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Ultrasound assessment of diaphragmatic movement post selective superior trunk block versus conventional interscalene block in shoulder arthroscopy

Sultan W. A., Metwally A. A., Soliman A. M., Mahdy W., Afify N.

Anesthesia and Intensive Care Department, Faculty of Medicine, Menoufia University, Egypt

Study objective: Our aim was to evaluate the incidence of hemidiaphragmatic paralysis after selective superior trunk block compared to conventional interscalene block.
Study design: A prospective double-blinded randomized controlled trial.
Setting: University Hospital of Faculty of Medicine.
Material and Method: Sixty-eight patients who were scheduled for shoulder arthroscopy were divided into two equal groups. The interscalene group received ultrasound-guided interscalene block and the superior trunk group received ultrasound--guided selective superior trunk block. A total volume of 15 ml of 0.25% bupivacaine was injected in both techniques. Incidence of hemidiaphragmatic paralysis was our primary outcome. Block characteristics (procedure duration, onset of sensory block, and duration of motor block), block quality (intraoperative hemodynamic parameters, intraoperative fentanyl consumption, and time to the first call of analgesia), and incidence of complications were assessed and recorded.
Results: The incidence of hemidiaphragmatic paralysis in the interscalene group was significantly greater than that in the selective superior trunk block (76.5% vs. 38.2%) with a p value of 0.001, and it was completely affected in 44.1% of the interscalene group compared to 11.8% of the selective superior trunk block group with a p value of 0.002. The procedure duration (min) was significantly greater in the selective superior trunk group than in the interscalene group (6.97±0.67) vs. (6.48±0.69), respectively, with no significant differences in the remaining block characteristics and block quality parameters as well. No significant complications were reported.
Conclusion: Although US-guided interscalene and selective superior trunk blocks addressed an equivalent quality, selective superior trunk block was associated with a significantly lower incidence of hemidiaphragmatic paralysis.

Key words: shoulder arthroscopy, interscalene block, selective superior trunk block.

Ultrazvukové hodnocení pohybu bránice po selektivní blokádě truncus superior brachiálního plexu ve srovnání s konvenční interskalenickou blokádou při artroskopii ramene

Cíl studie: Naším cílem bylo zhodnotit výskyt hemidiafragmatické parézy po selektivní blokádě truncus superior ve srovnání s konvenční interskalenickou blokádou.
Design studie: Prospektivní dvojitě zaslepená randomizovaná kontrolovaná studie.
Prostředí: Fakultní nemocnice.
Materiál a metodika: Šedesát osm pacientů, kteří měli podstoupit artroskopii ramene, jsme rozdělili do dvou stejných skupin. V jedné byla použita ultrazvukem navigovaná interskalenická blokáda a ve druhé skupině byla provedena ultrazvukem navigovaná selektivní blokáda truncus superior. Při obou technikách byl aplikován celkový objem 15 ml 0,25% bupivakainu. Primárním sledovaným parametrem byl výskyt hemidiafragmatické parézy. Zhodnotili a zaznamenali jsme charakteristiky blokády (trvání výkonu, nástup senzorické blokády a trvání motorické blokády), kvalitu blokády (peroperační hemodynamické parametry, peroperační spotřebu fentanylu a dobu do prvního žádosti o analgetikum) a výskyt komplikací.
Výsledky: Výskyt hemidiafragmatické parézy v interskalenické skupině byl signifikantně vyšší než u selektivní blokády truncus

KORESPONDENČNÍ ADRESA AUTORA:
Wesameldin A. Sultan, wesamsultan@med.menofia.edu.eg

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superior (76,5 % vs. 38,2 %) s hodnotou p 0,001, přičemž kompletní paréza byla přítomna u 44,1 % v interskalenické skupině ve srovnání s 11,8 % ve skupině se selektivní blokádou truncus superior (p 0,002). Doba trvání výkonu (min) byla významně delší ve skupině se selektivní blokádou truncus superior než ve skupině interskalenické (6,97 ± 0,67) resp. (6,48 ± 0,69), přičemž ve zbývajících charakteristikách blokády a parametrech kvality blokády nebyly zaznamenány signifikantní rozdíly. Rovněž nebyly hlášeny významné komplikace.

Závěr: Ačkoli ultrazvukem navigovaná interskalenická a selektivní blokáda truncus superior byly z hlediska kvality analgezie rovnocenné, selektivní blokáda truncus superior byla spojena s významně nižším výskytem hemidiafragmatické parézy.

Klíčová slova: artroskopie ramene, interskalenická blokáda, selektivní blokáda truncus superior.

Introduction

Shoulder arthroscopies are associated with significant post-operative pain [1]. Interscalene brachial plexus block (ISB) is considered the standard and effective analgesic modality after shoulder arthroscopy; however, it has been shown to be associated with undesirable adverse effects, such as hemidiaphragmatic paralysis (HDP), especially with high volume local anesthetics due to the involvement of the phrenic nerve. This represents a major issue among patients with pre-existing pulmonary diseases [2, 3].

Laurent et al. defined the superior trunk block (STB) which is a new modification of the interscalene block. A local anesthetic was injected selectively around the superior trunk. They have reported that this technique limits the local anesthetic extension to the phrenic nerve and, hence, decreases the incidence of hemidiaphragmatic paralysis [4].

This randomized trial investigated whether selective STB would reduce hemidiaphragmatic paresis in participants undergoing arthroscopic shoulder surgery.

The primary outcome of the trial was the incidence of diaphragmatic paralysis after ultrasound (US) guided selective STB and interscalene block (ISB) in shoulder arthroscopy. Block characteristics (procedure duration, duration of motor block and onset of sensory block), block quality (intraoperative hemodynamic parameters, intraoperative fentanyl consumption, and time to the first call of analgesia), and incidence of complications of either block were our secondary outcomes.

The hypothesis of our research was that selective STB would be associated with a lower incidence of diaphragmatic paralysis compared to that of interscalene block.

Materials and methods

This prospective double-blinded randomized controlled trial was performed at Menoufia University Hospital. The study protocol was reviewed and approved by the ethics committee (IRB approval number 2/2022 ANES 37), Menoufia University Hospital, Menoufia, Egypt on 20 February 2022. It was prospectively registered at https://pactr.samrc.ac.za (PACTR 202202483221034) prior to enrollment of the first patient on 23 February 2022. The trial was conducted in accordance with the World Medical Association Declaration of Helsinki and following the Reporting Trials (CONSORT) guideline Consolidated Standards. All eligible patients provided written informed consent, and the privacy rights of human subjects have been observed.

The trial included sixty-eight patients of both sexes, aged 18 to 80 years old, who were scheduled for arthroscopic shoulder surgery and had an ASA I or II physical status according to the American Society of Anesthesiologists (ASA). Patients who had pre-existing neuropathy in the operated limb, ASA ≥ III, coagulation disorders, local infection at the puncture site, known allergy to local anesthetics, respiratory failure or chronic obstructive pulmonary disease, breastfeeding, pregnancy, a BMI ≥ 35 kg/m^2, failure to cooperate, and patient refusal were excluded.

Eligible patients who satisfied all inclusion criteria and did not satisfy any exclusion criteria were randomized 1:1 using a computerized software program (GraphPad software QuickCalcs, Inc., California, USA) (website: http://www.graphpad.com/quickcalcs). The allocation was concealed from the clinical staff, trial investigators, trial statisticians, and participants. The patients were randomly assigned to receive either US-guided ISB or selective STB. An anesthesiologist who was not involved in the data collection of the trial conducted the entire drug preparation and block administration.

All patients were administered bromazepam (1.5 mg) the night prior to surgery and two hours prior to the call to the operating room. Upon entering the operating room, standard monitoring was implemented, an 18-gauge cannula was inserted in a peripheral vein and lactated ringer infusion was initiated. Before performing the block, an assessment of diaphragmatic movement at baseline was done using a curvilinear probe. Both hemidiaphragms were visualized using B-mode while the excursion was measured using M-mode.

To achieve a Ramsey Sedation Scale score of 2 to 3, all patients were administered intravenous midazolam 2 to 5 mg and fentanyl up to 100 µg, which were titrated.

Interscalene block

The same anesthesiologist administered both blocks in accordance and complete compliance with the antiseptic regulations. A linear US transducer of high frequency (13-6 MHz) (Sonosite, M-Turbo, Washington) was employed to conduct both blocks. The patient was positioned in a semi-recumbent position. The probe was positioned transversely over the interscalene groove at the level of the C6 transverse process to identify the interscalene muscles and the C5 and C6 ventral cervical nerve roots, which are referred to as the spotlight sign. The interscalene groove was reached by introducing a 22-gauge echogenic needle from the lateral to the medial side using the in-plain technique. Subsequently, 15 ml of 0.25% bupivacaine were deposited between the C5 and C6 nerve roots.

Tab. 1. *Socio-demographic and surgical data of the studied groups*

Studied variables	ISB group (N = 34)	STB group (N = 34)	Test of sig	P value
Age / years			U	
Mean ± SD	41.1 ± 14.2	41.2 ± 13.9	0.147	0.883
Median (IQR)	43.0 (27.7–56.2)	39.5 (28.0–57.2)		
Sex N (%)			χ^2	
Male	21 (61.8)	22 (64.7)	0.063	0.801
Female	13 (38.2)	12 (35.3)		
BMI			t-test	
Mean ± SD	25.8 ± 0.95	25.7 ± 0.96	0.621	0.537
Median (IQR)	25.9 (25.0–26.6)	25.7 (24.8–26.4)		
ASA N (%)			χ^2	
I	16 (47.1)	17 (50.0)	0.059	0.808
II	18 (52.9)	17 (50.0)		
Duration of surgery				
Mean ± SD	72.9 ± 10.1	73.9±11.3	U	
Median (IQR)	75.0 (65.0–80.0)	72.5 (65.0–85.0)	0.298	0.766

ISB – interscalene group; STB – selective superior trunk group; U – Mann-Whitney test χ2;chi square test; IQR – Interquartile range

Tab. 2. *Diaphragmatic movement involvement between the study groups*

Studied variables	ISB group (N = 34)		STB group (N = 34)		χ^2	P value
	No.	%	No.	%		
Diaphragmatic paralysis						
Present	26	76.5	13	38.2	10.1	0.001*
Absent	8	23.5	21	61.8		
Diaphragmatic movement affection						
Absent (0–25 %)	8	23.5	21	61.8	12.3	0.002*
Partial (> 25 %–75 %)	11	32.4	9	26.4		
Complete (> 75 %)	15	44.1	4	11.8		

*ISB – interscalene group; STB – selective superior trunk group; χ2 – chi square test; *significant*

Tab. 3. *Block characteristics and quality between the study groups*

Studied variables	ISB group (N = 34)	STB group (N = 34)	Test of sig.	P value
Performance duration (min)				
Mean ± SD	6.48 ± 0.69	6.97 ± 0.67	U	0.008*
Median (IQR)	6.50 (6.00–7.00)	7.00 (6.50–7.50)	2.46	
Onset (min)				
Mean ± SD	24.7 ± 3.54	23.7 ± 3.31	U	0.244
Median (IQR)	25.0 (21.5–27.0)	23.0 (20.0–27.0)	1.16	
Motor block duration (hr)				
Mean ± SD	12.5 ± 1.92	11.9 ± 1.62	U	
Median (IQR)	12.5 (11.0–14.0)	12.0 (10.0–13.2)	1.48	0.138
Intraoperative Fentanyl dose (µg/kg)				
Mean ± SD	0.41 ± 0.74	0.58 ± 0.82	U	
Median (IQR)	0.00(0.00–1.00)	0.00(0.00–1.00)	0.995	0.320
First call of analgesia (hr)				
Mean ± SD	9.47 ± 2.13	8.97 ± 1.29	U	
Median (IQR)	9.50 (8.00–11.2)	9.00 (8.00–10.0)	0.661	0.509

*ISB – interscalene group; STBf – selective superior trunk group; U – Mann-Whitney test; IQR – Interquartile range; *significant*

Selective superior trunk block

Using the same technique to identify the spotlight sign of the cervical roots and the scalenus muscles, the probe was moved distally to observe the convergence of the C5 and C6 which form the superior trunk. A 22-gauge echogenic needle was advanced from the lateral to the medial region using the in-plain technique until it reached the lateral border of the superior trunk. Half of the anesthetic solution was administered anteriorly, above the trunk, and the other half was administered posteriorly, below the trunk (a total volume of 15 ml of 0.25% bupivacaine) just prior to the branching of the suprascapular nerve.

The procedure time (the time from transducer positioning to the end of local anesthetic injection) and the onset of sensory block were recorded.

Every 5 minutes for the first 30 minutes after completing the block, the sensory block intensity was assessed using an 11-point scale (10 representing normal sensation, 0 representing no sensation to cold). A score of 0 was considered to indicate a complete sensory block. Additionally, the motor

block was assessed utilizing shoulder external rotation (suprascapular nerve) and shoulder abduction (axillary nerve) on a three-point scale. A total score of 2 indicates no block, a score of 1 indicates paresis, which is a reduction in force compared to the contralateral arm, and a score of 0 indicates paralysis, which is inability to overcome gravity. A score of 0 indicated a complete motor block. The block was considered successful if the sensory score was ≤ 3 and the motor score was ≤ 1. Patients with failed block were excluded. The motor block duration (the time from motor block onset to regaining full motor power with a motor score of 2) was recorded.

The grade of hemidiaphragmatic movement involvement was assessed after 30 mins of the block and before induction of general anesthesia by a low-frequency (5–2 MHz) curvilinear transducer (Sonosite, M-Turbo, Washington). The probe was placed in the ipsilateral position of the operated shoulder, subcostally between the mid-clavicular and mid-axillary lines on the right side, and between the anterior and posterior axillary lines on the left side, and directed medially, cephalad, and dorsally to obtain the best imaging using B-mode. M-mode was used to display the excursion of the diaphragm along the selected line.

Diaphragmatic excursion was calculated as follows:

- Complete (HDP) = was defined as a reduction in diaphragmatic excursion that exceeded 75% of the baseline or exhibited paradoxical movement.
- Partial = 25 to 75% decrease from the baseline.
- Normal (no paralysis) = changes between 0 and 25% from the baseline.

Complications (e.g., pneumothorax, hematoma formation, epidural anesthesia, hoarseness, Horner's syndrome, neurological complications, and hand grip weakness) were assessed.

Propofol (2 mg/kg), fentanyl (2 µg/kg), and atracurium (0.5 mg/kg) were administered to induce anesthesia. Following oral tracheal intubation, anesthesia was maintained using isoflurane (1–2%) on an O2/air mixture (FiO2 = 0.5) and atracurium (0.25 mg/kg). Targeting an ETCO2 of 35–40 mmHg, the lung was mechanically ventilated. To maintain a bispectral index of 40–50, an isoflurane MAC was modified. When the patient's hemodynamic parameters exceeded the baseline by 20%, 1 µg/kg fentanyl was administered. Glycopyrrolate 0.01 mg intravenously with 0.05 mg/kg neostigmine were administered to alleviate residual neuromuscular blockade following surgery. The postoperative ward was the destination for all patients after they were extubated. Acetaminophen (1 gram) was administered every 8 hours on the first postoperative day.

Block quality parameters (intraoperative hemodynamic parameters, intraoperative fentanyl consumption, and time to the first call of analgesia) were recorded.

Sample size

Sample size calculation was done by an independent statistician with a statistical test power of 80%, confidence interval of 95% based on a review of past literature by Mi Geum Lee, et al. [5]. A sample size of 68 patients, divided into two groups: interscalene group and selective superior trunk group with (34) patients in each was sufficient to detect the clinically important difference between both groups.

Fig. 1. *CONSORT Flow Diagram*

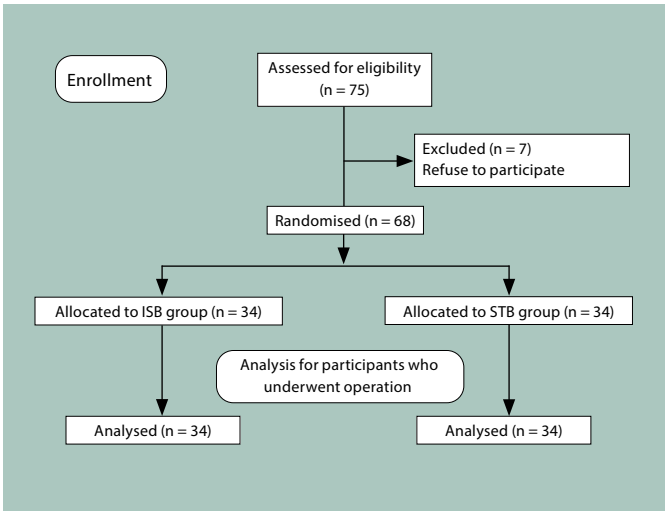


Fig. 2. *Mean pulse rate of studied groups*

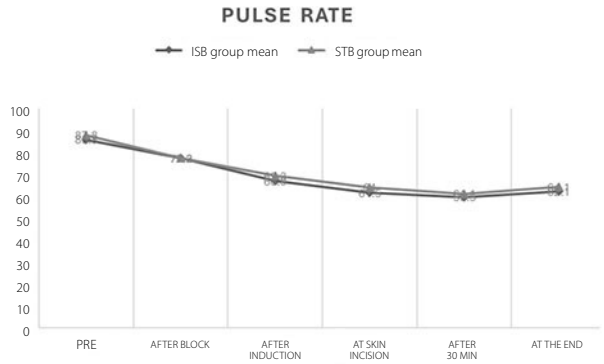
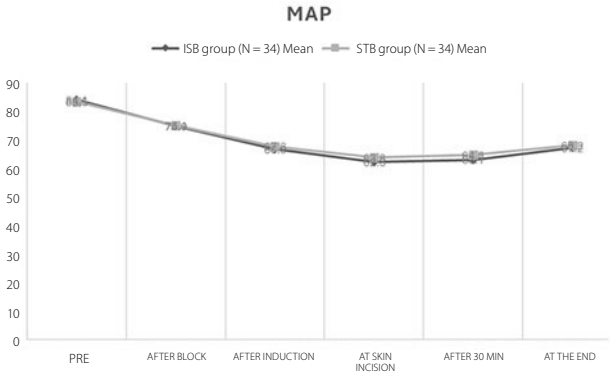


Fig. 3. *Mean blood pressure of studied groups*



Statistical analysis

Data were collected, tabulated, and statistically analyzed using an IBM personal computer with Statistical Package of Social Science (SPSS) version 20 (SPSS, Inc, Chicago, Illinois, USA). Quantitative data were presented in the form of mean, standard deviation (SD), range, and qualitative data were presented in the form of numbers and percentages.

Chi-square test ($\chi 2$) was used to study the relationship between two qualitative variables. Fisher exact (FE) was used to study the relationship between two qualitative variables when the expected cell count of 25% of cells was less than five. Student t-test was used for comparison

between two groups normally distributed having quantitative variables. Mann-Whitney test (U) was used for comparison between two groups not normally distributed having quantitative variables. A P value of < 0.05 was considered statistically significant.

Results

A Consolidated Standards of Reporting Trials (CONSORT) flow chart for patient enrollment, allocation, and analysis was presented in (Fig. 1). The trial involved seventy-five patients. Seven patients refused to participate, and sixty-eight patients successfully completed the trial after having provided a written informed consent. They were separated equally into two groups: (ISB) group and (STB) group. The demographic characteristics showed similarity between the groups. (Tab. 1).

There was a significant difference between the two groups regarding the occurrence of hemidiaphragmatic paralysis, which was greater in the ISB group than in the STB group (76.5% vs. 38.2%) (P value 0.001). Moreover, the degree of movement was completely affected in 44.1% of the ISB group compared to 11.8% of the STB group (P value 0.002) (Tab. 2). The procedure duration (min) was significantly higher in the STB group than in the ISB group (6.97±0.67) vs. (6.48±0.69), respectively (P value = 0.008). There was no significant difference between the study groups regarding block onset or motor block duration (P value > 0.05) (Tab. 3). There was no significant difference between the study groups regarding the mean blood pressure and mean heart rate (Fig. 2, 3), time to the first call of analgesia, and intraoperative fentanyl consumption (P value > 0.05) (Tab. 3). No significant complications were observed. Two patients in the ISB group developed hand grip weakness which resolved completely 12 hours after the block.

Discussion

Our investigation revealed that the administration of local anesthetics to the superior trunk selectively results in a reduced incidence of diaphragmatic paralysis when compared with conventional interscalene blocks. However, both blocks provide equivalent analgesic efficacy without obvious side effects.

The traditional interscalene approach of brachial plexus block represents a good choice for postoperative pain control in shoulder arthroscopy. However, its association with a high incidence of diaphragmatic paralysis makes it of limited value for patients with pre-existing respiratory disease [6].

The known mechanism of phrenic nerve palsy after ISB is due to direct local anesthetic spread. However, there are other theories explaining the incidence of phrenic nerve palsy as nerve compression by local anesthetic volume, paracervical hematoma, local ischemic changes, and/or direct nerve injury [7–10].

Great efforts have been made to decrease the incidence of HDP, such as low-volume ISBs, but the occurrence of hemidiaphragmatic involvement is still high, ranging from 34% to 62.5% [11]. Therefore, phrenic-sparing techniques should be available to provide adequate analgesia and reduce the incidence of hemidiaphragmatic paralysis [12].

Burckett-St. Laurent et al. (2014) introduced selective STB as an alternative to ISB in shoulder surgery. They targeted the superior trunk inferolaterally. Injection was administered more distally after the union of the C6 and C5 nerve roots and before the suprascapular nerve branches off. Therefore, avoiding phrenic nerve block which consequently reduces the risk of respiratory depression, particularly in patients with underlying respiratory diseases, can improve the safety profile of these patients [4, 13].

In this trial, we found that STB was associated with a lower incidence of HDP than interscalene nerve block. This can be explained by the occurrence of diaphragmatic paralysis which is indirectly proportional to the distance from the nerve roots. Additionally, the analgesic efficacy of both blocks was comparable as evidenced by the intraoperative analgesic consumption and the first analgesia call. However, the duration of the STB was slightly longer but statistically comparable to that of the interscalene block, and there was no difference between the two blocks regarding the duration of the motor block or the onset of the sensory block. Patients in both blocks were hemodynamically stable, and no other complications were detected in either group.

Kim et al. carried out their trial with 126 patients, and compared STB with ISB as a sole anesthetic agent with sedo-analgesia. They used 15 ml of 0.5% bupivacaine. The superior trunk group exhibited a significantly lower incidence of HDP than did the interscalene group (4.8% vs. 71.4) as evidenced by a non-inferior worst pain score during the recovery period. This finding is consistent with our own findings [11].

In our study, the incidence of HDP in the STB and ISB groups was 38.2% and 76.5%, respectively. There was a greater incidence of HDP in the STB group than in the STB group in the Kim trial (38.2% vs. 4.8%). This can be explained by the use of different block techniques. In this study, we deposited local anesthetics immediately after the C5 and C6 roots united together. However, Kim and his colleagues performed the block more distally in the supraclavicular fossa.

In agreement with our results, Kang et al. reported similar findings. The incidence of HDP in the STB and ISB groups was 76.3% and 97.5%, respectively, with similar pain scores and analgesic requirements in both groups. The same block technique was used in our study [14].

We noticed that the STB was associated with less diaphragmatic movement involvement. This is because the distance between the C5 and the phrenic nerve root is 1.8 to 2.0 mm in adults at the cricoid cartilage level, and it increases by 3 mm for each distance of 1 cm [4, 15].

This decreases the incidence of local anesthetic spread to the phrenic nerve with superior trunk block [6].

The incidence of hemidiaphragmatic paresis is reduced when the volume of local anesthetics is reduced. However, a low volume may be associated with a high incidence of block failure and poor perioperative analgesic quality among less experienced anesthetists. Therefore, we used 15 ml of 0.25% bupivacaine for both blocks, which is in accordance with the reported practices of other centers [16–19].

The duration of the STB was longer than that of the ISB in our trial. However, the STB is clearly visible and easily defined because it is surround-

Tab. 4. *Complications between the study groups*

Studied variables	ISB group (N = 34)		STB group (N = 34)		FE	P value
	No.	%	No.	%		
Epidural anesthesia						
Yes	0	0	0	0	0.00	0.001*
No	34	100	34	100		
Horner syndrome						
Yes	0	0	0	0	0.00	0.002*
No	34	100	34	100		
Hematoma						
Yes	0	0	0	0	0.00	1.00
No	34	100	34	100		
Pneumothorax						
Yes	0	0	0	0	0.00	1.00
No	34	100	34	100		
Hoarseness						
Yes	0	0	0	0	0.00	1.00
No	34	100	34	100		
Neural injury						
Yes	0	0	0	0	0.00	1.00
No	34	100	34	100		
Hand grip weakness at 24 hr						
Yes	2	5.90	0	0	0.348	0.554
No	32	94.1	34	100		

ISB – interscalene group; STB – selective superior trunk group; FE – Fisher exact test

ed by a well-defined connective sheath without any anatomical variation, unlike the hypoechoic C5 and C6 roots which are enveloped by a thin facial layer and have anatomical variation in their course [4, 20, 21].

The opioid-sparing effect of the interscalene block was maintained in the superior trunk group due to the absence of any difference in opioid consumption or pain scores during the observation period. The STB is a more proximal block approach to the brachial plexus, which is likely the reason for this finding. It offers extensive coverage [22].

The main strengths of this trial were the limited number of papers in this field and our primary outcome, diaphragmatic movement involvement, which reflects the true impact of both blocks. Fortunately, the study was conducted on ASA I and II patients, none of whom exhibited respiratory compromise, either clinically through symptoms like shortness of breath or in terms of respirometric parameters. However, our trial is limited by the block performance done by a single experienced anesthesiologist in a single center, which can decrease the performance bias and increase the validity of the trial but limits the generalizability of the findings. Finally, we assessed perioperative analgesia only and not surgical anesthesia which is more important in patients with pre-existing pulmonary diseases.

Conclusion

We found that, compared with conventional ISB, selective STB was associated with a lower incidence of HDP and provided equipotent effective postoperative analgesia. Further studies are required to assess STB performance difficulty and determine the appropriate local anesthetic dose that decreases diaphragmatic paralysis and provides better analgesia.

PROHLÁŠENÍ AUTORŮ: **Declaration of authenticity:** The paper is original, has not been published elsewhere, and has not been submitted to peer-review in another medium. **Conflict of interest:** The authors declare that they have no conflict of interest. **Author contribution:** WAS designed the study and performed the practical part of the study. AS shared the practical part and collected and analysed the data with WR. NA completed the primary writing. AAM revised the manuscript for proofreading. All the authors have read and approved the final manuscript submitted to the Anaesthesiology and Intensive Care Medicine journal. **Funding:** None. **Acknowledgement:** N/A. **Registration:** It was prospectively registered at www.pactr.org (PACTR 202202483221034). **Ethics committee consideration:** (IRB approval number 2/2022 ANES 37), Menoufia University Hospital, Menoufia, Egypt on 20 February 2022.

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