Implementation of an Inpatient Pediatric Sepsis Identification Pathway
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Drs Bradshaw and Goodman conceptualized and designed the study, coordinated and supervised data collection, undertook acquisition of data of included patients, and drafted the initial manuscript; Dr Bandera carried out data collection; Dr Rosenberg conceived and designed the study, performed data analysis, and assisted with drafting the manuscript; Drs Fierman and Rudy conceived and designed the study, and assisted with drafting of the manuscript, including all revisions; all authors approved the manuscript as submitted.

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Septic shock remains a leading cause of mortality and hospitalization in children worldwide. The American Heart Association/American College of Critical Care Medicine Clinical Practice Parameters for Hemodynamic Support of Pediatric and Neonatal Shock and the Surviving Sepsis Campaign emphasize early, goal-directed therapy within the first hour of identification. Every hour of delay in therapy is associated with an escalating risk of mortality. In pediatric emergency rooms, triage tools and septic shock protocols have been shown to reduce time to the recognition of septic shock and the initiation of antibiotics and fluids. These also have been shown to positively affect outcomes including decreased length of stay and a trend toward decreased mortality. These tools may have a role on pediatric inpatient units; however, their use in these settings has not been widely studied.

In May 2013, the New York State Department of Health mandated that hospitals have a system in place to identify and manage severe sepsis and septic shock. We sought to identify and evaluate children with possible sepsis on a pediatric medical/surgical unit through successful implementation of a sepsis identification pathway.

METHODS: The sepsis identification pathway, a vital sign screen and subsequent physician evaluation, was implemented in October 2013. Quality improvement interventions were used to improve physician and nursing adherence with the pathway. We reviewed charts of patients with positive screens on a monthly basis to assess for nursing recognition/physician notification, physician evaluation for sepsis, and subsequent physician diagnosis of sepsis and severe sepsis/septic shock. Adherence data were analyzed on a run chart and statistical process control p-chart.

RESULTS: Nursing and physician pathway adherence of >80% was achieved over a 6-month period and sustained for the following 6 months. The direction of improvements met standard criteria for special causes. Over a 1-year period, there were 963 admissions to the unit. Positive screens occurred in 161 (16.7%) of these admissions and 38 (23.5%) of these had a physician diagnosis of sepsis, severe sepsis, or septic shock. One patient with neutropenia and septic shock had a negative sepsis screen due to lack of initial fever.

CONCLUSIONS: Using quality improvement methodology, we successfully implemented a sepsis identification pathway on our pediatric unit. The pathway provided a standardized process to identify and evaluate children with possible sepsis requiring timely evaluation and treatment.
sepsis by December 31, 2013 (New York Codes Rules and Regulations Sections 405.2 and 405.4). Before our intervention, there was no screening system for sepsis on the pediatric ward and no standardized protocol for management. Our primary objective was to identify and evaluate all pediatric inpatients with possible sepsis through successful implementation of a sepsis identification pathway. Our aim was to achieve 80% adherence by nursing and house staff with the pathway within 6 months. We also determined the percentage of patients with an abnormal screen and percentage of patients with an abnormal screen with a subsequent physician diagnosis of possible sepsis or severe sepsis/septic shock.

**METHODS**

**Study Design and Setting**

We performed a monthly chart review of patients admitted to the general pediatric ward at Tisch Hospital between October 2013 and October 2014 with vital signs consistent with possible sepsis. We used an interrupted time-series design to assess nursing and physician adherence to the sepsis pathway. The pediatric unit is a 32-bed medical/surgical unit within a tertiary academic medical center. There are multiple admitting services to the pediatric unit, including general pediatrics, pediatric subspecialties, and pediatric surgical subspecialties. There are 56 rotating pediatric residents who care for all inpatients with pediatric attending supervision. Before the intervention, a pediatric response team existed on the unit, but there was no early warning system.

**Pathway Development and Description**

The sepsis identification pathway was developed during the summer of 2013 as part of an institution-wide sepsis strategy involving a multidisciplinary improvement team of pediatric hospitalists, emergency department physicians, critical care physicians, nurse managers, a bedside nurse, a nurse educator, and a resident physician. The pathway was initiated on the pediatric unit in October 2013 in conjunction with a pediatric severe sepsis management protocol that was based on American Heart Association/American College of Critical Care Medicine guidelines.

The pathway consisted of a vital sign screen, followed by an immediate standardized physician evaluation (Fig 1). The criteria for the vital sign screen and physician evaluation were adapted from the 2005 Pediatric Sepsis Consensus Conference definitions for systemic inflammatory response syndrome (SIRS) and the American Heart Association/American College of Critical Care Medicine guidelines with several modifications. An abnormal screen was defined as a temperature abnormality as the initial trigger, combined with either a respiratory rate abnormality (from Warren et al and previously used in the BCCH Severe Sepsis Guideline) or a heart rate abnormality (adjusted for degree of fever as described by Cruz et al). White blood cell count was not included in the screen, as these data might not be readily available for all patients at the time of the assessment.

Per unit protocol, vital signs were taken on all patients every 4 hours. Once an abnormal set of vital signs consistent with an abnormal screen was identified, the bedside nurse notified the resident physician who was then required to evaluate the patient within 10 minutes. During the evaluation, the physician considered whether a condition other than sepsis could explain persistent vital sign abnormalities (eg, pain, anemia, dehydration) and whether the patient had a suspected or proven infection. The patient was then evaluated for signs of end-organ dysfunction consistent with severe sepsis/septic shock. The pathway recommended that patients with possible sepsis but without organ dysfunction be managed with continuous monitoring, attending physician notification, reassessment, and consideration of fluid resuscitation and antibiotics. Any patient with organ dysfunction was immediately managed according to the severe sepsis/septic shock protocol and transferred to the PICU. The resident physician was responsible for documenting an evaluation, a diagnosis based on examination (no sepsis, possible sepsis, severe sepsis/septic shock), and plan in the medical record for patients with an abnormal screen. If a patient had more than 1 abnormal screen during the admission, the physician was expected to continue to evaluate the patient and document a new evaluation for the patient every 12 hours until the abnormal screens ceased.

**Pathway Implementation and Physician and Nursing Education**

We took the following actions to educate nursing and physicians and to increase awareness of the pathway on the unit:

One month before implementation, the sepsis identification pathway was distributed to all unit nurses and resident physicians and posted in prominent locations on the inpatient ward and workrooms. A nurse educator and nurse champion educated all nurses and patient care technicians and highlighted the importance of identifying vital signs constituting an abnormal screen and notifying a pediatrician immediately.

Faculty were educated at a faculty meeting and received a copy of the pathway via e-mail. The pathway and severe sepsis protocol were posted on the pediatric department Web site. Faculty were reeducated...
at a faculty meeting 6 months into implementation. An order set for management of pediatric severe sepsis was included in the hospital electronic medical record (EMR).

Starting with month 1 of implementation and continuing throughout the study period, resident physicians beginning their monthly rotation on the pediatric ward underwent a short orientation. This orientation included a review of the proper use of the pathway as well as instruction in the diagnosis and management of SIRS, sepsis, severe sepsis, and septic shock.

During the first 6 months of implementation, physicians on their inpatient rotation, ward nurses, and patient care technicians participated in monthly sepsis mock codes usually based on difficult cases from the previous month.

Charts were reviewed monthly by members of the improvement team, and adherence data and feedback were provided via e-mail to the improvement team, nursing, and resident physicians on a monthly basis.

All patient care providers completed a mandatory hospital-wide online e-module on early recognition of management of sepsis.

**Interventions**

Several plan-do-study-act cycles were implemented to improve nursing and resident physician cooperation and adherence to the sepsis pathway.
adherence to the pathway. At the time of implementation, the screen was not integrated into the hospital EMR, and resident physicians and nurses on the unit relied on a paper screening tool. A "badge buddy" with an abbreviated version of the screen was provided to all ward nurses and resident physicians. This allowed nurses to quickly check if a patient had an abnormal screen whenever a temperature abnormality was recorded. To increase awareness of the pathway, discussion of all patients with an abnormal screen was added to a preexisting daily unit safety huddle.

Review of adherence during the first 3 months of implementation revealed that only 57% of abnormal vital sign screens identified by nursing had a physician note documenting evaluation for possible sepsis. Several interventions were undertaken to increase physician adherence to the pathway. Nurses were instructed to use the scripted phrase to convey the urgency of an abnormal screen when alerting physicians. This phrase was "Your patient meets criteria for possible sepsis, please evaluate the patient immediately." A noon-conference lecture on the sepsis identification pathway and the diagnosis and management of sepsis was given to all pediatric residents. Additionally, a sepsis evaluation note template was created in the EMR to decrease the time required for the physician to document the evaluation as well as to standardize documentation. This note required physicians to choose a diagnosis based on their findings by using a drop-down menu with choices including no sepsis, SIRS, possible sepsis, and severe sepsis/septic shock and included a definition of these diagnoses to assist resident physicians in their decision-making process.

Methods of Evaluation

We performed a monthly chart review of all patients with an abnormal screen on the pediatric unit during the year of implementation. Three of the authors developed a set of guidelines regarding data collection and a spreadsheet to input relevant data. The guidelines and spreadsheet were piloted over the first 3 months of the intervention and modified to improve data collection. Guidelines for abstraction of data are shown in Supplemental Table 2. Each month, a patient list was generated from the electronic health record for the previous month, identifying all patients with a temperature abnormality (>101.3°F or <96.8°F) at any time during hospitalization. All timing was noted using EMR time stamp. These charts were then evaluated to identify whether the patient had other vital sign criteria consistent with an abnormal screen at the time of the temperature abnormality. Nursing documentation was reviewed to determine if the nurse documented notification of the physician of an abnormal screen in the EMR. These charts were then further reviewed for presence of physician documentation of evaluation for sepsis within 12 hours after an abnormal screen. When questions arose about interpretation of data, the authors met, reviewed the chart and guidelines, and came to a consensus. Ten percent of charts were reviewed for adherence with the guidelines for abstraction. To ensure that patients with severe sepsis/septic shock were not missed by the vital sign screen, we also used EMR reports to identify all children with an EMR problem list of sepsis, severe sepsis/septic shock and reviewed a list of all patients with International Classification of Diseases, Ninth Revision and 10th Revision codes for sepsis, severe sepsis/septic shock. Our primary measure was nursing and resident physician adherence with the sepsis identification pathway. Each month we calculated the percentage of abnormal screens with associated nursing recognition and physician notification and the percentage of abnormal screens with documented evaluation for sepsis by a physician. Our secondary measure was the percentage of all patient admissions to the unit with ≥1 abnormal screens. We then calculated the percentage of patients with ≥1 abnormal screens who had a subsequent physician diagnosis of possible sepsis and severe sepsis/septic shock. These charts were re-reviewed by 2 physician reviewers for accuracy of diagnosis and concordance with the 2005 International Pediatric Sepsis Consensus Conference Definitions for Sepsis.9 Interrater reliability (κ) was calculated between the 2 reviewers. As the diagnoses of severe sepsis and septic shock received similar initial treatment according to the sepsis identification pathway and were difficult to differentiate based on the initial physician assessment, they were combined into the same diagnostic category. We also calculated the percentage of documented physician evaluations for possible sepsis with a plan for a diagnostic or therapeutic intervention (laboratories, imaging, normal saline bolus, antibiotics, ICU consult/ICU transfer).

Analysis

We used an interrupted time series design. A statistical process control p-chart was used to monitor adherence with the pathway over time. The center line represents the mean adherence calculated over the study period. The upper and lower control limits define 3 SDs above and below the mean. Nelson rules were used to determine criteria for special cause variation.12 QI Macros for Excel was used for production of charts and for statistical analysis.

This study was reviewed and approved as a quality improvement study by the New York University Langone Medical Center institutional...
RESULTS

During the first month of implementation, full completion of the sepsis identification pathway (abnormal vital sign recognition by nursing and bedside evaluation by a physician) was achieved in only 50% of cases. Reaching and exceeding 80% pathway adherence by nursing and physicians was accomplished over the first 6 months that the pathway was in use. The center line (mean) for the entire study period was 71.9%. Between months 7 and 12 we observed 4 of 5 consecutive points >1 SD above the center line, thereby meeting Nelson criteria for special cause variation due to our interventions. We therefore revised the center line (mean) to reflect the change (see Fig 2). The revised mean for the last 6 months of implementation was 82.8%.

Interventions that were associated with improved adherence to the pathway included nursing notification of the physician of an abnormal screen with the use of a scripted phrase, a resident lecture on sepsis, and introduction of a “sepsis evaluation” note in the EMR for physician use. During the first 3 months of implementation, only 57% of abnormal screens identified by nursing had associated physician documentation of evaluation. However, after our interventions, documentation of physician evaluation after notification of an abnormal screen reached 100% by month 7 and was sustained at ≥84% adherence for the following 5 months (Fig 3).

Of the 963 admitted patients, 161 (16.7%) had ≥1 abnormal vital sign screens. Of these 161 patients, 123 (76.3%) subsequently had a resident physician diagnosis of no sepsis, 32 (19.8%) possible sepsis, and 6 (3.7%) severe sepsis/septic shock. The number of patients with an abnormal screen per month and distribution of diagnosis of no sepsis, possible sepsis, and severe sepsis/septic shock is shown in Fig 4. These cases were rereviewed by 2 independent reviewers for consistency of diagnosis with the 2005 International Pediatric Consensus Conference Definitions.9 Interrater reliability between reviewers on sepsis classification was high (κ = 0.93, 95% confidence interval 0.6–1.0, P < .001). Twenty-nine of the 32 cases with resident physician diagnosis of possible sepsis (90.6%) were consistent with the consensus definitions; however, 3 actually met consensus definitions for severe sepsis/septic shock. All resident physician diagnoses of severe sepsis/septic shock were consistent with the 2005 Pediatric Consensus Conference Definitions for Sepsis.

Chart review revealed 1 patient identified with severe sepsis/septic shock on the pediatric unit who did not have an abnormal screen before diagnosis. This patient was neutropenic as a result of chemotherapy and did not mount an initial febrile response to infection. Thus, the sepsis screen identified 38 of 39 patients who were ultimately assessed to have possible sepsis or severe sepsis/septic shock. The

FIGURE 2
Control chart of percentage of abnormal screens with nursing recognition and physician evaluation, with center line shift, October 2013 to October 2014. N = number of abnormal screens. Arrows represent the interventions: A, Discussion of positive alerts at daily safety huddles; B, registered nurse scripting when notifying physician of abnormal screen; C, resident lecture; D, EMR sepsis evaluation note.
39 patients with possible sepsis or severe sepsis/septic shock represented 4% of patients admitted to the pediatric unit.

Of the 161 patients with an abnormal screen, 96 had 1 abnormal screen during the admission (60%), 28 patients had 2 abnormal screens (17%), and 37 patients had ≥3 abnormal screens (23%). Thus, 65 patients required >1 sepsis evaluation due to repeat abnormal
screens. Of the 6 patients with a resident physician diagnosis of severe sepsis/septic shock after an abnormal screen, all were diagnosed after the first abnormal screen except for 1 patient. This patient received a physician diagnosis of sepsis after the second abnormal screen and severe sepsis/septic shock after the third abnormal screen.

Of the 235 documented physician sepsis evaluations, 78 (33.2%) had plan for a diagnostic or therapeutic intervention. Type of diagnostic or therapeutic intervention is shown in Table 1.

**DISCUSSION**

To identify and evaluate children with possible sepsis on our pediatric unit, we implemented a sepsis identification pathway. After 6 months of education and plan-do-study-act cycles, >80% of children with an abnormal screen were recognized by nursing and subsequently evaluated by a physician for possible sepsis. We sustained mean nursing and physician adherence of 80% or higher for an additional 6 months while decreasing the amount of booster education we provided. Interventions found to be effective at increasing adherence included transparent data sharing, resident education, and scripting of the nurse’s message notifying physicians of abnormal screens. Of note, these interventions helped us succeed in implementing a pathway on a unit with multiple admitting services.

The pathway provided a standardized process for identifying and evaluating children with sepsis. Although most patients with an abnormal screen did not have sepsis, 23.5% of patients identified by the screen were determined to have possible sepsis or severe sepsis/septic shock. Additionally, there was 1 patient who developed severe sepsis/septic shock who was not identified by the screen. Considering that 4% of all inpatients admitted during the 1-year study period were identified as having possible sepsis or severe sepsis/septic shock while on the pediatric unit, we would argue that institution of an inpatient pediatric sepsis identification pathway could be a worthwhile endeavor.

Interestingly, 19.8% of patients with an abnormal screen were found to have possible or early sepsis but did not yet demonstrate organ dysfunction consistent with severe sepsis/septic shock. Previous studies of sepsis screens in the pediatric emergency room setting have focused on the identification of severe sepsis and septic shock. The literature is not clear regarding the best approach to patients with early sepsis. It is likely that early implementation of fluids and antibiotics will prevent progression to severe sepsis and septic shock in at least some of these cases. Screens that identify sepsis earlier in its course may have more widespread impact, especially in the inpatient setting. Thirty-three percent of the abnormal screens evaluated by a physician were associated with a subsequent diagnostic or therapeutic intervention. Further study is needed to determine whether earlier recognition and treatment of these patients will improve outcomes without significant negative impact on clinical status or health care utilization and cost.

We were not able to evaluate the impact of implementation of an inpatient sepsis identification pathway on patient outcomes, such as length of stay, morbidity, or mortality, given the large sample size required. However, early identification and treatment of pediatric patients with severe sepsis and septic shock has been shown to improve outcomes. A study of pediatric patients with septic shock who required transport from a community hospital to a tertiary care center showed a twofold increase in mortality for every hour a child remained in septic shock. Delayed antimicrobial therapy was shown to be an independent risk factor for mortality and prolonged organ dysfunction in patients identified with severe sepsis and septic shock in a large children’s hospital. Further studies are needed, however, to determine if inpatient sepsis identification pathways reduce time to recognition of sepsis and improve outcomes.

There are several additional limitations to this study. The study was performed in a single pediatric unit in a general tertiary care academic hospital, which may limit generalizability. However, our unit has a broad case mix, including medical and surgical patients, and may be similar to many pediatric units across the country. Second, data for this study were extracted from chart review. Although physicians were required to evaluate patients within 10 minutes of notification of an abnormal screen, we were not able to confirm that evaluations occurred within this time frame. In determining percentage of patients with possible sepsis and severe

**TABLE 1** Percentage of Documented Physician Evaluations With Plan for a Diagnostic or Therapeutic Intervention ($n = 235$)

<table>
<thead>
<tr>
<th>Type of Intervention</th>
<th>$n$ (%)</th>
</tr>
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<tbody>
<tr>
<td>Any diagnostic or therapeutic intervention</td>
<td>78 (33.2)</td>
</tr>
<tr>
<td>Laboratories or imaging</td>
<td>34 (14.5)</td>
</tr>
<tr>
<td>Normal saline bolus</td>
<td>29 (12.3)</td>
</tr>
<tr>
<td>Antibiotic initiation or broadening</td>
<td>36 (15.3)</td>
</tr>
<tr>
<td>ICU consult</td>
<td>17 (7.7)</td>
</tr>
<tr>
<td>ICU transfer</td>
<td>11 (4.7)</td>
</tr>
</tbody>
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PEDIATRICS Volume 137, number 3, March 2016
sepsis/septic shock we relied on resident physician documentation of clinical diagnosis. The 2005 Pediatric Sepsis Conference Definitions were developed for research and are difficult to apply in clinical settings. However, the physician diagnoses were reviewed by 2 physician reviewers for consistency with the 2005 Pediatric Sepsis Conference Definitions and were found to be relatively accurate. Although we achieved >80% adherence with the pathway, we did not achieve universal screening. It is possible that on a ward with higher incidence of sepsis, using a similar screening process, the rate of missed cases would increase. Finally, it would be beneficial to determine the time required for evaluations and measure the perceived burden of the pathway by nurses and residents.

Future work will include determining the sensitivity and specificity of the screen and determining whether modifications in screen criteria can increase its specificity without unduly compromising sensitivity. In this regard, the effect of specific patient populations on the test characteristics of the vital sign screen, such as neutropenic patients with compromised systemic responses to infection, warrants further investigation. Finally, further studies are needed to investigate whether inpatient sepsis identification screens will affect patient outcomes, such as length of stay, time to initiation of critical sepsis therapies, and ICU transfer.

CONCLUSIONS

Through the use of quality improvement initiatives, we were able to implement and sustain >80% adherence with a sepsis identification pathway on our pediatric ward. Continued education and feedback were central to improving adherence over time. The pathway provided the potential benefit of recognition of children with possible sepsis who required timely evaluation and treatment. Further studies are needed to determine if inpatient sepsis identification pathways reduce time to recognition of sepsis and ultimately improve patient outcomes.

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ABBREVIATIONS

EMR: electronic medical record
SIRS: systemic inflammatory response syndrome

REFERENCES

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