BRIEF TECHNICAL REPORT

Anatomic Basis for Brachial Plexus Block at the Costoclavicular Space

A Cadaver Anatomic Study

Xavier Sala-Blanch, MD,† Miguel Angel Reina, MD, PhD,‡§ Pawinee Pangthipampai, MD,|| and Manoj Kumar Karmakar, MD, FRCA, FHKCA, FHKAM||*

Background and Objectives: The costoclavicular space (CCS), which is located deep and posterior to the midpoint of the clavicle, may be a better site for infraclavicular brachial plexus block than the traditional lateral paracoracoid site. However, currently, there is paucity of data on the anatomy of the brachial plexus at the CCS. We undertook this cadaver anatomic study to define the anatomy of the cords of the brachial plexus at the CCS and thereby establish the anatomic basis for ultrasound-guided infraclavicular brachial plexus block at this proximal site.

Methods: The anatomy and topography of the cords of the brachial plexus at the CCS was evaluated in 8 unembalmed (cryopreserved), thawed, fresh adult human cadavers using anatomic dissection, and transverse anatomic and histological sections, of the CCS.

Results: The cords of the brachial plexus were located lateral and parallel to the axillary artery at the CCS. The topography of the cords, relative to the axillary artery and to one another, in the transverse (axial) plane was also consistent at the CCS. The lateral cord was the most superficial of the 3 cords and it was always anterior to both the medial and posterior cords. The medial cord was directly posterior to the lateral cord but medial to the posterior cord. The posterior cord was the lateral most of the 3 cords at the CCS and it was immediately lateral to the medial cord but posterolateral to the lateral cord.

Conclusions: The cords of the brachial plexus are clustered together lateral to the axillary artery, and share a consistent relation relative to one another and to the axillary artery, at the CCS.

(*Reg Anesth Pain Med* 2016;41: 387–391)

Ultrasound-guided (USG) infraclavicular brachial plexus block (ICBPB) is commonly performed at the lateral infraclavicular fossa (LICF) where the cords of the brachial plexus are located deep to the pectoral muscles and surrounding the second part of the axillary artery.[1–3] However, at the LICF, the cords are located at a depth (3–6 cm),[4] separated from one another,[5,6] there is substantial variation in the position of the individual cords relative to the axillary artery (second part),[5,6] and all 3 cords are rarely visualized in a single ultrasound image.[5] This may explain why relatively large volumes of local anesthetic[2] and/or multiple injections[1,2] are used for ICBPB. We have recently proposed[7] that the "costoclavicular space" (CCS),[8] which is located deep and posterior to the midpoint of the clavicle[6] and where the cords of the brachial plexus are relatively superficial in location,[8,9] clustered together,[8,9] and share a consistent relation with each other[8,9] may be a more suitable site for USG ICBPB.[7] However, currently, there is paucity of data on the anatomy of the brachial plexus at the CCS.[7–9] Published data describe the topography of the cords below the midpoint of the clavicle,[8,9] in the sagittal plane,[8,9] and in connection with the vertical infraclavicular block technique.[9] There are also no data describing the safety and efficacy of a USG ICBPB at the CCS. We undertook this cadaver anatomic study to define the anatomy and arrangement of the cords of the brachial plexus at the CCS and thereby establish the anatomic basis for USG ICBPB at this proximal site.

METHODS

This study was approved by the Research Ethics Committee of the University of Barcelona and performed in the dissection room of the Department of Human Anatomy and Embryology at the Medical School of the University of Barcelona. Eight unembalmed (cryopreserved), thawed, fresh adult human cadavers were studied. None of the cadavers studied had any obvious pathology or had undergone any intervention or surgery over the infraclavicular fossa.

Anatomic Dissection

The cadavers were positioned in the supine position, with the arm abducted to 90 degrees on the side to be dissected. The medial infraclavicular fossa (MICF), immediately caudal to the middle-third of the clavicle and above the medial border of the pectoralis minor muscle, was carefully dissected in layers in 3 cadavers on both sides (total 6 dissections). The identities of the cords were confirmed independently by the 2 dissectors (X.S.B. and M.K.K.). Thereafter, the pectoralis minor muscle was cut at its lateral edge (ie, from its origin from the coracoid process) and reflected medially to expose the LICF and its contents (Fig. 1A). A single red silicone loop was applied around the axillary artery, close to the origin of the thoracoacromial branch, and 2 yellow silicone loops were applied around the cords of the brachial plexus (Fig. 1B). The first yellow loop was applied to the cord that was most superficial and adjacent to the axillary artery and the second yellow loop was applied to the other 2 cords that were located slightly deeper and posterior to the above (Fig. 1B). The loops allowed gentle traction to be applied on the cords so that their relationship could be accurately defined. Once the cords were identified, the middle-third of the clavicle was cut and removed without disturbing the underlying anatomy of the CCS (Fig. 1C). The arrangement of the cords in the CCS[7] was then defined and their relationship to each other and the axillary artery was evaluated and documented photographically (Fig. 1).

Anatomic Section

Two cadavers with the arms abducted to 90 degrees were frozen at −20 °C for 24 hours. The frozen bodies were placed in

From the *Department of Anesthesiology, Hospital Clinic Barcelona; †Department of Human Anatomy and Embryology, University of Barcelona, Barcelona; ‡Department of Anesthesiology, Madrid-Montepríncipe University Hospital; §School of Medicine, CEU San Pablo University, Madrid, Spain; and ||Department of Anesthesia and Intensive Care, The Chinese University of Hong Kong, Shatin, Hong Kong, SAR, China.
Accepted for publication December 16, 2015.
Address correspondence to: Manoj Kumar Karmakar, MD, FRCA, FHKCA, FHKAM, Department of Anesthesia and Intensive Care, The Chinese University of Hong Kong, Prince of Wales Hospital, Shatin, New Territories, Hong Kong, SAR, China (e-mail: karmakar@cuhk.edu.hk).
The authors declare no conflict of interest.
This work was locally funded by the Department of Anesthesiology, University of Barcelona, Barcelona, Spain.

ISSN: 1098-7339
DOI: 10.1097/AAP.0000000000000393

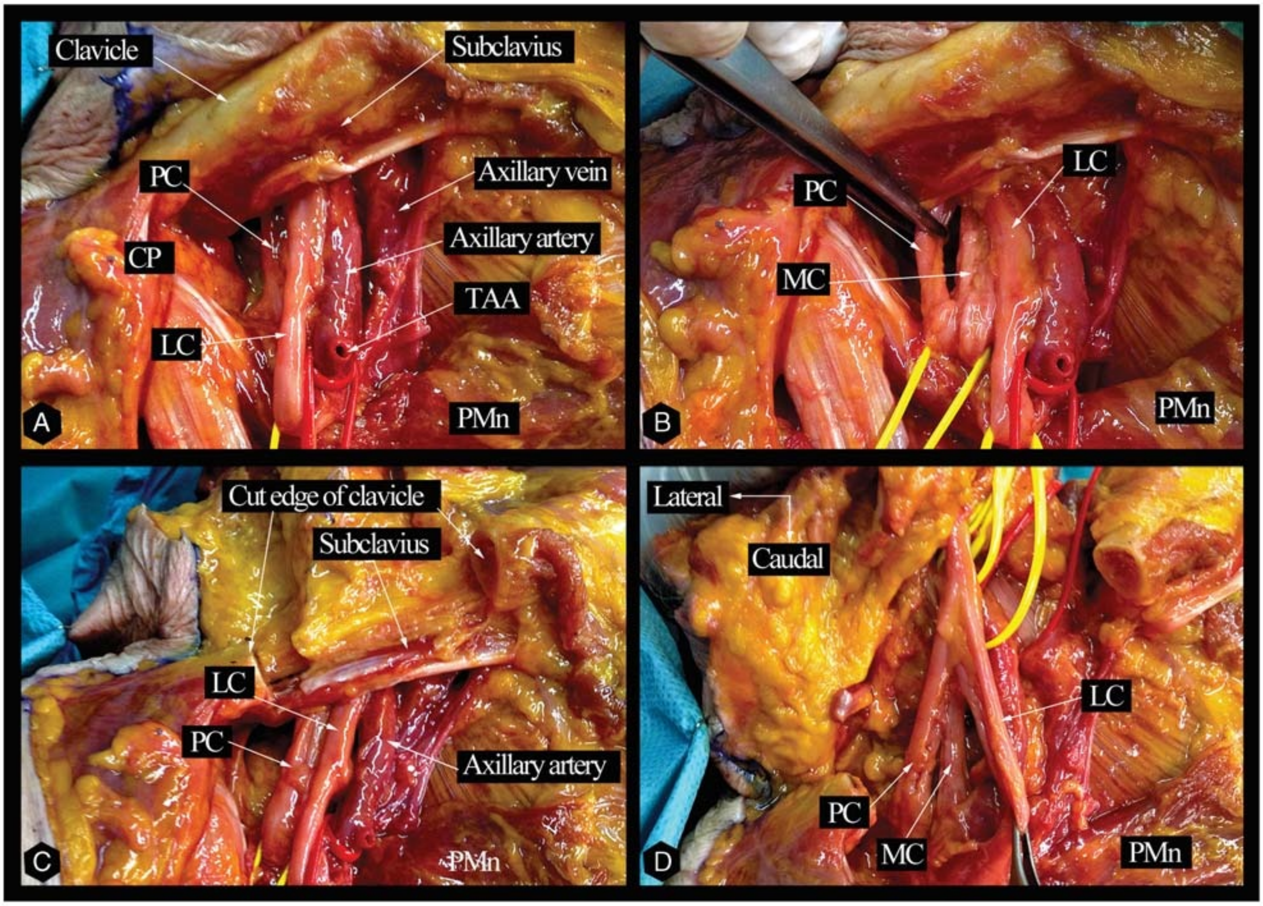

FIGURE 1. Cadaver anatomic dissection of the right MICF, below the middle-third of the clavicle and above the medial border of the pectoralis minor muscle, showing the anterior view of the relations of the cords of the brachial plexus to the first part of the axillary artery (AA). Note the legend for orientation of the images is presented in (D). The pectoralis minor muscle (PMn) has been cut at its origin from the coracoid process (CP) and reflected medially. A, Figure showing the lateral (LC) and posterior (PC) cords lying lateral and parallel to the axillary artery and the PC lying posterolateral to the LC. The medial cord (MC) is not visible in this image. Also note the origin of the thoracoacromial artery (TAA) from the axillary artery. B, Figure showing the MC lying posterior to the LC and medial to the PC. The connective tissue binding the PC and MC has been cut to separate the 2 cords. C, The middle-third of the clavicle has been removed to expose the subclavius muscle which with the pectoralis major muscle (clavicular head) forms the anterior boundary of the CCS. D, The subclavius muscle has been removed to expose the CCS and its contents. The LC is being retracted medially to expose the MC, which lies directly posterior to the MC and medial to the PC.

the supine position and serially sectioned in the transverse plane (1.5-cm-thick sections) and from a cranial to caudal direction (ie, from the base of the neck to the level of the nipple) using a band saw. Three anatomic sections (2 right and 1 left) from the level of the CCS were then identified and the anatomic arrangement of the cords within the CCS was defined in these sections and documented photographically (Fig. 2).

Light Microscopy

Histological sections for light microscopic examination were prepared as follows from 3 cadavers. The cadavers were placed supine with the arm in 90 degrees abduction as in the dissected cadavers. The MICF was dissected in layers until the neurovascular complex was identified. This involved reflecting the pectoralis major and minor muscles and excising the midsection of the clavicle using an osteotome. Then a complete block of tissue that included the brachial plexus and neighboring blood vessels and extending from the lateral aspect of the first rib to the medial edge of the pectoralis minor muscle was excised and fixed in 10% buffered formaldehyde for 3 days. Thereafter, tissue slices (5–6 mm thick), which were perpendicular to the long axis of the brachial plexus, were cut from the block of tissue obtained. These tissue slices were processed using paraffin wax and serially sectioned (5 μm in thickness) using a microtome. The sections were stained using hematoxylin and eosin under standard conditions and examined under a light microscope to define the arrangement of the cords relative to one another and to the axillary artery in the CCS (Figs. 3–4).

RESULTS

Eight cadavers (5 women and 3 men) aged between 68 and 82 years at death were examined. Dissections showing the gross anatomic relationship of the cords of the brachial plexus at the CCS and upper part of the MICF are presented in Figure 1. A transverse anatomic section showing the relations of the cords to the undisturbed anatomy of the CCS is presented in Figure 2. Histological sections showing the anatomic arrangement and relations of the cords at the CCS and upper part of the MICF are shown in Figures 3 and 4, respectively.

The CCS was located between the posterior surface of the middle-third of the clavicle and the anterior chest wall. The cords

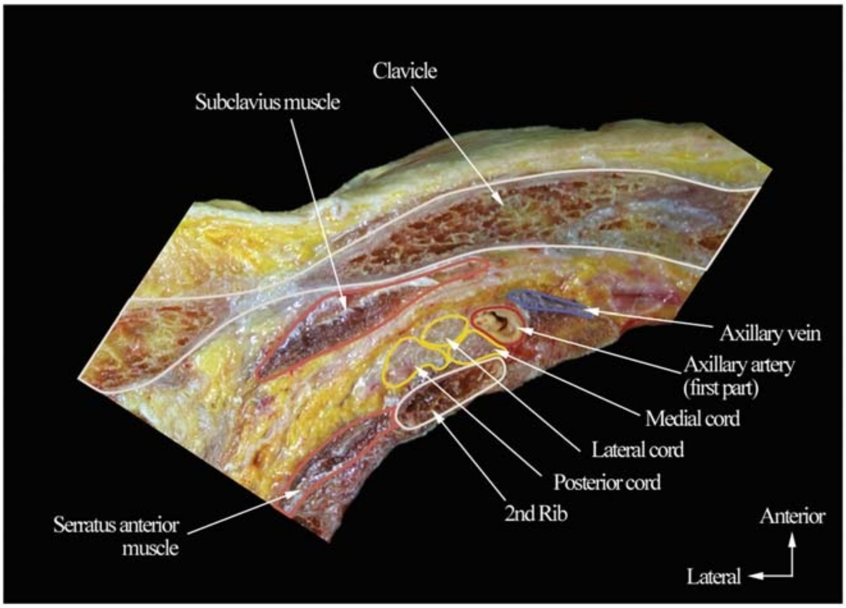

FIGURE 2. Transverse anatomic section through the right CCS showing the anatomic arrangement and relations of the cords of the brachial plexus. The anatomy is presented as though one were looking at it from caudal to cranial (caudocranial view).

of the brachial plexus with the axillary vessels were seen to traverse this space lying between the pectoralis major (clavicular head) and subclavius muscle anteriorly, and the upper slips of the serratus anterior muscle overlying the anterior chest wall posteriorly (Figs. 1, 2). The cords were located lateral and parallel to the axillary artery (Figs. 1, 2), and the gross relations of the cords to the axillary artery was consistent in all the cadavers studied (Figs. 1–3). The anatomic arrangement of the cords, relative to one another in the transverse (axial) plane, was also consistent at the CCS (Figs. 1–3). The lateral cord was the most superficial of the 3 cords and it was always anterior to both the medial and posterior cords (Figs. 1–3). The medial cord was directly posterior to the lateral cord but medial to the posterior cord (Figs. 1–3). The posterior cord was the lateral most of the 3 cords at the CCS and it was immediately lateral to the medial cord but posterolateral to the lateral cord (Figs. 1–3). Furthermore, at the CCS, it was fairly easy to separate the lateral cord from the medial and posterior cords but the medial and posterior cords were very closely apposed to each other, and required dissection of the connective tissue between them to separate them (Fig. 1B). This close relationship of the medial and posterior cords at the CCS was also seen in the histological section from the same region (Fig. 4).

DISCUSSION

This study aimed to define the anatomy and arrangement of the cords of the brachial plexus at the CCS and thereby establish the anatomic basis for USG brachial plexus block (BPB) at this

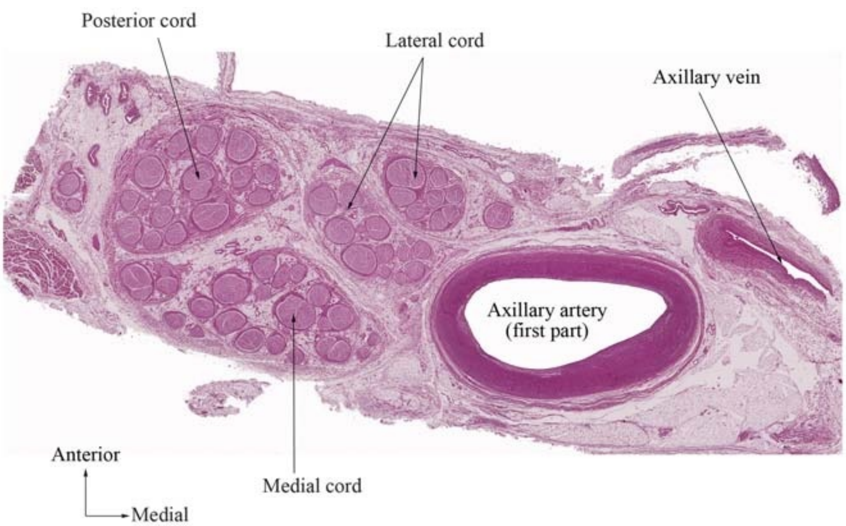

FIGURE 3. Histological section from the right CCS, stained with hematoxylin and eosin, showing the anatomic arrangement and relations of the cords of the brachial plexus (caudocranial view).

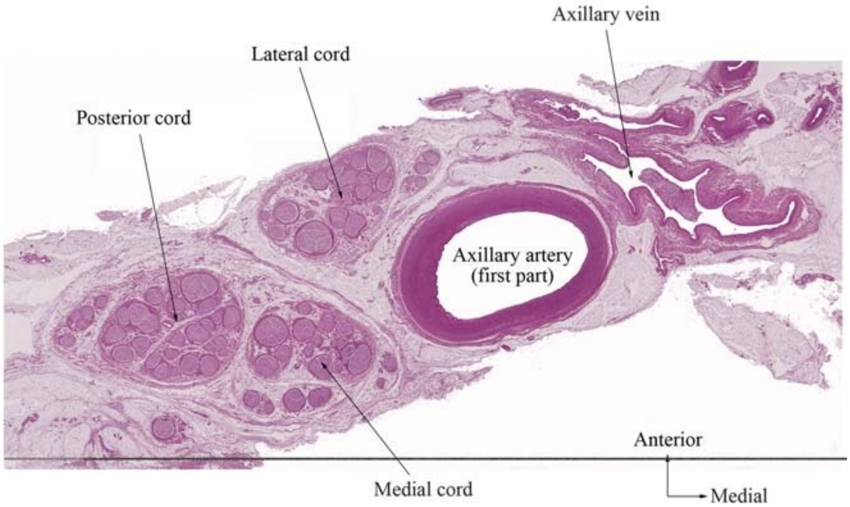

FIGURE 4. Histological section from immediately distal to the right CCS (same cadaver as in Fig. 3), stained with hematoxylin and eosin, showing the anatomic arrangement and relations of the cords of the brachial plexus (caudocranial view).

proximal infraclavicular site. We chose to study the anatomy in the transverse plane to mimic the plane of ultrasound imaging used during a USG ICBPB at the CCS, which we have recently described.[7] We have demonstrated that the cords of the brachial plexus are clustered together lateral to the axillary artery, and lying between the pectoralis major (clavicular head) and subclavius muscle anteriorly and the upper slips of the serratus anterior muscle overlying the anterior chest wall posteriorly, at the CCS. The arrangement of the cords, relative to one another, was also consistent with the lateral cord being most superficial, the medial cord lying deep and posterior to the lateral cord, and the posterior cord lying immediately lateral to the medial cord but posterolateral to the lateral cord. We are not aware of any published data describing the topography of the cords of the brachial plexus at the CCS in the transverse plane.

At the CCS, the cords of the brachial plexus were located lateral to the axillary artery and in between the pectoralis major (clavicular head) and subclavius muscle anteriorly and the upper slips of the serratus anterior muscle overlying the anterior chest wall posteriorly. Our observations are in agreement with Demondion and colleagues[8] who have demonstrated in sagittal sonograms of volunteers that the CCS is a triangular area wedged between the pectoralis major (clavicular head) and subclavius muscle anteriorly and the anterior rib cage posteriorly. As in this study, Demondion and colleagues[8] also found that the cords of the brachial plexus traversed this space lying lateral to the axillary vessels.

The anatomic arrangement of the cords, relative to one another, in the transverse (axial) plane was also consistent with the lateral cord being most superficial, the medial cord lying deep and posterior to the lateral cord, and the posterior cord lying immediately lateral to the medial cord but posterolateral to the lateral cord. There are no comparable data evaluating the topography of the cords of the brachial plexus at the CCS in the transverse plane but there are data describing similar consistency in the position and topography of the cords at the MICF in the sagittal plane.[8,9] Demondion and colleagues[8] studied the anatomic relations of the cords in sagittal sonograms of the CCS and observed that the cords were located above and posterior to the axillary artery. More recently, Moayeri and colleagues,[9] while studying the topography of the cords at the mid-infraclavicular area in sagittal cryomicrotome sections from cadavers found that the lateral cord was always anterior to either the medial or posterior cord and cranial to the axillary artery; the posterior cord was cranial to the medial cord, and all 3 cords were posterior to the axillary artery. Therefore, our findings on the topography of the cords at the CCS in the transverse plane are consistent with what has previously been reported in the sagittal plane.

The medial and posterior cords were very closely apposed to each other at the CCS, and the intervening connective tissue had to be dissected in all the cadavers studied to separate them. We are not aware of any previous report describing this close anatomic relationship of the medial and posterior cords at the CCS, although this is also evident at the mid-infraclavicular point in the report by Moayeri and colleagues.[9] Future research should evaluate this relationship in greater detail because it may partly explain why the success of a vertical infraclavicular block is enhanced when a medial or posterior cord motor response is elicited than after a lateral cord motor response.[9,10] The same may apply for BPB at the CCS.

Infraclavicular BPB is most frequently performed at the LICF,[1–4] and the coracoid approach has an excellent track record of safety.[11] However, although the coracoid approach is effective[1–4] and frequently avoids the chest wall[4] and pleura, the LICF may not be the optimal site for brachial plexus blockade because, at the LICF, the cords of the brachial plexus are located at a depth (approximately 3–6 cm),[4] separated from one another,[5,6] there are significant variations in the position of the individual cords relative to the axillary artery,[5,6] and all 3 cords are rarely visualized in a single ultrasound window[5] during a USG ICBPB. This probably explains why relatively large volumes of local anesthetic[2] and/or multiple injections[1,2] are used for ICBPB. In contrast, and as demonstrated in this study, at the CCS, the cords of the brachial plexus are located in a well-defined intermuscular space, clustered together lateral to the axillary artery, and share a consistent relation relative to one another and to the axillary artery. Therefore, the CCS may be a useful site for USG ICBPB. However, due to the close proximity of the cords of the BP to the axillary vessels, pleura, and the lung at the CCS, there may be potential risk for accidental puncture of these structures. Currently, there are limited data describing USG BPB at the CCS (costoclavicular approach),[7] and future research to evaluate the safety and efficacy of this proximal infraclavicular approach is warranted.

The anatomic relationship of the cords of the BP presented in this report was determined with the arm of the cadaver in 90 degrees abduction. This was done to mimic the position of the arm during a costoclavicular BPB.[7] Published data indicate that there are changes in the configuration of the neurovascular bundle at the LICF with position (ie, abduction or adduction) of the arm.[12] However, there are no data describing such variation at the CCS. It is our observation, during costoclavicular BPB, that the position of the cords remains relatively constant with change in the position of the arm. Future research to evaluate the topography of the cords at the CCS with change in arm position is warranted.

In conclusion, this anatomic study shows that the cords of the brachial plexus are clustered together lateral to the axillary artery, and share a consistent relation relative to one another and to the axillary artery, at the CCS. We believe our findings will simplify the task of identifying the individual cords of the brachial plexus using ultrasound, and form the anatomic basis for future research on USG BPB, at the CCS.

REFERENCES

1. Gaertner E, Estebe JP, Zamfir A, Cuby C, Macaire P. Infraclavicular plexus block: multiple injection versus single injection. *Reg Anesth Pain Med*. 2002;27:590–594.
2. Rodríguez J, Bárcena M, Taboada-Muñiz M, Lagunilla J, Alvarez J. A comparison of single versus multiple injections on the extent of anesthesia with coracoid infraclavicular brachial plexus block. *Anesth Analg*. 2004;99:1225–1230.
3. Sandhu NS, Capan LM. Ultrasound-guided infraclavicular brachial plexus block. *Br J Anaesth*. 2002;89:254–259.
4. Bigeleisen P, Wilson M. A comparison of two techniques for ultrasound guided infraclavicular block. *Br J Anaesth*. 2006;96:502–507.
5. Di Filippo A, Orando S, Luna A, et al. Ultrasound identification of nerve cords in the infraclavicular fossa: a clinical study. *Minerva Anestesiol*. 2012;78:450–455.
6. Sauter AR, Smith HJ, Stubhaug A, Dodgson MS, Klaastad O. Use of magnetic resonance imaging to define the anatomical location closest to all three cords of the infraclavicular brachial plexus. *Anesth Analg*. 2006;103:1574–1576.
7. Karmakar MK, Sala-Blanch X, Songthamwat B, Tsui BC. Benefits of the costoclavicular space for ultrasound-guided infraclavicular brachial plexus block: description of a costoclavicular approach. *Reg Anesth Pain Med*. 2015;40:287–288.
8. Demondion X, Herbinet P, Boutry N, Fontaine C, Francke JP, Cotten A. Sonographic mapping of the normal brachial plexus. *AJNR Am J Neuroradiol*. 2003;24:1303–1309.
9. Moayeri N, Renes S, van Geffen GJ, Groen GJ. Vertical infraclavicular brachial plexus block: needle redirection after elicitation of elbow flexion. *Reg Anesth Pain Med*. 2009;34:236–241.
10. Neuburger M, Kaiser H, Rembold-Schuster I, Landes H. Vertical infraclavicular brachial-plexus blockade. A clinical study of reliability of a new method for plexus anesthesia of the upper extremity [in German]. *Anaesthesist*. 1998;47:595–599.
11. Neal JM, Gerancher JC, Hebl JR, et al. Upper extremity regional anesthesia: essentials of our current understanding, 2008. *Reg Anesth Pain Med*. 2009;34:134–170.
12. Ruiz A, Sala X, Bargallo X, Hurtado P, Arguis MJ, Carrera A. The influence of arm abduction on the anatomic relations of infraclavicular brachial plexus: an ultrasound study. *Anesth Analg*. 2009;108:364–366.