

Predicting Pressure Ulcer Risk in Pediatric Patients

The Braden Q Scale

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- ▶ **Background:** While there are valid and reliable pressure ulcer risk assessment tools available for adult patients, none exist for infants and children. To remedy this, the Braden Scale was adapted for use in pediatrics, calling it the Braden Q Scale.
- ▶ **Objective:** The purpose of this study was to: (a) establish the predictive validity of the Braden Q Scale in an acutely ill pediatric population; (b) determine the critical cutoff point for classifying patient risk; and (c) determine the best time to assess patient risk.
- ▶ **Methods:** A multisite prospective cohort descriptive study with a convenience sample of 322 patients on bedrest for at least 24 hours without pre-existing pressure ulcers or congenital heart disease were enrolled from three pediatric intensive care units (PICU). The Braden Q score and skin assessment were independently rated and data collectors were blind to the other measures. Patients were observed up to 3 times per week for 2 weeks and then once a week until PICU discharge for a median of 2 observations reflecting 887 skin assessments.
- ▶ **Results:** Eighty-six patients (27%) developed 199 pressure ulcers; 139 (70%) were Stage I pressure ulcers, 54 (27%) were Stage II pressure ulcers, and 6 (3%) were Stage III pressure ulcers. Most pressure ulcers (57%) were present at the first observation. Using Stage II+ pressure ulcer data obtained during the first observation, a Receiver Operator Characteristic (ROC) curve for each possible score of the Braden Q Scale was constructed. The area under the curve (AUC) was 0.83. At a cutoff score of 16, the sensitivity was 0.88 and the specificity was 0.58. The Braden Q Scale was then modified to eliminate 4 subscales with an AUC <0.7. With 3 subscales (mobility, sensory perception, tissue perfusion/oxygenation) the AUC of this Modified Braden Q Scale was maintained at 0.84. At a cutoff score of 7, the sensitivity was 0.92 and the specificity was 0.59.
- ▶ **Conclusions:** The performance of the Braden Q Scale in a pediatric population is similar to that consistently reported for the Braden Scale in adult patients. The Modified Braden Q Scale, with 3 subscales, provides a shorter yet comparable tool.
- ▶ **Key Words:** Braden Q Scale • child • multisite study • pressure ulcer • risk prediction

Pressure ulcers represent a serious iatrogenic injury in the acute care environment. The cost of pressure ulcers is enormous, both in terms of human suffering and financial expense (Allman, Goode, Burst, Bartolucci, & Thomas, 1999; Gallagher, 1997; Maklebust, 1987). Pressure ulcers predispose patients to secondary infection and contribute to an increase in hospital length of stay (Bergstrom et al., 1994). Prevention and minimization of pressure ulcers is an important aspect of patient care and has been identified as a nursing research priority (Harrison, Wells, Fisher, & Prince, 1996) and an acute care nursing quality of care indicator (ANA, 1995).

When considering the broad spectrum of skin problems in infants and children, one may regard the phenomenon of pressure ulcers as irrelevant. However, similar to adult patients (Jiricka, Ryan, Carvalho, & Bukvich, 1995), acutely ill infants and children are at risk for pressure ulcers (Quigley & Curley, 1996; Zollo, Gostisha, Berens, Schmidt, & Weigle, 1996). The negative effect of immobility and physiological instability on a patient's skin does not discriminate on age or developmental level.

Pressure ulcer prevention is based on eliminating or ameliorating risk amenable to intervention. Many expensive yet unsupported strategies to prevent pressure ulcers are used in the pediatric intensive care unit (PICU). It is difficult to evaluate the effectiveness of any single preventative measure or device without knowledge of patient risk (Zollo et al., 1996). While there are valid and reliable pressure ulcer risk assessment tools available for adult patients,

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none exist for the pediatric patient. Quigley and Curley (1996) adapted the Braden Scale for Predicting Pressure Ulcer Risk for use in the pediatric population naming it the Braden Q Scale. The purpose of this study is to establish the predictive validity of the Braden Q Scale in a pediatric acutely ill population.

Relevant Literature

A pressure ulcer is any lesion caused by unrelieved pressure resulting in damage of underlying tissue (Bergstrom et al., 1994). Pressure ulcers can develop over any dependent skin surface. Although most pressure ulcers develop over the bony prominences of the sacrum and heels in adults (Allman, Goode, Burst, Bartolucci, & Thomas, 1999; Amlung, Miller, & Bosley, 2001; Whittington, Patrick, & Roberts, 2000), the sites of pressure ulcers in children are different (Zollo et al., 1996). In pediatrics, the occipital region of the scalp in infants and toddlers and the sacrum in children are prevalent sites for pressure ulcer formation (Escher Neidig, Kleiber, & Oppliger, 1989; Razmus, Roberts, & Curley, 2001; Solis, Krouskop, Trainer, & Marburger, 1988).

Braden and Bergstrom (1987) described a conceptual framework that organizes knowledge on the etiology of pressure ulcers. The framework identifies two critical determinants of ulceration: the intensity and duration of pressure and tissue tolerance. Factors that contribute to prolonged and intense pressure include mobility (ability to change and control body position), activity (degree of physical activity), and sensory perception (ability to respond meaningfully to pressure-related discomfort). Tissue tolerance includes both intrinsic (nutrition, and arterial pressure) and extrinsic (moisture, friction, and shear) factors that affect the ability of the skin and its supporting structures to endure the effects of pressure without adverse sequelae (Braden & Bergstrom, 1987).

Braden & Bergstrom's (1987) conceptual framework serves as the template for the Braden Scale for Predicting Pressure Ulcer Risk (Bergstrom, Braden, Laguzza & Holman, 1987). The Braden Scale has six subscales: (a) mobility, (b) activity, (c) sensory perception, (d) skin moisture, (e) friction and shear, and (f) nutrition. Each subscale includes a title and concept descriptor. The minimal score for each item is 1 (more risk) and a maximum score is 3 or 4 (less risk) with the potential scores ranging from 6 to 23 points. The subscales are mutually exclusive; that is, they do not overlap with each other. In acutely ill adult patients, cutoff points of 16 to 18 are used to categorize patients at risk for developing pressure sores (Bergstrom, Braden, Kemp et al., 1998; Bergstrom, Braden, Laguzza et al., 1987; Bergstrom, Demuth & Braden, 1987). At a score of 16, the Braden instrument has a sensitivity of 0.83 and specificity of 0.64 in predicting pressure ulcer formation in adult intensive care patients (Bergstrom, Demuth et al.). Because of its rigorous testing in diverse adult patient groups and its vivid categorical descriptors, the Braden Scale is a popular pressure ulcer risk prediction tool in adult-based clinical settings (Bergstrom et al., 1994).

Braden Q Scale for Predicting Pediatric Pressure Ulcer Risk

Quigley & Curley (1996) adapted the Braden Scale for use in the pediatric population (Appendix A). Changes from the original Braden Scale reflect the unique developmental needs of the pediatric patient, the prevalence of gastric/transpyloric tube feedings, and the availability of blood studies and noninvasive technology in the acute care pediatric setting. Modifications include the following:

1. Intensity and Duration of Pressure:
 - (a) Mobility: [2, Very Limited] From "unable to make frequent or significant changes independently" to "unable to completely turn self independently."
 - (b) Activity: All patients unable to walk from a developmental perspective are automatically scored a "4, walks frequently."
 - (c) Sensory Perception: Definition clarified: From "ability to respond meaningfully to pressure-related discomfort" to "ability to respond in a developmentally appropriate way to pressure-related discomfort."
2. Tolerance of the Skin and Supporting Structures:
 - (a) Moisture: [1, Constantly Moist] From "perspiration and urine, etc." to "perspiration, urine and drainage, etc."; [2, Very Moist] from "linen must be changed at least once a shift" to "linen is changed at least every 8 hours"; [3, Occasionally Moist] from "extra linen change approximately once a day" to "linen change every 12 hours"; [4, Rarely Moist] from "linen only requires changing at routine intervals" to "routine diaper changes, linen only requires changing every 24 hours."
 - (b) Friction and Shear: Operational definitions were added (friction occurs when skin moves against support services; shear occurs when skin and adjacent bony surfaces slide across one another). The number of levels increased from 3 to 4 by splitting Braden's level 1 as the patient descriptors reflect different pediatric patient groups; specifically, Braden Q's level 1 is labeled "Significant Problem" and includes "spasticity, contracture, itching, or agitation leads to almost constant thrashing and friction" and Braden Q's level 2, is labeled "Problem" and includes "Requires moderate to maximum assistance in moving. Complete lifting without sliding against the sheets is impossible. Frequently slides down in the bed or chair requiring frequent repositioning with maximum assistance." Braden's Q level 3 is labeled "Potential Problem" and is unchanged from Braden's level 2. Braden Q's level 4 is labeled "No Apparent Problem" and includes Braden's level 3 descriptors with the addition of "Able to completely lift patient during a position change."
 - (c) Nutrition: "Feedings" were added as descriptors for meals. [1, Very Poor] "albumin < 2.5 mg/dl"

was added; [2, Inadequate] "albumin < 3 mg/dl" was added and the statement was revised to include "Is on liquid diet or tube feedings/total parenteral nutrition (TPN) which provide inadequate calories and minerals for age;" [3, Adequate] statement revised to include "Is on tube feedings/TPN which provide adequate calories and minerals for age;" [4, Excellent] statement revised "Is on a normal diet providing adequate calories for age."

- (d) Tissue Perfusion and Oxygenation: This subscale was added to quantify tissue perfusion. [1, Extremely compromised] "Hypotensive (mean arterial pressure < 50 mmHg or < 40 mmHg in a newborn) or the patient does not physiologically tolerate position changes;" [2, Compromised] "Normotensive, oxygen saturation may be < 95 % or hemoglobin may be < 10 mg/dl or capillary refill may be > 2 seconds and serum pH is < 7.40;" [3, Adequate] "Normotensive, oxygen saturation may be < 95 % or hemoglobin may be < 10 mg/dl or capillary refill may be > 2 seconds, and serum pH is normal;" [4, Excellent] "Normotensive, oxygen saturation > 95%, normal hemoglobin, and capillary refill < 2 seconds."

The tissue perfusion and oxygenation subscale is an intrinsic aspect of tissue tolerance (Braden & Bergstrom, 1987). As reported by Braden and Bergstrom, low arteriolar pressure may predispose patients to pressure ulcer development and, when compared to normotensive patients, hypertensive patients withstand increased external pressure before vasculature occlusion occurs. Intuitively, it makes sense that factors that impact tissue perfusion and oxygenation will lower tissue tolerance to withstand pressure. This is a particularly important subscale for critically ill patients as many require vasopressor medications and fluid resuscitation (Jiricka et al., 1995). Since patients experience low cardiac output, the body compensates by shunting blood away from nonvital organs; specifically, the skin. This vasoconstriction may jeopardize a patient's reactive hyperemic response to local compression ischemia (Maklebust, 1987). Also, the patient's hemodynamic instability is often cited as the primary reason why intensive care nurses do not always follow unit-based protocols to reposition patients every two hours (Batson, Adam, Hall & Quirke, 1993; Escher Neidig et al., 1989).

The Braden Q subscales are mutually exclusive; that is, they do not overlap with each other. The minimal score for each subscale is 1 (more risk) and the maximum score is 4 (less risk). Potential total scores range from 7 to 28 points, the lower the score the higher the patient's risk for pressure ulcers.

Content validity for the Braden Q Scale was established by a group of pediatric nurses with a special interest in pediatric skin issues. These nurses independently scored 178 children on the Braden Q Scale then asked the patient's bedside nurse to rate the patient's level of risk for skin breakdown as high, moderate, or low. The Braden Q scores and subjective ratings for each child were then com-

pared and showed that children considered at low risk for skin breakdown scored an average of 25 on the Braden Q Scale, children at moderate risk scored an average of 21, and children at high risk for skin breakdown scored an average of 16. Confidence intervals indicated that children scoring < 23 were at moderate or high risk for skin breakdown. Thus, patients with a Braden Q score < 23 were considered at risk for pressure ulcers (Quigley and Curley, 1996).

The specific aim of this study is to test the predictive validity of the Braden Q Scale; specifically, the ability of the Braden Q Scale to predict the development of Stage I-IV pressure ulcers in acutely ill pediatric patients. The hypothesis was that the Braden Q Scale would demonstrate high sensitivity and specificity for the identification of acutely ill pediatric infants and children at risk for pressure ulcer development. Secondary objectives were to determine the critical cutoff point for classifying patient risk and determine the best time to assess patient risk.

Methods

Settings

Three PICUs participated in this multisite prospective cohort study. In addition to the organizing center, more sites were added to provide a diverse pediatric population and to eliminate the influence of institution-specific practice patterns on the Braden Q subscales. Two of the three PICUs are located in the northeast region of the United States and one is located in the Midwest; all three units have at least 17 beds and are contained within free-standing university-affiliated Children's Hospitals. The study was reviewed and approved by the Clinical Investigation Committee of the hospital Institutional Review Board at each site.

Sample

The convenience sample included 322 consecutive PICU patients on bedrest for at least 24 hours. To ensure equal distribution of the PICU and age within the patient sample, each of the three sites sequentially sampled a maximum of 30 patients in each of the following four age groups: (a) infant (21 days to 12 months); (b) toddler (12 to 36 months); (c) preschool (3 to 5 years); and (d) young school (5 to 8 years). Exclusion criteria included patients admitted to the PICU with pre-existing pressure ulcers, intracardiac shunting and/or unrepaired congenital heart disease. The age of 21 postnatal days was selected because at 3 weeks of age the skin reaches relative maturity comparable to a full term infant regardless of the infant's gestational age at birth (Malloy & Perez-Woods, 1991). The selection of 8 years of age reflects conventional norm; specifically, the American Heart Association considers patients > 8 years to be an adult in terms of treatment (Chameides & Hazinski, 1994). Patients with congenital heart disease were excluded because the impact of chronic hypoxemia on pressure ulcer development is unclear.

Instruments

In addition to the Braden Q Scale (previously described), four instruments were used for data collection. The Pedi-

atric Cerebral Performance Category (PCPC) and the Pediatric Overall Performance Category (POPC) scales were used to quantify cognitive impairment and overall pediatric functional morbidity (Fiser, 1992). The PCPC scores range from 1 (normal cognitive development) to 6 (brain death). The POPC scores range from 1 (good overall performance) to 6 (brain death). Fiser (1992) reported the initial validity and reliability of the PCPC and POPC scores. Both scales are associated with traditional measures of PICU morbidity (length of hospital stay, total hospital charges and discharge care needs) and severity of illness and injury scores ($p < .01$); interrater reliability is high ($r = 0.88$ to 0.96 ; $p < .01$). The Pediatric Risk of Mortality III (PRISM III) score was used to describe pediatric patient acuity (Pollack, Patel, & Ruttimann, 1996). The PRISM III score is derived from 17 physiologic variables subdivided into 26 ranges. The PRISM III score is computed using the most abnormal values during the first 24 hours of PICU admission. Higher scores are associated with more severe physiologic instability (Pollack, Patel, & Ruttimann, 1997) and higher mortality (Pollack, Patel, & Ruttimann, 1996). Hosmer-Lemeshow χ^2 goodness-of-fit evaluations demonstrated the absence of significant calibration errors ($p = .14$) and the area under the receiver operating curve (AUC, 0.96) supported the instrument's discrimination and accuracy (Pollack, Patel, & Ruttimann, 1996).

The Skin Assessment Tool (Braden & Bergstrom, 1987) delineated each bony prominence and required the assessor to rate the presence or absence of ulcers at each site. Pressure ulcers were staged according to the National Pressure Ulcer Advisory Panel (1989) recommendations:

- Stage I. Nonblanchable erythema not resolving within 30 minutes of pressure relief, epidermis remains intact.
- Stage II. Partial thickness loss of skin layers involving epidermis and possibly penetrating into but not through dermis, may present as blistering.
- Stage III. Full-thickness tissue loss extending through dermis to involve subcutaneous tissue.
- Stage IV. Deep tissue destruction extending through subcutaneous tissue to fascia and may involve muscle layers, joint, and/or bone.

Protocol

Prior to data collection, the principal investigator trained the site investigators and research assistants in study procedures, scoring the Braden Q, and staging pressure ulcers. Attention was given to assessing pressure ulcers in patients with darker skin tones; specifically, pressure ulcers in this population may appear with persistent red, blue, or purple discoloration (NPUAP Task Force on Darkly Pigmented Skin and Stage I Pressure Ulcers, 1998; Smith & Burns, 1999). The principal investigator, site investigators, and research assistants (graduate students in pediatric nursing or PICU staff nurses) scored patients together as a team until conceptual clarity was reached on each subscale of the Braden Q Scale. Team members then scored ten patients independently until there was 90% agreement of Braden Q scores and until differences within each subscale of the Braden Q Scale varied by only one point. Thereafter, percent agreement between the site

investigators and research assistants was re-evaluated bimonthly.

Two nurses, blind to the others' assessments and scores, observed patients up to 3 times a week (Monday, Wednesday, and/or Friday) for 2 weeks, then once a week (Wednesdays) until PICU discharge. Nurse I enrolled patients who met study criteria, completed the Demographic Data Collection Tool, the Daily Patient Assessment and Intervention Tool, then rated each patient using the Braden Q Scale. Nurse II completed a head-to-toe skin assessment using the Skin Assessment Tool. Initial skin assessment occurred within a few hours of enrollment. If a pressure ulcer was identified, the patient's nurse was notified so that treatment could be implemented and/or continued.

Data Analysis

Parametric and nonparametric statistics were used to describe the patient sample and compare for potential differences among sites. Pressure ulcer positive (PU +) subjects were compared to pressure ulcer negative (PU -) subjects using data obtained during the first observation because most pressure ulcers (58%) were noted to be present at this time. To decrease the likelihood of misclassification of Stage I pressure ulcers, only Stage II + data were considered to be pressure ulcer positive. Diagnostic probabilities (sensitivity, specificity, positive predictive value, and negative predictive value) were calculated over a range of possible Braden Q scores (Sackett, Haynes, Guyatt, & Tugwell, 1991). Sensitivity is the proportion of patients with the target disorder who have a positive test (i.e., the percentage of PU + patients whose scores are \leq cutoff). Specificity is the proportion of patients without the target disorder who have a negative test (i.e., the percentage of PU - patients whose scores are \geq cutoff). Positive predictive value (PPV) is the proportion of patients with a positive test who have the target disorder (i.e., the percentage of patients with scores \leq cutoff who developed PU). Negative predictive value (NPV) is the proportion of patients with a negative test who are free of the target disorder (i.e., percentage with scores $>$ cutoff who do not develop PU).

Receiver operator characteristic (ROC) curve analysis plotting sensitivity against $1 -$ specificity over the range of Braden Q scores was constructed to confirm the critical value of the Braden Q Scale. As described by Bergstrom, Braden, Kemp and others (1998), a ROC curve provides a visual representation of the trade off between sensitivity and specificity for a test that has a range of values. Using the same scale on both axes, the true positive rate (sensitivity) is plotted on the vertical axis against the false positive rate ($1 -$ specificity) on the horizontal axis over a range of potential cutoff scores. The AUC is a commonly used summary measure for ROC curves, with higher AUC arising from more accurate tests. When the test has no diagnostic ability to predict the outcome, the AUC would equal 0.5.

The optimal cutoff point (where error is minimized) is usually identified in the region where the ROC curve changes direction—the inflection point. Since predicting patients at risk for pressure ulcers is more important than predicting patients not at risk, the optimal cutoff point was determined by that which provided high sensitivity and adequate specificity. The likelihood ratio (LR) is defined as

the sensitivity divided by 1-specificity, and can be interpreted as the ratio of the probabilities that a positive test results from a patient with pressure ulcers to that for a patient without pressure ulcers.

Results

The three PICUs enrolled 322 pediatric patients (Table 1). On average, patients were 3 years of age, male (60%), White (67%), developmentally appropriate for age, and of low predictive risk of mortality (PRISM: median 3; interquartile range [IQR]: 0-7). The most common diagnoses involved the pulmonary (38%), neurological (28%), and gastrointestinal (9%) systems. Most patients (75%) were supported on mechanical ventilation for a median of 3 days; of those, several (21%) required chemical paralysis to facilitate mechanical ventilation. A majority (76%) of the patients received comfort medications (i.e., narcotics and/or benzodiazepines). While a smaller number (20%)

were rated to be anxious, agitated, or restless, over a third (34%) were rated to be at least sluggish in their response to a stimulus. The PICU median length stay was 6 days; most patients were transferred to an inpatient pediatric unit.

As expected, there were demographic differences between the three sites (Table 1). Unit A enrolled more non-White, non-Black patients; when compared to the other two units more patients in Unit A were rated to be of low predictive risk of mortality on admission and were functionally disabled. Unit B enrolled more White patients; when compared to the other two units more patients in Unit B group were rated to be cognitively and functionally normal. Unit C enrolled more Black patients; when compared to the other two units more patients in Unit C group were supported on mechanical ventilation for longer periods of time. There were no significant differences in the incidence of pressure ulcers between the three sites ($\chi^2(2) = 2.26, p = .32$) so pressure ulcer data are reported in the aggregate.

TABLE 1. Patient Demographic Information

	All Units N = 322	Unit A n = 121	Unit B n = 106	Unit C n = 95	Statistic ^a	Significance
Number of patients enrolled (%)	37	33	30	34	$X^2 = 49.92$	NS
Mean age in months (SD)	36 (29)	37 (29)	36 (28)	34 (29)	$X^2 = .61$	NS
Male (%)	60	53	67	62	$X^2 = 4.88$	NS
Race						
White (%)	67	67	80	51	$X^2 = 43.39$	<.001
Black (%)	20	13	9	41		
Other (American Indian, Hispanic, Asian) (%)	13	20	11	9		
PRISM III score, Median (IQR)	3 (0-7)	0 (0-5)	5 (0-9)	4 (0-9)	$X^2 = 17.80$	<.001
Functional health on admission						
Pediatric cerebral performance category						
Normal (%)	70	66	79	65	$X^2 = 6.20$.05
Mild disability (%)	11	12	6	17		
Moderate disability (%)	7	8	4	7		
Severe disability (%)	11	12	11	11		
Coma or vegetative state (%)	1	2	0	0		
Pediatric overall performance category						
Good overall performance (%)	65	56	75	64	$X^2 = 8.28$.02
Mild overall disability (%)	12	12	7	18		
Moderate overall disability (%)	9	12	8	6		
Severe overall disability (%)	13	18	9	12		
Coma or vegetative state (%)	1	2	2	0		
Supported on mechanical ventilation (%)	75	69	70	86	$X^2 = 9.86$.007
Duration of mechanical ventilation (Days), Median (IQR)	3 (0-7)	2 (0-7)	3 (0-6)	5 (2-8)	$X^2 = 10.40$.006
Use of chemical paralysis (%)	21	14	19	15	$X^2 = 1.19$	NS
Length of intensive care unit stay (Days), Median (IQR)	6 (3-10)	5 (3-10)	7 (4-12)	5 (4-9)	$X^2 = 2.62$	NS
Number of patients with pressure ulcers (% total)	86	36 (42)	30 (35)	20 (23)	$X^2 = 2.26$	NS

Note. IQR = interquartile range (range of values extending from the 25th percentile to the 75th percentile).

^aThe Kruskal-Wallis test was used for ordinal data and the chi-square test was used for nominal data. NS = not significant $p > .05$.

? Median duration (days) of mechanical ventilation (IQR).

? Median length (days) of intensive care unit stay (IQR).

TABLE 2. Summary of Patient Observation and Pressure Ulcer Data (N = 322)

Number of observations per patient, Median (IQR)	2 (1-4)
Total number of study observations	877
Number of patients developing pressure ulcers	86 (27)
Total number of pressure ulcers	199 (100%)
Stage I (% total)	139 (70)
Stage II (% total)	54 (27)
Stage III (% total)	6 (3)
Stage IV (% total)	None
Patients with more than one pressure ulcer (% with pressure ulcers)	42 (49)
Observations when pressure ulcer first noted to be present (% with pressure ulcers)	
First observation	49 (57)
Second observation	20 (23)
Third observation	10 (12)
Fourth observation	6 (7)
Eighth observation	1 (1)

Note. IQR = interquartile range (range of values extending from the 25th percentile to the 75th percentile).

Table 2 provides a summary of patient observations and pressure ulcer data. Of the 60 Stage II/III pressure ulcers, 19 (32%) involved the patient's head. Stage III pressure ulcers involved the patient's occiput, ear, chest, and/or coccyx. There were significant differences in the Braden Q

scores between ulcer positive and negative patients. Pressure ulcer positive patients had significantly lower mean (M) Braden Q scores (PU + M = 13; PU - M = 17; $t = 6.21, p < .001$).

Using Stage II + pressure ulcer data obtained during the first observation, a Receiver Operator Characteristic (ROC) curve plotting sensitivity and 1 - specificity for each possible score of the Braden Q Scale was constructed (Figure 1). The AUC was 0.83 (CI: 0.76 to 0.91). A cutoff score of 16 provided a high sensitivity and adequate specificity. At a score of 16 the sensitivity was 0.88 and the specificity was 0.58 producing a Likelihood Ratio (LR = sensitivity/1 - specificity) of 2.11 (Table 3). Data were similar when the three sites were evaluated separately (Table 4).

The ROC curves were then constructed for each subscale of the Braden Q Scale (Figure 2). Only three subscales contributed greater than 0.7 AUC (Table 5). While sensory perception, mobility, and tissue perfusion/oxygenation contributed to the Braden Q score, activity, moisture, friction, and shear, and nutrition did not. The confidence intervals of these four subscales included or were close to 0.5 indicating no significant effect.

The Braden Q Scale was then modified to include the three subscales with an AUC >.7 (mobility, sensory perception, tissue perfusion/oxygenation). Subscale selection was based on the magnitude of the contribution and not the statistical significance of the contribution. This Modified Braden Q Scale with three subscales resulted in a ROC curve with an AUC of 0.84 (CI: 0.77 to 0.91; Figure 3). A cutoff score of 7 provided a high sensitivity and adequate specificity. At a score of 7 the sensitivity was

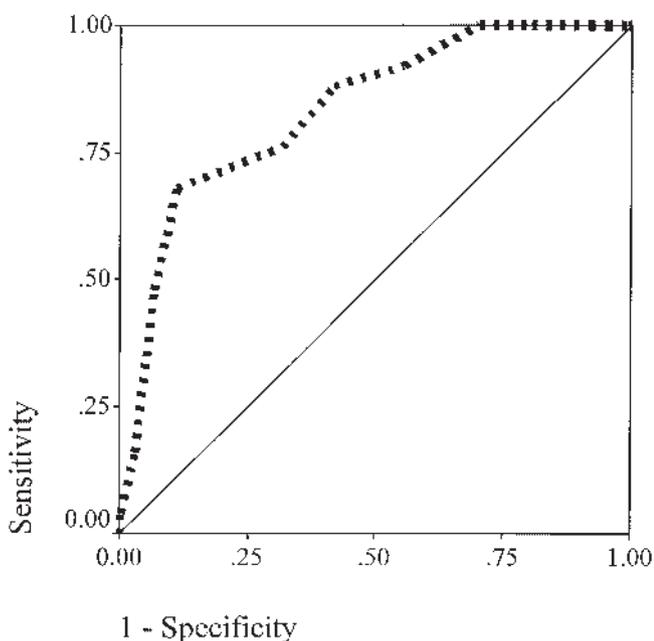


FIGURE 1. Braden Q Scale receiver-operating characteristic curve. The receiver-operating characteristic (ROC) curve plotting sensitivity and 1-specificity or each possible score of the Braden Q Scale.

TABLE 3. Characteristics of Each Value of the Braden Q Scale

Braden Q Score	Sensitivity	Specificity	PPV	NPV	Likelihood Ratio
≤ 20	1.00	.08	.08	1.00	1.09
≤ 19	1.00	.20	.10	1.00	1.25
≤ 18	1.00	.30	.11	1.00	1.43
≤ 17	.92	.44	.12	.99	1.64
≤ 16	.88	.58	.15	.98	2.11
≤ 15	.76	.68	.17	.97	2.38
≤ 14	.72	.79	.22	.97	3.43
≤ 13	.68	.89	.34	.97	6.18
≤ 12	.48	.93	.38	.96	6.86
≤ 11	.16	.97	.31	.93	5.33
≤ 10	.04	1.00	.50	.93	

Note. A Braden Score of 16 provides high sensitivity and adequate specificity. Likelihood Ratio of 2.11 indicates that a pediatric patient with a Stage II pressure ulcer is twice as likely to have a Braden Q score of = 16 compared to a patient without Stage II pressure ulcer. PPV = positive predictive value; NPV = negative predictive value.

0.92 and the specificity was 0.59 producing a LR of 2.22. As a second check, a final ROC curve was constructed adding the friction and shear subscale to the Modified Braden Q Scale (mobility, sensory perception, tissue perfusion/oxygenation) and the AUC decreased to 0.82 (CI: 0.73 to 0.91).

Although not reported, ROC curves using Stage I + pressure ulcer data obtained during the first observation were constructed and resulted in similar findings.

Discussion

Pressure ulcers do occur in acutely ill children. Consistent with previous research (Escher Neidig et al., 1989; Huffines and Logsdon, 1997; Zollo et al., 1996), this paper reports a 27% incidence of pressure ulcers in a pediatric acutely ill patient group. Escher Neidig et al. described a 17% incidence of pressure ulcers in children hospitalized in the PICU following cardiac surgery; Huffines and Logsdon reported a 19% incidence of pressure ulcers in neonates hospitalized in a Neonatal ICU and Zollo et al. reported a 26% incidence of alterations in skin integrity in a multidisciplinary PICU sample. Although

these incidence rates are similar, they cannot be compared without adjusting for patient risk for pressure ulcers—thus the need for a pediatric-specific pressure ulcer risk assessment scale.

Acutely ill pediatric patients with a Braden Q score of 16 can be considered at risk for Stage II pressure ulcers. These data were consistent among the three sites and with Quigley and Curley's (1996) initial report; specifically, when the Braden Q scores and subjective ratings of patient risk for pressure ulcers were compared, children thought to be at high risk for skin breakdown averaged a Braden Q score of 16.

Braden Q scores of 16 are not comparable to the original Braden score of 16 because the potential ranges are different; specifically 7–28 for the Braden Q Scale and 6–23 for the original Braden Scale. The lower relative Braden Q scores that identify patients at risk for Stage II pressure ulcers may reflect a unique characteristic of pediatric skin. Younger skin with sufficient collagen and elastin may be more resilient to normal and shearing pressures. Also, lower scores in this population may reflect the concurrent implementation of standard intensive care practices that are thought to help preserve patient skin; for

TABLE 4. Site Performance on the Braden Q Scale

	Area Under the Curve	Confidence Interval		Significance	Sensitivity at 16	Specificity at 16
		Lower	Upper			
All units	.83	.76	.91	<.001	.88	.58
Unit A	.85	.72	.97	.001	.87	.68
Unit B	.79	.67	.91	.001	.86	.47
Unit C	.89	.77	1.02	.02	1.00	.71

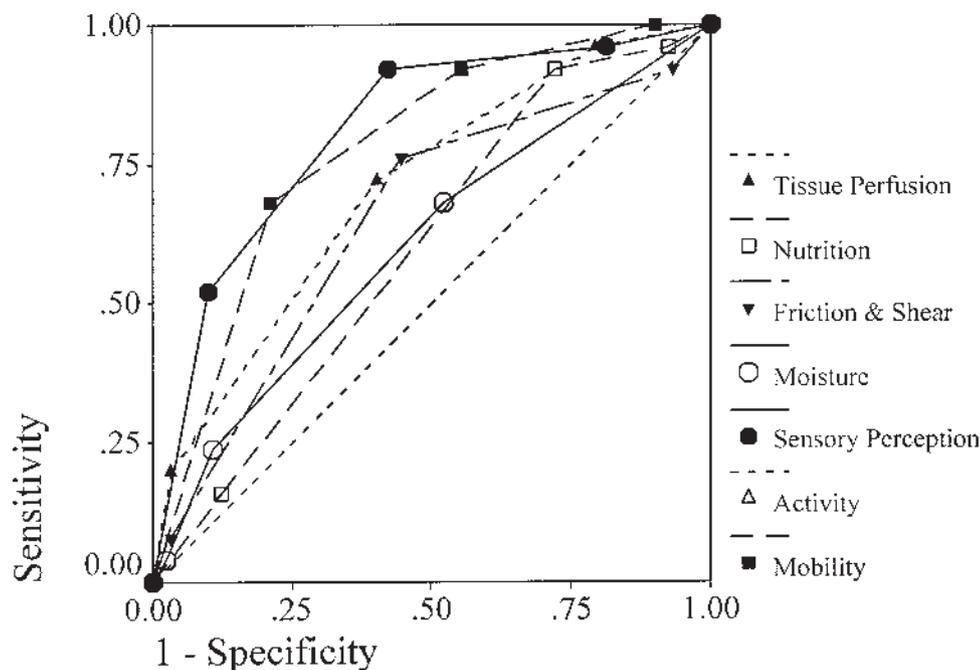


FIGURE 2. Braden Q Scale subscale receiver-operating characteristic curves. The receiver-operating characteristic (ROC) curve plotting sensitivity and 1-specificity for each possible score of each subscale of the Braden Q scale. All patients were on bedrest so the activity subscale lost all predictive capacity.

example, early enteral nutrition, turning schedules, and the use of supportive bed surfaces.

There are several limitations to this study. First, calling attention to pressure ulcer risk may have resulted in more preventative strategies (Bergstrom, Braden, Laguzza et al., 1987) and we did not attempt to control nursing care aimed at preventing pressure ulcers. Second, the study nurses scoring the Braden Q were not involved in the patient's care. The study nurses relied on data available in the medical record and/or on interview data obtained from the bedside nurse. Braden Q Scale performance may improve when the instrument is completed by the nurse caring for the patient. Next, the results of this study cannot be applied to all acutely ill infants and children. Patients with intracardiac shunting and/or unrepaired congenital heart disease were excluded because their blood oxygen saturation levels are often below the "normal" cutoff in the tissue perfusion subscale. In some PICU, this patient population constitutes a major patient group.

Because the benefit of preventing pressure ulcers in a high-risk group exceeds the risk posed by implementing preventative interventions in a low-risk group, a score that minimizes the number of false negatives (high sensitivity, high NPV) is desirable (Braden & Bergstrom, 1994). Using a Braden Q score of 16 with a sensitivity of 0.88 and a specificity of 0.58 will ensure that most pediatric patients at high risk for PUs will not be missed but also allows the implementation of preventative therapies on patients who may not have developed PUs. Specifically, only 15% of those predicted to develop PUs would develop them while 98% of those not predicted to develop PUs will not develop them. Using a lower cutoff score will improve the number of true positives but will not result in an important increase in the number of false negatives as the NPV is high (>.93) across a wide range of scores. While higher Braden Q scores can be used to prompt the implementation of standard preventative therapies (e.g., mattress replacement systems, turning every 2 hours), a

TABLE 5. Area Under the Curve for Each Subscale of the Braden Q Scale

Subscale	Area Under the Curve	Confidence Interval		Significance
		Lower	Upper	
Sensory perception	.81	.72	.90	<.001
Mobility	.78	.69	.86	<.001
Tissue perfusion and Oxygenation	.70	.60	.81	.001
Friction and Shear	.65	.54	.77	.01
Moisture	.60	.49	.72	.08
Nutrition	.60	.49	.70	.11
Activity	.50	.38	.62	1.00

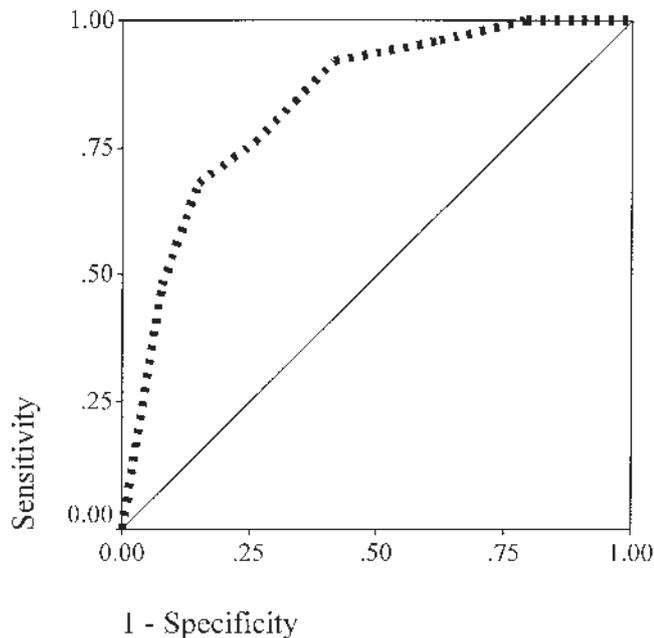


FIGURE 3. Modified Braden Q Scale receiver-operating characteristic curve. The receiver-operating characteristic (ROC) curve plotting sensitivity and 1-specificity for each possible score of the modified Braden Q scale containing only 3 subscales: Sensory Perception, Mobility and Tissue Perfusion/Oxygenation.

Braden Q score of 16 can be used as a trigger for implementing more aggressive preventative interventions (e.g., use of therapeutic bed surfaces) (Inman, Sibbald, Rutledge & Clark, 1993).

Most pressure ulcers developed soon after PICU admission. The best time to assess a pediatric patient for pressure ulcer risk is within 24 hours of PICU admission. This may be difficult because, as noted by Bergstrom, Braden, and Kemp et al. (1998) clinicians must acquire adequate knowledge of the patient to accurately score the patient on the Braden subscales. If most patients develop pressure ulcers within a day of PICU admission, a valid and reliable pressure ulcer risk assessment tool that performs well soon after PICU admission is needed. Of the seven Braden Q subscales, five subscales (mobility, activity, sensory perception, friction and shear, and tissue perfusion/oxygenation) can be scored after a nurse performs an initial shift assessment whereas two subscales (moisture and nutrition) require trending of patient data over time. Of the five subscales that can be initially assessed, the activity subscale seldom varies among bedrest intensive care unit patients and, in pediatrics, most patients under 8 years of age can be lifted to prevent friction and shear.

Parsimony is a desirable characteristic of measurement tools used within the clinical environment because clinicians will not use a tool that is burdensome. The Modified Braden Q Scale with three subscales (mobility, sensory perception and tissue perfusion/oxygenation) performed as well as the longer Braden Q Scale. These three subscales paint the picture of the acutely ill pediatric patient at risk for pressure ulcers; specifically, the immobile, sedated/unresponsive, and/or hemodynamically compromised infant/child.

Finally, tool performance should also be assessed within context of the care environment and patient population. The subscales not included in the Modified Braden Q Scale (activity, moisture, friction and shear, and nutrition) may be more important in the general pediatric population. Until further study, all seven subscales of the Braden Q Scale should be used for interinstitutional unit and cross-institutional comparisons. ▣

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APPENDIX A. The Braden Q Scale

Intensity and Duration of Pressure					Score
<p>Mobility The ability to change and control body position</p>	<p>1. Completely immobile: Does not make even slight changes in body or extremity position without assistance</p>	<p>2. Very limited: Makes occasional slight changes in body or extremity position but unable to completely turn self independently</p>	<p>3. Slightly limited: Makes frequent though slight changes in body or extremity position independently</p>	<p>4. No limitations: Makes major and frequent changes in position without assistance</p>	
<p>Activity The degree of physical activity</p>	<p>1. Bedfast: Confined to bed</p>	<p>2. Chair fast: Ability to walk severely limited or nonexistent. Cannot bear own weight and/or must be assisted in to chair or wheelchair</p>	<p>3. Walks occasionally: Walks occasionally during day, but for very short distances, with or without assistance. Spends majority of each shift in bed or chair</p>	<p>4. All patients too young to ambulate or walks frequently: Walks outside the room at least twice a day and inside room at least once every 2 hours during waking hours</p>	
<p>Sensory perception The ability to respond in a <i>developmentally</i> appropriate way to pressure-related discomfort</p>	<p>1. Completely limited: Unresponsive (does not moan, flinch, or grasp) to painful stimuli, due to diminished level of consciousness or sedation <i>or</i> limited ability to feel pain over most of body surface</p>	<p>2. Very limited: Responds only to painful stimuli. Cannot communicate discomfort except by moaning or restlessness <i>or</i> has sensory impairment which limits the ability to feel pain or discomfort over 1/2 of body</p>	<p>3. Slightly limited: Responds to verbal commands, but cannot always communicate discomfort or need to be turned <i>or</i> has some sensory impairment which limits ability to feel pain or discomfort in 1 or 2 extremities</p>	<p>4. No impairment: Responds to verbal commands. Has no sensory deficit, which limits ability to feel or communicate pain or discomfort</p>	
Tolerance of the Skin and Supporting Structure					
<p>Moisture Degree to which skin is exposed to moisture</p>	<p>1. Constantly moist: Skin is kept moist almost constantly by perspiration, urine, drainage, etc. Dampness is detected every time patient is moved or turned</p>	<p>2. Very moist: Skin is often, but not always moist. Linen must be changed at least every 8 hours</p>	<p>3. Occasionally moist: Skin is occasionally moist, requiring linen change every 12 hours</p>	<p>4. Rarely moist: Skin is usually dry, routine diaper changes, linen only requires changing every 24 hours</p>	
<p>Friction and Shear <i>Friction:</i> occurs when skin moves against support surfaces <i>Shear:</i> occurs when skin and adjacent bony surface slide across one another</p>	<p>1. Significant problem: Spasticity, contracture, itching, or agitation leads to almost constant thrashing and friction</p>	<p>2. Problem: Requires moderate to maximum assistance in moving. Complete lifting without sliding against sheets is impossible. Frequently slides down in bed or chair, requiring frequent repositioning with maximum assistance</p>	<p>3. Potential problem: Moves fuebly or requires minimum assistance. During a move, skin probably slides to some extent against sheets, chair, restraints, or other devices. Maintains relative good position in chair or bed most of the time but occasionally slides down</p>	<p>4. No apparent problem: Able to completely lift patient during a position change; Moves in bed and in chair independently and has sufficient muscle strength to lift up completely during move. Maintains good position in bed or chair at all times</p>	

(Continues)

APPENDIX A. The Braden Q Scale (Continued)

<p>Nutrition Usual food intake pattern</p>	<p>1. Very poor: NPO and/or maintained on clear liquids, or IVs for more than 5 days or albumin <2.5 mg/dl or never eats a complete meal. Rarely eats more than 1/2 of any food offered. Protein intake includes only 2 servings of meat or dairy products per day. Takes fluids poorly. Does not take a liquid dietary supplement</p>	<p>2. Inadequate: Is on liquid diet or tube feedings/TPN which provide inadequate calories and minerals for age or albumin <3 mg/dl or rarely eats a complete meal and generally eats only about 1/2 of any food offered. Protein intake includes only 3 servings of meat or dairy products per day. Occasionally will take a dietary supplement</p>	<p>3. Adequate: Is on tube feedings or TPN, which provide adequate calories and minerals for age or eats over half of most meals. Eats a total of 4 servings of protein (meat, dairy products) each day. Occasionally will refuse a meal, but will usually take a supplement if offered</p>	<p>4. Excellent: Is on a normal diet providing adequate calories for age. For example: eats/drinks most of every meal/feeding. Never refuses a meal. Usually eats a total of 4 or more servings of meat and dairy products. Occasionally eats between meals. Does not require supplementation</p>
<p>Tissue perfusion and oxygenation</p>	<p>1. Extremely compromised: Hypotensive (MAP <50mmHg; <40 in a newborn) or the patient does not physiologically tolerate position changes</p>	<p>2. Compromised: Normotensive; oxygen saturation may be <95% or hemoglobin may be < 10 mg/dl or capillary refill may be > 2 seconds; Serum pH is <7.40</p>	<p>3. Adequate: Normotensive; oxygen saturation may be <95% or hemoglobin may be < 10 mg/dl or capillary refill may be > 2 seconds; Serum pH is normal</p>	<p>4. Excellent: Normotensive, oxygen saturation >95%; normal hemoglobin; & capillary refill < 2 seconds</p>

Total:

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