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Original Article

Serratus plane block: a novel ultrasound-guided thoracic wall nerve block

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Summary

We present a novel ultrasound-guided regional anaesthetic technique that may achieve complete paraesthesia of the hemithorax. This technique may be a viable alternative to current regional anaesthetic techniques such as thoracic paravertebral and central neuraxial blockade, which can be technically more challenging and have a higher potential side-effect profile. We performed the serratus block at two different levels in the midaxillary line on four female volunteers. We recorded the degree of paraesthesia obtained and performed fat-suppression magnetic resonance imaging and three-dimensional reconstructions of the spread of local anaesthetic in the serratus plane. All volunteers reported an effective block that provided long-lasting paraesthesia (750–840 min). There were no side-effects noted in this initial descriptive study. While these are preliminary findings, and must be confirmed in a clinical trial, they highlight the potential for the serratus plane block to provide analgesia following surgery on the thoracic wall. We suggest that this novel approach appears to be safe, effective, and easy to perform, and is associated with a low risk of side-effects.

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Surgery on the chest wall is relatively common and can be associated with considerable postoperative discomfort and pain. Breast cancer has continued to be the most common cancer afflicting women, accounting for 31% of all new cancer cases in the female population [1, 2]. Every year, thousands of patients undergo surgery in the region of the breast and axilla. These procedures cause significant acute pain and may progress to chronic pain states in 25–60% of cases [3]. Blockade of the lateral cutaneous branches of the thoracic intercostal nerves (T2–T12) will provide analgesia to the anterolateral chest wall in this patient population [4]. Patients undergoing other surgical procedures involving the chest wall, including anterior thoracotomy, may also benefit from thoracic nerve blockade to reduce postoperative pain.

Following on from our previous work on the Pecs I and II blocks [5–7], we performed a detailed ultrasound examination of the relevant anatomy of the thoracic cage. This revealed two potential spaces, superficial and deep underneath the serratus anterior muscle, between the muscle and the intercostal nerves

[8–11]. Based on these findings, we have developed a new, safe and easily performed regional anaesthetic block. This is designed to block primarily the thoracic intercostal nerves and to provide complete analgesia of the lateral part of the thorax. We believe that this may be a viable alternative to paravertebral blockade and thoracic epidural analgesia in this patient population, and may theoretically be associated with a more desirable side-effect profile. We therefore decided to test this new technique, which we have called the serratus plane block.

Methods

We obtained approval from our local ethics committee and then collected informed written consent from volunteers. These volunteers were given a full and detailed explanation of the intended study protocol and informed of the potential benefits of the development of a successful technique as well as the potential side-effects.

We used ultrasound in all instances (S-Nerve; SonoSite Iberica S.L, Madrid, Spain), with a linear ultrasound transducer (10–12 MHz). The volunteers were placed in the supine position and the probe was placed over the mid-clavicular region of the thoracic cage in a sagittal plane. We counted the ribs inferiorly and laterally, until we identified the fifth rib in the midaxillary line. The latissimus dorsi (superficial and posterior), teres major (superior) and serratus muscles (deep and inferior) were then easily identifiable by ultrasound overlying the fifth rib. The needle depth required to reach the identified region was constant at between one and two centimetres in these volunteers. As an extra reference point, we used the thoracodorsal artery; this aids in the identification of the plane superficial to the serratus muscle. The needle (22-G, 50-mm 'Stimuplex A'; BBraun, Melsung, Germany) was introduced in-plane with respect to the ultrasound probe from supero-anterior to postero-inferior (Fig. 1). This injection differs from the Pecs I and II blocks (Figs. 2 and 3). Under continuous ultrasound guidance, we then injected a mixture of 0.4 $ml.kg^{-1}$ levobupivacaine 0.125% mixed with 0.1 $mmol.kg^{-1}$ gadolinium. We performed two blocks on each volunteer, one on each side. The first was superficial to the serratus anterior muscle and the other was deep underneath the muscle on the contra-lateral side.

After 30 min, we carefully delineated the area of sensory loss to pinprick using a hypodermic needle. We defined the anterior hemithorax as arising from the anterior axillary line to the sternum, the posterior hemithorax as being from the posterior axillary line to the spinous processes of the vertebra, and the lateral hemithorax as the area in between the other two.

We then performed magnetic resonance imaging (MRI) after one hour (Gyroscan Intera 1.5 T; Philips Healthcare, Eindhoven, The Netherlands). Our radiologist used two sequences to show T1-weighted, fat-suppressed and T1 dynamic 3D-gradient fast-field echo, high-resolution images. The images were processed (Amira 4.2; Visage Imaging, Berlin, CA, USA) to allow view and manipulation of biomedical data. Volume and surface rendering techniques were performed to show the distribution of gadolinium at different anatomical levels. Except for some bright/dark contrast, no

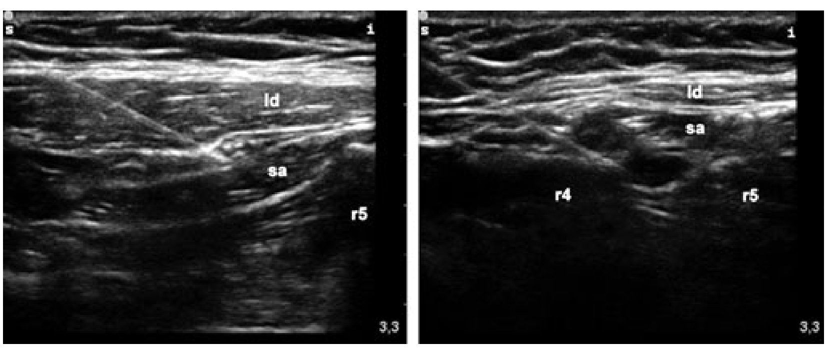

Figure 1 Sonographic images when the planes above (left) or below (right) the serratus muscle are dissected using local anaesthetic. The latissimus dorsi muscle (ld) lies superficial to serratus anterior (sa). In both options, the needle is directed passing the fourth rib (r4) towards the fifth rib (r5).

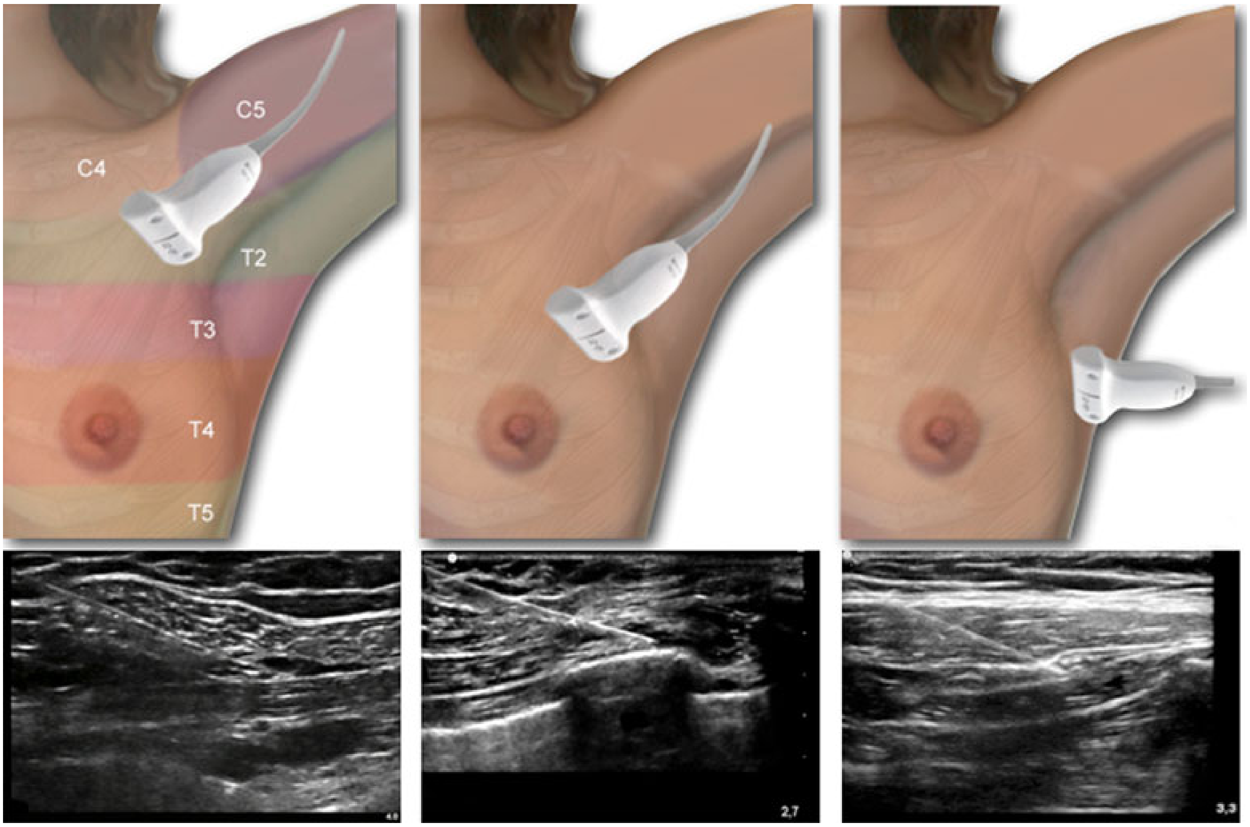

Figure 2 Graphic representing probe position and ultrasound image obtained during a Pecs I block (left), Pecs II block (middle) or a serratus plane block (right).

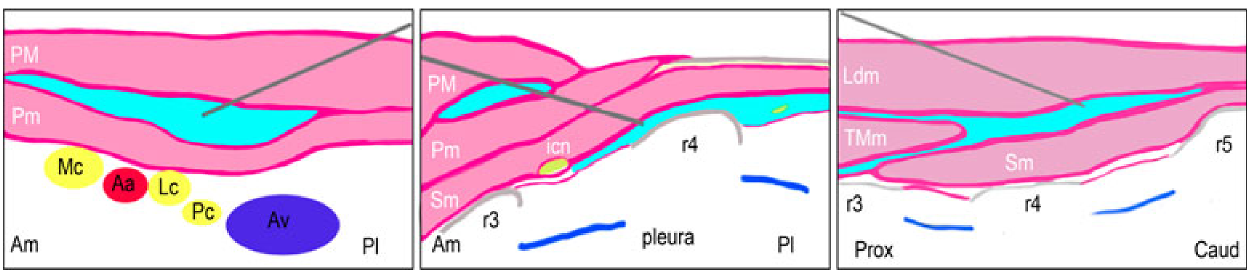

Figure 3 Graphic representing the distribution of local anaesthetic (blue) during a Pecs I block (left), Pecs II block (middle) and serratus plane block (right). PM, pectoralis major; Pm, pectoralis minor; Ldm, latissimus dorsi; Tmm, Teres major; Sm, serratus muscle. Icn, intercostal nerve; Lc, lateral cord; Pc, posterior cord; Mc, medial cord of the brachial plexus. Aa, axillary artery and Av, axillary vein together with the ribs, three (r3), four (r4) and rib five (r5). Am, orientation anteromedial; PI, posterolateral; Prox, proximal and Caud, caudal.

smoothing or other image post-processing techniques were performed in this image modality.

To identify the anatomical structures, two experienced observers analysed and compared the images with published MRI atlases. High thresholds of intensity and brightness were applied to avoid the artefactual effect of fat in the reconstructions (image intensity threshold of 1000). The spread of the contrast was analysed and correlated with our clinical results.

Results

Four volunteers, with no relationship with the study authors, were recruited and studied (Table 1). Thirty minutes after the injection, we demonstrated dermatomal paraesthesia from T2 to T9 and numbness in all volunteers (Table 2). Weak crossed-arm adduction movement after superficial injection was also observed in all four subjects. The mean (SD) duration of paraesthesia was 752 (21) min for the intercostal nerves and 778 (43) min for the motor nerves after injection superficial to serratus anterior. After injection deep underneath serratus anterior, the mean (SD) duration of action was 386 (160) min for the intercostal nerves and 502 (150) min for the motor nerves (Table 3). The area of sensory loss to pinprick was consistent whether the injection was superficial or deep underneath the muscle (Fig. 4).

The MRI scan with gadolinium delineated the spread of the injection, and again there was a well-defined band of high-intensity signal with good spread whether the injection was superficial or deep (Fig. 5). We observed a tendency for spread into the more posterior compartment after the superficial injection. When the contrast after MRI was increased to 1400, the spread of the superficial injection was better seen both anteroposteriorly and along the hemithorax (Fig. 6).

Table 1 Baseline characteristics of the four volunteers.

Subject	Age; years	Height; m	Weight; kg	Sex
1	23	1.63	56	F
2	23	1.69	60	F
3	32	1.70	48	F
4	46	1.71	73	F

Discussion

We have shown that injection of local anaesthetic superficial or deep underneath serratus anterior provides predictable and relatively long-lasting regional anaesthesia, which would be suitable for surgical procedures performed on the chest wall. We propose this as an alternative to other regional anaesthetic techniques. The choice of technique will of course vary depending on practitioners' and patients' preferences, comorbidity and type of surgery. Possible techniques include: local wound infiltration (with or without wound catheter insertion); Pecs I and II blocks; selective intercostal nerve blockade; thoracic paravertebral blockade; and thoracic epidural analgesia. Each of these techniques has advantages and disadvantages. In general, local or wound infiltration is safe but limited in terms of duration of action, depending on the pharmacodynamics of the local anaesthetic agent used. More invasive techniques such as selective intercostal nerve blocks and thoracic paravertebral blockade may lead to pneumothorax or transient Horner's syndrome if particular attention is not paid to the procedural technique and dosage of drugs used. These techniques have also been shown to be associated

Table 3 Duration of action of serratus plane block in four volunteer subjects, with respect to the intercostal nerves (T_i) and the long thoracic nerves (T_m).

	Superficial to serratus muscle		Deep underneath serratus muscle	
Subject	T_i; min	T_m; min	T_i; min	T_m; min
1	730	750	330	600
2	750	770	270	540
3	780	840	625	575
4	750	750	330	330

Table 2 Dermatomal distribution of sensory loss obtained by skin prick testing with a hypodermic needle 30 min after performing the serratus plane block.

	Superficial to serratus muscle			Deep underneath serratus muscle		
Subject	Anterior	Lateral	Posterior	Anterior	Lateral	Posterior
1	T2–T9	T2–T9	T2–T9	T2–T6	T2–T7	T2–T8
2	T2–T8	T2–T8	T2–T8	T2–T5	T2–T7	T2–T7
3	T2–T6	T2–T9	T2–T9	T2–T6	T2–T8	T2–T9
4	T2–T7	T2–T9	T2–T9	T2–T6	T2–T8	T2–T8

Figure 4 Area of sensory loss following superficial (above) or deep (below) serratus plane block.

with rapid rises in plasma concentrations of the local anaesthetic agents injected [12]. In addition, the central neurological side-effect profiles associated with neuraxial blockade have been well documented [13–15], precluding their routine use in the setting of day-case surgery.

The serratus muscle is a superficial and easily identified muscle that we consider a true landmark to implement thoracic wall blocks because the intercostal nerves pierce it. In our previously described block, Pecs II, we targeted it by an anterior approach near pectoralis minor. By moving our probe into the mid-axillary line, the serratus plane is more superficial and easier to identify, making it a much simpler block. We also identified two possible compartments that could be used in this block: one superficial to serratus muscle and one deep underneath it. By assessing the distribution of the injection and sensory mapping, we conclude that the superficial plane is more effective; however, this is a descriptive study and further randomised control trials will be required to definitively assess this block.

This novel regional anaesthetic technique may be suitable for peri-operative analgesia for a number of surgical procedures. These include any surgery that involves incision on the anterolateral chest wall, such as chest drain insertion, reconstructive breast surgery and cosmetic breast surgery. The innervation of the abdominal wall is derived from the thoracic level of T6–L1, so blockade of these sensory dermatomes in the thoracic region should provide some degree of analgesic efficacy, particularly in upper abdominal wall incisions.

Our initial work with the Pecs blocks extended from our belief that we could provide an analgesic profile similar to that of thoracic paravertebral block [16], without the unwanted and potentially catastrophic associated side-effect profile. This technique was successful [17]; however, we decided to target the thoracic nerves more selectively and hence we developed the serratus anterior block.

During our investigation of this block, we decided to use MRI segmentation followed by 3D reconstruction as opposed to methylene blue dissecting techniques. This is because dilution of the solution by the methylene

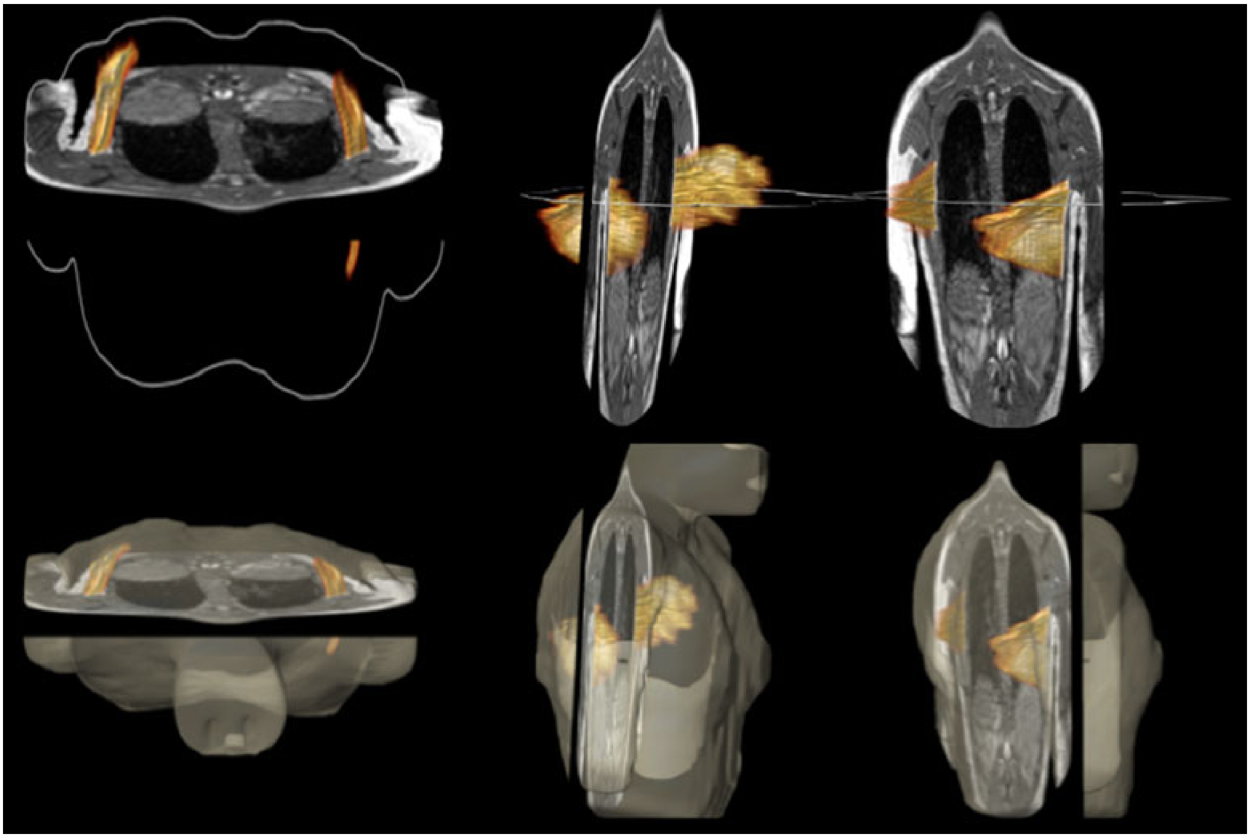

Figure 5 Coronal MRI reconstructions of craniodorsal (left), ventrolateral (centre) and dorsolateral (right), views, showing the contrast distributing between latissimus dorsi and serratus anterior (right side of the volunteer) or between serratus anterior and the external intercostal muscles (left side of the volunteer). In both sides we have obtained effective blocks but with different duration of action.

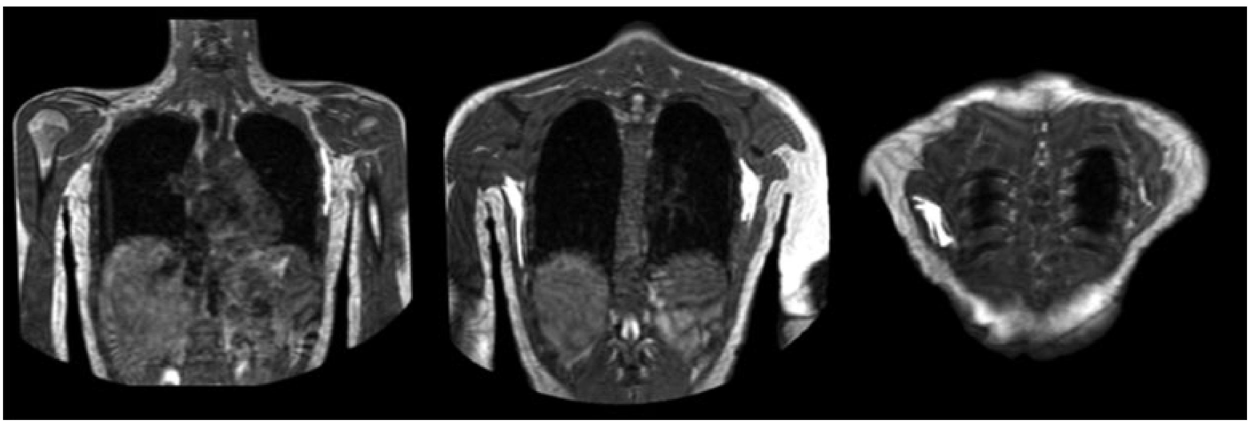

Figure 6 Coronal MRI viewed from front, at anterior (left), middle (centre) and posterior (right) axillary lines. The gadolinium spreads more anteriorly in the left hand side (deep to serratus muscle) but descends more in the right hemithorax (superficial to serratus muscle).

blue dye makes it difficult in determining the true distribution of the injection.

The main problem we had in this imaging study was that the distribution of gadolinium may mimic that of fat around the tissues, which also appears white on an MRI scan; this may give a false impression of the extent of the spread of the solution. We used image analysis software to overcome this problem by obtaining a numerical representation of the white intensity associated only with the gadolinium. Fat gives a low-intensity image value, so by applying certain thresholds we were able to identify the gadolinium, which gives the higher intensity image value. This may explain why we obtained greater extension of the clinical effect than that suggested from the MRI images.

We chose not to test the block at shorter intervals and map its progression with time because our intended endpoint was to demonstrate that the technique would provide demonstrable paraesthesia of the anterolateral thoracic wall. However, future studies should investigate the progression of the paraesthesia at shorter intervals.

The serratus plane block is a progression from our work with the Pecs I and II blocks. We have strived to make the technique easier in its application and to lower the potential side-effect profile associated with injection in close proximity of vascular structures [18]. This technique has removed the requirement of possible multiple needle insertion points and changes in needle orientation. This is coupled with the fact that deposition of the local anaesthetic solution at the effective site should correlate with superior analgesic profiles as the local anaesthetic solution does not need to track back to the effector site.

This new compartment we have described is another step towards a new generation of ultrasound-guided regional blocks. It is simple to perform via this novel approach and should potentially be associated with few side-effects. Pending comparative randomised controlled clinical trials, this block might prove to be an important clinical tool for the treatment of pain after thoracic and chest wall surgery.

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Competing interests

No external funding and no competing interests declared.

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