SCIENTIFIC ARTICLE

Randomized prospective study of three different techniques for ultrasound-guided axillary brachial plexus block

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Abstract
Introduction: Randomized prospective study comparing two perivascular techniques with the perineural technique for ultrasound-guided axillary brachial plexus block (US-ABPB). The primary objective was to verify if these perivascular techniques are noninferior to the perineural technique.
Method: 240 patients were randomized to receive the techniques: below the artery (BA), around the artery (AA) or perineural (PN). The anesthetic volume used was 40 mL of 0.375% bupivacaine. All patients received a musculocutaneous nerve blockade with 10 mL. In BA technique, 30 mL were injected below the axillary artery. In AA technique, 7.5 mL were injected at 4 points around the artery. In PN technique, the median, ulnar, and radial nerves were anesthetized with 10 mL per nerve.
Results: Confidence interval analysis showed that the perivascular techniques studied were not inferior to the perineural technique. The time to perform the blockade was shorter for the BA technique (300.4 ± 78.4 s, 396.5 ± 117.1 s, 487.6 ± 172.6 s, respectively). The PN technique showed a lower latency time (PN – 655.3 ± 348.9 s; BA – 1044 ± 389.5 s; AA – 932.9 ± 314.5 s), and less total time for the procedure (PN – 1132 ± 395.8 s; BA – 1346.2 ± 413.4 s; AA – 1329.5 ± 344.4 s). BA technique had a higher incidence of vascular puncture (BA – 22.5%; AA – 16.3%; PN – 5%).
Conclusion: The perivascular techniques are viable alternatives to perineural technique for US-ABPB. There is a higher incidence of vascular puncture associated with the BA technique.
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Estudo prospectivo randomizado de três diferentes técnicas para o bloqueio do plexo braquial via axilar guiado por ultrassom

Resumo

Introdução: Estudo prospectivo randomizado, compara duas técnicas perivasculares com a técnica perineural para o bloqueio do plexo braquial via axilar guiado por ultrassom (BPVA-USG). Objetivo primário foi verificar se essas técnicas perivasculares são não inferiores à técnica perineural.

Método: Foram randomizados 240 pacientes para receber as técnicas: abaixo da artéria (TA), ao redor da artéria (TR) ou perineural (PN). O volume de anestésico usado foi 40 ml de bupivacaína 0,375%. Em todos os pacientes, fez-se o bloqueio do nervo musculocutâneo com 10 ml. Na técnica TA, injetaram-se 30 ml abaixo da artéria axilar. Na técnica TR, injetaram-se 7,5 ml em quatro pontos ao redor da artéria. Na técnica PN, os nervos mediano, ulnar e radial foram anestesiados com 10 ml por nervo.

Resultados: Análise dos intervalos de confiança mostrou que as técnicas perivasculares estudadas não são inferiores à técnica perineural. A técnica TA apresentou menor tempo para o bloqueio (300,4 ± 78,4 seg; 396,5 ± 117,1 seg; 487,6 ± 172,6 seg; respectivamente). A técnica PN apresentou menor tempo de latência (PN - 655,3 ± 348,9 seg; TA - 1044 ± 389,5 seg; TR - 932,9 ± 314,5 seg) e menor tempo total de procedimento (PN - 1132 ± 395,8 seg; TA - 1346,2 ± 413,4 seg; TR 1329,5 ± 344,4 seg). A técnica TA apresentou maior incidência de punção vascular (TA - 22,5%, TR - 16,3%; PN − 5%).

Conclusão: As técnicas perivasculares são opções viáveis à técnica perineural para o BPVA-USG. Ressalta-se maior incidência de punção vascular associada à técnica TA.

Introduction

The ultrasound-guided technique for axillary brachial plexus block (ABPB) ensures the needle correct placement regarding the plexus, reduces the need for high volume and concentration of local anesthetic when it is injected around the nerves.[1–3] With this ultrasound-guided technique, known as perineural technique, the local anesthetic is deposited around the brachial plexus terminal branches in the axilla. Although effective, this technique may be difficult to apply by anesthesiologists in training, particularly because of the difficulty in locating the radial nerve despite the use of ultrasound due to its position in relation to the artery.[4] Moreover, to apply this technique, the needle is repositioned a few times to reach the nerve structures, which increases the chance of paresthesia during the procedure.

The use of ultrasound in regional anesthesia has provided a redefinition for accomplishing some blockades, allowing the application of optional techniques to perform the same blockade. For axillary route, in order to facilitate the blockade and decrease the number of times the needle is repositioned during its accomplishment, ultrasound-guided techniques with the local anesthetic application only around the axillary artery were described in the literature.[5–7] These techniques were apparently as effective as the perineural technique without altering the procedure time and decreased the incidence of paresthesia during the blockade.[5–7] However, the perivascular technique increased the risk of inadvertent vascular puncture.[6,7]

Thus, in order to reduce the blockade procedure duration, without altering the time and success rate and ensuring patient safety, our group intended to compare two techniques of perivascular injection with the perineural technique for ABPB, all guided by ultrasound. Consequently, we tested the hypothesis that the perivascular techniques are not inferior to the standard perineural technique regarding axillary brachial plexus block (BPVA) success. Blockade time, latency time, total procedure time, and vascular puncture incidence for each technique were recorded.

Case series and method

The study was approved by the Ethics Committee of our institution under the number 296,974 and registered in clinicaltrials.gov under the code NCT02073383.

Inclusion criteria were age over 18 and below 65 years; provision of written informed consent; indication for brachial plexus block for candidates undergoing anesthesia for elective hand surgery; ASA I or II, according to the American Society of Anesthesiology; and body mass index (BMI) < 35 kg.m^{-2}. Exclusion criteria were cognitive impairment or active psychiatric condition, infection at the puncture site, coagulopathy, and history of allergy to bupivacaine.

After patient's inclusion, demographic data were recorded and routine monitoring was performed for surgical procedure, with electrocardioscope, noninvasive blood

Table 1 Motor test.[1,2]

Grade	Definition
4	Full power in relevant muscle group
3	Reduced power but ability to move muscle group against resistance
2	Ability to move against gravity but not against resistance
1	Flicker of movement in relevant muscle group
0	No movement in relevant muscle group

pressure, and pulse oximetry. Intravenous access was obtained in the contralateral upper limb.

Brachial plexus block was made through the axillary pathway using ultrasound (M-Turbo R System with HFL 38 × linear transducer 6–13 MHz, SonoSite, Bothell, WA, USA), with the patient placed in the dorsal horizontal decubitus position. The needle used was 22 G × 50 mm (AEQ2250, BMD Group, Venice, Italy). After asepsis and skin antisepsis with chlorhexidine, analgesia at the puncture site was performed with 1 mL lidocaine 1%. Patients were divided into three groups:

Around the artery technique (AA): 30 mL of 0.375% bupivacaine were injected around the artery with 7.5 mL of anesthetic deposited clockwise at zero, 3, 6, and 9-o'clock positions.
Below the artery technique (BA): 30 mL of 0.375% bupivacaine were injected below the artery at the 6-o'clock position.
Perineural technique (PN): 10 mL of 0.375% bupivacaine were injected around the median, ulnar, and radial nerves.

Additionally, the musculocutaneous nerve was blocked with 10 mL of 0.375% bupivacaine for all patients.

During procedure, the time required for the blockade, defined as the time between needle insertion and the end of local anesthetic injection, was recorded. Blockades were performed by residents and fellows of the institution and supervised by two of the authors (L.H.C.F. and A.T.).

After local anesthetic injection, an observer who was not present during the procedure and who was blinded to the technique evaluated the blockades. This evaluation was done every five minutes until surgical anesthesia was obtained or up to 30 min after local anesthetic injection. The blockade latency was recorded, defined as the time between the end of local anesthetic injection and the patient achieving a satisfactory block for the procedure.

Blockade evaluation

Motor function assessment
The modified Bromage scale was used (Table 1).

The following muscles were evaluated: finger flexor (median nerve), finger extensor (radial nerve), thumb abductor (ulnar nerve), and elbow flexion (musculocutaneous nerve).

Thermal sensitivity assessment
The upper limb thermal sensation evaluation was performed with gauze and alcohol to test the sensitivity of dermatomes innervated by the ulnar (hypothenar eminence), medial (volar region of the thumb), radial (dorsum of hand), and musculocutaneous (lateral region of the forearm) nerves. The cold sensation was considered as one and the non-perception of cold as zero.

Pain sensitivity assessment
The upper limb pain sensation evaluation was performed with the pinprick test using a 23 G needle to test sensitivity in regions of the ulnar, median, radial, and musculocutaneous dermatomes.

Satisfactory blockade was defined as within 30 minutes the patient had motor function ≤ 2 on the modified Bromage scale, absence of thermal sensitivity and of response to pinprick in the regions of the median, ulnar, radial, and musculocutaneous nerves. Additionally, the procedure should be performed without additional analgesia to confirm the anesthetic procedure success. The satisfactory blockade rate of each group was recorded.

Subsequently, the total procedure time, defined as the sum of the time required for the blockade plus latency was recorded.

Finally, the occurrence of accidental vascular puncture during blockade was recorded.

In case of blockade failure, patients received anesthetic supplementation at the elbow level with the previously used solution. After blockade assessment, patients were released for surgical procedure and received midazolam 0.05 mg.kg^{-1} for sedation.

After surgical procedure, patients were admitted to the post-anesthesia care unit, where the postoperative analgesia was assessed using the visual analog scale, up to four hours after the blockade in the unit.

Statistical analysis

To calculate the sample size needed to show that the BA and AA techniques are non-inferior to PN technique regarding surgery success rate the following assumptions were considered.

Hypotheses

Null hypothesis. **H$_0$.** $p_{SAA} - p_{SP} \leq -\delta \times$ optional hypothesis: H$_a$: $p_{SAA} - p_{SP} > -\delta$.

With p_{SAA} being the proportion of success expected in the BA technique sample and p_{SP} the expected success rate in the PN technique sample; δ = non-inferiority margin.

Null hypothesis. **H$_0$.** $p_{SRA} - p_{SP} \leq -\delta \times$ hipótese opcional: H$_a$: $p_{SRA} - p_{SP} > -\delta$.

With p_{SRA} being the proportion of success expected in the AA technique sample and p_{SP} the expected success rate in the PN technique sample; δ = non-inferiority margin.

Non-inferiority hypothesis test
1. Level of significance 1.25% ($\alpha = 0.0125$ – unilateral hypothesis test and two primary objectives).
2. Sample power 80% ($1 - \beta = 0.80$).

The expected proportion of success among the techniques was obtained through the analysis of the literature and a pilot sample of the three techniques performed by our group. Thus, a sample size of 240 patients (80 per group) reached a power of 80% and a significance level of 1.25% (non-inferiority test with two primary objectives) to show that the below the artery and around the artery techniques are non-inferior to the perineural technique, with a non-inferiority margin lower than 12.5%. The non-inferiority hypothesis between groups was tested by comparing the lower limit of the 97.5% confidence intervals.[8]

To compare the techniques regarding the quantitative variables (age, BMI, blockade time, latency, procedure time), the analysis of variance (ANOVA) was used with multiple comparisons of Bonferroni or, if necessary, the non-parametric Kruskal–Wallis test, followed by the non-parametric Mann–Whitney test. For the qualitative variable vascular puncture, the chi-square test was used.

Results

A total of 252 patients were included in the study, 12 of whom were excluded due to a change in intraoperative surgical technique, with removal of iliac bone graft and therefore conversion to general anesthesia was necessary. The groups were similar regarding demographic data and preoperative clinical parameters (Table 2).

According to the results shown in Table 3 at the 5% significance level there was a significant difference between techniques regarding the following variables: time in seconds (s) required for blockade, latency, procedure time and vascular puncture.

Regarding the blockade required time, the BA technique showed a median time significantly lower than that for the AA and PN techniques. In turn, the PN technique showed a blockade median time significantly longer than that for the BA and AA techniques (Table 3).

Later, the PN technique showed a mean latency significantly lower than the average times for the BA and AA techniques, which did not differ significantly between them in mean latency time (Table 3). Furthermore, the PN technique showed a mean procedure time significantly lower than that for the BA and AA techniques, which also did not differ significantly from each other regarding mean procedure time (Table 3).

Regarding vascular puncture, the BA technique showed a percentage of vascular puncture significantly higher than that for the PN technique. However, AA technique did not differ from the BA and PN techniques regarding this variable (Table 3).

Regarding non-inferiority, the results in Table 4 show the lower limits of CI (97.5%) for the percentage difference between surgical success rates. Comparing the techniques, they are higher than the lower margin of the non-inferiority interval, not rejecting the hypothesis of non-inferiority between techniques (Table 4).

Surgical procedures were uneventful. Regarding postoperative analgesia, no patient, whose blockade was considered satisfactory, referred pain up to 4 h after the blockade. There was no complication, such as local anesthetic intoxication, during the study. All patients were discharged on the same day of the procedure.

Discussion

In this prospective randomized study our group compared two perivascular techniques with the perineural technique for ultrasound-guided ABPB. We found that the single injection below the artery and the injection around the artery techniques are not inferior compared to the perineural technique.

Imasogie et al. demonstrated that the local anesthetic injection near the artery provides a circumferential dispersion around it (donut sign).[5] A possible explanation for this is that the tendency is for the anesthetic to disperse to areas of lower pressure in adjacent tissues. Thus, when the technique is applied below the artery, the fascial pressure of the *latissimus dorsi* posteriorly to the artery causes the anesthetic to disperse around the artery and not only to the region below it.[6] Other possible explanation is a longitudinal dispersion of the local anesthetic through the neurovascular sheath of the axillary region.[9] In order to apply the perivascular techniques, the use of ultrasound is fundamental because it allows visualizing the needle tip and local anesthetic dispersion during the blockade and ensures the local anesthetic correct dispersion around the artery. Without using ultrasound, the success rate of perivascular techniques is lower, as local anesthetic dispersion becomes unpredictable, needle tip may be too deep (within the *latissimus dorsi* fascia) or too superficial—outside the neurovascular sheath.[9]

Previous studies have suggested that the success rate among perivascular techniques is similar to that of perineural technique for ultrasound-guided axillary brachial plexus block. The rates ranged from 87.5% to 97.5%, similar to those found in our study.[5–7,9] Moreover, studies have shown that perivascular techniques were performed in a shorter time compared to perineural technique.[5–7] However, in these studies, as perineural technique had a shorter latency, the total blockade time that is the sum of blockade execution time plus latency was similar among the techniques.[5–7] These results differ somewhat from the results found in the present study. Our study also showed that perivascular techniques are applied in less time than perineural technique. Additionally, it has also been demonstrated that perineural technique has a lower latency. However, in this study, perineural technique had a shorter total procedure time than perivascular techniques. This difference may perhaps be explained by the different scales used to evaluate blockade latency or by the fact that the perineural technique is the most used in our service, which may decrease the difference in execution time between techniques. However, although statistically significant, the difference in total procedure time between groups ranged from two and three minutes, which may have no clinical significance.

Table 2 Demographic characteristics of patients.

Technique variables	BA	AA	PN	Total	p
Age (years)					
Mean (SD)	40.8 (13.6)	40.7 (14.1)	38.4 (12.4)	40 (13.4)	0.433[a]
Median (min–max)	41.5 (18–65)	39 (19–67)	36 (18–65)	39 (18–67)	
BMI (kg.m^{-2})					
Mean (SD)	25.9 (4.6)	26.7 (3.8)	25.6 (3.8)	26.1 (4.1)	0.265[a]
Median (min–max)	25.6 (14.7–39.1)	25.8 (15.1–37.9)	25.2 (16.8–34.5)	25.6 (14.7–39.1)	
ASA					
I	35	36	37		
II	45	44	43		
Total	80	80	80		

BA, below the artery; AA, around the artery; PN, perineural; SD, standard deviation.
 [a] Analysis of variance (ANOVA).

Table 3 Comparison of blockade techniques according to variables: blockade, latency and procedure time, surgical success, and incidence of vascular puncture.

Technique variables	BA $n = 80$	AA $n = 80$	PN $n = 80$	p
Blockade time (s)				
Mean (SD)	300.4 (78.4)	396.5 (117.1)	487.6 (172.6)	<0.001[a]
Median (min–max)	284 (169–512)	396 (184–716)	471 (196–927)	
BA × AA				<0.001
BA × PN				<0.001
AA × PN				<0.001
Latency time (s)				
Mean (SD)	1.044 (389.5)	932.9 (314.5)	655.3 (348.9)	<0.001[b]
Median (min–max)	900 (300–1.800)	900 (300–1800)	600 (300–1500)	
BA × AA				0.17
BA × PN				<0.001
AA × PN				<0.001
Procedure time (s)				
Mean (SD)	1346.2 (413.4)	1329.5 (344.4)	1132 (395.8)	0.001[b]
Median (min–max)	1207 (689–2264)	1284 (732–2216)	1074.5 (523–2225)	
BA × AA				1
BA × PN				0.002
AA × PN				0.006
Surgical success				
Yes	75 (93.8)	73 (91.3)	75 (93.8)	Not calculated
No	5 (6.3)	7 (8.8)	5 (6.3)	
Vascular puncture				
Yes	18 (22.5)	13 (16.3)	4 (5)	0.006[c]
No	62 (77.5)	67 (83.8)	76 (95)	
BA × AA				1
BA × PN				0.009
AA × PN				0.12

BA, below the artery; AA, around the artery; PN, perineural; SD, standard deviation.
 [a] Kruskal–Wallis test.
 [b] Analysis of variance (ANOVA).
 [c] Chi-square test.

Table 4 Non-inferiority analysis of the surgical success rate of the BA versus PN and AA versus PN techniques.

Comparison	Lower bound interval	Upper bond interval	CI (97.5%)
BA × PN	−0.125	0.125	(−0.086; 0.086)
AA × PN	−0.125	0.125	(−0.118; 0.068)

BA, below the artery; AA, around the artery; PN, perineural.

One limitation of our study was not recording the number of needle repositioning attempts during blockades and the incidence of paresthesia found in each technique. However, this subject has already been well documented in previous studies showing that perivascular techniques are applied with less needle repositioning and lower rate of paresthesia.[6,7]

Thus, as perivascular techniques have a shorter execution time, comparable total procedure time, and lower incidence of paresthesia, they are recommended for ultrasound-guided ABPB. So a protocol of two injections was recommended: one injection into the musculocutaneous nerve and one injection below the artery.[7] Furthermore, it is believed that this technique is more appropriate for people with less experience it may be the technique of choice for training this block.

However, a fact concerning the safety procedure of the BA technique should be mentioned. One of the great advantages brought by the ultrasound-guided regional anesthesia technique, compared to other techniques for locating nerve structures, was the reduced number of accidental vascular puncture, which is one of the most important factors related to local anesthetic systemic intoxication.[10] Thus, ultrasound was able to reduce the incidence of local anesthetic intoxication compared to the neurostimulation and paresthesia techniques.[10] However, studies using the BA single injection technique for ultrasound-guided ABPB showed a relatively high incidence of accidental vascular puncture, rates well above that of perineural technique. Vascular puncture rates for BA and PN techniques were, respectively: Bernucci et al. (24% × 0%); Cho et al. (7% × 0%); and Tran et al. (15%) for BA technique.[6,7,9] Our results show an incidence of vascular puncture similar to previous studies: 22.5% for BA technique; 16.3% for AA technique, and 5% for perineural technique. Vascular anatomical variations in axillary region are common and may complicate the axillary brachial plexus block. Kutiyanawala et al. demonstrated that 21 of 100 patients undergoing axillary dissection had anatomical variations in this region, 10 of them had two axillary veins.[11] Artery variations are also common in this region.[12] This shows that, despite the other benefits demonstrated by the BA technique, such as reduced needle repositioning and lower incidence of paresthesia, it significantly increases the chance of accidental vascular puncture and, perhaps, it should not be the technique of choice for patients with coagulation disorders or vascular anatomical variations. Moreover, as in the single injection BA technique, a large amount of local anesthetic is deposited[13] and frequent aspirations are suggested to increase the safety of not applying an intravascular injection. Future studies should try to compare whether this increased incidence of

vascular puncture may increase the risk of local anesthetic systemic toxicity with the use of this technique. However, no hematoma or sign of systemic intoxication by local anesthetic was recorded in the present study.

Finally, it should be recognized that the perineural technique allows the use of smaller volumes compared to perivascular techniques, which decreases the total mass of anesthetic used and ensures a greater margin of safety compared to the toxic dose of local anesthetic.[1,2,13]

In conclusion, the present study showed that the perivascular techniques studied are not inferior to the perineural technique, which makes them viable options for ultrasound-guided axillary brachial plexus block. However, care should be taken regarding the increased incidence of vascular puncture when using these techniques, particularly the single puncture below the artery technique.

Conflicts of interest

The authors declare no conflicts of interest.

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