Original Article

# Analysis of the Characteristics and Intricacies of Arrangement of Neural Elements in the Costoclavicular Block Using Ultrasound: A Retrospective Qualitative Study

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## Abstract

**Background:** Ultrasound (US)-guided costoclavicular block (CCB) is a promising new approach to brachial plexus (BP) block which is increasingly being utilized. Conventionally, the costoclavicular space (CCS) has been described to contain three cords. However, there may be variations in the neural pattern of the BP which is important to know to prevent inadvertent injury. We intend to describe the variations in neural patterns from retrospective scans of patients receiving costoclavicular BP block. **Methods:** The stored US images of patients who had received BP block using the CCB for surgery at the level of the elbow or below in the last year (from March 2021 to March 2022) were analyzed by two investigators independently. The clinical data were retrieved from the records of the same patients for the study outcomes. We collated the variations of the neural pattern, the number of neural structures seen, and the echogenicity of the structures in the costoclavicular BP space. **Results:** In the CCS, the median number of neural structures was 4.5 (minimum of 3 to maximum of 8). With the BP lateral to the axillary artery and sandwiched between the subclavius-pectoralis minor superiorly and the serratus anteriorly inferiorly, numerous variations in the neural structures were noted. The most common arrangement was caterpillar-like (28.6%) and pecker-like (20.3%). The neural structures were found to be hypoechoic in the majority (66%). **Conclusion:** The CCS hosts several mostly hypoechoic neural structures which may be the variations of the cords or the extension of BP divisions. These new findings have been unreported in the recent past.

**Keywords:** Axillary artery, brachial plexus block, brachial plexus, local anesthesia

## Introduction

An ultrasound (US)-guided costoclavicular block (CCB) was first described in 2015[1] and has increasingly been used ever since for anesthesia for surgeries of the upper limb below the shoulder.[2] This approach targets the cords of the brachial plexus (BP) which lie lateral to the axillary artery in the costoclavicular space (CCS).

Classically, the costoclavicular anatomical space has been described to contain three BP cords based on studies using anatomic dissection, sonoanatomy, and histological slides.[3] The purported advantage of the costoclavicular BP block (CCB) is that all three cords are visualized in a single US window and are clustered together and share a probable consistent anatomical position.[3] However, the identification of BP in the CCS is considered challenging because of the depth of the space.[4] We observed several neural structures of the BP during the US scans of the CCS. The increasing number of neural structures in the CCS may signify the extension of BP divisions or variations in the infraclavicular area.[5,6] This may be clinically relevant because we ought to be aware of the variation in the neural arrangement at the block site before injecting the local anesthetic (LA) while performing the block. Therefore, we designed this retrospective study to assess if there were variations in the pattern of nerve structures in the CCS.

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**Received:** 30-12-2022 **Revised:** 29-04-2023 **Accepted:** 17-06-2023 **Available Online:** 21-03-2024

Access this article online

Quick Response Code:

Website: https://journals.lww.com/jmut

DOI: 10.4103/jmu.jmu_125_22



**How to cite this article:** Diwan S, Gupta A, Sancheti P, Dadke M. Analysis of the characteristics and intricacies of arrangement of neural elements in the costoclavicular block using ultrasound: A retrospective qualitative study. J Med Ultrasound 2024;32:139-42.

## Methods

After obtaining institutional ethics committee approval (IEC-STOR/Agenda-070), this descriptive retrospective study was conducted at a tertiary care orthopedics and rehabilitation center. The patient consent was waived by the Institutional Ethics Committee. A total of 965 patients received CCB, of which we included data from 182 patients, who revealed various patterns of BP. Of the 182 patients, 115 were males and 67 were females [Table 1].

All the blocks were performed by anesthesiologists experienced in US-guided nerve blocks. A linear US high-frequency probe (L13-6 MHz SonoSite Edge; FUJIFILM SonoSite, Amsterdam, The Netherlands) was used to identify the BP. All blocks were performed with an in-plane technique, and, ropivacaine 0.5% (20–25 mL) was injected.

### Technique

The linear probe is deployed below the clavicle in the transverse axis and tilted toward the clavicle to insonate beneath it and obtain the following view [Figure 1a].

Typically, in a transverse axis of US, the arrangement of BP in CCS is between the subclavius and the serratus anterior, from medial to lateral would be the axillary artery and the BP nerve structures. After obtaining an appropriate image and excluding vascular structures with color mode, an insulated needle is brought in-plane from lateral to medial.[3]

The images of the costoclavicular BP before and following the block are routinely stored in all cases for teaching and research purpose. In this study, the stored US images of patients of 182 undergoing surgery at the level of the elbow or below who had received BP block using the costoclavicular approach in the last year (from March 2021 to March 2022) were analyzed for nerve pattern and the number of nerve structures, by two investigators independently. Their interpretations were collated by a third investigator who finally recorded the data. We charted the variation in the pattern of nerve placements in various forms, the number of nerve structures, and the echogenicity.

### Statistical analysis

The data collected were collated and entered into an Excel sheet for descriptive statistical analysis using Microsoft Excel software (Microsoft Corporation, Redmond, Washington, United States). The results were expressed as mean ± standard deviation for continuous data and categorical data were expressed as numbers and percentages.

**Table 1: Details of demographic data, details of surgeries performed, needle tip identification, types of spread**

| Parameter | Value |
|---|---|
| Age, median (range) | 42 (22–87) |
| Gender (male/female) (*n*) | 115/67 |
| Type of surgery (*n*) | |
| Hand | 56 |
| Forearm | 75 |
| Elbow | 51 |
| Neural elements seen, median (range) | 4.5 (3–8) |
| The pattern of elements (*n*) | |
| Caterpillar | 52/182 |
| Pecker | 37/182 |
| Squarish | 25/182 |
| Sponge | 28/182 |
| Seal | 20/182 |
| Oval | 12/182 |
| Dumbleshape | 8/182 |
| The volume of LA (mL), mean±SD | 23.4±4.0 |
| Need for GA, *n* (%) | 3/182 (1.6) |

LA: Local anesthetic, GA: General anesthesia, SD: Standard deviation

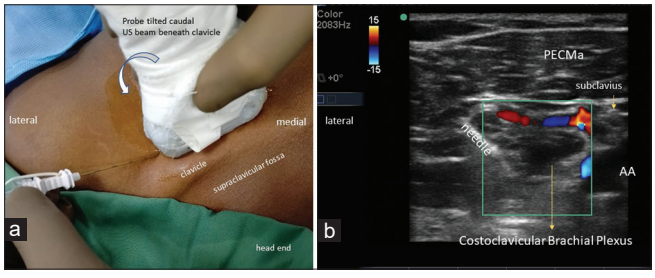


**Figure 1:** (a) Probe and Needle Placement; (b) Intraplexus abnormal vasculature in the costoclavicular space. PECMa: Pectoralis major

## Results

A variety of patterns were noted regarding the BP neural structures. The neural structures were positioned lateral to the axillary artery and between the subclavius or pectoralis minor superiorly and the serratus anterior inferiorly. The most common arrangement was caterpillar-like (52/182; 28.6%) and pecker-like (37/182; 20.3%) [Figures 1 and 2]. The other arrangements were squarish, sponge-like, seal, ovalish, and dumble-shape [Table 1 and Figures 3, 4]. The median number of BP elements was 4.5 (minimum of 3 to maximum of 8). In 22 cases, the divisions forming the cords could be visualized in the space. The plexus elements were found to be hypoechoic in the majority (66%), 22% of patients had hyperechoic elements while the rest of the cases had a mix of both. Intraplexus abnormal vasculature was seen in 5/182 (2.7%) cases [Figure 5].

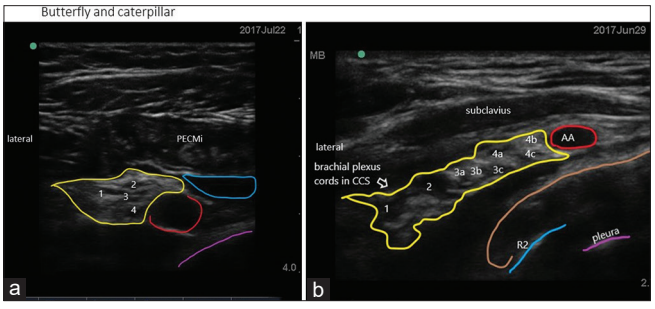


**Figure 2:** Various topographical placements of the neural elements in the costoclavicular space. (a) butterfly; 1, 2, 3, 4: Separate neural elements, (b) caterpillar; 1, 2: Separate neural elements; 3a, 3b, 3c: Seem to be neural elements from one origin and 4a, 4b, 4c = Seem to be neural elements from one origin

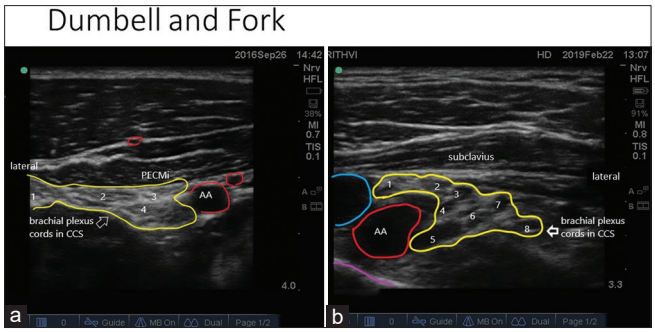


**Figure 3:** Various topographical placements of the neural elements in the costoclavicular space. (a) dumbbell; AA: Axillary artery; PECMi: Pectoralis minor; 1, 2, 3, 4: Separate neural elements, (b) fork. AA: Axillary artery; CCS: Costoclavicular space; 1, 2, 3, 4, 5, 6, 7, 8: Separate neural elements

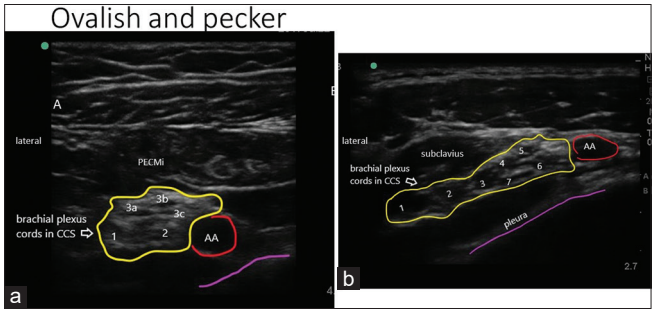


**Figure 4:** Various topographical placements of the neural elements in the costoclavicular space. (a) Ovalish; 1, 2: Separate neural elements; 3a, 3b, 3c: Seem to be neural elements from one origin, (b) Pecker; 1, 2, 3, 4, 5, 6, 7, 8: Separate neural elements

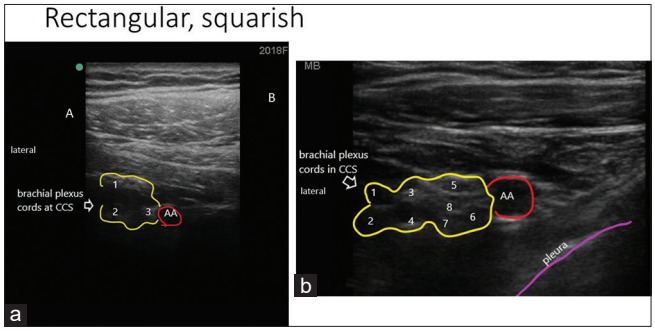


**Figure 5:** Various topographical placements of the neural elements in the costoclavicular space. (a) squarish; 1, 2, 3: Separate neural elements, (b) rectangular; 1, 2, 3, 4, 5, 6, 7, 8: Separate neural elements

## Discussion

In this retrospective qualitative analysis of patients undergoing upper limb surgeries under CCB, converse to the popular belief that only three BP cords are located in the CCS, we found a higher number of neural elements in the majority of the cases and in 66% of cases, the neural elements were hypoechoic and caterpillar-like arrangement of neural elements was the most common.

The ventral rami of spinal nerves of C5, C6, C7, C8, and T1 combine to form the BP. It is grouped into five anatomical assemblages known as roots, trunks, divisions, cords, and their terminal branches. The roots combine to form the superior, middle, and inferior trunk which further gives rise to anterior and posterior divisions.[7] The posterior division of all trunks forms the posterior cord (PC), the anterior division of the superior and middle trunks forms the lateral cord (LC), and the anterior division of the inferior trunk continues as the medial cord (MC).[8]

The US-guided CCB block is the recently described alternative approach to the traditional sagittal paracoracoid approach of the infraclavicular block at the CCS immediately caudal to the midpoint of the clavicle. The three cords in the costoclavicular area exhibit a triangular arrangement with the LC most superficial and anterior to the MC and PC. The MC is posterior to the LC and medial to the PC. The PC is lateral to the middle cord and posterolateral to the LC. The main purported advantage of this approach is that the three BP cords are compactly arranged at this level clustered lateral to the artery and are, therefore, amenable to blockade by single or two injections with lower volumes of LA.[1,3,5,9] However, in our study, the majority of the US images of the CCB block revealed more than three neural elements which were likely the divisions of the BP or the variations of BP cords.[3]

A US imaging study recently described the anatomical aspects of the CCS.[10] They identified that the neural elements lie lateral to the artery and the transition from trunks to the cords of the BP occurs at this level. We reiterate that the CCS is not a simple arrangement of three cords lateral to the artery but as described in our study, is relatively complex with a variable pattern and a varying number of neural structures, depending upon whether divisions have united in the retroclavicular area or they unite distal to the inferior edge of the clavicle. Failure to identify these neural elements might affect the success rates and may be the reason for inconsistent results with this approach.[11]

A recent cadaveric study documented that during the CCB, the needle may contact the medial antebrachial cutaneous nerve, medial brachial cutaneous nerve, and pectoral nerves and was found to even puncture the LC in 3 out of 8 cases.[12] Despite using the US and being well aware of the placement of the LC, its puncture was noticed in these instances, thereby restating the importance of awareness of the topography and variations in the number of neural structures, since it would be relevant in preventing neural injury and ensuring adequate spread using this approach. These individual branches encountered in the CCS in this study may be some of the neural structures witnessed, but more likely, these neural structures were the divisions or anomalous variations of the cords. Since the CCS is the proximal-most part of the BP in the infraclavicular area and extends behind the clavicle, the area is likely a transition zone for the truncal divisions to the cords. A cadaveric study[13] investigating the division of the BP below the clavicle observed that the LC was formed at the inferior edge of the clavicle.

Further, anatomical variations are the next possibilities. A meta-analysis of anatomic anomalies and variations of the BP

revealed an incidence of 16%.[14] A cadaveric study indicated several variations in the origin, location, and course of the brachial cords in relation to the axillary artery.[15] Moreover, communicating branches exist between the cords increasing the neural structures in this particular region. A double LC, communicating branches from PC to the medial root of the median and the LC, and a communicating branch from the posterior division to the MC are a few of the many variations described.[15] These can add to the number of neural structures in the costoclavicular area.

In a cadaveric study, neurovascular structures have been observed in the vicinity of the needle especially the thoracoacromial artery or its branches during both medial-lateral or lateral to medial CC-BP approaches.[12] We found an abnormal vessel in 2.7% of the cases. We would recommend a cautious approach using a color Doppler before needle placement in this area.

There are some limitations to our study. The retrospective design is a limitation of the present study. Furthermore, whether the neural structures seen were the divisions or individual nerves could not be established. This would require anatomical correlation in future. However, we found the maximum neural structures were 8 in the CCS which attests to our hypothesis that elements other than cords are present in this space. The use of neurostimulation could have possibly helped us evaluate the exact identity of the nerve and could be a limitation. Moreover, a similar scan should have been performed on the contralateral side to evaluate the differences. Likewise, considering the anatomic variation, the local anesthetic volume leading to success rate and the postblock diaphragmatic movements were not evaluated.

The study would have implications in many ways. Although microscopic ultrastructural anatomy[16] and US investigation[10] have found a paraneural sheath around the 3 BP cords in the costoclavicular area, as an antithesis to this concept, we observed numerous neural structures. Further, the usual technique of needle tip position and subsequent LA injection is central to the three cords. A clinical study mentions double injection is superior to a single injection and postulates that a third injection would be necessary to improve block efficacy.[17] The present study suggests the possibility of several neural structures and different nerve patterns, based on which we perceive a multiple injection technique would be imperative.

## Conclusion

A retrospective US scan of costoclavicular area revealed several neural structures in various patterns which are possibly the divisions of trunks or variations of the cords unlike what is seen with the classical lateral infraclavicular approach. To our knowledge, such variations are unreported in the literature. Whether these findings can have several implications for future clinical practice and research on CCB remains to be explored.


## Financial support and sponsorship

Nil.

## Conflicts of interest

There are no conflicts of interest.


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