Predicting Pressure Injury Risk in Pediatric Patients: The Braden QD Scale

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Objective To describe the development and initial testing of the Braden QD Scale to predict both immobility-related and medical device–related pressure injury risk in pediatric patients.

Study design This was a multicenter, prospective cohort study enrolling hospitalized patients, preterm to 21 years of age, on bedrest for at least 24 hours with a medical device in place. Receiver operating characteristic curves using scores from the first observation day were used to characterize Braden QD Scale performance, including areas under the curve (AUC) with 95% CIs.

Results Eight centers enrolled 625 patients. A total of 86 hospital-acquired pressure injures were observed in 49 (8%) patients: 22 immobility-related pressure injuries in 14 (2%) patients and 64 medical device–related pressure injuries in 42 (7%) patients. The Braden QD Scale performed well in predicting immobility-related and medical device–related pressure injuries in the overall sample, with an AUC of 0.78 (95% CI 0.73-0.84). At a cutoff score of 13, the AUC was 0.72 (95% CI 0.67-0.78), providing a sensitivity of 0.86 (95% CI 0.76-0.92), specificity of 0.59 (95% CI 0.55-0.63), positive predictive value of 0.15 (95% CI 0.11-0.19), negative predictive value of 0.98 (95% CI 0.97-0.99), and a positive likelihood ratio of 2.09 (95% CI 0.95-4.58).

Conclusions The Braden QD Scale reliably predicts both immobility-related and device-related pressure injuries in the pediatric acute care environment and will be helpful in monitoring care and in guiding resource use in the prevention of hospital-acquired pressure injuries. *(J Pediatr 2018;192:196-202).*

Pediatric patients, regardless of age and developmental level, are at risk for developing immobility-related pressure injuries due to bed rest as well as medical device–related pressure injuries (MDPIs).[1-4] The personal suffering and financial costs associated with hospital-acquired pressure injuries (HAPIs) are significant.[5,6] Pressure injury per 1000 patient-days commonly is tracked by high-reliability organizations that focus on eliminating iatrogenic harm associated with pediatric care.[7-9] Although preventable, 1.4% of hospitalized infants and children experience pressure-related skin injuries.[10,11]

The prevention of pressure injury requires the accurate identification of patients at risk and the reliable implementation of prevention strategies in patients identified as being at risk.[12] Critical to this process is the availability of pediatric-specific, valid, and reliable instruments that predict the risk of pressure injury.[13] The Braden Q Scale is a widely used pediatric pressure injury risk assessment tool.[3,13,14] However, initial predictive validity testing of the Braden Q Scale only included immobility-related pressure injuries in critically ill pediatric patients aged 2 weeks to 8 years and excluded patients with congenital heart disease.[15] The purpose of this study was to build on our previous work and construct a new, parsimonious Braden QD Scale describing combined immobility-related and MDPI risk in a broader, more diverse sample of pediatric patients typically cared for in acute care environments. Our hypothesis was that a new scale would demonstrate sufficient sensitivity and specificity to predict both immobility-related pressure injuries and MDPIs. Secondary objectives were to determine the critical cutoff point for classifying risk of HAPI.

AUC	Area under the curve
HAPI	Hospital-acquired pressure injury
IRR	Inter-rater reliability
MDPI	Medical device–related pressure injury
PICU	Pediatric intensive care unit
RACHS-1	Risk Adjustment for Congenital Heart Surgery – Version 1
WOCN	Wound, ostomy, and continence nursing

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Methods

We conducted a multicenter, prospective cohort study. Patients were recruited from 8 pediatric academic medical centers across the US, each selected based on their capacity to enroll a broad, clinically diverse patient population under the leadership of an advanced practice nurse with expertise in wound, ostomy, and continence nursing (WOCN). Human subject approval was obtained from each hospital's institutional review board, and written informed consent was obtained from the parent/legal guardian of each enrolled patient. The first subject was enrolled on March 25, 2013 and the last on July 15, 2015.

Eligible patients were preterm to 21 years of age, on bedrest for at least 24 hours from hospital admission with a medical device attached to or traversing their skin or mucous membrane. Bedrest was operationalized per developmental age; specifically, infants not being held, toddlers not cruising, or children not walking per usual. We excluded patients with a pre-existing pressure injury or a do-not-resuscitate order. To ensure a study population generalizable to acute care pediatrics, we stratified enrollment by age, patient type (medical/surgical or cardiovascular), and unit type (pediatric intensive care unit [PICU] or ward). Each site limited enrollment to 25 subjects in each of the following age groups: preterm to 42 weeks, 43 weeks to 12 months, 13 months to 5 years, 6-12 years, and 13-21 years, with approximately 50% from each patient type. To avoid oversampling critically ill patients, we limited the number of endotracheally intubated subjects to 50% of each age group. We aimed for a target population of 600 subjects, so that subgroup analyses with 100 subjects would have half-widths of 95% CIs for proportions to be 0.10 or less.

Before data collection, WOCN leads and study nurses were trained in study procedures, scoring the Braden QD Scale, and staging of pressure injuries using digital photographs. Inter-rater reliability (IRR) was established before the start of data collection and was a 2-stage process. First, the lead WOCN nurses from each site were trained by the study investigators. After training, IRR was established by jointly rating 10 clinical scenarios. The percent agreement between raters was calculated, and a minimum agreement of 0.80 was established. Second, each site's lead WOCN nurse then replicated the IRR process with their respective nurse teams. IRR was re-established every 4 months during the data-collection period and whenever a new nurse joined the local data-collection team.

Each hospital screened for eligible subjects 3 times per week on Mondays, Wednesdays, and Fridays. To avoid selection bias, subjects were screened in sequence based on a randomization scheme that included all inpatient units (except inpatient psychiatric units) and the last digit of a patient's medical record number. Before enrollment, eligibility criteria were confirmed by the subject's bedside nurse. Once confirmed, the study nurse was introduced to the patient and parent/legal guardian to initiate the consent process. Patients were approached for assent if they were ≥8 years of age, not sedated, and cognitively capable (Pediatric Cerebral Performance Category ≤3).[16]

Severity of illness scores were completed on each enrolled subject by use of the worst-documented physiologic values from the first 12 hours of hospital admission. Medical-surgical subjects ≤2 weeks of age were scored with the Score for Neonatal Acute Physiology with Perinatal Extension II, and subjects ≥2 weeks of age were scored with the Pediatric Risk of Mortality score, Version III, first 12 hour model (PRISM III-12).[17,18] All cardiac subjects received a Risk Adjustment for Congenital Heart Surgery – Version 1 (RACHS-1) score based on their cardiac procedure/operation type.[19] The Pediatric Cerebral Performance Category and the Pediatric Overall Performance Category scales were used to quantify cognitive and overall functional status at admission.[16]

Pressure injury risk was described with the Braden Q Scale.[15] The Braden Q Scale reflects Braden and Bergstrom's conceptual framework[20] that identifies 2 determinants of immobility-related pressure injury: the intensity and duration of pressure and tissue tolerance. The Braden Q Scale operationalizes these 2 dimensions in 7 subscales: mobility, activity, sensory perception, skin moisture, friction and shear, nutrition, and tissue perfusion and oxygenation. Each subscale has 4 mutually exclusive levels that range from 1 (least favorable) to 4 (most favorable). Total Braden Q scores range from 7 to 28 points. Braden Q scores of ≤16 identify pediatric patients at risk for immobility-related pressure injuries with a sensitivity of 0.88 and specificity of 0.58.[15] To address risk specific to MDPI, 2 additional subscales were added to the Braden Q Scale to form the Braden QD Scale: total number of diagnostic or therapeutic devices that were attached to or traversed the patient's skin or mucous membrane and whether each of these devices could be repositioned and/or the skin under each device was protected.

Study procedures were separate from usual care. Two nursing teams evaluated enrolled subjects up to 3 times per week (Mondays, Wednesdays, and Fridays) for 2 full weeks, then weekly for 2 more weeks. Subject data were considered complete at hospital discharge or hospital day 28, whichever occurred first. Nurses in team I completed an intervention and device log through data extraction from the medical record or by observation of the subject's bed space. They also scored the subject's risk for HAPI using the Braden Q scale with a member of the subject's clinical team. Within 6 hours of the evaluation by nurses in team I, nurses in team II completed a head-to-toe skin assessment for HAPI with the assistance of the subject's bedside nurse. Nurses in teams I and II, blind to the other's assessments, used separate password-protected devices to enter data directly into a secure, web-based Research Electronic Data Capture (REDCap) application (hosted at the University of Pennsylvania).[21]

All HAPIs were photographed and then categorized as immobility-related or device-related and staged according to National Pressure Ulcer Advisory Panel guidelines.[4] The HAPI staging was determined by the local WOCN and confirmed by the core team's WOCN. After identification, all HAPIs were managed at the discretion of the clinical team.

Statistical Analyses

Demographic and admission characteristics were reported for the entire population and according to HAPI development. Comparisons between HAPI-positive patients and HAPI-negative patients were made with the use of regression methods, accounting for enrolling site.

Receiver operating characteristic curves were created by the use of Braden Q scores from the first observation day for the entire population and by enrollment subgroup (age category, medical/surgical or cardiovascular diagnosis, and endotracheal intubation or not). Endotracheal intubation was used as a proxy for PICU location at enrollment to ensure the same level of criticality across all sites. Summary statistics including sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio, and area under the curve (AUC) were calculated for the Braden Q Scale.

To develop the Braden QD Scale from the Braden Q Scale, Braden Q subscales that performed poorly (AUC ≤0.70) in all enrollment subgroups were eliminated. To simplify the remaining 4 level subscales, we compared AUCs for 3 level subscales that combined adjacent categories (lowest 2 risk groups combined, middle 2 risk groups combined, or highest 2 risk groups combined). The simplified, 3-level subscale that provided the highest AUC was selected. Clinical review of the subscales was used to select among 3 level subscales with equal AUCs. New device-related subscales were added to the remaining 3 level Braden Q subscales to create the Braden QD score. Summary statistics and AUC estimates were then reported for each Braden QD threshold to identify an optimal Braden QD threshold to classify patients at high risk for the development of pressure injury. To internally validate the accuracy of the new Braden QD Scale, the mean AUC from 1000 bootstrapped samples was used as the bias-corrected AUC estimate for the overall study population. All analyses were performed with SAS, version 9.4 (SAS Institute, Cary, North Carolina).

Results

Eight pediatric centers across the US enrolled 625 pediatric patients (**Table I**). Each center enrolled 28-123 subjects within a median 2 days (IQR 1-2) of hospital admission. Reflecting age stratification, the mean age for enrolled subjects was 6 (SD, 6) years; 17% were <1 month of age (gestational age: median, 39 weeks; IQR 37-40), and 31% were >8 years of age. Most subjects were male (53%) and non-Hispanic white (68%), followed by Hispanic/Latino (17%), non-Hispanic black (7%), or multiracial (2%). Most patients were cognitively (76%) and functionally (74%) appropriate for age and had a low predictive risk of mortality by Score for Neonatal Acute Physiology with Perinatal Extension II or Pediatric Risk of Mortality III, 12-hour model. The RACHS-1 scores were high in cardiac subjects, with one-half assigned a RACHS-1 score of ≥3.

Reflecting stratification by patient type, 45% of subjects were cardiovascular patients. In medical/surgical subjects, the most common diagnoses included pulmonary (25%), neurologic (24%), musculoskeletal (15%), or gastrointestinal (14%) dysfunction. Almost one-half of subjects (45%) had more than 1 body system problem that commonly involved pulmonary (29%), gastrointestinal (14%), or cardiovascular (14%) systems. At enrollment, 64% of subjects were cared for in the PICU, of whom 48% (193/403) were intubated. Admission skin assessments were documented on almost all subjects (99%); 93% had an admission Braden Q score documented, of whom 18% (N = 106) scored at-risk (≤16) for immobility-related pressure injury (median 22; IQR, 19-25).

The 625 enrolled subjects provided 2049 paired team I and II observations, with a median of 2 observations (IQR 1-5) per subject and 7 medical devices (IQR 4-10) at first observation (**Table II**; available at www.jpeds.com). Subjects were followed for a median of 4 days (IQR 2-11). A total of 86 HAPIs were observed in 49 (8%) subjects; 22 immobility-related pressure injuries in 14 (2%) subjects and 64 MDPI in 42 (7%) subjects. Of these, approximately one-third of HAPI-positive subjects (31%) had >1 HAPI. Of subjects who developed a HAPI, 51% developed it by the second observation period and 44% of observed HAPI were Stage 1. Common sites for immobility-related pressure injuries included the anterior rib, sacrum, buttock, and head. External monitoring, oxygen delivery, and airway maintenance devices caused the most MDPIs.

No patients were missing Braden Q subscale or pressure injury outcomes. To revise the Braden Q and create the Braden QD scale, 2 subscales, activity and skin moisture, were eliminated because of poor performance and the remaining 5 subscales, mobility, sensory perception, friction and shear, nutrition, and tissue perfusion and oxygenation, were retained and simplified to 3 levels (**Tables III** and **IV**; available at www.jpeds.com). Reflecting the norm of aligning greater numbers with increased risk, the 3 level subscales were ranked as 0, no risk; 1, risk; and 2, high risk. For the number of medical devices, 1 point was assigned for each medical device to a maximum of 8 points for 8 or more medical devices. For medical device repositionability and skin protection, 1 point (potential problem) was given to the presence of any medical devices and 2 points (problem) for any one or more medical device(s) that could not be repositioned or the skin under each device was not protected. Thus, the new Braden QD Scale consists of 7 subscales and sums to a total score of 0-20, with greater scores indicating greater risk (**Table V**).

We constructed receiver operating characteristic curves for each potential risk threshold of the Braden QD Scale (**Figure** and **Table VI**). At a cutoff score of 13, the AUC was 0.72 (95% CI 0.67-0.78), providing a sensitivity of 0.86 (95% CI 0.76-0.96), specificity of 0.59 (95% CI 0.55-0.63), and positive likelihood ratio of 2.09 (95% CI 0.95-4.58). Despite a low positive predictive value at this risk threshold (0.15; 95% CI 0.11-0.19), we report a high negative predictive value (0.98; 95% CI 0.97-0.99).

Table VII (available at www.jpeds.com) compares the AUC for the Braden Q Scale and the Braden QD Scale in the overall sample and in each enrollment subgroup. To address the low prevalence of observed HAPIs, enrollment age categories were collapsed to ensure that a sufficient number of HAPIs from

Table I. Characteristics of study population in overall sample and stratified by pressure injury development

Characteristics	Overall n (%)* (n = 625)	HAPI-positive n (%)* (n = 49)	HAPI-negative n (%)* (n = 576)	*P* value†
Demographics				
Age at enrollment				.15
Preterm to <1 mo	109 (17)	7 (14)	102 (18)	
1 mo to 8 y	325 (52)	24 (49)	301 (52)	
9 y to 21 y	191 (31)	18 (37)	173 (30)	
Male	334 (53)	29 (59)	305 (53)	.30
Race/ethnicity‡				.08
Non-Hispanic white	418 (68)	39 (80)	379 (67)	
Hispanic/Latino of any race	103 (17)	7 (14)	96 (17)	
Non-Hispanic black	46 (7)	1 (2)	45 (8)	
Multiracial	15 (2)	1 (2)	14 (2)	
Other	36 (6)	1 (2)	35 (6)	
Severity of illness				
SNAPPE-II, median (IQR)§	5 (0-18)	30 (N/A)	5 (0-18)	<.001
PRISM III-12, median (IQR)¶	2 (0-6.5)	5 (3-16)	2 (0-6)	.005
RACHS-1 category**				<.001
1-2	106 (50)	5 (22)	101 (54)	
≥3	104 (50)	18 (78)	86 (46)	
Unassignable operative lesion	12	1	11	
Nonoperative cardiovascular disease	55	3	52	
Functional health on admission				
Cognitive impairment (admission PCPC >1)	150 (24)	22 (45)	128 (22)	<.001
Functional impairment (admission POPC >1)	164 (26)	22 (45)	142 (25)	<.001
Hospital admission characteristics				
Cardiovascular diagnosis	279 (45)	27 (55)	252 (44)	.06††
Medical/surgical diagnosis	346 (55)	22 (45)	324 (56)	
Pulmonary	85 (25)	7 (32)	78 (24)	
Neurologic/neurosurgical	83 (24)	7 (32)	76 (23)	
Musculoskeletal	53 (15)	4 (18)	49 (15)	
Gastroenterologic	49 (14)	1 (5)	48 (15)	
Other	76 (22)	3 (14)	73 (23)	
Enrolled from PICU	403 (64)	44 (90)	359 (62)	.06
Intubated at enrollment	193 (31)	33 (67)	160 (28)	<.001
Wheelchair- or chair-bound	62 (10)	11 (22)	51 (9)	<.001
Hemiparesis, paraplegia, or quadriplegia	29 (5)	9 (18)	20 (3)	<.001
Able to verbally communicate pain	380 (61)	27 (55)	353 (61)	.43
Admission skin assessment performed‡‡	619 (99)	49 (100)	570 (99)	—
Admission Braden Q, median (IQR)	22 (19-25)	19 (17-21)	22 (19-25)	<.001

N/A, not available; *PCPC*, Pediatric Cerebral Performance Category; *POPC*, Pediatric Overall Performance Category; *PRISM III-12*, Pediatric Risk of Mortality III, 12-hour model; *SNAPPE-II*, Score for Neonatal Acute Physiology with Perinatal Extension II.

*Unless otherwise noted.

†*P* values for comparison between groups were calculated with linear, cumulative logit, and logistic regression accounting for site as a cluster variable via the use of generalized estimating equations with an independence working assumption for continuous, ordinal, and binary variables, respectively.

‡Overall n = 618 (7 parents/guardians declined to answer). *P* value compares non-Hispanic white with remaining categories.

§Overall n = 44 (43 HAPI-negative and 1 HAPI-positive), IQR for HAPI-positive could not be calculated.

¶Overall n = 304 (283 HAPI-negative and 21 HAPI-positive).

**Overall n = 277 (250 HAPI-negative and 27 HAPI-positive). *P* value compares RACHS-1 score 1-2 vs RACHS-1 score ≥3, excluding patients with unassignable operative lesions or nonoperative cardiovascular disease.

††*P* value compares cardiovascular diagnosis with medical/surgical diagnosis.

‡‡Nearly all study subjects had admission skin assessments; therefore, the *P* value could not be computed.

previously unstudied age groups were included. The mean Braden QD score was 11 (SD, 5); 11 (SD, 4) for HAPI negative and 15 (SD, 3) for HAPI positive. The Braden QD Scale performed well in the overall sample with an AUC of 0.78 (95% CI 0.73-0.84) and in each enrollment subgroup. Specifically, the Braden QD Scale outperformed the Braden Q Scale in previously unstudied populations with the largest improvements in subjects >8 years (AUC 0.83; 95% CI 0.77-0.90) and nonintubated patients (AUC 0.77; 95% CI 0.67-0.87). When we compared the Braden Q and Braden QD Scale's ability to predict immobility-related pressure injuries, the AUC improved from 0.78 (95% CI 0.66-0.90) to 0.86 (0.78-0.93), respectively. The observed Braden QD AUCs for the overall sample to predict any HAPI, immobility-related pressure injuries, and MDPI were unbiased, with an average difference of ≤0.001 for all AUCs among the bootstrapped samples.

Discussion

We describe the development and initial testing of the Braden QD Scale for predicting HAPI in the pediatric acute care environment. The instrument was developed from data derived from a broad, diverse sample of hospitalized pediatric patients and predicts both immobility-related and device-related pressure injuries. The Braden QD Scale is parsimonious in design, with clear mutually exclusive levels that are easy to score. Braden QD scores of ≥13 indicate that a patient is at risk for HAPI. Risk-prevention interventions can then be

Table V. Braden QD Scale

Intensity and duration of pressure				Score
Mobility	**0. No limitation**	**1. Limited**	**2. Completely immobile**	
The ability to independently change and control body position.	Makes major and frequent changes in body or extremity position independently.	Makes slight and infrequent changes in body or extremity position **OR** unable to reposition selfindependently (includes infants too young to roll over).	Does not make even slight changes in body or extremity position independently.	
Sensory perception	**0. No impairment**	**1. Limited**	**2. Completely limited**	
The ability to respond meaningfully, in a developmentally appropriate way, to pressure-related discomfort	Responsive **and** has no sensory deficits that limit ability to feel or communicate discomfort.	Cannot always communicate pressure-related discomfort **OR** has some sensory deficits that limit ability to feel pressure-related discomfort.	Unresponsive due to diminished level of consciousness **OR** sedation or sensory deficits limit ability to feel pressure-related discomfort over most of body surface.	
Tolerance of the skin and supporting structure				
Friction and shear	**0. No problem**	**1. Potential problem**	**2. Problem**	
Friction: occurs when skin moves against support surfaces. Shear: occurs when skin and adjacent bony surface slide across one another.	Has sufficient strength to completely lift self up during a move. Maintains good body position in bed/chair at all times. Able to completely lift patient during a position change.	Requires **some** assistance in moving. Occasionally slides down in bed/chair, requiring repositioning. During repositioning, skin often slides against surface.	Requires **full** assistance in moving. Frequently slides down and requires repositioning. Complete lifting without skin sliding against surface is impossible **OR** spasticity, contractures, itching, or agitation leads to almost constant friction.	
Nutrition	**0. Adequate**	**1. Limited**	**2. Poor**	
Usual diet for age—assess pattern over the most recent 3 consecutive days.	Diet for age providing **adequate** calories **and** protein to support metabolism and growth.	Diet for age providing **inadequate** calories **OR inadequate** protein to support metabolism and growth **OR** receiving supplemental nutrition any part of the day.	Diet for age providing **inadequate** calories **and** protein to support metabolism and growth.	
Tissue perfusion and oxygenation	**0. Adequate**	**1. Potential problem**	**2. Compromised**	
	Normotensive for age, **and** oxygen saturation ≥95%, **and** normal hemoglobin, **and** capillary refill ≤2 seconds.	Normotensive for age, **with** oxygen saturation <95%, **OR** hemoglobin <10 g/dl, **OR** capillary refill > 2 seconds.	Hypotensive for age **OR** hemodynamically unstable with position changes.	
Medical Devices				
Number of medical devices	**Score 1 point for each medical device* up to 8 (score 8 points maximum)**			
Repositionability/skin protection	**0. No medical devices**	**1. Potential problem**	**2. Problem**	
		All medical devices can be repositioned **OR** the skin under each device is protected.	Any one or more medical device(s) cannot be repositioned **OR** the skin under each device is not protected.	
				Total (≥13 considered at risk)

Patients are scored on each of the 7 subscales. The subscale scores are then summed. Total scores ≥13 identify patients at risk for HAPI. Patient risk is assessed within 24 hours of hospital admission and repeated with changes in patient condition. Interventions to manage patient risk are directed to the subscales scored ≥1.
*Any diagnostic or therapeutic device that currently is attached to or traverses the patient's skin or mucous membrane.

targeted, on an individual basis, to the subscale contributing points to the patient's overall Braden QD score.

Compared with our previous report of 322 medical-surgical critically ill subjects 3 weeks to 8 years of age,[15] we now report a decrease in immobility-related pressure injuries across a broader pediatric sample. More than a decade ago, we reported that 86 patients (27%) developed 199 pressure injuries; 60 (30%) of which were Stage 2 or worse pressure injuries. When we used Stage 2 pressure injury data obtained during the first observation period, the AUC of the Braden Q Scale was 0.83 and, at a cut-off score of 16, the sensitivity was 0.88 and the specificity was 0.58. Now, more attention is paid to the prevention of immobility-related pressure injuries. Bedrest is seldom prescribed, and a major focus of the clinical team is to get children up and moving as soon as possible. We report the high use of medical devices in hospitalized children and note that these devices are the primary cause of HAPIs. The new Braden QD Scale performs slightly better than the origi-

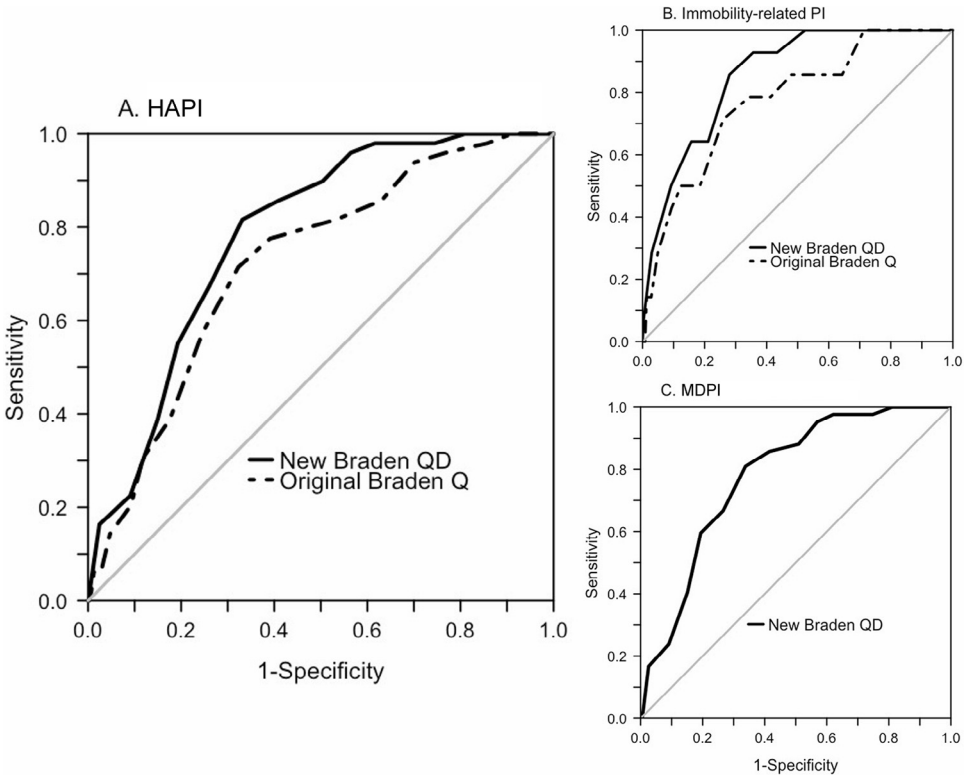

Figure. Original Braden Q and new Braden QD ROC curves for any HAPI and for each pressure injury type. Shown is a comparison of the Braden Q and Braden QD Scale's ability to predict **A,** any HAPI; **B,** an immobility-related PI; and **C,** an MDPI. The Braden Q Scale was not designed to predict MDPI so it's ROC curve was not drawn in **C**. *PI*, pressure injury; *ROC*, receiver operating characteristic.

nal Braden Q Scale and now predicts both immobility-related and device-related pressure injures.

In our previous work,[15] we chose to remain consistent with Braden and Bergstrom's conceptual framework of pressure injury risk[20] and retained 4 of 7 subscales that provided small, incremental improvements in the instrument's predicative ability; specifically, we retained the activity, skin moisture, friction and shear, and nutrition subscales. Our rationale was that these subscales might be more important in a broader but untested pediatric population. Having now confirmed that 2 of these 4 subscales (activity and skin moisture) do not perform well in our new sample, we dropped them from the Braden QD Scale. The activity subscale has been problematic in that young patients considered too young to ambulate were automatically scored most favorably, decreasing the spread of scores across all levels. Skin moisture is now less of a problem, given

Table VI. Sensitivity, specificity, PPV, NPV, and AUC, with 95% CIs, for potential Braden QD risk thresholds (n = 625)

Braden QD risk thresholds	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	AUC (95% CI)
≥10	0.98 (0.94-1.00)	0.38 (0.34-0.42)	0.12 (0.09-0.15)	1.00 (0.99-1.00)	0.68 (0.65-0.71)
≥11	0.96 (0.90-1.00)	0.43 (0.40-0.47)	0.13 (0.09-0.16)	0.99 (0.98-1.00)	0.70 (0.66-0.73)
≥12	0.90 (0.81-0.98)	0.49 (0.45-0.53)	0.13 (0.10-0.17)	0.98 (0.97-1.00)	0.70 (0.65-0.74)
≥13	0.86 (0.76-0.96)	0.59 (0.55-0.63)	0.15 (0.11-0.19)	0.98 (0.97-0.99)	0.72 (0.67-0.78)
≥14	0.82 (0.71-0.92)	0.67 (0.63-0.71)	0.17 (0.12-0.22)	0.98 (0.96-0.99)	0.74 (0.68-0.80)
≥15	0.67 (0.54-0.80)	0.74 (0.70-0.78)	0.18 (0.12-0.24)	0.96 (0.95-0.98)	0.71 (0.64-0.78)
≥16	0.55 (0.41-0.69)	0.81 (0.78-0.84)	0.20 (0.13-0.26)	0.95 (0.94-0.97)	0.68 (0.61-0.75)

NPV, negative predictive value; *PPV*, positive predictive value.

improved barriers and wicking materials than products used in the past. Dropping 1 subscale from each of the 2 determinants of immobility-related injury, that is, the activity subscale from the intensity and duration of pressure dimension and the skin moisture subscale from the tissue tolerance dimension, maintained measurement balance within Braden and Bergstrom's conceptual framework.

The use of medical devices is pervasive in acute care pediatrics.[22] Here, we note that the occurrence of MDPIs far surpassed the occurrence of immobility-related pressure injuries. Furthermore, the number of medical devices was proportional to the level of pressure injury risk up to 8 devices per patient. Modulating this effect was the capacity to rotate placement of the medical device and/or to protect the patient's skin under each device. Also important are Braden and Bergstrom's[20] intensity and duration of pressure and tissue tolerance dimensions in the prediction of MDPI; specifically, patient mobility, sensory perception, friction and shear, nutrition, and tissue perfusion and oxygenation all contribute to patient risk for MDPI.

The benefit of preventing pressure injuries exceeds the risk posed by implementing preventative interventions in a low-risk group, so identifying a risk threshold that maximizes the true positive rate (high sensitivity) is desirable. The use of a Braden QD score of 13 with a sensitivity of 0.86 and a specificity of 0.59 ensures that patients at-risk for developing a pressure injury will be identified but recommends implementation of preventative therapies on patients who are less likely to develop pressure injuries.

There are several limitations to this study. First, the low rate of HAPIs increased the variability of the data and may have influenced accuracy of the instrument. Second, no attempt was made to control interventions nor nurse staffing aimed at pressure injury prevention. The pragmatic nature of this study assumes that local pressure injury prevention standards were in place. Third, aside from considering whether a medical device could be repositioned or the skin under each device could be protected, we did not consider the potential variation of MDPI risk by device type. Fourth, study results can be applied only to the acute care pediatric population on bedrest with a medical device in place that is broad in age, diagnoses, and criticality. Unless practice patterns are similar in long-term pediatric care facilities, the Braden QD score predicting HAPI risk may need to be adjusted in these settings. Lastly, testing the new Braden QD Scale outside the research environment in a broader pediatric population is warranted.

The Braden QD Scale provides acute care pediatric clinicians with one instrument to predict both immobility- and device-related pressure injuries across its diverse age and clinical population. This instrument may be helpful in preventing iatrogenic injury, in facilitating quality monitoring of care, and in helping to guide resource allocation in the prevention of HAPIs in acutely ill infants and children. ■

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Acknowledgments

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Table II. Summary of patient observations and pressure injury development

Parameters Observed	Overall n (%)* (n = 625)
Total number of study observations	2049
Number of observations per patient, median (IQR)	2 (1-5)
Number of devices observed per patient on first observation, median (IQR)	7 (4-10)
Number of patients who developed pressure injuries	49 (8)
Patients with more than 1 pressure injury (% of patients with pressure injuries)	15 (31)
Total number of pressure injuries	86
Observation when first pressure injury noted to be present (% of patients with pressure injuries)	
First	13 (27)
Second	12 (24)
Third	9 (18)
Fourth or later	15 (31)
Observed pressure injury stage at first observation (% of pressure injuries)	
Suspected deep tissue injury	12 (14)
Stage 1	38 (44)
Stage 2	27 (31)
Unstageable	4 (5)
Mucosal pressure injuries	5 (6)
Type of pressure injury developed	
Immobility (n = 14 patients)	22
Medical device–related (n = 42 patients)	64
Medical devices resulting in device-related pressure injuries	
External monitoring devices	19
Oxygen delivery devices	9
Airway maintenance device	8
GI tubes and drains/transdermal tubes/monitors	7
Vascular devices	6
Immobilizers/supportive/securing devices	4
Other (blood pressure cuff, indwelling urinary catheter, nasal packing)	3

GI, gastrointestinal.
*Unless otherwise noted.

Table III. AUC for each Braden Q subscale to predict an immobility-related pressure injury, stratified by enrollment subgroup

		Age category			Diagnosis at admission		Endotracheal intubation at enrollment	
Braden Q Subscale	Overall	<1 mo	1 mo to 8 y	9-21 y	Medical/surgical diagnosis	Cardiovascular diagnosis	Intubated	Not intubated
No. subjects/total	14/633	2/109	3/325	9/191	6/346	8/279	11/193	3/432
Mobility, AUC (95% CI)	0.74 (0.62-0.86)	0.79 (0.57-1.00)	0.76 (0.50-1.00)	0.72 (0.54-0.89)	0.87 (0.80-0.95)	0.65 (0.47-0.83)	0.63 (0.46-0.79)	0.76 (0.54-0.98)
Activity,*,† AUC (95% CI)	0.63 (0.48-0.78)	—	0.66 (0.45-0.86)	0.69 (0.56-0.82)	0.64 (0.37-0.91)	0.66 (0.47-0.84)	0.62 (0.44-0.79)	0.70 (0.50-0.91)
Sensory perception, AUC (95% CI)	0.74 (0.62-0.87)	0.83 (0.68-0.98)	0.69 (0.26-1.00)	0.73 (0.58-0.88)	0.84 (0.73-0.96)	0.67 (0.47-0.86)	0.70 (0.58-0.82)	0.52 (0.16-0.88)
Skin moisture,† AUC (95% CI)	0.53 (0.41-0.64)	0.50 (0.15-0.84)	0.67 (0.64-0.69)	0.54 (0.37-0.71)	0.55 (0.34-0.76)	0.57 (0.46-0.68)	0.49 (0.35-0.64)	0.66 (0.63-0.68)
Friction and shear, AUC (95% CI)	0.76 (0.66-0.86)	0.67 (0.10-1.00)	0.79 (0.63-0.95)	0.70 (0.58-0.82)	0.64 (0.45-0.82)	0.86 (0.78-0.94)	0.73 (0.60-0.87)	0.78 (0.62-0.94)
Nutrition, AUC (95% CI)	0.65 (0.55-0.76)	0.57 (0.00-1.00)	0.78 (0.47-1.00)	0.66 (0.56-0.77)	0.68 (0.51-0.85)	0.64 (0.49-0.79)	0.55 (0.38-0.72)	0.69 (0.52-0.87)
Tissue perfusion and oxygenation, AUC (95% CI)	0.63 (0.52-0.73)	0.61 (0.19-0.83)	0.74 (0.49-0.99)	0.62 (0.50-0.75)	0.71 (0.55-0.88)	0.53 (0.39-0.68)	0.57 (0.42-0.71)	0.46 (0.43-0.49)

*To be included in the final Braden QD Scale, each subscale needed to perform with an AUC >0.70 (considered to have good discrimination) in at least 1 subgroup. Therefore, both activity and skin moisture were excluded from the Braden QD Scale.
†All subjects <1 mo were assigned a Braden Q Activity score of 4; therefore, the AUC could not be calculated.

Table IV. Simplifying the number of risk levels from 4 to 3 in each Braden Q subscale in subjects with an immobility-related pressure injury

Braden Q Subscale	Original 4-level risk groups AUC (95% CI)	Lowest-risk groups combined AUC (95% CI)	Moderate-risk groups combined AUC (95% CI)	Highest-risk groups combined AUC (95% CI)
Mobility	0.74 (0.62-0.86)	0.73* (0.60-0.86)	0.72 (0.60-0.84)	0.71 (0.60-0.82)
Sensory perception	0.74 (0.62-0.87)	0.73 (0.60-0.86)	0.73 (0.60-0.86)	0.73* (0.61-0.85)
Friction and shear	0.76 (0.66-0.86)	0.64 (0.50-0.77)	0.74 (0.65-0.84)	0.76* (0.66-0.86)
Nutrition	0.65 (0.55-0.76)	0.60 (0.46-0.74)	0.63 (0.54-0.72)	0.66* (0.55-0.76)
Tissue perfusion and oxygenation	0.63 (0.52-0.73)	0.56 (0.43-0.69)	0.63* (0.52-0.73)	0.63 (0.52-0.73)

*Selected to be included in final Braden QD Scale.

Table VII. Comparing the AUC for Braden Q vs Braden QD in the overall sample and stratified by enrollment subgroups

Cohort	No. subjects/total	Braden Q AUC (95% CI)	Braden QD AUC (95% CI)
Overall—any HAPI	49/625	0.72 (0.65-0.79)	0.78 (0.73-0.84)
Any immobility-related pressure injury	14/625	0.78 (0.66-0.90)	0.86 (0.78-0.93)
Any MDPI*	42/625	—	0.78 (0.72-0.84)
Age category†			
Preterm to <1 mo	7/109	0.61 (0.36-0.85)	0.65 (0.45-0.86)
1 mo to 8 y	24/325	0.75 (0.65-0.84)	0.77 (0.69-0.86)
9-21 y	18/191	0.72 (0.61-0.83)	0.83 (0.77-0.90)
Diagnosis at admission†			
Medical/surgical diagnosis	22/346	0.81 (0.74-0.87)	0.84 (0.76-0.91)
Cardiovascular diagnosis	27/279	0.67 (0.56-0.77)	0.73 (0.65-0.81)
Endotracheal intubation at enrollment†			
Intubated	33/193	0.64 (0.55-0.73)	0.64 (0.54-0.73)
Not intubated	16/432	0.66 (0.53-0.80)	0.77 (0.67-0.87)

*The Braden Q Scale was not designed to predict MDPIs; therefore, the AUC was not computed.
†AUC for each enrollment subgroup is reported for any HAPI development.