https://doi.org/10.24884/2078-5658-2026-23-2-25-33

Сравнение ипсилатерального гемидиафрагмального пареза после надключичной и реберно-ключичной блокады (рандомизированное слепое исследование)

ARUNA PARAMESWARI, DEEPSHIKHA RAMESH, SAIF ALI*

Sri Ramachandra Institute of Higher Education and Research, Chennai, Tamil Nadu, India

Поступила в редакцию 04.11.2024 г.; дата рецензирования 05.01.2025 г.

РЕЗЮМЕ

Введение. Гемидиафрагмальный парез (ГДП) после блокады плечевого сплетения возникает в результате непреднамеренного поражения диафрагмальных нервных корешков C_3–C_5. В то время как блокада плечевого сплетения, выполненная надключичным доступом (SC), обычно ассоциируется с ГДП, частота возникновения этого осложнения при блокаде плечевого сплетения, выполненной реберно-ключичным доступом (CC) остается неясной.

Цель – сравнить частоту возникновения ипсилатеральной ГДП при блокадах плечевого сустава, выполненных SC- и CC-доступом, с использованием ультразвуковой оценки экскурсии диафрагмы и пиковой скорости выдоха (PEFR).

Материалы и методы. В проспективное, слепое, рандомизированное исследование включено 48 пациентов, перенесших плановую операцию в зоне ниже локтевого сустава. Пациенты были разделены на две группы: проведение блокады плечевого сустава SC-доступом (n = 24) или CC-доступом (n = 22). Всем пациентам вводили по 30 мл смеси 0,5% бупивакаина и 2% лидокаина с адреналином в соотношении 1:1. Экскурсию диафрагмы измеряли с помощью ультразвукового исследования в М-режиме во время обычного вдоха, глубокого вдоха и нюхательного движения, а PEFR регистрировали до начала блокады и через 30 мин после операции. ГДП определяли как уменьшение экскурсии диафрагмы: > 50% – полное, 25–50% – частичное и < 25% – без паралича. Вторичные показатели включали время наступления блокады, общее время, связанное с анестезией, и частоту нежелательных явлений.

Результаты. Частота возникновения ГДП была значительно выше в группе SC по сравнению с группой CC при выполнении всех дыхательных маневров. Постблокадная экскурсия диафрагмы и PEFR в большей степени снижались в группе SC (p < 0,05). Начало блокады и время до завершения сенсорной и моторной блокады были более длительными в группе CC, при этом ни у одного пациента не наблюдалось клинического нарушения дыхания или побочных эффектов.

Вывод. Блокада плечевого сплетения CC-доступом под ультразвуковым контролем связана с меньшей частотой ипсилатеральной ГДП и лучшим сохранением функции легких по сравнению с SC-доступом, несмотря на несколько более медленное начало блокады.

Ключевые слова: блокада плечевого сплетения, реберно-ключичная блокада, надключичная блокада, гемидиафрагмальный парез, диафрагмальный нерв, ультразвуковое исследование

Для цитирования: Aruna Parameswari, Deepshikha Ramesh, Saif Ali Сравнение ипсилатерального гемидиафрагмального пареза после надключичной и реберно-ключичной блокады (рандомизированное слепое исследование) // Вестник анестезиологии и реаниматологии. – 2026. – Т. 23, № 2. – С. 25–33. https://doi.org/10.24884/2078-5658-2026-23-2-25-33.

Comparing ipsilateral hemidiaphragmatic paresis after supraclavicular & costoclavicular block (randomised observer-blinded study)

ARUNA PARAMESWARI, DEEPSHIKHA RAMESH, SAIF ALI*

Sri Ramachandra Institute of Higher Education and Research, Chennai, Tamil Nadu, India

Received 04.11.2024; review date 05.01.2025

ABSTRACT

Introduction. Hemidiaphragmatic paresis (HDP) after brachial plexus block results from inadvertent involvement of the C3–C5 phrenic nerve roots. While brachial plexus block performed by supraclavicular approach (SC) is commonly associated with HDP, the incidence of this complication in brachial plexus block performed by costoclavicular approach (CC) remains unclear.

The objective was to compare the incidence of ipsilateral HDP between supraclavicular (SC) and costoclavicular (CC) blocks using ultrasound-assessed diaphragmatic excursion and peak expiratory flow rate (PEFR).

Materials and methods. In this prospective, observer-blinded, randomized study, 48 patients undergoing elective below-elbow surgery were allocated to receive either SC-BPB (n = 24) or CC-BPB (n = 22). Patients received 30 ml of a 1:1 mixture of 0.5% bupivacaine and 2% lignocaine with adrenaline. Diaphragmatic excursion was measured via M-mode ultrasonography during normal inspiration, deep inspiration, and sniff manoeuvre, and PEFR was recorded pre-block and 30 minutes postoperatively. HDP was defined as a reduction in diaphragmatic excursion: > 50% as complete, 25–50% as partial, and < 25% as no palsy. Secondary outcomes included block onset time, total anesthesia-related time, and incidence of adverse events.

Results. HDP incidence was significantly higher in Group SC compared with Group CC across all respiratory manoeuvres. Post-block diaphragmatic excursion and PEFR declined more in Group SC (p < 0.05). Block onset and time to complete sensory and motor block were longer in Group CC, while no patient experienced clinical respiratory compromise or adverse events.

Conclusion. Ultrasound-guided costoclavicular brachial plexus block is associated with a lower incidence of ipsilateral HDP and better preservation of pulmonary function compared with the supraclavicular approach, despite a slightly slower onset of block.

Keywords: brachial plexus block, costoclavicular block, supraclavicular block, hemidiaphragmatic paresis, phrenic nerve, ultrasound guidance

For citation: Aruna Parameswari, Deepshikha Ramesh, Saif Ali. Comparing ipsilateral hemidiaphragmatic paresis after supraclavicular & costoclavicular block (randomised observer-blinded study). *Messenger of Anesthesiology and Resuscitation*, 2026, Vol. 23, № 2, P. 25–33. (In Russ.). https://doi.org/10.24884/2078-5658-2026-23-2-25-33.

* Для корреспонденции:
Deepshikha Ramesh
E-mail: deepshiganga@gmail.com

* Correspondence:
Deepshikha Ramesh
E-mail: deepshiganga@gmail.com

Introduction

Brachial plexus block is a well-established anesthetic technique for upper-limb surgeries[8, 19]. Although the supraclavicular approach to brachial plexus block is favoured due to the rapid onset of predictable analgesia, it is associated with significant hemidiaphragmatic paresis which assumes significance in patients with pre-existing respiratory disease[12]. This is due to the unintended spread of local anaesthetic to the C3–C5 roots of phrenic nerve, causing phrenic nerve palsy. The relatively novel technique of ultrasound-guided costoclavicular brachial plexus block (CC-BPB) [8] developed by Li J.W. et al. is an alternative to the traditional lateral infraclavicular fossa block strategy [7, 15, 27, 30]. The CC-BPB targets the three cords lateral to the axillary artery in the costoclavicular space.

PNP occurrence depends on site of injection, the technique used, volume of local anaesthetic injected [22, 23, 25]. The incidence of HDP is reported up to 28 to 67% for supraclavicular approach from the available published studies [12, 26]. Costoclavicular approach blocks the cords of brachial plexus in the costoclavicular space [15]. The phrenic nerve and brachial plexus are separated by 2 mm of each other at the level of cricoid cartilage, with an additional 3 mm separation for every cm more caudal in the neck [10]. The lesser the distance between the block site and the phrenic nerve, higher will be the occurrence of hemidiaphragmatic paresis. Although a few published studies have shown that there is a 3% incidence of HDP after costoclavicular approach [2, 4–6, 14, 20, 24, 30, 32], the actual incidence is unclear. We have done this study to compare the incidence of ipsilateral hemidiaphragmatic paresis after supraclavicular and costoclavicular approach. The primary outcome was to assess the incidence of ipsilateral HDP and hence phrenic nerve palsy between supraclavicular and costoclavicular block by comparing parameters – the diaphragmatic excursion in cm and peak expiratory flow rate (PEFR) in Litres/min before and after block. The diaphragmatic excursion was measured in cm using ultrasound 30 minutes before the block and reassessed 30 minutes after surgery in the post-anesthesia care unit. A reduction in the excursion of > 50% as compared to the pre-block values was considered as complete palsy, 25–50% as partial palsy and < 25% as no palsy. The secondary outcome was to compare time to onset of block,total anaesthesia related time,incidence of adverse events and vascular injury.

Materials and methods

Sample size was calculated assuming the proportion of hemidiaphragmatic paresis in the supraclavicular block group as 45% and in the costoclavicular block group as 5%, as per the previous study by T. Sivashanmugam et al. [29]. We assumed 90% power of the study and 5% alpha error for sample size calculation. The required sample size was calculated using the following formula as proposed by B. R. Kirkwood et al. [13]. The required number of subjects as per the above mentioned calculation was 22 in each group. To account for non-participation, another 2 subjects were added to the sample size. Hence the final required sample size was 24 subjects in each group.

All procedures were performed in compliance with relevant laws and institutional guidelines and was approved by the Institutional Ethics Committee at Sri Ramachandra Institute of Higher Education and Research with reference number CSP/MED/24/MAR/100/69 on 10th of April, 2024 and was registered with the Clinical Trial Registry of India (CTRI) with number CTRI/2024/05/066749. The date of registration in CTRI was on 3/5/2024 and the date of the first patient enrolment was on 19/5/2024. The privacy rights of participants have been observed and informed consent was obtained.

After obtaining written informed consent, patients of age 18 to 80 years, American society of Anaesthesiologist (ASA) physical status I–III, undergoing elective below-elbow surgeries with BMI ranging between 18–35 kg/m^2 were included in this study. The exclusion criteria included patient refusal, inability to give consent to the study, presence of coagulopathy, sepsis, hepatic or renal failure, allergy to local anesthetics, pre-existing musculocutaneous/ median/ radial/ ulnar neuropathy, infection at the site of injection, presence of rib fractures, BMI > 35 kg/m^2, patients with impaired pulmonary function (obstructive or restrictive) and inability to perform the bedside spirometry. The patients were randomised into two groups Group CC and Group SC using a computer-generated randomisation sequence with 1:1allocation ratio. The study was observer-blinded.

The primary outcome was to assess the incidence of ipsilateral HDP and hence phrenic nerve palsy between supraclavicular and costoclavicular block by comparing parameters – the diaphragmatic excursion in cm and PEFR in Litres/min before and after block. The diaphragmatic excursion was measured in cm using M-mode ultrasound 30 minutes before the block and reassessed 30 minutes after surgery in the post-anesthesia care unit. A reduction in the excursion of > 50% as compared to the pre-block values was considered as complete palsy, 25–50% as partial palsy and < 25% as no palsy. The secondary outcome was to compare time to onset of block, total anaesthesia related time,incidence of adverse events and vascular injury.

During the pre-operative visit, after obtaining the informed consent, patients were instructed on how to blow into a hand-held peak-expiratory flow meter (MCP Healthcare Peak Flow Meter Spirometer Exerciser

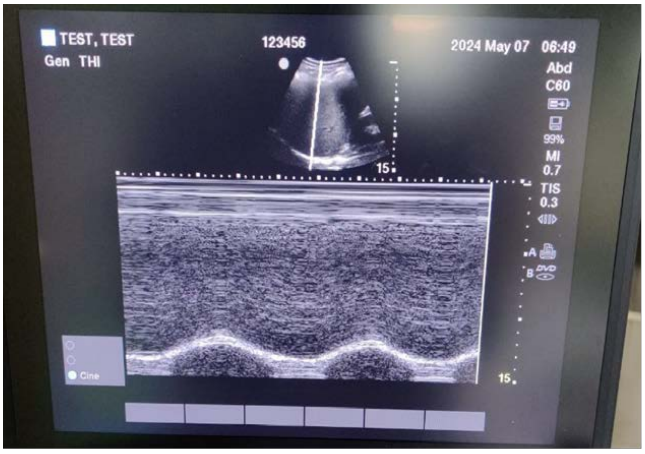

Fig. 1. Normal Inspiration

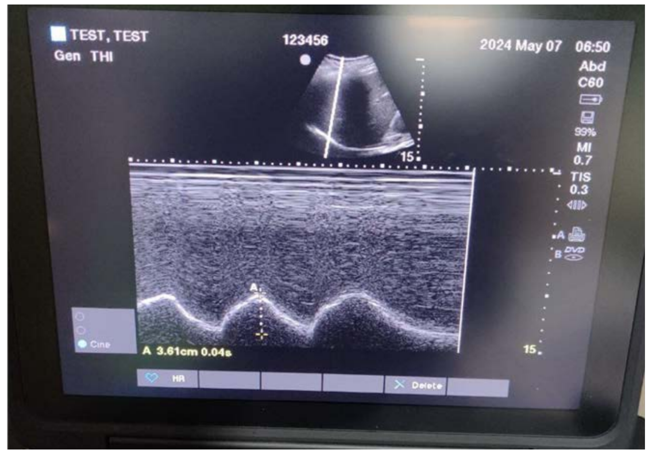

Fig. 2. Deep Inspiration

Fig. 3. During Sniff

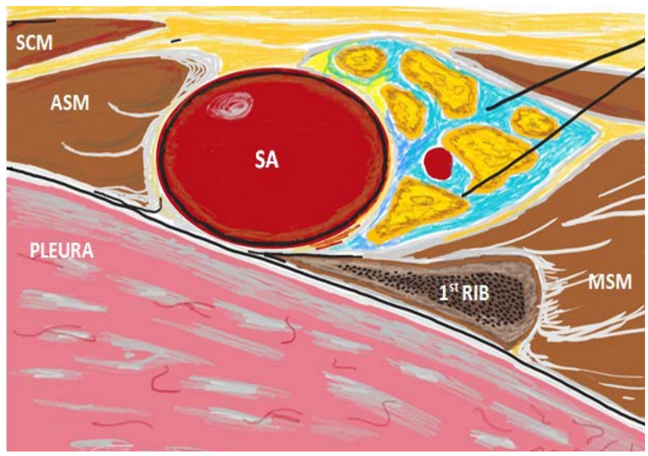

Fig. 4. Supraclavicular Block: SCM – Sternocleidomastoid, ASM – Anterior Scalenus Muscle, MSM – Middle Scalenus Muscle, SA – Subclavian artery

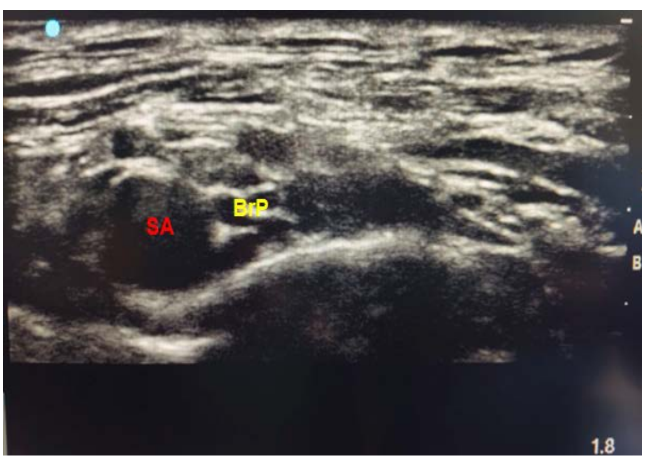

Fig. 5. Sonoanatomy of Supraclavicular block: SA – Subclavian Artery, BrP – Brachial Plexus

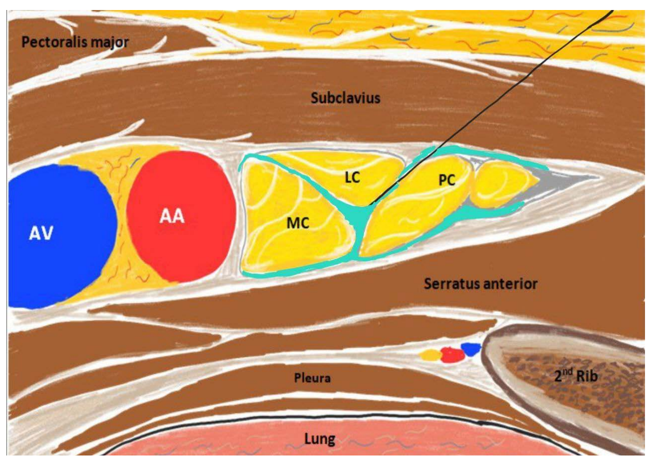

Fig. 6. Costoclavicular Block: AA – Axillary artery, AV – Axillary Vein, LC – Lateral Cord, MC – Medial Cord, PC – Posterior Cord

Breath Monitor for Adult & Child, Medicare Products Inc. New Delhi, India) for the measurement of PEFR. They were also instructed on how to do a sniff maneuvre by quick inspiration through the nose with their mouth closed. All the patients were kept fasted and received pre-medication as per institutional protocol.

Patient was transferred to pre-operative holding area approximately an hour prior to the elective surgery. Baseline vitals – heart rate, oxygen saturation, blood pressure were monitored. We took three sets of PEFR measurement with the patient in sitting position and the average of these three measurements was recorded as the baseline value. A Sonosite Edge II Ultrasound System (FUJIFILM Sonosite, Inc. Bothell, Washington, USA) with a low frequency (1–5 MHz) curved array transducer was used for M-mode ultrasound

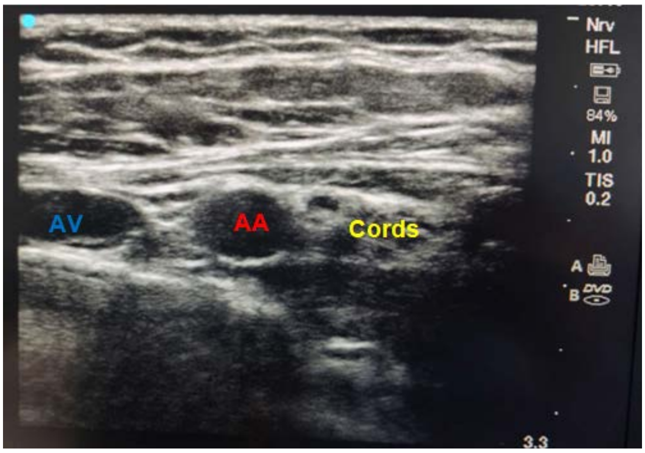

Fig. 7. Sonoanatomy of Costoclavicular Block: AA – Axillary Artery, AV – Axillary Vein

assessment of diaphragmatic excursion. Patient was made supine and hemidiaphragm was seen via anterior subcostal route (with liver as the acoustic window) as a hyperechoic line. During normal inspiration, the diaphragm moved towards the transducer and during expiration, the diaphragm moved away from the transducer in a M-mode trace producing an upward and downward deflection respectively. During deep inspiration, the distance from the baseline to the point of maximal inspiration was measured in centimetres on the ultrasound machine interface. Similar measurements were made during a sniff manoeuvre. Each of these measurements was performed thrice and the average value was recorded. Sonographic assessment of diaphragm excursion was repeated 30 minutes after surgery in the post-anesthesia care unit. Figure 1 shows sonographic assessment of diaphragm during normal inspiration, Figure 2 during deep inspiration and Figure 3 during a sniff manoeuvre.

Inside the operating room, standard monitoring (ECG, SpO_2, non-invasive blood pressure monitor) were connected and baseline values were recorded prior to the performance of block. Intravenous access was established in the arm contralateral to the side of surgery. The brachial plexus block was performed with the patient in supine position and head turned slightly to the contralateral side. The patients according to the group allocation, received 30 ml of an equal mixture of 0.5% bupivacaine and 2% lignocaine with adrenaline under the dual guidance of ultrasound and peripheral nerve stimulation to guide the needle tip to the target site. The time taken for administering the block, time to onset of block and time for complete sensory and motor blockade was assessed.

For the Supraclavicular approach, the ipsilateral arm was adducted, and Sonosite Edge II Ultrasound System (FUJIFILM Sonosite, Inc. Bothell, Washington, USA) with high frequency linear transducer (6–15 MHz) was placed parallel to and just above the middle one-third of clavicle at the supraclavicular fossa. The scan was commenced to visualise the subclavian artery lying on top of the first rib with brachial plexus trunks and division appearing as 'cluster' of hypoechoeic nerves on posterior and lateral aspect of subclavian artery. A B Braun 50 mm Stimuplex A insulated stimulating needle (22G × 2") (Hakko Co. Ltd., Isobe, Chikuma-Shi, Nagano, Japan) was used. With the needle tip at target location, peripheral nerve stimulation was done (0.5–0.8 mA, 0.1 msec) and response was elicited. The needle was repositioned if a response was elicited at less than 0.5 mA. A small volume of local anaesthetic was given under ultrasound guidance to confirm the location. Local anaesthetic of 10 ml was injected at the corner pocket and 20 ml was injected at the center of the cords. This was achieved by redirecting the block needle and thereby uniform distribution of local anaesthetic was ensured. Figure 4 and Figure 5 show the schematic anatomy and sonoanatomy of supraclavicular block respectively.

For the costoclavicular approach, the ipsilateral arm was abducted to 90 degrees with the palm of the hand facing the ceiling, and Sonosite Edge II Ultrasound System (FUJIFILM Sonosite, Inc. Bothell, Washington, USA) high frequency linear transducer (6–15 MHz) was placed in the infraclavicular region parallel to the middle third of the clavicle. Ultrasound image was optimised until all three cords of brachial plexus were visualised lying lateral to axillary artery, bounded anteriorly by the clavicular head of pectoralis major and the subclavius muscle, and posteriorly by the serratus anterior muscle overlying the second rib. A 50 mm or a 100 mm B Braun Stimuplex A insulated stimulating needle(22G × 2")(Hakko Co. Ltd., Isobe., Chikuma-Shi., Nagano., Japan) was used depending on the depth of visualisation of the cords on ultrasound. With the needle tip at target location, peripheral nerve stimulation was done (0.5–0.8 mA, 0.1 msec) and response was elicited. The needle tip was repositioned if a response was elicited at less than 0.5mA. A small volume of local anaesthetic was given under sonogram to confirm the location. Local anaesthetic of 30 ml was injected lateral to the the axillary artery as 4–5 ml smaller aliquots at multiple sites by redirecting the block needle. Figure 6 and Figure 7 show the schematic anatomy and sonoanatomy of costoclavicular block. During surgery, all patients were sedated for comfort using small doses of Intravenous Fentanyl (maximum 1 mcg/kg). If patient complained of severe pain or required more than 1 mcg/kg of rescue fentanyl during surgery, block was considered a failure.

Postoperatively, in the post-anesthesia care unit, the PEFR in Litres/min using peak-expiratory flow meter (MCP Healthcare) and the diaphragmatic excursion in cm was reassessed during normal inspiration, deep inspiration and during sniff in supine position using Sonosite Edge II Ultrasound System (FUJIFILM Sonosite, Inc. Bothell, Washington, USA) low frequency (1–5 MHz) curved array transducer. The data was used to compare the percentage change in hemidiaphragm movement pre- and post-block in both the groups, Group SC and Group CC. A reduction in the diaphragm movement of more than 25% was taken as cut-off for ipsilateral hemidiaphragmatic paresis in our study.

Results

The Consolidated Statement of Reporting Trials is as shown in the Figure 8.

The data was entered in excel sheet and analyzed using Statistical Package for Social Sciences (SPSS) – Version 21(SPSS Inc, Chicago, Illinois, USA). Descriptive statistics with mean, standard deviation and proportions (%) were calculated for quantitative variables. To test the hypothesis, Chi Square test, Independent sample T test, paired T test and Mann–Whitney U, Wilcoxon test were used, appropriately. A p-value of < 0.05 was considered as statistically significant.

A total of 48 patients were assessed for eligibility, of whom 46 were included in the final analysis. Fisher's exact test showed that there was no statistically significant difference between Group CC and Group SC with respect to age, body mass index, or gender distribution, indicating that the two groups were comparable at baseline (Table 1).

As given in Table 2, there was a statistically significant difference in the block onset time (p 0.000). It was more in the costoclavicular block Group CC with a mean onset time of 9.1 ± 4.5 min as compared to supraclavicular block Group SC with a mean onset time of 5.1 ± 2.5 min. The time to complete sensory and motor block was also significantly more in costoclavicular nerve block Group CC with mean time of 23.4 ± 8.7 min as compared to supraclavicular nerve block Group SC with a mean time of 14.4 ± 6.4 min which was statistically significant ($p = 0.001$). However, there was no difference in block administration time ($p = 0.379$).

Table 3 demonstrates that pre-block diaphragmatic excursion during normal inspiration, deep inspiration, and sniff manoeuvre was comparable between the two groups ($p > 0.05$). Post-block, diaphragmatic excursion during normal and deep inspiration was significantly reduced in Group SC compared with Group CC ($p < 0.05$), whereas no significant difference was observed during the sniff manoeuvre ($p > 0.05$).

Table 4 and Figure 9 show a significantly higher incidence of hemidiaphragmatic paralysis (HDP) in Group SC compared with Group CC across all respiratory manoeuvres. The difference was highly significant during normal and deep inspiration ($p < 0.0001$) and remained significant during the sniff manoeuvre ($p = 0.0115$). Hemidiaphragmatic paralysis was defined

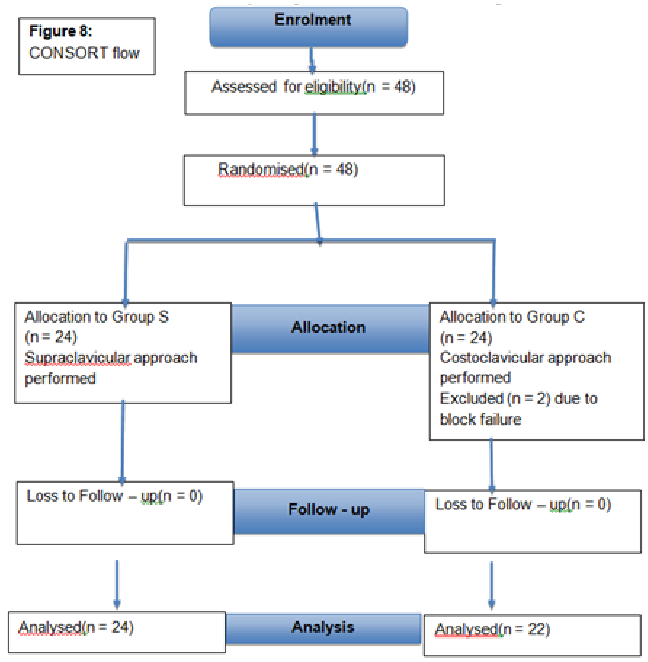

Fig. 8. CONSORT flow

***Table 1*. Comparison of patient demographics between two groups ($n = 46$)**

Variables	Group CC (n = 22)	Group SC (n = 24)	p
Age (in years)	43.3 ± 12.7	42 ± 16.8	0.582
BMI (in kg/m²)	27.7 ± 3.2	26.8 ± 4.5	0.415
Female	9 (19.6)	9 (19.6)	0.813
Male	13 (28.3)	15 (32.6)	

***Table 2*. Comparison of block time parameters between two groups ($n = 46$)**

Variables	Group CC	Group SC	p
Block administration time (in mins)	6.8 ± 3.4	6.3 ± 3.4	0.379
Block onset time (in mins)	9.1 ± 4.5	5.1 ± 2.5	0.0001*
Time to complete sensory and motor block (in mins)	23.4 ± 8.7	14.4 ± 6.4	0.001*

***Table 3*. Comparison of diaphragmatic excursion between two groups**

Variables (in cms)	Group CC	Group SC	p
Pre-block normal Inspiration	2.2 ± 0.5	2.2 ± 0.5	0.886
Pre-block – Deep Inspiration	3.5 ± 0.6	3.7 ± 0.8	0.613
Pre-block – Sniff	1.7 ± 0.4	1.7 ± 0.5	0.618
Post-block normal Inspiration	2.2 ± 0.5	1.8 ± 0.6	0.009*
Post-block – Deep Inspiration	3.5 ± 0.9	2.8 ± 1.1	0.026*
Post-block – Sniff	1.7 ± 0.4	1.5 ± 0.5	0.194

Table 4. **Incidence of hemidiaphragmatic paralysis**

Variables	Group CC	Group SC	Total	*p*
During Normal Inspiration				
HDP Present	4	20	24	< 0.000*
HDP Absent	18	4	22	
During Deep Inspiration				
HDP Present	3	23	26	< 0.000*
HDP Absent	19	1	20	
During Sniff				
HDP Present	4	13	17	0.0115*
HDP Absent	18	11	29	

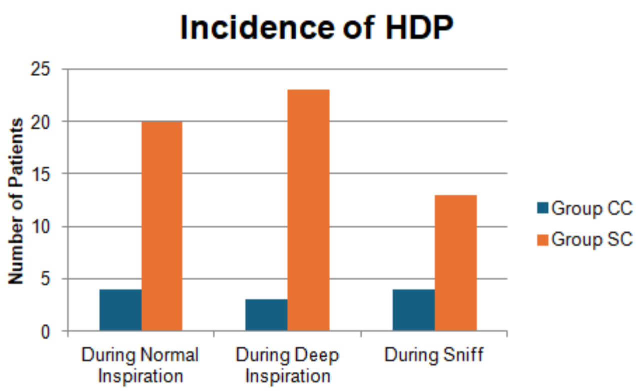

Fig. 9. Incidence of Hemidiaphragmatic Paresis

as a reduction of more than 25% in diaphragmatic excursion from pre- to post-block values.

As depicted in Table 5, the percentage reduction in diaphragmatic excursion was significantly greater in Group SC compared with Group CC during normal inspiration, deep inspiration, and sniff manoeuvre ($p < 0.05$ for all), indicating a greater impairment of diaphragmatic movement with the supraclavicular approach.

Table 6 and Figure 10 present the grading of HDP. During normal and deep inspiration, a significantly higher proportion of patients in Group SC developed complete (> 50%) and partial (25–50%) diaphragmatic paralysis compared with Group CC ($p < 0.001$). During the sniff manoeuvre, the incidence of partial and complete paralysis was also higher in Group SC, with the difference reaching statistical significance ($p = 0.032$).

Table 7 shows a comparison of pre- and post-block PEFR. Group SC demonstrated a statistically significant reduction in PEFR following the block ($p = 0.002$), whereas the reduction in Group CC was not statistically significant ($p = 0.079$). No adverse events were observed in either group.

Discussion

We used M-mode ultrasound to evaluate the hemidiaphragm excursion after costoclavicular or supraclavicular block. We have taken a difference of > 25% reduction in diaphragmatic excursion as cut off for hemidiaphragmatic paresis. The incidence of HDP was higher in the Supraclavicular group during normal inspiration and deep inspiration and during the sniff maneuvre reflecting the spread of local anesthesia drugs to the phrenic nerve. The time of onset of block was longer in costoclavicular nerve block group with mean onset of 9.1 ± 4.5 min as compared to supraclavicular nerve block group with mean onset time of 5.1 ± 2.5 min and was statistically significant. The time to complete sensory and motor block was significantly more in costoclavicular nerve block with mean time of 23.4 ± 8.7 min as compared to supraclavicular nerve block with mean time of 14.4 ± 6.4 min which was statistically significant ($p < 0.05$).

J. Aliste et al. investigated the postoperative analgesic efficacy of costoclavicular block with interscalene block for arthroscopic shoulder surgeries with 22 cases in each group using 20 ml of levobupivacaine 0.5% and epinephrine 5 μg/ml [1]. They evaluated HDP and defined it as the absence of diaphragmatic motion during normal respiration coupled with absent or cranial diaphragmatic movement when the patient forcefully sniffs. They found no evidence of HDP in 22 cases with costoclavicular block.

B. Hong et al. compared hemidiaphragmatic paralysis after costoclavicular block versus supraclavicular block in 80 patients using 25 ml of 1:1 mixture of 1% lidocaine and 0.75% ropivacaine. Complete and partial HDP were defined as less than 5% of diaphragm thickness fraction, and between 5 and 20% of diaphragm thickness fraction, respectively. The pulmonary function test and chest radiograph were assessed before and after the surgery. The incidence of HDP was 4/35 in the Group CC and 19/40 in the Group SC ($p = 0.002$). The mean change of diaphragm thickness fraction values were 30.3% and 56.9% in the Group CC and SC, respectively ($p = 0.007$) [7]. The pulmonary function was more preserved in the Group CC than in the Group SC. The elevation of the hemidiaphragm was determined by comparing its relative position to that on the contralateral side on pre- and post-operative chest radiographs. The determined diagnostic cut off value of the diaphragm elevation on chest radiograph was 29 mm. They concluded that costoclavicular block can significantly reduce the risk of HDP.

According to the study conducted by W. F. Urmey et al., there was a 100% incidence of HDP after interscalene block, which was identified by ultrasonography and resulted in substantial decrease in FVC and FEV_1

Table 5. **Percentage reduction in diaphragmatic excursion pre- and post-block between the two group**

Variables	Group CC	Group SC	*p*
Percentage reduction in diaphragmatic excursion during Normal Inspiration (in %)	2.0 ± 30.2	35.2 ± 23.1	0.0001*
Percentage reduction in diaphragmatic excursion during Deep Inspiration (in %)	2.3 ± 24.4	44.6 ± 10.5	0.0001*
Percentage reduction in diaphragmatic excursion during Sniff (in %)	2.6 ± 27.4	19.6 ± 25.8	0.026*

Table 6. **Grading of hemidiaphragmatic paralysis**

Variables	Group CC	Group SC	Total	*p*
Proportion of cases with HDP during Normal Inspiration				
Complete paralysis (> 50%)	1 (2.2)	4 (8.7)	5 (10.9)	
Partial paralysis (25–50%)	3 (6.5)	15 (32.6)	18(39.1)	0.000*
No paralysis (< 25%)	18 (39.1)	5 (10.9)	23 (50)	
Proportion of cases with HDP during Deep Inspiration				
Complete paralysis (> 50%)	1 (2.2)	8 (17.4)	9 (19.6)	
Partial paralysis (25–50%)	2 (4.3)	15 (32.6)	17 (37)	0.0001*
No paralysis (< 25%)	19 (41.3)	1 (2.2)	20 (43.5)	
Proportion of cases with HDP during Sniff manoeuvre				
Complete paralysis (> 50%)	0 (0)	2 (4.3)	2 (4.3)	
Partial paralysis (25–50%)	4 (8.7)	11 (23.9)	15 (32.6)	0.032*
No paralysis (< 25%)	18 (39.1)	11 (23.9)	29 (63)	

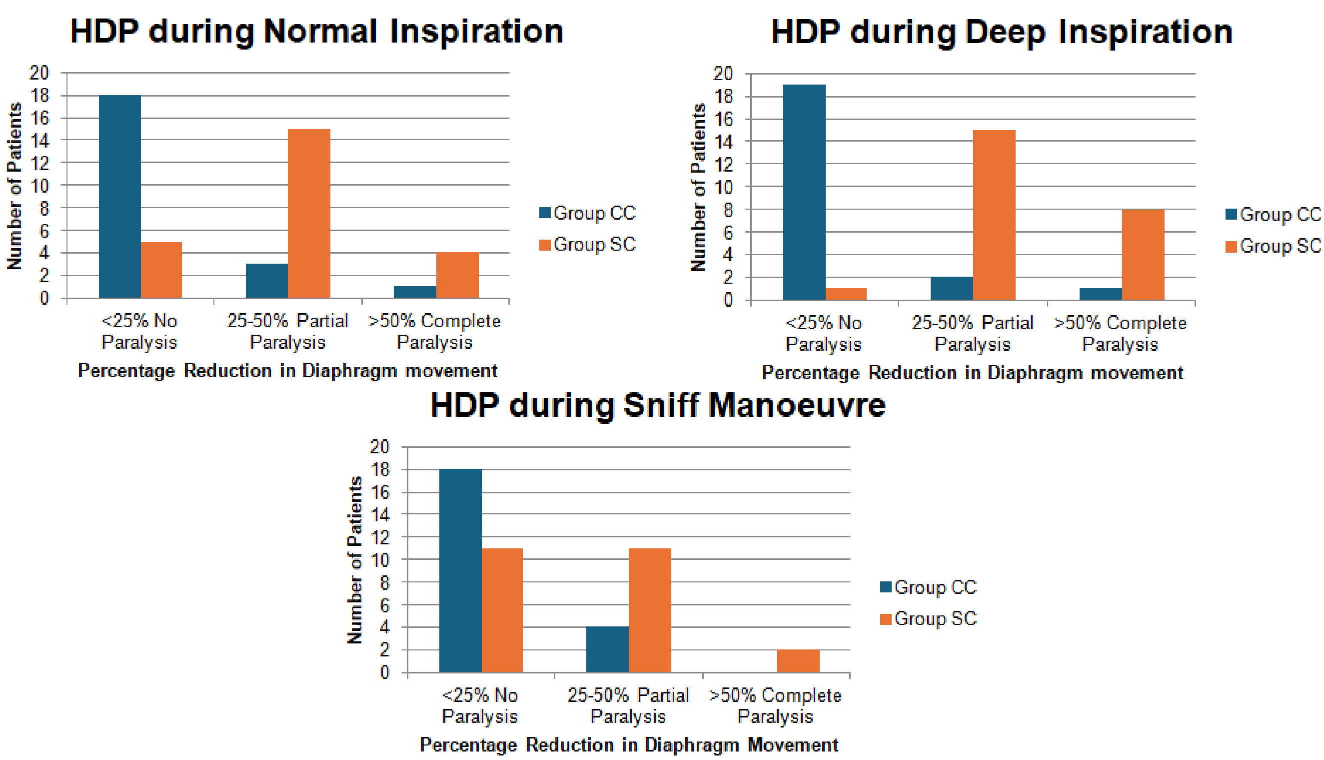

Fig. 10. Grading of HDP

Table 7. **Comparison of pre- and post-PEFR**

Group	N	Pre-PEFR	Post-PEFR	*p*
Group CC	22	332.4 ± 103.6	316.7 ± 101.6	0.079*
Group SC	24	322.5 ± 124.6	294.1 ± 127.2	0.002*

[34]. The larger decrease was associated with higher volumes of local anaesthesia. Increasing the volume may be associated with a greater retrograde spread of the drug towards phrenic nerve roots although higher volume is a factor attributed to prolonging the duration of analgesia. The duration of analgesia can also be prolonged by other interventions like addition of an adjuvant, using a continuous catheter block, by the

use of vasoconstrictors decreasing the local anaesthetic absorption into the systemic circulation. A study by Tran D.Q. et al. demonstrated significantly lower incidence of HDP with the costoclavicular approach (0%) compared to the supraclavicular technique (67%) [31].

In the study conducted by T. Sivashanmugam et al., 40 patients were randomised and they received a 20 ml of 2% lidocaine with 1:200000 epinephrine and 0.5% bupivacaine as costoclavicular block or supraclavicular block [29]. They measured ipsilateral hemidiaphragmatic excursion using M-mode ultrasound during normal inspiration, deep inspiration and during sniff manoeuvre and also measured PEFR taken before and at 30 min after the BPB. Ipsilateral phrenic nerve palsy was defined as a reduction in hemidiaphragmatic excursion by at least 50% during deep inspiration at 30 min after the BPB [29]. The incidence was lower (p 0.008) in the costoclavicular group (5%) than in the supraclavicular group (45%) [29]. PEFRs were similar between the groups. This was explained by site of injection being farther away from ipsilateral phrenic nerve. As the costoclavicular space and the supraclavicular fossa are contiguous anatomical spaces and an injection above or below the clavicle can spread anterograde or retrograde from one location to the other, factors other than just «distance from the phrenic nerve» could have played a part in producing phrenic nerve palsy in the costoclavicular BPB group [29]. In our study, we used 30 ml of equal mixture of 2% lidocaine with 1:200000 epinephrine and 0.5% bupivacaine in both the groups as we wanted to prolong the duration of analgesia and to compare whether larger volume of drugs might increase HDP in CC block. There was a greater reduction in PEFR values in the Group SC than in the Group CC and this difference between groups was statistically significant. However, no patients had any signs and symptoms of respiratory compromise after brachial plexus block.

R. K. Saraswat et al. compared ultrasound-guided supraclavicular and costoclavicular blocks and evaluated diaphragmatic excursion, thickness, contractility and pulmonary function [28]. The block was performed with 25 ml of 0.5% Levobupivacaine. The diaphragmatic function was assessed using ultrasonographic evaluation of diaphragm thickness and diaphragmatic thickness fraction pre- and post-block. Pulmonary function tests (FVC, FEV_1, PEFR) were performed pre-block and two hours post-block. The SC group exhibited a significantly larger reduction in diaphragm thickness fraction compared to the costoclavicular group ($p < 0.01$). Both groups showed significant declines in FVC, FEV_1, and PEFR post-block, but the magnitude of deterioration was significantly greater in the SC group.

In our study, we have taken a difference of > 25% as cut-off for hemidiaphragmatic paresis. The incidence of HDP was higher in the supraclavicular group during normal inspiration, deep inspiration and during sniff manoeuvre. This reflects that the spread of local anesthesia drugs and hence the involvement of phrenic nerve is higher in the supraclavicular approach. The findings of this study have important clinical implications, particularly in the context of ambulatory and outpatient surgeries, where patients are discharged soon after the procedure. Diaphragmatic dysfunction and respiratory impairment may not be immediately apparent, potentially leading to delayed recognition [21]. Therefore, careful selection of brachial plexus block technique and monitoring are crucial to mitigate the risk of adverse respiratory events.

There were some limitations to our study. Firstly, it was a single centre trial. A multicentric study could have offered diverse data over a larger population. Secondly, we recruited patients irrespective of side of surgery and assessed the diaphragm movements before and after performing the block. However, the collected data was not sub grouped during analysis and it was a limitation in our study. Thirdly, patient blinding was not achieved. However, we suspect the impact of this unblinding on the patient's breathing effort to be neglectable.

In our study, we did not assess the diaphragm thickness fraction to evaluate hemidiaphragmatic paresis. Diaphragm thickness fraction is given by Thickness at inspiration – Thickness at expiration / Thickness at expiration. Instead we used the diaphragm movement in cms assessed pre-block and post-block. Assessing the diaphragm thickness fraction which is calculated as a single figure might have eased the analysis and yielded a better appreciable number to assess the diaphragmatic paresis.

Finally, only the peak expiratory flow rate was used to assess the pulmonary function in this study. We agree FEV_1 and FVC are more specific tests for assessment of pulmonary function and could have provided a more comprehensive assessment of pulmonary function. We used PEFR as it is a bedside method, quicker and reliable.

Conclusion

Costoclavicular block is associated with lesser incidence of ipsilateral hemidiaphragmatic paresis as compared to supraclavicular block but onset time was longer and time to complete sensory and motor block was significantly higher in costoclavicular nerve block group.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of Interests. The authors states that he has no conflict of interests.

Authors' contribution. All authors made a substantial contribution to the conception of the work, acquisition, analysis, interpretation of data for the work, drafting and revising the work, final approval of the version to be published and agree to be accountable for all aspects of the work.

REFERENCES

1. Aliste J., Bravo D., Layera S. et al. Randomized comparison between interscalene and costoclavicular blocks for arthroscopic shoulder surgery. *Regional Anesthesia & Pain Medicine*, 2019, vol. 44, pp. 472–477. https://doi.org/10.1136/rapm-2018-100055.

2. Arcand G., Williams S. R., Chouinard P. et al. Ultrasound-guided infraclavicular versus supraclavicular block. *Anesth Analg*, 2005, vol. 101, pp. 886–890. https://doi.org/10.1213/01.ANE.0000159168.69934.CC.

3. Boussuges A., Gole Y., Blanc P. Diaphragmatic motion studied by M-mode ultrasonography: methods, reproducibility, and normal values. *Chest*, 2009, vol. 135, pp. 391–400. https://doi.org/10.1378/chest.08-1541.

4. Dullenkopf A., Blumenthal S., Theodorou P. et al. Diaphragmatic excursion and respiratory function after the modified Raj technique of the infraclavicular plexus block. *Reg Anesth Pain Med,* 2004, vol. 29, pp. 110–114 https://doi.org/ 10.1016/j.rapm.2003.12.001.

5. El-Sawy A., Mohamed N. N., Mansour M. A. et al. Ultrasound-guided supraclavicular versus infraclavicular brachial plexus nerve block in chronic renal failure patients undergoing arteriovenous fistula creation. *Egypt J Anaesth*, 2014, vol. 30, pp. 161–167.

6. Gentili M. E., Deleuze A., Estebe J. P. et al. Severe respiratory failure after infraclavicular block with 0.75% ropivacaine: a case report. *J Clin Anesth*, 2002, vol. 14, pp. 459–461. https://doi.org/10.1016/s0952-8180(02)00387-2.

7. Hong B., Lee S., Oh C. et al. Hemidiaphragmatic paralysis following costoclavicular versus supraclavicular brachial plexus block: a randomized controlled trial. *Sci Rep*, 2021, vol. 11, 18749. https://doi.org/10.1038/s41598-021-97843-x.

8. Hsu A. C., Tai Y. T., Lin K. H. et al. Infraclavicular brachial plexus block in adults: A comprehensive review based on a unified nomenclature system. *J Anesth*, 2019, vol. 33, no. 3, pp. 463–477. https://doi.org/10.1007/s00540-019-02638-0.

9. Karmakar M. K., Sala-Blanch X., Songthamwat B. et al. Benefits of the costoclavicular space for ultrasound-guided infraclavicular brachial plexus block: description of a costoclavicular approach. *Reg Anesth Pain Med,* 2015, vol. 40, pp. 287–288. https://doi.org/10.1097/AAP.0000000000000232.

10. Kessler J., Schafhalter-Zoppoth I., Gray A. T. An ultrasound study of the phrenic nerve in the posterior cervical triangle: implications for the interscalene brachial plexus block. *Reg Anesth Pain Med*, 2008, vol. 33, pp. 545–550. PMID: 19258969.

11. Khurana J., Gartner S. C., Naik L. et al. Ultrasound identification of diaphragm by novices using ABCDE technique. *Reg Anesth Pain Med*, 2018, vol. 43, no. 2, pp. 161–165. https://doi.org/10.1097/AAP.0000000000000718.

12. Kim B. G., Han J. U., Song J. H. et al. A comparison of ultrasound-guided interscalene and supraclavicular blocks for post-operative analgesia after shoulder surgery. *Acta Anaesthesiol Scand*, 2017, vol. 61, pp. 427–435. https://doi.org/10.1111/aas.12864.

13. Kirkwood B. R., Sterne J. A. Calculation of Required Sample Size. *Essential Medical Statistics, Blackwell Science, Oxford,* 2003, pp. 420–421.

14. Koscielniak-Nielsen Z. J., Frederiksen B. S., Rasmussen H. et al. A comparison of ultrasound-guided supraclavicular and infraclavicular blocks for upper extremity surgery. *Acta Anaesthesiol Scand,* 2009, vol. 53, pp. 620–626. https://doi.org/10.1111/j.1399-6576.2009.01909.x.

15. Li J. W., Songthamwat B., Samy W. et al. Ultrasound-guided costoclavicular brachial plexus block: sonoanatomy, technique, and block dynamics. *Reg Anesth Pain Med*, 2017, vol. 42, no. 2, pp. 233–240. https://doi.org/10.1097/AAP.0000000000000566.

16. Lloyd T., Tang Y. M., Benson M. D. et al. Diaphragmatic paralysis: the use of M mode ultrasound for diagnosis in adults. *Spinal Cord*, 2006, vol. 44, pp. 505–508. https://doi.org/10.1038/sj.sc.3101889.

17. Naik L. Y., Sondekoppam R. V., Jenkin Tsui J. et al. An ultrasound-guided ABCDE approach with a sniff test to evaluate diaphragmatic function without acoustic windows. *Can. J. Anaesth*, 2016, vol. 63, pp. 1199–1200. https://doi.org/10.1007/s12630-016-0685-z.

18. Neal J. M., Gerancher J. C., Hebl J. R. et al. Upper extremity regional anesthesia: essentials of our current understanding, 2008. *Reg Anesth Pain Med,* 2009, vol. 34, pp. 134–170. https://doi.org/10.1097/AAP.0b013e31819624eb.

19. Neumeister E. L., Beason A. M., Thayer J. A. et al. Perioperative pain management in hand and upper extremity surgery. *Clin Plast Surg*, 2020, vol. 47, № 2, pp. 323–334. https://doi.org/10.1016/j.cps.2019.12.004.

20. Oh C., Noh C., Eom H. et al. Costoclavicular brachial plexus block reduces hemidiaphragmatic paralysis more than supraclavicular brachial plexus block: retrospective, propensity score matched cohort study. *Korean J Pain*, 2020, vol. 33, pp. 144–152. https://doi.org/10.3344/kjp.2020.33.2.144.

21. Petrar S.D., Seltenrich M.E., Head S.J. et al. Hemidiaphragmatic paralysis following ultrasound-guided supraclavicular versus infraclavicular brachial plexus blockade: a randomized clinical trial. *Reg Anesth Pain Med*, 2015, vol. 40, № 2, pp. 133–138. https://doi.org/10.1097/AAP.0000000000000215.

22. Renes S. H., Rettig H. C., Gielen M. J. et al. Ultrasound-guided low-dose interscalene brachial plexus block reduces the incidence of hemidiaphragmatic paresis. *Reg Anesth Pain Med*, 2009, vol. 34, pp. 498–502. https://doi.org/10.1097/AAP.0b013e3181b49256.

23. Renes S. H., Spoormans H. H., Gielen M. J. et al. Hemidiaphragmatic paresis can be avoided in ultrasound-guided supraclavicular brachial plexus block. *Reg Anesth Pain Med*, 2009, vol. 34, pp. 595–599. https://doi.org/10.1097/aap.0b013e3181bfbd83.

24. Rettig H. C., Gielen M. J., Boersma E. et al. Vertical infraclavicular block of the brachial plexus: effects on hemidiaphragmatic movement and ventilatory function. *Reg Anesth Pain, Med,* 2005, vol. 30, pp. 529–535. https://link.springer.com/article/10.1007/s00540-019-02638-0.

25. Riazi S., Carmichael N., Awad I. et al. Effect of local anaesthetic volume (20 vs 5 mL) on the efficacy and respiratory consequences of ultrasound-guided interscalene brachial plexus block. *Br J Anaesth*, 2008, vol. 101, pp. 549–556. https://doi.org/10.1093/bja/aen229.

26. Ryu T., Kil B. T., Kim J. H. Comparison between ultrasound-guided supraclavicular and interscalene brachial plexus blocks in patients undergoing arthroscopic shoulder surgery: a prospective, randomized, parallel study. *Medicine (Baltimore),* 2015, vol. 94, e1726. https://doi.org/10.1097/MD.0000000000001726.

27. Sala-Blanch X., Reina M. A., Pangthipampai P. et al. Anatomic basis for brachial plexus block at the costoclavicular space: A cadaver anatomic study. *Reg. Anesth. Pain Med*, 2016, vol. 41, pp. 387–391. https://doi.org/10.1097/AAP.0000000000000393.

28. Saraswat R. K., Deganwa M., Verma K. et al. Diaphragmatic and pulmonary functions following an ultrasound-guided supraclavicular approach versus a costoclavicular approach of a brachial plexus block: a randomized study. *Cureus*, 2024, vol. 16, № 6, e62586. https://doi.org/10.7759/cureus.62586.

29. Sivashanmugam T., Maurya I., Kumar N. et al. Ipsilateral hemidiaphragmatic paresis after a supraclavicular and costoclavicular brachial plexus block: A randomised observer blinded study. *Eur J Anaesthesiol*, 2019, vol. 36, № 10, pp. 787–795. https://doi.org/10.1097/EJA.0000000000001069.

30. Songthamwat B., Karmakar M. K., Li J. W. et al. Ultrasound-guided infraclavicular brachial plexus block: Prospective randomized comparison of the lateral sagittal and costoclavicular approach. *Reg. Anesth. Pain Med*, 2018, vol. 43, pp. 825–831. https://doi.org/10.1097/AAP.0000000000000822.

31. Tran D. Q., Layera S., Bravo D. et al. Diaphragm-sparing nerve blocks for shoulder surgery, revisited. *Regional Anesthesia & Pain Medicine*, 2020, vol. 45, pp. 73–78. https://doi.org/10.1136/rapm-2019-100908.

32. Tran de Q. H., Russo G., Munoz L. et al. A prospective, randomized comparison between ultrasound-guided supraclavicular, infraclavicular, and axillary brachial plexus blocks. *Reg Anesth Pain Med*, 2009, vol. 34, pp. 366–371. https://doi.org/ 10.1097/AAP.0b013e3181ac7d18.

33. Tsui J. J., Tsui B. C. A novel systematic ABC approach to diaphragmatic evaluation (ABCDE). *Can J Anaesth*, 2016, vol. 63, pp. 636–637. https://doi.org/10.1007/s12630-015-0566-x.

34. Urmey W. F. Regional anesthesia and pain management: What's new. *European Journal of Pain Supplements*, 2008, vol. 2, pp. 36–39. https://doi.org/10.1016/S1754-3207(08)70062-2.

35. Xing T., Ge L. Ultrasound-guided brachial plexus block by costoclavicular space approach: a narrative review. *Med Sci Monit*, 2023, vol. 29, e939920. https://doi.org/10.12659/MSM.939920.

INFORMATION ABOUT AUTHORS:

Sri Ramachandra Institute of Higher Education and Research, Chennai, Tamil Nadu, India

Deepshikha Ramesh, Assistant Professor, Department of Anesthesiology and Pain Medicine, Sri Ramachandra Institute of Higher Education and Research (Chennai, Tamil Nadu, India), e-mail: deepshiganga@gmail.com; **Saif Ali,** Senior Resident, Department of Anesthesiology and Pain Medicine, Sri Ramachandra Institute of Higher Education and Research (Chennai, Tamil Nadu, India), e-mail: saifali669@gmail.com; **Aruna Parameswari,** Head of the Department of Anesthesiology and Pain Medicine, Sri Ramachandra Institute of Higher Education and Research (Chennai, Tamil Nadu, India), e-mail: reetharun@gmail.com.