CLINICAL MANAGEMENT

extra

Differentiating a Pressure Ulcer from Acute Skin Failure in the Adult Critical Care Patient

Barbara Delmore, PhD, RN, CWCN, DAPWCA, IIWCC-NYU • Program Manager • Wound & Ostomy Service • NYU Langone Medical Center • New York
Jill Cox, PhD, RN, APN-C, CWOCN • Advanced Practice Nurse/Wound, Ostomy, Continence Nurse • Englewood Hospital and Medical Center • New Jersey • Assistant Professor • Rutgers University • Newark, New Jersey
Linda Rolnitzky, MS • Research Scientist • NYU Langone Medical Center • New York
Andy Chu, MS, RD, CDN • Registered Dietitian • NYU Langone Medical Center • New York
Angela Stolfi, PT, DPT, Cert MDT • Director of Physical Therapy • Rusk Rehabilitation, NYU Langone Medical Center • New York

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PURPOSE:

The purpose of this learning activity is to provide information regarding the differentiation between pressure ulcers and acute skin failure (ASF) in critically ill patients.

TARGET AUDIENCE:

This continuing education activity is intended for physicians and nurses with an interest in skin and wound care.

OBJECTIVES:

After participating in this educational activity, the participant should be better able to:

1. Describe the purpose, methodology and impact of this research.
2. Differentiate the pathophysiology of pressure ulcers and ASF.
3. Identify risk factors and diagnostic criteria for ASF.

ABSTRACT

OBJECTIVE: To develop a statistical model to predict the development of acute skin failure in patients admitted to the intensive care unit (ICU) and to validate this model.

DESIGN: Retrospective case-control, logistic regression modeling

PARTICIPANTS: 552 ICU patients.

MAIN OUTCOME MEASURES: Intensive care unit patients with and without pressure ulcers (PrUs) were studied and compared on key variables sorted into the following categories: (1) disease status, (2) physical conditions, and (3) conditions of hospitalization.

RESULTS: The variables, peripheral arterial disease (odds ratio [OR], 3.8; $P = .002$), mechanical ventilation greater than 72 hours (OR, 3.0; $P < .001$), respiratory failure (OR, 3.2; $P < .001$), liver failure (OR, 2.9; $P = .04$), and severe sepsis/septic shock (OR, 1.9; $P = .02$), were found to be statistically significant and independent predictors of acute skin failure in ICU patients. These variables created a predictor model for acute skin failure in the ICU.

CONCLUSIONS: Lack of objective criteria to define acute skin failure presents a clinical conundrum for practitioners—the acknowledgment that skin failure exists, but no clear-cut diagnostic criteria in which to support its existence as a result of a paucity of empirical evidence. In certain populations, such as the critically ill patient, the phenomenon of acute skin failure may be occurring, and with the current level of evidence, these ulcers may be incorrectly identified as PrUs. Accurately distinguishing risk factors that lead to a PrU from factors that result in a lesion due to acute skin failure is crucial in the quest to provide evidence-based practice to patients.

KEYWORDS: pressure ulcer, acute skin failure, multiple organ dysfunction syndrome, intensive care unit

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INTRODUCTION

Although pressure ulcers (PrUs) have been observed and recorded in the historical nursing and medical literature, the concept of skin failure has not been as well defined, leaving clinicians with the difficult task of trying to prospectively differentiate an ulcer caused by pressure from the condition known as skin failure. Today, patients are surviving illnesses that were once thought to end in certain death. The price for this survival may be the manifestation of what is now termed a PrU, an adverse patient condition. However, it is often forgotten that the skin, the largest organ of the body, receives up to one-third of the body's circulating blood volume[1] and, as with any organ, can fail because of critical or terminal illness.[2] In 1991, La Puma[3] questioned that if the heart and lungs can fail, why not the skin?

REVIEW OF THE LITERATURE

Pressure ulcers and skin failure are 2 distinct, yet related, clinical phenomena. Pressure ulcers are defined as localized injury to the skin and underlying tissue that occur over bony prominences because of pressure or pressure in combination with shear,[4] whereas skin failure is defined "as an event in which the skin and underlying tissue die due to the hypoperfusion that occurs concurrent with severe dysfunction or failure of other organ systems."[5] Pressure ulcers and skin failure can occur simultaneously, as failing skin increases susceptibility to the forces of pressure and shear.[6] However, PrUs are distinguishable from skin failure in that PrUs occur because of unrelieved pressure resulting in tissue ischemia and necrosis and can occur in healthy individuals.[5] Pressure ulcers have been identified as a "marker" or "messenger" of coexisting illness and not an independent risk factor for increased mortality,[5,7–11] whereas skin failure[12] "mirrors" general health and is often an indicator of other body system failures.[13]

The pathophysiologic development of PrUs has been explored for more than 50 years, with the work of early theorists emphasizing the relationships of intense and prolonged pressure in addition to tissue tolerance for pressure in the development of PrUs.[14–16] Similarly, Braden and Bergstrom[17] applied the work of these early researchers and identified the 2 critical determinants for PrU development as intensity and duration of pressure and tissue tolerance for pressure in their conceptual schema for PrU development. Berlowitz and Brienza[18] hypothesized 4 pathophysiologic changes that explain the development of a PrU: (1) ischemic changes caused by capillary occlusion, (2) reperfusion injury, (3) impaired lymphatic function, and (4) prolonged mechanical deformation of tissue cells due to prolonged pressure. Berlowitz and Brienza[18] also theorized that PrUs develop at the deep tissue layers with damage progressing outward toward the skin surface, whereas others hypothesize that the development of PrUs is really a "top-down" phenomenon, with tissue destruction proceeding downward to the deeper tissue layers.[19]

More than 100 risk factors have been cited in the literature to be related to PrU development,[20] affirming the multifactorial etiology of PrU development. Although PrU risk assessment scales such as the Braden Scale[21] capture some of these risk factors, other risk factors have also been empirically correlated with PrU development. Some of these factors include comorbidities, such as diabetes, infection, vascular disease, cardiovascular disease, anemia,[22–27] hypotension,[25] advancing age,[23,24,27–29] vasopressor agents,[22,24,27] and history of PrUs.[30] An ongoing debate as to whether all PrUs are preventable[31] has left clinicians to find answers to why they develop despite optimal care.

In the acute care setting, the concept of the unavoidable PrU is ambiguous and lacks regulatory support at this time to substantiate

its existence. According to expert consensus in 2010 and reaffirmed in 2014, the National Pressure Ulcer Advisory Panel (NPUAP) defined the unavoidable PrU as an ulcer that forms because of the individual's clinical conditions and risk factors, despite all standard prevention measures that are applied and revised as appropriate.[32,33] Although agreement exists among experts and clinicians that the phenomenon of the unavoidable PrU exists in acute care patients,[31–33] this determination usually occurs after ulcer development. Situations favoring the development of an unavoidable PrU would include circumstances such as hemodynamic instability that prohibits mobility, septic shock, impaired cardiopulmonary status, sustained head elevation, or the presence of malnutrition and cachexia.[33]

Skin failure occurs when blood is shunted away from the skin to maintain perfusion and nutrients to vital organs, such as the heart, lungs, and kidneys.[34] As vital organs begin to fail, perfusion to the skin diminishes with resulting ischemic changes leading to tissue and skin necrosis.[34] Langemo and Brown[5] further categorized skin failure as either chronic, end stage, or acute. Chronic skin failure is characterized by skin and tissue death that occurs in conjunction with chronic disease. It is not a transient process but is gradual and occurs in tandem with multiple chronic comorbidities leading to organ failure and subsequently skin failure. End-stage skin failure occurs at the end of life in the final days or weeks before death. With ensuing death, the physical manifestations of skin failure can often occur over a short period, typically with a deep destruction of the skin visible within days or even hours.[5] In 2009, a panel of experts was convened to develop a consensus statement termed SCALE (Skin Changes at Life's End) to define the presence of end-of-life skin failure. To date, the majority of research or opinions on skin failure have been aimed at the terminally ill or palliative care populations.[9–12,35–37]

Acute skin failure (ASF) describes the hypoperfusion state that leads to tissue death that occurs simultaneously to a critical illness. Based on Langemo and Brown's[5] work, Shanks et al[25] defined ASF as "pressure-related injury concurrent with acute illness as manifested by hemodynamic instability and/or major organ system compromise." The heavy burden of illness experienced by critical care patients makes them a prime population in which ASF can occur. Clinical manifestations, such as compromised circulation and impaired perfusion[38]; prolonged hypotension[38]; organ failure, including respiratory, renal, cardiac, or liver failure[38,39]; and sepsis,[38] have all been found to be related to ASF in the critical care population.

Experts agree that the occurrence of a PrU differs from an ulcer due to ASF; however, no formal diagnostic criterion currently exists to identify ASF.[32] A review of the empirical literature yields the following influential factors that have been associated with ASF: impaired nutrition,[40–45] multisystem organ failure, limited tissue perfusion, severe anemia, sepsis, severe sepsis, septic shock, multiple organ dysfunction syndrome (MODS), diabetes, immobility,[46,47] surgery greater than 3 hours,[48] prolonged hypotension,[25] vasopressors,[24,49] and prolonged mechanical ventilation.[50] Thus, it is plausible in the critical care population that many of the ulcers that develop are often classified as PrUs, but could represent manifestations of ASF. However, lack of diagnostic criteria to define ASF impedes this conclusion. Hence, this presents a clinical challenge, as well as an opportunity for practitioners—the acknowledgment that ASF exists, but no clear-cut diagnostic criteria in which to support its existence and lack of empirical evidence to define and describe this phenomenon.

The purpose of this study was to identify and describe the factors that contribute to ASF in adult critical care patients and to determine the predictors of ASF in a sample of adult critical care patients. Based on the works of both Langemo and Brown[5] and Shanks et al,[25] ASF has been defined in this study as a pressure-related injury concurrent with critical illness that manifests as a result of the hemodynamic instability and/or hypoperfusion that occurs as a result of organ system compromise and/or failure. Thus, the authors are investigating factors that potentially contribute to ulcer formation due to ASF, yet were previously identified in the patient record as PrUs.

METHODS

A retrospective case-control methodology was used for this study. The sites for this study were 2 Magnet-designated medical centers in the Northeast. Site 1 is a tertiary urban medical center with 702 beds, including 55 adult intensive care unit (ICU) beds. Site 2 is a suburban teaching hospital with 500 beds, including 18 adult ICU beds.

The sample sizes for both the main and validation analyses were calculated based on the clinical assumption that approximately 10% of patients (between 2009 and 2011) admitted to the ICU would develop ulcers within 3 days after admission. The percentage of possible "at-risk" patients, that is, the combined average of ICU-acquired PrUs (hospital-acquired PrUs), was calculated for both institutions using the National Database of Nursing Quality Indicators (NDNQI) PrU estimate of incidence rate methodology.[51] Per the NDNQI, the formula used to estimate PrU incidence is as follows: number of patients who acquired a PrU after admission to the hospital/total number of patients in the population studied; multiply quotient by 100 to obtain a percentage. In order to adequately power this study, the authors chose to use case-control data, with cases (patients who developed ulcers) and controls (patients who did not) selected at the ratio of 1:2, respectively. The authors fitted a prospective logistic model to these case-control data.

For the main analysis, with the authors' conservative estimate that the variable or variables that significantly predict the occurrence of ASF have an odds ratio (OR) of 2 or more in favor of developing ASF within 3 days, assuming an r^2 for the covariates of 0.3, and assuming that the breakdown of patients for the binary predictor variables is no more divergent than 30%/70%, they estimated that 450 patients were required to detect an OR of 2 or higher for at least 1 variable. Thus, 150 patients who had ulcers and 300 patients who did not would be sufficient to detect an OR of 2.0 at a level of .05 with 80% power (calculated using PASS 2008; NCSS Statistical Software, Kaysville, Utah).

The validation analysis tested the predictive accuracy of the final model. The validation data set consisted of a total of 102 patients, 34 with ulcers and 68 ulcer-free to obtain the predictive accuracy of the final model. The validation data set was selected so that one-third of the total number of patients was in the PrU group, as was the case in the main data set.

This study was approved by the institutional review board of both medical centers. Because this research involved chart extraction only, no consent was required. All data were recorded on data collection sheets designed for this study and devoid of all personal identifiers to protect patient confidentiality.

All charts were reviewed to determine if they met the inclusion or exclusion criteria. The inclusion criteria consisted of adult patients (≥18 years of age) who were admitted into the critical care setting of the participating medical center, with at least a 3-day ICU stay. A 3-day length of stay (LOS) was chosen, as this timeframe would be adequate to detect the development of a new PrU, which can take at least 48 to 72 hours to develop.[48] Exclusion criteria included actively dying patients with the rationale that end-of-life patients are believed to develop chronic skin failure; patients with a preexisting PrU with the rationale that this study sought to find those factors associated with the development of ASF during a patient's ICU stay; patients younger than 18 years as this study sought to determine factors in an adult population; lack of PrU prevention measures without justification for nonadherence with the rationale that the detection of true ASF may be construed as a PrU that occurred as a result of nonadherence to prevention measures. Data for the main and validation analyses were collected on patients who were discharged from both medical centers in 2011. For both the main and validation analyses, patients with PrUs were purposively selected, but patients without PrUs were randomly selected, providing the patients for both these groups met the inclusion criteria and from the same time period. Both facilities possess PrU prevention protocols based on the NPUAP/European Pressure Ulcer Advisory Panel clinical practice guidelines current at the time of study inception.

The following variables, empirically found to be associated with ASF, were included as variables in this study: (1) impaired nutrition defined as any of the following: body mass index of less than 18.5 kg/m^2, C-reactive protein of more than 10 mg/dL, 5- to 10-lb unintentional weight loss before admission (>2% in 1 week or >5% in 1 month or >10% in 6 months)[40–45], first value recorded for ICU admission and for patient with PrUs, most recent values before PrU development; (2) organ failure defined as respiratory failure, renal (acute or chronic) failure, cardiac failure, and/or liver failure based on the *International Classification of Diseases, Ninth Revision* coding; (3) limited tissue perfusion evidenced by documentation of 1 of the following variables: myocardial infarction diagnosed during current admission, severe anemia (hemoglobin <7 g/dL),[52] vasopressor use resulting in peripheral necrosis (toes, fingers), peripheral arterial disease (PAD), and cardiac arrest sustained during current admission; (4) diagnosis of sepsis, severe sepsis, septic shock, or MODS; (5) diabetes diagnosis; (6) immobility[46,47] defined as completely dependent in all transfers and position changes due to one of the following: sedation, intubation, balloon pump, restraints, active CVA (diagnosed during current admission); (7) surgery of more than 3 hours[48]; (8) prolonged hypotension: greater than 48 hours with any of the following: systolic blood pressure of less than 90 mm Hg and/or diastolic blood pressure of less than 60 mm Hg and/or mean arterial pressure of less than 60 mm Hg; (9) vasopressors: use during the ICU admission inclusive of norepinephrine, epinephrine, phenylephrine, vasopressin, and dopamine, and/or use of any of these vasopressor agents prior to PrU development; and (10) mechanical ventilation: greater than 72 hours.

For analysis purposes, these variables were then grouped into categories to help describe their significance to ASF: (1) disease status: diabetes, organ failure; (2) physical conditions: impaired nutrition, limited tissue perfusion, sepsis bundle, immobility, prolonged hypotension; and (3) conditions of hospitalization: surgery greater than 3 hours, vasopressors, and ventilator days.

The following baseline variables were also included in the analysis: (1) sex, (2) race, (3) age, (4) admitting and ICU diagnoses and total hospital and ICU LOS, (4) admission Braden Scale score, (5) type of surgery, (6) Acute Physiology and Chronic Health Evaluation II score 19 or less (25% risk of death) or 20 or greater (40% risk or death),[53] and (7) evidence of adherence to PrU prevention measures as per the current prevention guidelines (note: both institutions use the same evidence-based guidelines).[4] Charts were reviewed for documentation to PrU prevention measures, and only patients with these measures in place, or with acceptable

justification, were included. In patients who developed an ulcer: (*a*) stage, (*b*) location, (*c*) date and time of PrU occurrence during the ICU admission, and (*d*) Braden Scale score on ICU admission, as well as day before and day of PrU discovery.

STATISTICAL ANALYSIS

Logistic regression modeling was used to select a set of patient characteristics and hospital conditions that predicted the occurrence of ASF after ICU admission. The following scheme was used for model building: univariate logistic regression analyses were initially used to select predictor variables that were significantly associated with development of ASF with an OR in favor of development of ASF of 2 or greater. In addition, exploratory analysis of variables describing sepsis (sepsis, severe sepsis, septic shock, and MODS), were performed to decide how to best use these variables in the analyses. Sepsis was not significantly associated with ASF and therefore was not used in further analyses. Severe sepsis and septic shock were significantly associated with ASF. Clinically, these 2 variables are the most common diagnoses that warrant an ICU admission and therefore were combined. On the sepsis continuum, MODS is clinically very different from the other conditions due to the multiorgan dysfunction-failure that ensues. Thus, ''sepsis bundle,'' consisting of either severe sepsis or septic shock, was used as a dichotomous (yes/no) variable in the model.

The predictor variables that were significantly associated with ASF were then used in a series of stepwise multiple regression analyses to select those variables that were significantly and independently associated with the development of ASF. Each stepwise analysis addressed a distinct set of predictors, representing (1) disease status: diabetes, organ failure; (2) physical conditions: impaired nutrition, limited tissue perfusion, sepsis bundle, immobility, prolonged hypotension; and (3) conditions of hospitalization: surgery greater than 3 hours, vasopressors, and ventilator days.

Variables from each stepwise analysis that were significantly associated with occurrence of ASF were then used in a comprehensive stepwise logistic regression model to select a final set of significant and independent predictor variables from the previous 3 categories. The Hosmer-Lemeshow goodness-of-fit statistic was used to assess the fit of the model.

A receiver operating characteristic (ROC) curve was constructed using the final model; the area under the ROC curve (AUC) was used to estimate the diagnostic accuracy of the ROC curve. Using the final regression model, a score consisting of the probability *P* of developing ASF can be estimated for each patient. The data obtained from the ROC curve can be used to select a cutoff point for the score that predicts the occurrence of ASF with a balance of sensitivity and specificity desired by the investigator.

In the validation stage of the authors' study, they tested their logistic model with patient data unrelated to the development of the model in the main analysis. The validation data set consisted of 102 patients. For each patient in the validation sample, the probability *P* of developing ASF was obtained using the regression coefficients from the model developed using the authors' original sample of 450. Classification tables were used for validation. These tables are commonly used to estimate overall classification accuracy (percentage of true positives + false negatives) of a logistic model. The tables cross-classify the observed ASF status (present/absent) by the predicted probability *P* of developing ASF, where *P* is dichotomized at an arbitrary cutoff point. Tables were constructed for both the original 450 patients and for the 102 patients comprising the validation subset, and the 2 tables were compared. The cutoff point chosen for both tables was .33, which is equal to the percentage of patients with ASF in the 450 original subjects.

RESULTS

Characteristics of the Study Sample

The mean age of the study sample was 71 (SD, 15.6) years, with 56% (n = 251) male and 79% (n = 356) white patients. The mean ICU LOS was 9 (SD, 9.8) days. The top 2 ICU admitting diagnoses were respiratory failure (27%, n = 120) and hemodynamic instability (22%; n = 101). Respiratory failure and renal failure were the most commonly reported organ system failures among this study sample at 50% (n = 224) and 25% (n = 114), respectively. The mean Braden Scale score on admission to the ICU was 14 (SD, 3.5) (Table 1). On analysis of the 150 PrU-positive patients, 82 developed a PrU on the sacrum (54.7%). The most common stage of PrU recorded was suspected deep tissue injury, and the most common location was reported as the sacrum (50%) (n = 75). The majority (67%) of the PrUs developed in the first week of the ICU admission (n = 101) (Table 2).

Main Analysis

Table 3 presents the final logistic regression model developed using the initial data set of 450 patients. All variables previously mentioned were analyzed, including those variables empirically found to be associated with ASF in addition to the baseline variables. However, only 5 variables were found to be significantly and independently related to ASF. The significant and independent predictors of skin failure are shown with their regression coefficients with SEs, their adjusted ORs with 95% confidence intervals, and their *P* values. The predictors in the final model are PAD, mechanical ventilation for more than 72 hours, respiratory failure, liver failure, and severe sepsis/septic shock. Each variable

Table 1.
DEMOGRAPHIC CHARACTERISTICS FOR THE MAIN AND VALIDATION ANALYSES

Variable	Main[a] (n = 450)	Validation[a] (n = 102)
Age, mean (SD), range, y	71 (15.7), 20–99	71 (15.7), 19–93
Sex		
Male	251 (56)	57 (55.9)
Female	199 (44)	45 (44.1)
Race		
White	356 (79.1)	78 (76.5)
Black/African American	36 (8)	8 (7.8)
Hispanic	35 (7.8)	7 (6.9)
Asian/Pacific Islander	22 (4.9)	9 (8.8)
Other	1 (0.2)	0 (0)
Hospital length of stay, mean (SD), range, d	9 (17), 2–208	20.2 (15.2), 3–80
ICU length of stay, mean (SD), range, d	9 (10), 2–85	11.5 (11.5), 3–58
Braden Scale score ICU admission, mean (SD), range	14 (3.5), 7–23	13.5 (3.2), 7–23
Braden Scale score ICU admission, patients "at risk" (18)	396/449[b]	96/102
APACHE II score		
19	280 (62)	58 (56.9)
≥20	170 (38)	44 (43.1)
ICU admitting diagnosis		
Respiratory failure	120 (27)	28 (28)[c]
Hemodynamic instability	101 (22)	20 (20)
Septic shock	36 (8)	3 (3)
Valve replacement	31 (7)	8 (8)
CABG/valve	26 (6)	7 (7)
Neuromedicine	22 (5)	9 (9)
Neurosurgery	18 (4)	0 (0)
Gastrointestinal surgery	18 (4)	3 (3)
Gastrointestinal medicine	15 (3)	5 (5)
CABG	15 (3)	2 (2)
Sepsis	14 (3)	3 (3)
Aneurysm	7 (2)	4 (4)
Vascular	6 (1)	0 (0)
Other	21 (5)	10 (10)
Cardiac surgery		
CABG valve replacement surgery	68 (22)	2 (7)[d]
CABG/valve replacement	44 (14)	8 (26)
Other	28 (9)	7 (23)
Thoracic aneurysm repair	9 (3)	10 (32)
	7 (2)	4 (13)

(continues)

Table 1.
DEMOGRAPHIC CHARACTERISTICS FOR THE MAIN AND VALIDATION ANALYSES, CONTINUED

Abbreviations: CABG, coronary artery bypass graft; ICU, intensive care unit.
[a]Values are number(%) unless otherwise specified.
[b]One case missing.
[c]Results in this category vary from 0.1 to 0.5 because of rounding errors.
[d]Results in this category vary from 0.1 to 0.5 because of rounding errors.

has an adjusted OR of 2 or more, except for severe sepsis/septic shock, with an OR of 1.9, and each variable is significantly associated with skin failure ($P < .04$). The Hosmer-Lemeshow statistic, measuring the fit of the model, was 1.37 ($P = .927$), indicating an excellent fit of the model to the data.

Figure 1 displays the ROC curve that is used to assess the overall utility of the final regression model. The AUC, equaling 0.793, indicates substantial predictive accuracy.

Validation Analysis

For the validation analysis, 102 subjects were selected in the same manner as the original 450 subjects. Thus, no bias was introduced by different selection methods. In this analysis, the validation subjects were classified as patients who will develop or not develop ASF, based on the regression coefficients estimated using the authors' original 450 subjects. Figure 2 shows the ROC curve using the model on the validation subset. The AUC is 0.788, showing substantial predictive accuracy when the final regression model is applied to the validation subset.

Table 4 displays the 2 classification tables created using the original sample and the validation sample. Note that the overall accuracy is high and is very close for the 2 samples: 73.6% for the original sample and 74.5% for the validation sample. These similar results are evidence of the substantial utility of our logistic regression model.

DISCUSSION

Acute skin failure has been conceptually defined as a pressure-related injury concurrent with acute illness that manifests as a

Table 2.
ANALYSIS OF PRESSURE ULCERS: MAIN AND VALIDATION ANALYSES

Variable	Main[a] (n = 150)	Validation[a] (n = 34)
Stage of worst ulcer		
Stage I	3 (2)	0 (0)[b]
Stage II	43 (29)	5 (15)
Stage III	7 (5)	1 (3)
Stage IV	5 (3)	1 (3)
Unstageable	17 (11)	3 (9)
Suspected deep tissue injury	75 (50)	24 (71)
Location		
Sacrum	82 (54.7)	15 (44)
Heel	28 (18.7)	1 (3)
Buttocks	25 (16.7)	10 (29)
Trochanter	4 (2.7)	1 (3)
Coccyx	4 (2.7)	1 (3)
Spinous process	4 (2.7)	1 (3)
Other	3 (2.1)	5 (15)
Days to pressure ulcer detection		
1–3	68 (45)	9 (27)
4–6	25 (17)	10 (29)
7–9	20 (13)	8 (23)
10–12	12 (8)	1 (3)
13–15	12 (8)	2 (6)
16–44	13 (9)	4 (12)

[a]Values are number (%) unless otherwise specified.
[b]Results in this category vary from 0.1 to 0.4 because of rounding errors.

result of hemodynamic instability and/or major organ system compromise.[25] Currently, however, there is a lack of distinct diagnostic criterion in which clinicians can distinguish the phenomenon of ASF from a PrU. The objective of this research was to determine factors that may lead to ASF in the critical care patient.

The variables for this research were selected based on the existing body of literature surrounding the concept of ASF despite the paucity of research available. Overall, the findings from this research demonstrated concurrence with the conceptual definition. In this research, the variables, PAD, mechanical ventilation greater than 72 hours, respiratory failure, liver failure, and severe sepsis/septic shock, were found to be statistically significant and independent predictors of ASF in the ICU patient.

In this study, patients with a concomitant diagnosis of PAD were found to be almost 4 times more likely to develop skin failure. Consistent with the literature, PAD was placed in the broader category labeled as limited tissue perfusion as this condition is believed to have influence on skin failure.[46,47] The term PAD is a general term that encompasses noncoronary arterial syndromes and is due to pathophysiologic processes that alter the structure and function of the aorta and peripheral arteries, such as atherosclerosis.[54] Thus, in concert with the definition of organ compromise as a manifestation of ASF, PAD represents a compromise in the vascular system, which can have deleterious effects on the skin, including the development of skin breakdown.

In this study, the variable mechanical ventilation greater than 72 hours was found to be significantly and independently related to the presence of ASF. In the empirical literature, the presence of respiratory failure has been significantly associated with both skin failure and the unavoidable PrU. For example, in their skin failure study involving a critical care population, Curry et al[38] found that 90% experienced respiratory failure, with 86% of

Table 3.
MAIN ANALYSIS RESULTS SHOWING SIGNIFICANT AND INDEPENDENT PREDICTORS OF ACUTE SKIN FAILURE IN THE FINAL LOGISTIC REGRESSION MODEL (N = 450)

Predictor Variable	Regression Coefficient[a]	SE	*P*	Odds Ratio	95% Confidence Interval
Peripheral arterial disease	1.33	0.42	.002	3.8	1.64–8.66
Mechanical ventilation >72 h	1.10	0.27	<.001	3.0	1.78–5.05
Respiratory failure	1.15	0.28	<.001	3.2	1.82–5.40
Liver failure	1.07	0.52	.04	2.9	1.05–8.08
Severe sepsis/septic shock	0.65	0.27	.02	1.9	1.14–3.20

[a]Each regression coefficient in the final logistic regression model is a log-odds ratio, equal to the logarithm of the ratio of the odds of developing ASF with and without a specified risk factor. Each log-odds ratio is adjusted for the other predictors in the model. The exponents of the log-odds ratios are adjusted odds ratios, which provide a more intuitive and interpretable description of the associations between predictors and outcome.

Table 4.

CLASSIFICATIONS TABLE FOR THE ORIGINAL PATIENTS (MAIN ANALYSIS) ON WHICH THE LOGISTIC REGRESSION MODEL WAS BASED (N = 450) AND FOR THE VALIDATION SAMPLE (N = 102)

Classification Tables[a]							
		Model Development Sample (n = 450)			Validation Sample (n = 102)		
		Predicted			Predicted		
		ASF Present			ASF Present		
Observed		No	Yes	Percentage Correct	No	Yes	Percentage Correct
ASF present	Yes	222	78	74.0	48	20	70.6
	No	41	109	72.7	6	28	82.4
Overall percentage				73.6			74.5

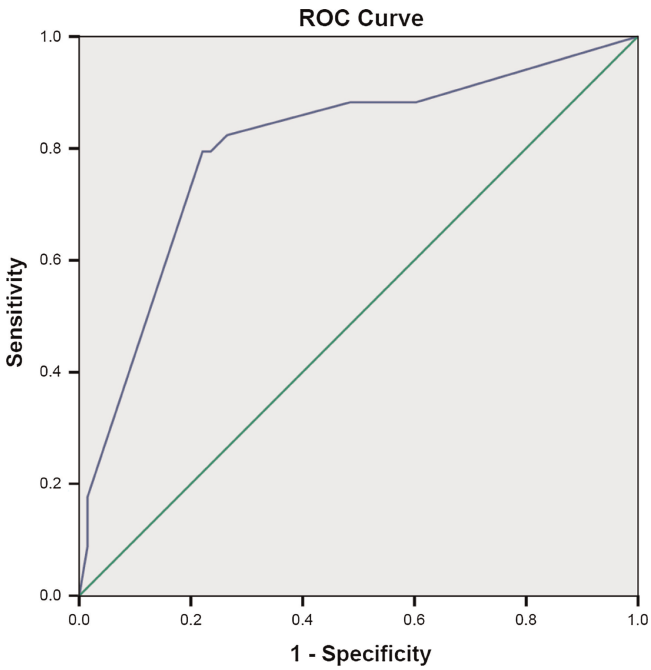
Abbreviation: ASF, acute skin failure.
[a]The cutoff value is 0.33.

the sample requiring mechanical ventilation. In another study of factors associated with unavoidable PrUs, 75% required the use of mechanical ventilation and were found to be in respiratory failure.[39] The need for prolonged mechanical ventilation may support the occurrence of prolonged organ compromise in concert with the definition of ASF.

In this study, liver failure emerged as one of the significant variables in the final predictive model for the main analyses and confirmed

Figure 1.

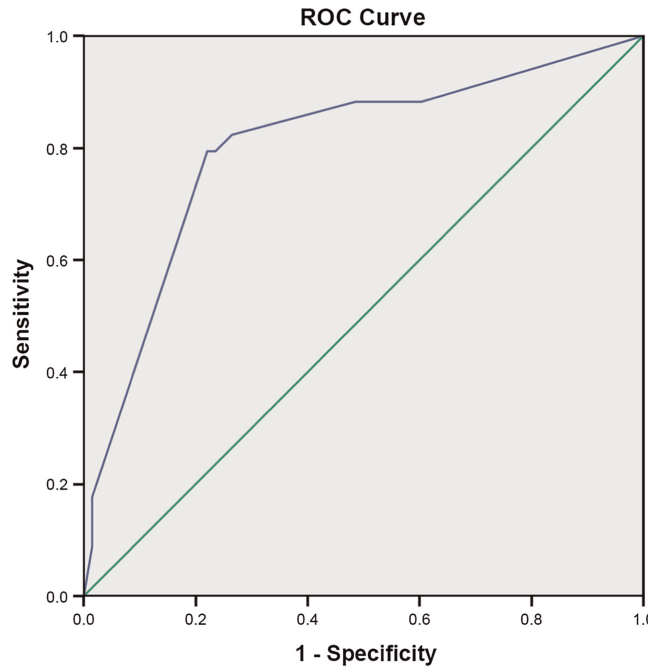
RECEIVER OPERATING CHARACTERISTIC (ROC) CURVE FOR THE MAIN ANALYSIS (N = 450)



This ROC curve plots sensitivity against (1– specificity) for each possible value of *P* (the probability of developing acute skin failure) based on the authors' original data using their final logistic regression model.

Figure 2.

RECEIVER OPERATING CHARACTERISTIC (ROC) CURVE FOR THE VALIDATION ANALYSIS (N = 102)



This ROC curve plots sensitivity against (1 – specificity) for each possible value of *P* (the probability of developing ASF) obtained using the authors' final logistic regression model with their validation dataset.

in the validation model. These findings were similar to Curry et al,[38] who found liver failure to be a contributor to skin failure. Moreover, Curry et al[38] found that 2 or more failed organ systems, including liver failure, also resulted in skin failure. In another retrospective study, Levine et al[39] also found liver failure to be significantly associated with what was categorized as the unavoidable PrU.

Consistent with the emerging literature regarding ASF, this research demonstrated a significant multivariate relationship between severe sepsis/septic shock and the presence of ASF. For the purpose of analysis, the variables severe sepsis and septic shock were combined into 1 variable as clinically these diagnoses commonly necessitate an admission into a critical care unit.[55] Sepsis overall is one of the leading causes of death in critical care patients with a mortality rate approaching 30%.[56] In septic shock, the overwhelming inflammatory response can lead to widespread tissue hypoxia and necrosis. Decreased perfusion to the vital organs ensues along with an alteration in the oxygen extraction from body cells.[54] All of these pathophysiologic events can set the stage for ASF. As decreased perfusion affects the functionality of the vital organs, the skin as an organ will also be impacted secondarily and begin to fail. In fact, in 1 study, sepsis was found in more than 60% of critical care patients with a diagnosis of skin failure.[38] Curry et al[38] noted that patients who experienced sepsis also experienced multiorgan failure in their population of patients with skin failure.

LIMITATIONS

One of the limitations of this study was its retrospective design. Data were collected via retrospective chart review, and therefore, this type of review may limit the availability and accuracy of the clinical information documented. The sampling methodology to include cardiac surgery patients may also be considered a limitation of this study as elective cardiac surgery patients are typically stable prior to surgery and rendered critically ill for only a short period in the immediate postoperative period. Use of a different surgical population may render different findings.

CONCLUSIONS

The purpose of this research was to test clinical factors that have been empirically associated with the phenomenon of ASF in the literature. In this study, this was accomplished via a retrospective review; however, a more compelling case using a prospective approach may provide stronger evidence and criterion for ASF in the critical care patient. Moreover, this may further assist the clinician in distinguishing clinical features of ASF from chronic skin failure and SCALE. Although the concept of the unavoidable PrU is gaining wider acceptance with improved understanding of the events that contribute to these ulcers emerging,[33] the concept of ASF remains an enigma. It is plausible that some clinical situations that now result in an unavoidable PrU may in fact be better categorized as ASF because of the pathophysiologic changes inherent in ulcer development. Critically ill patients with altered tissue perfusion, hemodynamic instability, and multiorgan failure may be ripe candidates for the development of ASF.

Consideration for the diagnosis ASF, however, must also take into account the presence of current PrU prevention/intervention strategies, as ASF cannot be accurately distinguished from a PrU if the current standard of PrU prevention has not been maintained. Clinicians are charged with continuing to prevent PrUs using evidence-based prevention strategies, with an awareness that in certain clinical situations and populations, such as the critically ill, the development of PrUs may continue despite the consistent application of these strategies in practice. In these situations, the possibility that ASF may be occurring should be taken into consideration in the critical care population. Failure to accurately distinguish clinical factors that lead to a PrU from factors that can result in a lesion better characterized as ASF can also result in serious financial and legal consequences for healthcare practitioners and institutions. An accurate diagnosis of ASF, rather than a PrU, has the potential to reduce litigation exposure and the subsequent financial impact absorbed by institutions. Medical costs associated with PrU development in hospitalized patients is conservatively estimated at $43,180.[57] Currently, regulatory bodies, such as state departments of health, require that institutions report facility-acquired Stage III/IV PrUs. Practitioners are thus in a quandary, as lesions that may be more accurately diagnosed as ASF are currently reported as PrUs. With more clearly defined diagnostic criterion for ASF, the clinician is afforded the ability to consider ASF as a possible differential diagnosis, especially in critically ill patients.

In this research, PAD, mechanical ventilation greater than 72 hours, respiratory failure, liver failure, and severe sepsis/septic shock emerged as significant independent predictors of ASF. Heightening awareness to the diagnosis of ASF has the potential to evoke an alternative thought process in all members of the critical care team, including administrators. Enlightening all members of the interdisciplinary team to the phenomenon of ASF undoubtedly will require a distinct educational focus that has the potential to profoundly impact care in the future. Although more research is warranted to further validate these findings, the impact of these findings can be significant. In the end, more concise diagnostic criteria provide clarity to clinicians regarding the etiology of these lesions, which can improve the quality of care delivered and potentially decrease healthcare costs.

PRACTICE PEARLS

• Acute skin failure has been conceptually defined as a pressure-related injury concurrent with critical illness that manifests as a result of hemodynamic instability and/or major organ system compromise.
• Pressure ulcers and ASF can occur simultaneously, as failing skin increases susceptibility to the forces of pressure and shear.
• Consideration for the diagnosis ASF however, must also take into account the presence of current PrU prevention/intervention strategies, as ASF cannot be accurately distinguished from a PrU if the current standard of PrU prevention has not been maintained. At the present time, no formal diagnostic criterion currently exists to identify an ulcer that occurs as a result of ASF.
• The variables PAD, mechanical ventilation greater than 72 hours, respiratory failure, liver failure, and severe sepsis/septic shock were found to be significant predictors of acute skin failure in this sample of ICU patients.
• It is plausible that some clinical situations, such as those that manifest in the critically ill population that now result in an unavoidable PrUs may in fact be better categorized as ASF due to the pathophysiologic changes inherent in ulcer development.

REFERENCES

1. Wysocki AB. Anatomy and physiology of skin and soft tissue. In: Bryant RA, Nix DP, eds. Acute and Chronic Wounds: Current Management Concepts. 4th ed. St Louis, MO: Elsevier Mosby; 2012:40-62.
2. Stokowski LA. A closer look at pressure ulcers. Medscape. http://www.medscape.com/viewprogram/12612_index. Last accessed August 26, 2015.
3. La Puma J. The ethics of pressure ulcers. Decubitus 1991;4(2):43-5.
4. National Pressure Ulcer Advisory Panel and European Pressure Ulcer Advisory Panel. Prevention and Treatment of Pressure Ulcers: Clinical Practice Guidelines. Washington, DC: National Pressure Ulcer Advisory Panel; 2009.
5. Langemo D, Brown G. Skin fails too: acute, chronic and end-stage skin failure. Adv Skin Wound Care 2006;19:206-11.
6. White-Chu E, Langemo D. Skin failure: identifying and managing an underrecognized condition. Annals of Long Term Care. http://www.annalsoflongtermcare.com/article/skin-failure-identifying-and-managing-underrecognized-condition. Last accessed August 26, 2015.
7. Berlowitz DR, Wilking SV. Risk factors for pressure sores. A comparison of cross-sectional and cohort-derived data. J Am Geriatr Soc 1989;37:1043-50.
8. Berlowitz DR, Wilking SV. The short-term outcome of pressure sores. J Am Geriatr Soc 1990;38:748-52.
9. Brown G. Long-term outcomes of full-thickness pressure ulcers: healing and mortality. Ostomy Wound Manage 2003;(10):42-50.
10. Shank J, Lutz JB. The Kennedy Terminal Ulcer-Twenty Years Later. Presented at the NPUAP 2009 Biennial Conference; February 27-28, 2009; Arlington, Virginia.
11. Hanson D, Langemo DK, Olson B, et al. The prevalence and incidence of pressure ulcers in the hospice setting: analysis of two methodologies. Am J Hosp Palliat Care 1991;8(5):18-22.
12. Hughes RG, Bakos AD, O'Mara A, Kovner CT. Palliative wound care at the end of life. Home Health Care Manage Pract 2005;17:196-202.
13. Sussman C, Bates-Jensen B. Wound Care: A Collaborative Practice Manual for Healthcare Professionals. 3rd ed. Baltimore, MD: Lippincott, Williams & Wilkins; 2007.
14. Husain T. An experimental study of some pressure effects on tissues with reference to the bedsore problem. J Bacteriol 1953;66:347-58.
15. Kosiak M. Etiology and pathology of ischemic ulcers. Arch Phys Med Rehabil 1959;40(2):62-9.
16. Kosiak M. Etiology of decubitus ulcers. Arch Phys Med Rehabil 1961;42(1):19-29.
17. Braden B, Bergstrom N. A conceptual schema for the etiology of pressure sores. Rehabil Nurs 1987;12(1):8-12.
18. Berlowitz DR, Brienza DM. Are all pressure ulcers the result of deep tissue injury? A review of the literature, Ostomy Wound Manage 2007;53(10):34-8.
19. Niezgoda JA, Mendez-Eastman S. The effective management of pressure ulcers. Adv Skin and Wound Care 2006;19(Supp 1):3-15.
20. Ayello E, Lyder C. Pressure ulcers: a patient safety issue. In: Hughes R, ed. Patient Safety and Quality: An Evidenced Based Handbook for Nurses. Rockville, MD: Agency for Healthcare Quality and Research; 2008. Publication 08-0043.
21. Bergstrom N, Braden B, Laguzza A, Holman V. The Braden Scale for predicting pressure sore risk. Nurs Res 1987;36(4):205-10.
22. Batson S, Adam S, Hall G, Quirke S. The development of a pressure area scoring system for critically ill patients: a pilot study. Intensive Crit Care Nurs 1993;9:146-51.
23. Bours G, De Laat E, Halfens R, Lubbers M. Prevalence, risk factors and prevention of pressure ulcers in Dutch intensive care units. Results of a cross-sectional survey. Intensive Care Med 2001;27:1599-1605.
24. Cox J. Predictors of pressure ulcers in adult critical care patients. Am J Crit Care 2011;20:364-74.
25. Shanks HT, Kleinhelter P, Baker J. Skin failure: a retrospective review of patients with hospital-acquired pressure ulcers. WCET 2009;29(1):6-10.
26. Slowikowski G, Funk M. Factors associated with pressure ulcers in patients in a surgical intensive care unit. J Wound Ostomy Continence Nurs 2010;37:619-26.
27. Theaker C, Mannan M, Ives N, Soni N. Risk factors for pressure sores in the critically ill. Anaesthesia 2000;55:221-24.
28. Eachempati S, Hydo L, Barie P. Factors influencing the development of decubitus ulcers in critically ill surgical patients. Critical Care Med 2001;29:1678-82.
29. Shahin ES, Dassen R, Halfens RJ. Pressure ulcer prevalence in intensive care patients: a cross-sectional study. J Eval Clin Pract 2008;14:563-8.
30. Horn SD, Bender SA, Ferguson ML, et al. The National Pressure Ulcer Long-term Care Study: pressure ulcer development in long term care residents. J Am Geriatr Soc 2004;52:359-67.
31. Wound, Ostomy and Continence Nurses Society position statement on avoidable versus unavoidable pressure ulcers. J Wound Ostomy Continence Nurs 2009;36:378-81.
32. Black J, Edsberg L, Baharestani M, et al. Pressure ulcers: avoidable or unavoidable? Results of the National Pressure Ulcer Advisory Panel Consensus Conference. Ostomy Wound Manage 2011;57(2):24-37.
33. Edsberg LE, Langemo D, Baharestani MM, Posthauer ME, Goldberg M. Unavoidable pressure injury: state of the science and consensus outcomes. J Wound Ostomy Continence Nurs 2014;41:313-34.
34. Goode PS, Allman RM. The prevention and management of pressure ulcers. Med Clin North Am 1989;73:1511-24.
35. Kennedy K. The prevalence of pressure ulcers in an intermediate care facility. Decubitus 1989:2(2):44-5.
36. Letezia M, Uebelhor J, Paddack E. Providing palliative care to seriously ill patients with nonhealing wounds. J Wound Ostomy and Continence Nurs 2010;37:277-82.
37. Trombley K, Brennan MR, Thomas L, Kline M. Prelude to death or practice failure: Trombley-Brennan terminal tissue injuries. Am J Hospice and Palliat Care 2012;29:541-5.
38. Curry K, Kutash M, Chambers T, Evans A, Holt M, Purcell S. A prospective, descriptive study of characteristics associated with skin failure in critically ill adults. Ostomy Wound Manage 2012;58(5):36-43.
39. Levine JM, Humphrey S, Levovits S, Fogel J. The unavoidable pressure ulcers: a retrospective case series. J Clin Outcomes Manage 2009:16:359-63.
40. Kee JL. Handbook of Laboratory & Diagnostic Tests with Nursing Implications. 5th ed. Upper Saddle River, NJ: Pearson, Prentice/Hall; 2005.
41. Medscape. Hypoalbuminemia clinical presentation. http://emedicine.medscape.com/article/166724-overview. Last accessed August 26, 2015.
42. Jensen GL, Wheeler D. A new approach to defining and diagnosing malnutrition in adult critical illness. Curr Opin Crit Care 2012;18:206-11.
43. Jensen GL, Hsiao PY, Wheeler D. Adult nutrition assessment tutorial. J Parenter Enteral Nutr 2012;36:267-74.
44. Ruiz-Santana S, Arboleda Sanchez JA, Abiles J; Metabolism and Nutrition Working Group of the Spanish Society of Intensive Care Medicine and Coronary units. Guidelines for specialized nutritional and metabolic support in the critically ill patient: update. Consensus SEMICYUC-SENPE: nutritional assessment. Nutr Hosp 2011;26(Suppl 2):12-5.

45. Vincent JL, Dubois MJ, Navickis RJ, Wilkes MM. Hypoalbuminemia in acute illness: is there a rational for intervention? A meta-analysis of cohort studies and controlled trials. Ann Surg 2003;237:319-34.
46. Korupolu R, Gifford JM, Needham DM. Early mobilization of critically ill patients: reducing neuromuscular complications after intensive care. Contemp Crit Care 2009;6(9):1-11.
47. Morris PE, Goad A, Thompson D, et al. Early intensive care unit mobility therapy in the treatment of acute respiratory failure. Crit Care Med 2008;36:2238-43.
48. Aronovitch SA. Intraoperatively acquired pressure ulcers: are there common risk factors? Ostomy Wound Manage 2007;53(2):57-69.
49. Delmore B, Lebovits S. Pressure ulcer risk in cardiovascular patients—what's the common thread? WCET 2010;30:34-7.
50. Senturan L, Karaback U, Ozdilek S, et al. The relationship among pressure ulcers, oxygenation, and perfusion in mechanically ventilated patients in an intensive care unit. J Wound Ostomy Continence Nurs 2009;36:503-8.
51. NDNQI. The National Database of Nursing Quality Indicators: Description & Glossary. April 2009. The American Nurses Association, Inc.
52. May AK, Mangalmurti N. Use of blood products in the critically ill. UpToDate. http://www.uptodate.com/contents/use-of-blood-products-in-the-critically-ill?source=search_result&search=use+of+blood+products+in+the+critically+ill&selectedTitle=1%7E150. Last accessed August 26, 2015.
53. Knaus W, Draper E, Wagner D, Zimmerman J. APACHE II: a severity of disease classification. Crit Care Med 1985;13:818-29.
54. Neschis D, Golden M. Clinical features and diagnosis of lower extremity peripheral artery disease. UpToDate. http://www.uptodate.com/contents/clinical-features-and-diagnosis-of-lower-extremity-peripheral-artery-disease?source=machineLearning&search=peripheral+arterial+disease&selectedTitle=1%7E150&sectionRank=4&anchor=H380412848#-H380412848. Last accessed August 26, 2015.
55. Martin GS. Sepsis, severe sepsis and septic shock: changes in incidence, pathogens and outcomes. Expert Rev Anti Infect Ther 2012;10:701-6.
56. Society for Critical Care Medicine. Critical care statistics. http://www.sccm.org/Communications/Pages/CriticalCareStats.aspx. Last accessed August 26, 2015.
57. Centers for Medicare & Medicaid Services. CMS proposes additions to hospital acquired conditions for fiscal year 2009. https://www.cms.gov/Newsroom/MediaReleaseDatabase/Fact-sheets/2008-Fact-sheets-items/2008-04-14.html. Last accessed August 26, 2015.