Clinical Communication

Ultrasound-guided infraclavicular approach to brachial plexus: A cadaveric study

INTRODUCTION

Quality clinical anaesthetic care is based on choosing the safest regional technique, for which in-depth anatomical knowledge of the process is essential.[1] The brachial plexus block provides effective analgesia and anaesthesia in the upper limb. Different techniques have been described[2] without differences in success rates (92% in ultrasound-assisted techniques) between supraclavicular, infraclavicular, and axillary brachial plexus blocks.[3]

Infraclavicular brachial plexus block (ICBPB) offers several advantages such as less pain secondary to tourniquet ischaemia, higher quality blockade of musculocutaneous nerve, shorter block performance time, ability to place a secure catheter and a decreased incidence of diaphragmatic paresis.[4] Various ultrasound-guided ICBPB techniques have been described: lateral in the infraclavicular fossa (LICF),[5] costoclavicular from lateral to medial (CLM)[6] or costoclavicular from medial to lateral (CML),[7] and retroclavicular (R).[8] All of them present disadvantages in needle visibility because of the steep angle of insertion, sympathetic block (LICF), the need for several punctures, multiple injections, larger volumes of local anaesthetic administration,[9] increased procedural time (LICF, CML, and CLM), risk of nerve lesion, and spread to the inter-scalene gap or paravertebral or epidural space.[10]

Although the incidence of complications associated with brachial plexus blocks is low, ultrasound has minimised it. Although some meta-analyses describe a greater association with infraclavicular approaches,[11] other reviews and clinical trials report the opposite.[12] There were no differences between several infraclavicular approaches, and the presence of neurovascular in the needle path is the most important safety factor.[10]

This study aimed to compare diverse infraclavicular subclavian brachial plexus block approaches: ultrasound characteristics, anatomical structures traversed by the block needle, and correct diffusion of local anaesthetic. This study aimed to assess the possibility for needle visualisation without requiring arm abduction and cervical mobility in subclavian block techniques.

METHODS

This descriptive study of formalin-embalmed volunteer body donor cadavers was was carried out after approval from the Autonoma University Research Ethics Committee in Madrid (vide approval number IP 7/2014, 7 June 2014). The study followed the Helsinki Declaration on human cadavers. None of the cadavers in this study had pathologies or scars in the clavipectoral triangle.

All the cadavers were positioned supine, with the arms close to the thorax and the head turned to the contralateral side of the investigation area [Figure 1]. After locating the clavipectoral triangle, an expert sonographer (defined by the Australian Sonographers Accreditation Registry)[13] performed an ultrasound scan by using a linear transducer (HFL50xz Sonosite® SII) over the clavicle until the brachial plexus trunks were located, avoiding acoustic shadows corresponding to bony structures and vascular puncture. The probe was placed in the clavipectoral triangle just medial to the deltoid muscles and under the clavicle [Figure 1], tilted slightly cephalad to optimise the visualisation of the subclavian artery and the three cords of the brachial plexus just lateral. Subsequently, the second researcher, supervised by the first, chose one approach, cranial or caudal in-plane or out-of-plane, to insert the blocking needle (90 mm, 22G Akus®, Akus Anaesthesia, Murcia, Spain) until it reached the brachial plexus. The investigator selected the optimal ultrasound approach for visualising the reference anatomical structures and the full needle path. After the puncture, 20 mL of mepivacaine 1.5% was administered while its diffusion around the artery was checked. The needle was left in place for subsequent dissection to check its correct location, the fluid surrounding the artery, and the structures crossed by the needle. The block was performed on both sides of the cadaver.

Each researcher evaluated the satisfaction with the technique based on the following parameters: number of structures located in the scan (0: nothing; 1: one cord; 2: two cords; 3: three cords; 4: artery and all the cords; 5: artery, plexus, and subclavian muscle; 6: artery, plexus, subclavian, and serratus anterior muscles; 7: all the structures identified in item 6 and the pectoralis major muscle; 8: the structures identified in item 7 and the pleura and 9: the structures identified in item 8 and other subclavian vessels); ease of puncture with a 0–10 categorical scale, where 0 corresponded to the minimum difficulty and 10 the maximum; another 0–10 categorical scale, where 0 corresponded to the minimum and 10 the maximum degree of subjective satisfaction/comfort with the technique; and correspondence with the anatomical dissection (2: tip needle located in the brachial plexus and 20 mL of fluid was aspirated after injection, 1: tip needle in the brachial plexus but less than 20 mL of local anaesthetic aspirated after injection, and 0: the needle went through structures that could cause major complication (subclavian vein or artery and pleura), tip needle outside the brachial plexus, or no fluid aspirated). If the needle traversed one of the structures mentioned, the punctuation was noted as 0 [Table 1].

Each hemithorax was carefully dissected to check the correct location of the needle and adjacent structures in the subclavian region. Two anatomical experts independently identified the structures. The correct aspiration of the volume of anaesthetic administered by employing negative pressure in the syringe used for its administration was also noted. Then, the skin, subcutaneous tissue, and the subclavian and pectoralis muscles were removed to expose back content. The arteries were then painted in red, veins in blue, and nerves in yellow along their entire length to facilitate the simulation for didactic purposes [Figure 2].

All analyses were performed using the Statistical Package for the Social Sciences® (SPSS) Statistics version 20 (International Business Machines SPSS, Inc., Chicago, Illinois, USA). A descriptive study of the variables studied was carried out. The data were expressed as mean and standard deviation (SD). The quantitative values have been compared using the Student's *t*-test. Values with $P < 0.05$ were considered significant.

RESULTS

Seven cadavers (five female and two male subjects) were studied. The cadavers had a mean (SD) age of 70.57 (6.30) years and a body mass index (BMI) of 24.35 (2.05) kg/m^2. None had previous thoracic surgery over the thorax or vascular abnormalities. The ultrasound landmarks were positively identified on both sides of the cadaver (14 dissections).

The three approaches used were caudal in-the-plane, cranial in-the-plane and cranial out-of-the plane [Figure 1 and Table 1]. All the approaches achieved high scores in ease and satisfaction. The mean (SD) of number of structures visualised with ultrasound was 7.57 (0.98). The mean (SD) of ease of puncture was 8 (0.84). The mean (SD) of satisfaction with the technique was 7.86 (0.83), and the mean (SD) match in dissection was 1.5 (0.5). Best punctuations were obtained in the out-of-plane approach, especially in

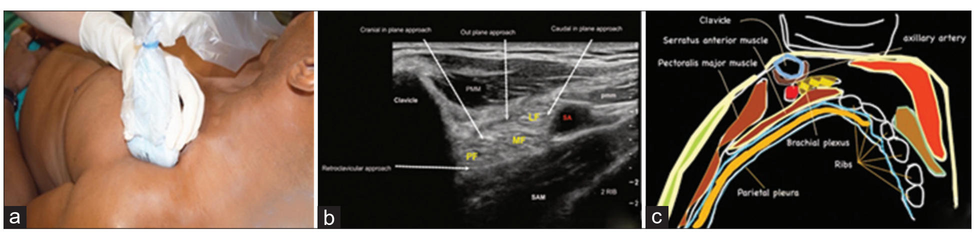

Figure 1: Echo-anatomy of the clavipectoral triangle. (a) Clavipectoral triangle and probe position. (b) Needle trajectories to reach the target: retroclavicular, cranial in-plane or out-of-plane, and caudal in-plane approaches. (c) Diagram of the anatomical structures visualised by ultrasound scanning. PMM = Pectoralis Major Muscle, PM = Pectoralis Minor Muscle, PF = Posterior Cord, MF = Medial Cord, LF = Lateral Cord, SA = Subclavian artery, PMM = Pectoralis minor muscle, SAM = Serratus Anterior Muscle, 2 RIB = Second Rib

Table 1: Evaluation of the techniques

	Gender	Age (years)	Puncture approach	Number of structures located by ultrasound scan*	Ease of puncture (0–10)	Satisfaction with the technique (0–10)	Match in dissection (0–2)
Left/right cadaver number 1	Female	76	Caudal in-plane	6/6	8/7	7/8	1/1
Left/right cadaver number 2	Female	71	Caudal in-plane	6/8	8/9	6/8	1/1
Left/right cadaver number 3	Male	69	Out-of-plane	8/8	9/9	8/7	2/2
Left/right cadaver number 4	Male	78	Out-of-plane	8/8	8/8	8/8	2/2
Left/right cadaver number 5	Female	57	Caudal in-plane	7/7	8/9	9/8	2/1
Left/right cadaver number 6	Female	73	Out-of-plane	9/9	6/7	9/9	1/1
Left/right cadaver number 7	Female	70	Cranial in-plane	8/8	8/8	8/7	2/2

*Ultrasound-guided puncture was not allowed to begin until at least the subclavian vessels, the three cords of the brachial plexus, and the subclavian muscle were identified. (The subclavian muscle lies deep to the clavicular head of the pectoralis major muscle.)[14]

the match in dissection items. Tables 1 and 2 show the values of parameters obtained using different approaches. No significant differences were found when comparing the caudal in plane and out of plane approaches ($P = 0.758$).

The subclavian artery constitutes the main reference structure for locating the brachial plexus at this level. The brachial plexus is divided into lateral, posterior, and medial cords, usually found at 9, 6, and 3 o'clock, respectively, to the subclavian artery [Figure 1b]. When the ultrasound scan was performed, anechoic structures corresponding to bones (clavicle, coracoid process, and ribs) and vessels (subclavian artery and vein) and hypoechoic structures corresponding to muscles (pectoralis, deltoid, and serratus anterior) were visualised and were found to be usually surrounded by hyperechoic lines (corresponding fasciae). Nerve structures were observed as hyperechoic structures [Figure 1]. After administering 20 mL of mepivacaine 1.5%, a 'U-shaped' hypoechoic shadow was visualised along the axillary artery's lateral, posterior, and medial aspects. The solution was aspirated with a mean (SD) volume of 17.5 (2.5) mL.

With the cadaver in the supine decubitus position and the probe parallel to the superficial border of the deltoid muscle, the needle was inserted in four different planes:

1. In-the-plane, from cephalad to caudal medial to lateral, starting just caudal to the clavicle and running to the lateral aspect of the axillary artery [Figures 1 and 2].
2. In-the-plane, from caudal to cranial [Figure 2b].
3. Out-of-plane [Figure 2c] from caudal to cranial and lateral to medial. The needle trajectory was often quite steep, which might have limited the visualisation of the needle tip. The needle could be inserted in plane or out of plane.

Subsequent dissections confirmed the needle placement between two cords of the brachial plexus [Figure 2]. The correspondence between ultrasound images and dissection was high [Table 1]. The needle did not pass through neurovascular structures (which could have caused serious complications), except for one in which the axillary vein was punctured.

DISCUSSION

The subclavian approach to brachial plexus is a newly described ultrasound-guided (USG) brachial plexus block technique that optimises sonographic needle visualisation. This technique provides broad anaesthesia of the upper extremities with a single injection visualised and away from the vital anatomical structures of the neck and thorax, thereby reducing complications. In addition, patient positioning for the technique is suitable for the awake and acutely traumatised patient as the upper extremity remains in adduction in a comfortable position at the patient's side without neck mobilisation or arm abduction requirement,[14-16] which makes it the regional approach of choice in the presence of a cervical collar or upper extremity splints.

Table 2: Comparison of the main variables for different approaches

	Structures located	Ease of puncture	Satisfaction	Match in dissection
Caudal in-plane	6.67 (0.74)	8.17 (0.69)	7.67 (0.94)	1.17 (0.37)
Out-of-plane	8.33 (0.47)	8.5 (0.5)	8.17 (0.69)	1.67 (0.47)
Cranial in-plane	8 (0)	8 (0)	7.5 (0)	2 (0)

Data expressed as mean (standard deviation)

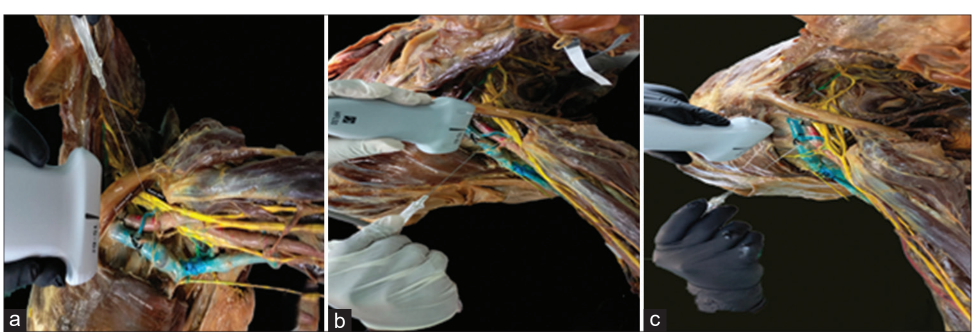

Figure 2: Cadaver probe position and needle position. (a) In-plane approach: cranial needle insertion. (b) In-plane approach: caudal needle insertion. (c) Out-of-plane approach: Yellow- brachial plexus, red- axillary artery, blue: axillary vein

ICBPB is indicated to provide analgesia/anaesthesia of the distal part of the upper limb, from the forearm to the wrist and the fingertips of the hand. ICBPB approaches are deeper than supraclavicular ones, making complications more frequent.[15] Multiple variations of Labat's technique have been described using anatomical references, neurostimulation, and direct visualisation by ultrasound.[2,17] These techniques can be classified into proximal or distal, depending on whether the anaesthetic injection is made over the first portion of the axillary artery, such as CLM[7] or CML[18] or over the second portion, such as or lateral sagittal block.[19-21] The subclavian block described in this article constitutes an example of a proximal block.

Numerous researchers have studied the visibility of the brachial plexus cords by ultrasound. In the current study, the three cords of the plexus were located in a constant relationship with the axillary artery [Figure 1], as described by Leurcharusmee[22], in contrast to Di Filippo's findings.[23] One of the disadvantages of infraclavicular blocks is the depth and the narrow-angle that the needle must follow. This means that it should be performed preferably by locoregional specialists with extensive experience in anatomy and ultrasound. Some authors have suggested that the arm abduction manoeuvre could reduce the depth of cords in the LICF approach, especially in obese patients.[22] However, the Sala-Blanch study did not demonstrate improved visualisation with arm abduction.[6]

We used 20 mL of local anaesthetic in the subclavian technique, which we think is sufficient to obtain a successful block. However, the high volumes of anaesthetic (40 mL) required for the LICF approach, the need for numerous punctures, the variability in the position of individual cords relative to the axillary artery, and the poor visualisation of the needle tip explain the higher incidence of complications with infraclavicular blocks.[24] Respiratory impairment or failure following an infraclavicular procedure may be caused by the phrenic nerve blockade or the local anaesthetic's epidural spread.[25,26] In the proposed approach, we avoid the medial insertion of the needle and the use of large volumes of anaesthetic.

Sala-Blanch[6] proposed that the costoclavicular space (CCS) is a suitable site for ultrasound-guided ICBPB because brachial plexus cords are relatively superficial in location. Costoclavicular block often unblocks the medial cord and the intercostobrachial nerve, attributed to septa that prevent spread between them, inhibiting a dorsal and medial spread around the subclavian or axillary artery.[1,15,24,27] Diaphragmatic paresis and prolonged Horner's syndrome secondary to this blockage have also been described.[25,28] The diffusion of local anaesthetic outside the target in the subclavian approach can be estimated by aspirating the administered content after visualising a U-shaped hypoechogenic shadow surrounding the artery. However, it is possible to find incomplete blocks due to the septa [Figure 2].

Distal approaches are associated with a higher probability of vascular puncture and, therefore, are not recommended in anticoagulated patients. Leurcharusmee *et al*. suggest the CLM approach in these patients as the needle tip is between the cords, but Sivapurapu *et al*.[10] confirmed that the acromio-thoracic artery is on the needle pathway. Our study found the needle far from the acromio-thoracic artery and its branches in the subclavian approach. Nevertheless, we think it is necessary to visualise the axillary vessel, which is highly variable in different subjects or even absent in clavicle fractures or subcoracoid shoulder dislocations. Other vessels (e.g., the cephalic vein) and the acromion-thoracic branch must be respected too because they can cause serious complications. In our study, the axillary vein was punctured in one case. In the Sivapurapu study, the retroclavicular block to the infraclavicular region (RAPTIR) obtained the best outcomes in tip visibility. However, the needle passes through an acoustic shadow behind the clavicle, and the structures located below (suprascapular nerve and vein) could be injured.[14] In the subclavian approach, the arm is placed in adduction, and the needle is inserted in the caudal to the cranial plane or out-of-plane to avoid these inconveniences.

This study presents several limitations. It involved cadavers where the stresses and deformations induced by muscular contraction could not be simulated in the non-clinical setting. Many parameters observed are subjective evaluations as the assessment of the sonographic images, but no cross-reference with external experts in ultrasound evaluators was carried out.

CONCLUSION

The subclavian approach to the brachial plexus is a newly described USG technique that optimises sonographic needle visualisation for ease of performance in different planes with a single injection away from the vital anatomical structures of the neck and thorax. It does not require neck mobilisation or arm abduction.

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Conflicts of interest

There are no conflicts of interest.

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