Effect of a point-of-care ultrasound (POCUS) curriculum on emergency department soft tissue management

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Abstract
Background: Pediatric emergency department (ED) visits for superficial skin and soft tissue infections (SSTI) have steadily been increasing and point-of-care ultrasound (POCUS) continues to be an effective modality to improve management and shorter ED length of stays (LOS).

Objective: We sought to determine the impact of a soft tissue POCUS curriculum on POCUS utilization, ED LOS, and cost-effectiveness.

Methods: This was a retrospective pre- and post-interventional study of pediatric patients aged 0 to 17 years. Patients presenting to ED with international classification of disease 9 or 10 code for abscess or cellulitis were included. Data were collected a year before and after curriculum implementation with a 1-year washout training period. Training included continuing medical education, greater than 25 quality assured examinations, and a post-test. We compared diagnostic imaging type, ED LOS, and mean charges in patients with SSTI.

Results: We analyzed data on 119 total patients, 38 pre- and 81 post-intervention. We found a significant increase in the total number of POCUS examinations performed pre- to post-curriculum intervention, 26 vs. 59 (p = 0.0017). Mean total charges were significantly decreased from $3,762 (± 270) to $2,622 (± 158; p = 0.0009). There was a significant trend towards a decrease in average ED LOS 282 (standard error of mean [SEM] ± 19) vs 185 (± 13) minutes (p = 0.0001).

Conclusions: Implementation of a soft tissue POCUS curriculum in a pediatric ED was associated with increased POCUS use, decreased LOS, and lower cost. These findings highlight the importance of POCUS education and implementation in the management of pediatric SSTI.

Keywords: Pediatric, Soft tissue, Ultrasound, Training, Curriculum, Emergency department, Point-of-care ultrasound, Infection, Curriculum, Pediatrics, Education

Introduction
Superficial skin and soft tissue infections (SSTI) including abscesses and cellulitis are common diagnoses in the pediatric population with recent literature showing a steady increase in emergency department (ED) visits [1, 2, 15–17]. The treatment of SSTI frequently depends on the location and depth of infection, and whether there is a fluid collection requiring incision and drainage [1].

POCUS is highly accurate for differentiating abscess from cellulitis and can be used to guide acute
management [1]. Its use in the pediatric ED for SSTI is emerging and recent literature has shown that when used with physical examination, POCUS can increase sensitivity and specificity for diagnosing SSTI [1–4]. This includes abscess and cellulitis when compared to physical exam alone. The POCUS application for SSTI has been shown to be favorable to patient outcomes in the acute care setting as it improves diagnostic accuracy for ruling in abscess while reducing invasive intervention that might not be needed [3, 13, 14]. Additionally, children receiving POCUS for SSTI experienced shorter ED length of stays (LOS) when compared to children receiving radiology-performed ultrasound (RUS) [3].

As the practice of pediatric POCUS continues to evolve, the effectiveness of training programs established to support various applications such as SSTI is vital to the success of implementation. Many training curriculums exist, but few assess the impact on patient care and management processes to support the routine use of POCUS for diagnostic evaluations in the pediatric emergency department [4, 6].

We sought to determine the impact of a soft tissue POCUS curriculum on the management of pediatric SSTI by assessing POCUS utilization, ED length of stay, and performing a cost analysis before and after implementation of a structured POCUS curriculum.

Materials and methods

Study setting and population

This was a retrospective pre- and post-study conducted 1 year before and after implementation of a POCUS SSTI training curriculum in a pediatric ED. The study took place at an urban academic pediatric ED with over 60,000 annual visits. It was deemed exempt by the Institutional Review Board.

Study participants

Pediatric patients (0–17 years of age) who presented to the ED from July 1st, 2016, to June 30th, 2017 (pre-implementation) and July 1st, 2018, to June 30th, 2019 (post-implementation) with an SSTI diagnosis met the inclusion criteria for the study. There was a 12-month washout period from July 1st, 2017, to June 30th, 2018, while the training curriculum was implemented. During this washout period, participants were trained and were able to successfully complete the curriculum while routine SSTI care was provided. Pre and post-assessment groups remained the same during the entire length of the study. Patients were included if they had a final diagnosis of SSTI as identified in the electronic medical record by international classification of diseases (ICD) revision codes, 9th (ICD-9 682.2, 682.3, 682.6, 682.8, 682.9, 685.0, 685.1, 686.8, 686.9, 709.8, and 709.9) and 10th (ICD-10 L03.319, L03.119, L03.11, L03.81, L03.818, L05.01, L05.91, L08.9, L99, L03.221, L03.22, L03.317, L03.312). Patients with a secondary diagnosis, complicated infection including those requiring hospital admission and surgical intervention were excluded (Fig. 1). We collected patient demographic information, diagnostic imaging type including POCUS and radiology ultrasound examinations performed, and patient disposition.

Soft tissue POCUS training

Pediatric emergency medicine faculty and fellows underwent training on soft tissue POCUS to improve knowledge, skill, and comfort to integrate this tool in clinical management of patients. At the time of the study, 14 fellowship-trained pediatric emergency faculty and 8 pediatric emergency fellows took part in training. For the training, faculty were required to complete 1-h didactic sessions, hands-on instruction with supervision by a fellowship-trained POCUS expert, complete 4 h of continuing medical education (CME), successfully pass a competency assessment, and complete 25 quality assured soft tissue POCUS examinations as described previously [3, 5]. Content covered during the didactic sessions included techniques, equipment selection, soft tissue anatomy, image acquisition, differentiating various SSTI and soft tissue edema pathology, differentiating common types of soft tissue foreign body and clinical integration. The hands-on education comprised clinical scans in the emergency department. Faculty obtained CME asynchronously on through institutional and departmental POCUS workshops.

Sonography and image software

POCUS examinations were completed using a Zonare ZS3 (Mindray, Shenzhen, China) with the linear transducer. Images from the ultrasound system were wirelessly saved to an image archiving and workflow solution (Qpath, Telexy Healthcare, Maple Ridge, BC, Canada) designed to provide immediate feedback and quality assurance.

Radiology ultrasound was conducted in a pediatric radiology department housed adjacent to the main ED with 24-h availability. The ultrasound department is staffed with sonographic technicians who acquire the images and upload them to the institution’s picture archiving and communicating system (PACS) for review and interpretation by a board-certified pediatric radiologist.

Billing

Using the corresponding CPT codes for SSTI for POCUS and RUS, data concerning charges toward the patients’ payer were collected via the institutions
professional billing services and our hospital system’s finance office. Cost was calculated from these charges which included technical and professional component of the radiology services. POCUS rates were set by payer-negotiated reimbursement through the institution’s finance office which included technical and professional fees billed through a third-party billing service.

Statistical analysis
For continuous measures, we reported descriptive summary statistics such as mean and standard error of the mean. The Wilcoxon test was used to test for differences over time. For categorical measures, we reported frequency and percentages. The Chi-square test was used to determine differences among proportions of ultrasound examination. $P<0.05$ was considered significant. All statistical analysis was performed using SAS 9.4. The study was powered by a sample size of 91 based on a confidence level of 95% and an alpha of 5% assuming a target population 100 which was based on approximately 50% of actual population of estimated patients with SSTI.

Results
A total of 242 patients were identified based on ICD-9 and ICD-10 codes for abscess or cellulitis in the pre-intervention cohort, with 220 patients meeting inclusion criteria. Thirty-eight out of 220 (17.3%) received ultrasound imaging as part of their ED workup, 26 out of 38 (68.4%) received POCUS, 12 (31.6%) received radiology-performed US, and 11 (28.9%) received both. Post-intervention, 224 patients were screened with 208 patients meeting inclusion criteria. Fifty-five out of 208 (26.4%) received ultrasound imaging as part of their ED workup, 39 out of 55 (71.0%) received POCUS, 16 (29.1%) received radiology-performed US, and 6 (10.9%) received both (Fig. 1).

There was no significant difference from pre- to post-intervention groups when comparing age and race. The average age of patients with ultrasound performed was 7.92 (standard error of mean [SEM] ± 0.99) years of age in the pre-intervention cohort and 6.83 (± 0.65) in the post-intervention cohort. Most study participants were Caucasian with 71% in the pre-intervention cohort and 58% in the post cohort (Table 1). The number of female patients included significantly increased from the pre- to post-intervention groups, 42%
Table 1 Demographics and characteristics of SSTI between pre-and post-intervention patients.

| Demographics | 2016–2017 N = 38 | 2018–2019 N = 81 | P-value |
|---------------|------------------|------------------|---------|
| Age in years  | 7.92 (±0.99)     | 6.83 (±0.65)     | 0.3252  |
| (± SEM)       |                  |                  |         |
| Gender (%)    |                  |                  | 0.0075  |
| Female        | 16 (42.1)        | 55 (67.9)        |         |
| Male          | 22 (57.9)        | 26 (32.10)       |         |
| Race (%)      |                  |                  | 0.1873  |
| Asian         | 0 (0.0)          | 1 (1.23)         |         |
| Black         | 10 (26.3)        | 33 (40.74)       |         |
| White         | 27 (71.0)        | 47 (58.02)       |         |
| Unknown       | 1 (2.63)         | 0 (0.0)          |         |
| SSTI infection|                  |                  | 0.1378  |
| Cellulitis    | 26 (69.4)        | 60 (73.4)        |         |
| Abscess       | 10 (26.5)        | 17 (20.2)        |         |
| Other         | 2 (5.31)         | 4 (4.94)         |         |
| SSTI location (%) |            |                  | 0.1727  |
| Upper extremity| 6 (15.7)        | 13 (16.0)        |         |
| Lower extremity| 18 (47.4)       | 36 (44.4)        |         |
| Buttock       | 9 (23.7)         | 11 (13.6)        |         |
| Cyst          | 3 (7.9)          | 11 (13.6)        |         |
| Other         | 2 (5.3)          | 10 (12.3)        |         |

P = < 0.05 denotes statistical significance
Min minimum, Max maximum

Table 2 Clinical experience. Description of imaging types, ED length of stay, and charges for corresponding imaging

| Imaging (N = 119) | 2016–2017 | 2018–2019 | P-value |
|-------------------|-----------|-----------|---------|
| Total ultrasound (%) | 38 (17.3) | 81 (38.9) | 0.000001 |
| POCUS alone (%)    | 26 (68.4) | 59 (72.8) | 0.6188  |
| POCUS + RUS (%)    | 0 (0.0)   | 6 (7.4)   | 0.3714  |
| POCUS + CT (%)     | 1 (2.6)   | 0 (0.0)   | 0.6286  |
| RUS alone (%)      | 10 (26.3) | 16 (19.7) | 0.9305  |
| RUS + CT (%)       | 1 (2.6)   | 0 (0.0)   | 0.6286  |
| Mean ED charges, $ | 3,762 (±219) | 2,193 (±13) | 0.0009  |
| POCUS charge (± SEM) | 3,491 (±345) | 2,193 (±116) | 0.00001 |
| RUS charge (± SEM) | 4,349 (±376) | 4,291 (±175) | 0.1411  |
| Mean ED LOS, minutes | 282 (±19)  | 185 (±13)  | 0.0001  |
| POCUS LOS (± SEM)  | 161 (±13)  | 140 (±10)  | 0.0001  |
| RUS LOS (± SEM)    | 266 (±28)  | 239 (±21)  | 0.0001  |

P < 0.05 denotes statistical significance
Min minimum, Max maximum

Discussion

POCUS is becoming more widely used in the pediatric ED to guide acute treatment decisions in patients with SSTI [3, 4]. Little is known about the clinical impact of POCUS training curriculums on patient management. Previous studies show that the use of POCUS can augment the clinical evaluation for management of ED patient with SSTI [3, 19]. In this novel study, we show the clinical impact of a soft tissue POCUS curriculum on pediatric ED patients with a presenting SSTI which can influence provider use of POCUS, improve ED metrics, and decrease cost burden. As a result, we found that a streamlined curriculum for faculty and fellows was associated with an increased frequency of POCUS being performed, significantly lower total mean charges, and a trend towards shorter ED LOS.

Unsurprisingly, we found the rate of POCUS examinations being performed was higher in the post-intervention group, (65/208) 31.2% from 26/220 (11.8%), p = 0.6188. This is consistent with prior research showing that SSTI training programs can enhance technical ability and POCUS utilization in the emergency department [1, 8]. Interestingly, a few of the patients (7.5%) in the post-intervention cohort received both POCUS and RUS evaluation. This is important because while most of the faculty and fellows were comfortable acquiring and interpreting the images, a few indeterminate scans may have required further evaluation and impression by the radiologist. The use of CT for further evaluation
of complex SSTI is common practice [15]. While 2 patients required additional CT in the pre-intervention, there were no CT scans utilized following the training. It is possible that this was associated with the implementation of the curriculum, but more likely due to the exclusion of patients with complex SSTI. Nevertheless, the practice of utilizing CT scans for non-complex SSTI was non-existent after the intervention. Further review of patient charts did not show any complications as a result of clinical management of SSTI in our patient cohort.

Evidence suggests that the use of ultrasound for bedside clinical evaluation is cost-effective [10–12, 18]. Common applications specific to the emergency setting such as the FAST not only decrease reliance on imaging such as the computed tomography (CT) for evaluation in stable patients, but also promote an efficient cost-effective approach to patient care [9]. Similarly, we
found significantly lower total mean charges from pre-
to post-intervention, $3,762 vs. $2,622, \( p = 0.009 \). In this
cost-effective analysis, the difference in cost when ultra-
sound alone was used compared to when radiology ultra-
sound was estimated at $1,100. As POCUS continues to
emerge, the cost-effectiveness is likely to be variable from
institution to institution and may also vary at various
time points due to internal fee adjustments based on fac-
tors such as professional and technical fees. We found no
cost variation during the time period of the retrospective
data analysis. Similarly, to prior POCUS studies, our data
suggest that although it may be limited, the inclusion of
POCUS promotes cost-effective care concomitantly with
ED efficiency [10].

It is well documented that SSTI can be made clinically
without POCUS, but its use can augment patient care
in the acute care setting [1–3]. Our retrospective cohort
sample was significantly smaller than other studies due
to stringent inclusion criteria applied to the data collect-
and because lower frequency of ultrasound use for
evaluation of SSTI at our instruction. Another primary
benefit of POCUS is the potential to enhance ED patient
experience metrics. This is most evident in evaluation of
SSTI as documented in prior literature where SSTI evalu-
ation by POCUS decreased LOS when compared to radi-
ology-performed ultrasound [11]. Similarly, to the study
by Lin et al., our study showed a trend toward a signifi-
cant decrease in ED LOS, 282 min pre-intervention vs.
185 min post-intervention, \( p = 0.001 \). However, while this
study adjusted findings for relevant clinical variables, it
included potential confounding diagnoses that may affect
LOS and cost-effectiveness. Furthermore, it is possible
that factors such as triage and registration, peak times,
and staffing may have had minimal effect on the LOS
time collected.

**Limitations**

There are several limitations to consider in this study.
This study is based on a one-group pre- and post-assess-
ment after an intervention which lacks a control group
for comparison. Additionally, this type of study may
have confounding factors that might not be associated
with the intervention which may affect the validity of
the study. The majority of our patients were Caucasian,
which raises concerns about whether this can be gen-
eralizable. Additionally, the lack of external validity in
single-center studies may limit the true effect of soft tis-
sue POCUS training. Of importance, the smaller sample
size which excluded a substantial portion of the patient
population may also underestimate the true effect of the
training curriculum. However, evidence does support
the beneficial impact of soft tissue training to enhance
management of SSTI in the pediatric ED [3]. Soft tissue
POCUS required that a trained faculty or fellow had to
be present and be confident enough in their skill and
interpretation to apply US findings clinically while avoid-
ing complete radiology ultrasound evaluation. However,
even though the majority of our physicians were creden-
tialed during this study, not all were confident enough to
use the study frequently, but this is likely to improve as
we gain more understanding into the longitudinal effects
of POCUS implementation curriculums on clinical out-
comes and patient experience.

**Conclusions**

After training pediatric emergency medicine faculty and
fellows to use POCUS for SSTI, clinical utilization of
this application increased while being cost-effective and
decreasing the LOS for patients presenting to ED with
SSTI. This suggests that investing in POCUS training for
applications such as SSTI can enhance the patient expe-
rience while keeping costs low and avoiding unnecessary
invasive procedures.

**Summary**

Soft tissue evaluation is a high-yield POCUS applica-
tion that can augment patient care while improving
management in the pediatric acute care setting. This
study emphasizes the importance of establishing a cur-
riculum to enhance its use by clinicians. To this regard,
our findings showed an improved utilization with an
associated impact on efficiency of patient care and
cost-effectiveness.

**Meetings**

American Academy of Pediatrics Virtual National Con-
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**Author contributions**

All authors conceived the study and design. FR supervised the conduct of the
study, data collection, and initial and revision of the manuscript. BN and WP
managed the data, including quality control. ES provided statistical advice
on study design and analyzed the data. BN drafted the manuscript, and all
authors contributed substantially to its revision. BN takes responsibility for the
paper as a whole. All authors read and approved the final manuscript.

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**Declaration**

**Competing interests**

Benjamin Nti and Frances Russell provide occasional consultation to various
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Electric had no involvement in the project development, data collection and
analysis, manuscript authorship, or any support regarding this study in its entirety.

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