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A return-on-investment model using clinical and economic data related to safe patient handling and mobility programs in the ICU

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ABSTRACT

Safe Patient Handling and Mobility (SPHM) programs are well-established to reduce patient-handling related injuries among healthcare workers (HCWs). Evidence also suggests SPHM practices promote early mobilization (EM) and help reduce preventable hospital-acquired complications among intensive care unit (ICU) patients. However, research on the economic benefits of SPHM is limited, particularly related to patient outcomes. These evidence gaps make it difficult for hospitals to accurately estimate return on investment (ROI) for a SPHM program implementation or expansion. The purpose of this paper is to summarize the evidence of SPHM programs on HCWs and patient outcomes necessary to develop a ROI model for the ICU setting. A structured search of SPHM literature on the following three key variables (1) HCW patient-handling related injuries, (2) hospital-acquired conditions, including pressure injuries (PI), ventilator-associated pneumonia (VAP), and venous thromboembolisms (VTE), and (3) ICU Length of Stay (LOS) and mechanical ventilator (MV) days, was conducted. Findings suggest significant heterogeneity in terms of sample sizes, patient populations, interventions, and outcome measures among studies conducted on these key variables. An example ROI model is presented to demonstrate how the published evidence and its variability can be used when estimating the potential economic benefit of SPHM in an ICU.

Relevance to industry. This work provides a summary of literature findings and a demonstration of how facilities can use the published evidence to customize a ROI estimate for any proposed SPHM program implementation or expansion in the ICU.

1. Introduction

Manual handling, moving, and mobilizing of patients in hospitals can result in substantial clinical and economic consequences for both healthcare workers (HCWs) and patients (Matz, 2019). According to the Bureau of Labor Statistics (BLS), it is the single greatest risk factor for musculoskeletal injuries in HCWs with back and shoulder injuries making up more than 71% of all workers' patient handling claims (Aon Commercial Risk Solutions, 2016; U.S. Bureau of Labor Statistics, 2018). On average, U.S. hospitals recorded 6.4 work-related injuries and illnesses for every 100 full-time equivalent (FTE) employees in 2013, compared to 3.3 per 100 FTE for all U.S. industries combined (Occupational Safety and Health Administration, 2021a). The Occupational Safety and Health Administration estimated direct and indirect costs, including costs of treatment, employee turnover, training, overtime, incident investigation time, productivity, and morale associated with only back injuries in the healthcare industry could reach $20 billion USD annually (Occupational Safety and Health Administration, 2021b). Interventions to promote safe patient handling and mobility (SPHM) have successfully helped reduce clinical and economic consequences for HCWs resulting from manual handling, moving, and mobilizing patients in hospitals. Effective SPHM programs include the use of assistive equipment, training and education, patient assessments, and continuing program evaluation (American Nurse Association, 2015). These programs have resulted in a significant reduction in patient-handling related injuries across all healthcare settings, workers' compensation (WC) costs, and lost workdays (LWDs) (Occupational Safety and Health Administration, 2013).

In addition to the risks to HCWs, manual patient handling results in significant clinical and economic consequences for patients. Dependent patients who are difficult to move through manual methods may be mobilized less often, and prolonged immobility puts patients at risk for

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serious complications. A recent series of publications by Knight et al. demonstrated almost every organ system is negatively affected when a patient is immobile (Knight et al., 2018). Prolonged immobility increases the risk of ICU-acquired conditions, such as pressure injuries (PI), ventilator-associated pneumonia (VAP), and venous thromboembolism (VTE) events. In addition, failure to mobilize can result in longer duration of mechanical ventilation and ICU length of stay (LOS). Moreover, prolonged immobility in patients can be very costly to hospitals (Agency for Healthcare Research and Quality Rockville, 2017). Despite the clinical and economic benefits of ambulating patients, it is often the most missed nursing care activity due to the lack of available assistive personnel and patient handling equipment (Kalisch et al., 2014). For hospitalized patients, although not directly linked to SPHM, early mobilization (EM) is associated with less delirium, pain, urinary discomfort, urinary tract infection, fatigue, deep vein thrombosis (DVT), pneumonia, mechanical ventilator (MV)- dependent days and improved ability to void, improved walking distance, and shortened time to return to independent ambulation (Kalisch et al., 2014).

While there are many suggested benefits of SPHM, the adoption rate of the practice is low (Dickinson et al., 2018). Benefits of SPHM associated with patient outcomes are not cohesively studied nor sufficiently quantified to inform hospitals' decisions about adopting and consistently implementing the intervention. The research gaps are most problematic for ICUs where the costs of adverse events related to prolonged immobility are highest. ICU patients have a greater likelihood of adverse events from complications of immobility compared to other hospital patients (Kress and Hall, 2014). Immobility can lengthen LOS and MV days, creating a continued cycle of opportunity for chance of increased complications, costs, morbidity, and mortality (Hermans et al., 2014; Hermans and Van den Berghe, 2015). Additionally, freeing up days in the ICU improves capacity to enable flow of patients through the hospital and surgical areas to improve access and generate critical hospital revenue. Furthermore, ICU nurses represent 7.4% of the nursing workforce and their advanced skills are particularly in short supply (National Center for Health Workforce Analysis, 2018). Any loss of this human capital due to injury or burnout may impact the quality of care, reduce capacity, and be costly for hospitals to replace. Because of these substantial clinical and operational costs in the ICU, it is particularly important the benefits of SPHM in the ICU environment are clearly defined and comprehensively summarized.

An array of equipment is used to execute an SPHM program in the ICU. Although ceiling or mobile lifts together with slings are an essential part of any SPHM program, other equipment often used includes friction reducing sheets, air assisted transfer devices, stand assist aids, stand-ambulation aids, and cardiac chairs. Much of this equipment may already be owned or procured by hospitals as part of traditional mobility programs based on manual handling, but some additional equipment requires added expense. For example, ceiling lifts are a particularly versatile tool supporting SPHM, but also require significant initial investment.

There is a need to develop a Return on Investment (ROI) model to examine the incremental clinical and economic benefits associated with the implementation of SPHM programs in the ICU setting. It is particularly timely given the extra burden of the COVID-19 pandemic on HCWs in the ICU. An effective ROI model could support decision makers to accurately assess the financial opportunity for wider adoption of SPHM. This paper summarizes the current evidence regarding the effects SPHM programs on HCWs and patients' outcomes and demonstrates how the evidence can inform development of an ROI model in the ICU setting.

2. Materials and methods

2.1. Developing a conceptual framework

A conceptual framework to determine key variables for the ROI model and identify gaps in the current body of literature regarding clinical and economic benefits of SPHM was developed. In our conceptual framework, we included *net savings* and *implementation costs* as two main components of a SPHM ROI model (Fig. 1). Net savings were calculated as the difference between current cost burden and projected cost reductions with a new or expanded SPHM program. The three key elements considered for net savings from SPHM intervention in an ICU are listed in Table 2. The first element was *ICU HCW patient-handling related injuries,* represented by HCWs' patient-handling injury rate per 100 clinical area FTE, average number of LWDs per injured worker per injury, total patient-handling injury cost, and cost to replace one injured worker shift. The second element was *patients' ICU-acquired conditions due to immobilization,* represented by annual incidence and average additional LOS days per event. The third element was *ICU volume and throughput*, represented by average ICU LOS days, MV days, and direct variable cost per ICU and MV day. Implementation costs of a SPHM program included: capital cost of purchasing the equipment, supplies and maintenance cost during usage, and training cost on the use of the equipment required for HCWs. Finally, these elements along with the SPHM costs were included in an example ROI model as presented in the Appendix.

2.2. Literature search

To gather evidence for key elements of the SPHM ROI model, we conducted a structured literature search using PubMed, Medline, CINAHL, Google Scholar, and grey literature in two rounds. The first round included the identification of key articles during the last five years (2016 to present), to capture the most recent trends in SPHM. For each variable, if two or more articles were not identified, the search was expanded to articles published in the previous ten years (from 2011 to present). After all relevant articles were identified, references from these articles were reviewed for additional relevant publications from 2000 onward.

The initial search revealed considerable evidence supporting the relationship between SPHM interventions and HCW patient handling related injuries, but little evidence on the direct connection between SPHM and ICU-acquired conditions was found. Therefore, the search related to ICU acquired conditions was expanded to consider SPHM interventions as an indirect effect through EM. We searched for evidence of associations between EM and reduced ICU-acquired conditions, and evidence connecting SPHM interventions to improve adoption of EM.

Our selection criteria followed a PICOT (P: Population, I: Intervention, C: Comparator, O: Outcomes, T: Timing) table, including the most critical outcomes for hospital decision makers, as listed in Table 1, and further described in Table 2. Only studies concerning the use of SPHM or EM program in the ICU setting, i.e., either a specific type of ICU or a typical patient-mix in a general ICU in the United States were considered. All costs were reported in US Dollars.

2.3. Definition of EM and SPHM

Finally, we defined EM as part of a comprehensive set of strategies known as the ABCDEF bundle. The ABCDEF bundle comprises *A*ssess, prevent, and manage pain; *B*oth spontaneous awakening trials and spontaneous breathing trials; *C*hoice of sedation/analgesia; *D*elirium monitoring and management; *E*arly mobility; and *F*amily engagement and empowerment (Jeffery et al., 2021; Morandi et al., 2017). In this bundle, we defined EM as any program targeting mobility progression for patients in the ICU setting, where patient mobility level ranges from bed rest to walking independently.

This ROI considers ceiling lifts as the primary capital investment together with other supply and maintenance costs. The use of ceiling lifts is consistent with the EM protocol at the Cleveland Clinic Foundation and the definition of SPHM by U.S. Department of Veteran Affairs (U.S. Department of Veteran Affairs, 2021). Ceiling lifts are associated with improved compliance compared to mobile lifts because they require less

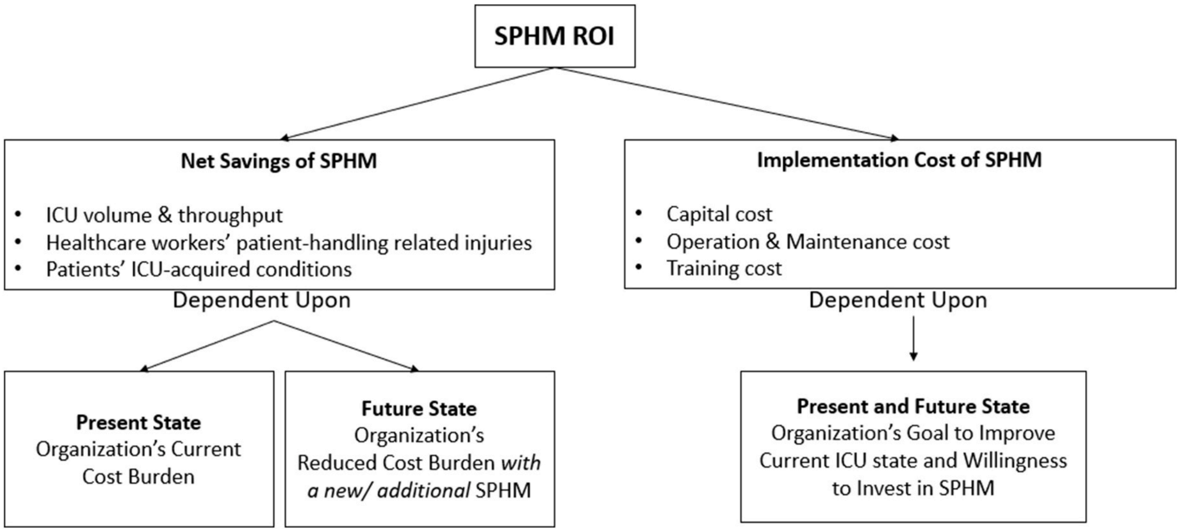

Fig. 1. ROI Conceptual Framework.

Table 1
PICOT table for Inclusion/Exclusion criteria.

Inclusion criteria	Criteria description	Exclusion criteria
P: Population	• ICU patients, representing a particular type of ICU or a typical patient-mix in a general ICU	• Any unit other than the ICU
I: Intervention (Defined in section II.3)	• Early mobilization • Safe Patient Handling and Mobility	• Any EM or SPHM intervention not as defined
C: Comparator	• Standard of care: Manual EM, manual SPHM, or no intervention at all	• Any standard of care not related to EM or SPHM
O: Outcomes (Defined in Table 2)	Inclusion of data points on the present and future state of the following measures: • HCWs' patient-handling related injuries • Patients' ICU-Acquired condition, i.e., PI, VAP, and VTE • ICU volume and throughput	• No outcomes of interest reported
T: Timing & Setting/Country	• 2000 till present • United States only	• Publication date prior to 2000 • Non-US ICU patient populations

Abbreviation: EM- Early Mobilization, SPHM- Safe Patient Handling and Mobility, ICU- Intensive Care Unit, HCW- Healthcare Workers, PI- Pressure Injuries, VAP- Ventilator Associated Pneumonia, VTE- Venous Thromboembolism.

time to use (Alamgir et al., 2009) and less force to operate (Marras et al., 2009). However, the ROI could be performed using mobile lifts provided proper adjustments are made for rates of adoption.

3. Results

3.1. Part 1: current cost burden- present state (Table 3)

3.1.1. Healthcare workers' patient-handling related injuries

Table 3 provides baseline data on cost burdens of HCWs in the ICUs prior to implementing a SPHM intervention. According to a 2018 report from Bureau of Labor Statistics (BLS), the rate of nonfatal occupational injuries and illnesses was 4.1 per 100 FTE workers in healthcare private industry (U.S. Bureau of Labor Statistics, 2018). In the Boston Hospital Workers Health Study in 2019, Sabbath et al. also reported an injury rate of nurses and patient care associates due to lifting or exertion as low as 2.23 and as high as 11.71 (Sabbath et al., 2019). Due to the limited research on HCWs' clinical burden in the ICU, we could not find the rate of patient-handling related injuries specifically for ICU HCWs. However, it is highly plausible this rate could be much higher in ICU HCWs than

Table 2
Summary of key variables in the ROI model.

Component	**Key variables**	**Required information- Present state**	**Required information- Future state**
Current cost burden	HCWs' patient-handling related injuries	• HCW patient-handling injury rate per 100 clinical area FTEs • Average number of LWDs per injured worker per injury • Total patient-handling injury cost • Cost to replace one injured worker shift	• Cost savings from decreased HCWs' patient-handling injury rate and number of LWDs
	Patients' ICU-Acquired condition, i.e., PI, VAP, and VTE	• Incidence per event • Average extra LOS days per event	• Cost savings from decreased incidence and extra LOS days for each of ICU-acquired conditions
	ICU volume and throughput	• Average ICU LOS and MV days • Average direct variable cost of ICU and MV day	• Cost savings from decreased ICU LOS and MV days
Implementation cost of a SPHM program	Equipment and labor costs	• Hospitals' ICU funding capacity for a SPHM program	• Hospitals' desired future state to establish standardized SPHM program for all HCWs

Abbreviation: SPHM- Safe Patient Handling and Mobility, ICU- Intensive Care Unit, HCW- Healthcare Workers, LWDs- Lost Workdays, PI- Pressure Injuries, VAP- Ventilator Associated Pneumonia, VTE- Venous Thromboembolism, LOS- Length of Stay, MV- Mechanical Ventilator.

Table 3
Key model assumptions supported by literature - Present state (without new/additional SPHM).

Key variables	Outcomes	Clinical burden[a]	Economic burden[b]
HCWs' patient-handling related injuries	• HCW patient-handling injury rate per 100 clinical area FTE • Average number of LWDs per injured HCW per injury • Total patient-handling injury cost • Cost to replace one injured worker shift	• HCW injury incidence rate: 4.1[3]-11.71[21]/100 FTE	• Average total cost of all workers compensation directly related to patient handing claims: [a]$14,100 USD per claim (Aon Commercial Risk Solutions, 2018)
Patients' ICU-Acquired condition, i.e., PI, VAP, and VTE	• Incidence rate per event • Average extra LOS days per event	• PI: Incidence of 10–25.9% (Chaboyer et al., 2018) • VAP: Incidence of 5–67% (Timsit et al., 2017) • VTE: Incidence of 5.4–31% (Minet et al., 2015)	• PI: Extra 5 ICU LOS days (Labeau et al., 2021) • PI: Additional cost of [a]$14,506 USD (-[a]$12,313–[a]$41,326)[a] per patient (Agency for Healthcare Research and Quality Rockville, 2017) • VAP: Extra 8.9 ICU LOS days (Kollef et al., 2012) • VAP: Additional cost of [a]$47,238 USD [a]$21,890–[a]$72,587)[a] per patient (Agency for Healthcare Research and Quality Rockville, 2017) • VTE: Extra 7.28 ICU LOS days (Malato et al., 2015) • VTE: Additional cost of [a]$17,367 USD ([a]$11,837–[a]$22,898)[a] per patient (Agency for Healthcare Research and Quality Rockville, 2017)
ICU volume and throughput	• Average ICU LOS and MV days • Average daily cost of ICU	• Average of 3.8 ICU LOS (Society of Critical Care Medicine, 2021) and 3.8 MV days (Lilly et al., 2011)	• Average direct cost per day of ICU day: [a]920 (Slight et al., 2014; PwC Health Research Institute, 2021) • Average direct cost per 1 day of ventilator day: [a]649 (Bice et al., 2013)

Abbreviation: SPHM- Safe Patient Handling and Mobility, ICU- Intensive Care Unit, HCW- Healthcare Workers, LWDs- Lost Workdays, PI- Pressure Injuries, VAP- Ventilator Associated Pulmonary, VTE- Venous Thromboembolism, LOS- Length of Stay, MV- Mechanical Ventilator.
[a,b]Values are not fixed and thus, vary and are dependent upon hospitals' data.
[a] These are total additional costs, most likely including 58% of hospital overhead and only 42% direct variable cost (Slight et al., 2014) associated with patients' complications.

HCWs as a whole. An elevated risk of injury may be incurred due to the additional medical care required for an ICU patient and increased physical dependency making it more physically demanding to mobilize the patient. Consequently, these injuries bring substantial costs for hospitals. A 2018 actuarial analysis of workers compensation claim data conducted by AON estimated patient handling claims had the highest average total cost of all workers compensation causes of loss at $14,100 USD per claim (Aon Commercial Risk Solutions, 2018). On top of direct costs, the Bureau of Labor Statistics also reported nursing assistants experienced a median of 6 lost workdays (LWDs) from nonfatal occupational injuries and illnesses in 2019 (Bureau of Labor Statistics, 2020). Based on U.S. national average salary of staff ICU nurses of $77,409 USD as of September 27, 2021 for a total of 156 12-h working shifts per year, the replacement cost associated with these lost days was estimated to be $496.21 USD per 12 h shift (Staff Nurse, 2021). Notably during COVID-19, it has been estimated travelling ICU nurses are making $150, 000-$300,000 USD a year. These higher salaries coupled with the absence of or poorly inadequately implemented SPHM may create a significant burden for patients, HCWs, and hospitals (Hawryluk et al., 2020).

3.1.2. ICU-acquired conditions

ICU patients are at high risk for many hospital-acquired conditions (HACs), such as hospital-acquired pneumonia (HAP), ventilator-acquired pneumonia (VAP), pressure injuries (PI), venous thromboembolism (VTE), and other immobility-associated conditions. The risk of these acquired conditions is increased due to the critical status of patients, use of MV, and immobility. Compared to patients who do not receive MV, those under MV have longer ICU LOS days, which consequently exposes them to a greater risk of developing ICU-acquired conditions (Kaier et al., 2019) (Fan et al., 2014). Patients developing these conditions may not only suffer significant clinical consequences, but also utilize more health services and incur higher costs.

For ICU patients, high disease burden, use of vasoactive medications, poor tissue perfusion, poor oxygenation, and coagulopathy can all increase their risk of PI. In a 2020 study of more than 13,000 patients in 1117 ICUs across 90 countries, the overall one-day point-prevalence for PI in the ICU in the U.S. was 35.1% (95% CI: 32.2–38.1%), and the ICU-acquired prevalence was 13.3% (95% CI: 11.7–15.1) (Labeau et al., 2021). Similarly, according to a systematic review and meta-analysis published in 2018, the 95% CI cumulative incidence of PI in adult ICU patients was 10.0–25.9% (Chaboyer et al., 2018). Labeau et al., 2020 showed patients with ICU-acquired PIs had significantly higher ICU LOS [Median, IQR: 27 (13–52)] compared to patients with PIs developed outside the ICU [Median, IQR: 22 (10–46)] and patients with no PIs [Median, IQR: 8 (3–21)] (Labeau et al., 2021). Prolonged ICU LOS not only affected patient outcomes but also had a significant impact on hospital charges (Bauer et al., 2016; Agency for Healthcare Research and Quality Rockville, 2014). A 2017 meta-analysis published by the Agency for Healthcare Research and Quality estimated for each PI, on average, hospitals incurred an incremental $14,506 USD (95% CI: -$12,313–$41, 326) in costs caring for one patient above and beyond the costs associated with an inpatient stay for the same patient without a PI (Agency for Healthcare Research and Quality Rockville, 2017). From these literature findings the following low-end, conservative assumptions for PIs in the ICU are a prevalence rate of 10% and an average additional LOS of 5 days.

Other than PI, VAP is among the most frequent life-threatening nosocomial infections in ICUs and also the leading cause of death from nosocomial infections in critically ill patients (Timsit et al., 2017; Rosenthal et al., 2012). Similarly, VAP is the leading cause of morbidity and mortality from device-associated infections, especially in the ICU. VAP was reported to affect 5–40% of patients receiving invasive MV for more than 2 days, with large variations across countries, ICU types, and criteria used to identify VAP (Papazian et al., 2020). VAP incidence ranged from 5% to 67% depending on different diagnostic criteria, and the highest rates were reported in immunocompromised, surgical, and elderly patients (Timsit et al., 2017). The estimated risk of VAP was

1.5% per day and decreased to less than 0.5% per day after the 14th day of MV (Timsit et al., 2017). Specifically, the Medicare Patient Safety Monitoring System reported a VAP rate of 9.7% (95% CI: 5.1–14.9%) during 2012–2013 among Medicare patients 65 years and older with principal diagnoses of acute myocardial infarction, heart failure, pneumonia and selected major surgical procedures (Metersky et al., 2016). On average, patients with VAP had longer mean durations of MV (21.8 vs 10.3 days) and ICU stay (20.5 vs 11.6 days) compared to MV patients without VAP (Kollef et al., 2012). This also resulted in substantially higher extra cost $47,238 USD (95% CI: $21,890–$72,587) for this patient population (Agency for Healthcare Research and Quality Rockville, 2017). Based on findings from the literature, the following conservative assumptions related to VAP were used in our model: VAP incidence rate of 5% and VAP average incremental LOS of 8.9 days.

In addition to PI and VAP, VTE is another common adverse ICU-acquired condition. Without preventive measures known as thromboprophylaxis, the incidence of VTE ranged between 5.4% and 31% depending on case mix and diagnosis methods used (Minet et al., 2015). Even with thromboprophylaxis, 9.6% of ICU patients developed VTE, specifically deep vein thrombosis (DVT) (Boonyawat and Crowther, 2015). Also, compared to critically ill patients without DVT, patients with DVT spent 7.28 extra days (95% CI: 1.41–13.15 days) in the ICU (Malato et al., 2015). Consequently, associated cost of VTE treatment resulted in an additional $17,367 USD (95% CI: $11,837–$22,898) per ICU patient (Agency for Healthcare Research and Quality Rockville, 2014). Based on these findings, we have conservatively used the following assumptions in our model: VTE incidence of 5.4% and additional average LOS of 7.28 days.

3.1.3. ICU volume and throughput

According to the Survey of Annual Staffing Workloads for Adult Critical Care Physicians Working in the United States published in 2016, the median reported total ICU daily census was 18 (IQR, 14–23) (Sevransky et al., 2016). The latest update from the Society of Critical Care Medicine reported the average ICU LOS was estimated at 3.8 days in the U.S. (Society of Critical Care Medicine, 2021). In addition, a large multi-center study representing more than 240,000 adult admissions from 271 ICUs across the U.S. revealed conventional MV supported 27% of patients, varying from 18.4% to 30.1% depending on different types of ICU with a mean MV duration of 3.8 days (SD: 6.2 days) (Lilly et al., 2011). In terms of ICU cost, findings from a financial analysis conducted by Slight et al., suggested the direct variable cost per LOS day in medical-surgery was $649 USD in 2014 (Slight et al., 2014). Based on the percentage increase of yearly costs to treat patients over time reported by PwC Health Research Institute, we determined that the cumulative direct variable cost per LOS day increased from $649 to $920 over six years from 2014 to 2020 (PwC Health Research Institute, 2021). Finally, we also found that ICU MV day had a direct variable cost ranging from $649 to $839 USD per day based on findings from Bice et al. (2013)

3.2. Part 2: net savings- future state (Table 4)

3.2.1. HCWs' patient-handling related injuries

Table 4 provides data on potential future net savings in ICUs after the implementation of a SPHM intervention. In a systematic review and meta-analysis, Teeple et al. reviewed all studies of SPHM program evaluations published through October 2016. The authors reported the combined effect incidence rate ratio (IRR) for HCW injuries from all SPHM programs across all healthcare settings was 0.44 (95% CI 0.36, 0.54), representing a 56% decrease in injury rate overall following the program implementation (Teeple et al., 2017). Out of all healthcare facilities, the ICU had the greatest relative reduction in injury rates after implementation of SPHM (ICU: IRR 0.14; Long-term care & Rehab: IRR 0.51; Inpatient hospital: IRR 0.47) (Teeple et al., 2017). In a more recent study by Adamczyk tracking injuries in a 20-bed medical ICU from 2016 to 2017, the author found HCWs' injuries were reduced by 57% with a SPHM initiative from 7 to 3 work-related lifting injuries per year (Ann Adamczyk, 2018). In addition, LWDs were reduced by 54%, from 112 to 52 LWDs per year. Although Adamczyk's study had a small sample at a single center, it is the only recent SPHM study conducted in the ICU setting and reinforced the findings from the meta-analysis conducted by Teeple et al. (2017). Using the findings from these studies which ranged from 34% to 86% across different healthcare settings, we conservatively assumed a 56% decrease in injury rate overall following the program implementation also resulted in a 56% decrease in the direct cost associated with LWDs for HCWs in ICUs.

Table 4
Key model assumptions supported by literature - Future state (with a new/additional SPHM).

Categories	Outcomes	Direct benefits of SPHM	Direct benefits of EM	Effect of SPHM on EM
Healthcare workers' PH-related injuries	• Reduction of HCW patient-handling injury rate per 100 clinical area FTE • Reduction of the number of LWDs per injured HCW per injury • Cost reductions associated with decreased patient-handling injury rate and numbers of LWDs[a]	• Injury rate reduced by 56% (Teeple et al., 2017) • Number of LWDs reduced by 56% (Teeple et al., 2017)	• N/A	• N/A
Patients' ICU-Acquired condition, i.e., PI, VAP, and VTE	• Reduction of ICU LOS days and incidence rate per event • Cost reductions associated with decreased ICU LOS days and incidence rate per event[a]	• PI: Incidence reduced by 30%–40% (Celona, 2010) • VAP: N/A • VTE: N/A	• PI: ICU LOS w/out PI reduced by 5 days (Labeau et al., 2021) Incidence reduced by 33%–71% (Nieto-García et al., 2021) • VAP: ICU LOS w/out VAP reduced by 8.9 days (Kollef et al., 2012) Incidence reduced by 20% (Clark et al., 2013) • VTE: ICU LOS w/out VTE reduced by 7.28 days (Malato et al., 2015) Incidence reduced by 55% (Cassidy et al., 2014)	• N/A
ICU volume and throughput	• Reduction of average ICU LOS and MV days • Cost reductions associated with decreased ICU LOS and MV days[a]	• N/A	• Average ICU LOS days reduced by 10.3%–45% (Hsieh et al., 2019) • Average MV days reduced by 22.3% (Hsieh et al., 2019)	• N/A

Abbreviation: SPHM- Safe Patient Handling and Mobility, ICU- Intensive Care Unit, HCW- Healthcare Workers, LWDs- Lost Workdays, PI- Pressure Injuries, VAP-Ventilator Associated Pulmonary, VTE- Venous Thromboembolism, LOS- Length of Stay, MV- Mechanical Ventilator, N/A: no studies found.

[a] Cost reductions are calculated based on rate reductions and economic burden in Table 3.

3.2.2. Patients' ICU-acquired conditions

3.2.2.1. Direct benefits of SPHM on patients' outcomes. While benefits of SPHM to HCWs were clearly defined by the literature, direct evidence of the effects of SPHM on patients' adverse events in the ICU was sparse. In fact, PI was the only condition found associating direct benefits with the use of SPHM. Most of the reviewed literature was either qualitative, e.g., connecting the use of SPHM and PI prevention (Dickinson et al., 2018; CLARK et al., 2015; Wyatt et al., 2020), or conducted in non-ICU healthcare settings, such as long-term care, nursing homes, rehabilitation facilities (Olinski and Norton, 2017; HARWOOD et al., 2016). For example, Stanford Hospital and Clinics (SHC) implemented a SPHM program in all nursing units and the Emergency Department (Celona, 2010). After a two-year period of SPHM use, Stage I and II PI rates were reduced by at least 30% (Celona, 2010). Although this study was not specifically conducted in the ICU, we considered it a reputable reference point for our ROI model. Use of this estimate for the ICU may also be conservative as ICU patients are more dependent and higher risk for PI than the general patient population included in the study.

3.2.2.2. Indirect benefits of SPHM on patients' outcomes through the effect of EM. Although there is limited evidence of the effect of SPHM on patients' outcomes, research suggests SPHM supports EM, for which the effect on patient outcomes is strong (Dickinson et al., 2018; Wyatt et al., 2020; Olinski and Norton, 2017). Therefore, SPHM equipment might be considered as an enabler of EM and not just a passive transfer method to help staff safely mobilize hospitalized patients to their highest level of mobility (Dickinson et al., 2018; Wyatt et al., 2020).

There is a substantial body of literature on the effect of EM on ICU-acquired PIs. However, these studies have heterogeneous results (Nieto-García et al., 2021; Doiron et al., 2018; Castro-Avila et al., 2015; Clarissa et al., 2019; Taito et al., 2016). Different systematic reviews and meta-analyses showing the effectiveness of EM in PI prevention indicate the quality of evidence was low due to small sample sizes, and heterogeneous populations, interventions, and outcome measures (Nieto-García et al., 2021; Doiron et al., 2018; Castro-Avila et al., 2015). Nieto-Garcio et al. found seven studies implementing EM programs in different ICU subspecialties (Nieto-García et al., 2021). Only two of the seven studies reported a statistically significant reduction of ICU-acquired PIs after the implementation of EM programs, in which PIs decreased by 33% (Azuh et al., 2016) and 71% (Klein et al., 2015). Although these studies provide critical data to inform an ROI model, more research is needed to better quantify the relationship between EM and PI and the circumstances in which the effects are strongest.

Similar to PI, with the implementation of a structured EM protocol, the incidence of ICU-acquired VTE decreased by 64%, from 21% in the retrospective pre-intervention to 7.5% in the prospective intervention (Booth et al., 2016). Similarly, the implementation of a standardized postoperative program including EM and other prevention measures reduced VTE by 55% for pulmonary emboli and 84% for DVT (Cassidy et al., 2014). In a retrospective cohort study, Clark et al. found the incidence of VAP decreased by 20%, from 27.9% to 22.4%, after the implementation of an EM program (Clark et al., 2013).

3.2.3. ICU volume and throughput

Most research on EM demonstrated reduced ICU LOS and some identified a reduction in MV days. A meta-analysis published in 2019 of randomized clinical trials investigating the efficacy of EM among critically ill adult patients found the duration of ICU stay was 1.54 days less with EM (95% CI: 3.33 to 0.25) (Okada et al., 2019). Notably, in an international five multicenter, randomized controlled trial of surgical ICU patients, Schaller et al. observed a 3-day shorter ICU LOS among patients who received early, goal-directed mobilization compared to those not receiving the intervention (Schaller et al., 2016). Similar results from these randomized trials were also reflected in real-world observational studies. Klein et al. found LOS days for post-intervention patients were 45% lower for the neuro ICU stay compared to pre-intervention patients (7.8 vs 4.3 days) (Klein et al., 2015). In a prospective study of two academic medical ICUs, Hsieh et al. also observed ICU LOS and MV days were significantly reduced when EM was added to a partial bundle of (B)reathing trials, (A)wakening from sedation, and (D)elirium monitoring/management for ICU mechanically ventilated patients (Hsieh et al., 2019). Specifically, there was a 10.3% decrease in ICU LOS (95% CI: −15.6 to −4.7%, $p = 0.028$) and 22.3% decrease in duration of MV (95% CI: −22.5 to −22.0%, $p < 0.001$) (Hsieh et al., 2019). Similarly, Schweickert et al. observed significantly more ventilator-free days in an EM group compared to a control group (23.5 vs 21.1 days), although not all studies identified significant differences for ventilator free days (Schweickert et al., 2009; Bounds et al., 2016). These studies clearly show that ICU LOS were reduced when patients experienced earlier mobilization. Although a reduction in ICU LOS has direct financial benefits for a hospital, it could further lead to fewer serious adverse outcomes in patients (Bagshaw et al., 2020; Rojas-García et al., 2018). A systematic review published in 2017 found delayed discharge was associated with an increased risk of mortality, infections, mental deterioration and reductions in patient mobility and their daily activities (Rojas-García et al., 2018). Moreover, prolonged ICU stay or delayed discharge strains capacity in the ICU and increases costs (Bagshaw et al., 2020). Therefore, a wider adoption of an EM intervention could help improve patients' outcomes and also meliorate the problem of insufficient capacity in the ICU (Bagshaw et al., 2020).

3.2.4. Effect of SPHM on EM implementation

Although there is limited evidence of the effect of SPHM on patient outcomes, the evidence of EM effect on patient outcomes is substantial. Moreover, findings from EM research suggest EM is a challenging practice for both HCWs and patients, but SPHM could address some of the challenges of EM and provide considerable benefit to patient outcomes by providing the tools to facilitate the adoption of EM. For example, researchers administering an EM intervention experienced lower than anticipated compliance (Hsieh et al., 2019; Balas et al., 2014). In a systematic review of barriers to implementing EM, Costa et al. identified issues such as staff and patient safety concerns, perceived workload, staffing, lack of equipment, and improper physical environment (Costa et al., 2017). Manually mobilizing a patient exposes caregivers to physical loads shown to have high risk of injury to the caregiver (Marras et al., 1999; Skotte et al., 2002). Without SPHM equipment, caregivers with insufficient strength may require additional staff to assist but these staff may be unavailable, resulting in HCWs being unwilling or unable to properly mobilize their patients manually. SPHM could potentially address each of these barriers by enabling fewer HCWs to mobilize a patient safely. Moreover, SPHM can allow physical therapists to administer more aggressive therapy sessions without the risk of injury to the therapist or patient, potentially driving better outcomes from EM (Haines and Arnold, 2019). Therefore, with evidence continuing to emerge early mobilization of critically ill patients could be safe and achievable, SPHM interventions in the ICU could be especially helpful for high-risk patients through the effect of EM to prevent complications, promote mobilization, and prevent patient injuries. Despite these probable benefits from SPHM, no studies were found by this review that assessed the effects of SPHM on the administration of EM programs. More research is needed to quantify the exact relationship between SPHM and EM. Until the relationship between SPHM and these outcomes are directly defined, ROI models might maintain credibility using conservative estimates for the benefits of SPHM on patient outcomes and ICU throughput. This approach assumes that SPHM is at least a small part of increasing compliance and therefore benefits of an EM program. This assumption is based off the definition of EM and SPHM as explained in section II.3 in our study. For example, the ROI model shown in the Appendix considers SPHM delivers 50% of the benefit achieved by EM in reducing HAPI, VAP, VTE, LOS, and MV days, with additional sensitivity analysis for 25% and 75%. This assumes that less EM practice is possible without the tools of SPHM and that a fraction of patients will be mobilized with SPHM that could not otherwise be mobilized safely.

3.3. Part III: implementation costs

Implementation costs of a SPHM program consist of equipment costs and labor costs. Equipment costs include initial equipment purchases, installation, and ongoing equipment maintenance and operation costs. Labor costs include initial and ongoing training and education costs. Labor costs may also include dedicated staff hours at the unit, hospital, or organization level to oversee the SPHM program, organize training, and collect data related to the performance of the program (Appendix). The breadth and scope of a SPHM program has a large effect on these costs as well as the attributes of the facility. Variation in the number of ICU beds, and ICU occupancy, and the types and size of ICUs can cause the implementation costs of a SPHM program to vary greatly (Wunsch et al., 2013).

3.4. ROI calculation

An example ROI calculation using the findings from the review is shown in Appendix A. This example details a conservative estimate for implementation of a SPHM program that includes installing ceiling lifts across a 15-bed ICU. This case identifies an annual net savings of $428,975 USD with a 13-month ROI. The appendix includes explanation so hospitals could modify the inputs to meet their assumptions and clinical circumstances.

4. Discussion

Our paper is the first to summarize the most current evidence of SPHM factors on HCWs and patient outcomes necessary to develop an ROI model in the ICU setting. Many studies showed positive clinical and economic outcomes on HCW patient-handling related injuries and practice from the introduction of SPHM. However, these studies were limited to long-term care, nursing homes, and rehabilitation facilities (Olinski and Norton, 2017; HARWOOD et al., 2016). In fact, we found only two quantitative studies that investigated the direct benefits of SPHM on HCW patient-handling related injuries in the ICU (Ann Adamczyk, 2018; Anyan et al., 2013). Both single center studies had a sample size of 20 ICU beds or fewer. In addition, there appeared to be larger gaps in the literature regarding effects of SPHM on patients' outcomes, especially with regards to the clinical burden of patients experiencing serious adverse conditions in the ICU. These gaps are illustrated in Table 4. Expanding our search to include the indirect benefits of SPHM on patients through the effect of EM, we found more research conducted on the effectiveness of EM among patients with ICU-acquired conditions, especially those with PIs. Nevertheless, there was great heterogeneity in the literature examined (Nieto-García et al., 2021; Doiron et al., 2018; Castro-Avila et al., 2015; Clarissa et al., 2019; Taito et al., 2016; Chatsis and Visintini, 2018). Many studies conducted on the impact of EM on patient outcomes did not specify methodological details, including quantity and quality of the intervention, making it challenging to generalize technology recommendations suitable for each ICU and patient population. Although most studies presented a statistically significant reduction in the number of ICU LOS and MV days with EM, research specifically focusing on the impact of SPHM programs on ICU volume and throughput remained sparse. More well-designed studies are needed to explore the effect of SPHM, EM, and the integration of SPHM and EM together on patient outcomes. Overall, because each ICU included patient populations with unique characteristics, we recommend hospitals to scrutinize the current state of their ICU to ensure the correct type and quantity of SPHM for their units as well as there is sufficient storage allocated for this equipment.

Given the evidential benefits of SPHM and EM on HCWs and patients in the ICU, there is a greater need for hospitals to develop an adequate ROI model to identify the true benefits of a wider adoption of these interventions. To create an ROI model, hospitals can use clinical and economic burden data from their ICUs, including the incidence and costs of HCW patient-related injuries, patients' ICU-acquired conditions, and incremental ICU LOS and MV days (Appendix). Hospitals may consider a limited, targeted intervention with the greatest estimated ROI, or a broader intervention that may affect more units. It is also important that hospital leaders continue to monitor the literature on the effects of SPHM on patients' outcomes to ensure they are use an ICU ROI model that reflects the latest evidence. Finally, our study provides a template for those wishing to model an ROI in other settings, including skilled nursing centers and home care although data on the comprehensive benefits SPHM in these settings also have limitations.

Our summary had several important limitations. While it was a structured review with two rounds of evaluation, it was a not a systematic review thoroughly assessing the breadth of literature, in part because the subject matter included so many topics. Furthermore, this summary did not include a formal evaluation of the quality of studies, though their limitations are described generally. Also, we excluded studies outside the U.S. in part because of the international variation in facility characteristics, clinical practice, and payment systems which could confound our exposure-outcome associations. In terms of patient population, we did not examine any specific type of ICU due to the narrow research scope in current literature but rather focused on a typical patient-mix in a general ICU. Different patient mixes can affect the assumptions and results for this type of ROI, especially when clinical severity vary widely among patients from different ICUs. For patients' outcomes, we did not consider studies specifically designed for bariatric patients. While routine manual handling without mechanical assistance of bariatric patients presented a more dangerous hazard for both HCWs and patients compared to normal-weight patients, we acknowledged there was also a critical need for further studies to explore the impact of SPHM and EM on this patient population. We did not differentiate the benefits of SPHM among different occupations such as nurses, nurse assistants, and physical therapists. Our summary also did not consider the effects of other demographic variables such as age and job tenure. Finally, our ROI model was built from data in the current literature, meaning it may not reflect the heterogeneity of each ICU in the United States. We recommend hospitals to consider differences between the assumptions within our model and their environment to provide as much precision to their ROI model as the available data allows.

5. Conclusions

Previous studies have demonstrated SPHM programs create value and support the practice of EM. However, existing literature does not comprehensively quantify how SPHM reduces injuries to healthcare workers, reduces HACs, and improves ICU volume and throughput. This leads to uncertainty among hospital decision makers when examining return on investment for a wider adoption of SPHM. Therefore, for SPHM to be successfully implemented and maintained in a continuously changing environment, it is important the impact of SPHM on all key elements of a healthcare facility is thoroughly quantified. The successful rollout of a SPHM program will not only improve clinical and economic outcomes but will also facilitate the much-needed cultural change where healthcare workers and patient well-being are valued equally important within a healthcare organization.

Author statement

Trang Dang: Conceptualization, Methodology, Investigation, Writing- Original draft preparation.

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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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Appendix

An example ROI calculation is presented below. Table A1 provides the fields for data entry and calculations performed in a ROI estimate. The fields in white require data entry and the fields in grey are mathematical calculations performed by the spreadsheet. References for each entered data point are shown in the "Source" column. Table A2 provides an executive summary of the calculations performed in the data entry table. Table A3 provides a sensitivity analysis of data entry and calculation relevant to Table A1 and A2. Values entered in practice could vary greatly by hospital and ICU due to patient mix, staffing, organizational performance, and data available. This example is intended to provide representative data when hospital specific data may be unavailable.

Approach

This model provides a conservative method for estimating ROI. A conservative approach is used because of uncertainty of the replicability of the results in the published literature due to the absence of specific details and the heterogeneity of ICU patients, practices, programs, unit size, and cost structures. Therefore, average values are used for current state performance metrics and more conservative values are used for future state outcomes that affect the ROI of SPHM.

This example represents a 15-bed ICU (Table A1, Line 1). The ICU LOS (Line 2) is equal to the national average (3.8 days). ICU LOS days and number of beds are used to calculate the annual number of discharges (Line 3) and the total number of patient days (Line 4).

Worker Injuries

The rate of HCW patient handling injuries requires hospital specific data, but the rate used in this ROI example is 6.6 per 100 FTE (Line 7). This value is the average of lifting and exertion injuries in two hospitals as reported by Sabbath et al. (2019). However, older studies have reported higher injury rates and have suggested that many injuries may go unreported (e.g., Goldman et al., 2000). Line 9 reflects BLS data reporting a median of 6 LWDs for nursing assistants in 2019 as a result of nonfatal occupational injuries and illnesses. These values from BLS, together with an average of 3.63 registered nurses reported per occupied hospital bed in the U.S. by Statista.com in 2016 (Line 5), are used to estimate the total number of patient handling-related injuries HCWs (Line 8) and LWDs anticipated in the ICU annually (Line 10). Average costs to replace shifts (Line 11) and medical costs (Line 12) are used from Salary.com (updated as of September 2021) and the 2018 Healthcare Workers Compensation Actuarial Analysis respectively. This ROI does not consider the cost of replacing nurses resigning due to injury or fatigue, but others may choose to include this. In terms of future state outcomes, this ROI assumes a 56% reduction (Line 27) in the incidence of patient handling injuries and number of LWDs based on the systematic review by Teeple et al. (2017). This is an average value across all inpatient settings, so it is likely conservative for the ICU. Given the findings by Teeple et al. (section 2.1), there is a reason to believe patient handling requirements and HCW injury rates are higher in the ICU.

ICU-Acquired Conditions

This ROI estimates the financial burden for ICU-acquired conditions in terms of the average incremental LOS days they incur. The role of SPHM in reducing these conditions is realized as a reduction in LOS and MV days when these conditions are prevented. This approach is used because there is little published data on the direct variable cost of care for these conditions (see Table 4 Notes), and because LOS is a better representation of both clinical and economic burden to the hospital. Incidences of ICU-acquired conditions and their extra LOS days are used as follows: 10% for PI (all stages I– IV) with an average of 5 extra LOS days, 5% for VAP with 8.9 extra LOS days, and 5.4% for VTE with 7.28 extra LOS days. These values are shown on lines 13–18. The pre-intervention additional LOS days caused by these conditions annually are shown in lines 20–22. To minimize double counting of increased LOS days where multiple ICU-acquired conditions may be present, each calculation is made more conservative by discounting by a factor of 48% (Line 19). This factor is based on data reported for a 5-hospital system in Australia that found patients with hospital acquired conditions on average had 1.93 conditions (Trentino et al., 2013).

Given the lack of evidence, the ROI assumes 50% of the documented benefits of EM are delivered through a SPHM program. The assumption is that with SPHM, at least 50% of the patients will be mobilized that may not otherwise be mobilized. Alternatively, it could be considered that less EM practice is possible without the tools of SPHM. Existing evidence of EM effect on reduced ICU-acquired conditions includes a 33.7% reduction in PI (Line 28), 20% reduction in VAP (Line 29), and a 55% reduction in VTE. Applying 50% of benefit for SPHM results in anticipated reductions of 16.85%, 5.0%, and 27.5% of PI, VAP, and VTE respectively (Lines 28–30). As there is currently no evidence indicating the proportion of EM achieved through SPHM, a sensitivity analysis was further conducted to highlight this variation (Table A3). As more data are published regarding the link between SPHM and patient outcomes, ROIs can become more accurate and the economic value for SPHM may be even stronger.

It is noteworthy the benefits of reducing ICU-acquired conditions are generally based on studies where EM is an intervention is applied across one or more units. If hospitals achieve EM at a rate different from the published studies, they will likely experience different results. This is another reason for the values in lines 28–30.

ICU volume and throughput

This ROI model uses an average ICU LOS of 3.8 (Line 2) and 3.8 MV days (Line 25) as reported by the Society of Critical Care Medicine and a retrospective study by Lilly et al. (2011), respectively. A rate of 27% of mechanical ventilation is also assumed in the ICU for this ROI (Line 23). As the literature does not clearly identify if all reduced LOS days were in the ICU, the ROI assumes the direct variable cost associated with Med Surg is $920 USD per day (Line 33).

In addition to the specific ICU-acquired conditions named above (i.e., PI, VAP, VTE), EM has been shown to generally reduce MV days and LOS. As with ICU-acquired conditions, there is little data on the impact of SPHM on ICU throughput, so again the ROI assumes that 50% of the documented benefits of EM are supported by a SPHM program. EM is shown to reduce MV days by 22.3% and LOS generally by 10.3%, so the benefit of SPHM was assumed to generate reductions of 11.15% and 5.15%, respectively (Line 31 and 32). Similar to the 48% adjustment (Line 19) to avoid double-counting of additional LOS from ICU acquired conditions, the overall ICU LOS reduction was also adjusted by 48%. A sensitivity analysis highlights the variation of EM benefits achieved through SPHM (Table A3).

Implementation Costs

A $13,000 USD estimate (Line 52) was used for the cost of purchasing and installing a ceiling lift in each ICU room. This represents an average value that could be more or less for different geographic regions and building codes. An annual recurring cost of $6000 USD per room was used for maintenance, slings, and other accessories (Line 54). Training costs for the ICU were estimated at $9500 USD. As with the many other inputs to the ROI model, the values for this representative case study would be adjusted to the circumstances of each hospital.

Final ROI Calculation

Table A1 summarizes the current cost burden and reduction in costs realized with a future implementation of SPHM. Based on the inputs in Table A1, Table A2 summarizes the anticipated returns and SPHM program costs.

The annual costs and savings shown in Table A2 are used to estimate monthly cash flow, 5-year cost savings, and 5-year net present value. For conservative purposes, year one savings in this ROI is reduced to 67% to account for the time required for adoption of SPHM and standard practice change. Based on this model, the annual net savings of the SPHM implementation is $34,365, $162,475, and $232,134 for injury reduction, reduction in ICU conditions, and reduction in ventilator use and LOS, respectively. In year 1, annual savings are $285,983 USD against an initial cost of $294,500 USD. After year 1, annual savings are $428,975 USD against a recurring annual cost of $99,500 USD, resulting in a 13-month break even with a $1,104,556 USD 5-year net present value. Associated changes in ICU-acquired conditions and ICU throughput are also shown in Table A2.

In this ROI, most of the financial benefit is achieved by reducing the additional ICU LOS and MV days. This underscores the importance of considering these factors when estimating the ROI. This also explains why the current ROI has a shorter breakeven than many previous studies as previous studies only considered financial benefits of injury reduction. Compared to previously published ROI estimates of SPHM interventions, the net savings from injury prevention in this ROI are relatively low. This is probably due to the higher baseline rates of injury in the study facilities compared to the asumptions in this ROI, as well this ROI does not consider indirect injury costs.

Table A1
Throughput and cost savings realized by the SPHM program implementation

	Hospital Information		Source
1	# Beds representing Avg. Daily Census	15	Estimated #ICU Beds
2	Average Length of Stay (LOS)	3.80	Society of Critical Care Medicine
3	Annual # of Discharges	1,441	
4	Annual # of Patient Days	5,475	
5	# of Full-Time Enployees (FTE) per bed	3.63	Statista.com, 2016
6	Total # of FTEs (Assigned to the clinical area)	54	
	HCW Patient Handling Related Injury		
7	Rate of Patient Handling Injuries per 100 FTE	6.6	Sabbath et al., 2019
8	Annual # of Patient Handling Injuries	3.6	
9	# of Lost Workdays (LWDs) per injury	6	Bureau of Labor Statistics, 2018
10	Annual # of LWDs per patient handling injury	21.6	
11	Average cost to replace an injured worker shift	$496	Salary.com, 2021
12	Average medical cost per patient handling injury	$14,100	AON 2018 Executive Summary
	ICU-Acquired Conditions and Throughput		
13	Average incidence rate of ICU Pressure Injuries (PI)	10.0%	Chaboyer et al., 2018
14	Increased LOS from PI (days)	5	Labeau et al., 2020
15	Average incidence rate of Ventilator-Associated Pneumonia (VAP)	5.0%	Timsit et al., 2017
16	Increased LOS from VAP (days)	8.9	Kollef et al., 2012
17	Average incidence rate of Venous Thromboembolism (VTE)	5.4%	Minet et al., 2015
18	Increased LOS from VTE (days)	7.28	Malato et al., 2015
19	Incidence of duplicate HACs	48%	Trentino et al., 2013
20	# of additional LOS days from PI	373	
21	# of additional LOS days from VAP	332	
22	# of additional LOS days from VTE	293	
23	Percentage of mechnically ventilated (MV) patients in the ICU	27.0%	Lilly et al., 2011
24	Annual # of MV patients	389	
25	Average MV days per patient	3.8	Lilly et al., 2011
26	Annual # of MV days	1478	
	Reductions with SPHM Programs		
27	Reduce patient-handling related injuries & LWDs by	56%	Teeple et al., 2017
28	Reduce ICU-Acquired PI by	16.85%	1/2 of 33.7% - Azuh et al., 2016
29	Reduce ICU-Acquired VAP by	10.00%	1/2 of 20% - Clark et al., 2013
30	Reduce ICU-Acquired VTE by	27.50%	1/2 of 55% - Cassidy et al., 2014
31	Reduce MV days by	11.15%	1/2 of 22.3% - Hsieh et al., 2019
32	Reduce ICU LOS days by	5.15%	1/2 of 10.3% - Hsieh et al., 2019
	Cost Estimates Before and After SPHM		
33	Medical Surgical Direct Variable Cost (DVC) per day	$920	Slight et al., 2014
34	Ventilator DVC per day	$649	Bice et al., 2013
35	Current medical cost from patient handling injuries	$ 50,671	
36	Future medical cost with SPHM	$ 22,295	
37	Current cost of LWDs from patient handling injuries	$ 10,695	
38	Future cost of LWDs with SPHM	$ 4,706	
39	Current DVC of ICU Acquired PI	$ 342,980	
40	Future DVC of ICU Acquired PI with SPHM	$ 285,188	
41	Current DVC of ICU Acquired VAP	$ 305,252	
42	Future DVC of ICU Acquired VAP with SPHM	$ 274,727	
43	Current DVC of ICU Acquired VTE	$ 269,665	
44	Future DVC of ICU Acquired VTE with SPHM	$ 195,507	
45	Current DVC of MV days	$ 959,384	
46	Future DVC of MV days with SPHM	$ 852,413	
47	Current DVC of LOS	$ 5,037,000	
48	Future DVC of LOS with SPHM	$ 4,911,837	
49	NPV Discount Rate	5.0%	Suggested Rate
50	Year One SPHM Effectiveness	67%	Conservative Estimate
	Technology Costs		
51	# of Rooms with SPHM equipment including ceiling lifts	15	
52	Cost of SPHM equipment per room	$13,000	Hospital Quote
53	Total cost of equipment	$195,000	
54	Annual cost of maintenance, accessories, and slings per room	$6,000	Hospital Quote
55	Total annual cost of maintenance, accessories and slings	$90,000	
56	Annual cost of training and staff	$9,500	Hospital Estimate
57	Total Invesment Costs Year One	$294,500	
58	Annual Costs (Years 2+)	$99,500	

[1]Out of a baseline total of 5475 total annual ICU days and 1478 ventilator days from 1441 annual admissions across 15 beds.

Table A2
Executive Summary

	ANNUAL COSTS			
	Present State	Future State	Net Savings	
Employee Patient Handling Injuries				
Medical Costs of Patient Handling Injuries	$50,671	$22,295	$28,376	
Costs of Lost / Restricted Work Days from Patient Handling Injuries	$10,695	$4,706	$5,989	
	$61,366	**$27,001**	**$34,365**	**(A)**
ICU Acquired Conditions				
Increased LOS from ICU Acquired Pressure Injuries	$342,980	$285,188	$57,792	
Increased LOS Days from ICU Acquired Ventilator Associated Pneumonia	$305,252	$274,727	$30,525	
Increased LOS Days from ICU Acquired Venous Thromboembolism	$269,665	$195,507	$74,158	
	$917,897	**$755,422**	**$162,475**	**(B)**
ICU LOS and Ventilator Days				
Cost of Ventilator Days	$959,384	$852,413	$106,971	
Cost from Length of Stay	$5,037,000	$4,911,837	$125,163	
	$5,996,384	**$5,764,250**	**$232,134**	**(C)**
		(A + B + C)	**$428,975**	
Investment				
Total Cost Year 1 (i.e., equipment, slings, maintenance, staffing)			$294,500	
Annual Costs (i.e., slings, maintenance, staffing)			$99,500	
Summary				
Current Annual Cost Burden for SPH Injuries, HAPI, VAP, VTE, ICU LOS and Vent Days			$6,975,647	
5 Year Net Present Value			$1,104,556	
Projected Break Even month			< 13 Months	

Table A3
Breakeven Sensitivity Analysis- Effect of SPHM on reducing ICU acquired conditions

	Published Benefit of EM	Incremental benefits achieved through SPHM		
Fraction of total benefit		1/4	**1/2**	3/4
Reduce ICU-Acquired PI by	33.7%	8.43%	**16.85%**	25.28%
Reduce ICU-Acquired VAP by	20.0%	5.00%	**10.00%**	15.00%
Reduce ICU-Acquired VTE by	55.0%	13.75%	**27.50%**	41.25%
Reduce MV days by	22.3%	5.58%	**11.15%**	16.73%
Reduce ICU LOS days by	10.3%	2.58%	**5.15%**	7.73%
ROI Breakeven		25 months	**13 months**	8 months

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