Surgical Site Infection Reduction by the Solutions for Patient Safety Hospital Engagement Network

Joshua K. Schaffzin, MD, PhD, Lory Harte, PharmD, CPhQ, Scott Marquette, MHSA, Karen Zieker, MS, Sharyl Wooton, MS, Kathleen Walsh, MD, MSc, Jason G. Newland, MD, Med

OBJECTIVE: Surgical site infections (SSIs) negatively affect patients and the health care system. National standards for SSI prevention do not exist in pediatric settings. We sought to reduce SSI-related harm by implementing a prevention bundle through the Solutions for Patient Safety (SPS) national hospital engagement network.

METHODS: Our study period was January 2011 to December 2013. We formed a national workgroup of content and quality improvement experts. We focused on 3 procedure types at high risk for SSIs: cardiothoracic, neurosurgical shunt, and spinal fusion surgeries. We used the Model for Improvement methodology and the Centers for Disease Control and Prevention SSI definition. After literature review and consultation with experts, we distributed a recommended bundle among network partners. Institutions were permitted to adopt all or part of the bundle and reported local bundle adherence and SSI rates monthly. Our learning network used webinars, discussion boards, targeted leader messaging, and in-person learning sessions.

RESULTS: Recommended bundle elements encompassed proper preoperative bathing, intraoperative skin antisepsis, and antibiotic delivery. Within 6 months, the network achieved 96.7% reliability among institutions reporting adherence data. A 21% reduction in SSI rate was reported across network hospitals, from a mean baseline rate of 2.5 SSIs per 100 procedures to a mean rate of 1.8 SSIs per 100 procedures. The reduced rate was sustained for 15 months.

CONCLUSIONS: Adoption of a SSI prevention bundle with concomitant reliability measurement reduced the network SSI rate. Linking reliability measurement to standardization at an institutional level may lead to safer care.

Surgical site infections (SSIs) are common, accounting for nearly one-third of all health care–associated infections among hospitalized adults.1,2 These infections increase patient morbidity and mortality and pose a high cost burden to the US health care system.3–5 In 1 study, the national SSI rate in children was reported to be 1.8%.6 Procedures that have been associated with higher SSI rates in children include cardiothoracic, neurosurgical ventricular shunt, and spinal fusion surgeries. Reported rates of infection have large institutional variability: 2.3% to 5% for cardiothoracic,7–9 5.7% to 10.4% for neurosurgical ventricular shunt,10–12 and 4.4% to 10.2% for spinal fusion surgeries.13–16 For this reason, these 3 types of procedures are commonly monitored for SSIs and targeted for SSI reduction.

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In 2011, a national hospital engagement network (HEN), Solutions for Patient Safety (SPS), was established to eliminate harm in hospitalized children.17 One goal of the HEN was to eliminate SSIs among cardiothoracic, neurosurgical ventricular shunt, and spinal fusion surgeries. Previous work among a collaborative network of 8 children’s hospitals in Ohio demonstrated an increase in the number of months in which no SSI occurred when a common prevention bundle was adopted.18 We describe the formation of a national pediatric SSI prevention network and its impact on reducing SSI rates among high-risk surgeries.

**METHODS**

**Setting**

Children’s Hospitals SPS is a national network of children’s hospitals working together to eliminate serious harm among children hospitalized in the United States.17 At the time of the study, January 2011 through December 2013, the network comprised 33 children’s hospitals nationwide. SPS was initiated as part of the federal Partnership for Patients initiative, a nationwide public-private collaboration to improve the quality, safety, and affordability of health care for all Americans.19 SPS is the only HEN focused on pediatric patient safety and prevention of common hospital-acquired conditions.

**Planning the Intervention**

A network leadership team of subject matter and quality improvement experts was recruited. The Model for Improvement was used, including root cause and failure mode analysis and key driver identification.20 Analyses of process and outcome data were used to design interventions. Interventions were tested through a series of plan/do/study/act cycles.20 The key driver diagram was updated periodically to incorporate learning from observations, feedback, and testing and to guide future work. This work was determined not to be human subjects research and therefore was exempt from institutional review.

**Operational Definitions**

A detailed operational definition document was generated and shared with all network hospitals (see Supplemental Information). An included procedure was defined as a spinal fusion, neurosurgical ventricular shunt, or cardiothoracic surgery in which the chest was fully closed in the operating room, in concert with National Health Safety Network (NHSN) definitions at the time.21,22 Procedures during which the patient had an active infection, growing construct adjustments, and refusion procedures were excluded. For neurosurgical ventricular shunts, facilities were given 2 options for reporting. The preferred method was dividing shunt procedures into 3 separate groups: primary shunts, secondary shunts, and revision shunts (Supplemental Appendix A). The second option was reporting all neurosurgical ventricular shunt procedures as 1 according to NHSN definitions.22

An SSI was defined according to definitions published by the Centers for Disease Control and Prevention and NHSN.21,22 Changes made to the national definition in January 2013, which shortened the postoperative surveillance period for certain surgical procedures, were incorporated into the network’s outcome definition.22 The incidence of SSI was measured as events per 100 included procedures.

Based on published evidence and team consensus, 6 elements believed to reduce the risk of SSIs were included in a recommended bundle for all participating hospitals (Table 1). The bundle was distributed to all network hospitals. Hospitals were given the option to implement all or a set of individual bundle components. Hospitals were expected to measure the reliability of the bundle elements implemented. Reliability was measured as the number of audited opportunities per month in which all components of the locally implemented bundle were completed divided by the number of audited opportunities multiplied by 100.

**Improvement Activities**

Bundle implementation began in January 2012. The network SMART (specific, measurable, attainable, relevant, and time-based) aim was to reduce the mean network SSI rate from 2.5 to 1.5 SSIs per 100 procedures by December 31, 2013. This goal was determined by consensus among network partners that a 40% rate reduction would be considered a significant improvement. Achievement of this aim would rely on the following key drivers: reliable implementation of SSI prevention bundle, focus on 3 key surgical procedure types (cardiothoracic, neurosurgical ventricular shunt, and spinal fusion surgeries), transparency of data to drive continual learning and improvements, and effective use of high-reliability methods (Fig 1).

Participating institutions created local improvement teams with institution senior leadership support to facilitate implementation of SSI prevention measures. Institutions were asked to review the bundle elements to select which best suited their context for immediate implementation. Institutions were not asked to report which components they chose but were expected to measure and report the reliability of completion of the components they chose to implement. For example, if an institution chose to implement 3 of the 6 recommended components, it would report the proportion of included patients for whom all 3 components were completed.
We encouraged all institutions to use high-reliability methods, including regular reporting of process and outcomes measures with senior leaders, daily huddles for process failure review, systematic analysis of infections as they occurred, and promotion of a safety culture.23,24 Quality improvement science and application webinars were delivered monthly to network participants. The webinar curriculum followed the Model for Improvement20 and included use of hospital case studies to demonstrate methodology.

Network Dissemination Methods

SPS developed a learning network, based on the Institute for Healthcare Improvement Breakthrough Series methodology,25 among member hospitals to improve several hospital-acquired conditions, including SSIs. SPS conducted regularly scheduled webinars and an annual in-person learning session. Webinars reviewed the current process and outcome data and discussed successes and barriers with the bundle. The All Teach, All Learn philosophy of open sharing of successes, failures, and lessons learned was discussed in all webinars. An SPS Sharepoint site was established for posting of relevant materials, as well as a discussion board where network members could post comments and questions. Network leaders were responsible for responding to questions and were available for informal coaching sessions for institutions as needed.

Data Collection and Analysis

Data on process and outcomes were collected locally and submitted on a monthly basis to SPS using a web-based form. Data submissions were due within 2 months, on the 10th of the month (eg, January data were due March 10). SSIs were counted according to the month when the procedure took place; hospitals could update the numbers of SSIs as they were identified. Network-level process control charts were maintained to track the bundle reliability (U-charts) and outcome measures (P-charts). Data were analyzed by using statistical process control methods. Initial centerline values were calculated by using the first 12 months of measurement (January through December 2011). Special cause, a pattern of performance that was not part of the existing system as a result of a change in the system, was defined as either ≥8 consecutive points above or below the mean or any single point outside of the upper or lower control limits.26

RESULTS

Demographics of Hospital Network

The 33 HEN hospitals were located in 20 states and the District of Columbia. Regionally, 15% were located in the Northeast, 15% in the Southeast, 45% in the Midwest, 9% in the Southwest, and 15% in the Northwest. The
average number of licensed beds was 317 (range 72 to 595).

**Bundle Adherence and SSI Rates**

Of the 30 hospitals reporting baseline SSI rates, approximately one-third (8 to 10 hospitals per month) submitted data from January to December 2011. These data were used to calculate mean baseline reliability, which was 89.9%. The number of hospitals submitting reliability data increased steadily, with close to 90% of hospitals submitting reliability data by June 2013. Within 6 months, mean adherence increased to 93.7%, then reverted to a sustained rate of 91.4% (Fig 2).

The baseline network SSI rate for all 3 procedure types combined was 2.5 per 100 procedures. Within 10 months of network formation, the SSI rate decreased to 1.8 per 100 procedures and was sustained for 15 months (Fig 3). During the same time period, rate reduction after bundle implementation was also seen among cardiothoracic surgeries (1.7 to 1.3 per 100 procedures) and neurosurgical ventricular shunt procedures (3.2 to 2.3 per 100 procedures). For spinal fusion surgeries, a reduction in rate (3.7 to 2.1 per 100 procedures) was observed, although the shift began before network formation (data not shown). Among individual hospitals, 12 (36%) of the 33 had a significant reduction (measured by a centerline shift) in SSI rates. Additionally, 27 (90%) of the 30 facilities reporting baseline data demonstrated a significant reduction in SSI rates in at least 1 of the 3 procedure types followed.

**DISCUSSION**

The collaborative SPS HEN successfully reduced the SSI rate of cardiothoracic, neurosurgical ventricular shunt, and spinal fusion surgeries by 21%. This study is the first in pediatrics to demonstrate on a national scale that increasing reliability of part or all of a recommended SSI prevention bundle for high-risk surgeries can result in significant improvement.

Our choice of recommended bundle components was driven by high-quality, rigorous evidence. Because such evidence is limited for prevention of pediatric SSIs in the included high-risk surgeries, the relevant pediatric literature was used along with adult literature. Surgical Care Improvement Project measures were evaluated because they represent a national standard and have been shown to reduce SSI rates among adult surgical patients. We were careful to choose only those measures we believed would be most appropriate for pediatric populations. Specifically, we chose to not include proper choice of intraoperative antibiotic, despite its inclusion in adult guidance. This decision was in part due to a lack at the time of comprehensive national guidance for antibiotic choice in pediatric populations. The most recent guidelines do include pediatric recommendations based on expert opinion.

The network operational definitions for surgical procedures and SSIs were aligned with national standards for consistency across network hospitals. During the study period, the NHSN surveillance definition for SSI changed, shortening the surveillance period for tracked procedures from 365 to 90 days after the procedure. This change would be expected to reduce SSI rates, and therefore to affect our outcome measure. When we applied the new definition to data collected before the change, 3% of the reduction observed was due to the definition change (data not shown). The remainder of change, 21%, is how much we reduced the network SSI rate.

An important aspect of the improvement observed was the willingness of a diverse group of hospitals to work as a collaborative. This strategy has been beneficial in improving other health care–acquired conditions, including central line–associated bloodstream infections and ventilator-associated pneumonia. As in similar cases, this allowed us to learn both as institutions and as a network. The Model for Improvement served as an excellent basis to enhance or initiate quality improvement work among network partners and ultimately to change outcomes. Network learning, rather than intense individual institutional training, seems to have been sufficient to enable groups to implement and measure successfully.

Institutional context is believed to affect organizational and practice change. In our study, the SPS network partners represented a heterogeneous group of children’s hospitals with respect to geography, catchment area population, size, and quality improvement experience at the onset of our project. Furthermore, we permitted heterogeneity in the interventions implemented among institutions. Despite this heterogeneity, success was achieved at a network level in process reliability and outcome, and 27 of 30 hospitals reported a significant rate improvement in at least 1 area measured. Our project was based on the belief that standardization of processes with high reliability leads to safer care. It is possible that the standardized approach played a significant role in the outcome improvement, perhaps to an extent equal to or greater than the bundle components themselves.

We established our goal SSI rate of 1.5 per 100 procedures based on group consensus seeking a 40% improvement from our baseline rate of 2.5 per 100 procedures. A national benchmark for pediatric SSI rates does not currently exist, and published rates are predominantly from single centers and may overestimate rates on a national scale. Although we did not
achieve our goal rate, we did achieve a ∼21% improvement in overall SSI rate across the network (Fig 3). The establishment of clear goals is believed to be an important factor in quality improvement efforts, which may have influenced our efforts as a network. In practice, many partners faced data-related challenges that caused delays in SSI rate determination and prevented timely SSI rate feedback to system participants. We instead focused on achieving high reliability with our processes, for which timely feedback was easily available. We used our rate chart as a long-term indicator of system change, in which movement toward our goal, if not beyond the goal, was considered a success.

High reliability is believed to be essential for a process to affect an outcome. The reliability of our system remained moderate throughout the study period. Therefore, it is unclear whether the increase in reliability observed during the study influenced the SSI rate directly. Specifically, system reliability improved by 1.5% (89.9% to 91.4%) and remained less than the >95% reliability standard established for other bundles. However, improvement in SSI rates may not be directly linked to bundle reliability. SSI prevention does not fit the original bundle model developed for catheter-associated infection or ventilator-associated pneumonia, mainly owing to a lack of a defined team in 1 geographic location. Additionally, a recently published SSI prevention bundle for colorectal surgery demonstrated significant improvement despite not demonstrating high reliability. Furthermore, significant improvement in outcomes has been reported with lower reliability rates than observed in our study, as low as 51% in 1 instance. Thus, it is likely that other factors contributed to the reduction in SSI rate, such as system learning and the development of a culture of safety, to which all SPS network partners commit.

Interpretation of our findings is subject to limitations common to quality improvement methodology. Specifically, facilities selected which bundle components to implement, so interventions are likely not the same among all hospitals. Therefore, we cannot determine which bundle components most affected the SSI rate, nor can we determine to what degree, if any, adherence to a portion of the components influenced the outcome. Future studies are necessary to understand the interaction of practice standardization, adherence to bundle components, and the specific bundle components that result in the lowest SSI rates. Additionally, the change in SSI rates could have been due to a secular trend. Identification of special cause
as well as sustainment of the lower SSI rate suggests it is indeed a result of our improvement work. Finally, our study was not designed to assess the effect on reliability and outcome of team composition, attendance at network sessions, or implementation strategy. Further study of these effects could inform future large-scale multicenter quality transformation efforts.

CONCLUSIONS
Using quality improvement methods to standardize care reduced SSI rates among high-risk pediatric surgeries. Despite the likely heterogeneity in actual interventions implemented across the network, we successfully reduced harm to patients and cost to the health care system. Future study is necessary to evaluate the effect of individual bundle elements on SSI prevention.

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ABBREVIATIONS
HEN: hospital engagement network
NHSN: National Healthcare Safety Network
SPS: Solutions for Patient Safety
SSI: surgical site infection

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