Refining a great idea: the consolidation of PECS I, PECS II and serratus blocks into a single thoracic fascial plane block, the SAP block

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ABSTRACT

The popularity of ultrasound-guided nerve blocks has impacted the practice of regional anesthesia in profound ways, improving some techniques and introducing new ones. Some of these new nerve blocks are based on the concept of fascial plane blocks, in which the local anesthetic is injected into a plane instead of around a specific nerve. Pectoralis muscles (PECS) and serratus blocks, most commonly used for post op analgesia after breast surgery, are good examples. Among the nerves targeted by PECS/serratus blocks are different branches of the brachial plexus that traditionally have been considered purely motor nerves. This unsubstantiated claim is a departure from accepted anatomical knowledge and challenges our understanding of the sensory innervation of the chest wall. The objective of this Daring Discourse is to look beyond the ability of PECS/serratus blocks to provide analgesia/anesthesia of the chest wall, to concentrate instead on understanding the mechanism of action of these blocks and, in the process, test the veracity of the claim. After a comprehensive review of the evidence we have concluded that (1) the traditional model of sensory innervation of the chest wall, which derives from the lateral branches of the upper intercostal nerves and does not include branches of the brachial plexus, is correct. (2) PECS/serratus blocks share the same mechanism of action, blocking the lateral branches of the upper intercostal nerves, and so their varied success is tied to their ability to reach them. This common mechanism agrees with the traditional innervation model. (3) A common mechanism of action supports the consolidation of PECS/serratus blocks into a single thoracic fascial plane block with a point of injection closer to the effector site. In a nod to transversus abdominus plane block, the original inspiration for PECS blocks, we propose naming this modified block, the serratus anterior plane block.

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INTRODUCTION

Ultrasound reflection occurs at the interface between two tissue planes with different impedance making the definition of fascial planes usually an easy task. Taking advantage of this, the transversus abdominis plane (TAP) block, first described as a landmark technique,[1] easily made the transition to an ultrasound-based technique.[2] The popularity of TAP block opened the door to other fascial plane blocks. With fascial plane blocks, a plane rather than a nerve is identified, and the injection made into it reaches its target in a volume-dependent fashion. Pectoralis muscles (PECS) blocks and the serratus block are examples of fascial plane blocks.[3–5] Prominent targets for PECS/serratus blocks are branches of the brachial plexus that have not traditionally been associated with the sensory innervation of the chest wall. This extraordinary and thus far unsubstantiated claim, if proven correct, would completely modify our understanding of such innervation, which until now has been considered to be a simple dermatomal innervation linked to sequential spinal nerves.

This communication intends to prove that the traditional model of sensory innervation of the chest wall, without contribution from the brachial plexus, is correct. This does not negate the effectiveness of PECS/serratus blocks. We only challenge the proposed mechanism of action, which appears to be the same for all three techniques. Based on this common mechanism of action, a consolidation of all three techniques into a single one is proposed.

DISCUSSION

PECS I was introduced in 2011 in a letter to the editor as an "alternative to both paravertebral and epidural blockade."[3] This block consists of injecting 30 mL of local anesthetic into the fascial plane between pectoralis major and pectoralis minor muscles, targeting the lateral and medial pectoral nerves.

PECS II was introduced in 2012 as a double injection technique to modify the original PECS block.[4] The first injection deposits 10 mL of local anesthetic into the plane between the two pectoralis muscles (as PECS I does), followed by a second injection of 20 mL at the junction between pectoralis minor and serratus anterior muscles. The targets in this modified technique are "at least the pectoral nerves, the intercostobrachial, intercostals III-IV-V-VI and the long thoracic nerve."[4] The block was also presented as an alternative to thoracic epidural and thoracic paravertebral blocks.

Serratus plane block was introduced in 2013 as an observational study based on four volunteers.[5] This technique requires injecting 30 mL of local anesthetic either superficially or deep to the serratus anterior muscle. The injection is performed posteriorly through the latissimus dorsi, with the goal of blocking the intercostobrachial nerve, intercostals third to sixth, long thoracic nerve and thoracodorsal nerve. This was also introduced as an alternative to thoracic epidural/paravertebral blocks.

INNERVATION OF THE CHEST WALL

The innervation of the chest wall has been extensively studied by anatomists and surgeons.[6–15] A review of these works reveals that the sensory innervation of the anterolateral wall of the chest, including the breast, derives mainly from the intercostal nerves second to sixth, specifically their respective lateral perforating cutaneous branches, shown in figure 1. These branches, after reaching the subcutaneous tissue, divide into anterior and posterior divisions, which supply the corresponding dermatome in a sequential manner.[6–15] Additionally, a small area immediately below the clavicle is supplied by the supraclavicular branches (C3–C4) of the superficial cervical plexus.[6–10] The parasternal region, on the other hand, is supplied by the perforating terminal cutaneous branches of the upper intercostal nerves.[6–14] The PECS/serratus blocks have indirectly challenged this traditional innervation model by listing as targets for these blocks, branches of the brachial plexus commonly considered motor nerves.[6–9]

Intercostal nerves

The intercostal nerves correspond to the ventral branches of the first 11 thoracic spinal nerves, while the ventral branch of the 12th becomes the subcostal nerve.[6–9]

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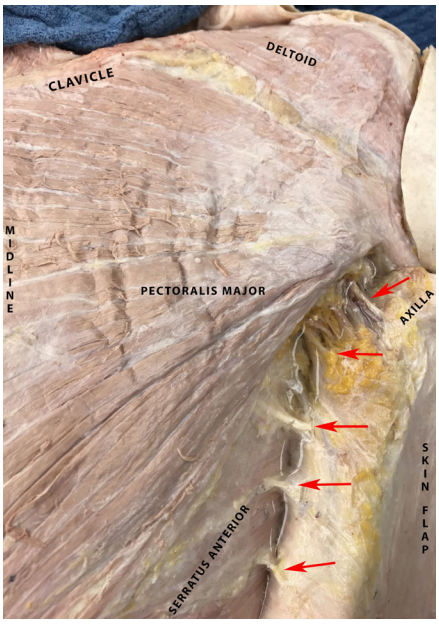

Figure 1 Lateral branches of second to sixth intercostal nerves. Dissection showing left upper chest and shoulder. A flap of skin has been dissected off and retracted laterally to expose the lateral branches of the second to sixth intercostal nerves (red arrows), piercing the serratus anterior muscle at the level of the anterior axillary line, and entering the skin. The most cephalad red arrow points to the intercostobrachial nerve, as it makes its way into the axilla. Also shown are deltoid and pectoralis major muscles. Cadaver dissection by Dr Franco.

A typical intercostal nerve runs in the respective intercostal space between the innermost intercostal and internal intercostal muscles. Around the anterior axillary line, the nerve gives off a lateral cutaneous branch that pierces its way through the internal intercostal, external intercostal, and serratus anterior muscles to reach the subcutaneous tissue where it divides into anterior and posterior branches. The lateral cutaneous branch, by its anterior and posterior components, is responsible for the sensory innervation of the skin, subcutaneous tissue and thoracic fascia of the corresponding dermatome. The intercostal nerve itself, after supplying the parietal pleura and intercostal muscles, ends close to the midline as a perforating anterior branch, which provides a small parasternal area of sensory innervation.[6–9]

The first thoracic spinal nerve divides into a larger component that joins C8 to form the inferior trunk of the brachial plexus, and a smaller component that becomes the first intercostal nerve. The first intercostal nerve is atypical because it has a very short trajectory and does not give off a lateral branch, so it usually lacks a dermatomal representation on the chest wall.[6–9 15]

The lateral branch of the second intercostal nerve gets pulled during embryological life into the emerging upper extremity, where it ends up innervating the skin and subcutaneous tissue of the axilla and proximal medial side of the arm. The lateral branch of the second intercostal, is known descriptively as the intercostobrachial nerve.[6–9]

MUSCLE PAIN

Skeletal muscle pain and cutaneous pain are different. Cutaneous pain is transmitted through fast A delta fibers and as a result, it is perceived as sharp and well localized. In contrast, muscle pain is transmitted by slower, non-myelinated C fibers, and is described as dull, achy and not as well localized.[16 17] Muscle nociceptors are modified nerve endings that can be activated by mechanical overloading as well as by endogenous inflammatory mediators including bradykinin, serotonin, and prostaglandin E2, but their main activator is muscle ischemia.[17–20] The fascias surrounding muscles, on the other hand, are innervated by cutaneous sensory nerves.[21]

Muscle pain perceived from muscles innervated exclusively by motor nerves (eg, pectoralis major muscle), is explained by the fact that motor roots in human nerves contain around 25% of C fibers in their structure, and a significant fraction of them are sensory afferent fibers transmitting pain.[22 23] This has been confirmed by electrophysiological studies on C fibers in the cat ventral root, which could explain the failure of dorsal rhizotomy to relieve chronic pain.[22 24]

EVIDENCE IN FAVOR OF THE TRADITIONAL MODEL OF SENSORY INNERVATION OF THE CHEST WALL

The traditional model of sensory innervation of the anterolateral wall of the chest is well established and based on studies from different fields.[6–15] This model involves branches of the upper intercostal nerves, without any contribution from the brachial plexus. We have failed to find a single reference that differs from it.

In addition to the anatomical and surgical evidence mentioned above, the traditional innervation model can also be supported by at least three different and independent arguments. The first one is the contradictory claims made by PECS and serratus blocks.[3–5] The second relates to the extensive successful experience using thoracic epidural and thoracic paravertebral blocks for anesthesia/analgesia of the chest.[25–32] The third argument derives from the analysis of nerve injuries affecting the branches of the brachial plexus that PECS and serratus blocks target.[33–37]

1. **Contradictory claims**: PECS/serratus blocks, which specifically target different branches of the brachial plexus were introduced as alternatives to thoracic epidural/paravertebral blocks, which only block spinal nerves. If the claims were correct, the blocks from both groups would be complementary at best, but never interchangeable.
   Moreover, although PECS/serratus blocks share some common targets, they are also individually different. For example, PECS I claims to be an alternative to thoracic epidural/paravertebral blocks simply by targeting the lateral and medial pectoral nerves. If this claim were correct, then serratus block, which does not target these nerves, would provide at best, incomplete anesthesia of the chest wall. On the other hand, if thoracodorsal nerve, targeted only by serratus block, were essential to achieve complete anesthesia of the chest, then PECS I and II would fail on that account. Therefore, on the claim that these three blocks are individual alternatives to thoracic epidural and paravertebral blocks, they could all be wrong, but they cannot all be right.
2. **Thoracic epidural/paravertebral blocks for anesthesia of the chest**: Thoracic epidural and thoracic paravertebral blocks have long been used to provide successful anesthesia/analgesia of the breast and chest wall, to the extent that they are considered the gold standard. The extensive literature on this subject strongly supports the traditional innervation model of the chest wall and fails to suggest any additional nerve contribution.[25–32] Pusch *et al*, for example, reported a 93% rate of successful surgical anesthesia with paravertebral blocks for breast surgery.[31] Since paravertebral blocks only anesthetize spinal nerves, this kind of success would not be possible if the brachial plexus provided sensory innervation to the chest wall.
   The successful use of thoracic epidural/paravertebral blocks for breast and chest wall surgery without the addition of a brachial plexus block, supports the traditional innervation model and strongly negates the potential contribution from any additional sources.

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3. **Isolated injury to the innervation of muscles of the chest wall**: A review of the literature concerning reported injuries to the innervation of pectoralis major, pectoralis minor, serratus anterior and/or latissimus dorsi muscles (PECS/serratus targets), shows that these patients suffered from the expected muscle denervation and atrophy, but did not develop any of the sensory deficits that would be expected if these nerves also carried A delta sensory fibers.[33–37] The isolated motor deficits exhibited by these patients strongly suggest that these nerves do not contribute to the sensory innervation of the chest wall.

Muscle relaxation claim

Some practitioners believe that PECS blocks could produce some degree of pain relief by muscle relaxation, or at least facilitate the insertion of a breast expander. This belief, although intuitive, is not supported by the available evidence. For example, Cooter *et al* in 2007 reported 100 cases of breast implants performed under thoracic paravertebral block.[30] The results showed an 87% rate of successful surgical anesthesia without any muscle relaxation issues being reported. Furthermore, PECS blocks are frequently used for postoperative pain control in combination with general anesthesia, where adequate muscle relaxation is not an issue.

Figure 2 Probe position and needle insertion. The probe is shown placed diagonally over the lateral border of pectoralis major muscle at its junction with serratus anterior, at around the fourth rib. The needle is inserted in plane from medial to lateral into the plane between the two muscles. One of the authors (KI) served as a model.

Proposed mechanism of action for PECS I, II and serratus plane blocks

Establishing that the brachial plexus does not contribute to the sensory innervation of the breast and chest wall is not the same as negating the effectiveness of PECS and serratus blocks. In fact, the evidence presented suggests that PECS and serratus block achieve different degrees of chest wall anesthesia by a common mechanism of action, which conforms to the traditional model of sensory innervation of the chest wall. As discussed earlier, the main sensory innervation of the chest wall comes from the perforating cutaneous branches of the upper intercostal nerves. Therefore, in order to anesthetize the anterolateral wall of the chest it is necessary to block either the pertinent intercostals at their origin (thoracic epidural, thoracic paravertebral, posterior intercostal nerve blocks, etc), or block their lateral cutaneous branches as they pierce their way into the subcutaneous tissue at around the anterior axillary line. The latter is what PECS/serratus blocks accomplish with variable degrees of success. This common mechanism of action explains for example why PECS II is more successful than PECS I, because only a small injection is made into the interpectoral plane, while 20 mL are injected closer to the target nerves. Serratus block moves the point of injection posterior to block the thoracodorsal nerve, but because this nerve is not contributory, its success should still depend on anterior diffusion.

Consolidating PECS/serratus blocks into one block

Having established a common mechanism of action for PECS/serratus blocks, is a strong argument in favor of consolidating them into a single thoracic fascial plane block, as originally envisioned by their authors.

As mentioned earlier, in order to anesthetize the anterolateral wall of the chest, it is necessary to block the lateral perforating cutaneous branches of the upper intercostal nerves. Therefore, as a logical next step, we propose to move the injection point closer to these target nerves, consolidating all three original techniques into a single thoracic fascial plane block. The technique is performed as follows. With the patient in a semi-seated position and the ipsilateral arm abducted, a high frequency linear probe is placed diagonally over the upper chest, around the fourth rib, to localize the plane where the lateral border of the pectoralis major meets serratus anterior, as shown in figure 2. The needle is inserted in plane from medial to lateral and directed to the plane between pectoralis major and serratus anterior, as shown in figure 3. Compared with the main injection point for PECS II, this new injection point is closer to the target nerves and easier to identify and does not include an injection between the two pectoralis muscles. We do not think that injecting any closer to the anterior axillary line is advisable because of the potential risk of injuring the long thoracic nerve or accompanying vessels. We propose to call this block serratus anterior plane block or SAP block. This name not only rhymes with TAP block, but also reinforces the notion that both blocks are based on the common concept of truncal fascial blocks. We should mention that we are not the first to propose a single injection point close to the axilla.[38] We have used this block for postoperative pain in breast surgery and found it easy to perform. Future studies should determine its role in our practice.

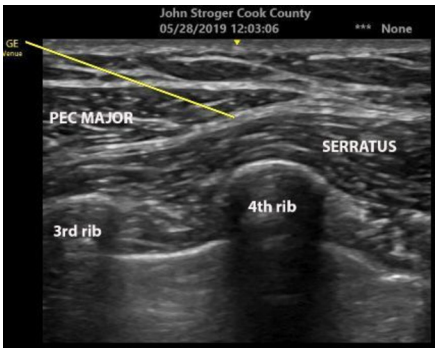

Figure 3 Needle path and injection point. Ultrasound image (left side) showing the plane where pectoralis (PEC) major and serratus muscles meet. The simulated path of the needle (in yellow) is shown passing through the most lateral part of pectoralis major muscle into the plane between this muscle and serratus anterior. PECS, pectoralis muscles.

CONCLUSION

We believe that we have made a compelling rational argument in favor of the traditional model of sensory innervation of the anterolateral wall of the chest.

We have postulated that PECS I, PECS II and serratus blocks have a common mechanism of action that conforms to the traditional innervation model and also that their variable success is linked to their different ability to spread to block the lateral cutaneous branches of the upper intercostal nerves. As a logical corollary, we have proposed to consolidate PECS/serratus blocks into a single block with an injection point located closer to the target nerves. We have called this block

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the serratus anterior plane block or SAP block, in a nod to TAP block, the original inspiration for PECS blocks. We believe that this new point of injection, closer to the only nerve branches implicated in the sensory innervation of the chest wall, should theoretically improve the chances for success, and facilitate the approach to thoracic wall anesthesia by the adoption of a single block. We acknowledge that the framework for this proposal, although rational, at this time remains theoretical and speculative. Future clinical studies should compare this proposed block to thoracic epidural/paravertebral and to PECS/serratus in common settings like postoperative analgesia in breast surgery.

The modifications to PECS block that originated PECS II and serratus blocks were efforts to find the single right technique, however the focus was on blocking branches of the brachial plexus. Recognizing the real targets and bringing the injection point closer to them refines a great idea.

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