Educational and clinical aspects of peripheral nerve blockade

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Chapter 5

Influence of arm position on ultrasound visibility of the axillary plexus

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Submitted

Abstract

Background and Objectives:

Contemporary axillary brachial plexus block is performed by separate injections targeting the radial, median, ulnar, and musculocutaneous nerve. These nerves are arranged around the axillary artery, making ultrasound visualization sometimes challenging. In particular the radial nerve can be difficult to see being frequently localized behind the artery. The primary aim of this study was to investigate which arm position optimizes the visibility of the radial nerve. Secondary aims were the visibility and position of the other axillary nerves during varying arm positions.

Methods

Following ethical committee approval, one anesthesiologist performed bilateral ultrasound examinations of the axillary plexus on 20 volunteers. Each arm was placed in different positions (shoulder (S) 90° or 180°, elbow (E) 0° or 90°) and scans were performed as far proximal as possible in the axilla, and additionally 5 cm distally to this point (proximal (P) vs. distal (D), respectively), resulting in eight different scans stored for off-line analysis. Two blinded anesthesiologists assessed visibility scores, distances and angles of the nerves relative to the artery.

Results

No significant differences between arm positions were found in the visibility score of radial ($p=0.359$) and musculocutaneous nerves ($p=0.073$). Visibility of the median nerve was improved in positions S90°/E0°/D and S180°/E0°/P ($p=0.02$). The ulnar nerve was more visible in position S180°/E 0°/P and D ($p=0.007$). The greatest distance between artery and radial nerve was 7.4±4.7mm at an angle of 120±14° in position S180°/E 0°/D.

Conclusions

The visibility of the radial nerve could not be significantly improved by varying the position of the arm. S180°/E0° provided the best overall visibility and accessibility of nerves.

Influence of arm position on ultrasound visibility of the axillary plexus

Introduction

During the last decade, the use of high-definition ultrasound has renewed the interest in peripheral regional anesthesia.[1] Surprisingly, although ultrasound is used to directly target nerves and plexus, extremities are still most often positioned as if performing landmark-oriented approaches. These positions were generally based on dissectional anatomical studies. For example, the brachial plexus in the axillary region is approached with the extremity positioned as described by Winnie.[2] However, because of the mobility of the shoulder, the brachial plexus at the axillary level is particularly susceptible to rearrangement of its structures according to position.

Axillary brachial plexus block is one of the most commonly used methods of regional anesthesia.[3] Separate blockade of the four main constituent nerves (radial, median, ulnar, musculocutaneous) significantly increases success rate.[4] These nerves are arranged around the axillary artery within a neurovascular sheath. The position of the nerves inside the sheath is not fixed and allows a certain extent of movement. Furthermore, fibers are to a variable degree, exchanged between individual nerves.[5] Anatomy in the axillary fossa is variable,[6] which may render axillary block by single nerve blockade more difficult. Moreover, at the level of intersection of pectoralis major and biceps humeri muscle, where the axillary block is usually performed, only the radial, median, and ulnar nerve are consistently found within the common neurovascular sheath. The musculocutaneous nerve usually separates more proximally, and is usually found between the biceps and coracobrachialis muscles.[7, 8] Due to its anatomic position behind the axillary artery, the radial nerve is the most difficult to visualize when using ultrasound.[9]

Determining the optimal position of the arm for visualization of the radial nerve during the performance of the axillary brachial plexus block might render ultrasound guided axillary blocks even more efficient and safe. Thus, we investigated the influence of arm positioning on the sono-anatomy of the axilla and the visibility of the nerves most proximal in the axilla and 5 cm distally to this point. The primary objective of the study was to assess the ultrasound visibility of the radial nerve at two levels in four different arm positions. Secondary objectives were visibility, position and distance of all four nerves to the brachial artery and the skin.

Methods

This prospective observational study was conducted at the Department of Anesthesiology of the Academic Medical Centre (AMC) Amsterdam in November 2012.

Volunteers

Following Local Ethical Committee approval and registration in the national trial register (NL42116.018.12), 20 volunteers were recruited by placing an advertisement on the Department's bulletin board. Inclusion criterion was age > 18 years. Exclusion criteria were: refusal of ultrasound examination, restriction in shoulder movement, local infection, Body Mass Index ≥ 30 kg/m2 to avoid poor visibility due to obesity. After obtaining written and informed consent from each volunteer, demographic data such as gender, age, size and bodyweight as well as handedness were collected.

Ultrasound Examinations

All examinations were performed by one anesthesiologist (V.F.) experienced in regional anesthesia, using one ultrasound machine (M-Turbo; Sonosite; Bothell, WA, USA) with a linear multifrequency probe 13-6 MHz (HFL38X; Sonosite; Bothell, WA, USA). After a short introduction and explanation of the procedure, volunteers were placed supine for a bilateral ultrasound examination of the axillary region. Depth and gain were optimized for each volunteer and 'resolution mode' was selected on the ultrasound machine. To avoid shifting of the nerves during scanning, minimal probe pressure was exerted on the skin with only light compression of veins. Each arm was placed in four different positions:
1. Shoulder 90°/elbow 90°(=S90/E90)
2. Shoulder 90°/elbow 0°(=S90/E0)
3. Shoulder 180°/elbow 90°(=S180/E90)
4. Shoulder 180°/elbow 0°(=S180/E0)

In these four positions scans were performed at two levels: Proximal level (=P): at the intersection between the lower border of the pectoralis major muscle and the biceps brachii muscle (marked as proximal). Distal level (=D): Five centimetres distally from the first level (marked as distal). In all positions the forearm was kept in a neutral position midway between pronation and supination. Thus, eight different scans of each axilla were performed, results are shown in Table 1.
During each scan a 4 second-long video clip was captured, saved and encrypted for subsequent retrospective blinded viewing and assessment.

Image assessments and measurements

After completion of all examinations, video clips were assessed independently by two blinded assessors (M.F.S., J.T.W.), experienced in regional anesthesia. In each clip radial, median, ulnar and musculocutaneous nerves were assessed on visibility using a six-point visibility scale:

0 = no nerve identified,
1 = nerve identified with a high probability,
2 = nerve identified, but most of it not visible,
3 = nerve identified, more than 50% of its borders can be precisely distinguished from surrounding structures,
4 = nerve completely visible, but fascicles poorly defined,
5 = nerve completely visible and multiple fascicles identifiable.

Any discrepancy in visibility scores was discussed afterwards and clips were reviewed in order to find a consensus for the score.

Distances from each nerve to the skin and to the artery and angles from each nerve to the artery were measured. The shortest distances from nerves to skin and to the artery were measured in millimetres. The centers of the artery and each nerve were reference points for angle measurement (degrees). In cases where the nerve was not visible on the clip, distances and angles were not recorded. All data obtained were entered in a computer spreadsheet (SPSS, Chicago, IL, USA) for statistical analysis. Mean measurements of distances and angles from the nerves to the artery were geometrically visualized.

Statistical Analysis

Power analysis had revealed that to detect a clinical meaningful increase of visibility of the radial nerve of 30%, assuming a standard deviation of 20% with a power of 80 and an alpha of $p < 0.001$ (compensated for 6 comparisons), a group size of n=18 would be required. Assuming a 10% dropout, we included 20 volunteers.

Volunteer demographics are expressed in mean ± SD or median and range, where appropriate. Visibility scores of the radial, median, ulnar and musculocutaneous nerve, distances to the axillary artery, distances to the skin and angle with respect to artery are represented in mean ± SD in each of the eight scan positions. One way repeated measures analysis of variance was used to compare visibility scores in different scan positions and validated by Mauchly's sphericity test to reduce the likelihood of type I errors. Therefore visibility scores were taken at interval level. Post hoc tests were used to test for the multiple comparisons where appropriate. A value of $p < 0.05$ was considered to be statistically significant. Statistics were calculated with use of SPSS 20.0 for Windows (SPSS, Chicago, IL, USA).

Eight positions for scanning the axillary plexus

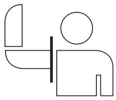
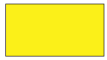
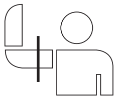
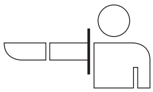
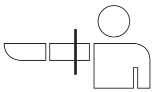
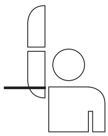
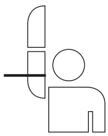
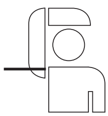
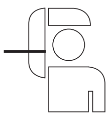
Position	Abbreviation	Picure	Colour
Shoulder 90^0 abduction Elbow 90^0 flexion Proximal scan	S90/E90/P		
Shoulder 90^0 abduction Elbow 90^0 flexion Distal scan	S90/E90/D		
Shoulder 90^0 abduction Elbow 0^0 flexion Proximal scan	S90/E0/P		
Shoulder 90^0 abduction Elbow 0^0 flexion Distal scan	S90/E0/D		
Shoulder 180^0 abduction Elbow 0^0 flexion Proximal scan	S180/E0/P		
Shoulder 180^0 abduction Elbow 0^0 flexion Distal scan	S180/E0/D		
Shoulder180^0 abduction Elbow 90^0 flexion Proximal scan	S180/E90/P		
Shoulder 180^0 abduction Elbow 90^0 flexion Distal scan	S180/E90/D		

Table 1 Eight positions for scanning the axillary plexus. Description of the positions, abbreviations and pictures. Last column represents corresponding colours, used in the results.

Results

Participant flow

Twenty volunteers were recruited in November 2012. All volunteers signed written informed consent without any drop-out. None of the volunteers experienced any harm or discomfort during the examinations. Demographic data of the volunteers are presented in Table 2.

Visibility Scores

For analysis of visibility scores, 320 video clips were captured from 40 axillary regions of twenty volunteers in 8 different scan positions. Mean ± SD visibility score in eight different scan positions are shown in Figure 1. We failed to identify the radial nerve in 10% of the clips (visibility score = 0) in scan position S180°/E90°/D, in 12.5% of cases in scan position S180°/E0°/P and in 22.5% in scan positions S90°/E90°/P, S90°/E0°/P and S90°/E0°/D. No significant differences in visibility score of the radial (p=0.359) and musculocutaneous nerve (p= 0.073) were found among the eight scan positions, whereas significant differences were found in visibility of the median (p= 0.02) and ulnar nerve (p=0.007). Post hoc testing demonstrated significantly improved visibility of median nerve in scan positions S90°/E0°/D and S180°/E0°/P compared to the 'classical' position of S90°/E90°/P (Fig 1b). Visibility of the ulnar nerve was significantly better in positions S180o compared to S90o (except S180o/E90°/D) (Fig. 1c).

Demographic data

Sex (male,female), n	10/10
Age, y	35±8
Body length, cm	180±9
Body weight, kg	71±12
BMI, kg/m2	22.0±2.1
Handedness (right/left), n	20/0

Table 2 Volunteer characterics. Continuous variables are presented as means±SDs; categorical variables are presented as counts.

Orientation of the nerves to the artery and the skin in different positions

Mean positions of the nerves in relation to the artery in the eight different scan positions with the artery as reference points are geometrically demonstrated in a transverse view in Figure 2.

Radial nerve

Significantly greater distances between the radial nerve and the artery were found in shoulder positions of 180°, whereas smallest distance was found in position shoulder 90°, elbow 90° or 0°, distal (p<0.001). Smallest distance to the skin of 6.9 mm (2.6) was found in a position shoulder 180°, elbow 0°, proximal, and greatest distance was 13.2 mm (3.5), found in a position shoulder 90°, elbow 90°, distal (p<0.001).

Median nerve

No significant differences in distance from the median nerve to the artery were found, ranging from 9.9±5.9 mm to 15.0±12.9 mm in different scan positions. However, significant differences were found in distances to the skin (*p*<0.001) with the smallest distance of 3.0±1.4 mm in position shoulder 90°, elbow 0°, proximal and a greatest distance of 5.4±2.1 mm in position shoulder 90°, elbow 90°, distal.

Ulnar nerve

No significant differences in distance from the ulnar nerve to the artery were found at different scan positions, ranging from 2.7±4.0 mm to 4.3±3.9mm, whereas distance to the skin was greatest in position shoulder 90°; elbow 0°; distal (5.3±1.8mm) and smallest in position shoulder 180°; elbow 90°; proximal. (p<0.001)

Musculocutaneous nerve

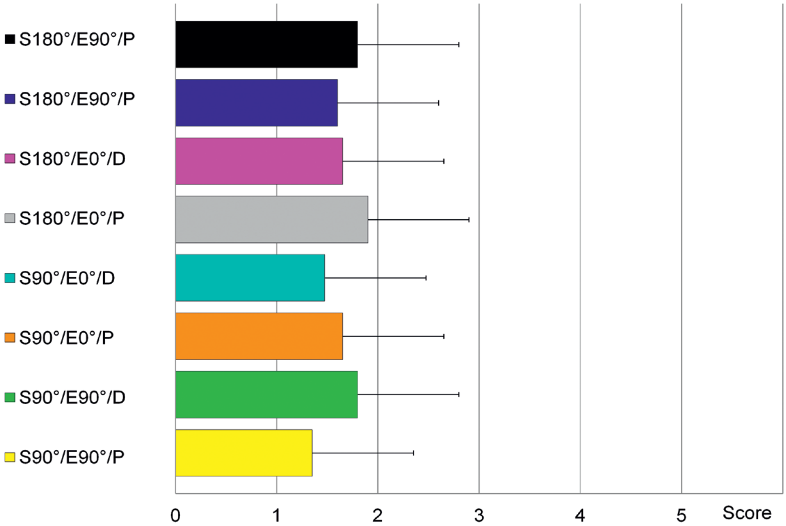
Distance to the artery was greatest in position shoulder 90°, elbow 90°, distal (13.9±5.4mm) and smallest in position shoulder 180°, elbow 0°, proximal (9.0±4.4mm, p<0.001). Distance to the skin was greatest in position shoulder 180°, elbow 90°, distal (12.6±4.2 mm) and smallest in position shoulder 90°, elbow 90°, proximal (9.8±3.4 mm) and in position shoulder 90°, elbow 0°, proximal (9.8±3.2 mm, p<0.001).

Discussion

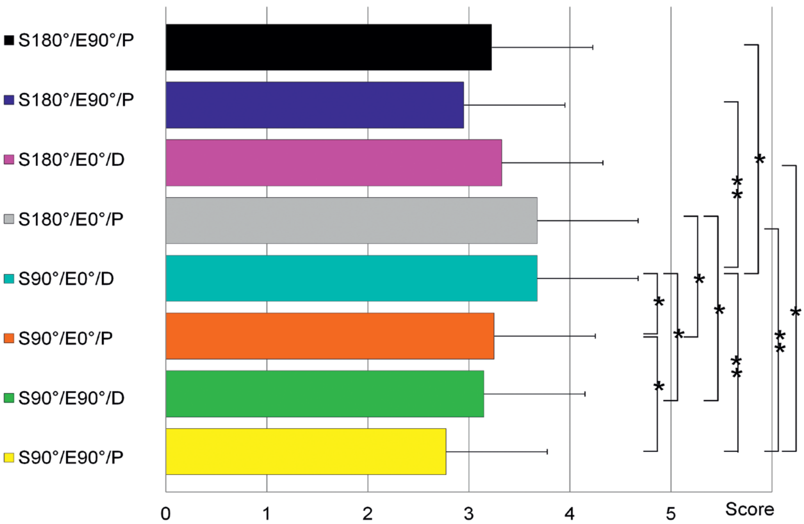
Visibility of the radial nerve was not affected by changing the position of the shoulder, elbow or the scan level in the axilla. However, within subjects, analysis demonstrated a significantly improved visibility of the median nerve when scanning in position shoulder 180°; elbow 0°; proximal or the position shoulder 90°; elbow 0°; distal. In addition, a significantly improved visibility of the ulnar nerve was found when the shoulder was positioned in 180° except when the elbow was flexed, while scanning at the distal level in the axilla. The arm position providing optimal visibility of all four nerves simultaneously is shoulder 180°; elbow 0°; proximal.

Remarkably, there was a wide variation in distance and angle from the radial nerve to the artery (Fig. 2a), while the varying positions of the arm and scan levels did not influence the visibility of the nerve. This may be due to the fact that the radial nerve is often obscured behind the axillary artery by dorsal enhancement and lateral shadowing artifacts. In contrast, despite being consistently located anterior to the artery, the visibility of the median and ulnar nerve changed significantly with differing arm positions. Median and ulnar nerve were consistently in front of the artery, but their visibility changed significantly in different positions. In the position shoulder 90°; elbow 0 °; proximal; the radial nerve is most often vertically located under the artery, making invisibility of the radial nerve very likely due to acoustic enhancement of the artery (Fig. 2a). The distance from the radial nerve to the artery was greatest when the shoulder was abducted 180° and the scan performed distal in the axilla, theoretically reducing the risk of a deterioration in visibility as a result of artifacts induced by the artery.[10] However, this scan position did not improve the visibility of the radial nerve. Aside from the influence of the artery, there are several other possible causes of poor to moderate visibility of the radial nerve. The radial nerve does not travel parallel to the artery and the skin, but after passing superficial to the latissimus dorsi tendon and teres major muscles in the axilla, it runs diagonally in the fascial plane of the long and median head of the triceps, and spirals oblique across the posterior surface of the humerus.[11] Thus scanning of the brachial plexus and artery in the short axis at the level of the axillary artery is not perpendicular to the axis of the radial nerve, resulting in poor reflection and visualization. Moreover, muscular branches to the heads of the triceps arise from the radial nerve at the level of the axilla and proximal humerus in highly variable numbers and levels, resulting in individual

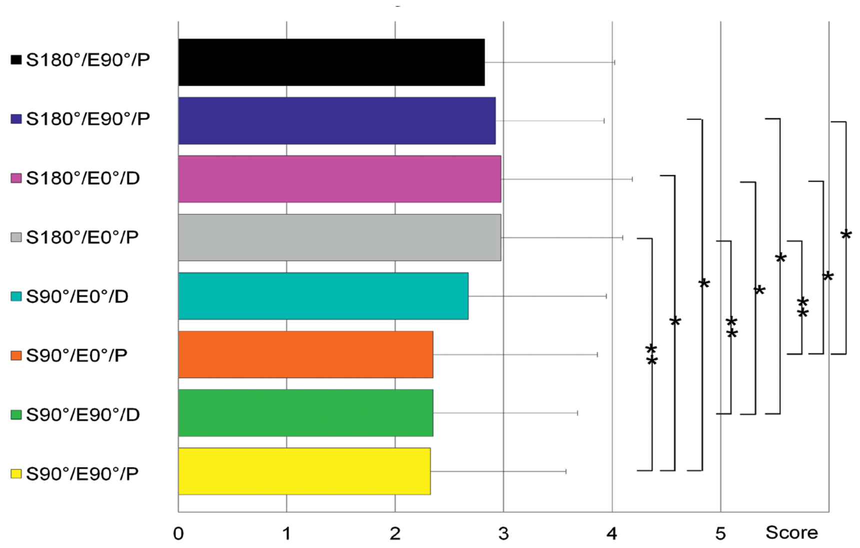
Visibility Radial Nerve



Visibility Median Nerve



Visibility Ulnar Nerve



Visibility Musculocutaneus Nerve

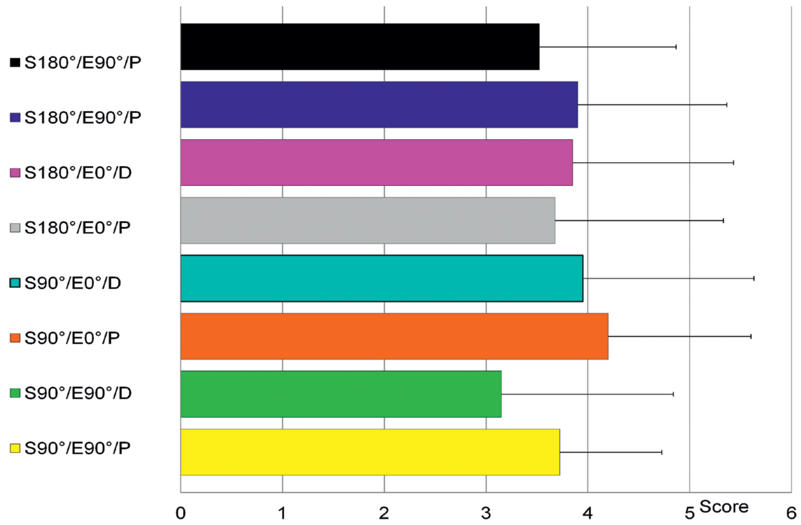
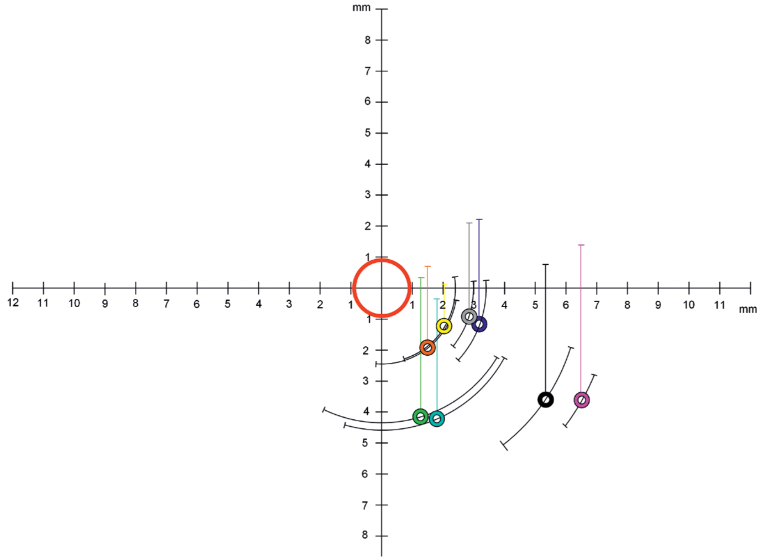
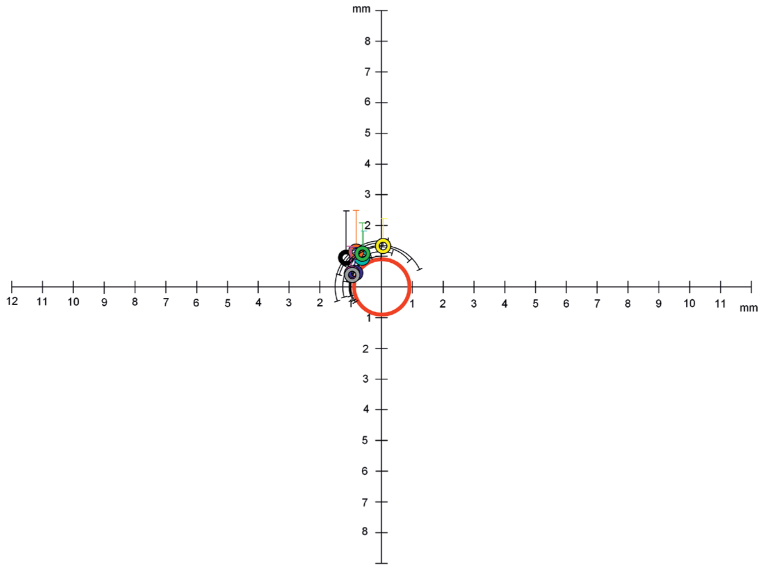


Figure 1 Visibility scores of the radial nerve (A), median nerve (B), ulnar nerve (C) and musculocutaneus nerve (D) in eight different positions, represented in corresponding color (see table 1). Visibility Score is 0-5, where score 0 represents 'nerve not visible' and score 5 represents 'nerve completely visible'. * $p<0.05$, ** $p<0.005$

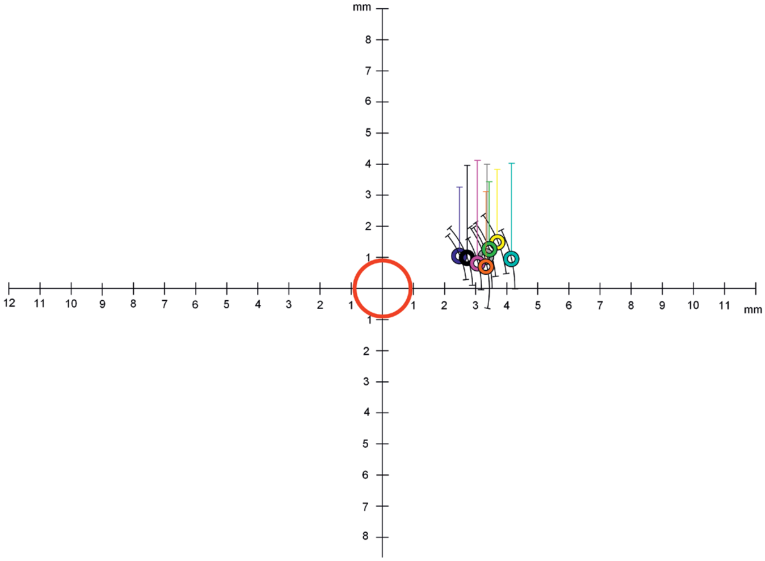
Radial Nerve



Median Nerve



Ulnar Nerve



Musc. Cut. Nerve

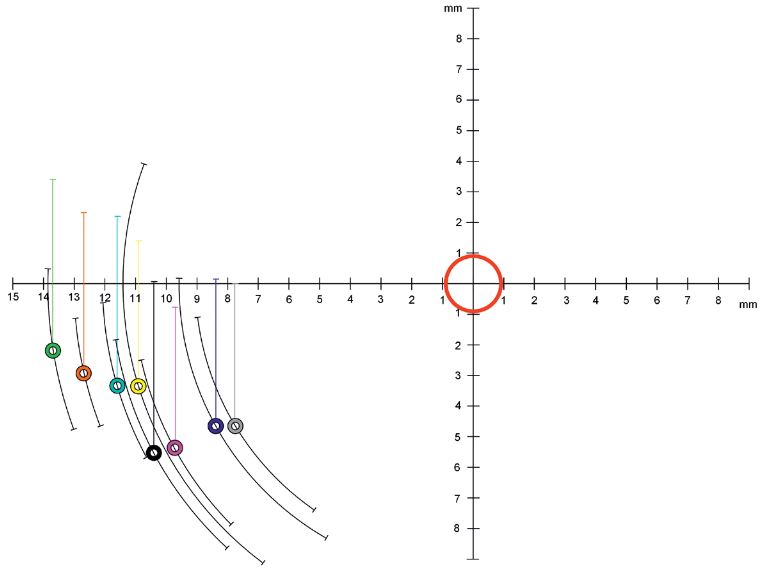


Figure 2 Geometric presentation of the distances (mm) and angles (degrees) of the radial nerve (A), median nerve (B), ulnar nerve (C) and musculocutaneus nerve (D) in relation to the brachial artery in eight different positions, represented in corresponding color (table 1).Lines represent SD of mean distance and curves represent SD of mean angle to the brachial artery. Brachial artery is the reference point on the X- and Y- axis.

differences in visibility scores.[12] In a similar study of the sciatic nerve undertaken in the popliteal fossa, visualization of the division of the sciatic nerve into the tibial nerve and common peroneal nerve was difficult because of differences in angulation, direction, depth and internal architecture of nerve tissue.[13]

Our results are partly in agreement with findings obtained by Wong et al., who found it impossible to visualize the radial nerve in two of 48 patients. In contrast to our current study, the latter examination was not performed in standardized views, and radial nerve identification was verified by nerve stimulation.[14]

The percentage of between 10 and 22.5 % of the video-clips wherein the radial nerve was not identifiable seems high, however, for methodological reasons the scans were very standardized and very little movement was allowed to identify the nerve. Thus, it is not surprising that the rate of identification is lower than when free scanning is possible. One may argue that nerve identification just by looking at short clips is fallible. Thus, transcutaneous identification might be an option in volunteers, but this has been shown in earlier studies to be almost of no value in locating the nerves where they are superficially located.[15] Although the visibility score of the radial nerve does not change significantly between the different arm positions, it is most superficial to skin and most distant to the artery at position shoulder 180°; elbow 0°; proximal. An additional benefit in this same position is the high visibility score of the median and ulnar nerve.

In addition, the location of the musculocutaneus nerve varied widely in differing arm positions, without affecting nerve visibility. Therefore, although this position (shoulder 180°; elbow 0°; proximal) does not increase the visibility of the radial nerve significantly, it seems to be the most advantageous for the integral visibility and location of all nerves.

Movement of the shoulder to 180° extends the coracobrachial muscle, and straightening the elbow extends the biceps muscles whilst shifting and decreasing the cross-section of the muscle layers. This is one of the reasons why in this arm position the nerves are most superficial to the skin and in the case of the median and ulnar nerve most visible.

Limitations

Before using this new position of the shoulder as a standard positioning in clinical practice a few things must be considered. The scans taken were short and the probe was only marginally moved in order to have a high degree of standardization. In clinical practice the probe is variably moved according to the individual anatomy. Nevertheless, we could identify a position that results in the

most superficial nerve depth, and leads to the highest visibility of two of the nerves. Furthermore, the volunteers were younger and leaner than the average patient population. Furthermore, some (older) patients might not able to abduct their shoulders to 180 ^{o}. As the radial nerve does not run parallel to the artery it would have been interesting to study the degree of tilting that is required for an improved visibility of the radial nerve in the arm position where the radial nerve is most far away from the artery. Nevertheless, in clinical daily practice it is worth attempting to position the patient arm to shoulder 180 ^{o}; elbow 0^{o}; proximal to optimize the visibility of the median and ulnar nerve.
We used a 6-point scale for the nerve visibility score, while a four step scale was used in the study of Wong and in a study about the visualization of the sciatic nerve.[14, 16] However, there is no standardized or validated scale for ultrasonic nerve visibility. In our opinion we could classify the visibility more precisely by defining each score in detail in advance. Other studies have been performed to determine a recommended patient position on the basis of nerve to skin distances measured with ultrasound for an infraclavicular block.[17, 18] In a study by Bigeleisen et al., success rate, performance- and onset time were measured in patients undergoing a supraclavicular block. We did not determine these variables since our study was performed in volunteers to explore a recommended position for the axillary brachial plexus block in order to increase visibility of the often 'problematic' radial nerve. Although we could not identify a position that enhanced the visibility of the radial nerve, we did identify a position that increased the visibility of median and ulnar nerve, and exposed most nerves to a more superficial position more distant from the artery. It remains to be determined whether selecting for an arm position with good overall visibility will also translate into a clinically appreciable benefit, such as shorter time to block, or a higher block success rate.

In conclusion, we recommend an arm position with the shoulder in 180 ^{o} abduction, elbow 0^{o} and a proximal scan level for ultrasound guided axillary brachial plexus block in order to allow the best visibility, especially of the ulnar and median nerve.

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