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 53 351 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

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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; Ms 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.

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(Continued on last page)
Both conventional and device-related PUs have been reported. 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. 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. 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-bound (SMART) 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.

Prework
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. 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 the hospital Patient Safety Program. Stage III and IV PUs were reported monthly to the hospital Patient Safety Program.

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. TOCs were conducted among small groups of patients and staff and evaluated for clarity, ease of completion, and impact on workflow. 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), tracheotomy 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](https://via.placeholder.com/150)

**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.
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 Q 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 admission 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.

### 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) × 1000. Statistical run charts 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; 14729 days). This represented a downward shift, defined as ≥8 consecutive points below the centerline, and a significant decrease in rate, as shown in...
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.
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 3 PU Event Review Form

<table>
<thead>
<tr>
<th>Date PU found</th>
<th>Device related Y N</th>
<th>Patient MRN</th>
<th>Primary Diagnosis</th>
<th>Wt (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category: high, moderate, low</td>
<td>Category: high, moderate, low</td>
<td>Category: high, moderate, low</td>
<td>Category: high, moderate, low</td>
<td></td>
</tr>
<tr>
<td>Mean oxygen saturation previous 24 h</td>
<td>Mean oxygen saturation previous 24 h</td>
<td>Mean oxygen saturation previous 24 h</td>
<td>Mean oxygen saturation previous 24 h</td>
<td></td>
</tr>
<tr>
<td>Capillary refill skin turgor</td>
<td>Capillary refill skin turgor</td>
<td>Capillary refill skin turgor</td>
<td>Capillary refill skin turgor</td>
<td></td>
</tr>
<tr>
<td>Score</td>
<td>Score</td>
<td>Score</td>
<td>Score</td>
<td></td>
</tr>
<tr>
<td>Temperature pulse</td>
<td>Temperature pulse</td>
<td>Temperature pulse</td>
<td>Temperature pulse</td>
<td></td>
</tr>
<tr>
<td>Risk assessment</td>
<td>Risk assessment</td>
<td>Risk assessment</td>
<td>Risk assessment</td>
<td></td>
</tr>
<tr>
<td>Hospital location 48 h before</td>
<td>Hospital location 48 h before</td>
<td>Hospital location 48 h before</td>
<td>Hospital location 48 h before</td>
<td></td>
</tr>
<tr>
<td>Circulatory status at PU site</td>
<td>Circulatory status at PU site</td>
<td>Circulatory status at PU site</td>
<td>Circulatory status at PU site</td>
<td></td>
</tr>
<tr>
<td>Nutrition type</td>
<td>Nutrition type</td>
<td>Nutrition type</td>
<td>Nutrition type</td>
<td></td>
</tr>
<tr>
<td>Patient diaphoretic Y N</td>
<td>Patient diaphoretic Y N</td>
<td>Patient diaphoretic Y N</td>
<td>Patient diaphoretic Y N</td>
<td></td>
</tr>
<tr>
<td>Time team notified</td>
<td>Time team notified</td>
<td>Time team notified</td>
<td>Time team notified</td>
<td></td>
</tr>
<tr>
<td>List devices</td>
<td>List devices</td>
<td>List devices</td>
<td>List devices</td>
<td></td>
</tr>
<tr>
<td>List, interventions in place</td>
<td>List, interventions in place</td>
<td>List, interventions in place</td>
<td>List, interventions in place</td>
<td></td>
</tr>
<tr>
<td>Before Discovery</td>
<td>Before Discovery</td>
<td>Before Discovery</td>
<td>Before Discovery</td>
<td></td>
</tr>
<tr>
<td>Position related Y N</td>
<td>Position related Y N</td>
<td>Position related Y N</td>
<td>Position related Y N</td>
<td></td>
</tr>
<tr>
<td>List surface used under patient</td>
<td>List surface used under patient</td>
<td>List surface used under patient</td>
<td>List surface used under patient</td>
<td></td>
</tr>
<tr>
<td>Z-flo used under? Y N</td>
<td>Z-flo used under? Y N</td>
<td>Z-flo used under? Y N</td>
<td>Z-flo used under? Y N</td>
<td></td>
</tr>
<tr>
<td>Patient immobilized? Y N</td>
<td>Patient immobilized? Y N</td>
<td>Patient immobilized? Y N</td>
<td>Patient immobilized? Y N</td>
<td></td>
</tr>
<tr>
<td>Describe how used</td>
<td>Describe how used</td>
<td>Describe how used</td>
<td>Describe how used</td>
<td></td>
</tr>
<tr>
<td>Patient in surgery Y N</td>
<td>Patient in surgery Y N</td>
<td>Patient in surgery Y N</td>
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<tr>
<td>Repositioned as indicated by risk level? Y N</td>
<td>Repositioned as indicated by risk level? Y N</td>
<td>Repositioned as indicated by risk level? Y N</td>
<td>Repositioned as indicated by risk level? Y N</td>
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<tr>
<td>Position Related</td>
<td>Position Related</td>
<td>Position Related</td>
<td>Position Related</td>
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<tr>
<td>List, interventions in place</td>
<td>List, interventions in place</td>
<td>List, interventions in place</td>
<td>List, interventions in place</td>
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<tr>
<td>Device Related</td>
<td>Device Related</td>
<td>Device Related</td>
<td>Device Related</td>
<td></td>
</tr>
<tr>
<td>Pulse oximeter</td>
<td>Pulse oximeter</td>
<td>Pulse oximeter</td>
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<td></td>
</tr>
<tr>
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<td>Changed past 48 h? Y N</td>
<td>Changed past 48 h? Y N</td>
<td></td>
</tr>
<tr>
<td>No attempts</td>
<td>No attempts</td>
<td>No attempts</td>
<td>No attempts</td>
<td></td>
</tr>
<tr>
<td>Mask: BiPAP, CPAP</td>
<td>Mask: BiPAP, CPAP</td>
<td>Mask: BiPAP, CPAP</td>
<td>Mask: BiPAP, CPAP</td>
<td></td>
</tr>
<tr>
<td>Washed daily? Y N</td>
<td>Washed daily? Y N</td>
<td>Washed daily? Y N</td>
<td>Washed daily? Y N</td>
<td></td>
</tr>
<tr>
<td>Alternated with other masks? Y N</td>
<td>Alternated with other masks? Y N</td>
<td>Alternated with other masks? Y N</td>
<td>Alternated with other masks? Y N</td>
<td></td>
</tr>
<tr>
<td>Tracheostomy (old)</td>
<td>Tracheostomy (old)</td>
<td>Tracheostomy (old)</td>
<td>Tracheostomy (old)</td>
<td></td>
</tr>
<tr>
<td>Brand</td>
<td>Brand</td>
<td>Brand</td>
<td>Brand</td>
<td></td>
</tr>
<tr>
<td>Size</td>
<td>Size</td>
<td>Size</td>
<td>Size</td>
<td></td>
</tr>
<tr>
<td>Tracheostomy with vent</td>
<td>Tracheostomy with vent</td>
<td>Tracheostomy with vent</td>
<td>Tracheostomy with vent</td>
<td></td>
</tr>
<tr>
<td>Where was it taped?</td>
<td>Where was it taped?</td>
<td>Where was it taped?</td>
<td>Where was it taped?</td>
<td></td>
</tr>
<tr>
<td>Orthotic device</td>
<td>Orthotic device</td>
<td>Orthotic device</td>
<td>Orthotic device</td>
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<tr>
<td>Describe how used</td>
<td>Describe how used</td>
<td>Describe how used</td>
<td>Describe how used</td>
<td></td>
</tr>
<tr>
<td>Repositioned as indicated by risk level? Y N</td>
<td>Repositioned as indicated by risk level? Y N</td>
<td>Repositioned as indicated by risk level? Y N</td>
<td>Repositioned as indicated by risk level? Y N</td>
<td></td>
</tr>
</tbody>
</table>

**Risk Factors**

- **Skin issues on admission**
  - Patient edematous Y N
  - Was skin team aware? Y N
  - Moisture-prone device(s) Y N

**Risk assessment**

- Hospital location 48 h before
- Circulatory status at PU site

**Nutrition type**

- Patient diaphoretic Y N
- Time team notified
- List devices
- List, interventions in place

**Position related**

- List surface used under patient
- Z-flo used under? Y N
- Patient immobilized? Y N

**Device related**

- Pulse oximeter
- Line: PICC, CVC, IV
- Mask: BiPAP, CPAP
- Tracheostomy (old)
- Tracheostomy (new)
- Tracheostomy with vent
- ET
- Orthotic device

**Other Issues: describe**

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

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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 and may indicate a susceptibility to iatrogenic injury in pediatrics, perhaps resulting from physiologic differences between adult and pediatric skin. Our NICU stage II device-related PU level is higher than in other reports. Fisher et al 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.

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

### TABLE 4 Characteristics (mean ± 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

<table>
<thead>
<tr>
<th></th>
<th>During QI Development</th>
<th>After QI Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>PICU</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of patients</td>
<td>293</td>
<td>381</td>
</tr>
<tr>
<td>Total patient-days</td>
<td>7879</td>
<td>14 729</td>
</tr>
<tr>
<td>Length of stay, d (median, range)</td>
<td>33.0 ± 53.0 (14, 1–383)</td>
<td>41.2 ± 57.1* (20, 0–365)</td>
</tr>
<tr>
<td>Weight, kg (median, range)</td>
<td>38.8 ± 25.0 (34.8, 2.2–160)</td>
<td>18.3 ± 21.0* (10.2, 2.5–122)</td>
</tr>
<tr>
<td>Age, y (median, range)</td>
<td>10.8 ± 6.3 (10.5, 0.2–28.0)</td>
<td>4.5 ± 5.4* (2.0, 0.1–25.2)</td>
</tr>
<tr>
<td>Gender, females/males</td>
<td>46%/54%</td>
<td>44%/56%</td>
</tr>
<tr>
<td>NICU</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of patients</td>
<td>461</td>
<td>280</td>
</tr>
<tr>
<td>Total patient-days</td>
<td>19 939</td>
<td>11 704</td>
</tr>
<tr>
<td>Length of stay, d (median, range)</td>
<td>44.5 ± 50.8 (28, 10–372)</td>
<td>44.3 ± 47.2 (27, 1–278)</td>
</tr>
<tr>
<td>Weight, kg (median, range)</td>
<td>3.90 ± 4.4 (4.44, 1.0–5.4)</td>
<td>2.60 ± 1.0 (2.59, 0.5–7.03)</td>
</tr>
<tr>
<td>Gestational age, wk (median, range)</td>
<td>34.4 ± 4.5 (36.0, 23–41)</td>
<td>34.0 ± 4.6 (36, 23–41)</td>
</tr>
<tr>
<td>Age, wk (median, range)</td>
<td>39.8 ± 5.9 (39.0, 25–91)</td>
<td>38.8 ± 5.1 (39.0, 24–63)</td>
</tr>
<tr>
<td>Gender, females/males</td>
<td>44%/56%</td>
<td>44%/56%</td>
</tr>
</tbody>
</table>

* Significant difference during QI development versus after implementation (P < .01).
development of PUs (e.g., sepsis, edema, and hypoperfusion). 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. 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.
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).\textsuperscript{43} Moist skin has a higher frictional coefficient,\textsuperscript{44} thereby exacerbating the effects of mechanical trauma.\textsuperscript{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

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