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SCIENTIFIC ARTICLE

The need for supplemental blocks in single versus triple injections in infraclavicular brachial plexus blocks with a medial approach: a clinical and anatomic study

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Abstract
Background and objectives: To evaluate the single-injection and triple-injection techniques in infraclavicular blocks with an ultrasound-guided medial approach in terms of block success and the need for supplementary blocks.
Methods: This study comprised 139 patients who were scheduled for elective or emergency upper-limb surgery. Patients who received an infraclavicular blocks with a triple-injection technique were included in Group T (n = 68). Patients who received an infraclavicular blocks with a single-injection technique were included in Group S (n = 71). The number of patients who required supplementary blocks or had complete failure, the recovery time of sensory blocks and early and late complications were noted.
Results: The block success rate was 84.5% in Group S, and 94.1% in Group T without any need for supplementary nerve blocks. The blocks were supplemented with distal peripheral nerve blocks in 8 patients in Group S and in 3 patients in Group T. Following supplementation, the block success rate was 95.8% in Group S and 98.5% in Group T. These results were not statistically significant. A septum preventing the proper distribution of local anesthetic was clearly visualized in 4 patients. The discomfort rate during the block was significantly higher in Group T ($p < 0.05$).
Conclusion: In ultrasound-guided medial-approach infraclavicular blocks, single-injection and triple-injection techniques did not differ in terms of block success rates. The need for supplementary blocks was higher in single injections than with triple injections. The presence of a fascial layer could be the reason for improper distribution of local anesthetics around the cords.

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PALAVRAS-CHAVE
Anestesia;
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Bloqueio infraclavicular;
Anestesia regional;
Cirurgia ortopédica de membro superior;
Bloqueio infraclavicular vertical

Bloqueio complementar de nervos no bloqueio de plexo braquial infraclavicular com técnica medial de injeção única *versus*tripla: estudo anátomo-clínico

Resumo

Justificativa e objetivos: Avaliar as técnicas de injeção única e tripla no bloqueio infraclavicular, empregando-se acesso medial guiado por ultrassonografia, comparando-se o sucesso do bloqueio e a necessidade de bloqueios complementares.

Método: O estudo incluiu 139 pacientes com indicação de cirurgia de membro superior eletiva ou de emergência. O Grupo T (n = 68 pacientes) recebeu bloqueio infraclavicular com técnica de injeção tripla e o Grupo S (n = 71), bloqueio infraclavicular com injeção única. Registrou-se o número de pacientes que necessitaram bloqueio complementar de nervo ou que apresentaram falha completa do bloqueio, o tempo de recuperação do bloqueio sensorial e as complicações precoces e tardias.

Resultados: A taxa de sucesso do bloqueio infraclavicular, sem necessidade de bloqueio complementar de nervo, foi 84,5% e 94,1% para os Grupos S e T, respectivamente. No bloqueio infraclavicular foi necessário bloqueio de nervos periféricos distais em 8 e 3 pacientes dos Grupos S e T, respectivamente. Após a complementação, a taxa de sucesso do bloqueio foi 95,8% e 98,5% para os Grupos S e T, respectivamente. Os resultados não foram estatisticamente significantes. Imagem de septo impedindo a distribuição adequada do anestésico local foi claramente visualizada em quatro pacientes. A taxa de desconforto durante a realização do bloqueio foi estatatisticamente mais alta no Grupo T ($p < 0,05$).

Conclusões: As técnicas de injeção única e tripla em bloqueio infraclavicular guiado por ultrasonografia com acesso medial não diferiram quanto à taxa de sucesso. A necessidade de bloqueio complementar foi maior com a técnica de injeção simples. A ocorrência de invólucro de fascia poderia justificar a distribuição inadequada do anestésico local ao redor dos fascículos do plexo.

Introduction

Theoretically, all surgeries below the mid-humerus can be performed under infraclavicular (IC) blocks. Following the introduction of ultrasonography (USG) to clinical anesthesia, plexus and nerve blocks under the guidance of USG have gained wide acceptance for the high rates of block success and low risk of complications.[1] At the same time, it has been shown that USG-guided IC blocks can shorten procedural times and accelerate the onset of blocks.[2]

Several methods for IC blocks have been described. The most popular approaches for IC blocks are coracoid,[3] lateral sagittal,[4] retroclavicular,[5] costoclavicular,[6] and vertical[7] approaches. The vertical (medial) approach is a simple technique; however, because of the close proximity of the puncture site to the lungs and major vessels, serious complications, including pneumothorax and vascular puncture, can occur. On the other hand, when compared with the lateral approach, the medial approach was reported to be faster, gave a better proximal block, and the brachial plexus could be visualized easier because it was closer to the surface than in the lateral approach.[8,9] Lateral blocks are mostly preferred because of the low-risk of pneumothorax while maintaining the efficacy of the blocks.[10–12] Although both lateral and medial IC blocks with multiple injections can provide excellent surgical conditions, it was shown in clinical studies that lateral IC blocks with triple-injections of local anesthetic around the axillary artery was not superior to a single-injection technique.[13–15] As far as we can ascertain, there are no studies comparing single and triple injections in medial-approach IC blocks.

Brachial plexus divisions unite to form medial, lateral and posterior fascicles in the clavicular region. At the proximal segments of this part of the plexus, these three cords are usually located superior to the axillary artery and close to each other as a group (Fig. 1). Distally along the course of the plexus these cords separate from each other, then turn and take its positions at medial, posterior and lateral sites around the axillary artery (Fig. 2).[16] Based on this anatomic knowledge, we hypothesized that in medial approaches, the need for supplementary blocks would be low with single injections as well as with triple injections. In this study, we aimed to evaluate single-injection and triple-injection techniques in IC blocks with a USG-guided medial approach in terms of block success and the need for supplementary blocks. Our secondary goals were to compare the complication rates, sensory block durations, and to discuss the possible reasons for the failure of the blocks.

Methods

From the hospital's electronic medical records, a total of 496 patients older than 14 years-old who were scheduled for elective or emergency hand, wrist, forearm, elbow, and distal arm surgery (under regional and/or general anesthesia) between October 2017 and March 2019 were extracted. Among them, it was found that 329 patients were performed regional (148 patients) or general anesthesia (181 patients)

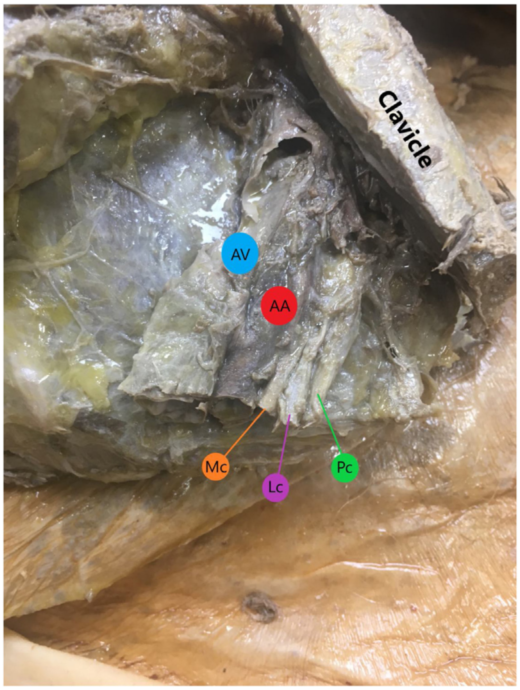

Figure 1 Cadaver dissection showing neurovascular bundle. (AA, Axillary Artery; AV, Axillary Vein; Mc, Medial cord; Lc, Lateral cord, Pc, Posterior cord). Cadaver information: Fixation: Thiel fixed, Age: 94, Gender: Female, Cause of death: Natural causes, Body mass index: 24.9. (Kocaeli University Anatomy Laboratory).

by 12 different anesthesiologists. After the approval by the ethics committee, the data of the remaining 175 patients (who were handled by the same anesthesiologist) were analyzed. The exclusion criteria included non-cooperative patients, refusal of regional anesthesia, known neuropathy that could prevent the evaluation of the efficacy of the block, and different techniques used for infraclavicular brachial plexus blocks (e.g. lateral sagittal, coracoid).

Written informed consent was obtained from all patients prior to the blocks as a routine procedure before anesthesia. USG-guided infraclavicular brachial plexus blocks were performed after routine monitoring of noninvasive blood pressure, Electrocardiogram (ECG) and oxygen saturation. Patients were premedicated with midazolam and/or fentanyl according to clinical judgement. All blocks were performed by a single senior anesthesiologist (first author, H.G.A.) or by residents under the supervision of the same anesthesiologist.

Patients were placed in the supine position with the arm to be blocked flexed and resting on the trunk. The head was turned to the opposite side. A 5 to 10 MHz linear probe (Mindray M5®, Shenzhen, P.R.C.) was placed in the sagittal plane, on the most medial part of the infraclavicular region, where the best image of the axillary artery was obtained.[17] Blocks were performed using an in-plane technique with a 21 G 100 mm insulated stimulator needle (SonoPlex STIM®, Pajunk®, Germany) and a total volume of a 30 mL mixture of bupivacaine 0.5% (15 mL) and prilocaine 2% (15 mL) was injected. If all the three cords were visualized as positioned at the posterior, medial, and lateral sides of the axillary artery, 10 mL of local anesthetic was injected at three points per cord around the axillary artery (Fig. 3). If three of the cords were visualized as located on the posterolateral side of the axillary artery, 30 mL of local anesthetic was given to the posterior of the axillary artery at a single point (in this group

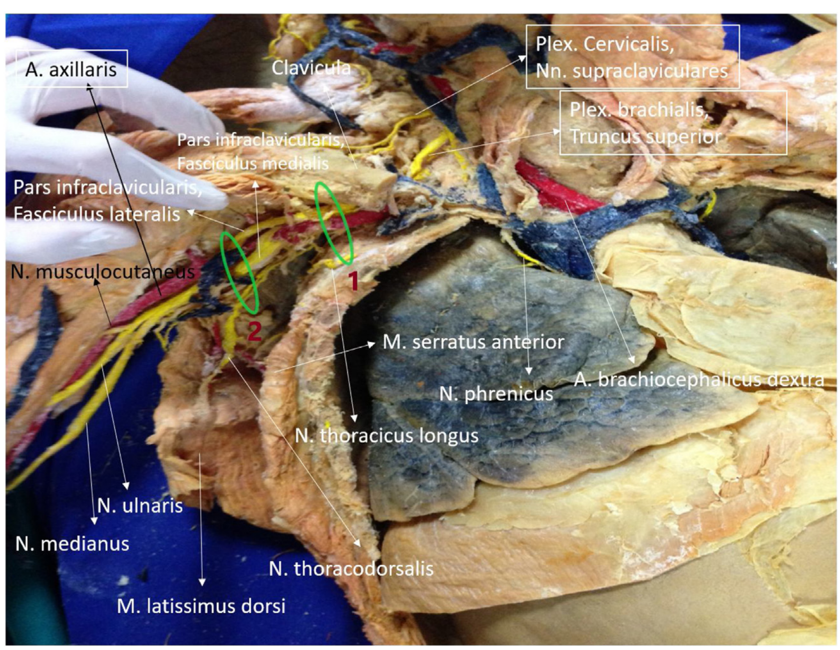

Figure 2 Neurovascular pathways are painted for educational purposes. Anatomical structures are marked on the figure. (1) Proximal segment: cords are located close to each other as a group. (2) Distal segment: Cords diverged from each other and located around the artery. Cadaver information: Fixation: Plastinated, Age: 52, Gender: Female, Cause of death: Cerebrovascular accident, Body mass index: 25.1. (Kocaeli University Anatomy Laboratory).

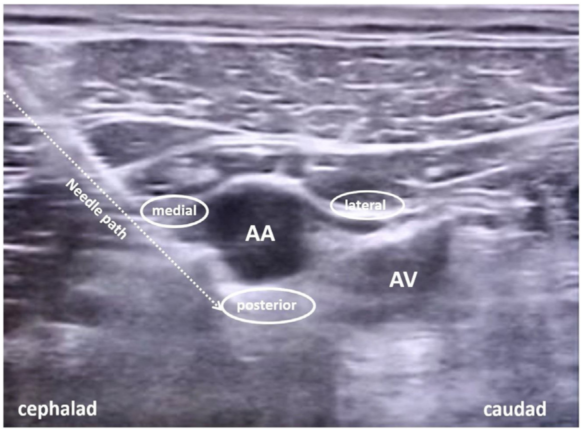

Figure 3 Sonogram showing local anesthetic injection points in infraclavicular block with a triple-injection technique. (AA, Axillary Artery; AV, Axillary Vein).

of patients, it was permitted to inject the local anesthetic to the lateral side of the axillary artery if improper distribution of local anesthetic was observed due to a fascia) (Fig. 4). However, when the cord images could not be obtained properly, local anesthetic was injected either at three points (3 o'clock: medial, 6 o'clock: posterior, and 9 o'clock: lateral) or at a single point posterior to the axillary artery, according to the physician's decision. Patients who received an infraclavicular block with a triple-injection technique were included in Group T. Patients who received an infraclavicular block with a single-injection technique were included in Group S.

Following the brachial plexus block, sensory block to pinprick was evaluated on the dermatomes of the ulnar nerve (palmar surface of the fifth finger and thenar eminences), median nerve (palmar surface of third and second fingers, and thenar eminences), radial nerve (lateral aspect of hand dorsum), lateral cutaneous nerve of the forearm (musculocutaneous nerve, lateral aspect of the forearm), medial cutaneous nerve of the forearm (medial aspect of the forearm), lateral cutaneous nerve of the arm (axillary nerve, lateral aspect of arm), and the medial cutaneous nerves of the arm (medial aspect of the arm). Sensory block to pinprick was graded on a scale score: 0: painful; 1: perceived as tactile sensation; 2: anesthesia to pinprick. Motor block was simply assessed by asking the patient (if they were able) to open their arm wide and then to point their nose with their index finger (care must be taken to prevent the arm from dropping and hitting the face). Through this maneuver, we could assess the radial nerve (extension of the index finger), median nerve (opposition, and the flexion of the third finger), ulnar nerve (flexion of the fourth and fifth fingers), musculocutaneous nerve (flexion of the elbow), and axillary nerve (abduction of the arm). If the motor block was inadequate with this maneuver, contraction against resistance for ulnar, radial, median, musculocutaneous, and axillary nerves were evaluated individually. Motor block was graded on a scale score: 0: normal; 1: minor movements; 2: paralysis.

Block success was defined as either tactile sensation or anesthesia to pinprick on the territories of the assessed nerves at 30 minutes. After 30 minutes, if the sensory block scores for median, radial, ulnar or musculocutaneous nerves were still at ''0'' point, the unblocked nerve was located either with a peripheric nerve stimulator or using ultrasound, in the axilla or on the more distal parts of their traces on the arm and forearm, and then supplemented. If more than two of these nerves remained unblocked, no supplementary blocks were applied, and it was considered as a failed block and general anesthesia was administered. All patients received a degree of intraoperative sedation according to clinical judgement. Patients who refused to stay awake during the surgery, patients with young ages and those who had even minor hand movements in tendon repairment surgeries 30 minutes after the block (although a satisfactory surgical anesthesia was achieved) received general anesthesia. These cases were not classified as failed block.

Early complications (i.e. inadvertent vascular puncture, paresthesia, and systemic local anesthetic toxicity) were

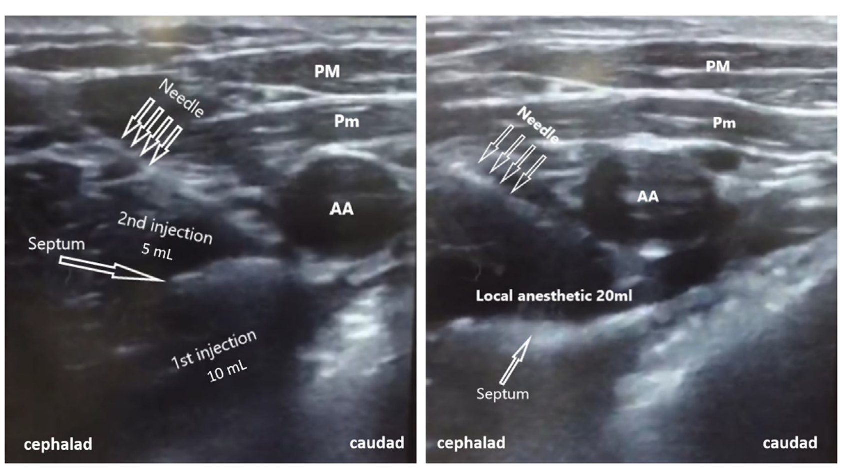

Figure 4 Left: Septum preventing the proper distribution of the local anesthetic. Following the first injection of 10 mL of local anesthetic, the needle was retracted about 1 cm, and then 5 mL of local anesthetic was given to the lateral site of the artery for the second injection. Right: Hydrodissection of the septum from the artery after a total of 20 mL of local anesthetic injection. (AA, Axillary Artery; PM, M. Pectoralis Major; Pm, M. Pectoralis Minor.

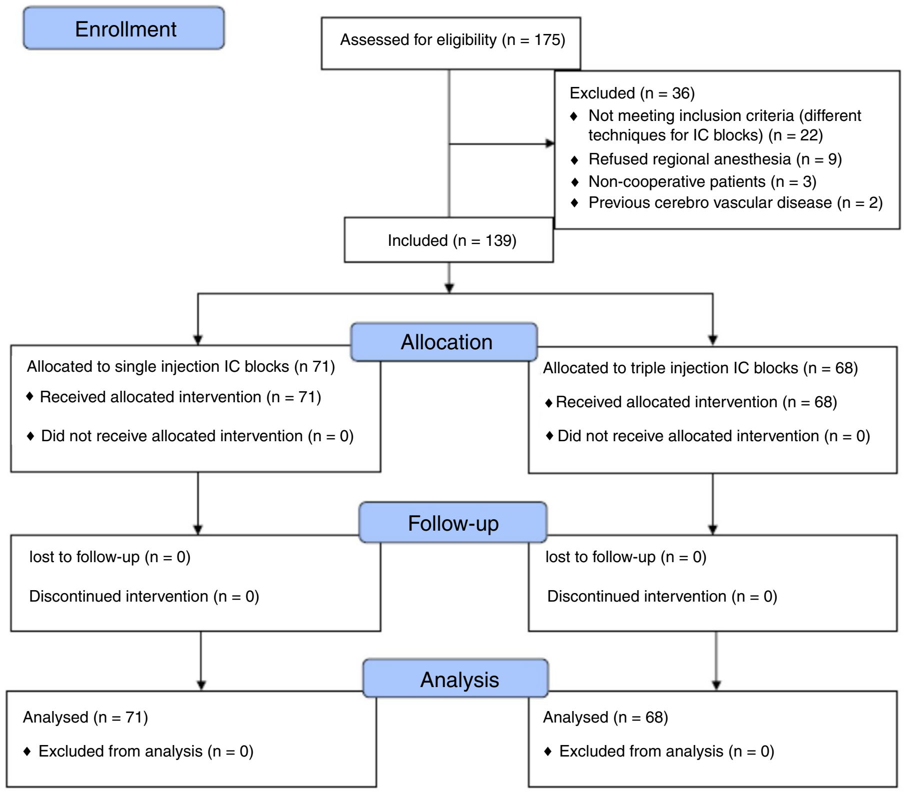

Figure 5 Flow diagram of the study. Supplemental video: USG-guided infraclavicular block: improper distribution of local anesthetic due to a fascial layer.

recorded. Patients were visited on the evening of the surgery and before their discharge on the surgical ward. All were examined on the ward by the senior anesthesiologist. At the bedside visit, patients were questioned about the time they lost sensory and motor block, and the first time they needed analgesics. Possible late complications such as persistent pain or paresthesia were noted.

Unidentified individual patient data (including snapshots and video images) can be accessed from Mendeley Data, https://data.mendeley.com/; doi: 10.17632/b4m9wjzph3.1.

Statistical analysis

The data analysis of the present study was conducted using the SPSS for Windows software package (ver. 20.0, Chicago, IL, USA). The normality of data distribution was tested using the Kolmogorov-Smirnov test. Normally distributed continuous data were tested using Student's *t*-test, whereas non-normally distributed continuous data was tested using the Mann-Whitney U test. Categorical variables were analyzed using Fisher's exact or Chi-Square (χ^2) tests. An alpha value of <0.05 was considered as statistically significant.

Results

Data from the 139 patients who precisely fulfilled the criteria of the study protocol are presented in Fig. 5. Patient characteristics and the location of surgery are presented in Table 1. The surgical procedures were open reduction and internal fixation of bone fractures (distal humerus, radius, ulna, carpal, metacarpal, and phalanx), palmar fasciectomies, tenosynovectomies, tumor and ganglion excision, fasciotomies, grafting, nerve release, amputations, amputation stump revisions and tendon and nerve repairs. Seven patients in Group S, and 11 patients in Group T received general anesthesia. Among them, three patients in Group S and one patient in Group T received general anesthesia due to complete failure of the infraclavicular block. Three patients who underwent tendon repair in Group S received general anesthesia because of minor hand movements at 30 minutes of the block, although there was successful surgical anesthesia. The remaining patients were those who refused to stay awake during the surgery. Sixty-seven patients (94.4%) in Group S and 63 patients (92.6%) in Group T underwent surgery in a bloodless surgical field with a pneumatic tourniquet. None of these patients reported tourniquet pain.

The block was successful in 60 patients (84.5%) in Group S, and 64 patients (94.1%) in Group T, without any need for supplementary nerve blocks. However, this difference was not statistically significant (p = 0.06; Fisher's exact, two tailed, $p < 0.05$). The blocks were supplemented with distal peripheric nerve blocks in eight patients in Group S and in three patients in Group T. Following supplementation, the block was adequate in 68 patients (95.8%) in Group S and 67 patients (98.5%) in Group T. Although the number of patients who needed supplementary local anesthetic infiltration in Group S was higher than in Group T, this difference was not statistically significant (p = 0.13). The Odds Ratio (OR) for

Table 1 Demographic characteristic of patients.

	Grupo S (n = 71)	Grupo T (n = 68)
Physical characteristics		
Age, years (mean ± SD)	44.2 (17.3)	42.7 (19.4)
Weight, kg (mean ± SD)	72.9 (14.8)	76.3 (8,9)
Sex (F/M), n	33/38	19/49
ASA I/II/III, n	40/31/0	42/23/3
Surgery location		
Arm (bone/soft tissue), (n; %)	2/0 (2; 2.8)	6/0 (6: 8.8)
Elbow (bone/soft tissue), (n, %)	0/2 (2; 2.8)	2/1 (3; 4.4)
Forearm (bone/soft tissue), (n; %)	10/0 (10; 14.1)	19/5 (24; 35.3)
Wrist (bone/soft tissue), (n; %)	0/4 (4; 5.6)	0/2 (2; 2.8)
Hand (bone/soft tissue), (n; %)	15/38 (53; 74.6)	12/21 (33; 48.5)
Surgical characteristic		
General anesthesia	7	11
Tourniquet	67	63

ASA, American Society of Anesthesiologists preoperative classification.

Table 2 Characteristics of the blocks.

	Grupo S (n = 71)	Grupo T (n = 68)	*p*
Block characteristics			
Supplemented blocks; n	8	3	0.13
Complete failure; n	3	1	0.33
Recovery of sensory block; hours[a]	10 (7–17)	9.5 (7–16)	0.11
Early complications			
Discomfort during IC block; n	6	16	0.02[b]
Inadvertent vascular puncture	2	0	0.5

[a] Values are expressde as median and the min–max values.
[b] $p < 0.05$.

supplemental blocks in Group S compared to Group T was 2.75 (95% CI). Complete failure rate in Group S was 4.2%, and 1.5% in Group T ($p < 0.05$; OR = 2.96) (Table 2). During the sonography, a septum was clearly visualized on the posterolateral aspect of the axillary artery in four patients in Group S (Fig. 4, Supplemental video). In these patients, local anesthetic was injected in both the posterior and lateral sides of the axillary artery. Cords could not be identified in some patients.

The times for the recovery of the sensory blocks were similar in both groups. Six patients in Group S (8.5%) and 16 patients (23.5%) in Group T felt discomfort during the infraclavicular block. This difference was statistically significant ($p = 0.02$). Inadvertent vascular puncture was observed in two patients in Group S. None of the patients had remaining tingling or numbness along the territory of a nerve that was related to infraclavicular block. No local anesthetic toxicity or pneumothorax events were observed in any patients. No central nervous system or cardiac complications developed.

Discussion

The main finding of this study was that patient discomfort was greater during the triple-injection IC brachial plexus block compared with the single-injection technique. Compared with triple-injection medial-approach IC blocks, the need for supplemental peripheral nerve blocks was greater and the complete failure rate was higher in medial-approach IC blocks with the single-injection technique.

Regarding the anatomic formation of the brachial plexus, the three fascicles are usually located on the superolateral side of the subclavian artery at the proximal segments. However, this plexus formation can also vary among patients.[18,19] Bigeleisen and Wilson[9] studied 98 patients with medial USG scanning and reported the incidence of superior positioning of lateral, posterior, and medial cords were 95%, 95% and 81% respectively. At these distal segments of the brachial plexus, medial cords were visualized posterior to the artery (18%) and between the artery and the vein (35%).[8] Brenner et al. demonstrated the change of the positioning of the cords relative to the artery using USG scout scanning from proximal to distal.[20] It was also demonstrated in our study with cadaver dissections (Figs. 1 and 2).

In the magnetic resonance study of Sauter et al.,[16] in the sagittal plane corresponding to the lateral sagittal IC blocks, most subjects' lateral cords were observed at cranial, cranioposterior or posterior to the artery. Thus, the authors suggested that a single injection with the needle tip positioned craniodorsal, close to the artery (approximately at 8 o'clock), would have adequate local anesthetic distribution to all three cords. This idea has since been supported by clinical studies and it was shown that, with the guidance of USG, a U-shaped distribution of local anesthetic was effective for a complete sensory block in more than 90% of patients.[21] In previous studies, multiple injections stimulating all cords were found to have higher success rates compared with the single-injection technique.[15,22] However, it was emphasized in other recent studies that a single local anesthetic injection to the posterior of the artery with USG guidance provided similar success rates to triple injections around the artery.[13,14,23] In the present study, complete failure was not significant between the groups (3/71 in Group S and 1/68 in Group T). The recovery of the sensory blocks was also not significant between the groups.

With consideration to the need for complementary blocks, this was found to be similar between the vertical and coracoid approaches with a nerve stimulator.[10] Additionally, Gürkan et al. reported a rate of 1.8% for supplementary nerve blocks and a rate of 3.9% for incision-site local anesthetic infiltration,[12] and Koscielniak-Nielsen et al. reported the need for supplementary blocks in 12 of 160 patients with lateral sagittal nerve stimulator-guided infraclavicular blocks.[4] On the other hand, the success rate was found to be significantly higher in nerve stimulator-guided multiple injection groups in comparison with single-injection techniques.[15,22] When the USG-guided single and multiple injections were compared on the basis of the need for supplementary blocks, Frederickson et al.[14] reported that the need for supplementary blocks was 26/51 in the single-injection group, and 22/49 in the triple-injection group, whereas Desgagnés et al.[13] reported 1/49 in the single-injection group and 3/51 in the triple-injection group. None of these results were found to be statistically significant. In this study, 8/71 blocks in Group S and 3/68 blocks in Group T were supplemented, which was statistically not significant. However, we believe that non-significance of these results in this study is because of the insufficient data, which means not that there is no difference.[24] A study with a large sample size would reveal this difference. One possible reason for the relatively high rate of supplementary blocks in Group S might be the variations of the brachial plexus.

Another reason, which should not be overlooked, for failure and patchy blocks is the presence of facial layers around the neurovascular bundle. In a sonography study by Morimoto et al.[25] among 28 patients, a septum was visualized in 4 of 6 patients who had a unilateral local anesthetic spread pattern instead of a circumferential pattern around the artery. Brenner et al.[20] demonstrated a restriction of the spread of dye through the neurovascular bundle in 7 of 12 cadaver dissections, and also the presence of a posterolateral or posterior fascial layer was clearly identified in these cadavers. This was a quite high rate for the presence of a fascial layer. Furthermore, the authors also concluded that the presence or absence of a facial layer was inconsistent with USG findings (such as scout scanning and visualization of a facial layer, or the visualization of the spread of the injectate) or haptic sensations (a bounce or pop-like sensation can be felt whether in the presence or absence of a facial layer). Certainly, the success of visualization of septa with USG is strongly associated with the technical specifications of the equipment. In this study, a septum could be visualized in only four patients. In these patients, local anesthetic solution was injected both at the posterior and lateral aspects of the artery until a satisfactory spread of injectate was achieved (Fig. 4, Supplemental video).

Recently, single-injection lateral-approach IC brachial plexus blocks have gained popularity due to the low incidence of complications (e.g. pneumothorax) and high success rates. The lateral approach allows staying a safe distance away from the lungs, and single injections reduce the risk of vascular puncture with the manipulation of the needle when moving between artery and vein.[26] In this study, two vascular punctures occurred during the performance of a single injection by the residents. Although a proximal block was performed, no other serious complications were observed such as pneumothorax, inadvertent intravascular injection, nerve injury. With an experienced practitioner, and with the guidance of USG, the risk of complications is more likely to be reduced. Therefore, we think that this situation reflects real life and shows the possibility of undesired events during the learning curve.

The limitations of this study are the lack of randomization and the fact that the study is under-powered. Another limitation is the lack of numeric documentation of the evaluation data of motor and sensory functions of the nerves. Also, the procedural time was not noted because at least half of the blocks were performed by residents.

Conclusions

In ultrasound-guided medial approach infraclavicular blocks, single-injection and triple-injection techniques did not differ in terms of block success rates. The need for supplementary blocks was greater in single injections than in triple injections. The presence of a fascial layer could be the reason for the improper distribution of local anesthetics around the cords. Complication rates were low even with a medial approach.

Clinical trial registration

NCT04102358.

Conflicts of interest

The authors declare no conflicts of interest.

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