Neonatal Jaundice: Improved Quality and Cost Savings After Implementation of a Standard Pathway

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OBJECTIVES: Seattle Children’s Hospital sought to optimize the value equation for neonatal jaundice patients by creating a standard care pathway.

METHODS: An evidence-based pathway for management of neonatal jaundice was created. This included multidisciplinary team assembly, comprehensive literature review, creation of a treatment algorithm and computer order sets, formulation of goals and metrics, roll-out of an education program for end users, and ongoing pathway improvement. The pathway was implemented on May 31, 2012. Quality metrics before and after implementation were compared. External data were used to analyze cost impacts.

RESULTS: Significant improvements were achieved across multiple quality dimensions. Time to recovery decreased: mean length of stay was 1.30 days for 117 prepathway patients compared with 0.87 days for 69 postpathway patients (P < .001). Efficiency was enhanced: mean time to phototherapy initiation was 101.26 minutes for 14 prepathway patients compared with 54.67 minutes for 67 postpathway patients (P = .03). Care was less invasive: intravenous fluid orders were reduced from 80% to 44% (P < .001). Inpatient use was reduced: 66% of prepathway patients were admitted from the emergency department to inpatient care, compared with 50% of postpathway patients (P = .01). There was no increase in the readmission rate. These achievements translated to statistically significant cost reductions in total charges, as well as in the following categories: intravenous fluids, laboratory, room cost, and emergency department charges.

CONCLUSIONS: An evidence-based standard care pathway for neonatal jaundice can significantly improve multiple dimensions of value, including reductions in cost and length of stay.
lights inconsistently produced irradiance meeting the AAP standards for intensive phototherapy of 30 µW/cm²².

**METHODS**

**Available Knowledge**

Delivering reliable high-quality care to children is a national challenge. In 1 study, children were noted to receive only 46.5% of established quality of care indicators³ with the consequence of such failure being avoidable adverse health outcomes. Even within a large managed care organization, adherence to AAP treatment guidelines for neonatal jaundice has been shown to be highly variable.⁴

**Rationale and Specific Aims**

In 2011, a multidisciplinary team at SCH convened to apply principles of continuous performance improvement toward creating a neonatal jaundice pathway (NJP) to guide nurses and practitioners in all phases of neonatal jaundice care. It was postulated that evidence-based standardization would enhance value for this population. We aimed to reduce waste in testing and interventions to minimize length of stay (LOS) and cost without compromising outcomes such as readmissions. The results of the first Plan-Do-Study-Act cycle for this work are summarized.

**Context**

A multidisciplinary team was assembled to design, implement, monitor, and improve a NJP. Work began in March 2011 with an analysis of the current state at SCH, followed by development of pathway content and materials. The NJP went live on May 31, 2012.

**Interventions**

The NJP team consisted of 3 physicians and 3 clinical nurse specialists (1 pair each from general medicine, the NICU, and emergency medicine), a librarian, a consultant, a data analyst, and a project manager. One of the 3 physicians acted as the pathway owner.

Sixteen clinical questions served as the basis for the initial evidence review. Evidence review started with a scout search to identify existing evidence-based clinical guidelines, systematic reviews, and meta-analyses, which was then augmented by searches of the primary literature. Searches were performed in July 2011 within the following databases: Ovid-Medline (1996–date), Cochrane Database of Systematic Reviews (2005–June 2011), National Guidelines Clearinghouse, Clinical Evidence, DynaMed, and Trip. Figure 1 illustrates the literature selection schema.

Each selected article answered 1 or more of the initial clinical questions. At least 2 team members reviewed each article. Clinical questions, relevant articles, and the corresponding recommendations were then organized on standardized evidence and recommendation (E&R) sheets. One E&R sheet was generated for each clinical question.

When possible, the Grading of Recommendations Assessment, Development, and Evaluation (GRADE)³ methodology of rating evidence quality was used. An “expert opinion” rating was assigned when evidence was lacking or did not meet GRADE criteria (eg, guideline recommendations, case-control studies, etc). Table 1 summarizes the clinical questions and corresponding recommendations.

An algorithm (Fig 2) was created with hyperlinks to levels of evidence (ie, GRADE ratings and summary statements of E&R sheets) and was made available on our hospital intranet, external Web site (http://www.seattlechildrens.org/healthcare-professionals/gateway/pathways/), and from within our Clinical Information System order sets (Cerner Millennium). An e-mail address was provided to correspond with the NJP team for commentary and real-time feedback from the full spectrum of stakeholders.

The algorithm was created in concert with an order set so that recommendations mirrored each

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**FIGURE 1**

Literature selection schema. Six studies were ultimately selected to construct the recommendations. Adapted from Moher D, Liberati A, Tetzlaff A, Altman DG, for the PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. BMJ 2009;339:b2535.
**TABLE 1 Sixteen Clinical Questions Were Generated by the Committee**

<table>
<thead>
<tr>
<th>Clinical Question</th>
<th>CSW Recommendation(s) and Evidence Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 What are admission criteria for the inpatient unit and ICU?</td>
<td>There is no evidence to guide a recommendation. Established AAP thresholds should continue to be used to determine the need for floor admission for phototherapy or ICU admission for exchange transfusion. Criteria for automatic admission to the ICU: 1. signs of acute bilirubin encephalopathy; 2. bilirubin &gt;5 mg/dL above the exchange level (AAP definition); 3. sepsis or ill-appearing (E).</td>
</tr>
<tr>
<td>2 What are consultation criteria for ICU?</td>
<td>Consult neonatology to discuss any patient with 1 or more of the following: 1. a bilirubin level above exchange level (to discuss the need to order appropriate blood products for possible exchange transfusion); 2. a bilirubin level remaining above the exchange level after 4 h of intensive phototherapy; 3. gestational age at birth of &lt;35 wk; 4. an infant &lt;24 h of age; 5. patients with immune-mediated hemolysis for consideration of IV immunoglobulin use; and 6. the presence of questions regarding management of hyperbilirubinemia (E).</td>
</tr>
<tr>
<td>3 What are high-risk criteria for developing kernicterus?</td>
<td>Identify infants with hyperbilirubinemia as being at increased risk of developing kernicterus if they have any of the following: 1. a serum bilirubin level &gt;20 mg/dL in infants with a gestational age of 35 wk or more; 2. a rapidly rising bilirubin level of &gt;0.5 mg/dL per h; 3. clinical features of acute bilirubin encephalopathy (neurologic symptoms); or 4. jaundice within the first 24 h of life. Consider other risks for developing bilirubin encephalopathy, including 1. isoimmune hemolytic disease; 2. G6PD deficiency; 3. asphyxia; 4. lethargy; 5. sepsis; 6. acidosis; or 7. albumin &lt;3.0 g/dL (E).</td>
</tr>
<tr>
<td>4 What are indications for IV hydration?</td>
<td>Supplemental IVFs may be beneficial for some infants with hyperbilirubinemia and should be given to infants who are clinically dehydrated or who have a total serum bilirubin approaching the exchange transfusion level (exchange level: −2 mg/dL) or with a rapidly rising bilirubin level (≥0.5 mg/dL per h).¹</td>
</tr>
<tr>
<td>5 What is the best nutritional management?</td>
<td>Infants undergoing conventional phototherapy (ie, infants not near the exchange level) should not routinely be supplemented with IVF or formula.² Interruption of phototherapy for breastfeeding up to 30 min should be encouraged. For infants undergoing intensive phototherapy (ie, near the exchange level or rapidly rising bilirubin), IVF and/or enteral feeds should be given such that phototherapy is not interrupted.³ Maternal expressed breast milk is the additional feed of choice, when available.⁴ For infants with bilirubin near the exchange transfusion levels, use IVFs and do not interrupt phototherapy.⁵ Lactation consultation support for every inpatient admission (E).</td>
</tr>
<tr>
<td>6 What is the best fluid management?</td>
<td>Offer feeds every 2 h (breast milk preferred; formula is an option if there is inadequate breast milk production) (E).</td>
</tr>
<tr>
<td>7 What is the optimal rehydration strategy?</td>
<td>Mothers should be assessed for adequate milk supply (E). For high-risk patients, maximize the time under phototherapy (no more than 20 min out per 3 h) (E).</td>
</tr>
<tr>
<td>8 What initial laboratories (diagnostic tests) are indicated?</td>
<td>Test the following for all patients (E): 1. total serum bilirubin and 2. blood glucose Additional laboratories for concern for hemolysis⁶: 1. hematocrit; 2. blood group; 3. DAT; 4. reticulocyte count, and 5. G6PD (for unexplained hemolysis).</td>
</tr>
<tr>
<td>9 What daily laboratories (diagnostic tests) are indicated?</td>
<td>There are no good studies in which laboratory timing is examined. Frequencies recommended in various guidelines span a wide range. Recommendations are aimed at detecting rapidly rising bilirubin, identifying phototherapy failure, and avoiding unnecessary testing in select infants (E).</td>
</tr>
<tr>
<td>10 What follow-up laboratories are indicated and with what timing?</td>
<td>Check serum bilirubin ~12 h after starting phototherapy or with morning laboratories.⁶ Check serum bilirubin at 4–6 h after starting phototherapy for the following criteria: near exchange transfusion, age &lt;72 h, or hemolysis.⁴ Subsequent checks every 6–24 h as clinically indicated.⁶</td>
</tr>
<tr>
<td>11 What intensity of phototherapy is indicated?</td>
<td>Use LED therapy covering maximal body surface area (excluding eyes, genitalia). The adequacy of phototherapy can be documented with a bili-meter measurement ≥30 µW/cm² per nm over multiple locations (abdomen, head, knees, etc). Fiberoptic therapy alone is not recommended.⁷</td>
</tr>
</tbody>
</table>

other, thereby reducing variation. Links to evidence were directly available during the ordering process. If appropriate to their scope of practice, physicians and advanced registered nurse practitioners in the Department of Pediatrics were enrolled in an NJP intranet-based training module. The module was designed to create awareness of the pathway and highlight the most salient clinical recommendations. The module consisted of 47 slides and a 10 question self-assessment. Training was tracked with a goal of 80% compliance within 1 year of enrollment. Compliance at the time of data collection was 88%.

For NJP implementation, new light-emitting diode blankets and overhead lights along with paired radiometers were purchased to allow for more reliable therapy and regular bedside irradiance measurement at a cost to SCH of $40,515. Additional fields were added to our electronic medical record for documentation of irradiance measurements.

Nursing staff received information about the practice changes in staff meetings, through an online module, in weekly bulletins, and at change-of-shift huddles. Drop-in sessions were provided for inpatient nurses to practice using the new phototherapy equipment. In the emergency department (ED), all nurses attended mandatory education and simulation sessions. Simulation scenarios were used to highlight the new recommendations and new equipment.

Study of the Interventions

After going live, the pathway owner monitored and responded to feedback from end users. The NJP group met quarterly to review progress and refine implemented processes. All metrics were followed by using run charts. Core measures (CMs) and process measures (PMs) were obtained from the SCH electronic medical records system through our Enterprise Data Warehouse.

For data collection, a patient was deemed eligible for the NJP if 1 or more of following International Classification of Diseases, Ninth Revision (ICD-9) codes was used as the primary or secondary diagnosis: 774.1, 774.5, 774.6, 774.0, 774.30, 774.31, 774.39, 277.4, 773.0, 773.1, and 773.2. Patients were excluded if any of the following conditions were present: age >14 days, gestational age <35 weeks; primary service designation of Cardiology, Pulmonology, or Hematology and/or Oncology; concern for sepsis; or ICU admission. The following ICD-9 codes were also used as ineligibility criteria: 782.4, 995.91, and 995.92. Table 2 lists the included and excluded ICD-9 codes and their definitions.

New literature was also reviewed quarterly by using the same search terms and databases that were used in development.

Measures

Six CMs were assigned to the NJP:

1. **Volume**: The count of inpatient discharges meeting population criteria;
2. **Inpatient LOS**;
3. **Use of pathway**: The number of discharges with an activated NJP order set divided by the total number of discharges meeting population criteria;
4. **Charges per discharge**: The total charges for all discharges divided by the number of discharges meeting population criteria;
5. **Readmissions**: The number of inpatient discharges meeting population criteria with a return
inpatient admission for any condition, planned or unplanned, within 7 days of discharge. The readmission rate within 7 days of discharge was chosen as a balancing measure for inpatient LOS; and

6. Admission rate from the ED: The number of ED visits admitted to inpatient divided by total ED visits of patients meeting population criteria.

Three PMs were also assigned. PMs were chosen on the basis of their degree of overlap with the Institute of Medicine’s dimensions of care (safety, effectiveness, family centeredness, efficiency, timeliness, and equality). Each PM was assigned a goal (aim statement). Goals were determined by using existing local institutional benchmarks. Each PM was described by 2 key components: aim statement and rationale.

1. Median time from admission to phototherapy initiation: Prepathway data were limited to patients admitted on or after February 1, 2012, when conversion from paper to electronic nursing charting occurred at SCH:

   a. Aim statement: Time to initiation of phototherapy will be reduced by 30%;
   b. Rationale: Timely initiation of treatment results in best outcomes. The ease and speed of treatment initiation can be improved by optimizing equipment availability;

2. Intravenous (IV) fluid order rate:

   a. Aim statement: Administration of IV fluids (maintenance or bolus) will be reduced by 30%;
   b. Rationale: Routine use of supplemental IV fluids is not supported by the evidence and can interfere with feeding. Enteral feeding is an important component of therapy;

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FIGURE 2
Neonatal jaundice treatment algorithm. Hyperlinks (bold blue underlined text) link to additional features, such as the training module, additional learning material, the bibliography, or the rationale behind treatment recommendations. Recommendations guide the clinician from admission to discharge. TSB, total serum bilirubin; v2, version 2. (Reprinted with permission from Seattle Children’s Hospital. Clinical standard work pathways and tools: neonatal jaundice. Available at: http://www.seattlechildrens.org/healthcare-professionals/gateway/pathways/#n).
The United States. These hospitals are tertiary care pediatric hospitals in use data from over 45 not-for-profit, administrative database that contains were obtained from the PHIS, an National cost data for this study and truncated at the 99th percentile. Costs were adjusted to 2013 dollars and compared. Patients included in other analyses. This did not overlap completely with patients included in other analyses. Comparisons of continuous outcomes were made by using 2-sample t tests to test the difference between prepathway and postpathway periods. Differences in binary outcomes, such as frequency of readmission or whether IV fluids were ordered were evaluated by using χ² tests. All statistical analyses were conducted by using Stata version 12 (StataCorp, College Station, TX).

Analyses were conducted among all eligible patients, even if the NJP order set was not activated. For analyses including only inpatients, 69 pre- and 117 postpathway patients were compared. For analyses including patients discharged from the ED, 157 pre- and 125 postpathway patients were compared. For time to phototherapy analysis, the prepathway population was limited to patients admitted beginning on February 1, 2012, because of unreliable paper charting before that date.

Statistical process control (SPC) charts were used to plot and analyze certain measures, with the centerlines representing the average value of the measure and the upper and lower control limits representing 3 SDs from the mean. Nelson rules for special cause variation were applied, and centerlines were adjusted.

Cost allocation methodology was used to generate pre- and postpathway cost data analyses. The cost allocation methodology is used to take all organizational costs, such as labor, supplies, and facilities, and apply them to all chargeable items. Because of this methodology, internal costs were an approximation of actual costs. Cost detail was granular for the direct labor, supplies, and other costs for each chargeable item. Costs in the pre- and postpathway time periods were compared by using 2-sample t tests with bootstrap resampling methods. Bootstrap resampling was used to account for non-normality in the distribution of charges. Bias-corrected confidence intervals were reported.

Ethical Considerations
We obtained SCH Institutional Review Board approval. It was determined that this research involved no greater than minimal risk.

RESULTS
All patients in the analyses were evaluated per chart review to ensure the population definition was met. Analysis was limited to patients admitted beginning on February 1, 2012, because of unreliability paper charting before that date.

TABLE 2 Definitions of ICD-9 Codes Used as Inclusion and Exclusion Criteria for the Patient Population

<table>
<thead>
<tr>
<th>ICD-9 Code</th>
<th>Definition</th>
<th>Included or Excluded</th>
</tr>
</thead>
<tbody>
<tr>
<td>774.1</td>
<td>Perinatal jaundice from other excessive hemolysis</td>
<td>Included</td>
</tr>
<tr>
<td>774.5</td>
<td>Perinatal jaundice from other causes</td>
<td>Included</td>
</tr>
<tr>
<td>774.6</td>
<td>Unspecified fetal and neonatal jaundice</td>
<td>Included</td>
</tr>
<tr>
<td>774.0</td>
<td>Perinatal jaundice from hereditary hemolytic anemias</td>
<td>Included</td>
</tr>
<tr>
<td>774.30</td>
<td>Neonatal jaundice due to delayed conjugation, cause unspecified</td>
<td>Included</td>
</tr>
<tr>
<td>774.31</td>
<td>Neonatal jaundice due to delayed conjugation in diseases classified elsewhere</td>
<td>Included</td>
</tr>
<tr>
<td>774.39</td>
<td>Other neonatal jaundice due to delayed conjugation from other causes</td>
<td>Included</td>
</tr>
<tr>
<td>774.4</td>
<td>Disorders of bilirubin excretion</td>
<td>Included</td>
</tr>
<tr>
<td>773.0</td>
<td>Hemolytic disease of fetus or newborn due to rhesus isoimmunization</td>
<td>Included</td>
</tr>
<tr>
<td>773.1</td>
<td>Hemolytic disease of fetus or newborn due to ABO isoimmunization</td>
<td>Included</td>
</tr>
<tr>
<td>773.2</td>
<td>Hemolytic disease of fetus or newborn due to other and unspecified isoimmunization</td>
<td>Included</td>
</tr>
<tr>
<td>782.4</td>
<td>Jaundice, unspecified, not of newborn</td>
<td>Excluded</td>
</tr>
<tr>
<td>995.31</td>
<td>Sepsis</td>
<td>Excluded</td>
</tr>
<tr>
<td>995.32</td>
<td>Severe sepsis</td>
<td>Excluded</td>
</tr>
</tbody>
</table>

ABO, blood types A, B, and O.
from pathway” orderable (for ordering flexibility, the practitioner could use individual orders within the NJP order set but exclude the patient from the pathway via an exclude from pathway orderable).

**CMs**

*Inpatient LOS*

Mean LOS in 117 prepathway patients was 1.30 days compared with 0.87 days in 69 postpathway patients (P < .001). SPC is depicted in Fig 3. Special cause variation was met when 9 sequential points fell below the original centerline.

**Use of Pathway**

The order set activation rate for eligible patients postpathway was 96%. Before going live, this was not tracked.

**Readmission**

There was no difference in readmission before and after implementation (3% vs 0%; P = .15).

**Admission Rate From the ED**

Sixty-six percent of prepathway patients were admitted from the ED to an inpatient setting (1 was diverted because of the high census at SCH), compared with 50% of postpathway patients (P = .01).

**PMs**

*Mean Time From Order to Phototherapy Initiation*

The mean time from phototherapy order to initiation in 14 prepathway patients was 101.26 minutes compared with 54.67 minutes in 67 postpathway patients (P = .03).

*IV Fluid Order Rate*

Eighty percent of prepathway patients had IV fluids ordered at some point in their ED or inpatient course, compared with 44% of postpathway patients (P < .001).

SPC is depicted in Fig 4. Special cause variation was met when 4 out of 5 sequential points fell at least 2 SDs below the original centerline.

**Irradiance Compliance**

After going live, measurement of blanket irradiance every 8 hours occurred 92% of the time, whereas measurement of overhead light irradiance every 3 hours occurred 52% of the time.

**Cost Comparisons**

At SCH, the prepathway mean cost per discharge was $4767, compared with $3989 postpathway (decrease of $778 per discharge). At other PHIS hospitals in the same pre- and postpathway time periods, the mean cost per discharge increased from $4626 to $5064 (increase of $438 per discharge).

A comparison of the mean costs per discharge pre- and postpathway is depicted in Table 3. Statistically significant reductions in the cost per patient encounter were observed in the following categories: IV fluids, laboratory, room cost, and ED charges. SPC for total charges is depicted in Fig 5. Special cause variation was met when 9 sequential points fell below the original centerline.
DISCUSSION

Summary and Interpretation

The NJP demonstrated quality improvements in timeliness of interventions, expedited recovery, and less invasive care because of fewer laboratory draws and decreased IV usage. It accomplished this with no increase in readmissions, a decreased admission rate, and lower cost. Notably, the SCH prepathway mean cost per discharge exceeded other PHIS hospitals, whereas the SCH mean cost per discharge dropped below that of other PHIS hospitals after NJP going live. Our results reveal that improved quality and health outcomes are drivers of cost containment. This enhanced value becomes multiplied by an institution’s ability to standardize that care process. Standardization is best achieved by providing clinicians with tools that facilitate implementation of recommendations and explain the rationale behind each recommendation. In this manner, value can be optimized across entire populations of patients with little variation.

Before the implementation of the NJP, there was high variability in care delivery to this patient population. Specifically, there were multiple types of phototherapy equipment in use, irradiance measurement was not standard, and the breadth and frequency of laboratory testing were determined by individual practitioner preference. There was a dearth of information to guide clinicians in their decisions to stop phototherapy. Furthermore, care for these patients was not delivered on the basis of risk stratification, so opportunities to reduce interventions and LOS were missed.

We postulate that the gains from this pathway were due to a combination of factors. Stratifying interventions on the basis of risk allowed for reduced invasiveness and shorter LOS for a significant portion of the population (ie, those more than 72 hours old and those whose total serum bilirubin was >2 mg/dL below the exchange threshold). This in turn led to cost reduction without an increase in the readmission rate for that subset of the population. Furthermore, by ensuring uniformity of phototherapy equipment and consistent delivery of high-intensity irradiance in alignment with the recommendations of the AAP, the efficiency of phototherapy was improved. Finally, we provided clear guidance for stopping phototherapy, discharge criteria, and follow-up, thereby allowing for reductions in rebound testing and LOS.

Ultimately, these improvements would not have been achieved without adherence to the recommendations by nurses and clinicians across our organization. In the process of developing, implementing, and improving the NJP, we strove to adhere as much as possible to the Institute of Medicine’s standards for trustworthy guidelines. Our end users could trust that the NJP was developed by a multidisciplinary group looking systematically at the available evidence and, where insufficient evidence was available, looking to internal and external experts to establish recommendations. NJP materials were made visible to

<table>
<thead>
<tr>
<th>Category</th>
<th>Mean Cost Pre ($)</th>
<th>Mean Cost Post ($)</th>
<th>Difference</th>
<th>95% Confidence Interval for Difference</th>
</tr>
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<tbody>
<tr>
<td>Total</td>
<td>5970</td>
<td>4416</td>
<td>-1553*</td>
<td>-2802 to -707</td>
</tr>
<tr>
<td>Pharmacy: IV fluid-related</td>
<td>145</td>
<td>57</td>
<td>-87*</td>
<td>-113 to -61</td>
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<tr>
<td>Pharmacy: other</td>
<td>13</td>
<td>4</td>
<td>-10</td>
<td>-40 to 4</td>
</tr>
<tr>
<td>Laboratory</td>
<td>559</td>
<td>370</td>
<td>-189*</td>
<td>-270 to -104</td>
</tr>
<tr>
<td>Blood bank</td>
<td>97</td>
<td>60</td>
<td>-37</td>
<td>-73 to 4</td>
</tr>
<tr>
<td>Room charges</td>
<td>3699</td>
<td>2423</td>
<td>-1276*</td>
<td>-1961 to -557</td>
</tr>
<tr>
<td>Occupational and/or physical therapy</td>
<td>53</td>
<td>46</td>
<td>-7</td>
<td>-49 to 40</td>
</tr>
<tr>
<td>Diagnostic imaging</td>
<td>49</td>
<td>15</td>
<td>-34</td>
<td>-101 to 13</td>
</tr>
<tr>
<td>Other</td>
<td>11</td>
<td>15</td>
<td>4</td>
<td>-9 to 28</td>
</tr>
<tr>
<td>ED: professional fees</td>
<td>1170</td>
<td>1328</td>
<td>158*</td>
<td>30 to 290</td>
</tr>
<tr>
<td>ED: IV fluid-related</td>
<td>4</td>
<td>14</td>
<td>10*</td>
<td>1 to 21</td>
</tr>
<tr>
<td>ED: other</td>
<td>164</td>
<td>73</td>
<td>-91*</td>
<td>-140 to -42</td>
</tr>
</tbody>
</table>

Costs are adjusted to 2013 dollars. All patients are included in the comparison. In this analysis, we use the mean outcomes from 1000 bootstrapped samples to generate a cost difference estimate and bias-corrected confidence intervals. OT, occupational therapy; PT, physical therapy.

* P < .05.

FIGURE 5

SPC chart for total charges. LCL, lower control limit; UCL, upper control limit.
end users in multiple formats to maximize transparency. Finally, our team was committed to regular assessments to address end-user feedback in a timely manner and to using our CMs and PMs to guide improvements.

Limitations
Our population included only neonates already discharged from newborn nurseries. Our pathway and results may therefore not be fully applicable to newborn nursery settings. Additionally, the trend in cost reduction for our NJP patients versus those at other PHIS hospitals may be attributable to differences in the patient populations served by each hospital.

During the timeframes of our analysis, we know of no other major interventions initiated by SCH surrounding the reduction of LOS for patients with conditions similar to jaundice in their complexity. Additionally, we know of no changes in how LOS was measured by our institution.

CONCLUSIONS
At SCH, we demonstrated an improvement in clinical and process outcomes with the implementation and monitoring of an evidence-based clinical pathway for management of neonatal jaundice. We conclude that an evidence-based standard care pathway for neonatal jaundice can significantly improve multiple dimensions of value, including reductions in cost and LOS.

The standardized development tools and processes described here are transferrable to other institutions. High-value care for patients with neonatal jaundice can therefore be optimized for patients in our large referral region, nationally, and worldwide. LOS data can be used to help identify hospitals that might benefit from adoption of our pathway. Because SCH had to invest $40 515 to achieve these efficiencies, which accrued to −$121 680 per year, there is an opportunity for payers to assess the value equation for this care to determine if they might subsidize these hospitals to obtain the equipment and training necessary to replicate this intervention.

ACKNOWLEDGMENTS
We acknowledge Mark Del Beccaro, MD, Chief Medical Officer, and Kathy Mullin, RN, for their oversight of this and other SCH Clinical Effectiveness initiatives. We acknowledge Suzanne Spencer, MBA, MHA, for providing knowledge management leadership.

REFERENCES

ABBREVIATIONS
AAP: American Academy of Pediatrics
CM: core measure
E&R: evidence and recommendation
ED: emergency department
GRADE: Grading of Recommendations Assessment, Development, and Evaluation
ICD-9: International Classification of Diseases, Ninth Revision
IV: intravenous
LOS: length of stay
NJP: neonatal jaundice pathway
PHIS: Pediatric Health Information System
PM: process measure
SCH: Seattle Children’s Hospital
SPC: statistical process control
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