

Blood Flow Changes in Forearm Arteries After Ultrasound-guided Costoclavicular Brachial Plexus Blocks: a Prospective Observational Study

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Abstract

Background

As a new approach, an infraclavicular brachial plexus block (BPB) at the costoclavicular space (CCS) has been shown to be effective in achieving a sensory and motor blockade in the forearm. However, no studies have assessed blood flow changes in the forearm arteries after a costoclavicular BPB. The purpose of the present study was to assess blood flow changes in the distal radial artery (RA) and ulnar artery (UA) after a costoclavicular BPB using color Doppler ultrasound.

Methods

Thirty patients who underwent amputated finger replantation and received an ultrasound-guided costoclavicular BPB were included in the study. The hemodynamic parameters of the RA and UA were recorded before the block and 10 min, 20 min, and 30 min after the block using color Doppler ultrasound to determine the peak systolic velocity (PSV), end-diastolic velocity (EDV), mean velocity (V_{mean}), pulsatility index (PI), resistance index (RI) and area. The volumetric flow rate (VFR) was calculated using the formula $Q = \text{area} \times V_{\text{mean}}$. The aforementioned parameters were compared not only before and after the BPB but also between the RA and UA.

Results

There was a significant increase in the PSV, EDV, V_{mean} , area, and VFR and a significant decrease in the PI and RI of the RA and UA 10 min, 20 min, and 30 min postblock compared with the respective baselines. The increase of 30 min postblock in EDV (258.68% in the RA, 279.63% in the UA) was the most notable, followed by that in the V_{mean} (183.36% in the RA, 235.24% in the UA), and the PSV (139.11% in the RA, 153.15% in the UA) changed minimally. The V_{mean} and VFR of the RA were significantly greater than those of the UA before the BPB, however, there was no significant difference in VFR between RA and UA after the BPB.

Conclusions

A costoclavicular BPB can increase blood flow in the forearm arteries. The RA had a higher volumetric flow rate than the UA before the BPB; however, the potential blood supply capacity of the UA is similar to that of the RA after a BPB.

Trial registration

This study was registered in Chict.org.cn registry system on 12 June 2019 (ChiCTR1900023796).

Background

Studies have reported that a brachial plexus block (BPB) can provide not only local analgesia but also a sympathetic blockade, which causes vasodilatation and increases blood flow in the forearm arteries.¹⁻⁶ This anti-sympathetic effect is of great significance in preventing vasospasm after vascular reconstruction and replantation.

The traditional lateral sagittal infraclavicular BPB can provide anesthetic effects for forearm surgery.⁷ However, the limitation of this technique is that three cords of the brachial plexus are located deep to the pectoral muscles, which are scattered around the axillary artery with great variability in position. Therefore, a large dose (up to 35-40 mL) of local anesthetic and multiple injections are required to produce a successful brachial plexus blockade.⁸ Recently, a new approach for infraclavicular BPBs via the costoclavicular space⁹ (CCS) was proposed. At the CCS, three cords of the brachial plexus are clustered together between the subclavius and serratus anterior muscles, which are consistently lateral to the axillary artery. Hence, a single injection of a smaller volume of local anesthetic (20-25 mL) at the center of the nerve cluster produces a blockade of the 4 major nerves of the brachial plexus.

Costoclavicular BPBs have been shown to be effective in achieving a sensory and motor blockade in the forearm. However, no studies have been conducted to assess whether this technique can successfully block the sympathetic fibers of the forearm and improve the blood flow of the forearm arteries. The current prospective study aimed to determine the blood flow parameters of the distal radial artery (RA) and the ulnar artery (UA) after a costoclavicular BPB using color Doppler sonography.

Methods

Study design

This prospective observational prospective study was registered in Chict.org.cn registry system on 12 June 2019 (ChiCTR1900023796) and has been approved by the institutional ethics committee (Approval Number: 2019-060-1). This study was conducted in Shanghai Sixth People's Hospital from September 2019 to March 2020.

Inclusion and exclusion criteria

After obtaining written informed consent from each patient, 32 patients aged 18 to 60 years, with American Society of Anesthesiologists (ASA) physical status I to II, who were scheduled to undergo finger replantation were included. Patients who had a history of coagulation disorders, peripheral arterial disease, heart disease, diabetes and hypertension were excluded from the study.

Interventions

After standard monitoring with noninvasive blood pressure, electrocardiography and peripheral oxygen saturation (SpO₂), an ultrasound-guided (Sonimage MX1, Konica Minolta, Japan) costoclavicular BPB was performed. The patient was in a supine position with arms abducted at 90 degrees and a soft

padding was placed on the back. After strict aseptic precautions, a high-frequency linear array was placed over the midpoint of the clavicle in the transverse orientation. Then, the transducer was moved caudally until the axillary artery and vein were visualized when it left the inferior border of the clavicle. All 3 cords of the brachial plexus were lateral to the axillary artery, which was located between the posterior surface of the clavicle and the second rib (Figure 1A). An 18-gauge needle was inserted in-plane from a lateral-to-medial direction after 2 ml of 1% lidocaine was injected subcutaneously. The needle tip was placed at the center of the nerve cluster by advancing the needle through the gap between the lateral and posterior cord and advancing it toward the medial cord. Then, 30 ml of 0.5% ropivacaine was injected at the center of the nerve cluster to surround the 3 cords with local anesthetic under sonographic imaging (Figure 1B). A complete block was defined as a loss of sensation to needle pricks in the area of the cutaneous distribution of the radial nerve, median nerve, ulnar nerve and musculocutaneous nerve.

Outcomes

Peak systolic velocity (PSV), end-diastolic velocity (EDV), V_{mean} , the pulsatility index (PI), the resistance index (RI) and the area of the RA and UA were measured at the level of the wrist in the distal forearm by color Doppler ultrasound before the block and 10 min, 20 min, and 30 min after the block. The volumetric flow rate (VFR) was calculated using the formula $Q = \text{area} \times V_{\text{mean}} \times \rho$; $\rho \approx 1 \text{ g/cm}^3$. One centimeter proximal to the radial-ulnar styloid process was marked as the examination point to provide consistency among all measurements taken. Color duplex Doppler ultrasound (Sonimage MX1, Konica Minolta, Japan) with a broadband 12-5 MHz linear array probe was used to image the vessels; ultrasounds were performed by two experienced physicians who had more than 10 years of experience with ultrasound. One physician performed the ultrasound examination of the patients, while the other adjusted the equipment parameters and performed the measurements. To maximize the intensity of the signal, the Doppler angle was maintained at 60°. The short-axis ultrasound image of the artery was obtained for the calculation of the artery cross-sectional area when the probe was placed at the examination point perpendicular to the artery (Figure 2 A and B). The long-axis ultrasound image of the artery was obtained by placing the transducer's midpoint at the examination point, parallel to the artery, and was used for the measurement of the flow velocity (Figure 2 C and D). Artery cross-sectional area (cm^2) and flow velocity (cm/s) were measured using manufacturer-installed software.

Sample size

The sample size was calculated based on our pre-trial of 10 patients in August 2019, in which the mean differences of PSV, EDV, MV, RI and PI of the forearm arteries before brachial plexus block were 7.56 cm/s , 1.65 cm/s , 4.56 cm/s , 0.12 cm/s and 0.58 cm/s , respectively, while those after block were 11.68 cm/s , 7.93 cm/s , 7.50 cm/s , 0.11 cm/s and 0.44 cm/s . A total of 32 cases are required by using standard sample size calculation formula to achieve a power of 0.8 at $\alpha = 0.05$, taking into account the 20 per cent increase in imperfect nerve block effect.

Statistical analysis

Comparisons of changes in the hemodynamic parameters of the RA and UA were assessed by independent-sample t tests. A P value <0.05 was considered statistically significant. Normally distributed quantitative variables are expressed as the mean \pm standard deviation. The SPSS for Windows version 23.0 (SPSS Inc, Chicago, Illinois) was used for statistical analysis and graphing.

Results

Demographic data of the patients

A total of 32 patients scheduled to undergo finger replantation signed informed consent forms to participate in the study. After the ultrasound-guided costoclavicular BPB, failure of the ulnar nerve blockade occurred in 2 cases. The remaining 30 patients' blockades of radial nerve, ulnar nerve, median nerve and myocutaneous nerve were effective and met the inclusion criteria. A description of the demographic data is presented in Table 1.

Comparison of hemodynamic parameters before and after the BPB

Changes in the hemodynamic parameters of the RA and UA before and after the BPB are summarized in Table 2. The relative changes in blood flow between baseline and 30 min postblock in the RA and UA are shown in Figure 3. Compared with baseline, the PSV ($P<0.001$), EDV ($P<0.001$), MV ($P<0.001$), VFR ($P<0.001$) and area of the RA ($P<0.05$) and UA ($P<0.01$) 10 min, 20 min and 30 min postblock were significantly increased, while the PI and RI were significantly decreased ($P<0.001$). There was no significant difference among the hemodynamic parameters of the RA and UA 10 min, 20 min, and 30 min after the BPB. The relative change in the PSV (139.11% in RA, 153.15% in UA) was significantly lower than that of the V_{mean} (183.36% in RA, 235.24% in UA) ($P<0.01$), while the relative change in the EDV (258.68% in RA, 279.63% in UA) was significantly greater ($P<0.05$) than that of the V_{mean} in both the RA and UA (Figure 3).

Comparison of the hemodynamic parameters of the RA and UA

Of all the parameters, the V_{mean} and VFR of the RA were greater ($P<0.05$) than those of the UA before the BPB (Table 2). However, no significant difference was found in between the hemodynamic parameters of the RA and UA after the BPB. The relative change in the V_{mean} of the UA between baseline and 30 min postblock was significantly greater than that of the V_{mean} of the RA ($P<0.05$; Figure 3). There was no significant difference in the relative change in the PSV and EDV between the RA and UA.

Discussion

The interscalene, supraclavicular, infraclavicular and axillary approaches are commonly used for BPBs and have been reported to achieve sympathetic blockades and vasodilation, which leads to increased blood flow in the forearm arteries.¹⁻⁶ In this study, similar results were obtained in the RA and UA by using the costoclavicular approach for a BPB. Blood flow velocity and area were increased, while the resistance

and pulsatility indexes were decreased after the BPB. Changes in these parameters eventually lead to a significant increase in blood flow. It should be noted that from 10 min to 30 min after the BPB, the hemodynamic parameters in the RA and UA did not change significantly with the passage of time, indicating that the sympathetic block had a capsulizing effect. Furthermore, the relative change between baseline and 30 min postblock was compared for the PSV, EDV and V_{mean} to investigate the influence of BPBs on blood flow velocity in the RA and UA. The increase in EDV was most notable change after the BPB, followed by that in the V_{mean} , and the PSV changed minimally. This phenomenon could be explained by the fact that the EDV and V_{mean} reflect vascular compliance and distal vascular resistance, which can partly reflect the degree of sympathetic block. However, PSV is mainly affected by cardiac function and vascular anatomy, so a BPB has a greater influence on EDV and V_{mean} than on PSV.

In this study, we compared the hemodynamic parameters of the RA and UA before and after a BPB. There was no significant difference between the area of the RA and that of the UA, either before or after a BPB. This is consistent with the results of an ultrasonography study conducted by Sunil on the size of the distal RA and distal UA in 204 patients in southern Rajasthan.¹⁰ Recently, it was suggested that whether the dominant artery for the hand blood supply is the RA or the UA is debatable. The UA is considered to be the dominant artery for the blood supply of the forearm and hand according to classic anatomical studies;¹¹ therefore, the RA is usually used for invasive procedures such as arterial catheterization, coronary artery bypass surgery and AV fistula formation for hemodialysis. However, Haerle's study revealed that the ulnar artery was only dominant to the elbow, while the radial artery was the dominant artery in the distal forearm.¹² In this study, the VFR of the RA was significantly greater than that of the UA under normal circumstances (i.e., preblock), indicating that the RA was the dominant artery for the hand blood supply, which was consistent with the conclusion of Haerle's study. However, the difference in VFR between the two arteries disappeared after the BPB due to the significant increase in the V_{mean} of the UA, indicating that the UA's potential blood supply capacity is similar to that of the RA because of the compensatory capacity.

A recent study¹³ showed that compared with the supraclavicular approach, the costoclavicular approach for a BPB was associated with a significantly lower incidence of hemidiaphragmatic paralysis. According to the experience with 32 costoclavicular BPBs in this study, this new technique can successfully block the four branches of the brachial plexus without complications such as hemidiaphragmatic paralysis and pneumothorax. However, failure of the ulnar nerve block occurred in 2 patients. We consider this incident to be due to the localization of the medial cord, which is deeper and closer to the axillary artery in this approach. After the needle tip passes through the narrow gap between the lateral cord and the posterior cord, liquid separation should be performed between the medial cord and the axillary artery to surround the medial cord with local anesthetic, which requires a high degree of skill. Nevertheless, the advantage of the CCS approach over the conventional approach is still significant because the three cords of the brachial plexus are lateral to the axillary artery, which is located more superficially. Therefore, because there is not a need to frequently change the direction of the needle with the CCS approach, it is easier to

operate for doctors who lack experience with the infraclavicular BPB approach, which reduces tissue damage.

Continuous brachial plexus blocks have been found to be effective in postoperative pain management and achievement of a sympathetic blockade, which can improve circulation in the replantation finger, prevent blood clots and reduce the incidence of vasospasm after replantation.¹⁴⁻¹⁸ However, there are still some problems with this technique, such as the imperfect blockade and the need for fixation of a catheter.¹⁹ In theory, the CCS approach is superior to the traditional approach for a continuous brachial plexus block. This approach only requires a single point puncture to block the four branches of the brachial plexus, providing effective postoperative analgesia for surgery in any part of the forearm, and at the same time, the catheter can be fixed to the flat infraclavicular skin area to prevent detachment. Therefore, studying blood flow changes in the forearm arteries after continuous costoclavicular brachial plexus blocks with lower concentrations of ropivacaine (0.2%) will be the direction of our future research.

Conclusions

As a new approach, the costoclavicular BPB can reduce peripheral vascular resistance and increase blood flow in the forearm arteries. The increase in EDV was the most notable, followed by that in the V_{mean} , and the PSV changed minimally. The RA had a higher volumetric flow rate than the UA before the BPB; however, the potential blood supply capacity of the UA is similar to that of the RA after a BPB.

Abbreviations

BPB: Brachial plexus block

CCS: Costoclavicular space

RA: Radial artery

UA: Ulnar artery

PSV: Peak systolic velocity

EDV: End-diastolic velocity

V_{mean} : Mean velocity

PI: Pulsatility index

RI: resistance index

VFR: Volumetric flow rate

ASA: American Society of Anesthesiologists

SpO₂: Peripheral oxygen saturation

Declarations

Ethics approval and consent to participate

This study was approved by the ethics committee of Shanghai Sixth People's Hospital (Approval Number: 2019-060-1) and registered at the Chinese Clinical Trial Registry (<http://www.chictr.org.cn/searchproj.aspx>, under the unique clinical trial number ChiCTR1900023796, date of registration June 12, 2019). Written informed consent was obtained from all participants before taking part.

Consent for publication

Not applicable.

Availability of data and materials

All the data used and analyzed are available from corresponding authors upon the reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

The authors have no sources of funding to declare for this manuscript.

Authors' contributions

DRC and JFZ designed the study and performed the ultrasound-guided costoclavicular brachial plexus block; QD and JD collect the data by color Doppler ultrasound; YX and YW analyzed the data, and wrote the manuscript.

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References

1 Ebert B, Braunschweig R, Reill P. Quantification of variations in arm perfusion after plexus anesthesia with color doppler sonography. *Anaesthesist* 1995;44:859–62. DOI: 10.1007/s001010050222.

- 2 Galvin EM, Niehof S, Verbrugge SJC, et al. Peripheral flow index is a reliable and early indicator of regional block success. *Anesth Analg* 2006;103:239–43. DOI: 10.1213/01.ane.0000220947.02689.9f.
- 3 Hermanns H, Braun S, Werdehausen R, et al. Skin temperature after interscalene brachial plexus blockade. *Reg Anesth Pain Med* 2007;32:481–7. DOI: 10.1016/j.rapm.2007.06.392.
- 4 Li J, Karmakar MK, Li X, et al. Regional hemodynamic changes after an axillary brachial plexus block. *Reg Anesth Pain Med* 2012;37:111–8. DOI: 10.1097/AAP.0b013e318234007e.
- 5 Sahin L, Gul R, Mizrak A, et al. Ultrasound-guided infraclavicular brachial plexus block enhances postoperative blood flow in arteriovenous fistulas. *J Vasc Surg* 2011;54:749–53. DOI: 10.1016/j.jvs.2010.12.045.
- 6 Palaniappan S, Subbiah V, Gopalan VR, et al. Observational study of the efficacy of supraclavicular brachial plexus block for arteriovenous fistula creation. *Indian J Anaesth* 2018;62:616–20. DOI: 10.4103/ija.IJA_293_18.
- 7 Sandhu NS, Capan LM. Ultrasound-guided infraclavicular brachial plexus block. *Br J Anaesth* 2002;89:254–9. DOI: 10.1093/bja/aef186.
- 8 Songthamwat B, Karmakar MK, Li JW, et al. Ultrasound-guided infraclavicular brachial plexus block: prospective randomized comparison of the lateral sagittal and costoclavicular approach. *Reg Anesth Pain Med* 2018;43:825–31. DOI: 10.1097/AAP.0000000000000822.
- 9 Li JW, Songthamwat B, Samy W, et al. Ultrasound-guided costoclavicular brachial plexus block: sonoanatomy, technique, and block dynamics. *Reg Anesth Pain Med* 2017;42:233–40. DOI: 10.1097/AAP.0000000000000566.
- 10 Beniwal S, Bhargava K, Kausik SK. Size of distal radial and distal ulnar arteries in adults of southern Rajasthan and their implications for percutaneous coronary interventions. *Indian Heart J* 2014;66:506–9. DOI: 10.1016/j.ihj.2014.08.010.
- 11 Coleman SS, Anson BJ. Arterial patterns in the hand based upon a study of 650 specimens. *Surg Gynecol Obstet* 1962;113:409–24. DOI: 10.1097/00006534-196201000-00028.
- 12 Haerle M, Häfner H-M, Dietz K, et al. Vascular dominance in the forearm. *Plast Reconstr Surg* 2003;111:1891–8. DOI: 10.1097/01.PRS.0000057529.76413.D7.
- 13 Oh C, Noh C, Eom H, et al. Costoclavicular brachial plexus block reduces hemidiaphragmatic paralysis more than supraclavicular brachial plexus block: retrospective, propensity score matched cohort study. *Korean J Pain* 2020;33:144–52. DOI: 10.3344/kjp.2020.33.2.144.
- 14 Liu SS, Salinas FV. Continuous plexus and peripheral nerve blocks for postoperative analgesia. *Anesth Analg* 2003;96:263–72. DOI: 10.1213/00000539-200301000-00053.

- 15 Berger A, Tizian C, Zenz M. Continuous plexus blockade for improved circulation in microvascular surgery. *Ann Plast Surg* 1985;14:16–9. DOI: 10.1097/0000637-198501000-00004.
- 16 Matsuda M, Kato N, Hosoi M. Continuous brachial plexus block for replantation in the upper extremity. *Hand* 1982;os-14:129–34. DOI: 10.1016/S0072-968X(82)80003-X.
- 17 Gaumann D, Lennon RL, Wedel DJ. Continuous axillary block for postoperative pain management. *Reg Anesth* 1988;13:77–82. DOI: 10.1016/0304-3959(88)90214-X.
- 18 Kurt E, Ozturk S, Isik S, et al. Continuous brachial plexus blockade for digital replantations and toe-to-hand transfers. *Ann Plast Surg* 2005;54:24–7. DOI: 10.1016/j.rapm.2005.07.110.
- 19 Tuominen M, Haasio J, Hekali R, et al. Continuous interscalene brachial plexus block: clinical efficacy, technical problems and bupivacaine plasma concentrations. *Acta Anaesthesiol Scand* 1989;33:84–8. DOI: 10.1111/j.1399-6576.1989.tb02866.x.

Tables

Table 1. Demographic data of the patients

Characteristics	Patients (n = 30)
Mean age (SD) in years	39.3 (18.5)
Sex, n (%)	22 (73.3)
Male	8 (26.7)
Female	
Mean BMI (SD) in kg/m ²	26.5 (4.3)
ASA classification, n (%)	18 (60.0)
I	12 (40.0)
II	
Replantation Digit, n (%)	11 (36.7)
D I	10 (33.3)
D II	6 (20)
D I+II	2 (6.7)
D I+II+III	1 (3.3)
D II+III+IV	

Abbreviations: SD, standard deviation; BMI, Body Mass Index; ASA, American Society of Anesthesiologists; D I–VI, affected fingers

Table 2. Hemodynamic parameters of the RA and UA at each time point

		PSV (cm/s)	EDV (cm/s)	V _{mean} (cm/s)	Area (cm ²)	RI	PI	VFR (ml/s)
RA	0 min	36.68 (7.26)	9.17 (1.71)	16.38 (4.87) ^ψ	0.056 (0.011)	0.87 (0.11)	3.21 (0.60)	0.92 (0.33) ^ψ
	10 min	55.07 (12.28) [†]	19.69 (7.45) [†]	27.20 (7.74) [†]	0.063 (0.012) [*]	0.74 (0.12) [†]	2.35 (0.49) [†]	1.70 (0.58) [†]
	20 min	57.26 (13.96) [†]	20.94 (8.63) [†]	28.43 (7.40) [†]	0.065 (0.014) [*]	0.73 (0.10) [†]	2.35 (0.43) [†]	1.87 (0.66) [†]
	30 min	58.97 (13.86) [†]	21.76 (7.11) [†]	29.58 (7.32) [†]	0.068 (0.015) [*]	0.72 (0.11) [†]	2.25 (0.37) [†]	2.01 (0.72) [†]
UA	0 min	35.29 (8.64)	8.82 (2.24)	13.38 (5.06)	0.054 (0.011)	0.87 (0.10)	3.10 (0.45)	0.72 (0.28)
	10 min	53.76 (11.98) [†]	18.69 (7.50) [†]	26.74 (6.67) [†]	0.063 (0.010) ^Σ	0.75 (0.10) [†]	2.22 (0.36) [†]	1.68 (0.51) [†]
	20 min	56.33 (10.79) [†]	20.44 (8.69) [†]	28.41 (7.59) [†]	0.065 (0.010) ^Σ	0.73 (0.13) [†]	2.10 (0.38) [†]	1.83 (0.52) [†]
	30 min	58.20 (10.72) [†]	22.12 (6.91) [†]	29.72 (7.97) [†]	0.066 (0.014) ^Σ	0.72 (0.12) [†]	2.07 (0.42) [†]	1.95 (0.62) [†]

Compared with the baseline (0 min) in the RA and UA, ^{*} $P < 0.05$, ^Σ $P < 0.01$, [†] $P < 0.001$; Parameters of the RA compared with those of the UA at baseline (0 min), ^ψ $P < 0.05$.

Figures

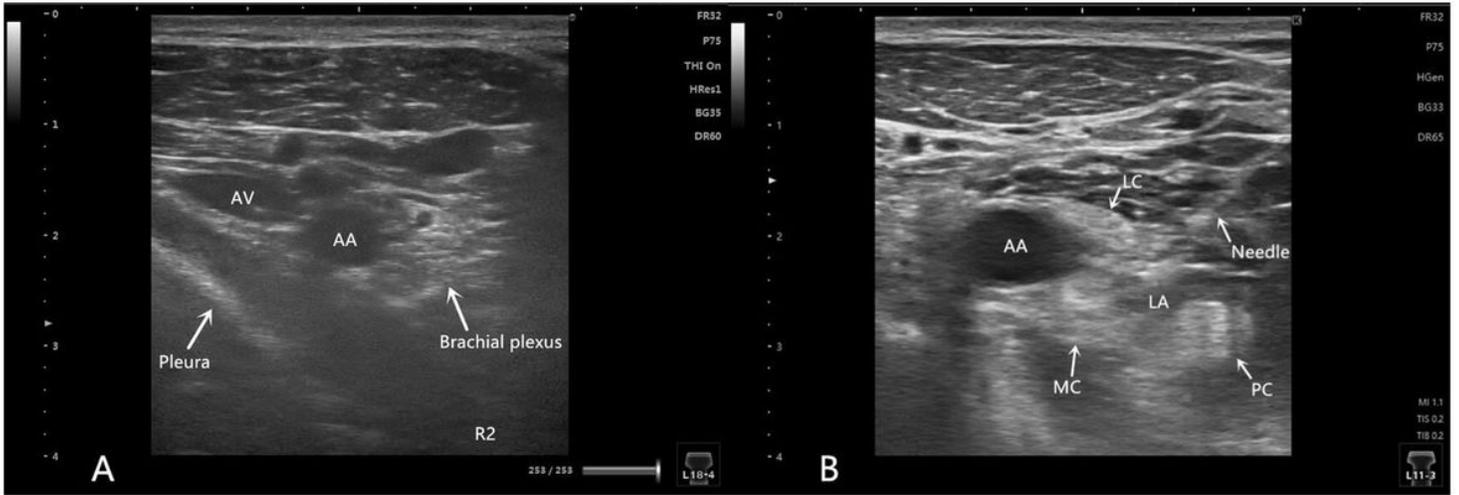


Figure 1

(A) Ultrasound image of the brachial plexus at the CCS. Three cords of the brachial plexus clustered together lateral to the axillary artery, which shares a consistent relation with the AA. (B) Ultrasound image of the brachial plexus block at the CCS. The needle tip was placed at the center of the nerve cluster by advancing the needle through the gap between the LC and PC and advancing it toward the MC. Ropivacaine was injected at the center of the nerve cluster to surround the 3 cords with local anesthetic. AA, axillary artery; AV, axillary vein; LC, lateral cord; MC, medial cord; PC, posterior cord; R2, second rib; LA, local anesthetic.

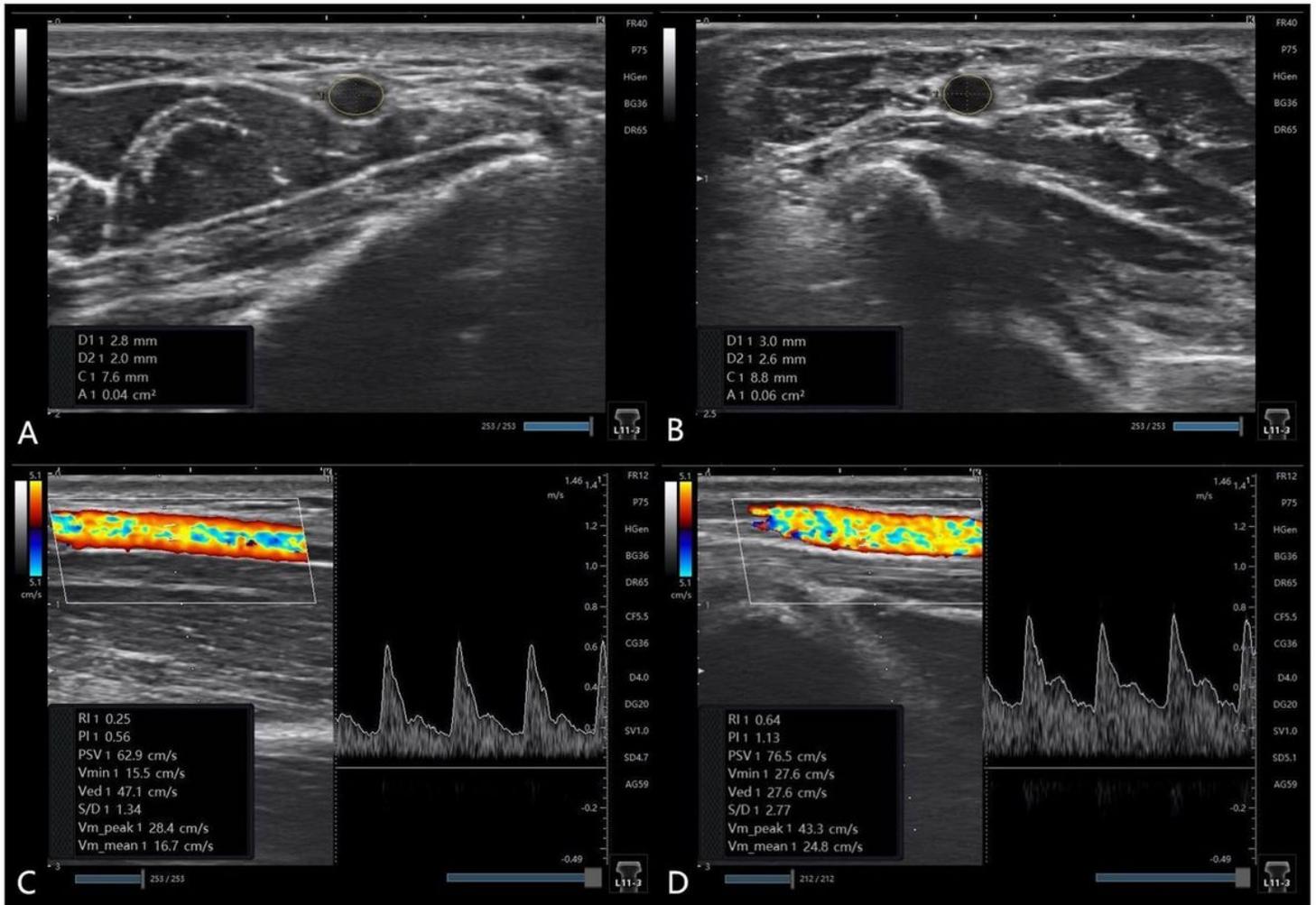


Figure 2

(A) Ultrasound image of the RA cross-sectional area. (B) Ultrasound image of the UA cross-sectional area. (C) Longitudinal duplex Doppler spectral waveform for the RA. (D) Longitudinal duplex Doppler spectral waveform for the UA.

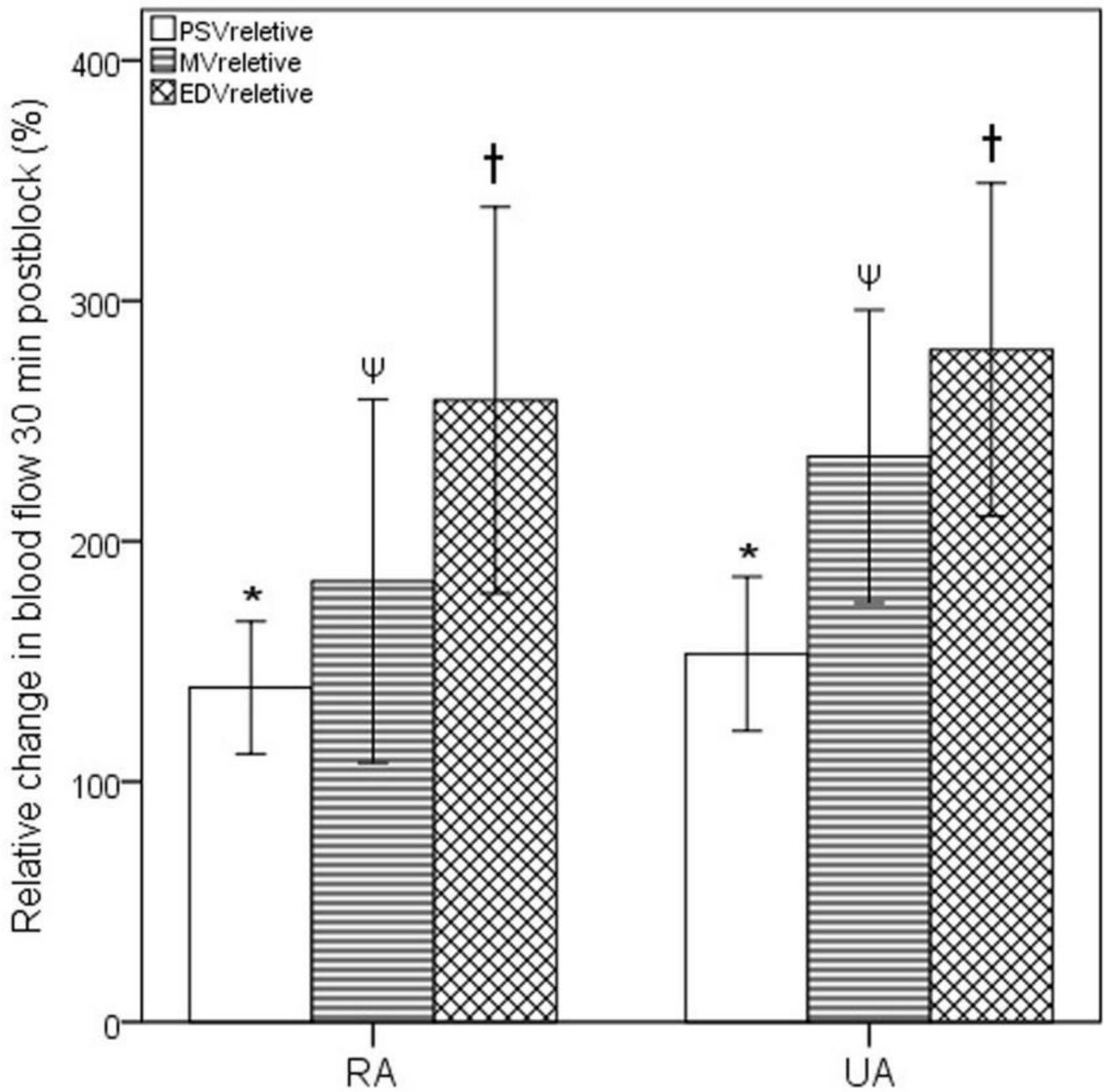


Figure 3

Relative change in the PSV, Vmean and EDV 30 min postblock measured in the RA and UA. Relative change in the PSV compared with that in the Vmean in the RA and UA, *P<0.01. Relative change in the EDV compared with that in the Vmean in the RA and UA, †P<0.05. Relative change in the Vmean in the RA compared with the Vmean in the UA, ψP<0.05.