Trauma Surgery & Acute Care Open

Serratus anterior plane block improves pain and incentive spirometry volumes in trauma patients with multiple rib fractures: a prospective cohort study

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Received 30 December 2023
Accepted 6 April 2024

To cite: Sadauskas V, Fofana M, Brunson D, *et al*. *Trauma Surg Acute Care Open* 2024;**9**:e001183.

ABSTRACT

Background Rib fractures are common injuries associated with considerable morbidity, long-term disability, and mortality. Early, adequate analgesia is important to mitigate complications such as pneumonia and respiratory failure. Regional anesthesia has been proposed for rib fracture pain control due to its superior side effect profile compared with systemic analgesia. Our objective was to evaluate the effect of emergency physician-performed, ultrasound-guided serratus anterior plane block (SAPB) on pain and respiratory function in emergency department patients with multiple acute rib fractures.

Methods This was a prospective observational cohort study of adult patients at a level 1 trauma center who had two or more acute unilateral rib fractures. Eligible patients received a SAPB if an emergency physician trained in the procedure was available at the time of diagnosis. Primary outcomes were the absolute change in pain scores and percent change in expected incentive spirometry volumes from baseline to 3 hours after rib fracture diagnosis.

Results 38 patients met eligibility criteria, 15 received the SAPB and 23 did not. The SAPB group had a greater decrease in pain scores at 3 hours (−3.7 vs. −0.9; p=0.003) compared with the non-SAPB group. The SAPB group also had an 11% (CI 1.5% to 17%) increase in percent expected spirometry volumes at 3 hours which was significantly better than the non-SAPB group, which had a −3% (CI −9.1% to 2.7%) decrease (p=0.008).

Conclusion Patients with rib fractures who received SAPB as part of a multimodal pain control strategy had a greater improvement in pain and respiratory function compared with those who did not. Larger trials are indicated to assess the generalizability of these initial findings.

INTRODUCTION

Rib fractures are common injuries known to be associated with considerable morbidity, long-term disability, and mortality.[1–3] Many adverse sequelae occur due to inadequate analgesia, which hinders deep inspiration leading to atelectasis, pneumonia, and respiratory failure.[4 5] Early, adequate analgesia is crucial to mitigate such complications.[6]

Current rib fracture pain management protocols include oral and intravenous analgesia and, more recently, neuraxial and intercostal nerve blocks.[6 7] Although efficacious, neuraxial and intercostal nerve blocks can be technically challenging procedures and require patient positioning that is not always conducive to the emergency department (ED) trauma environment. As such, placement of this block is often delayed. With the proliferation of point-of-care ultrasound-guided procedures in the ED, the serratus anterior plane block (SAPB) has been proposed as a readily accessible adjunct analgesic modality.[7–9] At present, published evidence for the efficacy of SAPB in the ED setting performed by emergency physicians is mainly limited to case series.[9–11] Although a recent study showed improvements in pain and incentive spirometry volumes (ISVs) among patients in the ED after receiving the SAPB, these effects were not compared with a non-intervention group.[12] A recent randomized controlled trial of SAPB for rib fractures demonstrated improved pain scores relative to control; however, the blocks were administered by trained anesthesiologists.[13]

We aimed to prospectively assess whether a SAPB performed in the ED shortly after arrival is associated with improved early analgesia among patients presenting with multiple acute rib fractures compared with a regimen without SAPB. We hypothesized that use of the SAPB would be associated with improved pain scores and ISV 3 hours after the initial rib fracture diagnosis.

METHODS

Study design

We conducted a prospective observational cohort trial using a convenience sample at our level I trauma center between March 2020 and July 2021.

Study population

Adults aged ≥18 years presenting to the ED between 07:00 and 23:00, within 24 hours of injury, and with ≥2 anterior and/or lateral (regions targeted by SAPB) rib fractures on CT met inclusion criteria. Exclusion criteria included: bilateral rib fractures (unknown safety profile of bilateral SAPB), posterior rib fractures, sternal fracture, pain from another distracting injury, inability to report pain, anesthetic allergy, pregnancy, coagulopathy, hemodynamic instability, need for emergent operative intervention or other emergent thoracic procedures (eg, tube thoracostomy). To screen patients, an automated messaging system was integrated into the electronic health record to alert investigators in real time when the words 'rib fracture(s)' appeared in a radiology report of a chest CT ordered from

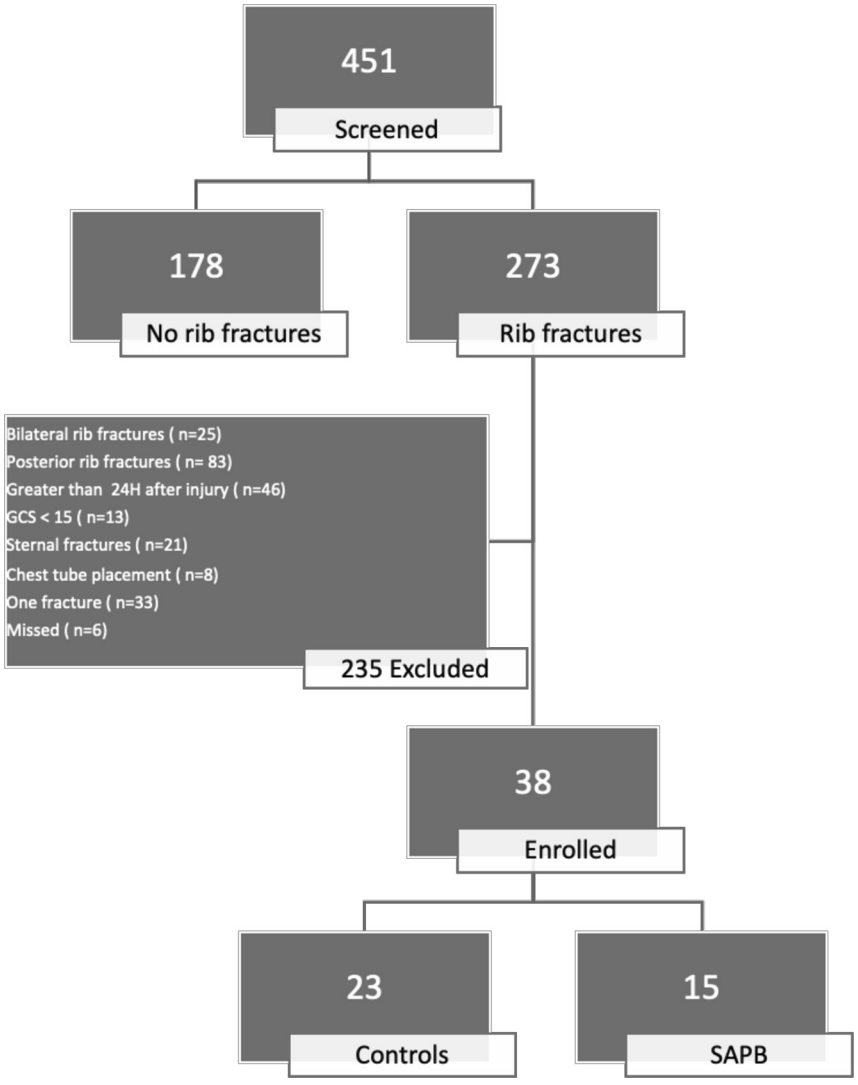

Figure 1 Screening, exclusion, and enrollment breakdown of potential participants after identification via automated electronic health record notification system. GCS, Glasgow Coma Scale; SAPB, serratus anterior plane block.

the ED. An investigator then reviewed the chart and spoke with the clinical team to determine eligibility.

Technique

The SAPB was performed under ultrasound guidance with a 6–14 MHz high-frequency linear probe. The probe was placed transversely at the midaxillary line at the level of the fifth rib, and 0.5 cc/kg of 0.25% bupivacaine was infused into the fascial plane superficial to the serratus anterior muscles under dynamic, in-plane ultrasound visualization. For patients who met inclusion and exclusion criteria, SAPB was offered as part of a multimodal analgesia strategy if an emergency physician trained in the procedure was present in the ED, regardless of the patient's initial pain score. If a SAPB-trained emergency physician was not available or if the patient declined the procedure, the patient was placed in the non-SAPB group.

Study protocol

We recorded initial ISV and Numeric Rating Scale pain scores of all patients at the time of rib fracture diagnosis. A second set of ISV and pain score was gathered 3 hours after diagnosis. If the patient received the SAPB, they received it promptly after rib fracture diagnosis, so the analgesic effects of the block would

Table 1 Baseline demographic characteristics of participants

	SAPB	Control	P value
N	**15**	**23**	
Age (years, SD)	58 (21)	64 (19)	0.35
Gender			0.53
Male	10 (66%)	10 (43%)	
Female	5 (33%)	13 (56%)	
Comorbidities			
Asthma	1 (6.7%)	1 (4.3%)	0.75
COPD	1 (6.7%)	2 (8.7%)	0.82
Coronary artery disease	2 (13.3%)	3 (13%)	0.98
Current smoker	2 (13.3%)	1 (4.3%)	0.32
Former smoker	3 (20%)	4 (17.4%)	0.84
Mean time from injury to ED arrival (hrs, SD)	2 (2.6)	2.1 (5)	0.97
Mean number of rib fractures (SD)	4.2 (1.7)	3.2 (1.24)	0.05
Baseline pain score	8.5 (1.1)	5.6 (2.6)	0.0001
Baseline % expected IS volume	60 (27)	71 (21)	0.22

COPD, chronic obstructive pulmonary disease; ED, emergency department; IS, incentive spirometry; SAPB, serratus anterior plane block.

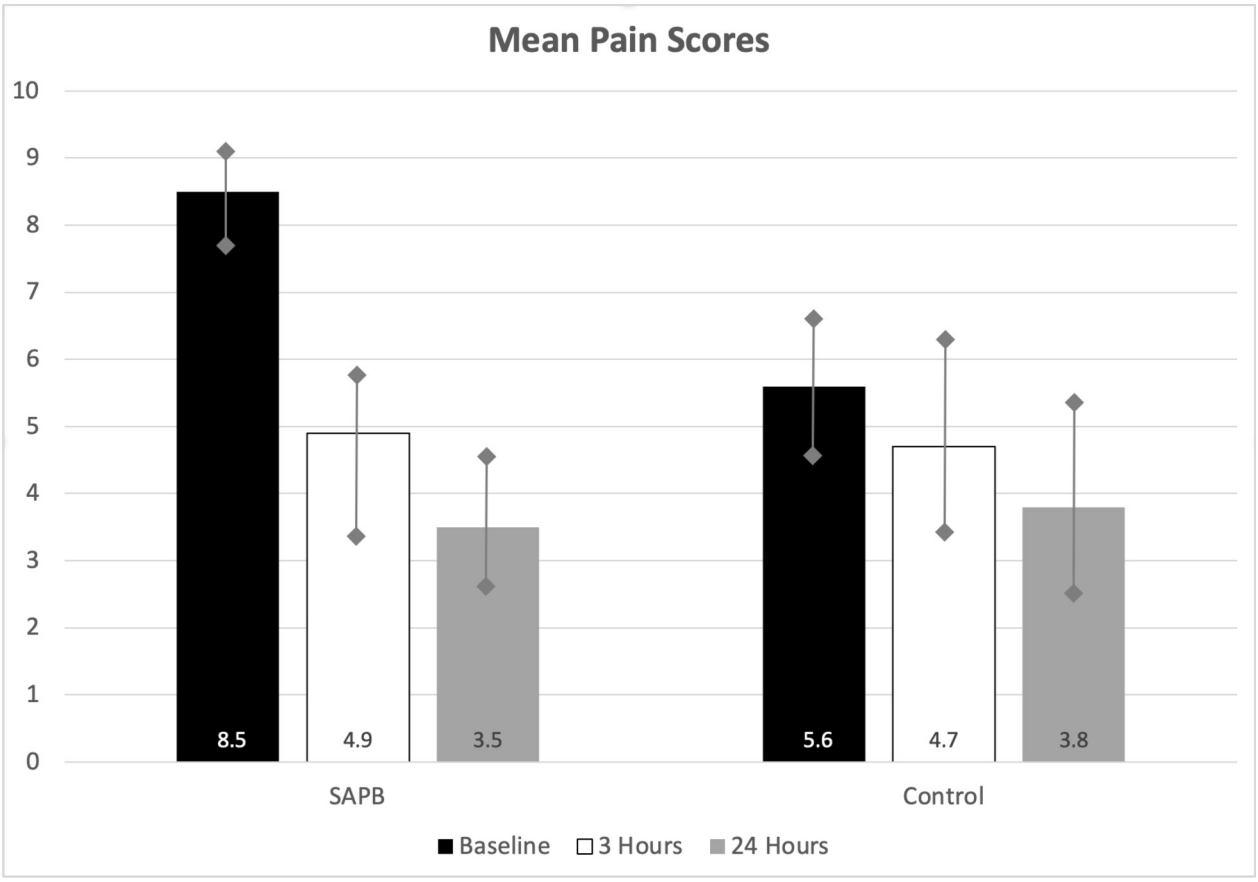

Figure 2 Pain scores at baseline, 3 hours, and 24 hours for the SAPB and the non-SAPB groups. SAPB, serratus anterior plane block.

be in effect by the 3-hour time point. ISV and pain scores were recorded at 3 hours from time of diagnosis to standardize data collection between the block and non-block groups, accounting for all pain control interventions in the same time window. Whether the patient underwent SAPB or not, they received standard of care therapy for rib fractures, including systemic analgesia, as deemed appropriate by the treating team.

Key outcome measures

The primary outcomes were the absolute change in pain scores and percent change in expected ISV from baseline to 3 hours. Expected ISV was calculated using reference values published by the Centers for Disease Control and Prevention.[14] Secondary outcomes included change in pain scores and expected ISV at 24 hours from baseline, morphine equivalents administered, hospital length of stay, and supplemental oxygen requirement.

Statistical analysis

We designed this study to detect a 10% or 1.5 mL/kg difference in ISV. Based on a two-sided alpha of 0.05 and 80% power, we determined that we would need 17 patients per group assuming 10% variance. For the outcome of pain, we designed this study to detect a 10% change. Based on 80% power and a two-sided alpha of 0.05, we determined that we would need a minimum of 16 patients in each group.

T-tests were used to compare the 3-hour and 24-hour changes in pain score and ISV between the SAPB and non-SAPB groups. T-tests were also used to assess the secondary outcomes of morphine equivalents and hospital length of stay between the two groups. X^2 analysis was used to assess the binary secondary outcomes of need for intensive care unit (ICU) admission and supplemental oxygen.

RESULTS

The study period was from March 2020 to July 2021, with an interruption in screening between May 2020 and September 2020 due to COVID-19-related research restrictions. 451 trauma patients were screened, 273 had rib fractures and among those, 38 patients met eligibility criteria (figure 1).

There were no significant differences in the baseline demographic characteristics of participants in the two groups (table 1). The patients in the SAPB group did have higher baseline pain scores.

The SAPB group had a greater decrease in pain scores at both 3 hours (−3.7 vs. −0.9; p=0.003) and 24 hours (−5.1 vs. −2.0; p=0.02) compared with the non-SAPB group (figure 2). The SAPB group also had an 11% (CI 1.5% to 17%) increase in mean expected ISV at 3 hours, whereas the non-SAPB group actually had a −3% (CI −9.1% to 2.7%) decrease (p=0.008). The improvement in ISV was no longer apparent at 24 hours, at which point SAPB and the non-SAPB group both had a decrease in mean percent expected ISV compared with baseline (−6% (CI −18% to 5.3%) vs. −9% (CI −18% to 0.9%); p=0.71, respectively) (figure 3).

There was no significant difference in morphine milligram equivalent (MME) administered to the SAPB group versus the non-SAPB group at 6 hours (5.4 mg (CI 3.1 to 7.8) vs. 4.2 mg (CI 1.9 to 6.6), p=0.47) or 12 hours (9.7 mg (CI 5.7 to 13.7) vs. 7.0 (CI 3.5 to 10.5), p=0.30) after rib fracture diagnosis (table 2). The SAPB group had a mean hospital length of stay of

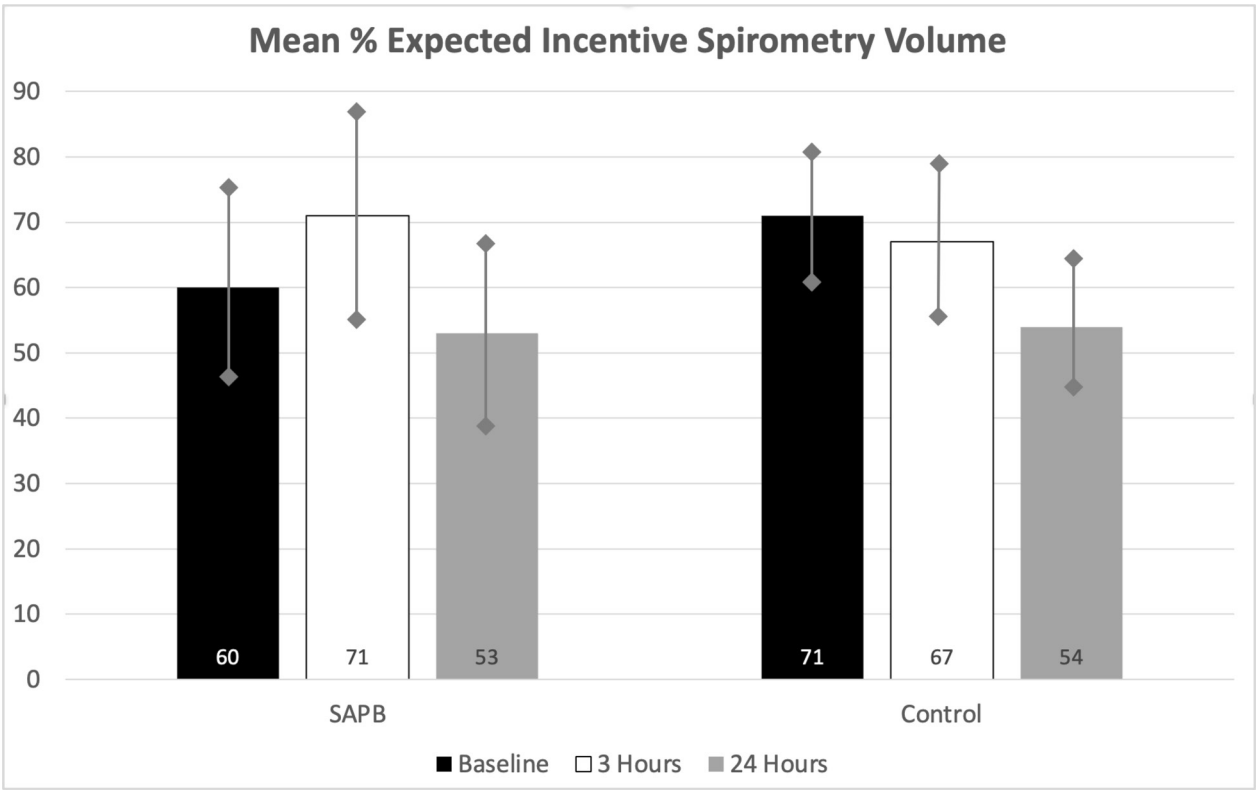

Figure 3 Incentive spirometer volumes at baseline, 3 hours, and 24 hours for the SAPB and the non-SAPB groups. SAPB, serratus anterior plane block.

2.9 days (CI 1.5 days to 4.5 days), whereas the non-SAPB group had a mean hospital length of stay of 2.3 days (CI −1.6 days to 6.2 days) (p=0.79). The SAPB group had a greater need for ICU admission with an OR of 3.24 (CI 0.82 to 12.82), but this was not statistically significant (p=0.09). There was no significant difference in need for supplemental oxygen requirement between the two groups (OR 1.78 (CI 0.48 to 6.62), p=0.391). There were no adverse outcomes of the SAPB, including no newly diagnosed pneumothoraxes, no allergic reactions and no local anesthetic toxicity. Neither group experienced a severe complication resulting from their rib fractures including no documented new diagnosis of pneumonia, no intubation due to rib fractures during the hospital stay and no deaths attributed to thoracic trauma.

DISCUSSION

Our findings suggest that the SAPB is a promising technique for use in the ED to provide early analgesia and improvement in respiratory function for patients with acute rib fractures. Prior to the introduction of the SAPB, patients would often rely solely on systemic analgesia, primarily opioids, until inpatient admission hours later. The significant decrease in pain seen in our SAPB group relative to the non-SAPB group suggests this approachable procedure could be a clinically important analgesia tool as part of a multimodal pain management strategy that can be initiated while the patient is still in the ED.

We also found that those who received an ED SAPB had a 3-hour improvement in mean percent of expected ISV, whereas the non-SAPB group had a decrease in mean percent of expected ISV in this time frame. Higher ISVs have been associated with more favorable rib fracture outcomes.[15 16] However, the improvement in ISV seen in our SAPB group at 3 hours was not maintained at 24 hours. More study is required to determine whether early SAPB has an effect on the later pulmonary complications associated with rib fractures. Although we looked at the need for supplemental oxygen and new diagnosis of pneumonia as secondary outcomes, this study was underpowered to detect these differences.

Table 2 Secondary outcomes

	SAPB	No SAPB	OR (95% CI)	P value
N	**15**	**23**		
Morphine equivalents, mean (95% CI), mg IV morphine				
6 hrs	5.4 (3.1 to 7.8)	4.2 (1.9 to 6.6)		0.47
12 hrs	9.7 (5.7 to 13.7)	7.0 (3.5 to 10.5)		0.30
Hospital length of stay, mean (95% CI), days	2.9 (1.5 to 4.5)	2.3 (–1.6 to 6.2)		0.79
ICU admission, n (%)	8 (53)	6 (26)	3.24 (0.48 to 6.62)	0.09
Supplemental oxygen required, n (%)	8 (53)	9 (39)	1.78 (0.82 to 12.82)	0.39

ICU, intensive care unit; IV, intravenous; SAPB, serratus anterior plane block.

The improved pain relief persisted at 24 hours post-diagnosis for patients who received SAPB, which suggests that early pain control may lead to lasting improvements in pain even after the effects of the block wear off. The lack of a difference in the MME received by the two groups suggests that although the SAPB group had higher initial pain scores, the improved analgesia was not secondary to an increased use of intravenous narcotics.

The average time from rib fracture diagnosis to placement of the SAPB was 58 minutes. Compared with the higher procedural complexity and difficult positioning required for an erector spinae block, the SAPB is technically simpler and can be performed with the patient supine, making it conducive to more rapid placement in the ED.

Of the 15 SAPBs that were performed in our study, 12 were by different operators, 10 of whom were resident physicians. Prior to this study, a group of emergency physicians at our institution underwent a training session on SAPB augmented by high-fidelity simulation.[17] The ability of these physicians to learn the SAPB during a single training session reflects the relative technical ease of this nerve block and suggests that it is feasible for a diverse group of acute care physicians to master. However, given the relative novelty of the procedure, there remains the possibility of operator-dependent block efficacy. Reassuringly, no adverse events were noted among the group who received the SAPB.

Limitations

This study had several limitations. The two cohorts had significantly different initial pain score measures, suggesting a baseline difference between cohort populations. As the study was not randomized, this difference in baseline pain scores likely suggests some selection bias, random variation, or patient-related discrepancy. It is possible that the treating team tended to choose to perform the SAPB on patients with higher baseline pain levels. Additionally, it is possible that patients with lower baseline pain scores may have been more likely to refuse the procedure, as they thought the risk of undergoing a procedure outweighed the perceived benefit.

Additionally, the study was limited by the failure to enroll to the desired sample size. The intervention arm was two patients short of goal enrollment when the study period ended due to personnel and resource constraints. Although clinically validated, the pain score is a subjective scale. There may have been variability between patients when reporting levels of pain. Finally, there may have been inter-rater variability when measuring ISV.

CONCLUSION

Patients with rib fracture who received the SAPB as part of a multimodal analgesia strategy had improved pain and improved respiratory function as measured by ISV when compared with patients who did not receive the SAPB. This study suggests that the SAPB is a promising technique that can be performed in the ED for early effective analgesia in patients with multiple anterior and lateral rib fractures. A larger, multicenter, randomized controlled trial could better assess the generalizability of these initial findings and determine other potential impacts of the SAPB, such as opioid administration, respiratory complications, hospital length of stay and mortality.

Contributors Study concept and design—VS, MF, DB, JC, JVQ, DS and YD. Acquisition of the data—VS, MF, DB and YD. Analysis and interpretation of the data—VS, MF, DB, JC and YD. Drafting of the article—VS, MF, DB and YD. Critical revision of the article for important intellectual content—JC, JVQ and DS. Statistical expertise—JC and YD. Acquisition of funding—VS, JVQ and YD.

Funding This study was funded by SAEM Foundation/Academy of Emergency Ultrasound Research Grant.

Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and ethical approval for this study was granted by the Stanford University Institutional Review Board (protocol #52801). Informed consent was not required for participation due to the observational design of the study.

Provenance and peer review Not commissioned; internally peer reviewed.

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