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Comparative study on efficacy of ultrasound-guided supraclavicular versus costoclavicular brachial plexus block in patients for arteriovenous fistula surgery

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Abstract

Background: Patients with end-stage renal failure (ESRF) who require arteriovenous fistula (AVF) creation often have multiple comorbidities, making the brachial plexus block a suitable choice for anaesthesia. The objective of this study is to compare the efficacy of ultrasound-guided supraclavicular and costoclavicular brachial plexus blocks for AVF creation.

Methods: A total of 70 patients scheduled for the creation of AVF in the distal upper extremity were randomly assigned to 2 groups: supraclavicular block (SCB), Group A: *n* = 35, and costoclavicular block (CCB), Group B: *n* = 35. Both groups received 20 ml of 0.5% ropivacaine and 10 ml of 1% lidocaine. The measured parameters included the speed of onset of motor and sensory blockade, the quality of blockade, procedural-related pain score, patient satisfaction, and regional perfusion.

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Results: The costoclavicular block demonstrated a significantly faster onset to achieve complete paralysis ($p = 0.01$) in all sensory and motor nerves compared to the supraclavicular block. Additionally, there was a significant difference in regional perfusion, with higher perfusion observed in the supraclavicular block ($p = 0.013$). However, there were no significant differences in the quality of block ($p = 0.573$), and procedural-related pain score ($p = 0.117$) between the 2 groups.

Conclusion: The costoclavicular block offers a faster onset of sensory and motor blockade compared to the supraclavicular block. However, they are comparable in terms of the quality of the block and procedural-related pain. This new technique can be considered as an alternative for providing anaesthesia in patients with ESRF undergoing AVF creation.

Keywords: arteriovenous fistula, brachial plexus, ultrasound-guided supraclavicular block, ultrasound-guided costoclavicular block

Introduction

The global incidence of end-stage renal failure (ESRF) is increasing. The preferred procedure for patients with ESRF undergoing maintenance haemodialysis (HD) is the placement of an arteriovenous fistula (AVF). Patients with ESRF might encounter severe complications that represent a great challenge to the anaesthesiologists, such as congestive heart failure, systemic hypertension, electrolyte imbalances, metabolic acidosis, coagulopathy, and unpredictable intravascular fluid volume status. These issues require anaesthesiologists to steer clear of general anaesthesia and explore alternative methods.[1,2]

In patients with ESRF, brachial plexus block (BPB) is frequently employed to administer anaesthesia for the establishment or modification of AVF. This technique offers pain relief, sympathetic blockade, ideal surgical conditions, and a sufficient duration of postoperative block, preventing arterial spasms and graft thrombosis.[2] Several methods are available for BPB, including axillary, supraclavicular, and infraclavicular approaches. These procedures have historically been performed using blind techniques or neurostimulation. However, these methods are associated with a high failure rate and serious complications.

The utilization of ultrasonography has become increasingly popular and more convenient. Its application in these blocks enhances the success rate and reduces

complications significantly.[3] Ultrasound-guided BPB improves the visualization of nerve bundles, enables real-time assessment of needle placement, helps in avoiding crucial structures such as blood vessels and pleura, and promotes the even spread of local anaesthetic along the targeted nerves. Incorporating this non-invasive technology for nerve blocks has substantially increased the success rate of the procedure and enhanced its safety. Additionally, the precise localisation and direct visualisation of nerves using ultrasound have led to a reduction in the total volume of drugs required.

Supraclavicular and costoclavicular BPB offer anaesthesia and pain relief to the upper extremities below the shoulder. These techniques are particularly suitable for surgeries involving the elbow and hand. Supraclavicular BPB is often referred to as the spinal anaesthesia of the upper extremities due to its rapid onset of blockade. However, it carries a higher incidence of complications. Common risks and complications associated with this technique include phrenic nerve block leading to diaphragmatic paralysis and sympathetic nerve block resulting in Horner's syndrome. Fortunately, these complications are usually self-limiting. More serious complications, such as intravascular injection causing systemic local anaesthetic toxicity, haematoma formation, and pneumothorax, can also occur. The use of ultrasound guidance can help reduce the risk of these complications.[3,4]

Costoclavicular BPB is a recently developed technique for infraclavicular BPB, introduced by Karmakar *et al.*[5] With the ultrasound-guided costoclavicular approach, all 3 cords of the brachial plexus are clearly visible in a single plane. These cords are relatively superficial and are clustered together lateral to the axillary artery within the costoclavicular space, forming a triangular arrangement.[6,7] In this space, the cords are positioned more superficially compared to the classical approach in the lateral infraclavicular fossa. They are clustered together yet maintain a consistent anatomical relationship with each other.[8] This results in a rapid onset of BPB similar to the supraclavicular approach, but with superior surgical effectiveness and fewer adverse events.

Methods

This study was a prospective, double-blinded, randomised-controlled trial conducted in the operation theatre, Hospital Universiti Sains Malaysia from November 2020 to October 2021. After receiving approval from the Human Research Ethics Committee at Universiti Sains Malaysia (USM/JEPeM/20120629) and written informed consent from the patients, 70 elective patients scheduled for creation of AVF in the distal upper extremity were recruited. The inclusion criteria were

American Society of Anesthesiologists (ASA) classification I–III and patient age ranging between 18 and 60 years old. The exclusion criteria included allergies to local anaesthetic drugs, pregnancy, prior history of brachial plexus injury, underlying coagulopathy, local infection at the block area, and neuropathy in the involved arm.

Patients were randomly assigned to 2 groups (Group A, $n = 35$, ultrasound-guided supraclavicular block; Group B, $n = 35$, ultrasound-guided costoclavicular block) using computer-generated numbers. The randomisation sequence was kept confidential in an opaque envelope until it was opened on the morning of the surgery by the anaesthesiology officer in charge.

A pre-anaesthetic evaluation was conducted before the scheduled surgery, and all patients fasted for at least 6 hours prior to the procedure. No premedication was administered to the patients. All patients in the study were undergoing chronic haemodialysis, with a session completed 1 day before the block procedure. Their routine preoperative laboratory investigations showed within acceptable values, particularly with urea levels less than 25 mg/dl. Both the patients and the assessor were unaware of the type of block being performed. The primary researcher served as the sole operator for the block, and the sealed envelope containing the group allocation was opened by an anaesthesiology officer responsible for the operating theatre (OT). The operator, a registrar in anaesthesiology training, had received hands-on workshops in peripheral nerve block and was trained and supervised in performing ultrasound-guided supraclavicular BPB on 15 patients before the research study. All nerve blocks were performed in the regional block bay within the OT.

Upon arriving at the regional block bay, an intravenous (IV) catheter was inserted using a 20-G or 18-G needle in the upper limb opposite to the surgical site. Haemodynamic parameters, such as non-invasive blood pressure, heart rate, oxygen saturation, and electrocardiography, were recorded for all patients. All patients were administered supplemental oxygen at a rate of 3 L/min through a nasal prong. Conscious sedation was adjusted with intermittent boluses of IV fentanyl (25 µg) and IV midazolam (1 mg) as necessary. The block was performed with the patient in the supine position, and the head was turned contralaterally away from the side where the block was administered. The supraclavicular and costoclavicular areas were prepared using an aseptic technique and draped. The skin was infiltrated with 2% lignocaine using a 22-G needle before introduction of the needle for the block.

Both ultrasound-guided approaches utilized a portable ultrasound machine, specifically the Wisonic Clover ultrasound (Clover, Wisonic, Shenzhen, China). A 22-gauge, 50–80 mm nerve stimulator needle model (B. Braun Medical Inc.,

Germany) was used for all participants. A depth of 3–4 cm and a frequency of 10–12 Hz were employed. In both groups, the local anaesthetic (LA) solution comprised 20 ml of 0.5% ropivacaine and 10 ml of 1% lidocaine, resulting in a total injected volume of 30 ml. The solution, a mixture of ropivacaine and lidocaine, was similar to that described by Oh *et al.*[1] and was administered incrementally with repeated aspiration in between, and its characteristic distribution around the nerves was observed.

In the supraclavicular group, the ultrasound probe was positioned in the supraclavicular fossa, directed caudal, and moved laterally and medially to locate the subclavian artery. The hyperechoic first rib was identified beneath the artery, and the pleura was visualised, observing its sliding movement during respiration. The brachial plexus was consistently identified with a characteristic "honeycomb" appearance, located laterally and superficially to the subclavian artery and superior to the first rib. After strict aseptic precautions and skin infiltration, the nerve block needle was inserted through the skin from lateral to medial, in line with the transducer, while maintaining constant visualization, and directed toward the deep border of the nerve group. Two separate injections were administered at various sites within the bundle, typically starting deep in the "corner pocket" near the artery and moving more superficially.

In the costoclavicular group, the patient's arm was abducted to 90° with flexion of the elbow, bringing the artery and plexus closer to the skin. The anatomical points were then identified and marked on the skin: clavicle, midpoint of the clavicle, and the tip of the coracoid process.[5] The coracoid process was identified by palpating the bony prominence just medial to the shoulder while the arm was elevated and lowered. Scanning began with the transducer positioned directly over the clavicle midsection in the transverse orientation. The transducer was gently moved caudally until it sliped off the inferior border of clavicle, revealing the visualisation of the axillary artery (first part) and vein.[6] While keeping the transducer in the same position, it was gently tilted cephalad to aim the ultrasound beam towards the costoclavicular space, which denotes the area between the posterior surface of the clavicle and the second rib.[6] The ultrasound image was optimised until all 3 cords of the brachial plexus were clearly visualized lateral to the axillary artery. After strict aseptic precautions and skin infiltration, the nerve block needle was inserted in-plane and from a lateral-to-medial direction. Our goal was to position the needle tip precisely at the centre of the nerve cluster by advancing the needle through the space between the lateral and posterior cord and advancing it toward the medial cord. A total volume of 20 mL of 0.5% ropivacaine and 10 ml of 1% lidocaine was injected in small aliquots and at a single site over 2 to 3 minutes.

The primary outcome measure for assessing the speed of onset was the

proportion of patients experiencing complete sensory and motor blockade at 30 minutes after the local anaesthetic (LA) injection. Sensory blockade of the 4 nerves was assessed every 5 minutes until 30 minutes post-injection by double-blinded observers using a 3-point scale (0 = no block, 1 = partial anaesthesia, 2 = complete anaesthesia). Similarly, motor block was evaluated and graded on a 3-point scale (0 = no block, 1 = paresis, 2 = paralysis). Overall sensory and motor scores were calculated for each patient at predefined intervals. To standardize the assessment, complete sensory or motor blockade was defined as a score equal to or greater than 7 points. The onset times were defined as the intervals measured when complete sensory or motor blockade was achieved.

Sensory blockade was assessed in the cutaneous distribution of each nerve using a cold test at specific locations: the lateral forearm for the musculocutaneous nerve (MCN), the palmar aspect of the second finger for the median nerve (MN), the dorsum of the hand between the thumb and second finger for the radial nerve (RN), and the ventral side of the fifth finger for the ulnar nerve (UN). Motor blockade of each nerve was evaluated by specific movements: elbow flexion for MCN, wrist flexion and opposition of the second and third fingers and the thumb for MN, wrist extension for RN, and flexion and opposition of the fifth finger toward the thumb for UN.

The quality of the block was determined based on the successful achievement of blockade within 30 minutes after needle withdrawal. Surgical anaesthesia, characterised by painless surgery without the need for block supplementation, and patient satisfaction were assessed using a procedural-related pain score. Pain scores were evaluated using a numerical rating scale ranging from 0 to 10 and documented. To assess regional perfusion and sympatholytic effects, the diameter of the basilic vein was measured using colour Doppler Wisonic Clover ultrasound before and 30 minutes after the administration of the local anaesthetic for the regional block.[9] Any changes in the vein diameter were recorded. The examination site was designated 1 cm proximal to the radial-ulnar styloid process to maintain consistency across all measurements. Vessels were imaged using a colour duplex Doppler ultrasound equipped with a 6–12 MHz linear array probe. To ensure reliability, multiple ultrasonography examinations were performed. Three images were obtained once the cross-sectional area of blood flow was confirmed. Subsequently, the results from the 3 measurements were compared. The incidence of pneumothorax, Horner syndrome, and hemidiaphragmatic paralysis were also documented. After the block procedure, patients were transported to the OT for surgery. Surgery began only if the block was deemed adequate. Block failure was defined as the need for an additional block, sedation, or general anaesthesia. After completion of the surgery, patients were transferred to the post-anaesthesia care unit (PACU) for observation.

Table 1. Patient demographic and clinical characteristics

Variable	Supraclavicular	Costoclavicular	p[a]
Age*	52.55 ± 13.11	49.35 ± 13.76	0.335
Weight*	63.70 ± 10.20)	67.06 ± 10.23	0.183[c]
Height*	159.70 ± 6.70	158.38 ± 5.94	0.408[c]
BMI*	24.96 ± (3.91)	26.74 ± (4.34)	0.082[c]
ASA[†]			
I –II	31 (93.9%)	29 (85.3%)	0.427[b]
III	2 (6.1%)	5 (14.7%)	
Gender[†]			
Male	16 (48.5%)	18 (52.9%)	0.715
Female	17 (51.5%)	16 (47.1%)	
Comorbidities[†]			
Diabetes mellitus			
Yes	26 (78.8%)	22 (64.7%)	0.201
No	7 (21.2%)	12 (35.3%)	
Hypertension			
Yes	27 (81.8)	28 (82.4)	0.954
No	6 (18.2)	6 (17.6)	
Hyperlipidaemia			
Yes	2 (6.1%)	7 (20.6%)	0.081
No	31 (93.9%)	27 (79.4%)	
Vital signs*			
SBP	155.30 ± 23.19	148.41 ± 20.75	0.204[c]
DBP	84.0 ± 13.11	79.26 ± 10.67	0.111[c]
HR	77.00 ± 16.35	81.26 ± 9.50	0.195[c]
SpO2	99.12 ± 1.36	99.3 ± 0.83	0.603[c]
Type of AVF[†]			
Radiocephalic	21 (48.8%)	22 (51.2%)	
Brachiocephalic	12 (50%)	12 (50%)	

*Reported as mean ± SD; [†]Reported as *n* (%); [a]Chi-square test; [b]Fisher exact test; [c]Independent t-test

Table 2. Onset of sensory blockade

Nerve	Costoclavicular		Supraclavicular		*p**
	Median	IQR (min)	Median	IQR (min)	
Musculocutaneous	10	5	15	10	< 0.001
Median	10	10	15	6	< 0.001
Radial	10	5	15	6	< 0.001
Ulnar	10	10	20	5	< 0.001
Sensory nerve set	10	5	15	5	< 0.001

*Mann-Whitney U test

Table 3. Onset of motor blockade

Nerve	Costoclavicular		Supraclavicular		*p**
	Median	IQR (min)	Median	IQR (min)	
Musculocutaneous	10	5	15	10	< 0.001
Median	10	10	15	10	< 0.001
Radial	10	5	15	10	0.01
Ulnar	10	5	15	5	0.012
Sensory nerve set	10	5	15	10	0.01

IQR: interquartile range
*Mann-Whitney U test

Table 4. Quality of blockade

Variable	Block	Supraclavicular		Costoclavicular		*p**
		n	%	n	%	
Quality of block	Complete	32	97.0%	32	94.1%	0.573
	Partial	1	3.0%	2	5.9%	

*Fisher exact test

Table 5. Procedural related pain score

Variable	Supraclavicular		Costoclavicular		*p*
	Mean/Median	(SD/IQR)	Mean/Median	(SD/IQR)	
Pain score	1.0	0.00	1.00	1.00	0.177

The sample size was calculated using G* power version 3.1 based on a previous study by Shyam Meena *et al.*[10] that indicated the percentage of visibility in the controls (P0) of 0.4, the percentage of visibility in the experimental group (P1) of 0.8, the power of 0.8, and the type I error of 0.05. The sample size was 32 patients in each group, and, after we considered 10% drop-out, the total sample for both groups was 70 patients. In this analysis, all categorical data are presented in frequency and percentage, while the numerical data are presented in mean and standard deviation or median and interquartile range based on their normality. The normality was tested using Kolmogorov-Smirnova test. We applied Chi-square, Fisher's exact test, independent T-test and Mann-Whitney U-test accordingly in the analysis. A p level of less than 0.05 was considered statistically significant. Statistical analysis was performed using version 26 of the SPSS software (IBM, Armonk, NY, USA).

Results

A total of 70 patients were initially enrolled in this study, with 35 patients assigned to each group. However, there were failed blocks observed in 2 patients in Group A (supraclavicular) and 1 patient in Group B (costoclavicular). Consequently, these 3 patients were excluded from the study. The final analysis included 67 patients, with 33 in Group A and 34 in Group B.

In terms of patient demographic data, no significant associations or mean differences were found between the supraclavicular and costoclavicular block groups regarding variables such as age, gender, ASA classification, weight, and height (Table 1). However, for the speed of onset of sensory blockade, it was observed that all sensory nerves of the costoclavicular block achieved complete anaesthesia significantly faster than those in the supraclavicular block group (10 ± 5 vs 15 ± 10; $p < 0.001$; Table 2). Similarly, for the speed of onset of motor blockade, it was found that all motor nerves of the costoclavicular block achieved complete paralysis significantly faster than those in the supraclavicular block group (10 ± 5 vs 15 ± 10; $p = 0.01$; Table 3).

The study revealed no significant association between the quality of block (complete anaesthesia without supplementation) in both types of anaesthesia blocks, with a rate of 97% in the supraclavicular block group compared to 94% in the costoclavicular block group ($p = 0.573$; Table 4). Patient satisfaction was assessed by procedural related pain score; there was no significant difference in the procedure-related pain scores between the 2 groups (1 ± 0 vs 1 ± 1; $p = 0.117$; Table 5). In this study, no incidence of pneumothorax, Horner syndrome, or hemidiaphragmatic paralysis was documented in either group.

Discussion

Our study found that ultrasound-guided costoclavicular block is superior to the conventional supraclavicular block in terms of the speed of motor and sensory onset. Additionally, both costoclavicular and supraclavicular approaches to the brachial plexus were found to be comparable in providing excellent blockade quality, procedure-related pain scores, and patient satisfaction. To the best of our knowledge, there has been no previous comparison between these 2 types of BPB (supraclavicular vs costoclavicular) for AVF creation. Nevertheless, we have compared our results with previous studies on both these nerve blocks.

The costoclavicular space was clearly visualized as a distinct intermuscular area situated deep to the midpoint of the clavicle posteriorly. The cords of the brachial plexus were observed as hypoechoic clusters, displaying a consistent anatomical arrangement in relation to each other and to the axillary artery. These findings are in line with the study conducted by Demondion *et al.*[10] This consistent anatomical arrangement of the brachial plexus could account for the high success rate of this approach.

In a study conducted by Li *et al.*[7], the ultrasound-guided costoclavicular BPB was successfully performed on 30 patients using 20 ml of 0.5% ropivacaine injection. This technique resulted in a rapid onset of sensory-motor blockade, with a median time to readiness for surgery of 10 minutes (ranging from 5 to 20 minutes). It proved to be effective as surgical anaesthesia in 97% of the patients. A more recent study by Koscielniak-Nielsen *et al.*[12] compared ultrasound-guided supraclavicular and infraclavicular blocks for upper extremity surgery in 120 patients. Their findings indicated that the infraclavicular block had a faster onset, better motor block, and higher surgical effectiveness, attributed to improved analgesia of the median and UN. After 30 minutes, 93% of patients in the infraclavicular group were ready for surgery compared to 78% in the supraclavicular group. The authors speculated that the lesser efficacy of the supraclavicular block in their patients might be due to parts of the plexus not being visualized and thus not surrounded by the local anaesthetic. In our study, we observed that the onset of sensory and motor blockade was significantly faster in the costoclavicular group compared to the supraclavicular group. Specifically, all sensory nerves (MCN, MN, RN, and UN) of the costoclavicular block achieved complete anaesthesia significantly faster (10 ± 5 vs 15 ± 10; $p < 0.001$), and all motor nerves of the costoclavicular block achieved complete paralysis significantly faster as well (10 ± 5 vs 15 ± 10; $p = 0.01$).

Royse *et al.* reported that they might have missed anatomical variations of the inferior trunk in up to 15% of the volunteers.[13] This could explain the poorer analgesia of the UN and MN, which originate from this cord, in supraclavicular group

patients. Similar to our findings, UN sparing was noted in the supraclavicular BPB, leading to a slower onset of blockade.

A more recent study by Yang *et al.*[14] compared infraclavicular and supraclavicular approaches to the brachial plexus using neurostimulation in 100 patients. They found no significant differences in the level of patient satisfaction between the 2 groups. The authors concluded that both the supraclavicular and infraclavicular approaches to the brachial plexus had similar clinical efficacy. Consistent with our study, we also found no significant association between the quality of the block and different types of anaesthesia block, with a success rate of 97% in the supraclavicular group and 94% in the costoclavicular group ($p = 0.573$).

Concerning block-related pain, the infraclavicular block has historically faced challenges due to uncertain surface landmarks and the perception that it is a more painful procedure,[7] which has been mitigated by the current use of ultrasound guidance. The reliability of ultrasonic landmarks has contributed to minimizing patient discomfort. In our study, the procedure-related pain scores for the supraclavicular block did not significantly differ from those for the costoclavicular block (1 ± 0 vs 1 ± 1; $p = 0.117$). This finding aligns with the results reported by Arcand *et al.*,[15] where the pain scores were (2.0 ± 2) and (2.0 ± 2) for the infraclavicular group and the supraclavicular group, respectively.

Sahin *et al.*[16] reported an increase in brachial artery diameter, blood flow, and AVF blood flow after BPB compared with controls. In our study, both the supraclavicular block and costoclavicular block exhibited a sympatholytic-like effect and an increase in regional perfusion. However, the supraclavicular block demonstrated higher perfusion (0.48 ± 0.19 vs 0.47 ± 0.13; $p = 0.013$).

Conclusion

Based on our study findings, it is clear that both the costoclavicular and supraclavicular approaches to the brachial plexus have demonstrated comparable efficacy in providing excellent blockade quality, procedure-related pain scores, and patient satisfaction. Therefore, we confidently conclude that the costoclavicular BPB can serve as a viable alternative technique to the supraclavicular approach for providing surgical anaesthesia in patients with chronic renal failure undergoing the creation of AVF in the distal upper extremity.

Declarations

Ethics approval and consent to participate

The clinical trial on which this study is based has been registered with the Human Research Ethics Committee of the Universiti Sains Malaysia (approval code: USM/JEPeM/20120629).Written formal consent for the study was obtained from all participants in accordance with the Declaration of Helsinki.

Competing interests

Dr. Rhendra Hardy Mohamad Zaini serves as Section Editor in Malaysian Journal of Anaesthesiology. He has not been involved in any part of the publication process prior to manuscript acceptance; peer review for this journal is double blind. The remaining authors have no competing interests to declare.

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