A Quality-Improvement Collaborative Project to Reduce Pressure Ulcers in PICUs

abstract

BACKGROUND AND OBJECTIVE: Pediatric patients are at risk for developing pressure ulcers (PUs) and associated pain, infection risk, and prolonged hospitalization. Stage III and IV ulcers are serious, reportable events. The objective of this study was to develop and implement a quality-improvement (QI) intervention to reduce PUs by 50% in our ICUs.

METHODS: We established a QI collaborative leadership team, measured PU rates during an initial period of rapid-cycle tests of change, developed a QI bundle, and evaluated the PU rates after the QI implementation. The prospective study encompassed 1425 patients over 54 351 patient-days in the PICU and NICU.

RESULTS: The PU rate in the PICU was 14.3/1000 patient-days during the QI development and 3.7/1000 patient-days after QI implementation ($P < .05$), achieving the aim of 50% reduction. The PICU rates of stages I, II, and III conventional and device-related PUs decreased after the QI intervention. The PU rate in the NICU did not change significantly over time but remained at a mean of 0.9/1000 patient-days. In the postimplementation period, 3 points were outside the control limits, primarily due to an increase in PUs associated with pulse oximeters and cannulas.

CONCLUSIONS: The collaborative QI model was effective at reducing PUs in the PICU. Pediatric patients, particularly neonates, are at risk for device-related ulcers. Heightened awareness, early detection, and identification of strategies to mitigate device-related injury are necessary to further reduce PU rates. *Pediatrics* 2013;131:e1950–e1960

AUTHORS: Marty Visscher, PhD,^{a,f} Alice King, MD,^{b,f} Ann Marie Nie, MSN,^{b,f} Pat Schaffer, MSN,^c Teresa Taylor, BSN,^c David Pruitt, MD,^{d,g} Mary Jo Giaccone, MSN,^c Marshall Ashby, MHSM,^e and Sundeep Keswani, MD^{b,f}

^a*Skin Sciences Program, Plastic Surgery, b*Pediatric Advanced Wound Care and Skin Service, ^cPatient Services, ^dPhysical Medicine and Rehabilitation, ^eJames M. Anderson Center for Health Systems Excellence, Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio; and Departments of ^fSurgery, and ^gPediatrics, College of Medicine, University of Cincinnati, Cincinnati, Ohio

KEY WORDS

pressure ulcer, skin, wound, device, quality improvement, bundle, intervention, neonatal, ICU

ABBREVIATIONS

CWOCN—certified wound ostomy and continence nurse
DTI—deep tissue injury
NIPPV—noninvasive positive pressure ventilation
PU—pressure ulcer
QI—quality improvement
QIC—quality improvement collaborative
TOC—test of change

Dr Visscher made a substantial contribution to the conception and design, acquisition of data, and analysis and interpretation of data and in drafting the article with critical revision for important intellectual content; Dr Leung made a substantial contribution to the design, analysis, and interpretation of data and in drafting the article with critical revision for important intellectual content; Mss Nie, Schaffer, and Taylor, Dr Pruitt, and Ms Giaccone made substantial contributions to the conception and design, acquisition of data, and interpretation of data; Mr Ashby made a substantial contribution to the conception and design, analysis of data, and interpretation and in drafting of article with critical revision for important intellectual content; Dr Keswani made a substantial contribution to conception and design, analysis and interpretation of data and in drafting the article with critical revision for important intellectual content; and all authors had final approval of the version to be published.

www.pediatrics.org/cgi/doi/10.1542/peds.2012-1626

doi:10.1542/peds.2012-1626

Accepted for publication Feb 13, 2013

Address correspondence to Marty O. Visscher, Skin Sciences Program, Division of Plastic Surgery, Cincinnati Children's Hospital Medical Center, 3333 Burnet Ave, Cincinnati, OH 45229. E-mail: marty.visscher@cchmc.org

(Continued on last page)

Pediatric patients are at risk for pressure ulcers (PUs) due to immature skin, compromised perfusion, decreased mobility, altered neurologic responsiveness, fluid retention, moisture, and medical devices.¹ PUs can develop from the surface or from below, at the level of muscle and dermal tissue interaction and compression.^{2,3} PUs are classified by the depth and severity. Stage I is nonblanchable erythematous skin that may be painful, soft, and warmer or cooler than adjacent tissue. Stage II involves partial dermal loss (eg, shallow open ulcer or intact blister). Stage III has dermal loss wherein subdermal elements (eg, subcutaneous fat) are visualized. Stage IV is full-thickness tissue loss with exposed bone, tendon, or muscle. Unstageable ulcers are full-thickness wounds covered by slough and/or eschar. Deep tissue injuries (DTIs) have grossly intact skin with obvious underlying injury related to pressure.⁴

Stage III and IV PUs are serious reportable events, considered “never events” by several national benchmarking organizations.⁵ PU incidence is higher in critically ill patients,⁶ with increased pain, infection, and prolonged hospitalization.⁷ Reductions in reimbursement for health care-acquired PUs have been implemented by the Centers for Medicare & Medicaid Services for adult institutions.⁸ They extend to Medicaid recipients, including pediatrics, as of July 2012.

More than 70% of adult PUs are “conventional” ulcers from pressure over bony prominences, such as the sacrum, shoulder, and heels.^{9,10} Up to 34% are associated with medical devices, such as nasal cannulas and facemasks.^{11,12} While PUs are relatively well studied in adults, the pediatric literature is sparse, perhaps due to a lack of awareness and/or an incomplete understanding of neonatal/pediatric skin physiology.^{13–15}

Both conventional and device-related PUs have been reported.^{16–19}

We established an interdisciplinary quality-improvement (QI) collaborative (QIC) focused on reduction of PUs in the pediatric and neonatal intensive care units and based on the Institute for Healthcare Improvement Breakthrough Series Collaborative.²⁰ We hypothesized that a QIC focused on pressure-related skin injury would reduce the PU rate. We describe the development, implementation and effectiveness of a QI intervention for reducing PUs.

METHODS

Setting

Cincinnati Children’s Hospital Medical Center is a 577-bed, free-standing quaternary care academic facility that serves patients from regional, national, and international locations. The 53-bed level III NICU serves infants who require surgery, have complex congenital conditions, or need specific diagnostic procedures. The 42-bed PICU treats older critically ill patients.

Human Subjects Protection

The institutional review board approved the quality improvement project and waived the requirements to obtain written parental permission and child assent.

QIC Leadership Team

The leadership team was established in August 2007 after a hospitalwide, single-day study revealed a PU prevalence rate of >10%, higher than reported for pediatric institutions.¹⁰ The team included key clinical personnel and subject matter experts from hospital departments; physicians, nursing leaders from the NICU and PICU, nursing and respiratory bedside staff, nurse educators, certified wound ostomy and continence nurses (CWOCNs), and skin researchers. The team was supported by QI consultants and outcome managers.

As a strategic priority, the collaborative received senior-level sponsorship from the board of trustees.

The leadership team generated an aim statement based on specific, measurable, attainable, relevant, and time-bound²¹ goals: to reduce the PU rate in the NICU and PICU by 50% by 1 year after implementation of a QI intervention. The team met every 2 weeks to review the detailed findings from the initial survey, published literature, experiences at other institutions, and unit-level processes.

Pework

Because the quarterly prevalence survey represented a single time point, we collected additional data to understand PU incidence, severity, and etiology. Designated nursing staff from each ICU received training on PU physiology, skin evaluation, and data collection. They performed head-to-toe skin evaluations on all inpatients on 1 day every 2 weeks beginning in September 2007. Patient clothing was removed, and all areas, including under devices, were examined for compromise and PUs. Anatomic location, suspected cause, and preliminary PU stage were documented. Suspected cause was classified as conventional pressure related or directly attributed to device use. Stage was verified by a CWOCN using the National Pressure Ulcer Advisory Panel staging system.⁴ The team reviewed the data every 2 weeks. The QI consultants provided training throughout the process. Progress was reviewed with the hospital Patient Safety Program. Stage III and IV PUs were reported monthly to management. Team minutes and PU rates were shared with all ICU patient care and management staff.

QI Intervention Development Process

From the data on location, stage and suspected cause, the team identified

key drivers: (1) skin assessments, (2) patient skin care, (3) patient care indirectly related to skin (pain control, nutrition, hydration), (4) products related to pressure, and (5) patient/family involvement (Fig 1). The key driver selection stemmed from the importance of close monitoring and early detection of skin compromise due to pressure and excess moisture. Our improvement model used rapid-cycle small tests of change (TOCs) to construct and refine the QI intervention.²² TOCs were conducted among small groups of patients and staff and evaluated for clarity, ease of completion, and impact on work flow. Modifications were made and subsequent TOCs were conducted. TOCs were performed on risk assessment (ie, selection of a validated tool), repositioning frequencies (eg, 4-hour intervals), daily head-to-toe skin and device assessment, moisture management, and education of staff and parents. Pressure redistribution mattresses were

used. Staff members were trained to use positioning aids and plan-do-study-act cycles were conducted.

Three months after QIC initiation, the skin assessment data continued to show that PUs occurred at multiple body sites. More than 50% were associated with medical devices, including facemasks for noninvasive positive pressure ventilation (NIPPV), tracheostomy tubes and ties, casts, and endotracheal tubes. The frequent, comprehensive skin assessments needed to examine the skin under devices. Multiple plan-do-study-act cycles were required to develop a systematic method for identification and documentation of “abnormal” skin features (eg, nonblanchable erythema, blistering) that were associated with pressure. Assessments were time consuming and difficult to conduct for skin under critical devices (eg, masks, tracheostomies, tubes). There was uncertainty about the cause of “abnormal” skin findings. However,

nonblanchable erythema and blistering were noted, suggesting that early-stage skin injury was being detected by bedside staff. The feedback suggested a need for detailed training on skin compromise and PU cause. The CWOCNs, unit-nursing educators, and content experts developed 6 online training modules (Table 1). Completion with demonstration of competency was mandatory for all patient care staff.

The importance of early detection of skin injury prompted the implementation of unit “skin champions.” These staff members, with interests in skin/wound care, underwent additional skin training and became resources to all unit staff. Several became wound care certified by the National Alliance of Wound Care. They conducted rounds twice weekly on all patients to identify skin issues, discussed patients with the CWOCNs, and conducted a bedside skin assessment. A patient-specific skin and wound plan was created, ordered

FIGURE 1

The key drivers and design changes that were tested during development of the QI intervention are shown for the aim of reduction in PU rate by 50% in both units.

TABLE 1 PU Education Modules

Module	Topic	Description/Objectives
t	Skin Anatomy and Physiology	Describe the basic structure and function of normal skin List where to assess for skin breakdown in the hospitalized pediatric patient Describe common pediatric skin conditions Discuss the causes and risk factors for the various skin breakdown conditions
2	Introduction to PUs	Define and recognize a PU Locate common locations of PUs on a child's body Describe risk factors of PU development in the pediatric population
3	Risk Assessment	List factors that contribute to PU development in pediatric patients Determine an accurate Braden Q assessment on a pediatric patient Identify those patients who do not meet the criteria for using the modified Braden Q
4	Interventions to Prevent PUs	Describe interventions used to manage moisture and device protection Describe the importance of positioning and pressure-relieving surfaces in PU prevention Identify interventions for PU prevention
5	Head-to-Toe Skin Assessment	Identify the skin features associated with pressure ulcers Conduct a head-to-toe skin assessment including examination of skin under devices Determine whether skin compromise is pressure related from images Describe the required assessment frequency and chart documentation requirements
6	PU Staging	Describe the features of each PU stage Describe procedures for documentation, notification of unit leadership, and/or PU collaborative members Differentiate PUs from non-pressure related irritant dermatitis and skin breakdown

by the physician or advanced practice nurse, and documented. "Skin integrity" was added to the individual plan of care. Unit educators provided the skin integrity goals for families. A skin champion consulted one-on-one with staff when suspected PUs were found and reinforced the skin assessment procedures.

Table 2 shows the final QI intervention implemented for all patients and staff in both ICUs in November 2008. Skin redness or compromise, observed during daily skin and device assessments, was recorded in the medical record along with modified Braden Q²³ risk levels of ≤ 16 (high risk), 17 to 21 (moderate risk), and 22 to 25 (mild risk) for patients ≥ 28 days of age. NICU patients were considered to be at high risk as there was no validated risk

assessment tool for infants. If a PU was detected, the stage was noted and reported to unit management. At QI implementation, unit champions and managers conducted an in-depth event cause analyses for all stage III PUs, unstageable PUs, and DTIs within 48 hours of detection. Event forms were developed to determine factors associated with failures including changes in patient risk, compliance with QI for assessment, positioning, and use of intervention elements (Table 3). Results were discussed with the QIC team, and specific interventions or processes were modified via TOC cycles.

Outcomes

The primary outcome was PUs/1000 patient-days from the every-2-week head-to-toe skin assessments. New

PUs occurring after admission²⁴ were counted and reported as rate (ie, number/1000 patient-days), which was calculated from the length of hospital stay summed for all evaluated patients. Key process measures (ie, daily skin assessments, daily device assessments, and moisture management) were determined quarterly from a review of the medical records.²⁴

Statistical Analysis

We calculated monthly PU rates by dividing the total number by the mean patient-days of all evaluated patients (ie, during QI development or after implementation) $\times 1000$. Statistical run charts^{25,26} were used to determine the effect of the QI intervention on PU rates over time. This method is also used to show special-cause variation.²⁷ Age, weight, length of stay, and gender were compared for patients before and after QI implementation using *t* test procedures (SigmaStat; SPSS, IBM Corporation, Somers, NY) with significance levels of $P < .05$.

RESULTS

Table 4 shows patient demographics. The mean hospital stay was longer and weights and ages were lower after QI implementation than during development in the PICU ($P < .01$). The gender distributions were similar for both periods. There were no differences for NICU patients in length of stay, weight, gestational age, adjusted age, or gender during and after QI development.

In the PICU, the mean PU rate during QI development was 14.3/1000 patient-days (100 PUs; 7979 days) After the QI bundle was fully implemented, the rate was 3.7/1000 patient-days (51 PUs; 14 729 days). This represented a downward shift, defined as ≥ 8 consecutive points below the centerline, and a significant decrease in rate, as shown in

TABLE 2 Elements of the PU QI Bundle

Risk assessment for all patients ^a
≥28 d of age, complete a modified Braden Q risk assessment on admission and daily to classify PU risk level as low, moderate, or high ^b
≤28 d of age, treat as high risk
All NICU patients, treat as high risk
Skin assessment for all patients ^a
Daily head-to-toe evaluation of entire body surface
Document specific body areas of nonblanchable erythema or skin trauma that may be due to pressure
Medical device assessment for all patients ^a
Examine skin under each device every 12 h
Document specific areas of nonblanchable erythema or skin trauma that may be due to pressure
Implement specific interventions for prevention of PUs based on risk assessment level of low, moderate, or high
Reposition at a minimum of every 2 h for moderate to high risk and 4 h for low risk
Use repositioning devices for all risk levels and pressure reduction surfaces for chairs and adult beds
Float heels
Use appropriate seat cushion for chair-bound patients and shift weight every 15 min
Reduce moisture for all risk levels
Check common moisture sites every 2–4 h
Use diapers with breathable outer cover (avoid plastic)
Remove moisture from under devices
Keep skin under casts, splints, braces, and collars dry and clean
In diaper area for all risk levels
Keep skin clean and dry and change diapers as soon as they are wet
Apply protective cream
Avoid diapers/products with nonbreathable plastic backing
Manage friction and shear for all risk levels
Use draw sheet to reposition
When bed elevated, use positioning products and/or elevate knees to prevent friction and shearing
Optimize nutrition via ongoing nutrition consults for all moderate- to high-risk patients
Education/awareness
All unit bedside staff (nurses, respiratory therapists, physical therapists) required to complete 6 PU-focused training modules and demonstrate competency via score on posttests
All unit bedside staff required to complete annual refresher training
Physician staff (attending, fellows, residents) participated in training provided by the QIC leadership team physician and CWO/CN
Results of every 2-wk skin assessments shared with all staff including continuous improvements to the QI bundle
Provide an educational brochure regarding pressure ulcers and skin assessments for families
Bedside staff actively engaged families in assessments and discussed observations with them
Implement skin champions and conduct collaborative skin rounds
Identify specific unit staff to serve as skin champions, resources to other unit staff
Participate in weekly collaborative skin rounds
Develop skin and wound plans for identified patients

^a The results of the daily or every 12-h risk skin and device assessments are charted in the medical record for the locations where the skin exhibits any redness, compromise, or damage. If a PU is detected, the stage is noted and reported to the unit management.

^b Risk levels from the modified Braden Q scale are as follows: ≤16, high risk; 17–21, moderate risk; and 22–25, mild risk. The interventions to be used on a patient are based on the modified Braden Q score.

the run chart (Fig 2). The change began in September 2008, toward the end of the baseline period, and was stable during the postintervention period. The PICU rates of stage I, stage II (Fig 3), and severe (stage III, unstageable, DTI) conventional and device-related (Fig 4) PUs were all lower after the QI intervention. There were no stage IV PUs.

In the NICU, the mean PU rate was 0.9/1000 patient-days (18 PUs; 19 939 days during development and 31 PUs; 11 704 days after development) and did not change over time. The mean did not increase, but there were 3 points above the upper control limit, indicating the process was out of control (Fig 5). The NICU staff and QIC team completed event forms to identify potential causes.

Stage II and III PUs from pulse oximeters and extracorporeal membrane oxygenation cannulas were noted. PUs from these devices had not been observed in the NICU during QI development. The skin under pulse oximeters had been assessed every 12 hours, and devices had been replaced at least once in 48 hours. There were no reports of increased edema, difficulty in obtaining an oxygen saturation reading, or device tightening (ie, increased pressure). The hospital had changed the pulse oximeter supplier before the months when PUs occurred. No specific problem with the pulse oximeter could be identified. There were no stage IV PUs.

A high number of PUs were associated with medical devices both before and after QI implementation, particularly from NIPPV facemasks and tracheostomy tubes and ties (Table 5). Of patients with facemask PUs, 46% had diagnoses associated with craniofacial anomalies (eg, micrognathia).

Process Measure: Compliance

Compliance with daily head-to-toe skin assessments averaged 81% in the PICU and 50% in the NICU after implementation. Conformity with skin assessments under devices was 57% and 50% in the PICU and NICU, respectively. Use of products to manage moisture was 92% and use of nutrition consults was 100% in both units.

DISCUSSION

We assembled a leadership team to reduce the PU rate by 50% in the PICU and NICU. Using iterative, rapid-cycle TOCs, the QIC developed a QI intervention based on the cornerstones of (1) frequent, thorough skin assessments, (2) preventative interventions, (3) comprehensive education, (4) clinical staff empowerment (eg, skin champions), and (5) systems change

TABLE 3 PU Event Review Form

Patient MRN		Primary Diagnosis		Wt (kg)	
Date PU found		PU location		PU stage	
Device related Y N		If yes, list device		Position related Y N	
Before Discovery					
Risk assessment		Category: high, moderate, low		Score	
Hospital location 48 h before		Mean oxygen saturation previous 24 h			
Circulatory status at PU site		Capillary refill skin turgor		Temperature pulse	
Risk Factors					
Skin issues on admission		Nutrition type		If NPO, how long	
Patient edematous Y N		Patient diaphoretic Y N		Skin moist Y N	
Was skin team aware? Y N		Time team notified		Incontinent Y N	
Moisture-prone device(s) Y N		List devices		Incontinence treated Y N	
		List, interventions in place			
Position Related					
List surface used under patient		Describe how used		Repositioned as indicated by risk level? Y N	
Z-flo used under? Y N		What between Z-flo and patient?		Patient at angle? Y N	
Patient immobilized? Y N		Patient in surgery Y N		Time immobilized	
Device Related					
Pulse oximeter	Changed past 48 h? Y N	Difficult to obtain oxygen saturation Y N		Other issues	
Line: PICC, CVC, IV	Placed at bedside? Y N	Extravasation Y N		How secured?	
	No attempts	Treatment		Dressing type	
Mask: BiPAP, CPAP	Washed daily? Y N	Brand		Flow rate	
	Alternated with other masks? Y N	Size		Leaks Y N	
		Anything under? Y N		What used under?	
Tracheostomy (old)	Brand	Anything under? Y N		Brand of ties	
	Size	Anything under ties? Y N		Ties changed?	
		What?		Y N	
Tracheostomy (new)	Date placed	Did ENT loosen ties? Y N		ENT loosened tape? Y N	
		Brand			
		Size			
Tracheostomy with vent	Product to prop tubing? Y N	Product to secure tracheostomy to vent? Y N			
ETT	Taped? Y N	What specific tape?		Was product under?	
	Where was it taped?			Y N If Y, what was used	
Orthotic device	Type	Removed? Y N		Other	

Other Issues: describe

NPO, nothing by mouth; BiPAP, bilevel positive airway pressure; CPAP, continuous positive airway pressure; ETT, endotracheal tube; IV, intravenous; N, no; Y, yes. Z-flo is the trade name for fluidized positioners made by Sundance, White Plains, NY.

This document is part of the quality assessment peer review and risk management activities of CCHMC and, as such, is a confidential document no subject to discovery pursuant to Ohio Revised Code Sections 2305.25, 2305.252, and 2305.253. All committees involved in the review of this document, as well as those individuals preparing and submitting information to such committees, claim all privileges and protection afforded by ORC Sections 2305.25, 2305.252, and 2305.253 and any subsequent legislation. The information contained is solely for the use of the individual or entity intended. If you are not the intended recipient, be aware that any disclosure, copying, or distribution of this information is prohibited. Source: Legal Department of Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio.

(eg, skin rounds). In the PICU, PUs decreased from 14.3/1000 patient-days during QI development to 3.7/1000 patient-days during the first year after implementation, thereby achieving the aim of a 50% reduction. In the NICU, the prebundle mean rate of 0.9 PU/1000 days did not change. The majority of PUs were stage II during both periods.

This is one of a limited number of studies to implement an effective intervention to reduce PUs in pediatrics.

Boesch et al¹⁹ developed a QI prevention bundle for tracheostomy patients, including a redesigned device, and significantly reduced the rate of patients who had a tracheostomy-related PU.¹⁹ Others have reported PUs as incidence, ranging from 0.8% to 17.5% in a large study of 9 PICUs²⁸ and up to 53% in smaller studies.^{16,29,30} The NICU rate of 0.9 PUs/1000 patient-days is lower than reported by other institutions³¹ and lower than our PICU rates.

The literature on neonatal PUs is sparse, with limited studies with small sample sizes. One multicenter national pediatric survey included 82 neonates and reported a 13% prevalence.¹⁰

We noted a high proportion of PUs associated with medical devices. Our PICU proportions of 51% pre and 69% post QI implementation are higher than previous reports wherein 50% to 62% of patients had device-associated PUs.^{16–29}

TABLE 4 Characteristics (mean $\pm$ SD of the mean) for Patients With and Without PUs During the Period of QI Development and After QI Implementation in the PICU and the NICU

	During QI Development	After QI Implementation
PICU		
No. of patients	293	391
Total patient-days	7979	14 729
Length of stay, d (median, range)	33.0 $\pm$ 53.0 (14, 1–383)	41.2 $\pm$ 57.1* (20, 0–365)
Weight, kg (median, range)	38.8 $\pm$ 25.0 (34.6, 2.2–160)	18.3 $\pm$ 21.0* (10.2, 2.5–122)
Age, y (median, range)	10.8 $\pm$ 6.3 (10.5, 0.2–28.0)	4.5 $\pm$ 5.4* (2.0, 0.1–25.2)
Gender, females/males	46%/54%	44%/56%
NICU		
No. of patients	461	280
Total patient-days	19 939	11 704
Length of stay, d (median, range)	44.5 $\pm$ 50.8 (28, 10–372)	44.3 $\pm$ 47.2 (27, 1–278)
Weight, kg (median, range)	3.90 $\pm$ 1.4* (4.44, 1.0–5.4)	2.60 $\pm$ 1.0 (2.59, 0.5–7.03)
Gestational age, wk (median, range)	34.4 $\pm$ 4.5 (36.0, 23–41)	34.0 $\pm$ 4.6 (36, 23–41)
Age, wk (median, range)	39.8 $\pm$ 5.9 (39.0, 25–91)	38.8 $\pm$ 5.1 (39.0, 24–63)
Gender, females/males	44%/56%	44%/56%

* Significant difference during QI development versus after implementation ($P < .01$).

The NICU levels of 61% and 90% have not been previously described. The high device-related PUs in pediatrics is distinct from that of adults^{16,29,32,33} and may indicate a susceptibility to iatrogenic injury in pediatrics, perhaps resulting from physiologic differences between adult and pediatric skin.^{13–15,34–38} Our NICU stage II device-related PU level is

higher than in other reports. Fisher et al³⁹ found 88% stage I ulcers from facemasks. Our stage II rates are concerning in light of reports suggesting that device-related stage II PUs have the propensity to progress to stage III or IV ulcers, already classified as “never events,” compared with conventional stage II PUs.¹²

We noted a decrease in the PU rate even before the QI intervention in the PICU (Fig 2). These changes during QI development could reflect increased awareness of PUs, focused attention on early indicators of skin compromise by PICU staff, and the implementation of some of the bundle elements. The NICU PU rate did not change after the QI implementation, during which 3 points were above the control limits. The increase was attributed to PUs from pulse oximeters and coincided with a change in manufacturer, suggesting that a single device can have a measurable impact on PU injury.

While designed to evaluate QI bundle efficacy, limitations of the study were the inability to (1) control for increased detection from heightened attention and organizational focus and (2) isolate the effects of the total QI bundle from changes that occurred during the TOCs and the QI process itself. We did not investigate specific patient-related characteristics that may contribute to

FIGURE 2

A control chart of PUs in the PICU shows a sustained reduction from the period of QI development to implementation.

FIGURE 3

A control chart of stage II PUs in the PICU shows a sustained reduction from QI development to implementation.

FIGURE 4

A control chart of device-associated PUs in the PICU shows a sustained reduction from QI development to implementation.

development of PUs (eg, sepsis, edema, and hypoperfusion).^{40–42} Examination of these factors is necessary to better predict PU risk in pediatrics.

We noted multiple groups at increased risk for PUs, including patients with lengthy hospital stays, patients using NIPPV facemasks, and neonates on extracorporeal membrane oxygenation. Craniofacial anomalies among patients

with facemask PUs may impact the mask fit, resulting in uneven pressure distribution. Poorly fitting masks may result in air leaks, a situation that may be remedied clinically with tighter mask application. Our results are consistent with reports of nasal trauma in 42.5% of infants on NIPPV for whom PUs developed despite interventions, including massage and ointments.³⁹ These

interventions may be ineffective, as they fail to address a basic design flaw, the facemasks are not designed for pediatric faces and may disregard normal developmental changes in craniofacial morphology. Our low NICU facemask PU rate may be due to low use of NIPPV. However, use of this intervention in neonates is increasing and may increase PU risk.

FIGURE 5

A control chart of PUs in the NICU shows no changes over time. After the QI implementation, 3 points were above the upper control limit. The majority were PUs due to pulse oximeters and the increase was attributed to a hospital change in the product supplier.

TABLE 5 PUs Associated With Medical Devices During QI Development and After Implementation

	During QI Development	After QI Implementation
PICU		
Overall percentage of total PUs	51	69
No.	51	35
Associated with NIPPV, %	24	40
Associated with casts, %	16	0
Associated with tracheostomy tubes and ties, %	8	26
NICU		
Overall percentage of total PUs	61	90
No.	11	18

The QI intervention was not especially effective for facemask-associated PUs. This highlights the need for application of novel measures to identify early indicators of at-risk areas of PU development. For example, patients with excess moisture are associated with more frequent and more severe ulcers (stage II).⁴³ Moist skin has a higher frictional coefficient,⁴⁴ thereby exacerbating the effects of mechanical trauma.⁴⁵ Color imaging of erythema and 3-dimensional imaging of shape may topographically identify patients at increased risk for PUs, particularly mask-related ulcers. We are currently

using this quality improvement strategy, along with color and 3-dimensional imaging, to implement interventions to reduce pressure-related injury from NIPPV masks, pulse oximeters, and cannulas. A redesign of pediatric facemasks may be required to effectively decrease the incidence and severity of mask-related injury.

CONCLUSIONS

We have demonstrated an underappreciated number of pediatric PUs and the association with medical device use. We implemented a QI bundle that

led to a significant decrease in the PU rate in the PICU. While this initial intervention has proved to be efficacious, we need to use established skin evaluation methods, identify early tissue changes, and test additional interventions to reduce harm from medical devices. The unanticipated increase in PUs from pulse oximeters indicates that new products must be evaluated before widespread use. We recommend rapid-cycle TOCs for all devices that have the potential to damage the skin, because the impact of design changes cannot presently be determined without such trials. Substantial reduction in device-associated PU rates remains an essential strategic focus.

ACKNOWLEDGMENTS

The authors thank Diana Bailey, MSN, Pattie Bondurant, DNPc, Christine Myers, BSN, Mary Stange, MSN, and the clinical staff in the ICUs for their diligence in conducting the skin assessments and the leadership of Cincinnati Children's

Hospital Medical Center for their organizational support of this work. We

thank Pamela Schoettker, MS, of the James M. Anderson Center for Health

Systems Excellence for her expert editorial assistance.

REFERENCES

- Schindler CA, Mikhailov TA, Fischer K, Lukasiewicz G, Kuhn EM, Duncan L. Skin integrity in critically ill and injured children. *Am J Crit Care*. 2007;16(6):568–574
- Bouten CV, Oomens CW, Baaijens FP, Bader DL. The etiology of pressure ulcers: skin deep or muscle bound? *Arch Phys Med Rehabil*. 2003;84(4):616–619
- Stekelenburg A, Strijkers GJ, Parusel H, Bader DL, Nicolay K, Oomens CW. Role of ischemia and deformation in the onset of compression-induced deep tissue injury: MRI-based studies in a rat model. *J Appl Physiol*. 2007;102(5):2002–2011
- National Pressure Ulcer Advisory Panel. Updated Staging System: National Pressure Ulcer Advisory Panel. 2007. Available at: <http://www.npuap.org/>. Accessed May 15, 2009
- National Quality Forum. Serious reportable events (SREs). Transparency, accountability critical to reducing medical errors and harm. www.qualityforum.org/Publications/2008/10/Serious_Reportable_Events.aspx. 2006. Accessed October 30, 2011
- Nijs N, Toppets A, Defloor T, Bernaerts K, Milisen K, Van Den Berghe G. Incidence and risk factors for pressure ulcers in the intensive care unit. *J Clin Nurs*. 2009;18(9):1258–1266
- Keller BP, Wille J, van Ramshorst B, van der Werken C. Pressure ulcers in intensive care patients: a review of risks and prevention. *Intensive Care Med*. 2002;28(10):1379–1388
- Centers for Medicare and Medicaid Services (CMS), Health and Human Services. Medicaid program; payment adjustment for provider-preventable conditions including health care-acquired conditions. Final rule. *Fed Regist*. 2011;76(108):32816–32838
- Sayar S, Turgut S, Doğan H, et al. Incidence of pressure ulcers in intensive care unit patients at risk according to the Waterlow scale and factors influencing the development of pressure ulcers. *J Clin Nurs*. 2009;18(5):765–774
- McLane KM, Bookout K, McCord S, McCain J, Jefferson LS. The 2003 National Pediatric Pressure Ulcer and Skin Breakdown Prevalence Survey: a multisite study. *J Wound Ostomy Continence Nurs*. 2004;31(4):168–178
- Black JM, Cuddigan JE, Walko MA, Didier LA, Lander MJ, Kelpie MR. Medical device related pressure ulcers in hospitalized patients. *Int Wound J*. 2010;7(5):358–365
- Apold J, Rydrych D. Preventing device-related pressure ulcers: using data to guide statewide change. *J Nurs Care Qual*. 2012;27(1):28–34
- Nikolovski J, Stamatas GN, Kollias N, Wiegand BC. Barrier function and water-holding and transport properties of infant stratum corneum are different from adult and continue to develop through the first year of life. *J Invest Dermatol*. 2008;128(7):1728–1736
- Visscher MO, Chatterjee R, Ebel JP, LaRuffa AA, Hoath SB. Biomedical assessment and instrumental evaluation of healthy infant skin. *Pediatr Dermatol*. 2002;19(6):473–481
- Visscher MO, Chatterjee R, Munson KA, Pickens WL, Hoath SB. Changes in diapered and nondiapered infant skin over the first month of life. *Pediatr Dermatol*. 2000;17(1):45–51
- Curley MA, Quigley SM, Lin M. Pressure ulcers in pediatric intensive care: incidence and associated factors. *Pediatr Crit Care Med*. 2003;4(3):284–290
- Waterlow JA. Pressure sore risk assessment in children. *Paediatr Nurs*. 1997;9(6):21–24
- Willock J, Hughes J, Tickle S, Rossiter G, Johnson C, Pye H. Pressure sores in children—the acute hospital perspective. *J Tissue Viability*. 2000;10(2):59–62
- Boesch RP, Myers C, Garrett T, et al. Prevention of tracheostomy-related pressure ulcers in children. *Pediatrics*. 2012;129(3). Available at: www.pediatrics.org/cgi/content/full/129/3/e792
- Kilo CM. Improving care through collaboration. *Pediatrics*. 1999;103(1 suppl E):384–393
- Langley GJ, Moen R, Nolan KM, Nolan TW, Norman CL, Provost LP. *The Improvement Guide: A Practical Approach to Enhancing Organizational Performance*, 2nd ed. San Francisco, CA: Jossey-Bass; 2009
- Langley GJ, Nolan K, Nolan M, Norman TW, Provost CL. *The Improvement Guide: A Practical Approach to Enhancing Organizational Performance*. San Francisco, CA: Jossey-Bass; 1996
- Curley MA, Razmus IS, Roberts KE, Wypij D. Predicting pressure ulcer risk in pediatric patients: the Braden Q Scale. *Nurs Res*. 2003;52(1):22–33
- Berlowitz D, Lukas CV, Parker V, et al. Preventing pressure ulcer in hospitals: a toolkit for improving quality of care. www.ahrq.gov/research/ltrc/pressureulcertoolkit. 2011. Accessed August 28, 2012
- Amin SG. Control charts 101: a guide to health care applications. *Qual Manag Health Care*. 2001;9(3):1–27
- Benneyan JC, Lloyd RC, Plsek PE. Statistical process control as a tool for research and healthcare improvement. *Qual Saf Health Care*. 2003;12(6):458–464
- Moen RD, Nolan TW, Provost LP. *Quality Improvement Through Planned Experimentation*, 2nd ed. New York: McGraw-Hill; 1999
- Schindler CA, Mikhailov TA, Kuhn EM, et al. Protecting fragile skin: nursing interventions to decrease development of pressure ulcers in pediatric intensive care. *Am J Crit Care*. 2011;20(1):26–34, quiz 35
- Willock J, Harris C, Harrison J, Poole C. Identifying the characteristics of children with pressure ulcers. *Nurs Times*. 2005;101(11):40–43
- Zollo MB, Gostisha ML, Berens RJ, Schmidt JE, Weigle CG. Altered skin integrity in children admitted to a pediatric intensive care unit. *J Nurs Care Qual*. 1996;11(2):62–67
- Baharestani MM, Ratliff CR. Pressure ulcers in neonates and children: an NPUAP white paper. *Adv Skin Wound Care*. 2007;20(4):208–, 210, 212, 214, 216, 218–220
- Ayoub AF, Xiao Y, Khambay B, Siebert JP, Hadley D. Towards building a photo-realistic virtual human face for craniomaxillofacial diagnosis and treatment planning. *Int J Oral Maxillofac Surg*. 2007;36(5):423–428
- Noonan C, Quigley S, Curley MA. Skin integrity in hospitalized infants and children: a prevalence survey. *J Pediatr Nurs*. 2006;21(6):445–453
- Eichenfield LF, Hardaway CA. Neonatal dermatology. *Curr Opin Pediatr*. 1999;11(5):471–474
- Visscher M, Odio M, Taylor T, et al. Skin care in the NICU patient: effects of wipes versus cloth and water on stratum corneum integrity. *Neonatology*. 2009;96(4):226–234
- Visscher M, deCastro MV, Combs L, et al. Effect of chlorhexidine gluconate on the skin integrity at PICC line sites. *J Perinatol*. 2009;29(12):802–807
- Visscher MO. Update on the use of topical agents in neonates. *Newborn Infant Nurs Rev*. 2009;9(1):31–47

38. Visscher MO, Utturkar R, Pickens WL, et al. Neonatal skin maturation—vernix caseosa and free amino acids. *Pediatr Dermatol*. 2011;28(2):122–132
39. Fischer C, Bertelle V, Hohlfield J, Forcada-Guex M, Stadelmann-Diaw C, Tolsa JF. Nasal trauma due to continuous positive airway pressure in neonates. *Arch Dis Child Fetal Neonatal Ed*. 2010;95(6):F447–F451
40. O'Sullivan KL, Engrav LH, Maier RV, Pilcher SL, Isik FF, Copass MK. Pressure sores in the acute trauma patient: incidence and causes. *J Trauma*. 1997;42(2):276–278
41. Pinchcofsky-Devin GD, Kaminski MV Jr. Correlation of pressure sores and nutritional status. *J Am Geriatr Soc*. 1986;34(6):435–440
42. Linares HA, Mawson AR, Suarez E, Biundo JJ. Association between pressure sores and immobilization in the immediate post-injury period. *Orthopedics*. 1987;10(4):571–573
43. Bates-Jensen BM, McCreath HE, Pongquan V. Subepidermal moisture is associated with early pressure ulcer damage in nursing home residents with dark skin tones: pilot findings. *J Wound Ostomy Continence Nurs*. 2009;36(3):277–284
44. Visscher MO, Robinson M, Fugit B, Rosenberg RJ, Hoath SB, Randall Wickett R. Amputee skin condition: occlusion, stratum corneum hydration and free amino acid levels. *Arch Dermatol Res*. 2011;303(2):117–124
45. Zimmerer RE, Lawson KD, Calvert CJ. The effects of wearing diapers on skin. *Pediatr Dermatol*. 1986;3(2):95–101

(Continued from first page)

PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

Copyright © 2013 by the American Academy of Pediatrics

FINANCIAL DISCLOSURE: Following the findings of this project, Marty Visscher has provided CareFusion with education regarding skin damage from respiratory devices; the other authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: No external funding.