Minimum effective volume of ropivacaine 0.25% in 90% of patients (MEV90) for ultrasound-guided superior trunk block: study protocol for a single-center, sequential-randomized trial

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Research Article

Keywords: superior trunk block, shoulder arthroscopic surgery, minimum effective volume

Posted Date: July 12th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1843215/v1

Abstract

Background General anaesthesia and interscalene brachial plexus block (ISB) are the main anaesthesia methods for patients undergoing shoulder arthroscopy. However, they usually result in severe complications, such as postoperative nausea and vomiting (PONV), postoperative cognitive dysfunction (POCD), and hemi-diaphragmatic paralysis (HDP). Compared with ISB, superior trunk block (STB) is associated with a lower incidence of HDP and greater hand strength. Previous studies of STB have proven that it could provide surgical anaesthesia and noninferior postoperative analgesia, but the incidence of partial HDP was still very high, which may be fatal for some specific populations, such as patients with preexisting pulmonary impairments. Moreover, a high dose of local anaesthetic (LA) can result in prolonged postoperative numbness and weakness in the affected upper limb. Adverse events can be avoided by reducing the dose of LA, namely by using the minimum effective volume (MEV) or concentration (MEC). In this study, we aimed to explore the MEV of ropivacaine 0.25%, providing satisfactory surgical anaesthesia during the performance of an STB. Methods/design Our study is a prospective cohort trial to determine the minimum effective volume of ropivacaine 0.25% in 90% of patients (MEV90) on the provision of surgical anaesthesia for shoulder arthroscopy. Trial designs apply the up-and-down Biased Coin Design (BCD) methodology, which has been adopted in recent years in dose-finding studies for regional anaesthesia. Participants will be enrolled and receive STB with different volumes of ropivacaine 0.25%. The volume of ropivacaine administered to each patient depends on the outcome of the previous one. A volume of 5 ml is chosen for the initial case on the basis of prior clinical experience. In case of failure, the next patient will receive a higher volume (defined as the previous volume with an increment of 2 ml). The successful block will be defined as not only achieving a minimal score of 9 points (out of 10 points) after 30 minutes of STB using a sensory composite scale but also completing the surgery with only STB without general anaesthesia. The volume of LA for the subsequent case is then randomized according to the BCD principle. Discussion This research will determine the MEV90 of ropivacaine 0.25% of STB in patients undergoing shoulder arthroscopy. The results of the study will be important for guiding clinical practice and making it possible to enhance recovery after surgery for patients in day wards undergoing shoulder arthroscopic surgery.

Background

Severe pain is common in patients undergoing shoulder arthroscopy. Interscalene brachial plexus block (ISB) has been the most commonly performed block for shoulder surgery [1]. Unfortunately, serious complications, such as partial or complete hemi-diaphragmatic paralysis (HDP) and discomfort numbness in the arm caused by ISB, restrict its use. Several alternatives to ISB have recently been used, such as supraclavicular nerve block, anterior suprascapular nerve combined with axillary nerve block and superior trunk block (STB) [2]. The advantages of STB in shoulder arthroscopy have been raised in two clinical trials [3, 4]. The volume and concentration reported were both 15 ml of 0.5% ropivacaine. It could provide noninferior analgesia compared with ISB and reduce the incidence of adverse events. However, the incidence of partial HDP still reached 71.1% and 65.7%, respectively, which was abysmal for some

restricted populations. Therefore, the dose of local anaesthetic (LA) of STB should be low enough to guarantee patient safety while providing complete surgical anaesthesia.

Our preliminary trial (ChiCTR2000036608) demonstrated that STB at a low volume (10 ml) and concentration (0.25%) of ropivacaine was sufficient to provide satisfactory surgical anaesthesia and postoperative analgesia. However, there is no consensus regarding what volume of ropivacaine should be used to achieve a successful STB. The primary objective of our study is to determine the minimum effective volume of ropivacaine 0.25% in 90% of patients (MEV90) in ultrasound-guided STB. The secondary objective is to explore numerical rating scale (NRS) pain scores at 3, 6, and 12 hours after blockade and the block duration.

Methods/design

Trial design

Our study is a prospective cohort trial to determine the effect of MEV90 on the provision of surgical anaesthesia for shoulder arthroscopy. The volume of LA administered to each patient depends on the outcome of the previous administration. Trial designs utilizing the up-and-down Biased Coin Design (BCD) methodology have been adopted in recent years in dose-finding studies for regional anaesthesia [5]. The starting volume will be 5 ml.

In this exploratory trial, we will determine whether the block is successful largely by a sensory composite scale. Sensory block at the level of these five portals according to the description by Paxton et al.[6] and surgeons' preferences located on the inferior and medial to the posterolateral acromion, on the inferomedial side of the anterolateral acromion, on the distal side of the lateral edge of the anterior acromion, on the inferior to the posterolateral edge of the acromion, and on the anterior and lateral to the posterolateral edge of the acromion (Fig. 1) relative to the contralateral side will be evaluated at 10, 20, and 30 minutes after STB using a 3-point scale: 0 = no block, 1 = analgesia (patient can feel touch, not cold), and 2 = anaesthesia (patient cannot feel touch). The sensory composite score will be the sum of the scores of these five sites.

If the patient’s score is less than 9 at 30 minutes after STB, the case will be considered a failure, and general anaesthesia will be a need while the next one will receive a higher volume (defined as the previous volume with an increment of 2 ml). Participants with a high scale of 9 or 10 after STB will undergo shoulder arthroscopy and be given a loading dose of 0.8 $\mu g \cdot kg^{-1}$ dexmedetomidine within 15 minutes, followed by a continuous infusion of 0.3 $\mu g \cdot kg^{-1} \cdot h^{-1}$ for discomfort in position and anxiolysis, provided that response to verbal stimulus is maintained. In patients with difficulty tolerating pain intraoperatively, supplemental general anaesthesia will be considered, and such a case will be defined as a failure. In contrast, operations that are successfully completed without general anaesthesia will be considered successful. The next administration will be randomized to a lower volume (defined as the

previous volume with a decrement of 2 ml), with a probability of b=0.11, or the same volume, with a probability of 1–b=0.89. The trial scheme is illustrated in Fig. 2.

Monitoring

Patients will receive no premedication before arriving at the operation room. After applying standard ASA monitoring (i.e., pulse oximetry and electrocardiogram) and supplemental oxygen (nasal, 4 L/min), radial artery catheterization of the nonsurgical upper extremity will also be performed.

Block protocol

We modified the STB procedure described by Burckett-St. Laurent et al. [7] and Kim et al. [4] according to our clinical practice. Ultrasonography will be performed with a high-frequency linear ultrasound probe (5–15 MHz), and the patient lays supine with the neck exposed. The transducer will be manipulated, starting from the supraclavicular fossa to the interscalene groove and then in the reverse direction to identify the superior trunk. During the sweeping motion, the C7, C6, and C5 nerve roots should be identified to better define the contiguous anatomy of the brachial plexus. The targeted level of insertion for the injection is proximal to the takeoff of the suprascapular nerve. The needle will be inserted in a lateral-to-medial direction using the in-plane technique. When the tip is identified inferior to the trunk, half of the volume of the LA will be injected toward the trunk. Then, the needle tip is redirected superiorly to the trunk, and the remaining LA will be injected. During the injection process, the needle tip should be moved slowly to achieve circumferential LA diffusion around the nerve. Moreover, the investigator should be able to visualize the entire beveled needle tip with ultrasound guidance and always keep it oriented toward the trunk (Fig. 3).

Intraoperative management

In case of failure, the patient will undergo general anaesthesia with tracheal intubation using IV propofol (1.5 to 2.0 $mg \cdot kg^{-1}$), rocuronium (0.6 to 0.8 $mg \cdot kg^{-1}$), and IV remifentanil (2 $\mu g \cdot kg^{-1}$). anaesthesia will be maintained with sevoflurane in an air-oxygen mixture. A continuous infusion of remifentanil (0.01 to 0.1 $\mu g \cdot kg^{-1} \cdot min^{-1}$) will be invoked as needed to maintain the heart rate and mean blood pressure within 20% of preinduction values.

Operation

All shoulder arthroscopy performed with the patients in the lateral decubitus position will be completed by the same team of skilled surgeons. No additional intraoperative analgesics will be given. Surgeons would

also not inject additional LA at the surgical sites. Cases with a surgery duration longer than 2 hours will be exempt from the study.

Ethics

The study was approved by the institutional human research ethics board (Changzheng Hospital, Second Affiliated Hospital of Naval Medical University, Shanghai, China) and was registered with the Chinese Clinical Trials Registry (ChiCTR2200059042). This trial will be performed according to the principles of the Declaration of Helsinki (Edinburgh 2000 version). Written informed consent will be obtained from each participant before enrollment.

Participants

Study population

Patients undergoing shoulder arthroscopic surgery aged 46–80 years will be recruited from Changzheng Hospital, Second Affiliated Hospital of Naval Medical University. The trial will occur from July 2022 to June 2023.

Inclusion criteria

- American Society of Anesthesiologists (ASA) Physical Status I–III
- Aged 46-80 years

Exclusion criteria

- Combined with chronic obstructive pulmonary diseases, diabetes, transient ischemic attacks, sleep apnea syndrome
- Contraindications for nerve block

Data collection

All assessments of sensory blockade scores will be carried out by two investigators working conjointly and blinded to the volume of LA administered. Each participant's characteristics, such as age and body weight as well as ASA grade, durations of STB and shoulder arthroscopic surgery, NRS scores and opioid consumption, will also be recorded in a designed data form by these two investigators.

Sample size

To estimate the minimum sample size required for stabilization of the MEV90 calculation, we used simulations (assuming a fixed-sample BCD design and a fixed minimum number of positive responses, that is, successful blocks) for different scenarios of dose distribution, sample size and number of positive responses. The different scenarios and starting rules were performed according to Durham et al. [8] The first simulation design showed stabilization of the estimated parameters after a minimum of 40 blocks. This result was supported by Pace et al. [9] and George et al. [10] A second simulation design was performed using the additional assumption that the probability of receiving a lower volume after a successful (previous) response was exactly equal to the theoretical probability (b=0.11). For this, it was necessary to keep the minimum number of successful responses fixed to a multiple of 9. Again, stabilization of estimated parameters occurred after 40 blocks; however, the SEs of the estimated parameters were smaller for this second simulation design. A fixed minimum number of 45 positive responses (the smallest multiple of 9 that is greater than 40) were then chosen for our dose-finding study. Thus, we will continuously perform STB until 45 successful blocks are obtained and 45 envelopes (containing the random volume assignments for successful blocks) were opened. The final sample size is not known a priori but is estimated from the simulations to be 52 ± 2.

Statistical analysis

The MEV90 will be calculated using isotonic regression with a 95% CI derived by bootstrapping. Following the notation of Stylianou et al. [11] , we used the dose estimator μ_3, which is defined as the interpolated dose that has an estimated toxicity exactly equal to 0.9. This estimator and the estimator μ_2 are less variable than the classic isotonic estimator μ_1.

The statistical analysis was performed using the R statistical software package V.4.0.3 (R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www. Rproject. org).

Discussion

Shoulder arthroscopy plays an important role in diagnosing and treating shoulder-related diseases with advantages including less invasive approaches, improved visualization, decreased risk of many postoperative complications, and faster recovery [6]. As a result, arthroscopy is often preferred by both orthopedic surgeons and patients. Although shoulder arthroscopy is a minimally invasive procedure, it causes significant postoperative pain attributed to significant bone resection, extensive removal of bursal tissue, insertion of suture anchors, and soft tissue distension from the irrigation fluid. General anaesthesia and ISB are common anaesthesia methods. However, their disadvantages include postoperative sore throat, PONV, POCD, HDP, postoperative prolonged numbness and weakness of the

arm. Thus, it is necessary to develop an alternative method that could provide satisfactory surgical anaesthesia and postoperative analgesia without the adverse events above. Among all the multiple alternatives, STB constitutes the most anticipated solution [2–4]. On the other hand, a high dose of LA can also increase the incidence of adverse events. Therefore, we designed this trial to explore the minimum effective volume of ropivacaine at a low concentration (0.25%) to provide adequate surgical anaesthesia.

We reason that it would be of value to receive an STB using the minimum effective volume, which can provide satisfactory surgical anaesthesia while avoiding unwanted adverse events.

Trial Status

The trial is currently in recruitment phase. Trial completion is expected by June 2025.

Abbreviations

ISB: interscalene brachial plexus block; PONV: postoperative nausea and vomiting, POCD: postoperative cognitive dysfunction, HDP: hemi-diaphragmatic paralysis, STB: superior trunk block, LA: local anaesthetic, MEV: the minimum effective volume, MEC: the minimum effective concentration, MEV90: the minimum effective volume of ropivacaine 0.25% in 90% of patients, BCD: Biased Coin Design, NRS: numerical rating, ASA: American Society of Anesthesiologists

Declarations

Ethics approval and consent to participate

The project has been reviewed and approved by the Shanghai Changzheng Hospital Ethics Committee. Written, informed consent to participate will be obtained from all participants

Consent for publication

Not applicable.

Availability of data and materials

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Funding

This work was supported by the Medical Innovation Research Project of Shanghai Science and Technology Commission (21Y11906400).

Authors' contributions

KW and MG conceived the trial, prepared the initial protocol, conducted the study, and helped draft the manuscript.They contributed to this work equally. DYZ and JXZ performed nerve block and anesthesia. YHL and YYZ designed the study and revised the manuscript. YYZ and YHL were listed as corresponding authors. YHL is responsible for the overall content as guarantor and accepts full responsibility for the finished work. All authors have read and approved the manuscript.

Acknowledgements

Not applicable.

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Figures

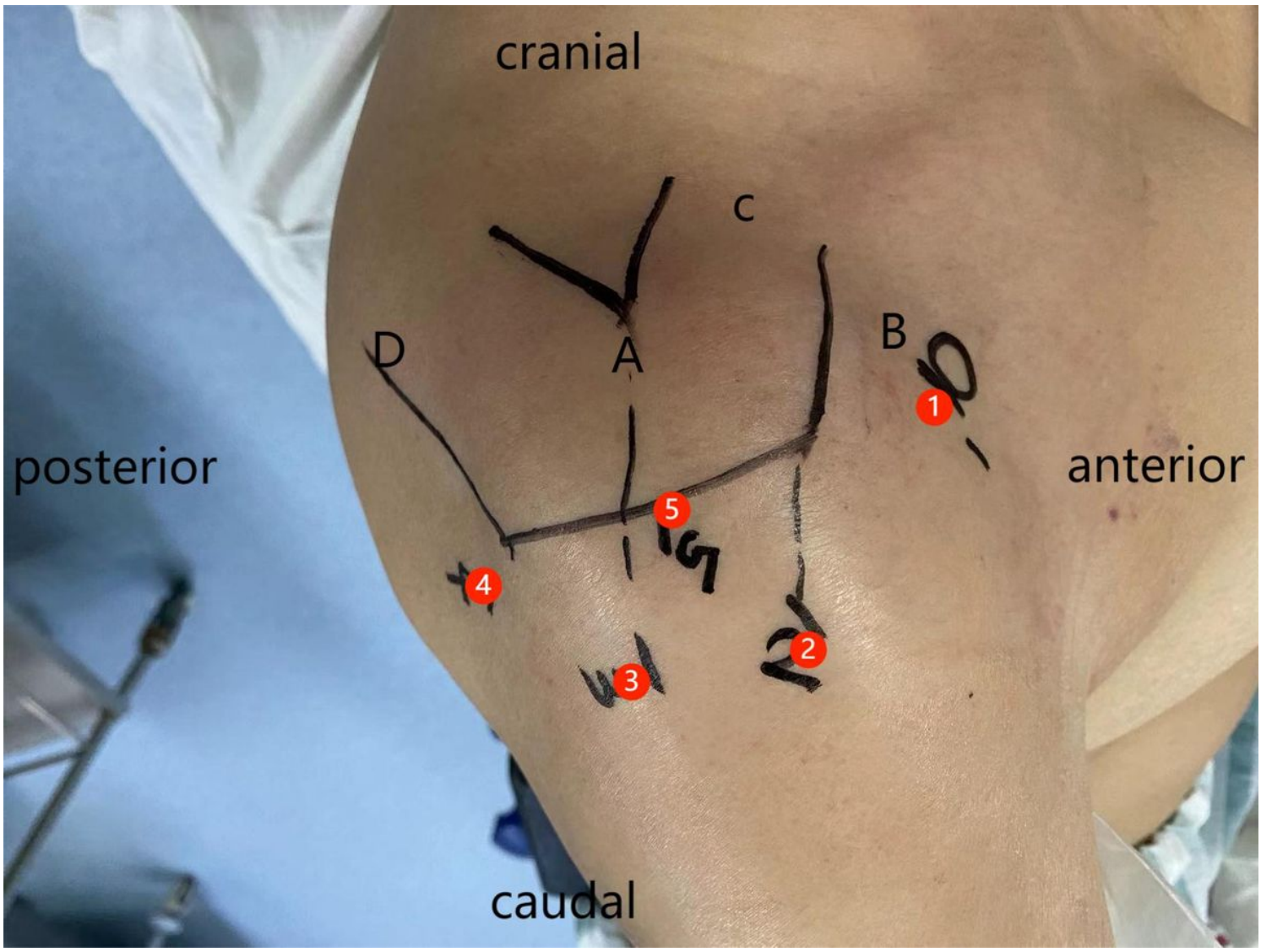

Figure 1

Preoperative photograph of a prepped shoulder arthroscopy patient with important bony landmarks and portal locations marked on the surgical shoulder. A, acromion; B, coracoid process; C, clavicle; D, scapular spine. The sensory block will be evaluated at the level of these five portals.

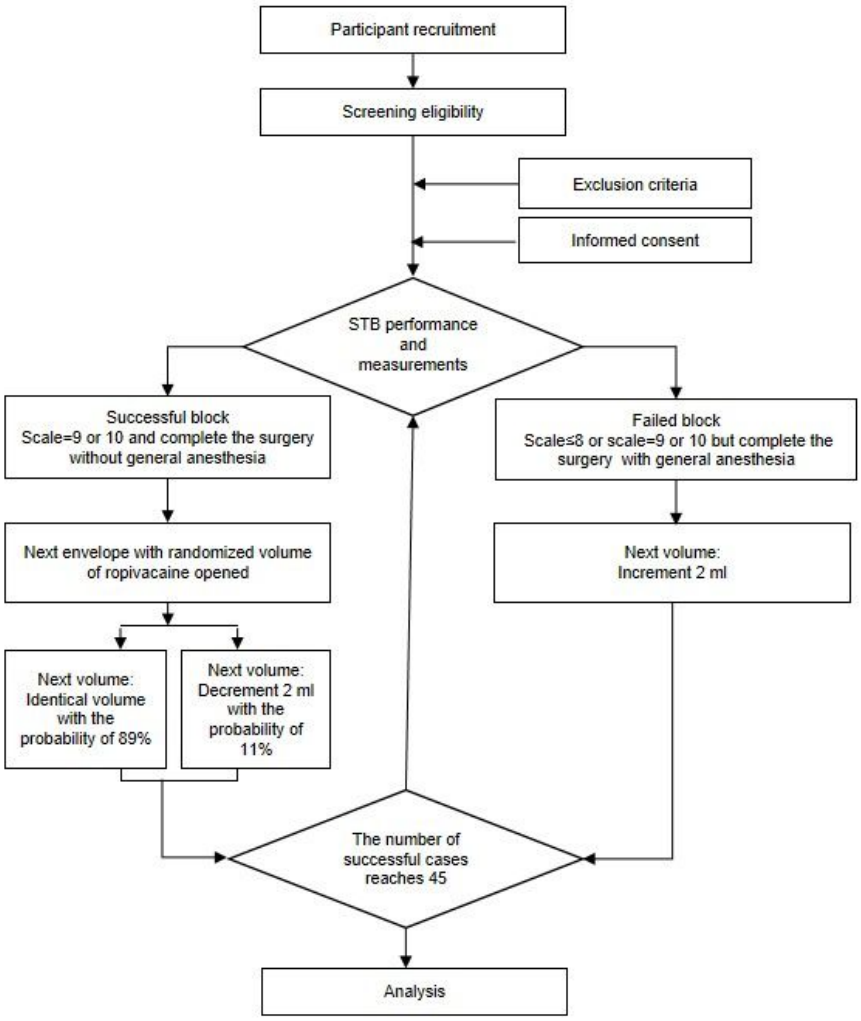

Figure 2

MEV90 trial scheme

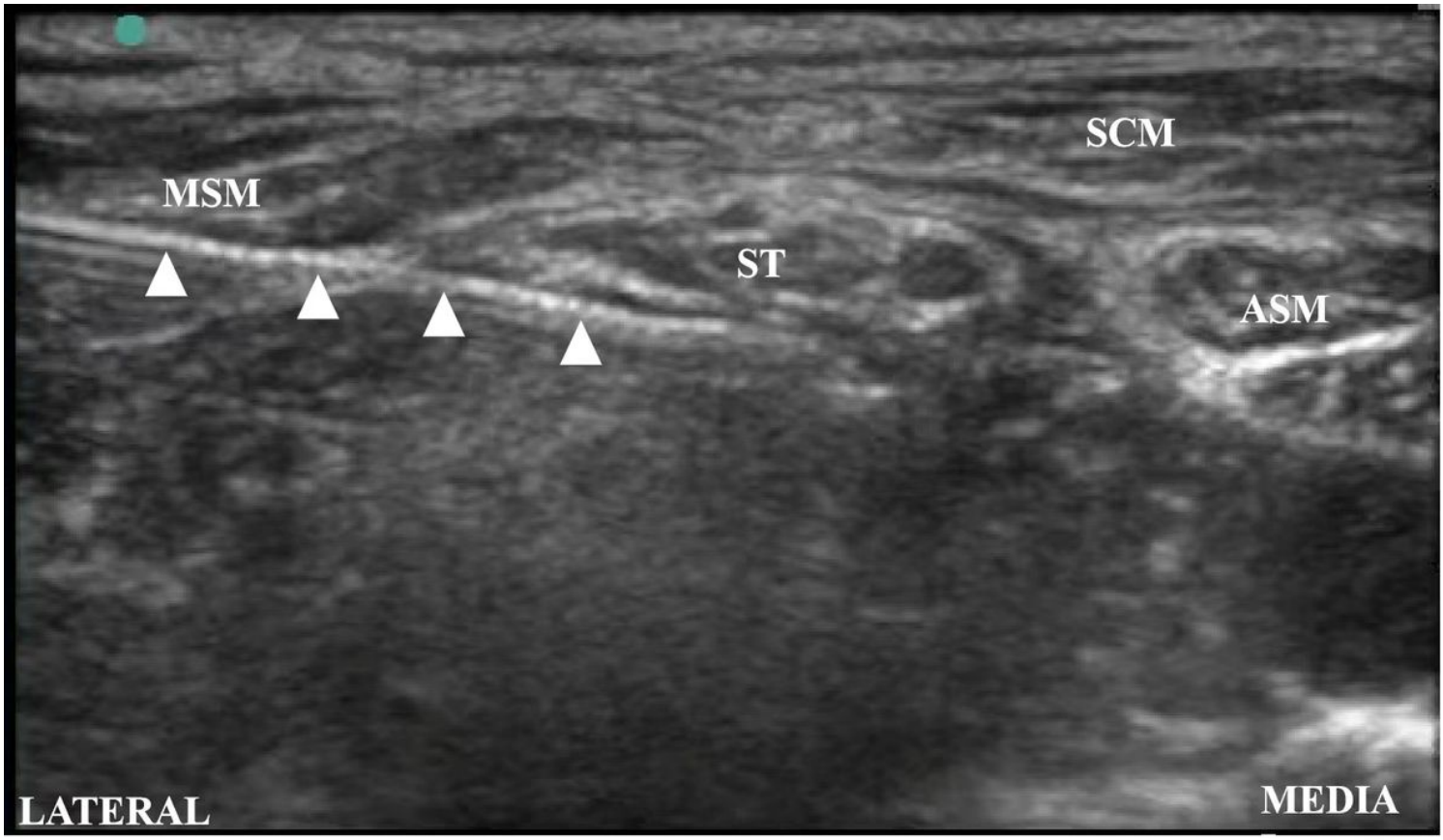

Figure 3

Ultrasonographic image of the superior trunk block. SCM, sternocleidomastoid; ASM, anterior scalene muscle; MSM, middle scalene muscle; ST, superior trunk. White upward pointing triangles indicate the needle route.

Supplementary Files

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