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# A Retrospective, Descriptive, Comparative Study to Identify Patient Variables That Contribute to the Development of Deep Tissue Injury Among Patients in Intensive Care Units

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**Abstract**

Deep tissue injury (DTI) may develop in critically ill patients despite implementation of preventive interventions. A retrospective, descriptive study was conducted in a 620-bed, level 1 trauma, academic medical center with 7 adult intensive care units ([ICUs] cardiac surgery, trauma surgery, burn surgery, med-surgery, neurosurgery, medical, and transfer) among patients treated from January 1, 2010 to January 1, 2015. All patients 18 years of age or older that developed a sacral DTI that evolved into a Stage 3, Stage 4, or unstageable hospital-acquired pressure ulcers (HAPU) in the ICU were included. Control group data were obtained from a sample of ICU patients who did not develop a DTI during 1 random day during that time period. Data were extracted from electronic medical records to compare ICU patients that developed a DTI (n = 47; age 55 [range 28–93] years, 28 men) to those who did not develop a DTI (n = 72; age 58.9 [range 18–94] years, 46 men). Twenty-five (25) potential sociodemographic and clinical risk factors were identified from root cause analysis and measured for significance. Systolic and diastolic blood pressure, length of surgery, hematocrit levels, international ratio, dialysis treatments, history of shock or vasopressor use, and total Braden score were significantly ($P$ <.05) different between the general and HAPU population. Braden scores were low for general ICU (15.0 ± 0.4) and HAPU patients (12.9 ± 0.3) ($P$ = 0.03). Multivariate, univariate, and regression analysis showed patients with poor perfusion (low blood pressure) (OR 0.93; 95% CI 0.88-0.99), prolonged surgical procedures (time in surgery OR 1.20; 95% CI 1.07-1.33), or a history of dialysis (OR 4.0; 95% CI 0.060-0.99) and shock (OR 10.0; 95% CI 0.025-0.43) were at greatest risk for the development of DTI evolving into a Stage 3, Stage 4, or unstageable HAPU. For every mm Hg decrease in diastolic blood pressure, the odds of a DTI increased by approximately 7.5% (1/0.93 = 1.075). For every hour increase in surgery, the odds of developing a DTI increased by 20%. These data suggest when all modifiable (Braden Scale-identified) risk factors are addressed, as was the case in this population, patient-related risk factors may be more important for HAPU development in ICU patients than quality of nursing care variables. Future research should focus on the role of and methods to increase perfusion to prevent DTI development, especially during dialysis and surgical procedures.

**Keywords:** outcome assessment, retrospective study, pressure ulcer, risk factors, critical care

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Hospital-acquired pressure ulcers (HAPU) represent a major burden of illness and can develop across the continuum of care (acute care hospitals, long-term care, skilled nursing facilities, and at home) despite best practices for prevention. According to a review of the literature,[1] deep tissue injuries (DTI) may be a precursor to the development of a HAPU in critically ill patients in intensive care units (ICU). The National Pressure Ulcer Advisory Panel[2] (NPUAP) guidelines state DTI presents as a "purple or maroon localized area of discolored intact skin or blood-filled blisters, due to damage of underlying soft tissue from pressure and/or shear." DTI may evolve into Stage 3, Stage 4, and unstageable pressure ulcers.[3,4]

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The incidence of HAPU in ICUs in the United States has been reported to range from 10% to 41%.[5,6]

Both DTI and pressure ulcers are localized areas of tissue necrosis that develop most frequently over a bony prominence when soft tissue is compressed by an external surface over a period of time.[2] The consequences of pressure-induced injury to skin range from nonblanchable erythema of the skin (Stage 1) to full-thickness deep ulcers involving muscle and bone (osteomyelitis) in Stage 4.[2] Berlowitz and Brienza[1] posited clinically superficial (Stage 1 and Stage 2) pressure ulcers may have a different etiology than DTI or perhaps all pressure ulcers arise from DTI. The NPUAP guidelines[2] suggest applied pressure, shear, friction, and moisture contribute to the development of a pressure ulcer. However, other patient-related factors may provide a greater contribution to the development of DTI that evolve into Stage 3, Stage 4, or unstageable pressure ulcers, especially in patients who receive interventions designed to prevent the modifiable risk factors of pressure, shear, friction, and moisture. The 2009 white paper by the NPUAP[2] suggested occurrences of HAPUs, despite all prevention interventions in critically ill patients, may not be preventable.[2]

Although other scales and tools have been developed for risk assessment, the literature review by Kelechi et al[7] found the Braden Scale is the most commonly used worldwide. The Braden Scale has 6 constructs in the areas of sensory perception, mobility, activity, moisture, friction/shear, and nutrition. These constructs are assigned a score on a scale of 1 to 4, with higher scores showing a lower risk for the development of HAPU. Modifiable risk factors included in the Braden Risk Assessment Scale include interface pressure, shearing forces, friction, moisture, and nutrition.[2]

According to the institutional policy of the authors' facility, nurses are responsible for performing HAPU risk assessment at regular, predefined intervals. However, the Braden Scale was developed for use in long-term care facilities and has been adopted by the acute care setting without further validation for acute care patient risk assessment.[8]

A significant gap in the knowledge exists in identifying and quantifying patient-related risk factors that contribute to the development of DTIs that evolve into Stage 3, Stage 4, and unstageable HAPU in ICUs. It has been suggested hospitals use their own data, over time, for pressure injury prediction and to develop risk models for their specific population.[8] Hospital-specific data were used in this study to further the science on the development of DTIs and pressure injury in critically ill patients in ICUs.

## Purpose

The purpose of this study was to identify common patient characteristics and factors (vulnerabilities) that contribute to the development of DTIs that evolved into Stage 3, Stage 4, and unstageable HAPU in ICU patients. The secondary purpose of this study was to define specific parameters for the risk factors to identify patients at risk for HAPU within the ICU population.

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### Key Points

- The authors conducted a retrospective study to identify patient characteristics and variables that contribute to the development of deep tissue injury (DTI) that evolves into Stage 3, Stage 4, or unstageable ulcers in intensive care unit (ICU) patients.
- Compared to the general ICU population sample (n = 72), patients who developed a DTI (n = 47) had significantly lower systolic and diastolic blood pressure, longer time in surgery, a higher international ratio unit, and lower Braden score and were more likely to have a history of dialysis, shock, and vasopressor use.
- Further analysis showed when all Braden-identified risk factors are addressed, patients with poor perfusion (low blood pressure), prolonged surgical procedures, or a history of dialysis or shock were at greatest risk for the development of DTI evolving into a Stage 3, Stage 4, or unstageable hospital-acquired pressure ulcer.
- The authors conclude more research is needed but that efforts to reduce hospital-acquired pressure ulcers rates in high-risk ICU patients who are receiving appropriate prevention interventions should be focused on patient-related and not on nursing care-related factors.

## Methods

This retrospective, descriptive, comparative study was conducted in a 620-bed, level 1 trauma, academic medical center that has 7 adult ICUs (cardiac surgery, trauma surgery, burn surgery, med-surgery, neurosurgery, medical, and transfer). Hospital Institutional Review Board approval was obtained. Inclusion criteria specified participants should be patients 18 years of age or older that developed sacral DTIs that evolved into Stage 3, Stage 4, and unstageable HAPU in the ICU.

The data were abstracted following an electronic medical record (EMR) review to identify patients who met the study criteria and were in the hospital at any point from January 1, 2010 to January 1, 2015.

**Data collected.** A root cause analysis was performed on each HAPU and 25 characteristics and factors were identified, abstracted, and entered into an Excel spreadsheet: gender and age; type of ICU; length of stay (LOS) in ICU; Braden score on admission and on the discovery of pressure ulcer; primary and secondary medical diagnosis; HAPU location, date discovered, initial stage, and final stage; type and length of surgical procedures for the 2-week period before the DTI was identified; body mass index (BMI); albumen level; lowest measured hemoglobin and hematocrit (HCT) for the 2-week period before the DTI was identified; international ratio (INR) for clotting of blood; lowest measured systolic

blood pressure (SBP) and diastolic blood pressure (DBP) for the 2-week period before the DTI was identified; and dialysis or no dialysis, vasopressor use or no vasopressor use, documented shock and type of shock (ie, neurogenic, hemorrhagic, septic, cardiogenic).

The demographic characteristics and factors collected were based on literature review and commonalities in patient characteristic findings in the data. The EMR data were abstracted by the primary investigator (a subject matter expert) and co-investigator (PI), who accessed the EMR of patients who had documented Stage 3, Stage 4, and unstageable HAPU. The EMR review process was performed by both the PI and co-investigator simultaneously to ensure the accuracy of the data collection.

**Data processing.** After all HAPU data were retrieved and entered into the Excel spreadsheet, a comparative group was created in order to define the differences between general, non-DTI ICU patients and patients that developed DTI. The EMR was accessed for all patients in the adult ICUs on 1 random day to have a comparison cohort of general ICU patients. The same risk data were abstracted from the general ICU patient group for comparison with the patients who developed DTI. Twelve (12) factors were eliminated after comparison analysis due to nonsignificance or no difference between ICU patients who did and did not develop DTI. The remaining characteristics and factors were gender, age, BMI, length of stay, SBP, DBP, LOS, HCT, INR, dialysis, shock, use of vasopressors, and Braden score.

**Data analysis.** The analysis of the data is both descriptive and comparative to determine common characteristics and factors in patients who developed DTIs that evolved into a Stage 3, Stage 4, or unstageable HAPU. The authors used a model selection procedure: first, possible risk factors were identified for a multivariable logistic regression model. A series of univariate tests was performed to identify the significant variables. Variables were considered for inclusion if they had a $P$ value <.2. $T$-tests were conducted to assess for association between DTI and SBP, DBP, Braden score, HCT, BMI, length of surgery (hours), and INR. Fisher's exact test was used to assess the association between DTI and dialysis, shock (hypovolemic, hemorrhagic, neurogenic, cardiogenic, or septic), and use of vasopressors. The authors also tested for multicollinearity between the continuous variables using Pearson's correlation. If any correlation between 2 variables was >0.6, only the variable with the larger or more clinically relevant effect size was included. The analysis was performed using SAS version 9.3 (SAS Institute Inc, Cary, NC). A logistic regression model including all the candidates identified was fit, and a backward selection procedure was employed to identify covariates significant at the .05 level.

## Results

A total of 119 patients with and without DTIs were included in the study. Of the 76 general ICU patients, 4 had developed DTI and a Stage 3, Stage 4, or unstageable HAPU; therefore, they were placed into the HAPU group, leaving 72 in the General ICU group (see Table 1). The general average age of the adult ICU population (n = 72) was 58.9 (range 18–94) years, with an average BMI of 29.9 (range 16–65.2) and average LOS of 12.8 (range 1–124) days. The HAPU population (n = 47) had an average age of 55 (range 28–93) years, with an average BMI of 30.6 (range 18.9–74.3) and average LOS of 24.9 (range 2–82) days.

**Table 1. Demographic characteristics**

| | General ICU population | HAPU population |
|---|---|---|
| N | 72 | 47 |
| Average age (years) | 58.9 | 55.0 |
| Range | 18–94 | 28–93 |
| Male (n) | 46 | 28 |
| % | 64 | 60 |
| Female (n) | 26 | 19 |
| % | 36 | 40 |
| Average BMI | 29.9 | 30.6 |
| range | 16–65.2 | 18.9–74.3 |
| Average LOS (days) | 12.8 | 24.9 |
| Range | 1–124 | 2–82 |

*ICU=intensive care unit; HAPU=hospital-acquired pressure ulcer; BMI=body mass index; LOS=length of stay*

The results of the univariate tests are shown in Table 2. Mean/average SBP was <92 mm Hg, DBP <49, cumulative length of surgery >6 hours, HCT <27, and elevated INR >1.3. Shock (documented by the physician), dialysis treatment, and vasopressor use were significant patient-related factors ($P$ <.001) in the development of DTIs in critically ill patients. A Braden score <18 was considered significant ($P$ = .03). BMI was not found to a significant risk factor.

SBP and DBP were strongly correlated, with an R = 0.7 ($P$ <.001). No other continuous risk factors were correlated above 0.60. Because a decrease in DBP in a hypotensive patient is more clinically significant for perfusion, only DBP was included in the regression model.

To identify the most significant risk factors, a backward selection procedure was performed. During this procedure, HCT ($P$ = .54), Braden score ($P$ = .36), vasopressor use ($P$ = .41), and INR ($P$ = .12) were eliminated.

The significant variables remaining after backward selection and their odds ratios were dialysis, shock, DBP, and time in surgery (see Table 3). The results show, after controlling for the covariant risk factors, patients receiving dialysis had approximately 4 times greater odds of developing a DTI compared to patients without dialysis. For patients with shock, the odds of a DTI development were 10 times greater than those who had no diagnosis of shock. For every mm Hg decrease in DBP, the odds of a DTI increased by about 7.5%

**Tables 2. Univariate tests**

| Variable (units) | General ICU population | HAPU population | *P* value |
|---|---|---|---|
| Systolic blood pressure (mm Hg) | 116±3.3 (109.5–122.5) | 88.8±1.8 (85.8–92.4) | <.001 |
| Diastolic blood pressure (mm Hg) | 62.2±2.0 (58.2–66.3) | 46.3± 1.3 (43.6–48.9) | <.001 |
| Length of surgery (hours) | 2.6±0.5 (1.5–3.7) | 9.7±1.7 (6.2–13.2) | <.001 |
| Hematocrit (g/dL) | 30.6±0.9 (28.9–32.2) | 25.4±0.7 (24.1–26.8) | <.001 |
| International ratio (units) | 1.2±0.03 (1.1–1.7) | 1.5±0.08 (1.3–1.7) | <.001 |
| Dialysis (yes %) | 29 | 71 | <.001 |
| Shock (yes %) | 2.5 | 87.5 | <.001 |
| Vasopressor (yes %) | 19.4 | 80.6 | <.001 |
| Braden score | 15.0±0.4 (14.2-15.8) | 12.9±0.3 (12.2-13.5) | .03 |
| Body mass index (kg/m$^2$) | 29.6±0.9 (27.8-31.5) | 31.0±1.3 (28.3–33.7) | .42 |

*HAPU=hospital-acquired pressure ulcer; ICU=intensive care unit*
*Values are expressed as mean ± standard error of the mean and (confidence intervals) for continuous values*

**Table 3. Odds ratio estimates**

| Effect (units) | Odds ratio | 95% Wald confidence limits | | *P* value |
|---|---|---|---|---|
| Dialysis (yes or no) | 4.0 | 0.060 | 0.99 | .05 |
| Shock (yes or no) | 10.0 | 0.025 | 0.43 | .002 |
| Diastolic blood pressure (mm Hg) | 0.93 | 0.88 | 0.99 | .02 |
| Time in surgery (hours) | 1.20 | 1.07 | 1.33 | .001 |

(1/0.93 = 1.075). For every hour increase in surgery, the odds of a DTI increased by 20%.

## Discussion

In this level 1 trauma center, a decrease in perfusion (low SBP and DBP) due to shock states (sepsis, hemorrhagic, hypovolemia, neurogenic, cardiogenic) and prolonged procedure times were found to be the most significant factors contributing to DTIs in this population. Retrospective studies[9,10] and a literature review[11] suggest the patient-specific factors found to predict an increased risk for HAPU in the ICU setting were decreased perfusion, advanced age, procedures lasting >2 hours, and sepsis with multiple end organ system failure. Although similar findings were noted in the current study, patients that developed DTIs that evolved into Stage 3, Stage 4, and or unstageable HAPU were younger than the patients in previous studies.[10,12] Previous studies included outcomes of Stage 1 and Stage 2 pressure ulcers, which are usually caused by modifiable risk factors that are associated with the Braden risk assessment.[10] This study focused on patients who developed DTIs that evolved into Stage 3, Stage 4, and unstageable HAPU only.

Combined low perfusion and high surface pressure over time was strongly associated with the development of DTIs in this ICU population. Longitudinal[13] and prevalence studies[14] (N = 102) also noted prolonged operating room or procedure time contribute to the development of HAPU; 1 study[14] suggested as little as 2 to 4 hours of general anesthesia during a procedure may be a contributing factor. During a previous study[15] (N = 49) on OR surfaces, the current authors showed standard OR surfaces do not provide pressure redistribution. This suggests pressure over the sacrum (pressure mapping >32 mm Hg) during patient low perfusion (DBP <50; SBP <90) and prolonged OR procedures may contribute to the development of DTI.

Previous studies measuring blood flow[16] and skin perfusion[17] found skin perfusion is decreased during hemodialysis because of hypovolemia related to fluid removal, inflammatory response, and blood flow redistribution. As a result, artificially lowered perfusion during hemodialysis treatment may contribute to DTI development. A prospective quasi-experimental repeat measure design study suggested low serum albumen,[18] higher creatinine, higher blood urea nitrogen[13,19] levels, and low HCT[19] are more significant predictors for the development of HAPU than the Braden score.[8] The results of the current study seem to confirm some of these findings. Dialysis — when used for stage 5 kidney disease or acute kidney failure (higher creatinine, higher blood urea nitrogen, and low HCT) — significantly increased the risk of developing a DTI, while the Braden score was not predictive once other risk factors were considered.

In the univariate test, the Braden score was significant (*P* = .03); however, during the backward elimination procedure, the Braden score was not considered significant (*P* = .4) and therefore eliminated. It is possible the Braden score was not significant because all (Braden-related) prevention interventions were implemented for patients with scores of 18 or below. This suggests that when basic prevention measures have been implemented the Braden Scale is not sensitive or specific enough to identify other risk factors associated with the development of HAPU in ICU patients. Evidence supporting the use of the Braden in predicting HAPU in ICU patients is limited because the scale does not take into consideration unique factors of critically ill patients in the ICU setting.[8,20] In a retrospective medical review on characteristics of hospitalized patients with vascular disease, Corniello et al[19] found 9 factors contribute to HAPU; the Braden score was the least sensitive for predicting risk of the development of HAPU. A retrospective electronic medical record review[20] on

ICU patients showed poor predictive validity and poor accuracy when using the Braden Scale for risk assessment for the development of HAPU in an ICU. These findings are consistent with the current study results for ICU patients who developed a DTI.

## Limitations

The limitations of this study are inherent to the retrospective design. All data were collected and reviewed at the end of 5 years and as risk factors were identified. The authors may have omitted risk factors that were unknown or unmeasurable at the time of this study. Previous identified possible nutrition-related risk factors such as weight fluctuations and prealbumen were not available for this study. A further limitation of the study may be in the comparative ICU patient data collection method.

## Conclusion

In this study, ICU patients with poor perfusion (low blood pressure) or who had prolonged surgical procedures or dialysis were at greatest risk for the development of DTI evolving into a Stage 3, Stage 4, or unstageable HAPU. For every mm Hg decrease in DBP, the odds of a DTI increased by about 7.5% (1/0.93 = 1.075). For patients with a diagnosis of shock, the odds of developing a DTI were 10 times greater than those who had no diagnosis of shock. For every hour increase in surgery, the odds of developing a DTI increased by 20%. Data presented also indicate patients with hemodialysis treatments had approximately 4 times greater odds of developing a DTI compared to patients who did not need hemodialysis treatments.

This study advances the knowledge of the specific risk factors, including the parameters of risk factors, that contribute to the development of DTI. The univariate test of the Braden score was significant with confidence intervals for the general ICU population, ranging from 14.2 to 15.8, comparable with the Braden scores of the HAPU population (12.2–13.5), suggesting all ICU patients were at high risk for the development of HAPU. The use of the Braden risk assessment for patients in this study was not found to predict the risk for developing a HAPU, which may be because all Braden-related prevention interventions were implemented and documented.

In turn, this suggests when all modifiable risk factors are addressed, patient-related risk factors may be a more important variable for HAPU development in ICU patients than quality of nursing care variables. In addition, the NPUAP should consider changing the nomenclature of DTIs which evolve into Stage 3, Stage 4, and unstageable pressure ulcers. DTIs that originate in the ICU from poor perfusion should not be confused with pressure ulcers that occur from moisture, poor nutrition, and lack of repositioning (Braden-related risk factors).

In addition, the study found blood pressure increases the odds of developing DTI and HAPU — information that can guide hemodialysis treatment. New guidelines may be needed to modify hemodialysis in hopes of maintaining perfusion to the sacral area (and possibly feet) during low perfusion states. Pressure-redistribution surfaces should be used in all patients during low perfusion states to include outpatient dialysis, the ICU, and during surgical procedures. Nurses should have the authority to order evidence-based prevention interventions that include pressure-redistribution surfaces and dressings to ameliorate the effects of pressure, moisture, and shear.

This study confirms other reports about the role of perfusion and HAPUs, suggesting a potential role for measuring perfusion in combination with surface interface pressure, especially over bony prominences during immobile events (eg, prolonged surgery or hemodialysis). In addition, further research should focus on pressure ulcers on other bony prominences that occur in low perfusion states and to investigate additional patient-related risk factors that may contribute to the development of DTIs and HAPU, despite implementation of all prevention interventions. As such, the authors are working with another academic medical center in order to replicate this study in their adult ICU population. ■



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