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Causal Association of Physician-in-Triage with Improved Pediatric Sepsis Care: A Single-Center, Emergency Department Experience

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ABSTRACT

Introduction: Approximately 75,000 children are hospitalized for sepsis yearly in the United States, with 5%–20% mortality estimates. Outcomes are closely related to the timeliness of sepsis recognition and antibiotic administration. **Methods:** A multidisciplinary sepsis task force formed in the Spring of 2020 aimed to assess and improve pediatric sepsis care in the pediatric emergency department (ED). The electronic medical record identified pediatric sepsis patients from September 2015 to July 2021. Data for time to sepsis recognition and antibiotic delivery were analyzed using statistical process control charts ($\bar{X}$-S charts). We identified special cause variation, and Bradford-Hill Criteria guided multidisciplinary discussions to identify the most probable cause. **Results:** In the fall of 2018, the average time from ED arrival to blood culture orders decreased by 1.1 hours, and the time from arrival to antibiotic administration decreased by 1.5 hours. After qualitative review, the task force hypothesized that initiation of attending-level pediatric physician-in-triage (P-PIT) as a part of ED triage was temporally associated with the observed improved sepsis care. P-PIT reduced the average time to the first provider exam by 14 minutes and introduced a process for physician evaluation before ED room assignment. **Conclusions:** Timely assessment by an attending-level physician improves time to sepsis recognition and antibiotic delivery in children who present to the ED with sepsis. Implementing a P-PIT program with early attending-level physician evaluation is a potential strategy for other institutions. *(Pediatr Qual Saf 2023;8:e651; doi: 10.1097/pq9.0000000000000651; Published online May 29, 2023.)*

INTRODUCTION

Pediatric sepsis is a leading cause of morbidity and mortality worldwide.[1] The prevalence of pediatric sepsis has increased in the last 20 years.[2] In 2012, pediatric sepsis was associated with 176,000 hospitalizations and mortality of 8.2% (11,000 deaths).[3] Refractory shock and persistent multi-organ dysfunction are common causes of death in pediatric sepsis, and many deaths occur within the first 48–72 hours of treatment.[4,5] Early identification with rapid resuscitation and appropriate management improves outcomes in children with sepsis, particularly in the emergency department (ED). The 2020 Surviving Sepsis Guidelines recommend initiation of antibiotics and intravenous fluids within the first hour after septic shock is suspected.[4] However, the clinical signs and symptoms of sepsis and septic shock in children can be subtle and nonspecific. Thus, the diagnosis is often delayed or missed. Further, ED crowding is associated with increased time to sepsis recognition and critical sepsis therapies, including antibiotics.[6]

Many institutions use care bundles, screening tools, clinical pathways, and other quality improvement interventions to standardize sepsis care, improve local processes, and expedite the time to treatments.[7,8] Studies in adults show that the use of electronic or manual screening tools in triage may lead to earlier diagnosis of sepsis and decrease the time from ED arrival to administration

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of antibiotics and fluids.[9–11]These studies primarily used vital signs to inform screening tools; however, this is challenging, as children frequently have abnormal vital signs from infections without organ dysfunction. A few pediatric studies have shown improved sepsis recognition using a screening tool and improved sensitivity in conjunction with an exam.[12,13]

Our institution sought to improve pediatric sepsis care in the pediatric ED. The study team evaluated data for time to first provider, time to blood culture order, and time to antibiotic administration. While examining the data over time, special cause variation was identified in the abovementioned measures, suggesting nonrandom differences in care delivery. The study team explored hypotheses for this special cause variation using Bradford-Hill Criteria for causality.[14] We suspected that the implementation of a screening process in triage, including an exam by an attending-level pediatrician, contributed to faster sepsis recognition and improved care delivery. This study uses statistical process control and Bradford-Hill Criteria for causality to explore the relationship between an attending physician's exam during ED triage and improvement in pediatric sepsis diagnosis and treatment.

METHODS

A local multidisciplinary team was formed to assess and improve the quality of pediatric sepsis care at our hospital. The team identified historic patient encounters to determine our performance over the previous four years, benchmarked to the newly published Surviving Sepsis Campaign International Guidelines for the Management of Septic Shock and Sepsis-Associated Organ Dysfunction in Children.[4] The study team specifically focused on performance in time to sepsis recognition and time to sepsis treatment for patients presenting with sepsis to the pediatric ED. After reviewing data in statistical process control charts over time, we noted special cause variation in the fall of 2018. In early 2020, a subcommittee was formed to investigate the potential causes of the special cause variation observed in our data to better understand our opportunities for improvement.

Study Design

This retrospective observational study used data from the EMR for patient visits from September 1, 2015, to July 31, 2021. The study received Institutional Review Board approval.

Study Setting and Population

The site for this study is an academic pediatric ED located within a large, urban academic ED with a level 1 trauma center and comprehensive stroke center. The pediatric ED has approximately 16,000 visits annually, constituting approximately 20% of total patient encounters. The waiting room and triage spaces are shared, serving pediatric and adult patients. A dedicated pediatric unit has ten rooms, including two pediatric resuscitation rooms. During the period of the study, the unit staffing included: a single-coverage pediatric-specific attending (fellowship-trained pediatric emergency medicine physicians covered 75% of hours and a designated cohort of general emergency medicine physicians covered 25% of hours), general emergency nursing staff, and resident physicians from several institutional residency programs including pediatrics, combined medicine-pediatrics, emergency medicine, and family medicine.

At our institution, a qualified attending-level physician-in-triage (PIT) performs an exam shortly after patient arrival. The goal of this brief history and physical examination is the early initiation of diagnostic and therapeutic interventions to expedite patient care. The pediatric physician-in-triage (P-PIT) practice in the ED started as a pilot trial on September 1, 2018, to address general ED efficiency metrics. P-PIT occurred five days per week during the peak patient arrival hours of 5:00 pm-11:00 pm. Before the initiation of P-PIT and during hours when P-PIT is inactive, pediatric patients are triaged by a clinical nurse. Patients are either taken to the pediatric ED if a room is available or asked to return to the general waiting room until a room is available. P-PIT remained active at our institution from September 1, 2018, to March 30, 2019 (pilot period), and from July 15, 2019, to Mid-March 2020. The stop in March 2020 occurred due to the COVID-19 pandemic and associated changes in ED arrival volumes and processes.

Other special processes at our institution for sepsis recognition in specific patient populations include call-ahead alerts for patients with fever, sickle cell disease, and suspected neutropenia. In addition, clinical care pathways exist for fever in infants under two months of age and patients with transplanted organs and indwelling central venous catheters. Therefore, we excluded these patient populations from this study.

Study Protocol and Population

Using the EMR, administrative and clinical data were extracted from the medical records of patients (N = 238) between the ages of 2 months and 18 years old who presented to the ED, were admitted to the hospital, and had a primary or secondary billing diagnosis code of sepsis. (**See figure 1, Supplemental Digital Content,** which describes the included ICD-10 codes. Eligible patients had at least one primary or secondary ICD-10 discharge diagnosis code related to sepsis. **http://links.lww.com/PQ9/A481**).[15]

Important time points collected included ED arrival time, triage time, time to physician assignment, blood culture order time, antibiotic administration time, time to ED room, and time to inpatient disposition. In addition, we also collected outcomes, which included intensive care unit (ICU) length of stay, hospital length of stay, and mortality. We excluded patients if their time to sepsis recognition or time to antibiotics were greater than 24 hours after ED arrival. A chart review of these patients suggested that signs and symptoms of sepsis were absent at the time of ED presentation.

Composition of Sepsis Task Force and Subcommittee

In February 2020, a task force of key individuals convened to improve the quality of pediatric sepsis care at our institution. The task force included multidisciplinary representation from the hospital system, including attending physicians, fellows, nurses, pharmacists, data support specialists and experts in clinical quality improvement. Three workgroups addressed the following specific goals: (1) define pediatric sepsis: craft local criteria for empiric treatment for sepsis; (2) treatment algorithm: standardization of sepsis treatment; (3) performance measures: evaluation of metrics and data, development of feasible and sustainable measurement strategies. The authors of this report represent a subgroup of the performance measures workgroup formed to explore the special cause variation noted in the pre-P-PIT data.

Key Measures

Our primary outcome measures were time to sepsis recognition and time to antibiotic administration. The time to sepsis recognition was defined as the time between ED arrival and blood culture order. We defined the time to antibiotics as the time between the blood culture order and antibiotic administration. P-PIT was not a pre-determined solution; thus, we analyzed time to the first provider as a secondary process measure to validate the association between the primary measures and P-PIT. We defined time to the first provider as the time from patient arrival to the electronic timestamp associated with the first physician assigned to the patient.

Secondary outcomes included hospital length of stay, ICU length of stay, and patient discharge disposition. We defined hospital length of stay as the time from ED arrival to the time of hospital discharge. We defined ICU length of stay as the total time of patient assignment to an ICU location. Discharge disposition included categories of home or self-care, home health service, skilled nursing facility, and death.

Bradford-Hill Criteria

Bradford-Hill Criteria is a framework of nine viewpoints used to help determine if observed epidemiologic associations are causal.[14] The nine criteria are the strength of association, consistency, specificity, temporality, biological gradient, plausibility, coherence, experiment, and analogy. The study team met to apply Bradford-Hill criteria several times and consider explanations for the observed special cause variation. First, the subgroup brainstormed using a whiteboard and created organized flow diagrams highlighting specific interventions (Fig. 1). The subgroup then mapped the entry points for patients with sepsis, and

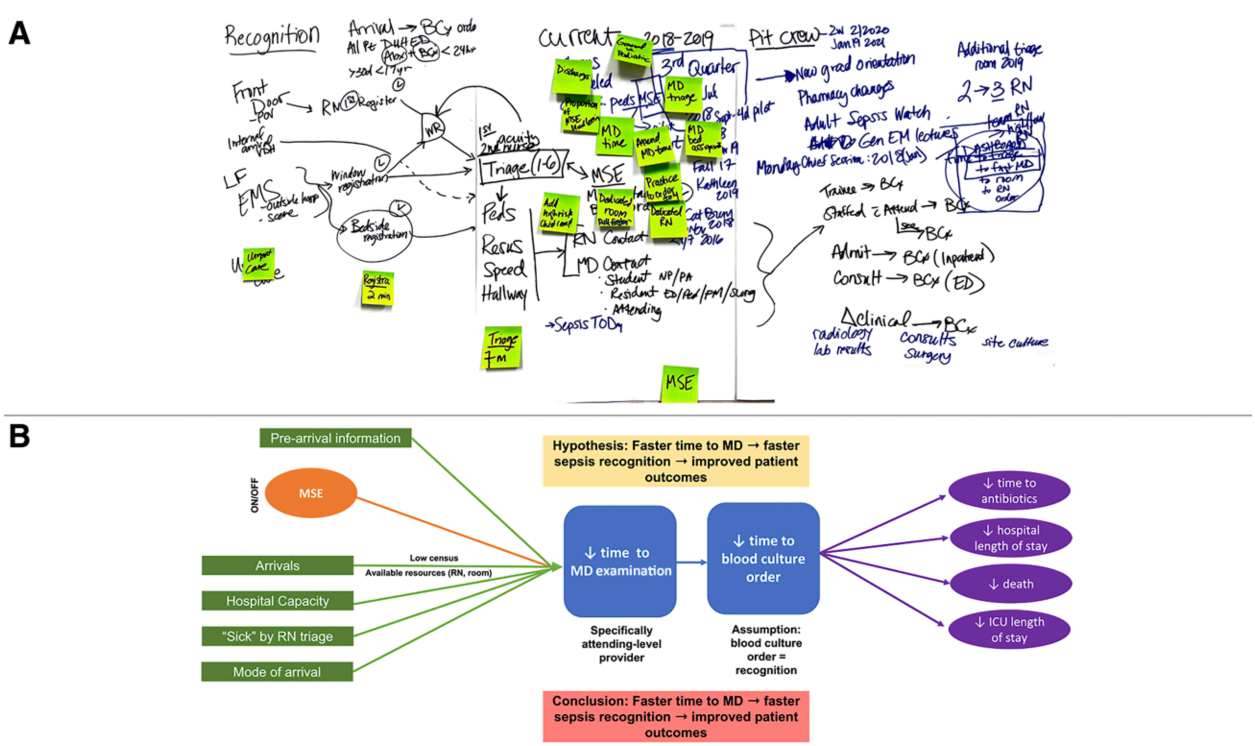

Fig. 1. Brainstorming and application of Bradford-Hill Criteria. The initial causal brainstorming session by the sepsis performance measures workgroup occurred using a whiteboard (A). The workgroup then created organized flow diagrams highlighting specific interventions, as seen in Figure 1B.

their progression through the ED, including registration, triage, and care once roomed.

The study team hypothesized that P-PIT substantially changed the ED workflow for patients presenting with sepsis by expediting attending-level patient evaluation, altering the triage process, and as a result, more timely interventions. The pediatric sepsis task force and additional hospital leaders and administration reviewed our findings and agreed with this hypothesis. To validate our hypothesis, the team analyzed the time to the first provider using the same techniques as our other measures.

Data Analysis

Measures were tracked quarterly using run and statistical process control charts ($\bar{X}$-bar –charts). Special cause variation was determined using traditional rules for statistical process control.[16] Statistical process control charts were made using QI Macros (KnowWare International Inc, Denver, CO) for Excel (Microsoft Corp, Redmond, WA).

RESULTS

Patient Characteristics

A total of 226 patient encounters identified between Q3 2015 and Q3 2021 met our criteria for inclusion. Table 1 describes patient demographics over this period. Patients were separated into pre-P-PIT and post-P-PIT groups based on the special cause variation observed in September 2018. Pre-P-PIT patients presented to the ED between Q3 2015 and Q3 2018 (n = 126), and the post-P-PIT group presented between Q4 2018 and Q3 2021 (n = 100).

Table 1. Demographics of Patients Included in Study

	Q3 2015–Q3 2018	Q4 2018–Q3 2021
Age (y), mean (SD)	7.97 (6.13)	8.62 (6.00)
Women, n (%)	64 (51%)	45 (45%)
Race, n (%)		
American Indian or Alaskan Native	3 (2%)	2 (2%)
Asian	6 (5%)	3 (3%)
Black or African American	35 (28%)	37 (37%)
Caucasian/White	51 (40%)	40 (40%)
Native Hawaiian or Other Pacific Islander	1 (1%)	0 (0%)
Not reported/declined	4 (3%)	3 (3%)
Other	21 (17%)	12 (12%)
Two or more races	5 (4%)	3 (3%)
Ethnicity, n (%)		
Not Hispanic/Latino	101 (80%)	82 (82%)
Hispanic Mexican	12 (10%)	8 (8%)
Hispanic Other	8 (6%)	8 (8%)
Hispanic Puerto Rican	2 (2%)	0 (0%)
Not reported/declined	3 (2%)	2 (2%)
Primary language, n (%)		
Arabic	0 (0%)	1 (1%)
English	112 (89%)	88 (88%)
Portuguese	1 (1%)	0 (0%)
Spanish	13 (10%)	11 (11%)
Primary payor, n (%)		
Medicaid/Medicare	54 (43%)	48 (48%)
Private/Commercial Insurance	60 (48%)	50 (50%)
Self-Pay	9 (7%)	1 (1%)
Other	3 (2%)	1 (1%)
Method of ED arrival, n (%)		
EMS	24 (19%)	27 (27%)
Private vehicle	84 (67%)	65 (65%)
Transport service	2 (2%)	1 (1%)
Carried/walk/wheelchair	16 (13%)	7 (7%)

Standard deviation (SD); number (n).

Primary Outcome Measures

The mean time to sepsis recognition was 2.10 hours before initiating P-PIT and improved to 1.15 hours post-initiation (Table 2). However, the average time to sepsis recognition was notably high in Q2 2019 (2.8 hours) and Q2 2021 (2.5 hours), although it did not exceed the upper control limit (Table 2). These points are associated temporally with a predetermined pause in the P-PIT pilot during Q2 2019 and increasing ED patient volumes following the initial phase of the COVID-19 pandemic in Q2 2021 (Fig. 2a).

The mean time to antibiotic administration decreased from 3.10 hours pre-P-PIT to 1.63 hours in the post-P-PIT group. Notably, special cause variation (10 consecutive points below the centerline) on the statistical process control chart of this metric occurred two quarters later (Q1 2019) than the shift in the two other primary outcomes (Fig. 2b).

The mean time to the first provider was 34.7 minutes before P-PIT and 21.4 minutes post-P-PIT. In addition, we noted special cause variation in Q2 2021 (one point exceeding the upper control limit), which is associated with increased PED arrival volumes without the P-PIT process being active (Fig. 2c).

Secondary Outcome Measures

No substantial differences in ICU LOS (7.69 days versus 9.15 days) or hospital LOS (13.59 versus 14.40) existed in the pre-P-PIT compared to post-P-PIT (Table 2). The mortality rate was 6% in the pre-P-PIT group compared with 13% in the post-P-PIT group. This study did not assess markers of disease severity at presentation, underlying medical conditions, or other factors that could impact mortality.

Bradford-Hill Criteria Analysis

Implementing P-PIT into our ED workflow met all nine Bradford-Hill Criteria for a causal association. Identifying

Table 2. Primary and Secondary Study Outcomes

	Quarter 3 2015–Quarter 3 2018	Quarter 4 2018–Quarter 3 2021
Time to sepsis recognition in hours (SD)	2.10 (3.66)	1.15 (2.08)
Time to antibiotic administration in hours (SD)	3.10 (4.15)	1.63 (2.60)
Time to first provider in hours (SD)	0.58 (0.81)	0.36 (0.36)
ICU length of stay in days (SD)	7.69 (10.83)	9.15 (14.03)
Hospital length of stay in days (SD)	13.59 (15.13)	14.40 (15.66)
Discharge disposition, n (%)		
Death	7 (6%)	13 (13%)
Rehabilitation facility	1 (1%)	0 (0%)
Home health	51 (40%)	20 (20%)
Self-care	67 (53%)	67 (67%)

Standard deviation (SD); number (n).

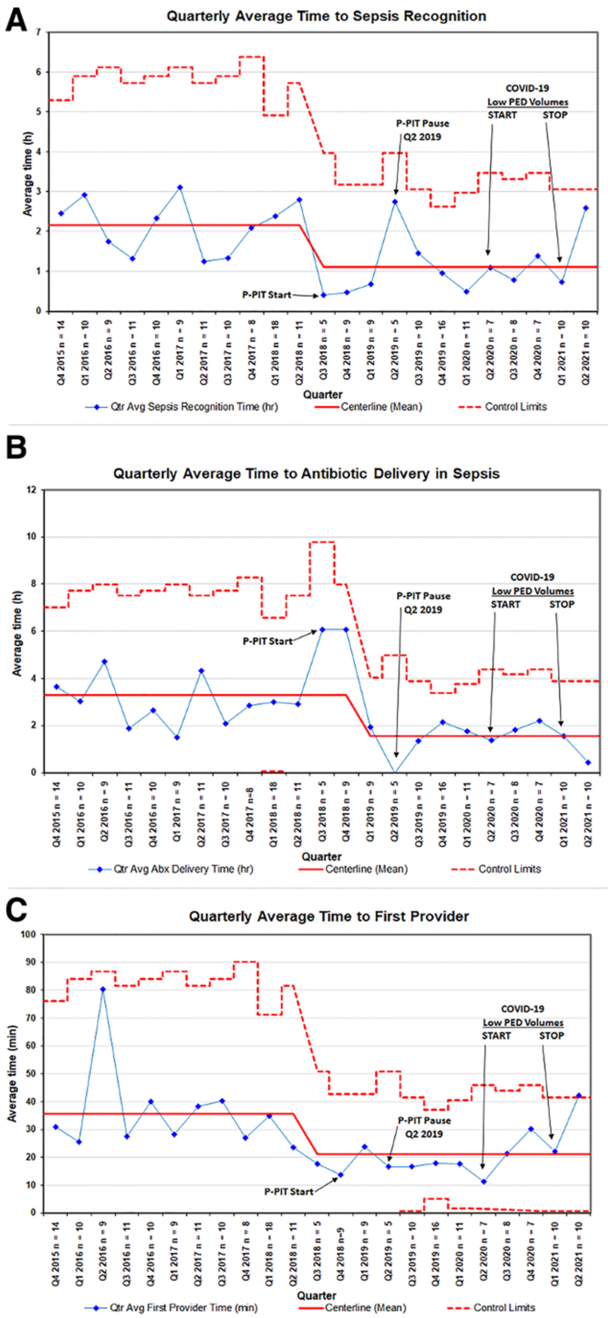

Fig. 2. Statistical process control charts of primary outcome measures. (A), Sepsis recognition, time to antibiotic delivery (B), and time to the first provider (C). A shift in the solid red centerline denotes special cause variation.

special cause variation in statistical process control charts suggests the strength of association temporality of P-PIT and improved primary outcome measures. There were sufficient baseline data points to understand the variation inherent in the system in the pre- and post-implementation periods. A multidisciplinary pediatric sepsis task force, hospital leaders, and administrators evaluated our hypothesis that P-PIT improved the primary outcome measures. After evaluating the ED processes and the subgroup brainstorming (Fig. 1), all attributed P-PIT as temporally associated with the noted special cause variation. During the pause in P-PIT in Quarter 2 of 2019, the time to sepsis recognition increased. The pause in P-PIT constituted the only change during this time without other staffing or ED flow modifications. We observed what occurred without P-PIT during Q2 of 2021. ED volumes returned to pre-pandemic levels during this time, and without P-PIT staffing in place, time to sepsis recognition and average time to first provider increased. These observations suggest specificity of association.

The Bradford-Hill criteria of biological gradient queries if increased effect is observed with higher fidelity of the intervention.[17] We noted improvements over time – particularly in sepsis recognition and time to the first provider – with the ongoing presence of and higher fidelity of P-PIT. Early physician assessment is a plausible explanation for more timely recognition of sepsis and expedited antibiotic delivery. Further, it is highly plausible that P-PIT allowed for earlier examination of ill patients and faster order entry for blood cultures and antibiotics. Concerning coherence, data suggest that earlier diagnosis of sepsis improves outcomes, and the Surviving Sepsis Guidelines recommend early intervention in children with sepsis.[4] We established analogy by evaluating similar adult and pediatric literature that show improvement in ED flow and patient outcomes with PIT evaluations.[18–20] Finally, we observed changes to the outcomes during periods when P-PIT was turned on and off. This finding fulfilled the Bradford-Hill criterion of experiment as we saw increased time to sepsis recognition during the pause and improvement after reinstating the intervention.

DISCUSSION

Physician-level ED triage improves patient flow efficiency and is associated with improved clinical care of children with sepsis. Using the Bradford-Hill Criteria and statistical process control, we illustrate that time to sepsis recognition and time to antibiotics are associated with the time to attending-level physician assessment.[21] Causal inference was determined using the Bradford-Hill Criteria as a framework to explore this hypothesis.[14,17] Qualitative review of known operational changes within our pediatric ED reinforced these correlations.

We used the epidemiologic principles of Bradford-Hill to establish cause after noting special cause variation using traditional quantitative improvement methodology (i.e., statistical process control). Importantly, P-PIT was not a predetermined solution; rather, in a qualitative review of our processes, no other identifiable intervention occurred to ED workflow during the periods of change. The primary outcome, time to provider, significantly improved after implementing P-PIT. The P-PIT process aimed to expedite physician assessment after ED arrival and as a part of the triage process. It is possible that prompt attending-level provider examination led to rapid recognition of potentially septic children, faster blood culture and antibiotic order entry, and expedited care delivery (eg, intravenous access, antibiotic preparation, and administration). The provider-in-triage (PIT) model is common in general EDs and has improved sepsis recognition; however, the impact of PIT on sepsis care is poorly reported in pediatric ED settings.[10] As previously discussed, pediatric sepsis can present with subtle signs, and an attending-level provider's additional training and expertise may contribute to faster and more nuanced recognition.

The special cause variation in time to antibiotics occurred after noting variation in time to sepsis recognition. This result likely occurred due to simultaneous changes in ED. Physicians began placing orders in triage, and nurses obtained IV access and started antibiotics in the triage space during room unavailability. Before this process change, the P-PIT may have ordered blood cultures and/or antibiotics, but the orders may not have been completed until the patient reached a traditional care room.

Improvements in the time to the first provider, time to sepsis recognition, and time to antibiotics continued during the active periods of P-PIT. In the first year of the COVID-19 pandemic, pediatric ED patient volumes substantially decreased, and subsequently, the burden on timely physician assessment was also reduced. Despite a pause in the P-PIT program during this time, we hypothesize that the sustained improvements in metrics occurred because low volumes allowed patients to be more quickly roomed and evaluated by a physician, as evidenced by the time to first provider remaining low during this period.

Our study further adds to the evidence that attending physician exams in triage are important for improving patient care and ED workflow.[18–20] Timely and effective ED throughput serve as markers of hospital system quality in metrics collected by the Centers for Medicaid and Medicare services.[22] One study of pediatric patients who left before being seen suggests that 5% were triaged as emergent and 31% as urgent.[23] This is a substantial percentage of patients who may have delayed presentation to care. Implementation of a PIT is one method to decrease wait times and these metrics. Our ED sees adults and children in a mixed triage setting; adding a pediatric-trained physician ensured that children were triaged appropriately, improved room allocation, and decreased the number of patients who left before being seen. In our setting, with limited real-time informatics and automated processes for sepsis recognition, a PIT improved sepsis outcomes and could be reproduced in similar EDs.

Considering the financial cost-benefit ratio of an additional PIT for improved sepsis outcomes is important. Incremental, though clinically important, improvements in the quality of sepsis care alone may not be enough for hospital administration to invest financially in similar programs. However, PIT models may also improve in other time-based performance metrics, and global improvement in quality of care may make the financial investment more compelling.[24] Less cost-intensive improvements could focus on more accurate triage, equitable allocation of resources or expanding the role of pediatric-specific emergency nursing in general EDs or pediatric advanced practice providers in the triage process.[25]

Finally, attending-level providers for rapid ED triage assessments alter trainee education in academic medical centers. In our model of P-PIT, resident physicians no longer provided the first assessment of children with possible sepsis. This intervention may have adversely impacted their ability to triage, assess, and initiate care for a subset of clinically ill children. However, this study did not measure the influence P-PIT had on resident satisfaction and educational outcomes. Additionally, some senior-level residents may perform similarly to attending-level physicians, and there could be a role for residents in a rapid triage system. Further research is needed to assess these topics to optimize patient care and trainee education in academic settings.

Limitations

There are limitations to this retrospective observational study. First, balancing measures were not captured or analyzed as part of this study. This limitation could include excessive laboratory orders or antibiotics due to the transient assessment with P-PIT or the increased cost to the healthcare system of adding a provider into the ED workflow. The identification of pediatric sepsis patients occurred retrospectively using billing codes. Additionally, the number of patients for each calendar quarter was small and subject to significant variance from outliers. Finally, our dataset included interventions and timestamps within our hospital system. If a patient received a blood culture or antibiotics at an outside clinic or hospital system, we would misclassify this as a delay in blood culture order or antibiotic administration.

CONCLUSIONS

Prompt attending-level physician assessment is associated with improved time to sepsis recognition and antibiotic delivery in children who present to the ED with sepsis. This intervention improved sepsis recognition and care delivery after implementing a pediatric initial provider assessment program where an attending-level physician evaluated the patient during the ED triage process. Pediatric physician engagement in ED triage may be an important strategy to improve sepsis care and other time-sensitive clinical outcomes among children in general EDs.

DISCLOSURE

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