Ultrasound-Guided Serratus Anterior Plane Block (SAPB) Improves Pain Control in Patients With Rib Fractures

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Objectives—The serratus anterior plane block (SAPB) is an ultrasound-guided compartment block; limited data suggest that it can decrease pain in patients with rib fractures or chest wall pain. We sought to determine the effect of SAPB on pain and incentive spirometry (IS) maximal vital capacity in adult patients with rib fractures.

Methods—We enrolled a prospective sample of adult patients with at least two unilateral rib fractures who were being admitted for pain control. SAPB was performed by trained emergency physicians. Patients reported pain on an 11-point Numeric Rating Scale at rest and during IS, before, 15, and 60 minutes after SAPB.

Results—Mean pain scores decreased by 1.8 (SD 2.17, 95% confidence interval [CI]: 0.79–2.81) at 15 minutes and 2.5 (SD 2.69, 95% CI: 1.24–3.76) at 60 minutes. Compared to pre-block pain scores during IS, mean pain scores decreased by 1.95 (SD 1.99, 95% CI: 1.02–2.88) at 15 minutes and 2.4 (SD 2.42, 95% CI: 1.27–3.53) at 60 minutes. Mean maximum vital capacity increased by 232 mL (SD 406, 95% CI: 36–427) at 60 minutes. Zero SAPB-attributable complications were identified in the 24 hours post-enrollment.

Conclusions—In patients with multiple rib fractures, SAPB reduced pain scores at rest and during IS, and increased maximal vital capacity. The SABP may be a safe and effective modality for pain control in trauma patients with multiple rib fractures.

Key Words—rib fractures; ultrasound-guided nerve block

Trauma is a major cause of morbidity and mortality worldwide. Rib fractures, typically due to blunt thoracic trauma from motor vehicle collisions and falls, are common and identified in up to 10% of all injured patients.[1] Rib fractures are associated with respiratory complications such as pneumonia, which has been shown to occur in up to 31% of patients with rib fractures.[2] Early initiation of aggressive pain control and pulmonary hygiene with incentive spirometry are standard of care to prevent the development of pneumonia and respiratory failure.[3,4] In the emergency department (ED), patients with rib fractures typically receive systemic analgesia with opiates.[5] This pain control strategy puts patients at risk for the side effects of opiates such as constipation, delirium, and opioid addiction. Patients who are admitted to the hospital will often have an epidural placed to improve pain control; however, because of the

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time and resources required for epidural placement, patients may not receive an epidural until many hours into their hospital stay, or longer if interfacility transfer is required.[5]

Regional ultrasound-guided anesthesia is well within the purview of emergency physicians and offers a safe and effective complement or alternative to systemic pain medications.[6] The serratus anterior plane block (SAPB) was recently described as a strategy for controlling pain related to rib fractures.[7] To perform this block, the operator identifies the serratus anterior muscle under ultrasound guidance, and instills local anesthetic in the fascial plane overlying the muscle. As the patient breathes, the anesthetic distributes throughout the fascial plane, anesthetizing the lateral cutaneous branches of the intercostal nerves. The distribution of anesthetic is suited to providing analgesia for anterior and lateral rib fractures, but not for posterior fractures.[7,8]

An added benefit of the SAPB is that it can be performed with the patient in a supine position in contrast to other plane blocks such as the erector spinae plane (ESP) block, allowing for its use in patients with pain that limits mobility. Several case reports have been published describing the SAPB as effective in controlling pain from rib fractures; however, these case reports have a small number of patients ($n = 1$–6), limiting their generalizability.[9,10] A retrospective study has shown that anesthesiologist-performed SAPB with delivery of continuous anesthetic via catheter placement improves pain scores and incentive spirometry volume.[11] Our prospective study aimed to evaluate the effect of emergency physician-performed single injection SAPB on chest wall pain and mean vital capacity as measured using incentive spirometry in adult trauma patients with rib fractures.

Materials and Methods

We conducted an interventional study at a single tertiary care referral center with a level I trauma designation; the approximate annual ED census is 90,000. A group of 6 emergency medicine physicians (3 senior residents, 2 ultrasound fellows, and 1 attending physician) completed a 1 hour didactic and hands-on training in performing the SAPB under ultrasound guidance and were eligible to enroll patients in the study. The methods of this study were approved by the Institutional Review Board.

Enrolling physicians screened study subjects via the hospital's trauma team activation paging system and reviewed the electronic medical record for detail of their injuries. Subjects were recruited as a convenience sample based on investigator availability. Inclusion criteria were patients ≥18 years of age with acute traumatic injuries including (but not limited to) ≥2 unilateral fractures of anterior or lateral ribs 2 to 9 with plan for admission to the trauma service. Exclusion criteria included patients who were intubated; clinically significant intracranial hemorrhage or traumatic brain injury; significant distracting injuries, defined as injuries we deemed likely to impair accurate assessment of effect of the SAPB on pain from rib fracture; clinical intoxication; a plan for the patient to go the operating room emergently; a preexisting chest tube, or anticipation that one would be placed; allergy to bupivacaine; or a weight <50 kg such that the standard dose of analgesic to be administered could not be safely given.

After informed consent was obtained, patients were asked to report their chest wall pain on the 11-point Numeric Rating Scale (NRS-11).[12] The NRS-11 is an 11-point scale where pain is rated from 0 (no pain) to 10 (worst pain imaginable).[12] Patients were then provided with an incentive spirometer (IS) and instructed in its use. Patients were asked to use the IS to their maximum vital capacity, and report their chest wall pain on the NRS-11 during incentive spirometry use. The SAPB was then performed under ultrasound guidance with the patient in the supine or left lateral decubitus position. A high-frequency linear transducer was placed in the mid-axillary line in transverse orientation at the level of the 5th intercostal space. The serratus anterior muscle, which lies just superficial to the ribs, was identified. An 18-gauge needle was guided in-plane just underneath the superficial fascial plane of the serratus anterior muscle and 30 mL of anesthetic solution, containing 20 mL of bupivacaine 0.5% and 10 mL of sterile saline, was injected (Figure 1).

Fifteen and 60 minutes after the SAPB was performed, patients were again asked to report their chest wall pain on the NRS-11 at rest and during incentive spirometry. For the 24 hours after the block was performed, patients were managed by the trauma

service and followed by investigators at bedside during data collection and then via chart review to determine if any complications attributable to the SAPB occurred, including pneumothorax, cardiac dysrhythmia, local anesthetic systemic toxicity, allergic reaction, infection or hematoma at SAPB site, or clinically significant bleeding.

The primary outcome was the change in pain score at rest 60 minutes after SAPB. Changes in pain score at 15 minutes, during incentive spirometry at both time points, and in maximum vital capacity were secondary outcomes.

Data were analyzed using SPSS statistical software for Windows (SPSS, Inc., Chicago, IL). Descriptive statistics were used to summarize the characteristics of the study population and to characterize the chest wall pain experience for participants at baseline, 15, and 60 minutes post-SAPB, both with and without incentive spirometry. We summarize these data as means, standard deviations (SDs), and associated 95% confidence intervals (CIs). In addition, we present medians and interquartile ranges (IQRs). Changes in chest wall pain are presented as differences in means and medians with their associated 95% CIs. CIs around differences in medians were constructed using bootstrap resampling.[13]

Figure 1. Transverse ultrasound image of serratus anterior plane block anatomy. SA, serratus anterior muscle; R, rib; asterisk, anesthetic deposit in the plane for the block; arrow, needle.

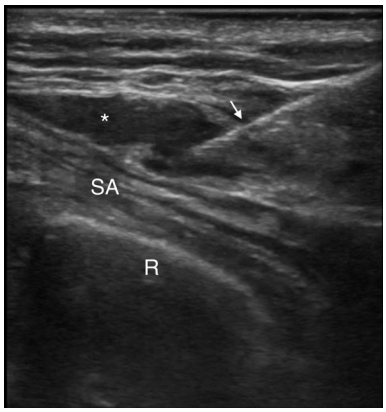


Table 1. Characteristics of Patients Enrolled

Age (mean)	62.3
Sex	50% (10) male; 50% (10) female
Median number of rib fractures (range)	4 (2–8)
Pneumothorax present	20% (4)
On antiplatelet medication	15% (3)
Transfer from outside hospital	30% (6)

Results

During the study period from January 2019 to June 2020, 24 patients were approached for enrollment and assessed for eligibility. Four patients declined enrollment; 20 patients, ages 33 to 95 (mean age 62.3), were enrolled by the 6 operators in the study (median 2.5 patients enrolled per operator). Patients were 50% male, 50% female. The median number of rib fractures was four; range (2–8) (Table 1).

The mean and median pain score at rest prior to the block were 5.4 (SD 3.28) and 6.5 (IQR 2, 8), respectively. Figure 2A provides a graphical depiction of individual pain scores at rest, before the SAPB was performed, compared to 15 and 60 minutes after the SAPB was performed. Baseline pain scores at rest and with IS, as well as changes after SABP, are presented in Table 2. Patient-level depiction of pain scores with IS are shown in Figure 2B. Mean pain scores at rest after the block decreased at both 15 and 60 minutes. The mean decrease in pain score at 60 minutes was 2.5 (95% CI: 1.24–3.76). Mean vital capacity pre-block was 1545 mL. At 60 minutes post-SABP, mean increase in vital capacity was 232 mL (95% CI: 36–427). Table 3 and Figure 3 show changes in IS parameters after the block at summary and patient level.

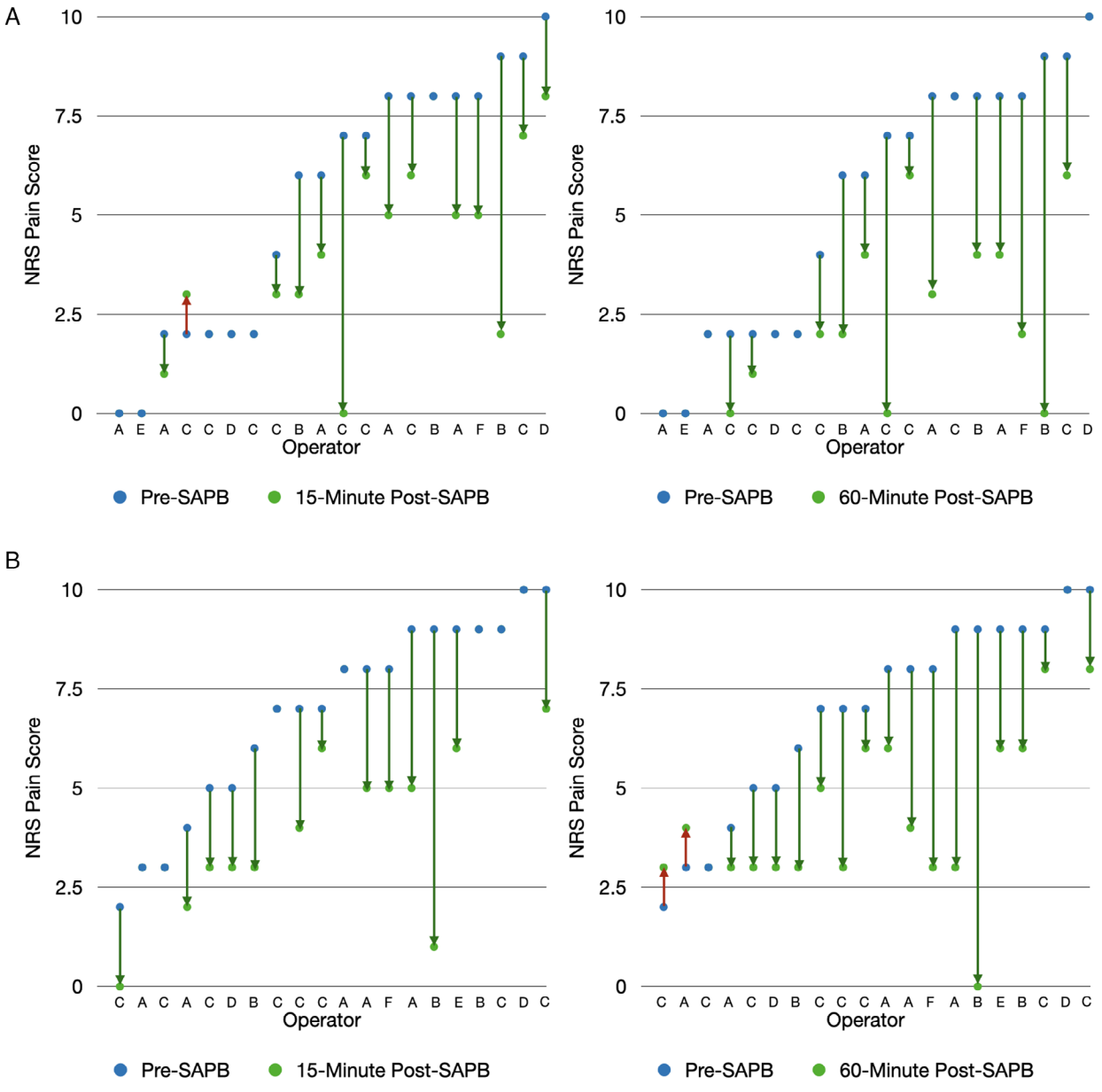
No complications attributable to the SAPB were identified in our study population in the 24 hours following enrollment.

Discussion

This study builds on the previous evidence that the SAPB is a safe and effective modality for pain control in trauma patients with multiple rib fractures.[9,10] Our data support the use of the SAPB as an effective adjunct for pain control in patients with multiple anterior and lateral rib fractures. We opted to

measure pain as scored on the NRS-11 and vital capacity at 15 and 60 minutes after the SAPB in order to obtain multiple data points on the effect of the SAPB on chest wall pain and respiratory performance. Data collected 15 minutes after the SAPB was performed capture patient experience just as the block is beginning to take effect; by 60 minutes after the SAPB, the block is in full effect. Mean and median pain scores were lower at both 15 and 60 minutes post-block compared to pre-block, demonstrating the effectiveness of the SAPB throughout this period. Our study population had moderate levels of pain pre-block (mean NRS-11 of 5.4); it is possible that a more selected population with higher mean pain

Figure 2. Patient-level depiction of pain scores at rest pre-block versus 15 and 60 minutes post-SABP (panel **A**), and pain scores during incentive spirometry pre-SAPB versus post-SAPB (panel **B**). Letters on X axis indicate the proceduralist performing the block.



scores would derive even greater benefit from the SABP. Visual inspection of patient-level data shows the effect of the block was most pronounced in patients with more severe pain (Figure 2). We recognize the NRS-11 does have limitations as a subjective measure of pain; for this reason, we also recorded

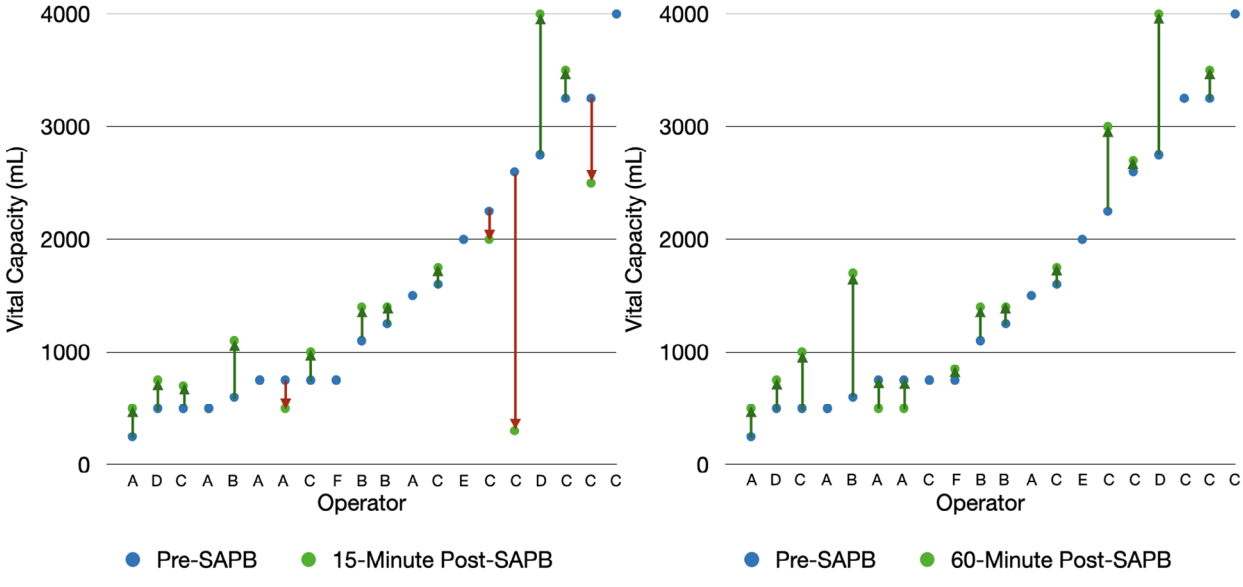
Table 2. Median and Mean Pain Scores at Rest and With IS, Pre-SAPB Compared to 15 and 60 Minutes Post-SAPB

	Median pain score (IQR)	Mean pain score (95% CI)	Change in mean pain score compared to pre-block (95% CI)
At rest, pre-SAPB	6.50 (2.00, 8.00)	5.40 (3.86–6.94)	
At rest, 15 minutes post-SAPB	3.00 (2.00, 5.75)	3.60 (2.40–4.80)	−1.80 (0.79–2.81)
At rest, 60 minutes post-SAPB	2.00 (0.25, 4.00)	2.90 (1.59–4.21)	−2.50 (1.24–3.76)
With IS, pre-SAPB	7.50 (5.00, 9.00)	6.90 (5.74–8.06)	
With IS, 15 minutes post-SAPB	5.00 (3.00, 7.00)	4.95 (3.65–6.25)	−1.95 (1.02–2.88)
With IS, 60 minutes post-SAPB	3.50 (3.00, 6.00)	4.50 (3.40–5.60)	−2.40 (1.27–3.53)

Table 3. Median and Mean Vital Capacity via IS, Pre-SAPB Compared to 15 and 60 Minutes Post-SAPB

	Median vital capacity (IQR)	Mean vital capacity (95% CI)	Change in mean vital capacity compared to pre-block (95% CI)
Pre-SAPB	1175 mL (637, 2512)	1545 mL (1021–2068)	
15 minutes post-SAPB	1250 mL (712, 2000)	1545 mL (1005–2084)	+0 mL (−288 to 288)
60 minutes post-SAPB	1500 mL (750, 3000)	1832 mL (1244–2419)	+232 mL (36–427)

Figure 3. Patient-level changes in vital capacity at 15 and 60 minutes post-SABP.



vital capacity during incentive spirometry. Modest improvements in mean and median vital capacity after the SAPB was performed also suggest the effectiveness of the block.

The SAPB is relatively simple to perform; it does not require delivery of anesthetic to a particular nerve, but to a plane. Similar to the popular fascia iliaca compartment block for patients with hip fractures, the SAPB is straightforward to perform with ultrasound guidance. With minimal training, our study investigators performed the block with zero complications attributable to the SAPB identified over the study period. The ease of performing the block, coupled with the clinical importance of managing pain from rib fractures with opioid-sparing approaches makes the SAPB attractive to emergency clinicians. The duration of action of a single-injection block is limited compared to placement of an epidural catheter, but a single block will fall within the scope of practice for more emergency clinicians, and may serve as a bridge to catheter placement, or to facilitate pain control during transfer from a smaller hospital to a trauma center or hospital that cares for patients with these injuries. It is important to note that the SAPB is not predicted to provide analgesia effective for posterior rib fractures, where an ESP block would be more suitable for regional anesthesia in the ED.

We used bupivacaine as the local anesthetic in this study per local availability, and performed the block without any steroid or other additives. Block effectiveness and duration might be affected by using another agent, such as ropivacaine, or with the addition of dexamethasone.

Our study has several limitations, including the small sample size and single center, nonrandomized design. Enrollment of study subjects was hindered by the relatively restrictive exclusion criteria we used in order to ensure patients would be able to report their chest wall pain scores as accurately as possible; we also excluded patients with posterior rib fractures who were unlikely to benefit from the block. Such patients might benefit from other plane blocks, such as an ESP block. Even with these exclusion criteria, our data are subject to error related to distracting injuries. Our study is also limited in its ability to control for the placebo effect of the SAPB. Future randomized, placebo-control trials could feasibly be performed given the existing evidence that the SAPB is safe and demonstrates effectiveness at improving chest wall pain in patients with rib fractures. As well, the proceduralists in this study had a range of clinical experience, but all had at minimum a baseline fund of experience with point-of-care ultrasound, which does not generalize to all clinicians. In addition, we did not evaluate the effect of the SABP on downstream patient-oriented outcomes, such as pain control after hospital admission, incidence of pneumonia, delirium, length of hospital stay, discharge disposition, or mortality; these would be relevant to explore in future studies.

Despite these limitations, treating pain is a critical patient outcome, and our data demonstrate that SABP decreased pain in this population of patients with rib fractures. Our data also support the placement of SABP by emergency physicians during the initial management of patients with rib fractures. We anticipate SAPB has the potential to become a standard management option for emergency physicians seeking an adjunct or opioid-sparing strategy for pain control in patients with anterior or lateral rib fractures.

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