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ORIGINAL INVESTIGATION

An alternative approach for blocking the superior trunk of the brachial plexus evaluated by a single arm clinical trial

Thiago Nouer Frederico [a], **Rioko Kimiko Sakata** [a,*], **Luiz Fernando dos Reis Falcão** [a], **Paulo Cesár Castello Branco de Sousa** [a], **Fernanda Melhmann** [a], **Cesar Augusto Simões** [b], **Leonardo Henrique Cunha Ferraro** [a]

[a] *Universidade Federal de São Paulo, São Paulo, SP, Brazil*
[b] *Universidade de São Paulo, São Paulo, SP, Brazil*

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Abstract
Background: Interscalene brachial plexus block is associated with phrenic nerve paralysis. The objective of this study was to evaluate an alternative approach to interscalene brachial plexus blocks in terms of efficacy, grade of motor and sensory blockade, and phrenic nerve blockade.
Methods: The study was prospective and interventional. The ten living patients studied were 18 to 65 years old, ASA physical status I or II, and submitted to correction of rotator cuff injury. A superior trunk blockade was performed at the superior trunk below the omohyoid muscle, without blocking the phrenic nerve. The needle was advanced below the prevertebral layer until contacting the superior trunk. In order to guarantee the correct positioning of the needle tip, an intracluster pattern of the spread was visualized. The block was performed with 5 mL of 0.5% bupivacaine in ten patients. In the six cadavers, 5 mL of methylene blue was injected. Diaphragmatic excursion was assessed by ultrasonography of the ipsilateral hemidiaphragm. In three patients, pulmonary ventilation was evaluated with impedance tomography. Pain scores and analgesic consumption were assessed in the recovery room for 6 hours after the blockade.
Results: In the six cadavers, methylene blue didn't reach the phrenic nerve. Ten patients underwent arthroscopic surgery, and no clinically phrenic nerve paralysis was observed. No patient reported pain during the first 6 hours.
Conclusions: This study suggests that this new superior trunk approach to block the superior trunk may be an alternative technique to promote analgesia for shoulder surgery in patients with impaired respiratory function.

* Corresponding author.
E-mail: rsakata@unifesp.br (R.K. Sakata).

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Introduction

Interscalene Brachial Plexus Block (ISB) is the most commonly performed regional anesthesia technique for perioperative shoulder analgesia. This technique promotes the blockade of all fibers responsible for the innervation of the bone and muscular components of the shoulder, promoting effective postoperative analgesia. However, in the ISB, the local anesthetic is injected close to the phrenic, causing blocking of this nerve in practically 100% of cases when large volumes of local anesthetic are administered.[1] Therefore, ISB technique may be contraindicated in patients with limited pulmonary reserve or who do not tolerate a 25% reduction in lung capacity. Low volumes of local anesthetics have been used to allow phrenic nerve sparing. Despite the low-volume technique has reduced the incidence of hemi-diaphragmatic paralysis to 27–45%,[2–4] the incidence of phrenic nerve block is still high.

An alternative to ISB could be the superior trunk block and the sub-omohyoid suprascapular nerve block.[5,6] Some studies have shown that both techniques promote similar analgesic effect as the ISB for shoulder surgeries,[7,8] therefore, they may be substitutes for ISB to allow phrenic nerve sparing.[7]

However, recent studies have shown that those two techniques could compromise respiratory function through phrenic nerve block.[8,9] One hypothesis for this impairment of the respiratory function could be the endpoint of injection chosen by the authors. The most common anatomical variations are: C5 root emerging anterior to the anterior scalene muscle and following its path between the anterior scalene muscle and the sternocleidomastoid muscle until it reaches the remainder of the plexus in the supraclavicular area; C5 root emerging from its foramen, inside anterior scalene muscle, transfixing it and following its path between the anterior scalene muscle and the sternocleidomastoid muscle until finding the remainder of the plexus in the supraclavicular area; and C5 and C6 roots emerging from its foramens inside anterior scalene muscle and transfixing it to find the remainder of the plexus in the supraclavicular area (Figure 1). This variation keeps superior trunk structures nearer to the phrenic nerve for a longer pathway or delay the formation of the superior trunk. In this case, C5 reaches the remaining of brachial plexus only in the supraclavicular area because it might travel around the antero-lateral border of the anterior scalene muscle.

An intra-cluster injection in the superior trunk below the prevertebral layer of the deep cervical fascia in the supraclavicular area could limit the dispersion to the phrenic nerve without compromising analgesic effect for patients undergoing shoulder surgery.

The aim of this study was to evaluate the analgesic effect and the respiratory function after a block of the superior trunk in the area below the omohyoid muscle.

Methods

Study design: The study was prospective and a descriptive single-arm clinical trial.

Settings: The data of the patients were collected at the Hand and Upper Limb Surgery Section. The cadaver data were collected at the Service of Verification of Deaths.

Register: The study was registered at ClinicalTrials NCT03512990.

Ethical aspects

The study was performed after approval by the Ethics Committee (CEP 1350/2017; Adress: Rua Botucatu 740; Reference person: Miguel Roberto Jorge), and written informed consent was obtained from the participants. It was conducted according to ethical principles and the Declaration of Helsinki.

Inclusion and exclusion criteria

Participants

Ten living patients of both genders aged between 18 and 65 years, American Society of Anesthesiologists (ASA) physical status I or II, body mass index of less than 35 $kg.m^{-2}$ and were submitted to shoulder correction of rotator cuff injury, were included. Patients with cognitive impairment, infection at the blockade puncture site, coagulopathy, using anticoagulants, allergic to drugs, and pregnant were excluded from the study.

Interventions

Block technique

The patients were monitored with cardioscope, noninvasive arterial blood pressure and pulse oximetry.

The superior trunk blockade was performed with no sedation for better assessment of respiratory function. After antisepsis with chlorhexidine and local anesthesia with 1% lidocaine without epinephrine, a high-frequency linear transducer (M-Turbo R System, a 38×, 6–13 MHz, Fujifilm SonoSite Inc, Bothell, WA, USA) was used for the examination of the area. At the lower anterolateral side of the neck (posterior triangle), the brachial plexus was visualized in the scalene area. A careful examination of the region was carried out, identifying the transverse processes of the C7 and C6 roots. The transverse process of C7 has only a posterior tubercle while C6 has both tubercles. With these structures identified, it was possible to identify the roots of C5 and C6 and follow them until the moment they joined, forming the superior trunk. This junction usually occurs in the interscalene cleft, different anatomical variations of the C5 and C6 roots.

Once the superior trunk was identified, it was followed more distally until the supraclavicular area, below the omohyoid muscle, where it was possible to identify the suprascapular nerve outflow from the superior trunk.[10]

The injection was performed at the point where the superior trunk was positioned in the supraclavicular area, distally to the point where the suprascapular nerve leaves the superior trunk of the brachial plexus.

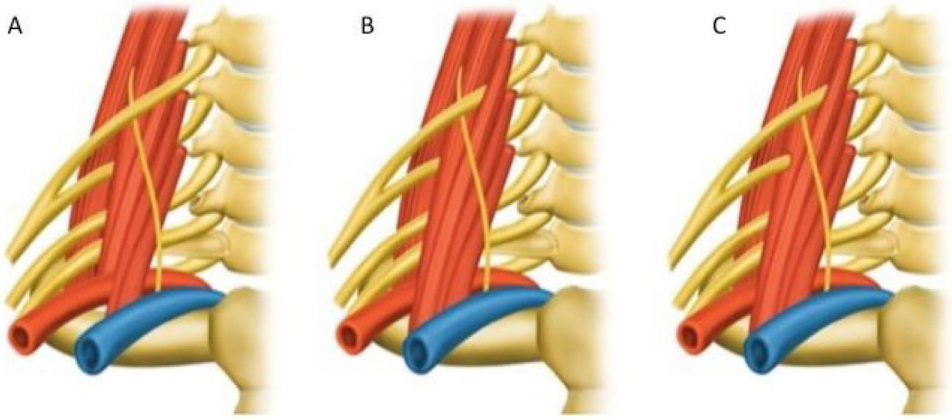

Figure 1 A, C5 root emerging anterior to the Anterior Scalene muscle and following its path between the Anterior Scalene Muscle and the Sternocleidomastoid muscle until it reachs the remainder of the plexus in the supraclavicular area. B, C5 root emerging from its foramen, inside Anterior Scalene muscle, transfixing it, and following its path between the Anterior Scalene Muscle and the Sternocleidomastoid muscle until finding the remainder of the plexus in the supraclavicular area. C, C5 and C6 roots emerging from its foramens inside Anterior Scalene muscle and transfixing it to find the remainder of the plexus in the supraclavicular area.

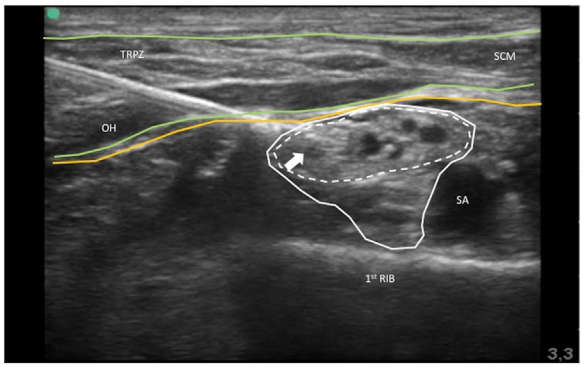

Figure 2 Final needle position, superior trunk intracluster/subparaneural: SA, Subclavian Artery; TRPZ, Trapezius muscle oh- omohyoid muscle; Green, Investing layer of deep cervical fascia; Orange, Pre-vertebral layer of deep cervical fascia; White, Brachial plexus; White dashed, Superior trunk; Solid arrow, Suprascapular nerve still inside brachial plexus sheath.

Block technique

The needle tip (Stimuplex A 50 mm, BBraun, Germany) was positioned deep into the prevertebral layer of the deep cervical fascia, preventing the needle tip from lying in the fascial plane between the investing layer of the deep cervical fascia and the prevertebral layer of deep cervical fascia. This is a loose fascial plane where the lymphatic chain and adipose brown fat are located and may allow easy dispersions towards the phrenic nerve. To ensure the correct position of the tip, an intra-cluster dispersion pattern of the local anesthetic was performed. At this site, 5 mL of 0.5% bupivacaine was injected into the patients (Figure 2).

General anesthesia

After the blockade and phrenic nerve evaluation, all patients underwent general anesthesia with 2 $\mu g.kg^{-1}$ of fentanyl, 2 $mg.kg^{-1}$ of propofol and 0.6 $mg.kg^{-1}$ of rocuronium. Anesthesia was maintained with sevoflurane. For postoperative analgesia, all patients received 2 g of dipyrone and 100 mg of ketoprofen at the end of the surgery. Postoperative analgesia was assessed in the recovery room by numerical scale and supplementary morphine for 6 hours after blockade.

Supplementary analgesia

All the patients could take 2 mg of morphine every 10 minutes as needed at the postanesthetic care room, before leaving the hospital.

Assessment

Analgesic effect

An anesthesiologist not involved in the block evaluated the nerve blocks. The modified Bromage scale[11] was used to assess motor function of the deltoid and biceps, muscles groups of the superior trunk. The sensory block was assessed using a pinprick test with a 25G hypodermic needle, a gauze, and alcohol. The thermal and painful sensitivities of the C5 and C6 dermatomes were examined. Blockade was considered positive when there was absence of thermal distinction, absence of pain to pinprick and motor function $\leq$ 2 by the modified Bromage scale. In the event of a failed block, an interscalene brachial plexus block with 5 mL of 0.5% bupivacaine at C7 level was performed.

Primary outcome was the analgesic effect, and the secondary outcome was the respiratory function.

Phrenic nerve block

The phrenic nerve block was assessed by ultrasound using the real-time movement of the ipsilateral diaphragm. Patients were asked to forcefully inhale through the nose in a sniffing fashion. The test was performed immediately before the block and at 30 minutes, 4 and 6-hours after blockade. The transducer was positioned at the midpoint of the clavicular lines and at the hemidiaphragm level on the ipsilateral side of the block. The movement of the diaphragm was evaluated with the patient in semi-seated position. Diaphragmatic excursion from baseline was measured in centimeters using the digital calipers. A decrease greater

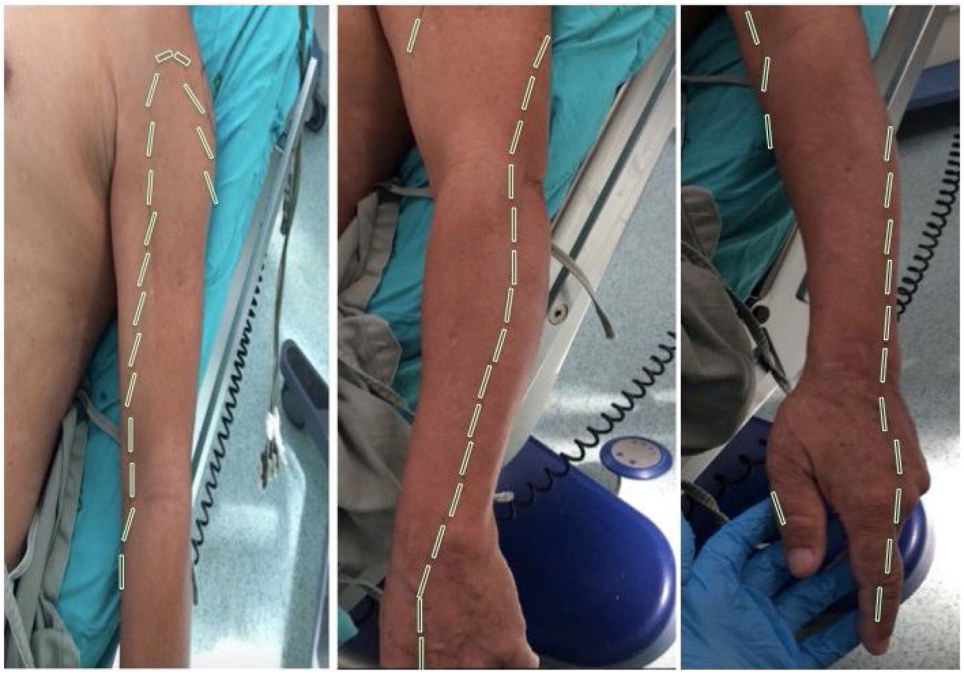

Figure 3 Area of sensory loss.

than 75% was considered hemidiaphragmatic paralysis.[12] In addition, in 3 cases, the evaluation of the respiratory function was performed using impedance tomography (Enlight 1800, Timpel Medical, Sao Paulo, SP, Brazil). This evaluation took place before the blockade, as well as 30 minutes and 4 hours after the blockade.

Cadaver dissection

Blocks were performed on six cadavers using the previously described technique, and only 5 mL of methylene blue was injected.

For the evaluation of the dispersion in cadavers, the cervical region was dissected, exposing the brachial plexus region from the interscalene cleft to the supraclavicular region.

Results

Clinical evaluation

Ten patients undergoing shoulder surgery due to rotator cuff injury received the selective superior trunk block. Participants data is in Table 1. In the evaluation of the blockade, all patients presented motor block of the biceps and deltoid muscles and experienced no pain to the pinprick in the C5 and C6 dermatomes (Figure 3).

No patient presented with phrenic nerve palsy when evaluated by diaphragm ultrasonography (Table 1). In addition, the three patients who were evaluated by impedance tomography showed no variation in the respiratory function.

All procedures occurred without complications. Regarding postoperative analgesia, no patient reported pain (score zero) until 6 hours after the blockade. They were discharged from the hospital without complications and didn't need hospital readmission.

Table 1 Demographic data and diaphragmatic excursion–median (IQR).

Age (years)	48.4 (21–68)
Gender.M / F, n (%)	7 (70) / 3 (30)
ASA,I / II, n (%)	6 (60) / 4 (40)
BMI (kg. m^{-2}) mean (±SD)	25.9 (± 4.2)
Operated side,R / L, n (%)	6 (60) / 4 (40)
Diaphragmatic excursion (cm)	
Baseline	4 (3,0 – 4,3)
30 min	3 (2,5 – 4,0)
4 h	4 (2,5 – 4,5)
6 h	4 (3,0 – 4,5)

M, Male; F, Female; R, Right; L, Left; ASA, American Society of Anesthesiologists physical status; BMI, Body Mass Index; IQR, Interquartile Range; SD, Standard Deviation.

Cadaver dissection

In all dissections, it was observed that methylene blue dispersed inside the brachial plexus but did not reach the phrenic nerve neither by cephalic dispersion nor by medial dispersion (Figure 4). In addition, in all cases, the contrast showed that the solution reached the suprascapular nerve as well.

Discussion

The findings of this study suggest that an intra-cluster injection into the superior trunk, right where suprascapular nerve

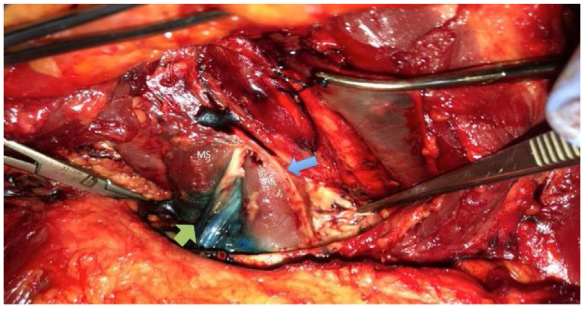

Figure 4 Brachial plexus dissection after methylene blue injection showed that methylene blue was restricted to the brachial plexus, without reaching the phrenic nerve. AS, Anterior Scalene Muscle; MS, Medium Scalene Muscle; Blue Arrow, Phrenic Nerve; Yellow arrow, Accessory nerve.

is branching off, deep to the omohyoid muscle, is an easy, reproducible technique and may be an alternative to a classic interscalene block.

This study shows that, by performing superior trunk block, it was possible to promote satisfactory analgesic effect for patients submitted to shoulder surgery, without compromising respiratory function.

Due to respiratory complications associated with interscalene blockade, new techniques have been studied to promote analgesic effect for shoulder surgeries. In 2014, Burckett-St. Laurent et al.[5] described the selective superior trunk block. This procedure targets the C5 and C6 components of the brachial plexus more distally after they unite into the superior trunk but before the suprascapular nerve branches off. However, the incidence of diaphragmatic involvement may be indirectly proportional to the distance from the nerve roots. Therefore, in this study, a more distal block was chosen, in the supraclavicular area, exactly where the suprascapular nerve is leaving the superior trunk. The results of this study suggest that this more distal approach may be as effective as the superior trunk block described by those authors, but with the potential to further decrease the chance of blocking the phrenic nerve.

Recently, Kim et al. (2019)[8] presented a study with 4.8% of phrenic paralysis with 15 mL of bupivacaine injected at the superior trunk. Renes (2009)[13] described a posterolateral supraclavicular nerve block was used as phrenic nerve sparing. This approach is less suitable for shoulder surgery because of reduced block effect to the suprascapular nerve.[8]

According to the anatomy, the superior trunk is preserved from the time that C5 and C6 join the same sheath, until the suprascapular nerve leaves the common sheath that surrounds the C5 and C6 neural structures. This takes place in the supraclavicular area where the suprascapular nerve starts its antero-posterior trajectory following the omohyoid to scapula.

Kim et al. (2019)[8] used the targeted level of insertion for the injection immediately before the branching point of the suprascapular nerve. We think that identifying the suprascapular nerve branching inside the same sheath is not the end of the superior trunk, but it is a nerve fascicle seen inside the trunk. Just after the suprascapular exits this sheath (in supraclavicular area) we can say that the superior trunk is over and blockade for the shoulder might fail. So, we propose a more distal approach to the superior trunk, outside the interscalene cleft, in the supraclavicular area where the first rib and the subclavian artery are visible.

In 2012, Siegenthaler et al.[6] described the blockage of the suprascapular nerve in the supraclavicular area, inferior to the belly of the omohyoid muscle. However, because of the proximity to the superior trunk, the fluid injected at this point was expected to reach some regions of the brachial plexus, which was recently been demonstrated in the cadaver study of Shembi et al. (2019).[9] The authors showed that 5 mL of contrast injected around the suprascapular nerve, below to the omohyoid muscle, reached the superior and middle trunk of the brachial plexus.

The study of Abdallah et al., (2020)[14] showed that suprascapular route consistently blocks the superior trunk and qualify it as an effective interscalene block alternative.

In addition, Shembi et al. (2019)[9] also demonstrated that in 20% of the cases, the dissections presented phrenic nerve involvement, suggesting a possible risk of diaphragmatic hemiparalysis with this technique. Despite the similar injection site to that of Sehmbi et al. (2019),[9] this study did not find the dispersion of contrast in the phrenic nerve in any of the dissections. We believe that the difference in results is due to the endpoint of the injection. Sehmbi et al. (2019)[9] performed the injection deep to the investing layer of deep cervical fascia, outside the prevertebral layer of deep cervical fascia (brachial plexus sheath), laterally within the inferior posterior triangle of the neck. At this point, the injection can be done in a loose fascial plane and may allow larger dispersions reaching the phrenic nerve. In our technique, it was performed as an intra-cluster injection in the superior trunk deep to the prevertebral layer of the deep cervical fascia which probably limited the dispersion of contrast to the phrenic nerve.

It is known that the brachial plexus sheath or axillary sheath is an extension of the prevertebral fascia that extends from the neck to the axilla. Therefore, it probably prevents the latero-medial spread at this level, keeping most of the injected fluid contained inside the brachial plexus sheath. Moreover, when the blockade is performed in the supraclavicular area, the injected fluid probably flows more easily distal than proximal, as the scalenes muscles make a constriction around the trunks, preventing the injected fluid from reaching the phrenic nerve through proximal (cranial) spread.[15–17]

A topic point of our study was to evaluate the same injection volume and location as the injection performed on the cadavers. It was observed that the injection of this volume using this technique was enough to promote satisfactory analgesic effect for the patients submitted to shoulder surgery, proving that the dispersion also reached the suprascapular nerve.

In addition, the non-impairment of the respiratory function of these patients was recorded, suggesting that this technique may be safe in patients with compromised respiratory function.

Therefore, new studies can evaluate if this technique could be used as an anesthetic technique for shoulder surgeries. In this case, it has to be considered that most the part of the skin around the shoulder is innervated by supraclavicular nerves (C3–C4) that come from the superficial cervical plexus and the nerve trajectory towards the

shoulder between the investing layer of the deep cervical fascia and the prevertebral layer of deep cervical fascia. The technique potentially spares those cutaneous branches. Therefore, light sedation is probably enough to tolerate this mild pain stimuli from arthroscopy portals, or better a local skin infiltration may be performed.

It was opted for 5 mL of methylene blue or local anesthetic because previous study has demonstrated that this volume is sufficient to promote analgesic effect for shoulder surgeries through the superior trunk block.[11]

In conclusion, this study demonstrates that a superior trunk block, below the omohyoid muscle may be an alternative technique to promote analgesic effect for shoulder surgery. Study limitations included lack of comparison with other techniques as well as a low number of participants.

Availability of data and material

With author and at Universidade Federal de São Paulo.

Funding Statement

Institutional.

Conflicts of interest

The authors declare no conflicts of interest.

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