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Original Research Article

Comparing Efficacy of a Single and Triple Injection Techniques in Ultrasound-Guided Costoclavicular Block for Forearm and Hand Surgery: A Single-Blind Randomized Clinical Study

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Abstract

Aim: This study aimed to compare triple injections (TI) in each of the three cords in the costoclavicular (CC) space would result in a greater spread in the four major terminal nerves of the brachial plexus compared to a single injection (SI) in the CC space without increasing the local anesthetic (LA) volume.

Methods: Fifty patients with ASA physical status 1, 2, and 3 who underwent upper extremity surgery randomly received either a single injection (SI group, n = 25) or a triple injection (TI group, n = 25) using the CC approach. 20 ml of 0.5% ropivacaine was used for BPB in each group. Sensory-motor blockade of the ipsilateral median, radial, ulnar, and musculocutaneous nerves was assessed by a blinded observer at 5-minute intervals for 30 minutes immediately after LA administration.

Results: The rate of blockage of all four nerves was significantly higher in the TI group than in the SI group after the 30-minute block, except for the patients with the radial nerve block at 15 minutes, those with the musculocutaneous nerve block at 20 minutes, and those with the median nerve at 25 and 30 minutes. The performance time was similar in the two groups (3.0 ± 0.9 minutes in the SI group vs. 3.2 ± 1.2 minutes in the TI group, respectively; P=.54).

Conclusion: Our study found that ultrasound-guided costoclavicular brachial plexus block is a quick and effective method for providing sensory-motor blockade, and TI of CC approach increased the consistency of US-guided infraclavicular BPB without increasing the procedure time or LA volume.

Keywords: Brachial Plexus Block, Infraclavicular Block, Costoclavicular Approach, Triple Injection, A Single Injection.

Introduction

Ultrasound-guided Infraclavicular (IC) brachial plexus blocks (BPB) have high success rates and a low risk of complications compared to the traditional supraclavicular approach for manage pain and anesthesia in upper extremity procedures. [1,2,3] Several IC block approaches include coracoid, lateral sagittal, retro clavicular, costoclavicular, and vertical (medial) approaches. [4] The lateral approach is preferred due to the low risk of pneumothorax while maintaining efficacy. In contrast, the vertical approach may result in severe complications due to proximity to major vessels and lungs. [5] The para coracoid approach, in which the

LA is deposited dorsally to the axillary artery in the lateral infraclavicular fossa, requires a large volume of LA. [6] Therefore, it can be technically challenging, despite its efficacy and safety, compared with the supraclavicular or axillary block, which appears preferable. The costoclavicular (CC) approach of BPB is a modification of the infraclavicular approach, where we inject LA into the CC space near the clavicle and can cover the four major terminal nerves of the brachial plexus, offering the potential for improved efficacy and longer duration of analgesia through wider diffusion of local anaesthetic (LA) to target nerves. [7]

Li et al. suggested that the costoclavicular approach targets the brachial plexus immediately caudal to the midpoint of the clavicle in the costoclavicular space. [8] Songthamwat et al. indicated that the three cords of the brachial plexus are clustered together but are widely distributed laterally to the axillary artery. [9]

Thus we hypothesized that a single injection targeted at the center of the cords versus triple injections of individual cords of BPB under ultrasound guidance would result in an increased rate of blockage of all four nerves of BPB without an increase in the LA volume.

Materials and Methods

The study was conducted at Indira Gandhi Institute of Medical Sciences, Patna, Bihar, India to investigate the efficacy and safety of an anaesthetic technique for patients aged 18-80 years of ASA grade I, II, and III undergoing forearm and hand surgeries. It was a single-blinded randomized clinical trial with a control group.

The study enrolled hundred patients between the ages of 18 to 80 years with an ASA physical status of I-III, who were scheduled for surgery of the forearm and hand. Exclusion criteria included failure to cooperate, refusal to participate, known allergy to local anaesthetic, pre-existing neuromuscular disease/nerve injury, prior surgery on the infraclavicular fossa, coagulation disorders, , local infection, chronic obstructive pulmonary disease, respiratory failure, pregnancy. The study was a randomized controlled parallel-group trial, with patients randomly assigned to either the single injection group SI (n=50) or the triple injection group TI (n=50) at a 1:1 ratio. Randomization was performed by a researcher not involved in performing the block.

Before the surgery, all patients underwent thorough pre-anaesthetic evaluation, including routine and specific investigations based on their clinical assessment. They were educated on using a visual analogue scale (VAS) for postoperative pain assessment during the preoperative visit. Additionally, all patients were instructed to fast for 8 hours before the surgery. Upon arrival to the operating room, the patients underwent pre-procedural preparations, including supplemental oxygen, establishing an 18 G intravenous access in the contralateral hand or forearm, and connecting standard ASA monitors to measure vital signs such as electrocardiogram, non-invasive blood pressure, and SpO2.

All procedure was carried out by an experienced anaesthesiologist skilled in ultrasound-guided block techniques to ensure the safe and effective administration of the block. An independent observer monitored the outcome measures to minimize potential bias in the results to ensure accurate observations. Intravenous (IV) fluids were initiated for adequate hydration levels, while all patients received IV premedication consisting of 50mcg fentanyl and 1mg midazolam. Patients were in the supine position, with the ipsilateral arm abducted to 90° and the head slightly turned towards the contralateral side to facilitate the infraclavicular BPB procedure.

The BPBs were performed using a 22-gauge, 100mm procedural block needle (Stimuplex^{R} Ultra 360, B. Braun) and an ultrasound machine (Fujifilm Sonosite M Turbo) equipped with a high-frequency linear array transducer (13-6 MHz) under strict aseptic precautions and ultrasound guidance in both study groups.

The ultrasound transducer was positioned immediately below the midpoint of the clavicle and over the medial infraclavicular fossa with a slight cephalad tilt to direct the ultrasound beam towards the CC space. Within the CC space, the axillary artery was identified, which lies underneath the subclavius muscle. The ultrasound image was optimized to visualize all three cords of the brachial plexus laterally to the axillary artery in one plane, ensuring accurate targeting of the plexus for the block.

For each group, a total amount of LA (20 ml of 0.5% Ropivacaine) was administered, with 2 ml of 2% Lignocaine used for skin infiltration in all BPB blocks. The block needle was inserted in-plane in a lateral-to-medial direction, and the LA was injected in increments of 1 to 2 ml after intermittent negative aspiration, with direct ultrasound visualization used to observe the LA spread. If paresthesia was induced during the procedure, the needle was withdrawn by 2 to 3 mm, and the anaesthesiologist ensured its absence before LA administration. Before the LA injection, the needle tip was always visualized, and the ultrasound screen was placed in a position that prevented patient visibility in both groups. [10]

In the SI group, following skin puncture, the needle was advanced to the brachial plexus sheath, and needle placement was confirmed via direct visualisation and hydro-dissection (opens the perineural space until the needle tip was positioned at the center of the cord cluster) with 1 mL of 0.9% normal saline. [11] Subsequently, a total volume of 20mL of 0.5% Inj. Ropivacaine was gradually administered via small aliquots and a single site over 2-3 minutes. No visible swelling was detected in the cords of the brachial plexus, as shown in the US image.

In contrast, the TI group received the block needle advancement to the medial cord following skin puncture with hydro-dissection. One-third of the LA volume was then delivered into the medial cord, followed by redirection of the needle tip to the lateral and posterior cords. In each cord, one-third of the LA volume was slowly injected, and the spread of the LA around the three cords was observed.

The brachial plexus block (BPB) was evaluated immediately after the LA injection and every five minutes for up to thirty minutes by an independent observer who was blinded to the technique. The sensory block was assessed using an alcohol swab on the dermatomes of the ulnar (fifth finger), median (palmar aspect of the second finger), radial (dorsum of the hand between the thumb and second finger), and musculocutaneous (lateral aspect of the forearm) nerves. Patients quantified the level of the sensory block using an 11-point scale, where 10 indicated normal sensation and 0 indicated no sense to cold. A complete sensory block was defined as a score of 0 in each nerve dermatome. [12,13,14]

The motor block was evaluated using a 3-point scale where 2 indicated no block, 1 indicated paresis, i.e., reduced force compared with the contralateral arm, and 0 indicated paralysis, i.e., incapacity to overcome gravity, which was applied to the whole arm. Accordingly, a complete motor block was defined as a score of 0. [12,13,14]

At the end of the surgery, anesthesia grade was assessed using a 4-point scale as follows: excellent when the surgery was finished with only a brachial plexus block; good for complete analgesia, but the patient complained about their position necessitating intravenous (IV) medication

(<100mg fentanyl and 5mg midazolam); insufficient when IV medication of ≥100mg fentanyl and 5mg midazolam or propofol infusion (25–80mg/kg/min) or an additional local injection at the operative site was required, but the surgery was finished successfully; and failure when general anesthesia was required to complete the surgery.

The presence of hemidiaphragmatic paralysis (HDP), detected by comparison of the pre-and postoperative chest radiographs, and the presence of other complications, such as hematoma formation, Horner syndrome, hoarseness, respiratory distress, neurological complications, nausea, and vomiting, were evaluated in the postanesthetic care unit by an independent observer who was blinded to the group allocations.

This study's primary outcome variable was the blockage rate of all four nerves, while the secondary outcome variables were the performance time, onset time, and anesthesia grade.

Statistical analysis

The present study involved the collection of data and its entry into MS Excel using SPSS version 26.0 for analysis. Based on a statistical power of 90%, a significance level of 5%, and the standard deviation of this difference was found to be 0.8, a sample size of 42 patients (21 patients in each group) was determined to be adequate. However, a sample size of 50 patients (25 patients in each group) was considered to mitigate potential errors and attrition.

The hemodynamic variables were evaluated using the Student t-test. At the same time, the block's onset, sensory and motor block duration, and postoperative analgesia were statistically analyzed using the unpaired t-test. The categorical variables were analyzed using the Fisher exact test, and a P-value of <0.05 was deemed statistically significant.

Result

The performance time of both groups was comparable, and the block onset time of the TI group did not differ significantly from that of the SI group. However, the blockage rate of all four nerves was notably higher in the TI group than in the SI group. The proportion of patients with the complete sensory and motor block at each evaluation time up to 30 minutes after the block was comparable in both groups, with the exception of patients with radial nerve block at 15 minutes, musculocutaneous nerve block at 20 minutes, and median nerve block at 25 and 30 minutes.

No vascular or pleural punctures occurred during the procedures, and complications were limited to ptosis (1 case) and paresthesia (2 cases) in the SI group and nausea (1 case) and hoarseness (2 cases) in the TI group.

Table 1: Patient characteristics of the two groups

	SI group (n=25)	TI group (n=25)	P
Age, yr	41±19	40±15	0.940
Sex (M/F)	32/18	35/15	0.798
Height, cm	167.1±9.2	167.5±9.3	0.850
Weight, kg	66.1±11.0	67.0±12.6	0.700
ASA PS class (I/II/III)	14/34/2	10/38/2	0.470

Table 2: Ultrasound-guided costoclavicular brachial plexus block data

	SI group (n=25)	TI group (n=25)	P
Type of surgery (fracture vs non-fracture)	15/35	18/32	0.220
Needling time, min	2.5±0.8	2.6±1.1	0.630
Performance time, min	3.0±0.9	3.2±1.2	0.520
Tourniquet time, min	46.6±21.5	51.6±26.9	0.380
Surgery time, min	49.9±23.0	53.3±26.5	0.580
Onset time, min	22.2±3.1	21.9±5.1	0.810
Rate of all 4 nerves blockade (n, %)	26 (52%)	42 (84%)	0.003
Anesthesia grade (n) (excellent/ good/ insufficient/fail)	38/4/7/1	40/5/5/0	0.250
Hemidiaphragmatic paralysis (n) (normal/ partial/ complete)	45/5/0	48/2/0	0.090

Discussion

In this study, we conducted a prospective randomized, observer-blinded comparison of single and triple injection sites in the costoclavicular approach of brachial plexus block using ultrasound guidance. Our results showed that the triple injection group had increased consistency in blocking all four nerves compared to the single injection group, without an increase in procedure time, using the same volume of local anesthetic (20 mL) for ultrasound-guided infraclavicular brachial plexus blocks with a costoclavicular approach. These findings suggest that a triple injection approach may be more effective in achieving complete nerve blockade than a single injection approach without prolonging the procedure time or requiring an additional volume of local anesthetic. The study design, which included randomization and observer blinding, strengthens our results' validity.

Recently, Karmakar et al. introduced the CC approach to target the CC space where the three cords are tightly clustered. [8,9] In this study, we observed the cords as hypoechoic clusters that maintained a consistent anatomic arrangement to each other and the axillary artery. These findings are consistent with the research conducted by Demondion et al. [15], suggestive of a high success rate of this approach.

While surgical anesthesia was provided effectively, the blockage rate of all four nerves was about 50% 30 minutes after the block, similar to the results of the SI group in this study (52.9%).

A study conducted by Li et al. [8] aimed at describing the anatomy, technique, and block dynamics of an ultrasound-guided costoclavicular brachial plexus block.

In this study, we focused primarily on the success rate of all four nerves blockage because failure in blocking one nerve completely can lower the anesthesia grade if surgery is performed in an area innervated by an incompletely blocked nerve.

Moreover, the study found that the "excellent" anesthesia grade rates were similar in the two groups (SI group 64.7% vs. TI group 82.4%, P=.99). The study also utilized triple injections to target specific cords. However, the LA was divided so that only one-third of the total volume was injected into each cord. In addition, the CC approach is advantageous in the clinical setting as all three cords are rarely visualized in a single sagittal ultrasound scan in the conventional approach. It was found that the triple injections seemed to be effective in ensuring the even distribution of LA to each of the three cords.

The anesthesiologist who administered all blocks were not blinded to the group allocations. However, to minimize potential bias, sensory-motor test evaluations were conducted by an independent and blinded observer. Therefore, we believe that any unintentional bias from the anesthesiologist had little impact on the overall results, as a separate, unbiased party performed the evaluations. This approach is consistent with previous studies that have similarly attempted to control for potential sources of bias in the research design. [16]

However, the CC approach can be challenging to advance the needle to the desired site. In some cases, the out-of-plane technique was used where the in-plane technique was not possible. Needle advancement or LA injections without adequate needle tip visualization can cause unintentional vascular, neural, or visceral injuries. [17]

In conclusion, this study demonstrated that the TI group increased the consistency of infraclavicular BPB in terms of the blockage rate of all four nerves compared with the SI group without an increase in the procedure time, using the same volume of LA for US-guided infraclavicular BPBs with a CC approach.

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