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Risk Factors Associated With Pressure Ulcer Formation in Critically Ill Cardiac Surgery Patients

A Systematic Review

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ABSTRACT

BACKGROUND: Cardiac surgery patients are among those most at risk for developing pressure ulcers (PUs), with a reported incidence as high as 29.5%. Although numerous studies documenting PU risk factors and prevention strategies exist, the availability of literature examining risk factors specific to the cardiac surgery population is limited.

AIM: A systematic review was completed that aimed to identify the risk factors associated with PU development in critically ill, adult, cardiac surgery patients.

METHODS: The MEDLINE, CINAHL, and Cochrane databases were searched. Studies that focused on PU risk factors in critical care, surgical intensive care, or cardiac surgery populations and used PU occurrences as an outcome variable were included in the review.

FINDINGS: Twelve high-quality studies were retrieved and included in the review; they revealed 30 potential PU risk factors. Current evidence is limited in 2 important ways. First, the impact of intraoperative factors, such as cardiopulmonary bypass time or body temperature, appears to be underexplored. Second, a substantive discussion of the risk factors associated specifically with deep tissue injuries, a unique PU category, is absent.

CONCLUSION: The relatively high PU incidence among cardiac surgery patients suggests that typical PU prevention methods are insufficient for this population. Targeted prevention measures must be developed and implemented. Completion of this task required identification of risk factors unique to this population. Specific risk factors likely to increase risk among cardiac surgery patients include prolonged exposure to pressure during long surgical procedures, vascular disease, and/or vasopressor use postoperatively. Additional research concerning risk factors specific to this population is urgently needed.

KEY WORDS: cardiac surgery, deep-tissue injury, pressure ulcers, risk factors.

INTRODUCTION

Pressure ulcers (PUs) are a common and costly complication patients experience when hospitalized. Cardiac surgery patients are among those most at risk for PU development; the reported incidence in cardiac surgery patients is as high as 29.5%.[1] Patients who develop PUs suffer from a number of associated consequences including pain, infection, sepsis, disability, and, in rare cases, death.[1,2] Furthermore, the costs associated with treating PUs are significant, ranging from $500 to $70,000 per individual ulcer,[3] and increasing length of stay by up to 11 days.[4] The Centers for Medicare & Medicaid Services has included in-house acquired category III and IV PUs as "never events"[5] that negatively influence reimbursement for treatment of facility-acquired PUs.[6] Because of the burdens PUs exert on both patients and healthcare organizations, prevention is critical. The first step in successful prevention, however, is identifying the most important factors that render patients vulnerable to PU development.

Multiple studies have examined factors associated with PU development. Commonly cited risk factors include age, acuity of illness, immobility, moisture and comorbid conditions such as diabetes mellitus, and vascular disease.[2,3,7,8] The main physical factors linked to PU development are pressure and shearing forces.[9] In contrast, less is known about risk factors specific to the cardiac surgery population. The relatively high PU incidence among cardiac surgery patients suggests that typical PU prevention methods are insufficient for this population.[1,4] Targeted prevention measures must be developed and implemented.[1] In order to develop such measures, population-specific risk factors must be identified. The aim of this systematic review was to identify the risk factors associated with PU development among critically ill, adult, cardiac surgery patients.

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METHODS

The MEDLINE, CINAHL, and Cochrane databases were searched to identify peer-reviewed, English-language studies that focused on PU risk factors in critical care, surgical intensive care, or cardiac surgery populations. Studies that focused on patients outside these settings were excluded. We also limited our review to studies that used PU occurrences (category/stage I-IV, unstageable PUs, or deep tissue injuries) as an outcome variable.

An initial search was completed using combinations of the following key terms: "pressure ulcer," "decubitus ulcer," "critical care," "intensive care," "cardiac surgery," and "heart surgery." One of the articles retrieved via these searches and published in 2005 presented a review of PU risk factors among cardiac surgery patients.[1] The investigative team repeated the search described in this article to identify any additional relevant studies published after 2005. No new studies meeting the eligibility criteria were uncovered. In addition, a search using the term "deep tissue injury" was completed in CINAHL that identified no relevant studies. We then completed title and abstract reviews to determine which met eligibility criteria. Thirty-three eligible publications were subsequently graded against the Johns Hopkins Nursing Evidence-Based Practice Rating Scale (Figure 1).[10] Members of the investigative team initially graded the articles individually. Final grades were assigned to articles based on discussion; discussion continued until consensus was reached. Twelve studies graded by the team as high or good quality (grade A or B) were retained in the final sample. High-quality evidence included experimental, quasi-experimental, and/or nonexperimental studies conducted using well-defined, rigorous methods that achieved consistent results.[10] Studies retained in the final sample were read in their entirety to identify specific risk factors associated with PU development. This systematic review did not include data pooling or meta-analysis.

RESULTS

The final sample comprised 12 studies or review articles that reported risk factors pertinent to cardiac surgery patients (Table 1).[2,7,8,11–19] Four studies focused specifically on cardiac surgery patients, but the majority included cardiac surgery patients within a heterogeneous population of acute or critical care patients. A summative list of risk factors was compiled based on the findings from each of these studies. Thirty unique risk factors were identified. These risk factors, their associated odds ratios, and confidence intervals are presented in Table 2.

While all patients undergoing major surgery share an increased risk for PU development, findings from the studies identified in this review demonstrate that prior to, during, and after cardiac surgery, patients are exposed to a variety of factors that may account for the particularly high incidence of PUs seen in this vulnerable population. Conceptual models suggest that PU risk factors can be organized into categories, namely, compressive and shearing forces that directly contribute to pressure and the tissue's tolerance for pressure (including its oxygenation) that ultimately mediate tissue damage[20,21] (Figure 2). Specific risk factors in each of these categories increase cardiac surgery patients' PU risk. For example, cardiac surgery patients are exposed to compressive and shearing forces during their procedures. In particular, when patients remain on the operating room table for extended periods of time during long surgeries, they have prolonged exposure to pressure. Concurrently, their tissue tolerance is likely to be reduced due to vascular disease and/or the use of vasopressors postoperatively.

DISCUSSION

Findings from this systematic review identify multiple factors that contribute to PU vulnerability in all patients undergoing major surgery resulting in a brief period of critical illness as they recover from these procedures; existing evidence does not adequately account for the particularly high incidence of PUs seen in cardiac patients. We hypothesize that cardiac surgery itself puts patients at risk, given the comparatively high incidence of PUs in this population and the short time frame within which they develop. Therefore, we advocate for additional research focusing on the relative contributions of unique factors on PU occurrences in patients undergoing cardiac surgery. For example, cardiac surgery–specific factors such as vasopressor

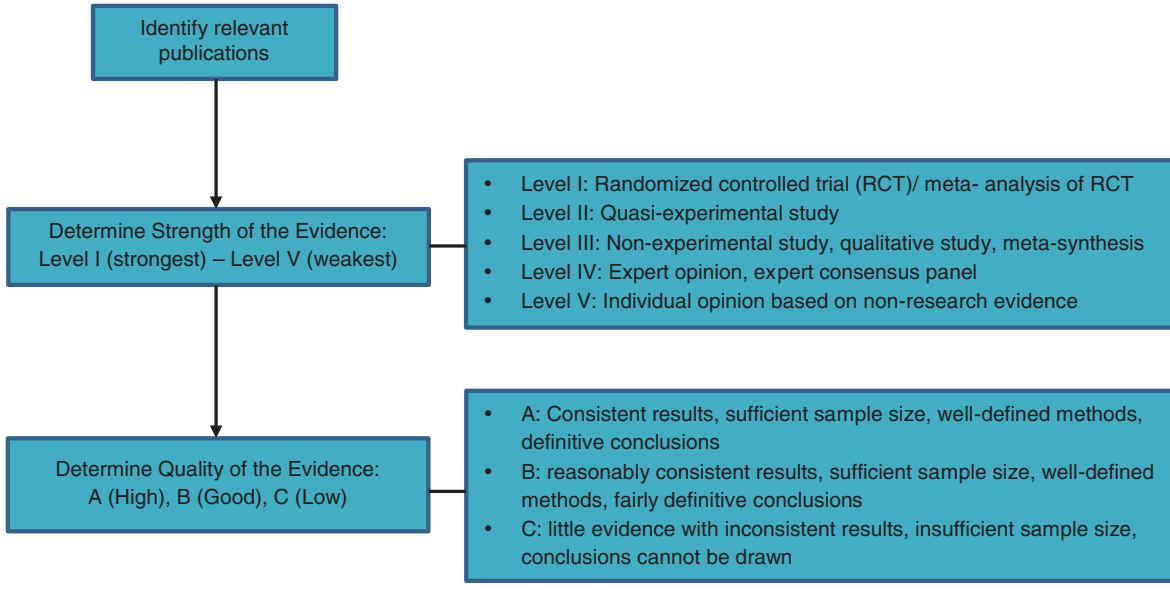

Figure 1. Applying the Johns Hopkins Nursing Evidence-Based Practice Evidence Rating Scales to grade evidence.

TABLE 1.
Summary of Studies Included in Systematic Review

Study	Rating[a]	Design	Setting	Sample Size, N	Patients With PU, n	Outcome Variable	Significant Findings
1. Cox (2011)[7]	III-A	Retrospective correlational	Medical-surgical ICU	347	65	PU stage I-IV	[b]Braden Scale score, mobility, sensory perception, friction/shear, nutrition, age, low mean arterial, systolic, and/or diastolic pressure, hours in the ICU, APACHE II score, use of vasopressors, cardiovascular disease, infection [c]Age, hours in the ICU, mobility, cardiovascular disease, use of vasopressors, friction/shear
2. Frankel and colleagues (2007)[11]	III-A	Retrospective correlational	Surgical ICU	820	25	PU stage II-IV	[b]High blood urea nitrogen/creatinine, vascular patients, diabetes, paraplegia, use of vasopressors [c]Diabetes, spinal cord injury, age >60 y, creatinine >3 mg/dL
3. Fred and colleagues (2012)[12]	III-A	Retrospective explanatory, nonexperimental	Acute surgical (cardiac surgery)	164	82	IAPU development	[b]Female gender, weight, temperature drop, ASA score, preoperative Braden Scale score, gender/temperature interaction [c]Weight, ASA score, Braden Scale score
4. Kemp and colleagues (1990)[13]	III-B	Prospective observational	Acute surgical (cardiac surgery)	125 (28)	15	PU stage I-IV	Combination of time on the operating room table, extracorporeal circulation, and age was a strong predictor of PU development
5. Lewicki and colleagues (1997)[14]	III-B	Retrospective correlational	Cardiac surgery	337	16	PU stage I-IV	[b]Preoperative: low hemoglobin, hematocrit, and albumin, greater comorbidity, diabetes; Postoperative: rapid return to preoperative temperature, being turned only once per day, presence of intra-aortic balloon pump No intraoperative risk factors significantly associated with PU development
6. Nijs and colleagues (2008)[2]	III-A	Prospective descriptive	Surgical ICU	520	104	PU stage II-IV	[b]History of vascular disease, use of vasopressors, hemodialysis/hemofiltration, mechanical ventilation, preventative measures [d]Use of sedatives, body temperature >38.5°C, sitting in a chair [c]Use of vasopressors, history of vascular disease, hemodialysis/hemofiltration, mechanical ventilation, adequate prevention, turning frequency
7. Nonnemacher and colleagues (2009)[8]	III-A	Survey	Acute/ICU	34,238	625	PU stage I-IV	[b]Age, LOS, frequency of surgery and stay in the ICU, mobility/activity [c]Limited mobility/activity, presence of malignant tumor, presence of pain, insufficient nutrition/hydration, use of sedatives, inhibited sense of pain, obstructive arterial disease of abdominal/pelvic arteries, skin problems in areas at risk for PU development, previous PU occurrence, general skin problems, friction/shear
8. Papantonio and colleagues (1994)[15]	III-B	Prospective observational	Cardiac surgery	136	37	PU stage II or III	[b]Age (>70 y), diabetes, respiratory disease, low hematocrit preoperatively, transfer from another hospital; No intraoperative risk factors significantly associated with PU development [c]Diabetes, age >70 y, respiratory disease, low hematocrit, low albumin (reported as relative risk)
9. Pokorny and colleagues (2003)[16]	II-A	Interrupted time series	Cardiac surgery	351	24	PU stage I-IV	[b]Age, female gender, LOS, long wait before surgery, heart failure
10. Stordeur and colleagues (1998)[17]	III-B	Prospective observational	Cardiac surgery	163	48	PU stage II or III	[b]Norton and Braden Scale scores, admission hemoglobin, presence of ulcers at admission, use of antihypertensive drugs, steroid therapy, nosocomial infection, reintervention and readmission in ICUs [c]Admission hemoglobin, postoperative Braden Scale score, postoperative steroid therapy
11. Theaker and colleagues (2000)[18]	III-A	Prospective observational	ICU	286	77	PU stage I-IV	[b]Age, anemia, APACHE II score, coagulopathy, diabetes, use of vasopressors, fecal incontinence, LOS, low albumin, moisture/perspiration, edema, pain, peripheral vascular disease, reduced nutritional intake, smoker, steroid therapy, too unstable to turn [c]Use of vasopressors, APACHE II score, fecal incontinence, anemia, LOS >3 d
12. Tschannen and colleagues (2012)[19]	III-A	Retrospective cohort	Surgical/ICU	3225	383	PU stage I-IV	[b]Age, low BMI, total time in operating room, maximum time in operating room, admission Braden Scale score, diabetes, use of vasopressors, more than 1 surgery, increased risk of mortality [c]Low BMI, diabetes, use of vasopressors, number of surgeries, total time in operating room, admission Braden Scale score, risk of mortality

Abbreviations: APACHE II, Acute Physiology and Chronic Health Evaluation; ASA, American Society of Anesthesiologists; BMI, body mass index; ICU, intensive care unit; IAPU, Intraoperatively associated pressure ulcer; PU, pressure ulcer; LOS, length of stay.
[a]Ratings based on Johns Hopkins Nursing Evidence-Based Practice Evidence Rating Scales.[10]
[b]Risk factors statistically significantly associated with PU development.
[c]Risk factors statistically significant predictors of PU development.
[d]Risk factors statistically significantly negatively associated with PU development.

TABLE 2.
Preoperative, Intraoperative, and Postoperative Risk Factors Associated With PU Development[a]

Risk Factor	Source of Evidence	Level of Risk: Odds Ratio [95% Confidence Interval]
Preoperative risk factors		
Spinal cord injury	Frankel and colleagues (2007)[11]	16.8 [1/5-183]
Previous PU	Nonnemacher and colleagues (2009)[8]	13.51 [10.3-17.7]
Skin problems in areas at risk for PU	Nonnemacher and colleagues (2009)[8]	4.70 [3.6-6.1]
Hemodialysis	Nijs and colleagues (2008)[2]	3.77 [1.0-13.9] (24 h)/9.43 [3.0-29.5] (48 h)[2]
Creatinine >3 mg/dL	Frankel and colleagues (2007)[11]	3.70 [1.2-9.3]
Limited mobility	1. Cox (2011)[7] 2. Nonnemacher and colleagues (2009)[8]	1) 2.27 [1.1-4.8][a] 2) 4.42 [3.50-5.59]
Fecal incontinence	Theaker and colleagues (2000)[18]	3.27 [1.3-8.3]
Age	1. Cox (2011)[7] 2. Frankel and colleagues (2007)[11] 3. Papantonio and colleagues (1994)[15]	1) 1.03 [1.0-1.1] 2) 2.90 [1.2-7.1] 3) 5.38 [2.0-14.8][15]
Vascular disease	1. Cox (2011)[7] 2. Nijs and colleagues (2008)[2] 3. Nonnemacher and colleagues (2009)[8]	1) 2.95 [1. 3-6.4] 2) 4.51 [2.0-10.2] (24 h)/2.85 [1.3-6.3] (48 h)[2] 3) 1.80 [1.1-3.1]
Anemia	Theaker and colleagues (2000)[18]	2.81 [1.2-6.3]
Severity of illness	1. Fred and colleagues (2012)[12] 2. Theaker and colleagues (2000)[18] 3. Tschannen and colleagues (2012)[19]	1) 2.49 [N/A] 2) 3.40 [1.4-7.9] 3) 2.32 [1.5-3.6] (mortality risk score 2)/ 5.50 [3.6-8.5] (mortality risk score 3)/11.15 [7.1-17.5] (mortality risk score 4)
Diabetes	1. Frankel and colleagues (2007)[11] 2. Papantonio and colleagues (1994)[15] 3. Tschannen and colleagues (2012)[19]	1) 2.70 [1.1-6.4] 2) 1.85 [1.1-3.2][15] 3) 1.49 [1.1-2.0]
Insufficient nutrition	Nonnemacher and colleagues (2009)[8]	1.61 [1.2-2.2]
Malignant tumor	Nonnemacher and colleagues (2009)[8]	1.48 [1.2-1.8]
Presence of pain	Nonnemacher and colleagues (2009)[8]	1.43 [1.2-1.8]
General skin problems	Nonnemacher and colleagues (2009)[8]	1.34 [1.1-1.7]
Inhibited sense of pain	Nonnemacher and colleagues (2009)[8]	1.29 [1.0-1.7]
Low preoperative Braden Scale score	1. Fred and colleagues (2012)[12] 2. Tschannen and colleagues (2012)[19]	1) 1.22 [N/A][b] 2) 1.12 [1.1-1.2][b]
Low weight/body mass index	1. Fred and colleagues (2012)[12] 2. Tschannen and colleagues (2012)[19]	1) 1.01 [N/A][b] 2) 1.03 [1.02-1.05][b]
Admission hemoglobin	Stordeur and colleagues (1998)[17]	
Intraoperative or process risk factors		
Friction/shearing force	1. Cox (2011)[7] 2. Nonnemacher and colleagues (2009)[8]	1) 5.72 [1.2-23.0] 2) 1.72 [1.3-2.2]
Length of stay >3 d	Theaker and colleagues (2000)[18]	2.76 [1.1-7.1]
Total number of surgeries	Tschannen and colleagues (2012)[19]	2.23 [1.5-3.4]
Total time in operating room	Tschannen and colleagues (2012)[19]	1.07 [1.0-1.1]
Hours in intensive care unit	Cox (2011)[7]	1.01 [1.00-1.01]
Postoperative risk factors		
Use of vasopressors	1. Cox (2011)[7] 2. Nijs and colleagues (2008)[2] 3. Theaker and colleagues (2000)[18] 4. Tschannen and colleagues (2012)[19]	1) 1.02 [1.00-1.03] 2) 6.05 [1.9-19.5] (24 h)[2] 3) 8.11 [3.6-18.0] 4) 1.33 [1.0-1.7]
Mechanical ventilation	Nijs and colleagues (2008)[2]	4.82 [1.7-13.3] (48 h)[2]
Application of sedative drugs	Nonnemacher and colleagues (2009)[8]	1.61 [1.2-2.1]
Postoperative steroid use	Stordeur and colleagues (1998)[17]	
Postoperative Braden Scale score	Stordeur and colleagues (1998)[17]	

Abbreviation: PU, pressure ulcer.
[a]Significant in multivariate logistic regression. Nijs and colleagues[2] presented significant results for both 24 and 48 hours before the occurrence of a pressure ulcer; Fred and colleagues[12] reported severity of illness based on ASA (American Society of Anesthesiologists) score; Theaker and colleagues[18] reported severity of illness based on APACHE II (Acute Physiology and Chronic Health Evaluation) score; Tschannen and colleagues[19] reported severity of illness based on a risk of mortality rating system that accounted for patients' comorbidities and ranged from 1 (low risk) to 4 (high risk).
[b]To simplify interpretation, the value presented is the reciprocal of the authors' reported statistics.

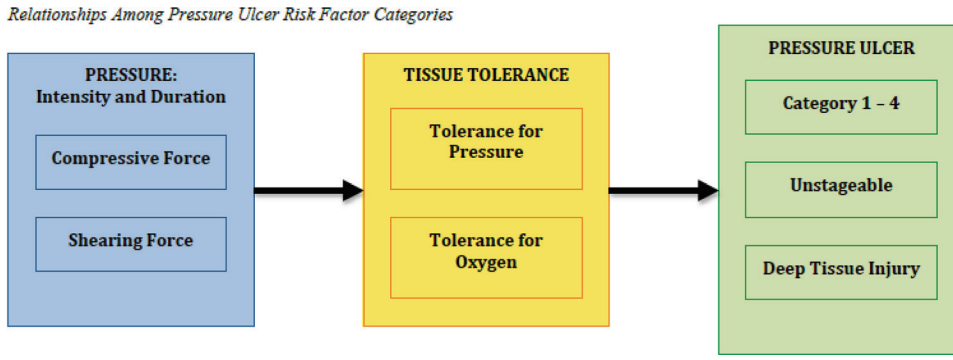

Figure 2. Model depicts that pressure is comprised of compressive and/or shearing forces. Pressure ulcers, which include category I-IV ulcers, unstageable ulcers, and suspected deep tissue injuries, develop in the presence of compressive and shearing forces. Tissue tolerance is an intermediate variable comprised of an individual's tolerance for pressure (based on factors such as age and nutritional status) and an individual's tolerance for oxygen (based on oxygen supply and oxygen needs).[1,20,21]

use postoperatively, intraoperative cardiopulmonary bypass time, and body temperature affect tissue tolerance for oxygen and may contribute to PU development.

Our review also revealed absence of adequate evidence or even a substantive discussion of suspected deep tissue injuries (SDTIs) in cardiac surgery patients. Suspected deep tissue injuries are defined as a "purple or maroon localized area of discolored intact skin or blood-filled blister due to damage of underlying soft tissue from pressure and/or shear."[22(p9)] They often begin as a blister and evolve to become covered by thin eschar before rapidly evolving further to expose layers of tissue; progression may occur despite optimal treatment.[22] In 2007, the National Pressure Ulcer Advisory Panel (NPUAP) recognized SDTIs as a distinct category of skin injury by adding them to their PU classification system.[6] Despite this inclusion, none of the studies we retrieved explicitly discussed SDTIs. In order to evaluate this term further, we searched the CINAHL database using the key term "deep tissue injury" and found only 8 articles. Findings for this search revealed that SDTIs may be caused by hypoxic reperfusion versus pressure,[23] which is not accounted for in existing PU risk models. Current investigations of SDTIs tend to focus on the physiology of these injuries, while evidence concerning their prevalence, incidence, and natural history is limited.[6] Yet, since 2007, when the SDTI classification was advocated by the NPUAP, the proportion of PUs categorized as SDTIs has increased while the proportion of PUs reported in other categories has decreased.[6] These trends in reporting suggest that SDTIs are prevalent, and only now being recognized, and may require different prevention and management strategies than other PU categories. Additional research is needed to more fully establish SDTIs as a distinct PU category[6] and to understand the unique risk profile of cardiac surgery patients.

CONCLUSION

Multiple factors have been identified that contribute to the high incidence of PUs in cardiac surgery patients. In contrast, evidence about unique factors strongly associated with cardiac surgery is lacking. Intraoperative risk factors that affect tissue tolerance have not been thoroughly investigated. Further research examining the epidemiology and pathophysiology of SDTIs is also needed to better understand the significance of this PU category among cardiac surgery patients and to design effective preventative interventions.

KEY POINTS

- Cardiac surgery patients are among those most at risk for PU development, and current PU prevention methods do not adequately address these patients' unique needs.
- Published investigations about PU risk factors among critically ill patients do not account for unique risk factors associated with cardiac surgery, particularly intraoperative factors.
- Suspected deep tissue injuries have been identified by the NPUAP as a category of pressure injuries, but little is known about their underlying mechanism of injury or epidemiology. Effective preventive interventions for SDTIs cannot be designed until more is known about the injuries.

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