Serratus Muscle Block for Analgesia after Mastectomy

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Abstract

Regional anesthesia has been believed as one of the formats for effective perioperative pain control. Regional blocks using ultrasound-guide has become a perfect supplement to general anesthesia for extending analgesia after modified radical mastectomy. The advantage includes post-operative pain relief prolongation, a decrease in analgesic requirement post-operatively, a reduction in nausea and vomiting scores and probability for ambulatory discharge and hospital stay. The serratus anterior is a fan-shaped muscle that originates on the superolateral surfaces of the first to eighth ribs or the first to ninth ribs at the lateral wall of the thorax and inserts along the superior angle, medial border, and inferior angle of the scapula. The main part of the serratus anterior lies deep to the scapula and the pectoral muscles and is easily palpated between the pectoralis major and latissimus dorsi muscles. This large muscle is generally divided into 3 distinct parts according to the points of insertion: serratus anterior superior (insertion near the superior angle), serratus anterior intermediate (insertion along the medial border), and serratus anterior inferior (insertion near the inferior angle). Breast surgery, especially radical mastectomy, is often accompanied by moderate to severe acute pain, which significantly reduces postoperative quality of life. Effective pain management can accelerate patient recovery. Serratus anterior plane block (SAPB) is a new type of fascial plane block technique, which can better target the nerve network innervating the chest wall and breast and provide good analgesia in the anterolateral chest wall. Current clinical research evidence indicates that SAPB has significant benefits in breast surgery.

Keywords: Serratus Muscle block, Analgesia, mastectomy

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Introduction

Breast surgery, especially radical mastectomy, is often accompanied by moderate to severe acute pain. Acute pain is closely related to the occurrence and duration of postoperative chronic pain, which significantly reduces postoperative quality of life [1]. There is an urgent need to alleviate postoperative pain and achieve rapid recovery. Serratus anterior plane block (SAPB) provides

regional analgesia on the anterolateral chest wall by blocking T2–9 intercostal nerves passing through the intercostal and serratus anterior muscles as well as the long thoracic and dorsal thoracic nerves [2]. It is mainly used in breast surgery, rib fracture treatment, and thoracotomy [3–5]. SAPB can target the neural network innervating the chest wall and breast well [6], and there have been some studies on the use of SAPB in breast surgery in recent years. In this review, we begin with the technical characteristics of SAPB, then discuss the perioperative background of different breast surgeries, and comprehensively review the impact of SAPB on acute and chronic pain, speed of recovery, and likelihood of tumor recurrence after breast surgery. The direction of future SAPB development is then discussed, followed by prospects of SAPB for broader application in breast surgery.

1) Serratus Muscle block

The serratus anterior is a fan-shaped muscle that originates on the superolateral surfaces of the first to eighth ribs or the first to ninth ribs at the lateral wall of the thorax and inserts along the superior angle, medial border, and inferior angle of the scapula. The main part of the serratus anterior lies deep to the scapula and the pectoral muscles and is easily palpated between the pectoralis major and latissimus dorsi muscles. This large muscle is generally divided into 3 distinct parts according to the points of insertion: serratus anterior superior (insertion near the superior angle), serratus anterior intermediate (insertion along the medial border), and serratus anterior inferior (insertion near the inferior angle) [7].

Structure and Function

The serratus anterior muscle pulls the scapula forward around the thorax which allows for anteversion and protraction of the arm. Although this motion is antagonistic to that of the rhomboids, when the serratus anterior superior and the serratus anterior inferior act together, the scapula is subsequently pressed against the thorax in conjunction with the rhomboids, thereby creating a synergistic effect. In addition, the serratus anterior inferior is responsible for the anterolateral motion of the scapula which allows for arm elevation. When the shoulder girdle is fixed, all 3 parts of the serratus anterior muscle work together to lift the ribs, assisting in respiration [7].

The serratus anterior is occasionally called the "big swing muscle" or "boxer's muscle" because it is largely responsible for the protraction of the scapula that is, the pulling of the scapula forward and around the rib cage that occurs when someone throws a punch [8].

The serratus anterior also plays an important role in the upward rotation of the scapula, such as when lifting a weight overhead. It performs this in sync with the upper and lower fibers of the trapezius [8].

Origin and insertion:

1st -9th ribs (Costae 1-9)

The serratus anterior muscle originates at the 1st to 9th rib and inserts at the ventral surface of the medial border of the scapula. The muscle is further divided into three parts:

- Superior part: 1st to 2nd rib → superior angle of the scapula
- Intermediate part: 2nd to 3rd rib → medial border of the scapula
- Inferior part: 4th to 10th rib → medial border and inferior angle of the scapula.

The inferior part of the muscle is the most prominent and powerful one [7].

Physiologic variants

The rib attachments and origin of the serratus anterior may vary between each person. For instance, the serratus anterior can be found attached to the tenth rib, or there may be an absence of attachments to the first rib. The serratus anterior fibers may sometimes be found in union with fibers of the levator scapulae, external intercostals, or external oblique muscles. Furthermore, there have been reported vascular variants, specifically in the blood supply to the serratus anterior myo-osseous flap, such that the lateral thoracic artery is the dominant supplier to the lower muscular slips [9].

In addition, from harvested sixth and seventh ribs, the presence of vascular connections between the anteriorly placed lateral thoracic pedicle, and the periosteum of the ribs was observed, which contrasts the more commonly described connections of the branches from the thoracodorsal pedicle. Also, the upper digitations of the serratus anterior may be innervated by C4 or C5 independently, without the nerves joining to form the main trunk of the long thoracic nerve [9].

Indications:

The serratus anterior plane block can be used as one of the modalities in managing the pain of patients undergoing MRM surgery. Tis procedure was efective in reducing the need for post-operative opioids usage, better patient satisfaction with fewer side effects. It is simple, easy-to-learn technique, making it an excellent alternative to the conventional thoracic epidural, intercostal nerve, and paravertebral nerve blocks for breast surgeries [10].

Contraindications:

As any regional nerve block:

1- Patient refusal &un-cooperation.

2- Infection at site of injection.

3- Bleeding disorder.

4- Local anesthetic allergy. [10].

Advantages:

SAPB reduced intraoperative and postoperative opioid consumption and postoperative dynamic pain scores with improved postoperative pulmonary function in patients undergoing thoracotomy [11].

Complications:

Nerve damage, epidural hematoma, and inadvertent intravascular injection, Local anesthetic allergy, Failure of Block and Pneumothorax also has been reported [12].

Blood Supply

The vascular supply to the serratus anterior includes the lateral thoracic artery, the superior thoracic artery, and the thoracodorsal artery. The lateral thoracic artery, also known as the external mammary artery, originates from the axillary artery. It courses along the lower margin of the pectoralis minor muscle and supplies oxygenated blood to the serratus anterior muscle and pectoralis major muscle. Branches travel across the axilla to the axillary lymph nodes and subscapularis muscle [13].

The superior thoracic artery is typically the first division of the axillary artery but may arise from the thoracoacromial artery. The superior thoracic supplies the superior part of the serratus anterior as well as the first and second intercostal spaces. The thoracodorsal artery supplies the lower portion of the serratus anterior and the latissimus dorsi [13].

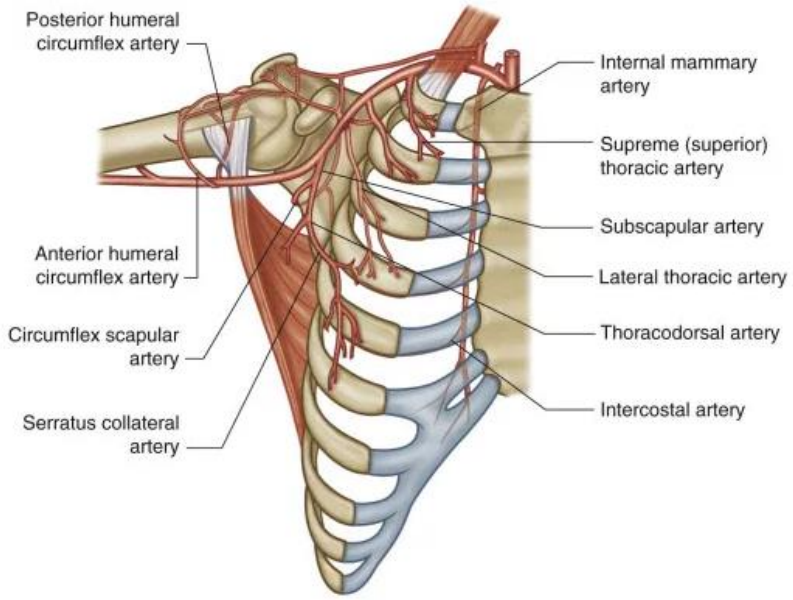

Figure (1): Blood Supply of Serratus Muscle [13].

Nerves

The long thoracic nerve (LTN) , which originates from the upper portion of the superior trunk of the brachial plexus and is typically composed of cervical nerves C5, C6, and C7, is responsible for innervation of the serratus anterior. The long thoracic nerve courses inferiorly on the surface of the serratus anterior, and, as such, is susceptible to damage during certain surgical procedures, especially with axillary lymph node dissection. The nerve's relatively smaller diameter in comparison to other nerves of the brachial plexus, its minimal connective tissue, and superficial course over the surface of the serratus anterior muscle, lead to greater exposure along its course [14].

Injury to the long thoracic nerve may be due to other non-surgical causes, including compression of the nerve by the middle scalene muscle, second rib, or fascial sheath; entrapment within the middle or posterior scalene muscles; and traction on the nerve itself [14].

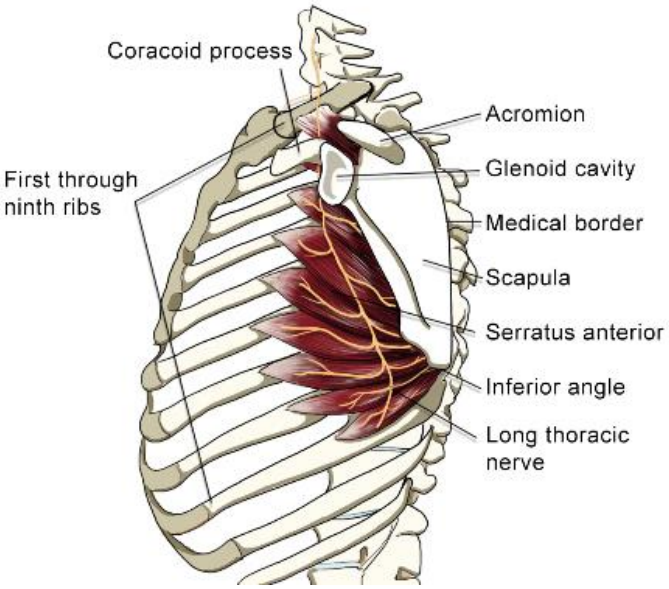

Figure (2): Nerve Supply of Serratus Muscle [15].

Preparation

Consistent with all regional anaesthesia blocks, the patient must have intravenous access and standard monitoring, including electrocardiogram, non-invasive blood pressure and oxygen saturation probe, applied. In addition to the anaesthetist conducting the SPB, appropriately trained personnel should be present, and resuscitation facilities must be available. In order to decrease the risk of wrong-side and/or wrong-site block, the World Health Organization surgical safety checklist and Stop Before You Block initiative should be followed. In the performance of the SPB, standard aseptic precautions must be followed, and the patient and the ultrasound machine should be positioned in an ergonomic manner [16].

Parameter	Specification
Position	Supine with the arm abducted to 90° or lateral, ultrasound machine on the ipsilateral side
Ultrasound probe	High-frequency linear ultrasound probe, 6-13 MHz
Needle	22G regional block needle, 50-100 mm in length
Approach and depth	In plane or out of plane, 1-4 cm
Local anaesthetic	0.3-0.4 mL/kg of 0.25% levobupivacaine, aiming for a minimum local anaesthetic volume of 20 mL, within maximum recommended doses for the patient

Table 2. Characteristics of the performance of the serratus plane block

Ultrasound Probe Position and Sonography

SPB is a progression from the PECS block with similar initial anatomical landmarks and ultrasound imaging steps. The reader is encouraged to review the tutorial for the PECS block (ATOTW Tutorial 346, PECS Blocks) before proceeding to review this part of the tutorial on SPB:

- Commence the ultrasound scan by placing the ultrasound probe in a parasagittal plane immediately inferior to the clavicle and in the deltopectoral groove adjacent to the coracoid process. Here, identify the pectoralis major and minor muscles, the axillary artery and vein as well as the underlying second rib.

- Move the ultrasound probe inferiorly and posteriorly with increasing coronal orientation until the fifth rib is found in the midaxillary line. In this position, identify a superficial and thick muscle, the latissimus dorsi, overlying the deeper serratus anterior muscle. Since the thoracodorsal artery is located in the fascial plane between the latissimus dorsi and the serratus anterior muscles, its identification with ultrasound imaging and use of colour Doppler is helpful to delineate the plane and decrease the risk of inadvertent accidental arterial puncture on introduction of the needle [17].

Needling Technique

- Prior to the insertion of the needle, identify the location of the pleura

- Introduce the needle in plane, advancing it from a superoanterior to posteroinferior direction.

- If performing a superficial SPB, use hydrolocation with either local anaesthetic or saline to confirm the needle tip is positioned in the space between the latissimus dorsi and the serratus anterior muscles in the mid-axillary line.

- If performing a deep SPB, direct the needle toward the fifth rib, as this will form a bony safety back stop and reduce the risk of puncture of the pleura. Use hydrolocation with either local

anaesthetic or saline to verify the needle tip is positioned in the space between the serratus anterior muscle and the fifth rib in the mid-axillary line. [18].

Figure 3. Ideal ultrasound probe position for the serratus plane block at the level of the fifth rib in the mid-axillary line. The arrow indicates the point of insertion and the direction of the needle.

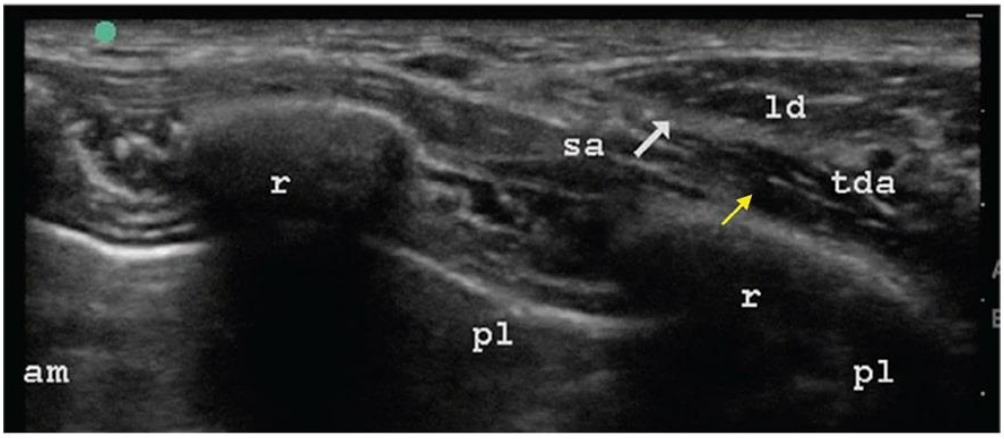

Figure 4. Ultrasound image demonstrating the serratus anterior muscle deep to the latissimus dorsi muscle and superficial to the ribs and the intercostal muscles. The yellow arrow indicates the fascial plane between the serratus anterior muscle and the rib, where the local anaesthetic should be deposited for the deep serratus plane block. The white arrow points to the fascial plane between the serratus anterior and the latissimus dorsi muscles, where the local anaesthetic should be deposited for the superficial serratus plane block. am, anteromedial; ld, latissimus dorsi; pl, posterolateral; r, rib; sa, serratus anterior; tda, thoracodorsal artery. [19].

- Once the needle tip is in a satisfactory position and subsequent to negative aspiration, taking into account the potential for multiple small blood vessels to be present here, inject the remainder of the local anaesthetic and in small aliquots of 5 mL .

- Given that SPB is a fascial plane block, the distribution of analgesia is dependent on the diffusion of local anaesthetic and therefore its volume. In view of this, a minimum local anaesthetic

volume of 20 mL should be used, adjusting the concentration of local anaesthetic if needed so that the maximum recommended dose is not exceeded.

If it is required, bilateral SPBs can be undertaken, but the maximum recommended dose of local anaesthetic must not be exceeded, and should moderate to severe postoperative pain be anticipated for more than 12–16 hours, a catheter can be considered for insertion. [20].

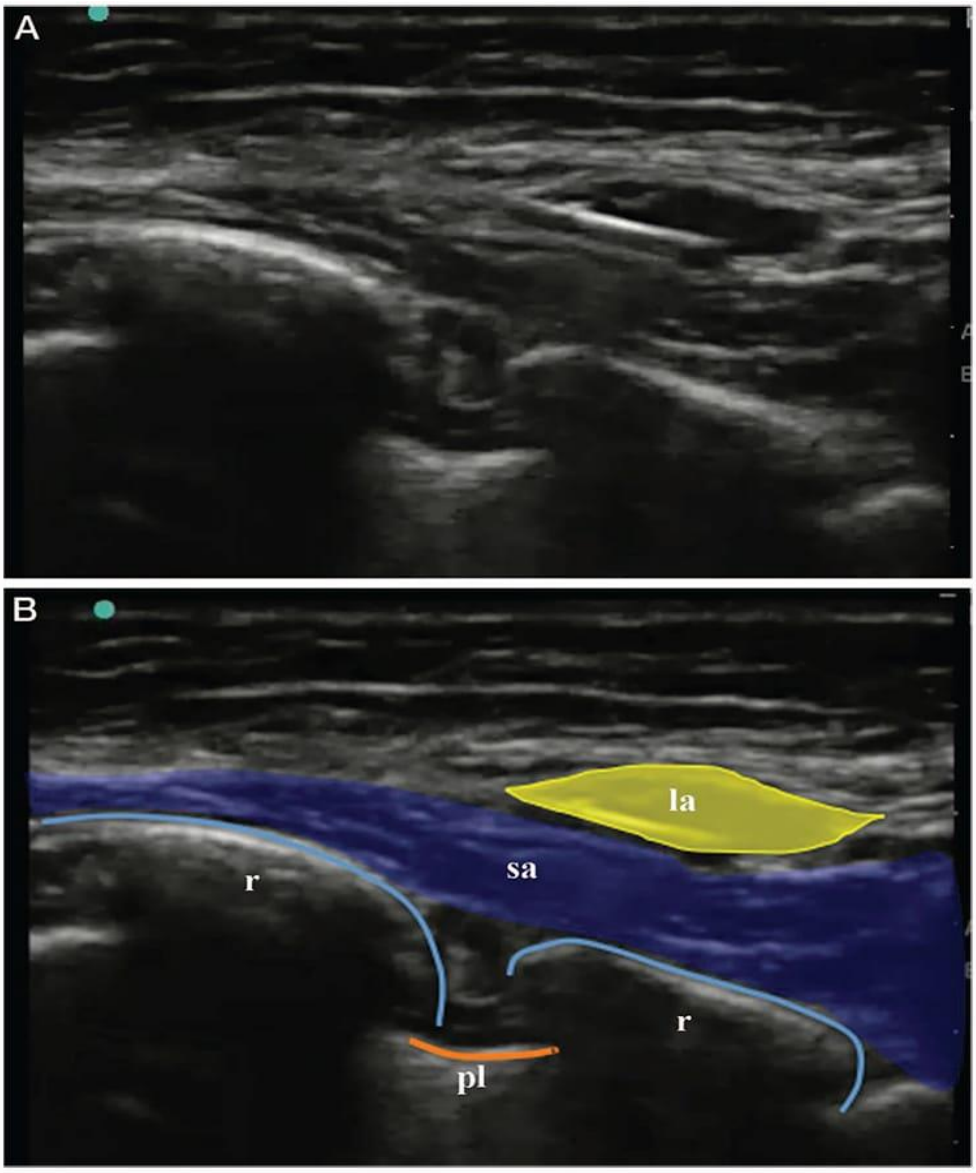

Figure 5. Ultrasound images showing the distension and the opening up of the fascial plane between the serratus anterior and the latissimus dorsi muscles subsequent to the injection of local anaesthetic. la, local anaesthetic; pl, pleura; r, rib; sa, serratus anterior. [21].

SAPB is a widely used regional block technique in breast surgery. The serratus anterior plane shows obvious muscle layers under ultrasound, and the position of needle insertion is superficial and away from the pleura and blood vessels. Compared with other regional block techniques, SAPB is less

difficult, the potential complications are less serious, and the single-point block range is sufficiently wide to provide regional analgesia for breast surgery. [22].

Application of SAPB in Breast Surgery

In mastectomy, the injection site of the superficial serratus anterior block is close to the surgical area, which may cause muscle edema or hematoma, affecting the operation; furthermore, the local anesthetic injected may be flushed away and suctioned, impacting the effect of the block. In contrast, deep serratus anterior block is not affected by surgery. Edwards et al. reported that deep serratus anterior block improved postoperative analgesia to a greater extent and reduced opioid consumption than superficial serratus anterior block in mastectomy patients [23]. Additionally, Piracha et al. suggested the use of deep serratus anterior block in breast surgery to avoid long thoracic nerve block that may occur in superficial block, and to avoid the blockage of nerve response leading to unclear nerve identification and impairment of scapular function [24]. Modified serratus anterior block can effectively block the thoracodorsal nerve, which is especially suitable for patients undergoing breast reconstruction with a latissimus dorsi myocutaneous flap [25].

Xiao et al. applied SAPB before breast cancer surgery and for 3 days thereafter. The authors reported that preoperative continuous serratus anterior block can reduce postoperative pain and adverse reactions in these patients, reduce anxiety, and improve postoperative outcomes. Regarding the quality of early recovery, analgesia and rehabilitation effects are better than postoperative intervention [5]. Regardless, there are some problems when continuous SAPB is utilized for modified radical mastectomy. First, continuous SAPB may increase the risk of catheter-related infections. Second, continuous SAPB may delay the patient's early postoperative activity, and moving the affected upper limb early may shift the position of the indwelling catheter; the position of the catheter is easier to fix in deep serratus anterior block.

Deep SAPB with an indwelling catheter may be suitable for use in modified radical mastectomy for breast cancer. SAPB alone can provide regional analgesia for nearly all anterolateral breast procedures. If the surgery involves the medial area of the breast, an anterior cutaneous branch of the intercostal nerve can be added to increase medial analgesia during breast surgery [26]. If the surgery involves the pectoral muscles, the combination of a type I thoracic nerve block and SAPB can provide good regional analgesia in the surgical area.

Efficacy of SAPB in Breast Cancer Surgery

Modified radical mastectomy is the main treatment for breast cancer, which involves the breast and axillary region, has a wide range and large trauma, and is accompanied by moderate to severe postoperative pain. The problems of postoperative pain and rapid recovery of patients with breast cancer need to be solved urgently. At present, there have been some reports on the use of SAPB for postoperative analgesia and rapid recovery of breast surgery

Effect of SAPB on Acute Pain After Breast Cancer Surgery

Patients with breast cancer experience moderate to severe pain. A series of prospective clinical studies have shown that preoperative SAPB can reduce postoperative pain scores after breast cancer surgery, the probability of rescue analgesia, and the need for perioperative opioids, suggesting that SAPB can provide good postoperative analgesia in patients with breast cancer [27–30]. A systematic review of regional block techniques for postoperative analgesia in breast tumors showed that paravertebral block and SAPB had a high probability of reducing pain at 24 h after major oncologic breast [31]. Gupta et al. reported that although patients in the classic thoracic paravertebral block and serratus anterior block groups had similar intraoperative fentanyl requirements and similar postoperative visual analog scale (VAS) scores and both blocks exerted good analgesic effects, the duration of muscle blockade and analgesia was shorter in the serratus anterior block group (245.6 ± 58 min vs. 346 ± 57 min). Considering the difficulty and related complications of thoracic paravertebral block, SAPB can be used as an alternative for postoperative analgesia in breast cancer surgery [32].

Application of SAPB in PMPS

Some studies have shown that approximately 25–60% of mastectomy patients may experience progression to postmastectomy pain syndrome (PMPS) [33]. The current main treatment methods for PMPS include drug therapy, physical therapy, and minimally invasive therapy [34], with drug therapy as the classic method. When pharmacological treatment is ineffective, a regional block technique is recommended as an alternative; among these techniques, serratus anterior block better targets the neural network that innervates the chest wall and breast [6] and is considered beneficial.

Prevention of Pain by SAPB Before Surgery

In the basic concept of pain physiology, a block of nociceptive nerve fibers before a stimulus will reduce the central sensitization and wind-up of pain, and reduce perceived pain for a long period [35]. Preoperative SAPB conforms to this rationale. Fuzier et al. suggested that SAPB before breast surgery appeared to be a protective factor for the risk of pain at 3 months [36]. In a prospective controlled study of SAPB, Qian et al. found that the incidence of chronic pain syndrome 3 months after the operation was 46/89 (51.7%) in the control group and 22/99 (25.6%) in the SAPB group, suggesting that preoperative SAPB reduced the incidence of postoperative chronic pain syndrome in patients with breast cancer [1]. Most of the analgesic benefit of the preoperative block was short-lasting and modest, and it may be that an even longer block period utilizing catheter techniques and repeated local analgesia dosing for several days is necessary to yield maximal benefit [37].

SAPB After Occurrence of Postoperative Chronic Pain Syndrome

Takimoto et al. applied the serratus anterior block technique in a patient with PMPS with a pain score of 10. Sustained pain reduction occurred, and the patient did not require any interventional management for pain for 11 months after the last injection [38]. Silva et al. [39] conducted a

retrospective study. On the basis of analysis of pain data, 74.1% of the patients reported at least a 30% decrease in pain intensity after 24 h, 44% a 30% decrease in pain intensity after 1 week, and 71.4% a decrease in pain intensity of at least 50% after 1 month. It is worth noting that SAPB has not been effective in all studies [40]. Studies have shown that patients with implant-filled breast reconstruction who describe pain as tightness have good results with SAPB; in contrast, patients with iatrogenic scar tissue have more fascia surrounding the scar tissue, which is thicker and less flexible and hinders full diffusion of the anesthetic and thus renders SAPB less effective [38, 41].

The hypothesis that SAPB can alleviate PMPS is a research area worthy of further exploration. Overall, there is a lack of consensus regarding the measurement of PMPS; there have been few studies on SAPB for PMPS, and most to date have been case reports. More such trials are needed to evaluate the efficacy of SAPB for PMPS. Future research should focus on determining which types of PMPS are most suitable for SAPB intervention and which level of SAPB is most suitable to guide doctors in making the best choice for patients.

Acceleration of Rapid Patient Recovery

SAPB reduces perioperative opioid use and the incidence of nausea and vomiting to some extent and improves patient comfort [29]. SAPB can also provide a good postoperative analgesic effect, reduce the use of opioids, the acute inflammatory response, and the release of serum inflammatory factors, and accelerate the time to first flatus and ambulation. Yao et al. conducted a prospective study to observe the effect of preoperative SAPB on the quality of recovery after breast cancer surgery. The results showed significantly higher 40-item recovery quality scores in the SAPB group than in the control group at 24 h after surgery, suggesting that SAPB improved the quality of recovery after breast cancer surgery [42]. Hards et al. also reported that SAPB could control nausea and vomiting after mastectomy well and was helpful for reducing the time to ambulation, with only 64% of patients in the control group able to ambulate on the first day after surgery [28].

The use of SAPB for adequate postoperative analgesia and minimal opioid use can further help to control postoperative nausea and vomiting, promote early recovery of gastrointestinal function, and facilitate early activity and rapid postoperative recovery [43].

Effect of Regional Blockade on Cancer Recurrence and Patient Prognosis

In terms of cancer recurrence, regional blockade may offer some benefits: (1) reduction of the stress response may reduce associated immunosuppression [44], (2) pain reduction may reduce opioid use and thus the possible adverse effects of opioids on cancer recurrence [45], and (3) amide local anesthetics may have direct antitumor effects [46, 47].

Most studies in which the authors are evaluating the effect of regional blockade on recurrence and prognosis in patients with breast cancer have been retrospective, with uncertainty regarding the direction of the association and conflicting results [48–50]. First, there are many interfering factors. Complications, nosocomial infection, tumor biology, immunity, and timely tumor treatment

(radiotherapy, chemotherapy) after surgery all have an impact on recurrence and prognosis [51]. Second, regarding the prognosis of patients with tumor recurrence, the follow-up period required is long, and it can be difficult to track details over long periods. Another limitation in the study of breast cancer recurrence and prognosis is that the recurrence rate is not high, and small sample sizes will increase the difficulty of determining a statistically significant difference.

Overall, proving the efficacy of a single intervention (regional block) in a complex multifactorial tumor setting is very challenging. A well-designed, standardized, prospective randomized controlled trial with a sufficient sample size is required to determine whether SAPB may have clinical benefits in terms of tumor recurrence and patient prognosis.

SAPB is a simple, safe and effective emerging regional block technique. Compared with other regional block techniques, it can target the nerve network innervating the chest wall and breast well and provide good analgesia in the anterolateral chest wall. It is expected to be used as an independent regional anesthesia in minimally invasive breast surgery. The application of SAPB in breast surgery can reduce the use of opioids in the perioperative period, relieve acute pain after surgery, reduce the incidence of postoperative PMPS to a certain extent, and is conducive to rapid patient recovery. Nevertheless, the impact on tumor recurrence and patient prognosis remains controversial, and more trials are needed to demonstrate the effect of SAPB on the prognosis of recurrent tumors. With the promotion of day surgery and fast track surgery, the clinical application of SAPB will be more extensive.

No Conflict of interest.

References:

1. Qian B, Huang S, Liao X, Wu J, Lin Q, Lin Y. Serratus anterior plane block reduces the prevalence of chronic postsurgical pain after modified radical mastectomy: a randomized controlled trial. J Clin Anesth. 2021;74:110410.

2. Blanco R, Parras T, McDonnell JG, Prats-Galino A. Serratus plane block: a novel ultrasound-guided thoracic wall nerve block. Anaesthesia. 2013;68(11):1107–1113.

3. Hanley C, Wall T, Bukowska I, et al. Ultrasound-guided continuous deep serratus anterior plane block versus continuous thoracic paravertebral block for perioperative analgesia in videoscopic-assisted thoracic surgery. Eur J Pain. 2020;24(4):828–838.

4. Bossolasco M, Bernardi E, Fenoglio LM. Continuous serratus plane block in a patient with multiple rib fractures. J Clin Anesth. 2017;38:85–86.

5. Xiao YK, She SZ, Xu LX, Zheng B. Serratus anterior plane block combined with general analgesia and patient-controlled serratus anterior plane block in patients with breast cancer: a randomized control trial. Adv Ther. 2021;38(6):3444–3454. doi: 10.1007/s12325-021-01782-y.

6. Zocca JA, Chen GH, Puttanniah VG, Hung JC, Gulati A. Ultrasound-guided serratus plane block for treatment of postmastectomy pain syndromes in breast cancer patients: a case series. Pain Pract. 2017;17(1):141–146.

7. Lotfipour S, Kaku SK, Vaca FE, Patel C, Anderson CL, Ahmed SS, Menchine MD. Factors associated with complications in older adults with isolated blunt chest trauma. West J Emerg Med. 2009 May;10(2):79-84.

8. Khalil AE, Abdallah NM, Bashandy GM, Kaddah TA. Ultrasound-Guided Serratus Anterior Plane Block Versus Thoracic Epidural Analgesia for Thoracotomy Pain. J Cardiothorac Vasc Anesth. 2017 Feb;31(1):152-158.

9. Park MH, Kim JA, Ahn HJ, Yang MK, Son HJ, Seong BG. A randomised trial of serratus anterior plane block for analgesia after thoracoscopic surgery. Anaesthesia. 2018 Oct;73(10):1260-1264.

10. Smith R, Nyquist-Battie C, Clark M, Rains J. Anatomical characteristics of the upper serratus anterior: cadaver dissection. J Orthop Sports Phys Ther. 2003 Aug;33(8):449-54.

11. Blanco R, Parras T, McDonnell JG, Prats-Galino A. Serratus plane block: a novel ultrasound-guided thoracic wall nerve block. Anaesthesia. 2013 Nov;68(11):1107-13.

12. Biswas A, Castanov V, Li Z, Perlas A, Kruisselbrink R, Agur A, Chan V. Serratus Plane Block: A Cadaveric Study to Evaluate Optimal Injectate Spread. Reg Anesth Pain Med. 2018 Nov;43(8):854-858.

13. Petersen RH, Holbek BL, Hansen HJ, Kehlet H. Video-assisted thoracoscopic surgery-taking a step into the future. Eur J Cardiothorac Surg. 2017;51(4):694–695.

14. Umari M, Carpanese V, Moro V, et al. Postoperative analgesia after pulmonary resection with a focus on video-assisted thoracoscopic surgery. Eur J Cardiothorac Surg. 2018;53(5):932–938.

15. Bai Y, Sun K, Xing X, et al. Postoperative analgesic effect of hydromorphone in patients undergoing single-port video-assisted thoracoscopic surgery: a randomized controlled trial. J Pain Res. 2019;12:1091–1101.

16. Zhang X, Zhang C, Zhou X, et al. Analgesic effectiveness of perioperative ultrasound-guided serratus anterior plane block combined with general anesthesia in patients undergoing video-assisted thoracoscopic surgery: a systematic review and meta-analysis. Pain Med. 2020;21(10):2412–2422.

17. Jiang C, Li Y, Li X, et al. Postoperative analgesic effect of acupotomy combined with patient-controlled analgesia in patients undergoing video-assisted thoracoscopic surgery: a study protocol for a randomized controlled trial. Trials. 2020;21(1):998.

18. Steinthorsdottir KJ, Wildgaard L, Hansen HJ, Petersen RH, Wildgaard K. Regional analgesia for video-assisted thoracic surgery: a systematic review. Eur J Cardiothorac Surg. 2014;45(6):959–966.

19. Colley CM, Fleck A, Goode AW, Muller BR, Myers MA. Early time course of the acute phase protein response in man. J Clin Pathol. 1983;36(2):203–207.

20. Wallace AM, Sattar N, Mcmillan DC. The co-ordinated cytokine/hormone response to acute injury incorporates leptin. Cytokine. 2000;12(7):1042–1045.

21. Erb J, Orr E, Mercer CD, Gilron I. Interactions between pulmonary performance and movement-evoked pain in the immediate postsurgical period: implications for perioperative research and treatment. Reg Anesth Pain Med. 2008;33(4):312–319.

22. Batchelor TJP, Rasburn NJ, Abdelnour-Berchtold E, et al. Guidelines for enhanced recovery after lung surgery: recommendations of the Enhanced Recovery After Surgery (ERAS®) Society and the European Society of Thoracic Surgeons (ESTS) Eur J Cardiothorac Surg. 2019;55(1):91–115.

23. Edwards JT, Langridge XT, Cheng GS, McBroom MM, Minhajuddin A, Machi AT. Superficial vs deep serratus anterior plane block for analgesia in patients undergoing mastectomy: a randomized prospective trial. J Clin Anesth. 2021;75:110470.

24. Piracha MM, Thorp SL, Puttanniah V, Gulati A. "A tale of two planes": deep versus superficial serratus plane block for postmastectomy pain syndrome. Reg Anesth Pain Med. 2017;42(2):259–262.

25. Khemka R, Chakraborty A, Ahmed R, Datta T, Agarwal S. Ultrasound-guided serratus anterior plane block in breast reconstruction surgery. A A Case Rep. 2016;6(9):280–282.

26. Sherwin A, Buggy DJ. Anaesthesia for breast surgery. BJA Educ. 2018;18(11):342–348.

27. Mazzinari G, Rovira L, Casasempere A, et al. Interfascial block at the serratus muscle plane versus conventional analgesia in breast surgery: a randomized controlled trial. Reg Anesth Pain Med. 2019;44(1):52–58.

28. Hards M, Harada A, Neville I, et al. The effect of serratus plane block performed under direct vision on postoperative pain in breast surgery. J Clin Anesth. 2016;34:427–431.

29. Pérez Herrero MA, López Álvarez S, Fadrique Fuentes A, Manzano Lorefice F, Bartolomé Bartolomé C, González de Zárate J. Quality of postoperative recovery after breast surgery. General anaesthesia combined with paravertebral versus serratus-intercostal block. Rev Esp Anestesiol Reanim. 2016;63(10):564–571.

30. Baytar Ç, Aktaş B, Aydin BG, Pişkin Ö, Çakmak GK, Ayoğlu H. The effects of ultrasound-guided serratus anterior plane block on intraoperative opioid consumption and hemodynamic stability during breast surgery: a randomized controlled study. Medicine. 2022;101(35):e30290.

31. Singh NP, Makkar JK, Kuberan A, Guffey R, Uppal V. Efficacy of regional anesthesia techniques for postoperative analgesia in patients undergoing major oncologic breast surgeries: a systematic review and network meta-analysis of randomized controlled trials. Can J Anaesth. 2022;69(4):527–549.

32. Gupta K, Srikanth K, Girdhar KK, Chan V. Analgesic efficacy of ultrasound-guided paravertebral block versus serratus plane block for modified radical mastectomy: a randomised, controlled trial. Indian J Anaesth. 2017;61(5):381–386.

33. Wang K, Yee C, Tam S, et al. Prevalence of pain in patients with breast cancer post-treatment: a systematic review. Breast. 2018;42:113–127.

34. Larsson IM, Ahm Sørensen J, Bille C. The post-mastectomy pain syndrome: a systematic review of the treatment modalities. Breast J. 2017;23(3):338–343.

35. Woolf CJ. Central sensitization: implications for the diagnosis and treatment of pain. Pain. 2011;152(3 Suppl):S2–S15.

36. Fuzier R, Salvignol G, Gilbert O, Bremaud M, Bataille B, Izard P. Influence of deep serratus anterior plane block on chronic pain at 3 months after breast-conserving surgery: prospective, cohort study. Clin J Pain. 2022;38(6):418–423.

37. Holmberg A, Sauter AR, Klaastad Ø, Draegni T, Raeder JC. Pre-operative brachial plexus block compared with an identical block performed at the end of surgery: a prospective, double-blind, randomised clinical trial. Anaesthesia. 2017;72(8):967–977.

38. Takimoto K, Nishijima K, Ono M. Serratus plane block for persistent pain after partial mastectomy and axillary node dissection. Pain Physician. 2016;19(3):E481–E486.

39. Dos Santos Rodrigues da Silva MJ, Ferreira MLN, Fernandez Gacio M, Miranda MLC, Agrelo A. The role of ultrasound guided serratus plane block on chronic neuropathic pain after breast surgery in cancer patient. Rev Esp Anestesiol Reanim (Engl Ed) 2021;68(6):338–345.

40. Liu Q, Khanna A, Stubblefield MD, Yue GH, Allexandre D. Ultrasound-guided superficial serratus plane block for persistent post-mastectomy pain: four case reports. Support Care Cancer. 2021;30:2787–2792.

41. Waltho D, Rockwell G. Post-breast surgery pain syndrome: establishing a consensus for the definition of post-mastectomy pain syndrome to provide a standardized clinical and research approach - a review of the literature and discussion. Can J Surg. 2016;59(5):342–350.

42. Yao Y, Li J, Hu H, Xu T, Chen Y. Ultrasound-guided serratus plane block enhances pain relief and quality of recovery after breast cancer surgery: a randomised controlled trial. Eur J Anaesthesiol. 2019;36(6):436–441.

43. Temple-Oberle C, Shea-Budgell MA, Tan M, et al. Consensus review of optimal perioperative care in breast reconstruction: enhanced recovery after surgery (ERAS) society recommendations. Plast Reconstr Surg. 2017;139(5):1056e–1071e.

44. Duff S, Connolly C, Buggy DJ. Adrenergic, inflammatory, and immune function in the setting of oncological surgery: their effects on cancer progression and the role of the anesthetic technique in their modulation. Int Anesthesiol Clin. 2016;54(4):48–57.

45. Boland JW, Pockley AG. Influence of opioids on immune function in patients with cancer pain: from bench to bedside. Br J Pharmacol. 2018;175(14):2726–2736.

46. Dan J, Gong X, Li D, Zhu G, Wang L, Li F. Inhibition of gastric cancer by local anesthetic bupivacaine through multiple mechanisms independent of sodium channel blockade. Biomed Pharmacother. 2018;103:823–8.

47. Chamaraux-Tran TN, Piegeler T. The amide local anesthetic lidocaine in cancer surgery-potential antimetastatic effects and preservation of immune cell function? A narrative review. Front Med. 2017;4:235.

48. Zhang J, Chang CL, Lu CY, Chen HM, Wu SY. Paravertebral block in regional anesthesia with propofol sedation reduces locoregional recurrence in patients with breast cancer receiving breast conservative surgery compared with volatile inhalational without propofol in general anesthesia. Biomed Pharmacother. 2021;142:111991.

49. Cakmakkaya OS, Kolodzie K, Apfel CC, Pace NL. Anaesthetic techniques for risk of malignant tumour recurrence. Cochrane Database Syst Rev. 2014

50. Sessler DI, Pei L, Huang Y, et al. Recurrence of breast cancer after regional or general anaesthesia: a randomised controlled trial. Lancet. 2019;394(10211):1807–1815.

51. Nair AS, Naik V, Saifuddin MS, Narayanan H, Rayani BK. Regional anesthesia prevents cancer recurrence after oncosurgery! What is wrong with the hypothesis? Indian J Cancer. 2021;58(3):447–454.