE (Standards for Quality Improvement Reporting Excellence) guidelines[10] for QI reporting as a framework, this pre/postcomparative design project was conducted over 6 months, February 2018 to July 2018. The number and proportion of HAPIs attributed to the OR, ICU aggregate HAPI data (incidence and prevalence), related costs of surfaces, and staff satisfaction were examined following implementation of an AP overlay in a large urban Indiana-based level 1 trauma academic health center. Data were collected in 8 OR suites and selected bed support surfaces in one 34-bed cardiovascular ICU. The 8 OR suites were chosen because complex and prolonged cardiovascular surgical procedures are performed in these suites. The ICU was selected because it provides care to patients operated on in the OR suites. Selection criteria included those ICU patients managed by extracorporeal membrane oxygenation (ECMO), ventricular assistive device (VAD), and undergoing heart and lung transplant and open chest procedures. In addition, we included patients with 10 hours or greater OR times required for thoracoabdominal aortic aneurysm repairs and complex surgeries involving deep hypothermic circulatory arrest.

Monthly HAPI prevalence and incidence density in the ICU were compared 3 months pre- and postintervention. The rationale for this outcome measure was due to the HAPI prevalence data that were readily accessible via the monthly quality unit data. Intensive care unit incidence data were reviewed throughout the project for relevance to the bed surface; specifically only those HAPIs that occurred on a body location such as sacrum, heels, scapula, and head that was in contact with the bed surface were included in the incidence data. Operating room-related HAPIs were identified using quality data and review of the medical record. Indiana University Institutional Review Board approved this study as an exempt study; no informed consent was necessary.

Evidence-based pressure injury prevention strategies are a standard of care in this healthcare organization. The standard of care for the complex cardiovascular population in the ICU included rental fluid immersion support surfaces, frequent repositioning, prophylactic foam dressings, heel protection, incontinence management, and nutrition strategies. Standard of care for the cardiovascular surgical population in the OR included 3-inch high-density foam surfaces, procedural positioning, gel pads, positioners, pads, blankets, prophylactic foam sacral dressings, heel elevation, eggcrate foam positioning devices, and nutrition and moisture management measures.

Application of the AP overlay (Dabir Micropressure Operating Table Surface, Dabir Surfaces, Chicago, Illinois) was the intervention used in addition to the standard pressure injury prevention strategies in the OR and the ICU (Figure 1). The cardiovascular surgery core had 8 OR suites where the AP overlay was designated and applied to those OR tables. The AP overlay remained in use during the entire length of the procedure.

In addition, the AP overlay was placed on the support surfaces of those patients meeting criteria in the cardiovascular surgical ICU. Instead of renting a fluid immersion support surface for the selected complex cardiovascular population in the ICU, the AP overlay was placed on top of the standard low air loss ICU surface/bed. The AP overlay was used during the entire patient stay in the ICU. All other standard care pressure injury prevention strategies continued during the time frame of this project.

All staff members in both the OR and the ICU received training related to the use of the AP overlay. Group training sessions were provided to staff by the manufacturer's clinical representative that included AP overlay purpose, use, pump, placement implementation, maintenance, cleaning, troubleshooting, and resources. Project team nurses (trained ICU nurses and clinical nurse specialists) rounded Monday through Friday and as needed to provide ongoing support to both OR and ICU staff. The project team nurses were also available by phone if problems or questions arose after hours or on weekends.

OUTCOME ANALYSIS

Monthly prevalence and incidence density data for the cardiovascular ICU were collected as they were readily available in the aggregate and were compared pre- and postintervention using unpaired Student's *t* tests. Unit incidence density was calculated using the number of unit HAPIs × 1000/unit patient-days. Operating room-related HAPIs were collected and compared using unpaired Student's *t* tests for those surgeries performed in the 8 OR suites that occurred during the study time frame. The HAPI cost information available in the literature was used to project HAPI avoidance costs.[11] Unit prevalence and incidence density data were obtained via quality and internal risk reporting mechanisms already in place. The unit rental cost of the fluid emersion surfaces used in the ICU preintervention and the estimated cost of the AP overlay for the same number of surface days were compared. Safety events occurring during the intervention time frame were also collected in both the OR and the ICU. Staff satisfaction was measured using a self-report 6-item Likert scale scored from 1 to 4 (strongly disagree to strongly agree). The items evaluated ease of use, comfort, and overall satisfaction and provided a space for comments. This questionnaire, designed for purposes of this study, was distributed to all staff members who used the AP overlay. The higher the score, the higher the satisfaction.

RESULTS

In the OR during the 3-month preintervention time frame, 11% (8/71) patients developed an OR-related HAPI. No OR-related HAPI occurred postintervention ($P = .008$; Figure 2). Cost analysis at the time of this project indicated an OR-related HAPI cost avoidance of $323,048 for 3 months (8 HAPIs preintervention at $40,381 each).[11] When

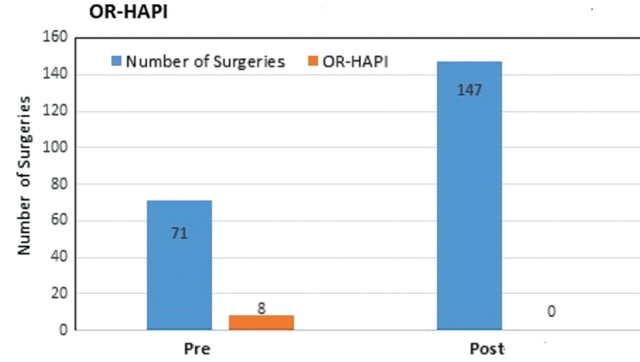

Figure 2. Operating room–related hospital-acquired pressure injuries pre- and postintervention. OR-HAPI indicates operating room–related hospital-acquired pressure injury.

annualized, this finding indicates a projected $1,292,192 potential total cost savings. Zero safety events occurred in the OR using the AP overlay. Operating room staff satisfaction surveys demonstrated positive results with a mean of 3.85 (1- to 4-point Likert scale).

In the ICU, HAPI incidence decreased from 14 HAPIs that developed in the 3-month preintervention period to 10 HAPIs postintervention. Following a review of these HAPI data, 10 HAPIs occurred on body locations (shoulder, coccyx, sacrum, ischium, heel) in contact with the AP overlay, while 4 occurred on body locations (ear, scalp, lip, Achilles tendon area) not in contact with the AP overlay. A reduction in ICU HAPI prevalence (all patients in the ICU) was still found, from 10 to 7 pre- to postintervention ($P = .29$). Although not statistically significant, this decrease demonstrated a 14% (N = 3) HAPI reduction, with a cost avoidance of $121,143 calculated by multiplying 3 HAPIs by recent cost figures to treat $40,381 each.[11] When annualized, the projected cost avoidance was $484,572. The ICU monthly incidence density decreased from 3.57 to 3.24; however, our analysis found no significant decrease in the monthly ICU prevalence of HAPIs. Due to the difference in charging methods per fluid emersion surface versus AP overlay base unit plus overlay and to more accurately compare costs, the usage cost was calculated using the actual preintervention fluid emersion surface rental cost and the estimated number of AP overlay units needed to replace these fluid emersion surfaces. Preintervention (over 3 months February through April) the fluid emersion surface cost was $12,870 for 234 surface-days. Replacing the AP overlay for the fluid emersion surface for 234 surface-days, the rental cost per AP overlay surface with 775 hours (~32 surface-days) was estimated at $7000. We calculated this amount as follows: $10,500 annual cost/12 months = $875/month/surface; 234 surface-days/32 surface-days/surface = 7.3 AP overlay surfaces; 8 surfaces × $875 = $7000. This would result in a cost savings of 48%. No adverse safety events were identified. Staff satisfaction was positive (mean = 2.95; 1- to 4-point Likert scale); most staff members preferred the AP overlay to the fluid immersion surface.

DISCUSSION

Pressure injury development continues to be a serious issue in the acute care setting and especially in the critical care population. Those HAPIs that develop following a complex or prolonged surgical procedure have become a primary area of concern for patient harm and a potential area for prevention opportunities. Our QI project demonstrates the preventive use of an innovative, low-profile AP overlay to reduce OR-related HAPIs and HAPIs in the complex cardiovascular population.

There is other evidence in the literature that demonstrates the potential benefit of the AP overlay to reduce pressure injuries.[9,12-14] Karg and colleagues[9] examined the effects of an AP overlay on sacral skin perfusion in 20 healthy subjects while on an OR surface. Although not statistically significant, the mean sacral blood flow of the subjects on the AP overlay was 40% greater than when on the OR pad alone during full inflation/deflation cycle and 76% greater during the deflation time. This study also demonstrated significant periodic off-loading of pressure to the sacral area when on the AP overlay.[9] Our project supports these findings, suggesting the AP overlay may provide time to restore blood flow and help prevent ischemia in the affected area during prolonged procedures.

Our project findings also confirm the work of Joseph and colleagues,[12] who compared 100 neurosurgical subjects placed on the AP overlay to 292 neurosurgical subjects with no AP overlay. No HAPIs were identified in the AP overlay group within 5 days postoperatively, and these researchers found that an AP overlay could be used safely in neurosurgery cases.[12]

The findings from the prospective case-control study by Ezeamuzie and colleagues[13] were also congruent with our results. In their study of 212 (108 control patients and 104 AP overlay patients) OR and neurosurgical intensive care patients, the investigators demonstrated a significant HAPI reduction in the AP overlay group ($P = .014$).[13] Only one pressure injury developed in the AP overlay group compared to 7 in the control group. Another significant difference noted between the groups in the Ezeamuzie[13] study was the AP overlay group surgical duration was significantly longer as compared to the control group. This aligns with our finding of reduced HAPIs in the OR and the ICU. Finally, in a pre- and postobservational study of 126 long-term care residents, HAPI incidence was compared before and after implementation of the AP overlay. A significantly lower HAPI incidence (0/25; 0%) was identified with the use of the AP overlay as compared with HAPI incidence (22/101; 21.8%; $P < .001$) before the AP overlay was implemented.[14] In summary, there is ample evidence of the positive effect the use of the AP overlay has on HAPI development.

The Association of periOperative Registered Nurses (AORN) has focused on the importance of pressure injury prevention in the OR and is one of the leaders in promoting new methods and strategies for HAPI prevention in the perioperative setting. The AORN has recently released an updated pressure injury tool kit for the perioperative setting that supports consideration of emerging positioning technologies to redistribute pressure.[15] The organization encourages leadership to be the voice for innovation and new technology, trialing cutting-edge products, and spreading the benefit of these new technologies to staff and OR teams.[16] Nurses in the OR face unique challenges to prevent HAPIs due to patients' specific positioning needs, prolonged immobility when undergoing complex surgeries, and the need to be efficient in maintaining the surgery schedule while considering patient safety through transitions across various aspects of immobility (ie, preassessment area, OR suite, and recovery area). Despite these unique challenges in the OR, our QI project demonstrated the preventive use of an emerging innovative surface (a low-profile AP overlay) to reduce pressure injuries and augment standard prevention strategies.

Our findings also support the recommendations provided in the 2019 International Prevention and Treatment of Pressure Ulcers: Clinical Practice Guideline.[17] The guideline recommends the use of a pressure redistribution surface in the OR for those individuals at risk of pressure injuries and recommends that a low-profile AP overlay should be considered.[17] The AP overlay used in our QI project fits this description.

In our project, unfortunately, the incidence of HAPIs was only slightly decreased, especially in the complex cardiovascular surgical ICU population; we were not able to show a significant decrease in ICU prevalence or incidence. This may be explained by the high number of patients in the unit who did not meet project selection criteria and who were not placed on the AP overlay during the 3-month time frame. Many of these patients were critically ill with respiratory conditions (not cardiovascular) and developed HAPIs on body locations such as

device-related injuries to the nose that were not impacted by a surface change. This QI project was designed to address the increased HAPI rates in the complex cardiovascular patients with ECMO, VAD, undergoing heart and lung transplant, and open chest procedures and who had prolonged OR times. Because aggregate unit HAPI data were the measured project outcome, this unusual influx of patients with respiratory conditions rather than cardiovascular patients influenced the diagnostic mix of the unit, thus the rationale for the number of patients selected for application of the AP overlay, influencing the HAPI monthly prevalence. However, importantly, we were able to identify a cost savings comparing usual care (rental of immersion surfaces) and the AP overlay use in the cardiovascular ICU.

The complexity of patients in the OR suite who are immobile for long periods of time with loss of sensation due to anesthesia and often with tissue perfusion deficits constitutes an especially high risk for pressure injury development. For this reason, identifying effective preventive interventions for the OR is an important consideration. The AP overlay used in our project is an example of an emerging innovative surface to address pressure injury prevention in complex surgical patients. In the OR, because we were not replacing any standard care prevention strategies, adding the cost of this AP overlay is a consideration. However, HAPI cost avoidance with the use of this AP overlay and prevention of OR-related HAPIs are major benefits and need to be considered. This concurs with the work of Padula and colleagues,[18] who examined whether prevention methods are cost-effective when compared to standard care. Padula and colleagues[18] demonstrated that it is more cost-effective to pay for HAPI prevention than for standard care alone. Our findings demonstrated that HAPI cost avoidance was substantial for this healthcare organization. In addition, staff satisfaction was positive and supported the use of the AP overlay in both the OR and the ICU.

STRENGTHS AND LIMITATIONS

One major limitation of this QI project was the choice of outcome data for the ICU. This was a pre/postcomparison of aggregate unit HAPI data, not individual patient data. Individual patients were not followed but rather aggregate unit data were collected. The rationale for this outcome measure was due to the availability and ease of obtaining the HAPI outcome data. The project team consisted of direct care nurses (ICU and OR), an OR nurse educator, and clinical nurse specialists who continued their usual clinical responsibilities and patient assignments. A more rigorous project design such as a randomized controlled trial is challenging when conducted by clinically active nurses in the acute care setting and still performing their usual responsibilities. Aggregate data as the outcome measure were selected because these were readily available through monthly quality prevalence and incidence data collection; however, this limited the rigor of this project. Another limitation of this project was the complexity of the setting (level I trauma setting) and the complex cardiovascular population. This setting performs the most complex and prolonged surgical procedures and cares for a very complex cardiovascular population. This limits the generalizability to other less complex settings and less complex populations.

A strength of this project was that it was clinically relevant and nurse-driven. The project was designed using a pragmatic or "real-world" approach that suited the situation and work of the project team to realistically accomplish and complete this QI project. The QI project team identified OR-related HAPIs as a major problem in the complex cardiovascular population in the ICU. In addition, the QI project team identified the potential HAPI-reducing innovative intervention (AP overlay) to examine. Another strength of the project was the expertise and clinical experience of the QI project team that added credibility and relevance to the work. This team was composed of 1 PhD-prepared nurse, 3 clinical nurse specialists, 2 ICU RNs, 1 OR educator, and 4 OR coordinators. This provided a diverse QI project team and represented the nurses in the OR and the ICU who advocated for additional HAPI prevention options for their patient populations.

IMPLICATIONS FOR PRACTICE

This project provides important information regarding the use of an innovative pressure redistribution surface for HAPI prevention in the OR and ICU setting. Both the OR and the ICU settings have unique challenges related to preventing HAPIs. However, our project suggests the effective use of an emerging innovative surface, a low-profile AP overlay, to reduce pressure injury and augment current prevention strategies. Immobility and patient safety are major aspects of care for both OR and the ICU nurses. Nurses must be mindful and integrate evidence-based prevention strategies into their work as their patient population is extremely immobile for prolonged periods of time and unable to self-turn and/or reposition. This project examined an evidence-based intervention that promotes safe passage or transition across the perioperative and critical care settings. Based on the outcome of this project, request for integration of the AP overlay into the organizational pressure injury prevention strategies has been submitted to leadership. However, full implementation has been delayed due to the COVID-19 pandemic. Implementation is currently being planned.

CONCLUSION

Despite pressure prevention strategies in the acute care setting, pressure injuries continue to increase. This QI project demonstrated that the addition of this AP overlay decreased OR-related HAPIs, resulted in cost savings, and provided a cost avoidance of potential HAPIs. The AP overlay was also safe and easy to deploy and be maintained by staff. It offers an additional innovative pressure injury prevention option for immobile patients in both the OR and the ICU, potentially decreasing costs for healthcare organizations.

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