Original Article

An anatomical evaluation of the serratus anterior plane block

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Summary
The serratus anterior plane block has been described for analgesia of the hemithorax. This study was conducted to determine the spread of injectate and investigate the anatomical basis of the block. Ultrasound-guided serratus anterior plane block was performed on six soft-fix embalmed cadavers. All cadavers received bilateral injections, on one side performed with 20 ml latex and on the other with 20 ml methylene blue. Subsequent dissection explored the extent of spread and nerve involvement. Photographs were taken throughout dissection. The intercostal nerves were involved on three occasions with dye, but not with latex. The lateral cutaneous branches of the intercostal nerve contained dye and latex on all occasions. The serratus plane block appears to be mediated through blockade of the lateral cutaneous branches of the intercostal nerves. Anatomically, serratus plane block does not appear to be equivalent to paravertebral block for rib fracture analgesia.

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Introduction
Over recent years, there has been enthusiasm in the search for a simple, safe and effective plane block for thoracic analgesia. Serratus anterior plane block is one such technique, providing paraesthesia for the ipsilateral hemithorax [1]. This block has been used for breast surgery, thoracoscopy, rib fracture analgesia and shoulder surgery [2–6]. The anatomical basis for analgesia in some of these situations is not entirely clear, and it is uncertain whether this block provides a suitable alternative to paravertebral block.

When local anaesthetic is deposited superficial or deep to the serratus anterior muscle, the lateral cutaneous branches are specifically targeted, but this does not obviously explain how analgesia for rib fractures or the whole hemithorax is achieved. No anatomical dissection of the spread of injectate in the serratus plane has been undertaken. We therefore decided to investigate the anatomical basis of the analgesic effect. Specifically, we investigated injection below the serratus anterior muscle as this plane block technique has been used for rib fracture analgesia.

Methods
Serratus anterior plane block was performed in six soft-fix embalmed (Thiel's method) cadavers in the Anatomy and Clinical Skills Centre at Newcastle University following institutional approval from the University Ethics Committee and Director of Anatomy

and Clinical Skills and the Human Tissue Act Designated Individual (DP).

We used a high-frequency (10–12 Hz) 6 cm linear ultrasound transducer (M-turbo; Fujifilm SonoSite, Bothell, WA, USA), imaging to approximately 4-cm depth. A sterile cover was applied over the probe. With the cadaver positioned supine, the probe was placed over the midclavicular region of the thoracic cage in a sagittal plane. Ribs were counted by ultrasound to locate the space between the 4th and 5th rib in the mid axillary line, and from there the serratus anterior muscle (Fig. 1). Serratus anterior plane block was performed as originally described by Blanco et al. [1]: a 50-mm Sonoplex needle (Pajunk Medical Produkt GmbH, Geisingen, Germany) was inserted within the serratus plane supero-anteriorly to postero-inferiorly until deep to the serratus anterior. Needle position was confirmed by observing spread along the serratus plane under real-time ultrasound guidance. Twenty millilitres of methylene blue 0.5% were injected, to assess the upper limit of spread. On the contralateral side, a 14 G hypodermic needle (BD, Oxford, UK) was similarly inserted, and 20 ml liquid latex (Artcoe, Salford, UK) injected, to assess the lower limit of spread. The latex was coloured with black ink to aid identification. Injections were performed at operator-determined clinical pressures to mimic in vivo block performance. Specific injection pressure was not recorded. The side of injection was not formally randomised but arbitrarily

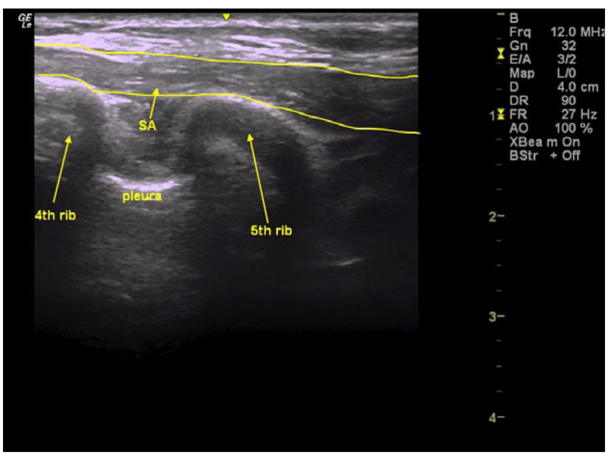

Figure 1 Ultrasound image of serratus anterior (SA) muscle.

chosen. It was not possible to blind injectors to the injectate, as latex suspension is more viscous and a larger gauge needle was required to facilitate injection. Dissectors were unaware of the injectate used before dissection but latex and dye were visibly different on dissection. There were a total of 12 injections performed by one of two consultants experienced in ultrasound-guided regional anaesthesia (JW and MV).

In dissection, the skin of the anterior thoracic wall was reflected 3–4 cm posterior to the midaxillary line. Subcutaneous fat was removed to expose the lateral cutaneous nerves exiting the serratus anterior muscle. Pectoralis major and minor were detached from their attachments on the upper six costal cartilages, and third to fifth ribs respectively. These were then reflected back to reveal the serratus anterior muscle, which was removed from its insertion to the upper eight or nine ribs, to reveal the sub-serratus plane where the dye or latex was injected. To evaluate the depth of injectate spread, the external, internal and innermost intercostal muscles were removed in stages, until the pleura was seen. In one cadaver, a median sternotomy was performed to visualise the internal thoracic wall and assess whether the pleura was stained, before the above dissection began. The dye or latex was defined as having spread to a structure if any staining was seen at along the observable course.

The extent of dye or latex spread was measured in the serratus plane anterior-posteriorly and superior-inferiorly, from the injection site to the limit of spread of injectate. Photographs were taken throughout dissection. Nerves were independently identified by three dissectors (JM, PP and ED), under the supervision of an anatomist (DP). The nerves stained were documented.

Results

Methylene blue dye spread a mean (SD) of 104 (6) mm anterior-posteriorly, and 136 (30) mm inferior-superiorly (Fig. 2). Latex spread a mean (SD) of 108 (25) mm anterior-posteriorly, and 101 (25) mm inferior-superiorly (Fig. 3).

Table 1 summarises the spread of dye or latex to involve structures identified in this study.

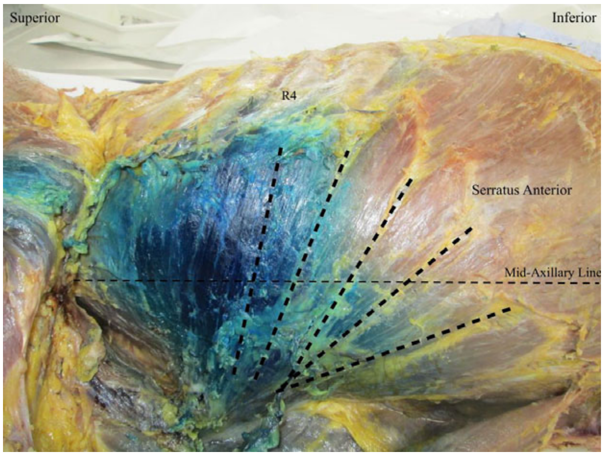

Figure 2 Spread of methylene blue dye on cadavers' right side after removal of serratus anterior, pectoralis major and perctoralis minor.

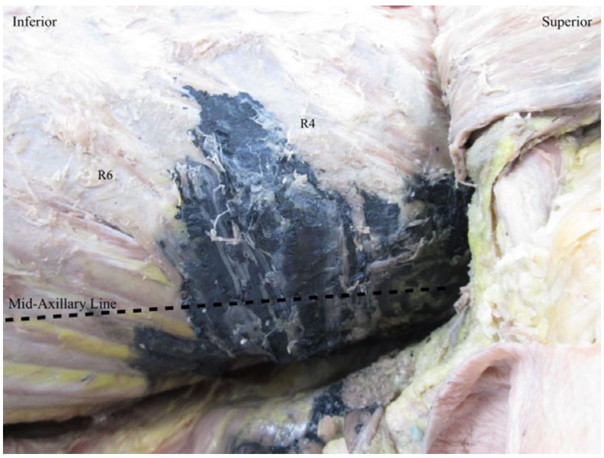

Figure 3 More limited spread of latex deep to serratus anterior, on cadavers' left side.

Table 1 Extent of spread of dye and latex in six cadavers, after injection deep to serratus anterior muscle.

	Methylene dye; n	Latex; n
Spread within serratus plane, including lateral cutaneous branches	6	6
Deep spread to internal intercostal muscle	5	2
Spread to intercostal nerve	3	0
Spread superficial to serratus anterior	6	2

Discussion

Our results suggest that serratus plane block appears to be mediated through blockade of the lateral cutaneous branches of the intercostal nerves, rather than through direct block of the intercostal nerves.

Compared with peripheral nerve blocks, fascial plane blocks rely on local anaesthetic diffusion across fascial planes and through muscle layers. In this study, latex and methylene dye were chosen as injectates to represent the lower and upper limits of local anaesthetic spread respectively. Being significantly more viscous than dye, latex spread is limited, whereas methylene blue diffuses extensively and is likely to overestimate the spread of the local anaesthetic.

The sensory innervation of the thorax is mostly via the ventral rami of the thoracic spinal nerves, the intercostal nerves (Fig. 4). The intercostal nerves run within the neurovascular bundle below the corresponding rib and between the innermost and internal intercostal muscles, and give rise to collateral and lateral cutaneous branches just posterior to the angle of the rib. The lateral cutaneous branch pierces the intercostal muscles, then divides into anterior and posterior branches before piercing the serratus anterior muscle (Fig. 5). Each intercostal nerve runs forward in its intercostal space and terminates as the anterior cutaneous branch emerging through transverse thoracis muscle just laterally to the sternum. Cutaneous innervation is derived either laterally or anteriorly. Cutaneous innervation medial to the midclavicular line is from anterior divisions of the lateral cutaneous branch of the intercostal nerve, and the terminal anterior cutaneous branches of the intercostal nerve. Cutaneous innervation lateral to the midclavicular line is from the lateral branches of the lateral cutaneous branch of the intercostal nerve. Branches of the supraclavicular nerve supply skin over the upper limit of the breast. Each rib is innervated directly by its corresponding intercostal nerve [7].

Sympathetic and muscular innervation is also derived from the thoracic roots, with the exception of the shoulder girdle muscles (pectoralis, latissimus dorsi and serratus), which are innervated by branches of the brachial plexus [7]. Of these branches, the long thoracic nerve and thoracodorsal nerve lie on the surface of the serratus anterior muscle. The extent to which these nerves contribute to postoperative analgesia is

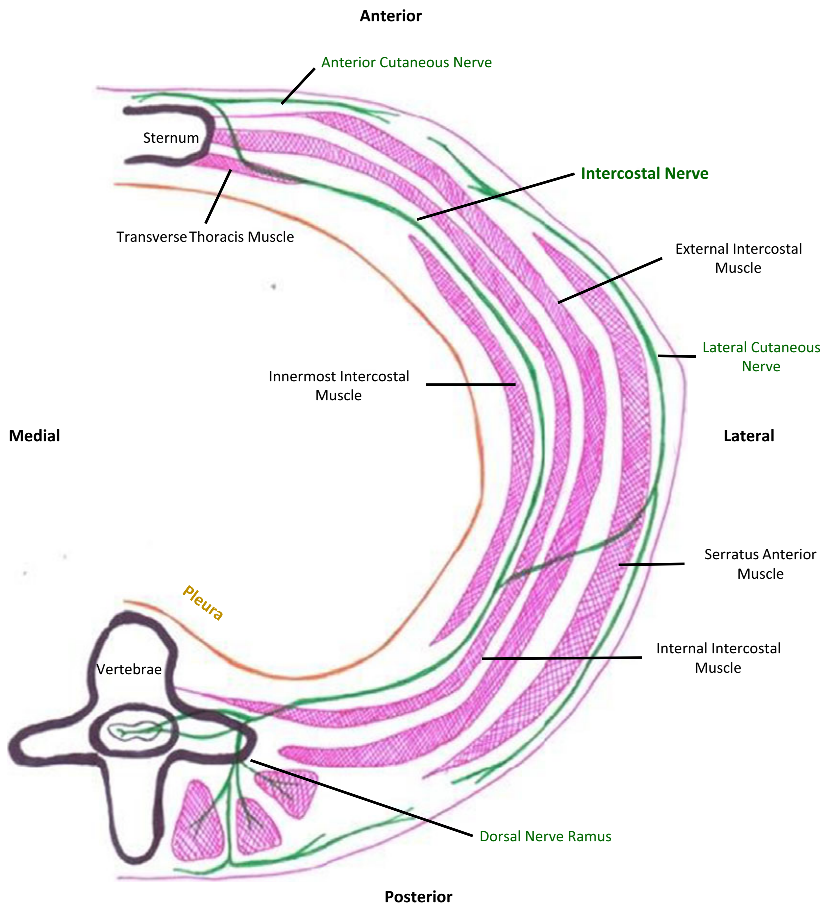

Figure 4 The path of the intercostal nerve and its associated branches. The site of injection for this block is marked with an X.

unclear, but mastectomies can be performed under paravertebral block alone [8].

The basis of regional analgesia is a simple concept. Local anaesthetic is deposited at an accessible point along the course of a sensory nerve, inhibiting conduction of impulses and impairing the transmission of pain sensation. However, this view has been challenged recently by nerve blocks that target what had classically been considered motor nerves, or targeting the area of referred pain rather than the primary injury [9, 10]. A study of transversus abdominis plane (TAP) block dermatomal spread in healthy volunteers demonstrated that the area of sensory block was often inadequate to explain the analgesic effect, but abdominal muscle relaxation was more consistently achieved [11].

The wide spread of both dye and latex along the sub-serratus plane suggests that lateral cutaneous branches of the intercostal nerves are reliably anaesthetised. This supports anaesthesia of the superficial structures of the lateral thorax and axilla, and reflects our clinical experience that serratus plane provides good analgesia for axillary dissection. Our dissection suggests that significant direct intercostal nerve spread is unlikely. Latex did not spread to the intercostal nerves on any occasion, suggesting that there is no direct communication between fascial planes and even the dye did not consistently spread as far as the intercosal nerve. Extrapolation of this cadaveric model to clinical practice obviously relies on assumptions, but this suggests that an intercostal nerve block is unlikely to be the mechanism of analgesia.

We acknowledge that none of the cadavers had rib fractures, which could potentially disrupt normal anatomy. However, the entire evidence base for the use of serratus plane block for rib fractures is based on only a small case series [4]. Our data suggest that serratus

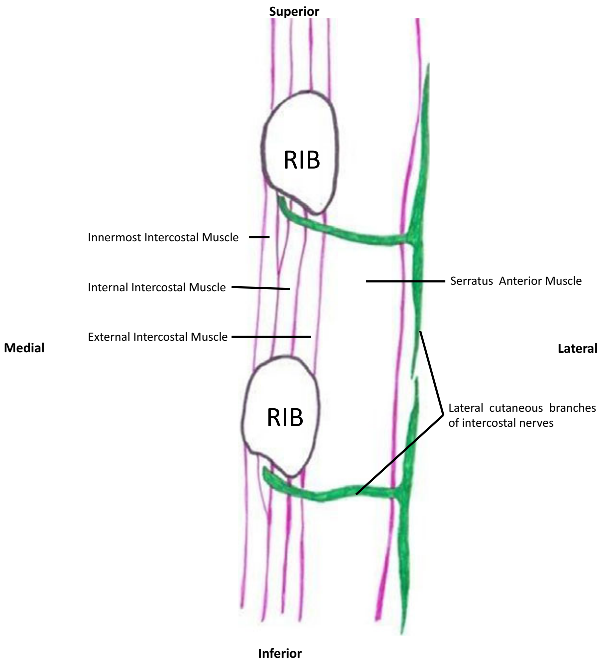

Figure 5 A parasagittal section of the ribs, associated muscles and nerves. The intercostal nerve runs between the innermost intercostal and internal intercostal, it then diverts through serratus anterior with cutaneous innervation of the lateral thorax.

plane block is only likely to provide successful analgesia for lateral rib fractures due to direct spread, but not anterior rib fractures, which rely on intercostal nerve block, or posterior rib fractures, which would require retrograde spread along the intercostal nerve to the paravertebral space.

Another mechanism for rib fracture analgesia may be possible. The external intercostal muscles are directly adjacent to the serratus anterior muscle, and thus to any pool of the injected local anaesthetic. The external intercostals are used in inspiration, so a motor block of these muscles would decrease rib movement in the area of the block and will perhaps allow for comfortable deeper diaphragmatic respiration. Forced expiration uses the other intercostal muscles (innermost and internal) that are deeper and perhaps less likely to be blocked, so it is possible that coughing would still be painful if this mechanism is correct. It is also possible that there is direct peri-osteal spread [12].

Other mechanisms are more speculative. Intravenous lignocaine is increasingly popular as an analgesic and perhaps some of the effect of the local anaesthetic is via systemic absorption into the accompanying lateral and anterior branches of the intercostal blood vessels. Perhaps, in a similar mechanism to supraclavicular nerve (a branch of the superficial cervical plexus) block for diaphragmatic pain, anaesthesia of the area of referred pain may result in analgesia. It is worth noting that the efficacy of supraclavicular nerve block for diaphragmatic pain is even more speculative than the use of serratus anterior block [13].

In conclusion, the analgesic effect of serratus plane block appears to be mediated through blockade of the lateral cutaneous branches of the intercostal nerves. This could be reasonably expected to be effective for superficial surgery of the lateral thorax. Serratus plane block does not appear to be equivalent to paravertebral block for rib fracture analgesia and further research is needed to establish its efficacy before it is considered as an established technique.

Competing interests

No external funding or competing interests declared.

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