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Medical Device–Related Pressure Injuries in Infants and Children

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ABSTRACT

PURPOSE: The purpose of this study was to describe medical device–related pressure injuries (MDRPIs) in hospitalized pediatric patients.

DESIGN: A prospective, descriptive study.

SAMPLE/SUBJECTS AND SETTING: The sample comprised 625 patients cared for in 8 US pediatric hospitals. Participants were aged preterm to 21 years, on bed rest for at least 24 hours, and had a medical device in place.

METHODS: Two nursing teams, blinded to the other's assessments, worked in tandem to assess pressure injury risk, type of medical devices in use, and preventive interventions for each medical device. They also identified the presence, location, and stage of MDRPI. Subjects were observed up to 8 times over 4 weeks, or until discharge, whichever occurred first.

RESULTS: Of 625 enrolled patients, 42 (7%) developed 1 or more MDRPIs. Two-thirds of patients with MDRPIs were younger than 8 years. Patients experiencing MDRPIs had higher acuity scores on hospital admission, were more frequently cognitively and/or functionally impaired, or were extreme in body mass index. Respiratory devices caused the most injuries (6.19/1000 device-days), followed by immobilizers (2.40/1000 device-days), gastric tubes (2.24/1000 device-days), and external monitoring devices (1.77/1000 device-days). Of the 6336 devices in place, 36% did not have an MDRPI preventive intervention in place. Clinical variables contributing to MDRPI development included intensive care unit care (odds ratio [OR] 8.9, 95% confidence interval [CI] 1.9-43.6), use of neuromuscular blockade (OR 3.7, 95% CI 1.7-7.8), and inotropic/vasopressor medications (OR 2.7, 95% CI 1.7-4.3). Multivariable analysis indicated that Braden QD scores alone predicted MDRPI development.

CONCLUSION: Medical devices are common in hospitalized infants and children and these medical devices place patients at risk for MDRPI.

KEY WORDS: Braden QD, hospital-acquired pressure injury, MDRPI, pediatrics, pressure injuries.

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INTRODUCTION

In the acute care environment, medical devices are commonly used for diagnostic and therapeutic purposes. While use of such devices is essential, evidence continues to emerge linking medical devices to medical device–related pressure injuries (MDRPIs). These iatrogenic injuries can lead to additional pain and suffering, pose an immediate risk for infection, and contribute to an altered lifelong body image related to scarring. In adults, MDRPIs have been reported to range from 29% to 60%.[1-5] In the pediatric population, MDRPI rates have been reported to be higher, ranging up to 70% in single-center studies.[6-8] MDRPIs can develop into serious full-thickness wounds or unstageable pressure injuries, especially in areas with minimal adipose tissue, for example, on the head and face.[7] Pediatric patients may be at risk for more serious device–related pressure injuries because of unique cutaneous, maturational, and developmental factors.[9,10] Pediatric patients also may be at increased risk for MDRPI due to variability in body habitus (size) and lack of access to proper sized medical devices. In addition, cognitive state immaturity prevents younger patients from understanding the vital nature of medical devices, and additional securement and immobilization devices are often necessary for patient safety.

In 2015, the Wound, Ostomy Continence Nurses Society developed an evidence-based position statement regarding

hospital-acquired pressure injuries; they defined an MDRPI as a "localized injury to the skin and/or underlying tissue including mucous membranes, as a result of pressure, with a history of an external medical device at the location of the ulcer, and mirrors the shape of the device."[11(p154)] This definition was adopted by the National Pressure Injury Advisory Panel (NPIAP), who in 2016 revised the pressure injury staging criteria, adding a category of MDRPI, which are staged using the same criteria as immobility related or mucosal pressure injuries.[12]

The purpose of this study was to describe (1) types of medical devices in use, (2) the incidence rates for MDRPI per 1000 device-days, (3) locations and stages of MDRPI, and (4) device–related prevention interventions used in pediatric acute care environments. These data serve as a foundation from which best MDRPI prevention practices can be developed and systematically evaluated.

METHODS

This is a further analysis of prospectively collected data that were used to build the Braden QD Scale for predicting pressure injury risk in pediatric patients. Data collection procedures are fully described elsewhere[13] and briefly outlined here. Patients were recruited from 8 pediatric academic medical centers across the United States. We systematically enrolled pediatric patients, preterm to 21 years, who were on crib/bed rest for at least 24 hours, with at least 1 medical device attached to or traversing through skin or a mucous membrane. We excluded patients with preexisting pressure injury or those with a do-not-resuscitate order. Study nurses, including wound, ostomy nurse leads, were trained in study procedures, staging of pressure injuries, and scoring of pressure injury risk. Data were collected between March 25, 2013, and July 15, 2015. Written informed consent was obtained from the parent/legal guardian and assent from children older than 8 years, not sedated and cognitively capable.

Upon enrollment, a severity of illness score was completed on each subject. We used the SNAPPE-II (Score for Neonatal Acute Physiology with Perinatal Extension II) for subjects younger than 2 weeks or less with noncardiac diagnoses[14]; the PRISM III-12 (Pediatric Risk of Mortality Score, Version III, first 12-hour model) for subjects older than 2 weeks[15]; and the RACHS-I (Risk Adjustment for Congenital Heart Surgery—Version 1) for all cardiac subjects.[16] We also described each subject's cognitive and functional status on hospital admission using the PCPC (Pediatric Cerebral Performance Category) and POPC (Pediatric Overall Performance Category).[17] In addition, admission body mass index (BMI) *z*-scores were computed on each subject to quantify each subject's nutritional status.

Enrolled subjects were evaluated by 2 nursing teams up to 3 times per week for 2 full weeks, and then weekly for 2 more weeks. These teams were blinded to the other team's assessments. The study end points were hospital discharge or hospital day 28, whichever occurred first. Study procedures were completed outside of usual care. Team I nurses extracted data from the medical record and observed the patient for all medical devices including any securing or protective interventions, and determined whether each particular device was repositionable. Team I nurses also completed the Braden Q score[18]—a 7-item pediatric-specific instrument describing patient risk for immobility-related pressure injuries.

Within 6 hours of the evaluation by nurses in Team I, nurses in Team II completed a head-to-toe skin assessment with the assistance of the subject's bedside nurse. Any hospital-acquired pressure injury (HAPI), identified by Team II nurses, was documented with photographs, and then staged and categorized as immobility-related HAPI or medical device–related HAPI. Pressure injury staging was done per NPIAP guidelines.[19] The local WOC nurse lead investigator determined pressure injury staging, and stages were confirmed by review of the study core team nurses. Data were collected using Research Electronic Data Capture (REDCap).[20] All identified HAPIs were managed at the discretion of the clinical team.

Data Analysis

Descriptive statistics were calculated for patient admission characteristics and relevant clinical summary variables, along with medical devices and associated prevention strategies. Continuous variables were reported as medians and interquartile ranges and categorical variables were described using frequency and percentages. For each medical device, device-days were calculated using the date the medical device was initiated to the date it was discontinued or study discharge (whichever came first). For devices that resulted in an MDRPI, device injury rate was calculated and standardized per 1000 device-days.

Unadjusted logistic regression was calculated to determine which patient characteristics were associated with MDRPI-positive status. All models accounted for site as a cluster variable using generalized estimating equations. All variables with $P < .10$ on univariate analysis were assessed for inclusion into a final multivariate model using a stepwise selection process. Covariates with a $P < .05$ after adjustment for all other variables were maintained. All analyses were performed using SAS version 9.4.[21]

RESULTS

Of the 625 enrolled subjects in the study, 42 (7%) developed an MDRPI. Table 1 compares the baseline characteristics of MDRPI-positive and -negative patients. The demographics of age, gender, and ethnicity were similar when patients with MDRPI were compared to those without pressure injuries. Two-thirds of patients with MDRPI were younger than 8 years, and 14% being younger than 1 month. Patients with MDRPI with higher acuity scores, specifically higher PRISM III-12 and RACHS-I scores, were more frequently, cognitively, and/or functionally impaired. Patients enrolled from the pediatric intensive care unit and/or who were intubated had a higher percentage of MDRPI. Lastly, MDRPI-positive patients were more frequent in patients with extreme BMI scores who were either underweight or overweight.

Table 2 outlines the MDRPI characteristics. Of the 42 patients with MDRPI, 12 patients had 2 or more MDRPIs for a total of 63 MDRPIs. Most (74%) MDRPIs were Stage 1 or 2, 11% were deep tissue injury, 8% were mucosal, and 6% were unstageable. No Stage 3 or 4 MDRPIs were identified. The 4 unstageable MDRPIs occurred secondary to external monitoring devices, specifically electroencephalogram leads. The head/face location and extremities predominated the locations of MDRPI, with 51% occurring in the head/face area and 35% occurring in extremities, which corresponds to the device types most frequently causing MDRPI, namely respiratory device, immobilizers, and external monitoring devices. Nearly two-thirds (63%) of MDRPIs were identified by the third observation day or within 1 week of admission; 30% identified on observation days 4 to 6 (week 2 of admission),

TABLE 1.
Patient Characteristics According to Medical Device–Related Pressure Injury Status

Characteristics	MDRPI+ (n = 42)	MDRPI− (n = 583)	Odds Ratio (95% CI)[a]	*P* Value[b]
Age at enrollment, n (%)				.18
Preterm to <1 mo	6 (14)	106 (18)	1.5 (0.6-3.5)	
1 mo to <1 y	4 (10)	105 (18)	1.0	
1-8 y	18 (43)	303 (52)	2.4 (1.0-5.7)	
9-21 y	14 (33)	177 (30)	2.1 (1.1-3.9)	
Male, n (%)	24 (57)	310 (53)	1.2 (0.7-1.9)	.51
Non-Hispanic White, n (%)	32 (76)	386 (67)	1.6 (0.8-3.6)	.21
Severity of illness				
SNAPPE-II score, median (IQR)	N/A	5 (0-18)	N/A	N/A
PRISM III-12[c] score, median (IQR)	5 (3-16)	2 (0-6)	1.8 (1.3-2.5)	<.001
RACHS-I score, n (%)				<.001
1-2	2 (11)	104 (54)	1.0	
≥3	16 (89)	88 (46)	9.5 (3.4-30.0)	
Unassignable operative lesion	1	11	N/A	
Nonoperative cardiovascular disease	2	53	N/A	
Functional health on admission				
Admission PCPC >1, n (%)	19 (45)	131 (22)	2.9 (1.7-4.6)	<.002
Admission POPC >1, n (%)	19 (45)	145 (25)	2.5 (1.5-4.2)	<.001
Patient characteristics on admission				
Primary reason for hospitalization, n (%)				
Medical-surgical	21 (50)	325 (56)	1.0	
Cardiac	21 (50)	258 (44)	1.3 (0.7-2.4)	.47
Enrolled from ICU, n (%)	38 (90)	365 (63)	5.7 (1.0-32.0)	.049
Intubated at enrollment, n (%)	29 (69)	164 (28)	5.7 (3.8-8.7)	<.001
Able to verbally communicate pain, n (%)	23 (55)	357 (61)	0.8 (0.4-1.4)	.37
Admission skin assessment, n (%)	42 (100)	577 (99)	N/A	N/A
BMI *z*-score, n/n total (%)				.004
Underweight ($z < -2$)	7/37 (19)	66/482 (11)	1.8 (1.2-2.9)	
Normal ($-2 \leq z \leq 2$)	18/37 (49)	310/482 (64)	1.0	
Overweight ($z > 2$)	12/37 (32)	106/482 (22)	2.0 (1.1-3.4)	

Abbreviations: BMI, body mass index; CI: confidence interval; ICU, intensive care unit; IQR, interquartile range; MDRPI, medical device–related pressure injury; N/A, not available; PCPC, Pediatric Cerebral Performance Category; POPC, Pediatric Overall Performance Category; PRISM III-12, Pediatric Risk of Mortality Score III-12; RACHS-I, Risk Adjustment for Congenital Heart Surgery-I; SNAPPE-II, Score for Neonatal Acute Physiology with Perinatal Extension-II.

[a]An odds ratio more than 1.0 indicates a higher risk of MDRPI. For the continuous PRISM III-12 score, the odds ratio represents the effect of an increase per quartile of the characteristic.

[b]*P* values calculated using univariable logistic regression to predict MDRPI using generalized estimating equations accounting for site as a cluster variable.

[c]A total of 277 patients had a PRISM III-12 score (MDRPI+: 21, MDRPI−: 256).

and 6.3% identified on observation day 7 or 8 (weeks 3 and 4 of admission).

Table 2 also outlines MDRPI per 1000 device-days per device type. The highest rate occurred in the respiratory device category where there were 17 injuries and a rate 6.19 per 1000 device-days. Thirteen of the 17 injuries (46%) had a preventive intervention in place. The next highest rate of HAPI per 1000 days occurred with use of immobilizers, followed by gastrointestinal (GI) tubes and drains, and external monitoring devices. Although vascular devices were the most frequently occurring device in 87% of patients, the rate of HAPI caused by these devices was low at 0.64 per 1000 days.

Table 3 describes the total number of medical devices in place on day 1 of observation, with the number of pressure injury interventions in place for each device type. In the total population (n = 625), there were 6336 devices in place. In more than one-third of cases (36%), a preventive intervention was not in place. The highest category of devices included vascular, followed by external monitoring devices, supportive/securing devices, then respiratory devices. Most vascular devices had a HAPI prevention intervention in place. External monitoring devices, the second most common device, had a higher rate of MDRPI and a higher percentage of patients without a HAPI prevention in place (67%). Figure 1 illustrates the proportion of devices in each category that had prevention in place across all observation days.

Figure 2 depicts the total number of devices in place, including range and median, over the 8 observational periods by total population and by subgroup. Out of the 625 patients enrolled, 64 patients remained enrolled through observation 8. Participants had a median of 7 devices in place on day 1 (range of 4-10). By the eighth observational period (week 4), there was a median of 5 devices in place (range of 4-8). These

TABLE 2.
Characteristics of Observed Medical Device–Related Pressure Injury

Device Category	Events Per Device-Days[a]	Rate per 1000 Device-Days	Location of Injury	Stage of Injury	Injuries With Prevention in Place	Prevention Type
External monitoring devices	25/14093	1.77	Hand (7) Head (7) Ankle/foot (6) Face (5)	Stage I (13) Stage II (6) Unstageable (4)[b] Deep tissue injury (2)	15/25 (60)	Redistribution (11) Securement (4) None (10)
Vascular devices	6/9345	0.64	Ankle/foot (4) Lower leg (1) Shoulder/arm (1)	Deep tissue injury (3) Stage II (2) Stage I (1)	6/6 (100)	Securement (6)
Gastrointestinal tubes and drains	7/3125	2.24	Abdomen (5) Face (2)	Stage II (4) Stage I (2) Mucosal membrane (1)	6/7 (86)	Securement (6) None (1)
Respiratory devices	17/2746	6.19	Face (16) Neck (1)	Stage II (7) Stage I (6) Mucosal membrane (4)	13/17 (46)	Securement (9) Padding (3) Barrier (1) None (4)
Compression devices	1/2597	0.39	Upper arm (1)	Stage I (1)	0/1 (0)	None (1)
Supportive/securing devices	2/2286	0.87	Ankle/foot (1) Shoulder/arm (1)	Stage I (1) Deep tissue injury (1)	2/2 (100)	Anchor tube (2) Padding (1)
Transdermal tubes/ drains/monitors	2/1996	1.00	Left flank (1) Right back (1)	Stage I (1) Stage II (1)	2/2 (100)	Anchor tube (2) Absorptive dressing (1)
Genitourinary tubes/ drains	1/1132	0.88	Urethral meatus (1)	Stage II (1)	0/1 (0)	Anchor tube (1)
Immobilizers	2/833	2.40	Face (1) Head (1)	Stage I (1) Deep tissue Injury (1)	0/2 (0)	None (2)

[a]Device-days were calculated for the entire study population (n = 625) for all devices (n = 6336) using the date the medical device was started to the device discontinuation date or study discharge (whichever came first). No medical device–related pressure injuries resulted from the soft cover device category. Additional details regarding the types of devices included in each device category are included in Table 5.
[b]Unstageable pressure injury was caused by electroencephalogram leads.

statistics were higher in the intensive care unit (ICU) and cardiac populations; this group had a median of 8 devices on study day 1 (range of 5-13), and a median of 6 devices (range 4-11) on day 8.

We also examined clinical variables contributing to MDRPI development (Table 4). Patients with more medical devices were at greater risk for MDRPI. Intensive care demonstrated the highest likelihood of MDRPI (odds ratio [OR] 8.9, 95% confidence interval [CI] 1.9-43.6), followed by neuromuscular blockade (OR 3.7, 95% CI 1.7-7.8), and use of inotropic/vasopressors (OR 2.7, 95% CI 1.7-4.3). The worst Braden QD score in these groups was 17 with a range of 15 to 19 in MDRPI-positive patients and 12, with a range of 8 to 15 in MDRPI-negative patients. Multivariate analysis of key clinical indicators revealed that worst Braden QD scores alone predicted MDRPI development (OR 1.45, 95% CI 1.27-1.57); specifically, for each Braden QD point increase, a patient's odds of developing an MDRPI was 45% higher.

DISCUSSION

In this large prospective study, we report that the use of medical devices in hospitalized infants and children is common and that 7% of patients developed 1 or more MDRPIs. As the number of medical devices increased so did the risk for MDRPI. Patients with MDRPI had higher acuity scores on hospital admission, were more frequently cognitively and/or functionally impaired, or had extremes in BMI. Respiratory devices have the highest MDRPI rate per 1000 device-days, followed by immobilizers, external monitoring devices, and GI devices. The pattern of MDRPI in terms of location corresponds to the device type, where respiratory device–related pressure injuries occur in the head, face, neck region, whereas vascular, external monitoring, and immobilizing devices occur in the extremities. Preventive practices, including anchoring/securement, pressure redistribution, and skin protection were used in about two-thirds of the devices. We found the Braden QD a good predictor of MDRPI risk in the pediatric population where the odds of MDRPI development increases incrementally for every 1-point increase in the Braden QD score.

Early pediatric research revealed infants and children were vulnerable to pressure injury related to medical devices.[22-24] These studies found that more than half of pressure injuries occurred with use of a variety of medical devices including casts, splints, endotracheal tubes, nasogastric tubes, and oxygen saturation probes. The NPIAP, European Pressure Ulcer Advisory Panel, and Pan Pacific Pressure Injury Alliance[25] recommended using a structured pressure injury risk assessment scale and to consider other clinical risk factors including medical devices. The new Braden QD Scale, revised from the Braden Q Scale, now predicts both immobility and MDRPI for pediatric patients.[13]

The types and numbers of medical devices frequently used in pediatric hospitals vary by patient population creating variability in device-related risk. In a secondary analysis of 2012 point prevalence data from the National

TABLE 3.
Device Prevention on First Day the Device Was Observed by Device Category

Device Category	Devices, n	Prevention Type					Multiple Prevention Techniques	No Prevention in Place
		Securement	Pressure Redistribution	Skin Protection				
				Padding	Barrier	Absorptive Dressings		
Vascular devices	1684	87%	<1%	11%	3%	8%	13%	6%
External monitoring devices	1663	11%	22%	<1%	1%	1%	1%	67%
Supportive/securing devices	523	70%	<1%	31%	1%	8%	35%	26%
Respiratory devices	491	60%	7%	5%	10%	2%	13%	28%
Transdermal tubes/drains/monitors	380	83%	2%	1%	1%	12%	13%	67%
Gastrointestinal tubes/drains	379	73%	<1%	4%	9%	4%	10%	13%
Compression devices	378	0	43%	0	0	0	0	19%
Genitourinary tubes/drains	223	86%	<1%	3%	<1%	2%	5%	97%
Immobilizers	182	2%	12%	15%	1%	0	2%	16%
Soft covers	10	10%	0	10%	0	0	0	80%
Other devices[a]	423	17%	25%	2%	31%	<1%	5%	31%
Total number of devices	6336	50%	11%	7%	3%	4%	10%	36%

[a]Other devices category includes any collection device sutured/attached to skin, any medical equipment lying on the skin, or any tubing sutured/attached to the skin. For details on which devices are included in each category, please refer to Table 5.

Database for Nursing Quality Indicators among acute care pediatric patients from across the United States, Razmus and Berquist-Beringer[26] reported the likely proportion of HAPI related to medical devices was 5.3%. Among 33 hospitals that participated in the Children's Hospital Solutions for Patient Safety Network from 2011 to 2013,

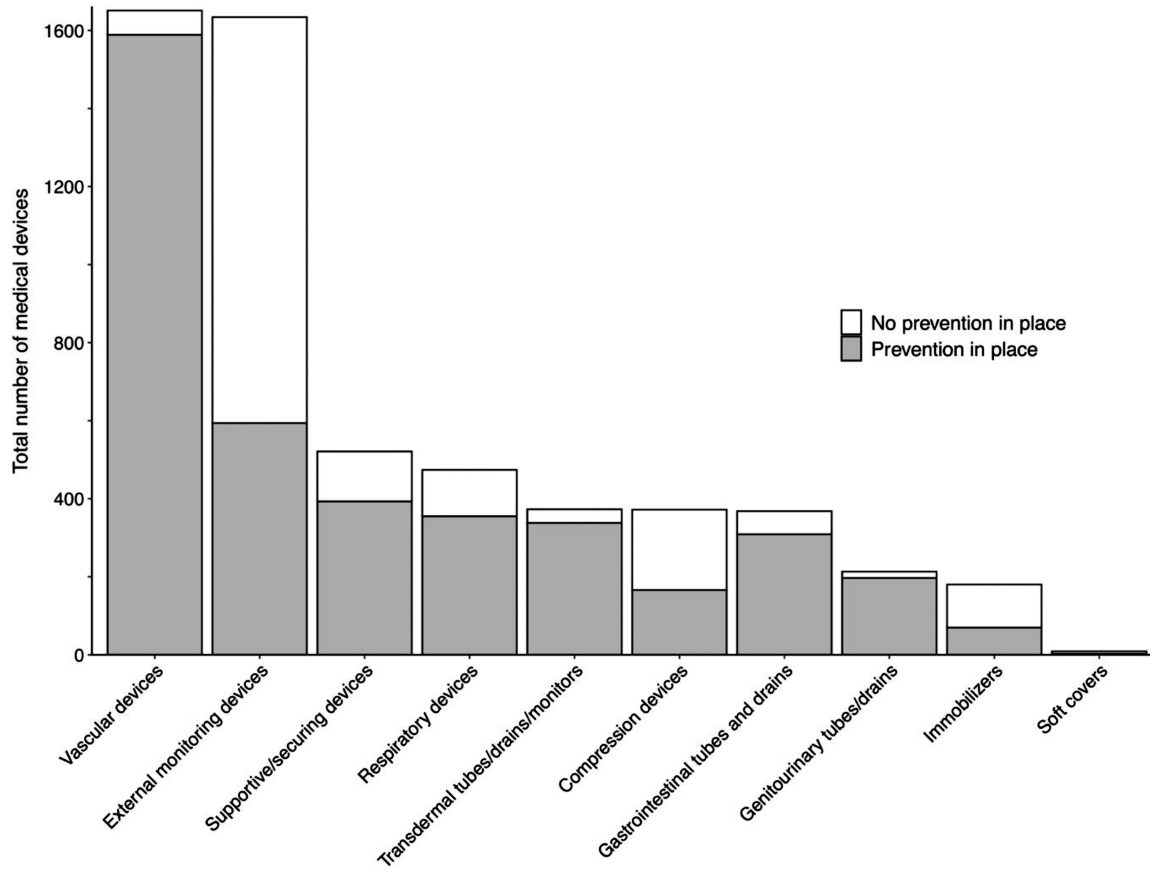

Figure 1. Number of medical devices by category with (gray) and without (white) MDRPI preventive interventions in place for all observation days. MDRPI indicates medical device–related pressure injury.

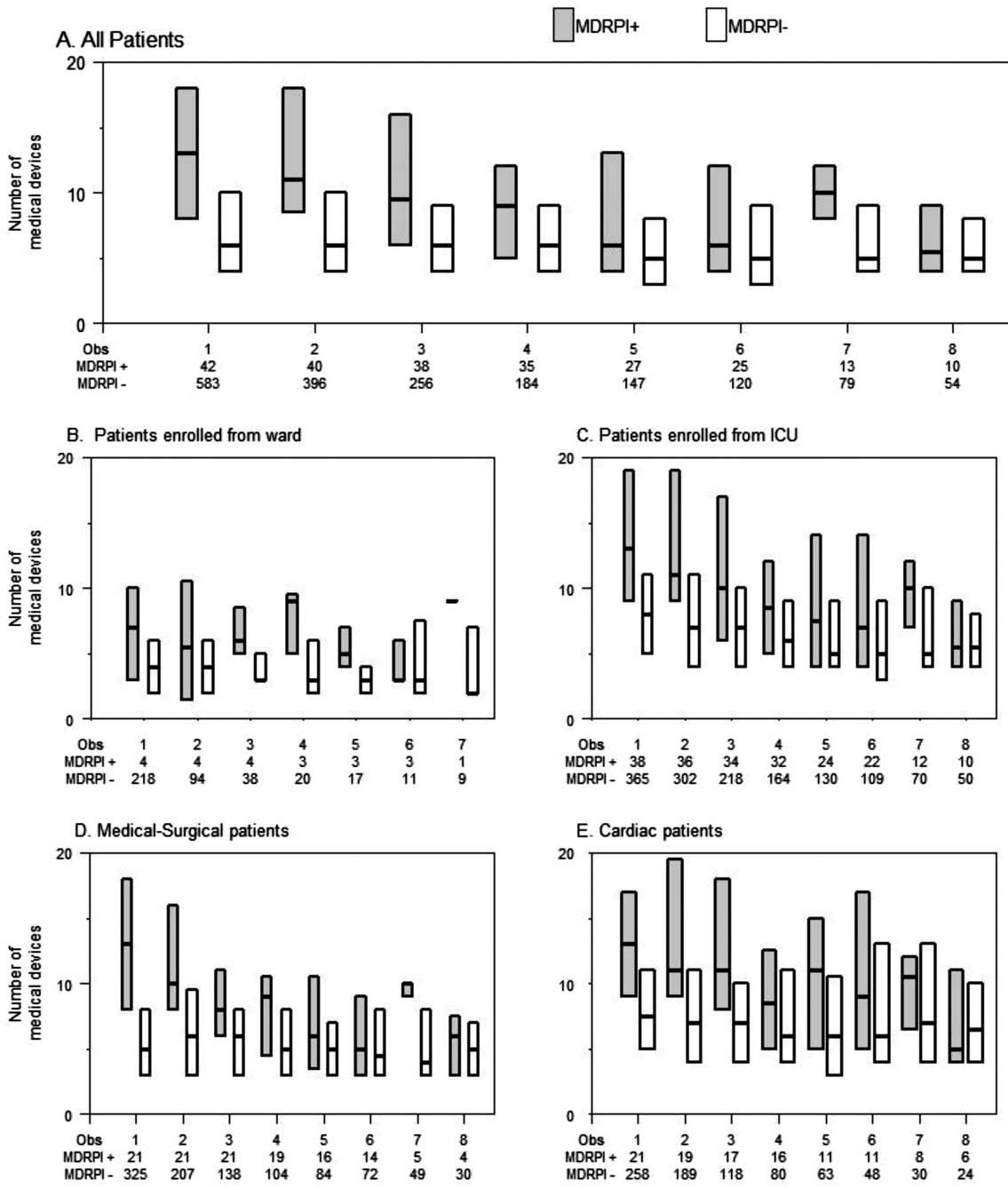

Figure 2. The range and median number of medical devices in place per patient with MDRPI (gray) and without MDRPI (white) over the 8 observational periods. (A) All enrolled patients. (B) Patients enrolled from the ward (any nonintensive care unit). (C) Patients enrolled from an intensive care unit (cardiovascular or pediatric). (D) All medical-surgical (noncardiac) patients. (E) All cardiac patients. Note that in group B (non-ICU group), there were no medical devices in place at observation 8. MDRPI indicates medical device–related pressure injury.

the overall national network rate of Stage 3 pressure injuries was decreased from 0.06 to 0.03 per 1000 patient days ($P < .001$); however, the proportion caused by medical devices was not identified. In ICUs, patients often need multiple medical devices for external monitoring, therapeutic care, or lifesaving advanced technology that exposes these vulnerable patients to an increased risk of MDRPI.[27] Studies in neonatal intensive care units report that the proportion of MDRPI ranged from 42.5% to 90%[28-30] primarily caused by respiratory devices. In pediatric intensive care units, the reported proportion of MDRPI ranged from 50% to 69%.[31,32]

LIMITATIONS

In this prospectively planned analysis of the Braden QD dataset, we found an overall low number of MDRPI. Because of this low number, we were unable to determine, with confidence, the effectiveness of specific preventative interventions in device-related pressure injuries.

IMPLICATIONS

Medical devices account for a significant number of HAPIs in the pediatric population. Razmus,[33] in reviewing pediatric pressure injury prevalence data over a 6-year period, found

TABLE 4.
Clinical Summary by Medical Device–Related Pressure Injury Status

Clinical Summary Variables	MDRPI+	MDRPI−	Odds Ratio (95% CI)[a]	*P* Value[b]
Physiologic variables				
Lowest O_2 saturation <85%, n (%)	10 (24)	69 (12)	2.3 (1.8-3.0)	<.001
Mean blood pressure ≤50 mm Hg, n (%)	11 (26)	132 (23)	1.2 (0.6-2.3)	.57
Clinical interventions				
Average number devices attached per observation, median (IQR)	11 (8-13)	6 (4-8)	2.6 (1.8-4.0)	<.001
Percent of protected devices per observations, median (IQR)	38 (27-52)	13 (6-28)	1.1 (1.0-1.1)	<.001
ICU care, n (%)[b]	40 (95)	402 (69)	8.9 (1.9-43.6)	.006
ICU LOS, median (IQR)	9 (5-22)	4 (2-10)	1.7 (1.3-2.3)	<.001
Days on mechanical ventilation, median (IQR)[c]	5 (2-8)	3 (1-8)	1.4 (1.0-1.8)	.02
Any HFOV, n (%)	1 (2)	11 (2)	1.3 (0.3-6.1)	.77
Any ECMO, n (%)	1 (2)	5 (<1)	2.8 (0.4-18.7)	28
Any neuromuscular blockade, n (%)	22 (52)	188 (23)	3.7 (1.7-7.8)	<.001
Any inotropic/vasopressors, n (%)	21 (50)	159 (27)	2.7 (1.7-4.3)	<.001
Braden QD scores				
First Braden QD Scale score, median (IQR)	16 (14-17)	12 (7-15)	2.9 (1.9-4.4)	<.001
Average Braden QD Scale score per day, median (IQR)[d]	13 (12-16)	12 (8-15)	2.6 (2.0-3.4)	<.001
Worst Braden QD Scale score, median (IQR)	17 (15-19)	12 (8-15)	3.4 (2.4-4.6)	<.001
Percent of observations with Braden QD ≥13, median (IQR)	67 (43-88)	0 (0-50)	2.6 (2.0-3.5)	<.001

Abbreviations: CI, confidence interval; ECMO, extracorporeal membrane oxygenation; HFOV, high-frequency oscillating ventilator; ICU, intensive care unit; IQR, interquartile range; LOS, length of stay; MDRPI, medical device–related pressure injury.
[a]An odds ratio more than 1.0 indicates a higher risk of MDRPI. For continuous clinical summary variables, the odds ratio represents the effect of an increase per quartile of the variable.
[b]*P* values calculated using univariable logistic regression to predict MDRPI using generalized estimating equations accounting for site as a cluster variable.
[c]Lowest O_2 saturation is miss ing for 3 MDRPI− patients.
[d]ICU information missing for 2 MDRPI− patients.
[e]Restricted to patients who received mechanical ventilation (MDRPI+: 29, MDRPI−: 164).

increased HAPI prevalence rates in pediatric ICU and rehabilitation units, however found no association in decreased HAPI rates when skin and risk assessment, repositioning, support surface, and moisture management were in place. A tool such as the Braden QD Scale assists in identification of patients at risk for both medical device *and* immobility-related HAPI in the pediatric population; the Braden Q Scale is now considered obsolete, and we assert that pediatric facilities should transition to the Braden QD Scale. Training resources have been developed for teaching nurses on how to use the Braden QD Scale for their patient population[34] (https://media.chop.edu/data/files/educational-modules/braden-qd/story_html5.html).

To accurately track, trend, and benchmark MDRPI, it is important to use consistent language when categorizing medical devices and MDRPI prevention strategies. Categorization will simplify data collection and interpretation. This is especially true given the wide variety of protective dressings, securement devices, and barriers used to manage the skin microclimate. Table 5 outlines a classification method for a wide variety of medical devices used in the hospitalized patient along with guidance on how to score each device when using the Braden QD.

We also recommend use of consistent metrics in reporting. In review of published data, MDRPI rates are reported differently; some as incidence density (per 1000 patient days),[6,26,35] some as prevalence (number of affected patients/total population),[7,27,35-37] and some as a rate per number of device-days.[8] Maximizing use of the electronic medical/health record to help identify the number of device-days can assist in MDRPI data tracking, leading to more effective evaluations of prevention strategies and improvements in care. We suggest using MDRPI rates per 1000 device-days for each device type. This metric is similar to other harm indicators such as central line–associated bloodstream infection rates.

Some note the importance of a single intervention such as securement or particular dressings in prevention of certain MDRPI.[38-40] Boyar[41] reported use of a single intervention (dressing) for MDRPI related to use of nasal cannula and found this one intervention significantly decreased the incidence of nasal columella injuries in preterm infants. Although single interventions may be very beneficial in preventing pressure injuries from specific devices, many recommend use of multiple targeted interventions and bundles is helpful in decreasing MDRPI in the pediatric population; often a "bundle" of interventions as opposed to 1 type of intervention is linked to positive outcomes.[8,26,29,30,35,42-45] Essential components of an effective MDRPI prevention bundle include frequent assessment and monitoring of the skin or mucous membrane beneath the device and assessing the proper fit and securement of the device. This is especially important for patients who exhibit significant fluid shifts or changes in body shape due to their underlying disease and treatment. A multidisciplinary approach to assessment and management is key where nurses partner with respiratory therapists, physical and occupational therapists, critical care, pulmonary, and subspecialty physicians to assess the fit, securement, and need for the device at designated intervals. Pressure redistribution is also important in MDRPI prevention such as interval lifting of the device or rotation of the location of the device whenever possible. Managing the skin microclimate is a prevention strategy that includes use of skin barriers, absorbent foams and dressings, and padding. Table 6 outlines an MDRPI prevention bundle that can be modified to comply with local policy and procedures.

CONCLUSIONS

Clinicians must continue to partner with members of the medical device industry—giving feedback on the design and making recommendations for device refinement to prevent

TABLE 5.
Braden QD Device Resource List

Reminder: Wrist bands (ID, Allergy, Falls) are *not* counted as devices. Tubing laying across skin but not sutured or attached are *not* counted. Remember—reposition means *routinely* repositioned. This is *a guide* each patient should be assessed individually.

Device Examples		*Guidelines* for Repositionability/Skin Protection Score
Vascular Devices		
• Arterial line • Central venous line • CRRT/hemodialysis catheters • ECMO cannulas (count as 1) • Implanted port if accessed • Intracardiac line	• Peripheral IV • Pheresis line • PICC/midline • Transvenous pacing catheter • Umbilical arterial line • Umbilical venous line • VAD	• Most vascular lines such as tunneled catheters (Broviac) and percutaneous lines are not repositionable and have no skin protection under dressing (score 2) • Exception is PIV, which is often padded under the hub (score 1), if not padded (score 2) • Remember to also count an IV board and a NoNo as separate devices for PIVs • VAD—count as 1 device and score 2 • PICC line with Statlock count as 2 devices, but if it has a Securacath, count as 1 device
GI Tubes and Drains		
• Fecal/rectal collection bag • Gastrojejunal tube • Gastrostomy tube • GI ostomy bag/pouch • Jejunostomy tube • Nasogastric sump tube (large bore)	• Nasointestinal feeding tubes (small bore) • Oroesophageal tube (monitoring) • Orogastric tube (OG or OJ) • Rectal tube • Replogle tube	• Large-bore NG tubes (sump, replogle) are usually not repositionable and not padded (score 2) • Same small-bore feeding tubes can be repositioned at the nare and also can be removed and replaced if needed (score 1) • Transanastomotic tubes (eg, for esophageal atresia) are not repositionable or padded (score 2) • NJ tubes with bridle—count as 2 devices, cannot routinely reposition and not padded • OG-OJ—can usually retape and reposition one side to the other; also is secured with Duoderm/Tegaderm—consider this skin protection • Ostomy appliance—whether 1 or 2 pieces—count as 1 device; if there is a belt count as a separate device. These can be repositioned (score 1)
GU Tubes and Drains		
• Indwelling urinary catheter • Nephrostomy • Peritoneal drain/dialysis catheter	• Suprapubic catheter • Ureteral stent (externalized) • Urinary diversion (GU ostomy bag/pouch)	• Foley catheter—score 2—cannot reposition at meatus and cannot pad • If drainage tubing attached/secured to skin (with a Statlock or Grip-Lock), count as another device • Other GU tubes, if can reposition the tubing or if has padding—score 1
Tubes/Drains/Monitors		
• Chest tube • Epidural catheter • Externalized ventriculostomy • Indwelling subcutaneous catheter (eg, Insuflon) • Intracranial bolt/catheter • Lumbar drain	• Negative-pressure wound therapy dressing • Pericardial/mediastinal drain • Peripheral nerve catheter • Pleural pigtail catheter • Rectal probe for temperature • Subdural drain • Wound catheter/drain	• Chest tubes, epidural catheters are not repositioned *routinely* and usually not padded—score 2; however if padded, then score 1 • VAC dressing—only count the track pad tubing—score 1 if padded, score 2 if not padded • Rectal probe usually can be repositioned if needed • Other drains—if cannot reposition the tubing and not padded, then score 2
Compression Devices		
• BP cuff/tubing • Pneumo boots/SCDs (count pair as 1) • TED hose (count pair as 1)		• These are all repositionable • Count SCDs as 1 device if on as a pair; if only on 1 extremity count as 1 device

(*continues*)

TABLE 5.
Braden QD Device Resource List (*Continued*)

Device Examples		*Guidelines* for Repositionability/Skin Protection Score
Respiratory Devices		
• Airway/bite block • Nasal endotracheal tube (NTT) • Nasal pharyngeal airway (trumpet) • Noninvasive pressure (BiPAP/CPAP) ventilation device	• Oral endotracheal tube (OTT) • Oxygen delivery device (prongs, masks) • Tracheostomy tube	• Nasal and oral ETT cannot usually be *routinely* repositioned—score 2; exception may be an older child with Anchorfast (count as another device) and can reposition the tube within the Anchorfast • NIPPV interface: if can rotate, and if padded score 1; if a neonate and cannot rotate interface or does not tolerate, score 2 • Oxygen prongs, masks—score 1 • Trach—score 1 if flange padded, score 2 if not
External Monitoring Devices		
• BIS electrode • ECG electrode (count set as 1) • EEG leads (count set as 1) • Epicardial pacing wires (count set as 1) • NIRS electrode	• O_2 saturation probe (Spo_2) • Skin temperature probe • Temporary pacemaker • Transcutaneous CO_2 monitor • Transcutaneous pacing/defib pads	• EEG leads always score 2 • EEG, ECG, and pacing wires—count as 1 device • ECG, Pox probe, skin temp probe, NIRS can be routinely repositioned • Others in this category—If not *routinely* repositioned and not padded, then score 2
Supportive/Securing Devices		
• Abdominal binder • Belts (EEG, ostomy, etc) • V board • V protective device (cover) • NTT holder • NIPPV headgear/securement	• Oral endotracheal tube (OTT) holders/Logan bow • Tracheostomy ties • Tube securing device) • Umbilical arterial line/umbilical cord clamp	• Most of these supportive/securement devices can be routinely repositioned • Or they can be padded—eg, trach ties • Exception ETT holders—not *routinely* repositioned—score 2 • Oxygen dots, Tender Grips are securement devices designed to secure the cannula without causing pressure so would score 1 for protection/padding if these are in place
Immobilizers		
• Brace (count individually) • Cast • Cast (bivalved) • Cervical collar • Continuous passive motion machine • External fixator/distractor • Orthotics	• Restraint (count each separate) • Spica cast • Splint (count individually) • Traction attached to skin • Welcome sleeve/NoNo	• Casts are not repositionable and only edge is padded but would not consider that skin protection as pressure points are not only at the edges but also under the cast over the bony prominence (eg, heels)—score 2 • Ex-fix, distractors, halo—score 2 • Multi Podus boots and splints—count each individually • Count helmet for cranial reshaping
Soft Covers/Other		
• Eye patches/Bili shades/ foamy ear muffs • Other—any collection device sutured/attached to skin	• Other—any medical equipment lying on the skin • Other—any tubing sutured/attached to the skin	• *Equipment* lying on the skin we count—this is miscellaneous in case we have not covered a device • Do not count cooling/warming blankets or Bili blankets • However, *tubing* laying across the skin we do not count unless it is attached with Statlock, Grip-Lock, or tape. So do not count vent tubing, vascular tubing, inline suction

Abbreviations: BiPAP, bilevel positive airway pressure; BP, blood pressure; BIS, bispectral index; CPAP, continuous positive airway pressure; CRRT, continuous renal replacement therapy; ECG, electrocardiogram; ECMO, extracorporeal membrane oxygenation; EEG, electroencephalogram; ETT, endotracheal tube; GI, gastrointestinal; GU, genitourinary; IV, intravenous; NIPPV, non-invasive positive pressure ventilation; NIRS, near-infrared spectroscopy; NJ, nasojejunal; NTT, nasal tracheal tube; OJ, orojejunal; PICC, peripherally inserted central catheter; PIV, peripheral intravenous; SCD, sequential compression device; TED, thrombo-embolus deterrent; VAC, vacuum assisted closure; VAD, ventricular assist device.

TABLE 6.
Proposed Standardized Medical Device Pressure Injury Prevention Intervention ("AAPPS" Bundle)[a]

Assessment Includes frequent assessment of skin beneath the device as well as proper fit of the device	• Skin, mucous membrane assessment beneath and around device • Device inspection for proper fit • Frequent assessments during periods of fluid shifts, weight gain/loss, distention • Device inspection for soilage and trapping of body fluids
Anchoring/securement Includes proper securement of the device and use of specifically designed devices for safe securement	• When possible, utilize securing devices or taping techniques designed for safe securement/anchoring of the device without undue amount of pressure • For adjustable securement straps—ensure these are not overly tight • Consider rotating site of anchoring/securing (eg, alternate thigh for Foley drainage tubing securement) • For devices that are temporarily sutured in place—discuss with the team standardized suture removal time frame (eg, new tracheostomy tube) • Adjusting securement during periods of fluid shifts
Pressure redistribution Includes lifting, removal, and/or rotation of devices	• Periodic lifting of device, preferably every 4 h • For devices that can be—rotate to different location • Daily or every 12-h multidisciplinary discussion of patient need for the device • Proper (neutral) positioning of patient
Partnering Collaborate with pertinent disciplines for MDRPI prevention	• Partnering with other disciplines for joint assessment and care (eg, respiratory therapy, trauma, orthopedics, ECMO, vascular team, PT, and OT) • Periodic rounding for compliance • Multidisciplinary review of all reportable MDRPIs to address practice, product, or systems concerns
Skin protection Includes management of microclimate of skin beneath the device and protection from friction and shear	• Padding • Skin barrier • Moisture control

Abbreviations: ECMO, extracorporeal membrane oxygenation; MDRPI, medical device–related pressure injury; OT, occupational therapy; PT, physical therapy.
[a]Key components of medical device–related pressure injury prevention bundle outlined in left column; right column can be individualized per institution or per device type or product.

MDRPI in the clinical setting for a broad range of patient populations. Using technology to customize device fit, such as 3D printing models, can help adapt medical devices to patients with anatomical differences. This is particularly relevant in the pediatric population where care is provided to 2300-g infants to 180-kg adolescents, each with unique anatomy, where clearly not every size fits all.

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