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A Magnetic Resonance Imaging Study of Modifications to the Infraclavicular Brachial Plexus Block

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A previously described infraclavicular brachial plexus block may be modified by using a more lateral needle insertion point, while the patient abducts the arm 45° or 90°. In performing the modified block on patients abducting 45°, we often had problems finding the cords of the brachial plexus. Therefore, we designed an anatomic study to describe the ability of the recommended needle direction to consistently reach the cords. Additionally, we assessed the risk of penetrating the pleura by the needle. Magnetic resonance images were obtained in 10 volunteers. From these images, a virtual reality model of each volunteer was created, allowing precise positioning of a simulated needle according to the modified block, without exposing the volunteers to actual needle placement. In both arm positions, the recommended needle angle of 45° to the skin was too shallow to reach a defined target on the cords. Comparing the two arm positions, target precision and risk of contacting the pleura were more favorable with the greater arm abduction. We conclude that when the arm is abducted to 90°, a 65°-needle angle to the skin appears optimal for contacting the cords, still with a minimal risk of penetrating the pleura. However, this needs to be confirmed by a clinical study.

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Infraclavicular brachial plexus blocks aim at the cords of the brachial plexus and have been designed to obtain complete nerve block of the upper extremity while minimizing the risk of pneumothorax (1–6). In a previous magnetic resonance (MR) study of the infraclavicular block described by Raj et al. ("Raj's block") (1), we proposed a more lateral needle insertion point (7). This would bring the needle closer to the cords and farther away from the pleura.

Our group had been introduced to such a modification of Raj's block during a workshop at a meeting in 1993. Regrettably, this method has not been published. We will refer to it as "the lateral approach." According to our recollection, it was performed as follows (Figs. 1, 2B, 3B): The supine patient abducts the arm to 45°. Two arterial points are palpated and marked where the subclavian artery dips under the superior border of the clavicle (alternatively at the base of the interscalene cleft) and approximately where the brachial artery crosses the lateral border of the pectoralis major. A line between these points is drawn. The needle insertion point is on this line, at a radial distance of 2.5 cm from the line's intersection with the inferior border of the clavicle. The needle is directed laterally along the line while kept at an angle of 45° to the skin. A nerve stimulator aids in exact positioning of the needle.

The lateral approach may also be performed with the patient abducting the arm 90° (workshop 1996, San Diego). This position brings the needle insertion point more cephalad and the needle course more lateral than with lesser degrees of abduction. Theoretically, this should reduce the risk of pneumothorax. This variant has not been published.

The lateral approach differs from Raj's block only regarding the point of needle insertion (Fig. 1). By using Raj's block, the patient abducts the arm, preferably to 90°. The needle insertion point is 2.5 cm below the inferior border of the clavicle, on a paramedian line through the point at which the subclavian artery is palpated dipping under the clavicle, or on a paramedian line through the midpoint of the clavicle.

During the first 28 months after the 1993 meeting, we have tried the lateral approach in 161 patients with the arm abducted to 45°. Frequently, we had to redirect the needle to find the nerves, and in 18 patients (11%), we finally discontinued the method. No patients demonstrated clinical signs of pneumothorax.

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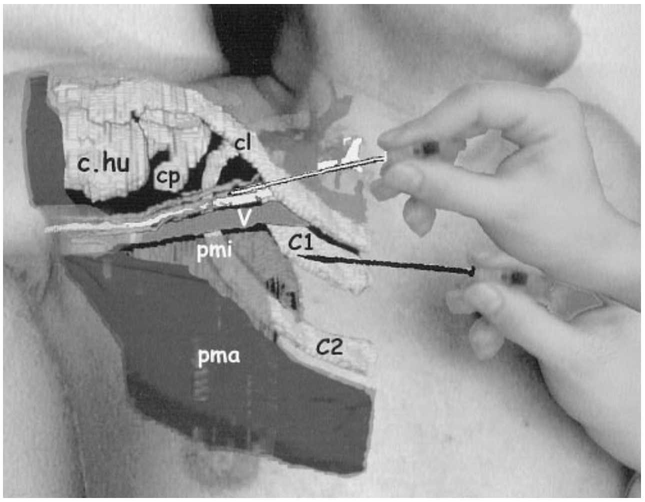

Figure 1. Front view of infraclavicular anatomy, right side, arm 90° abducted (Volunteer 1). Merging segmented magnetic resonance images with a correlated surface picture of the identical person created the picture. The hand-held white and black needles demonstrate point of needle insertion and needle direction by using the lateral approach for infraclavicular brachial plexus block and the infraclavicular brachial plexus block described by Raj et al. (1), respectively. The subclavian/axillary artery (white) is not marked, but is located cephalad to the corresponding vein (V). The cords (gray), not marked, surround the artery longitudinally. Only parts of the pectoralis major muscle (pma, dark) and the pectoralis minor muscle (pmi, gray) are presented, caudad to the axillary vein. cl = clavicle, C1 = first costa, C2 = second costa, cp = coracoid process, c.hu = caput humeri.

Because of the difficulties with the technique, we questioned if the recommended needle angle to the skin guides the needle close enough to the cords and therefore initiated the present study.

The primary aim of this anatomical study was to investigate the ability of the lateral approach to reach the brachial plexus by using a variety of needle angles to the skin. Additionally, we wanted to confirm the clinical impression of a decreased risk of pneumothorax. We were also interested in comparing the results of the method with the arm abducted 45° and 90°. For the study, we used MR imaging because it easily demonstrates the brachial plexus (5,7–9).

Methods

The protocol, approved by the regional ethical committee, was similar to our first study and used the same 10 healthy volunteers (7). A needle was never inserted in the volunteers. MR images were taken with arm abduction at 45° and 90°, and a virtual reality model of each volunteer's infraclavicular region was created.

In the model, the needle insertion point was determined after marking the position of two anteroposterior lines in the coronal (frontal) plane (Fig. 2B). The first line abutted the superior border of the clavicle and went through the midaxis of the subclavian artery. The second line went through the junction of the brachial artery (its midaxis) and the lateral edge of the pectoralis major muscle. The plane between these anteroposterior lines was the first of two planes defining the recommended needle direction (the needle trajectory). A third anteroposterior line was determined in this plane, 2.5 cm from the inferior border of the clavicle. The point at which this line hit the chest surface defined the needle insertion point.

The target was determined as in our first study: Through the point at which the perpendicular line from the most anterocaudad point of the coracoid process hit the first plane defining the needle trajectory, a sagittal (paramedian) plane was constructed. The middle point of all nerve structures around the artery in this plane defined the target.

The second plane, defining the needle trajectory, was perpendicular to the axial (transverse) plane (Fig. 3B), went through the needle insertion point, and had a 45° medial angle to the coronal plane. The final position of the needle point was defined as where the needle trajectory hit the sagittal plane through the target.

The needle trajectory's distance from the target was measured in coronal and axial planes. From these measurements, the true distance between the trajectory and the target was calculated and could be controlled by direct measurements in the sagittal plane through the target. The needle angle to the skin contacting the target was measured in the axial plane. Needle depths to the target and the final position of the needle point were calculated after measurements in axial and coronal planes. The trajectory's relation to the pleura was analyzed in the axial plane through the simulated needle insertion site, measuring the needle angle to touch the pleura.

The results are presented as mean ± SD or mean (range). Student's paired *t*-test was used to assess differences of the lateral approach by 90° and 45° arm abduction. Probability values < 0.05 were considered significant.

Results

The volunteers, five women and five men, were 30 ± 9 (24–51) yr old with a height of 175 ± 11 (160–193) cm and a weight of 68 ± 16 (50–102) kg.

The deviation of the simulated needle trajectory from the target was great, approximately 2 cm, with both 45° and 90° abduction of the arm (Table 1). In both arm positions, the needle angle to the skin (in the axial plane) necessary to contact the target was practically identical (mean, 68° and 67°) and considerably greater than the 45°-needle angle recommended. The precision was much better in the coronal than in the axial plane, particularly with 90° abduction, having a near 100% precision.

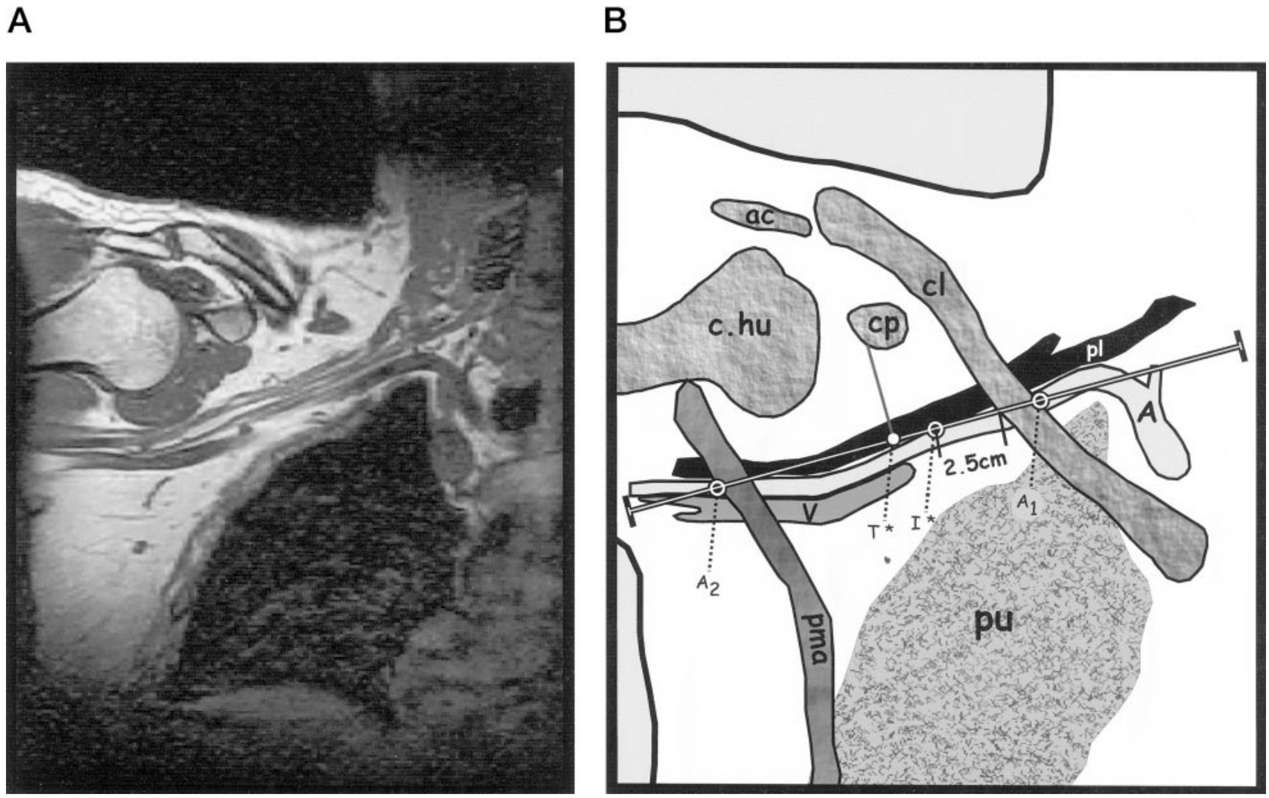

Figure 2. A, Coronal magnetic resonance image, right side, arm 90° abducted (Volunteer 1). B, Drawing based on the coronal image in A. Right infraclavicular region, arm 90° abducted (Volunteer 1). Illustrations of the lateral approach for infraclavicular brachial plexus block in the coronal plane. Added to the figure are the complete projection of the clavicle (cl) and a large part of the lateral border of the pectoralis major muscle (pma). In the lower half of the picture is part of the right lung (pu). The artery (A) is depicted in its complete length, whereas only a shorter distal part of the corresponding vein (V) is seen, caudad to the artery. Part of the brachial plexus (pl) is marked black cephalad to the artery. The recommended needle direction (the needle trajectory) is defined by two planes, of which the first goes through A_1 and A_2, perpendicular on the coronal plane. In this volunteer, the needle trajectory did not deviate from the target in the coronal plane. Therefore, the final position of the needle point is identical to the position of the target, and the corrective angle to bring the needle point to the target is zero, in the coronal plane. The target on the cords is defined periarterially in the sagittal plane (not marked) through the point at which the perpendicular line from the most anterocaudad point of the coracoid process hit the first plane defining the needle trajectory. The posterior projection of the perpendicular line is indicated. cp = coracoid process, ac = acromion, c.hu = caput humeri, I* = the posterior projection of the needle insertion point, T* = the anteroposterior projection of the target, A_1 = an anteroposterior line through the point at which the subclavian artery would have been palpated at the superior edge of the clavicle, A_2 = an anteroposterior line through the point at which the brachial artery would have been palpated at the lateral border of the pectoralis major muscle.

The needle depths were similar in both arm positions, approximately 4 cm when the simulated needle contacted the target.

The needle angle to the skin necessary to touch the pleura was great in both arm positions, never <80°, and distinctly greater with 90° arm abduction than with 45° abduction. With 90° arm abduction, also when applying the optimal needle angle to contact the target, the sector between the needle and the pleura was considerable, 39° (28°–54°).

Discussion

The present noninvasive MR study of the lateral approach for infraclavicular brachial plexus block demonstrates that the deviation of the recommended needle direction from the target on the cords was great with both 45° and 90° arm abduction, mostly because the needle angle to the skin was too shallow. This probably explains the difficulties we had locating the brachial plexus in patients.

In both arm positions, the risk of contacting the pleura appeared minimal, confirming our clinical impression. An approximate doubling of the recommended 45° needle angle to the skin was required for the simulated needle to touch the pleura.

We consider the lateral approach more favorable with 90° arm abduction than 45° because the needle trajectory was more precise in reaching the cords and had a larger gap to the pleura in the former position.

With 90° arm abduction, the precision can be enhanced by increasing the needle angle to the skin from 45° to 65°. One might prefer starting with an angle of 40° and, when necessary, increasing it in steps of 10° to a maximum of 80°. The risk of penetrating the pleura would remain small within this angle range, provided

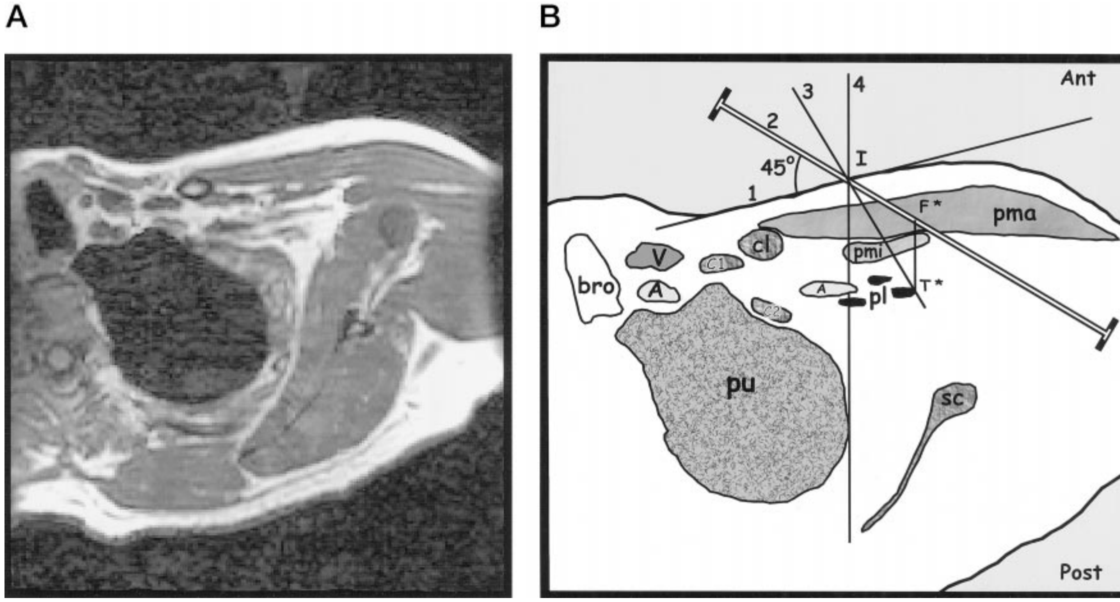

Figure 3. A, Axial magnetic resonance image, right side, arm 90° abducted. Image through the point of needle insertion (Volunteer 1). B, Drawing based on the axial image in A, through the point of needle insertion (I). Right infraclavicular area, arm 90° abducted. Illustrations of the lateral approach for infraclavicular brachial plexus block in the axial plane. Through I, four lines are drawn, marked by the numbers 1, 2, 3, and 4. 1 = the tangent to the skin, 2 = the recommended 45° medial needle angle to the skin, 3 = the needle angle to the skin necessary to contact the target; in this volunteer 74° and 4 = the needle angle to the skin necessary to touch the pleura, 102° in this volunteer. The recommended needle direction (the needle trajectory) is defined by two planes, of which the second goes through Line 2, perpendicular to the axial plane. The angle difference between Lines 3 and 2 represents the deviation of the needle trajectory from the target, 74° − 45° = 29° in this volunteer. The angle between Lines 4 and 3 is the medial deviation of the simulated needle contacting the target necessary to touch the pleura, in this volunteer 102° − 74° = 28°. Ant = anterior, Post = posterior, T* = cephalad projection of the study defined target at the level of the cords, I-T* is the projection of the recommended needle direction (the needle trajectory) to the axial plane through I, F* = cephalad projection of the final position of the needle point, pl = cords of the brachial plexus, A and V = cross sections of the artery and vein, respectively, pma = the pectoralis major muscle, pmi = the pectoralis minor muscle, pu = the right lung, bro = the right main bronchus, sc = scapula, cl = clavicle, C1 = cross section of first costa, C2 = cross section of second costa.

Table 1. Proximity of the Needle Trajectory to the Target and to the Pleura

	Target deviation (mm)			Target angle	Needle depth (mm)		Pleura angle	Pleura-target angle
	Coronal[a]	Axial[b]	Sagittal	Axial	Before	After	Axial	Axial
Mean 45° abduction	8 ± 3	21 ± 8	24 ± 7	68 ± 7	24 ± 8	41 ± 8	91 ± 6	23 ± 5
Mean 90° abduction	3 ± 3	18 ± 6	19 ± 6	67 ± 10	25 ± 8	38 ± 5	106 ± 5	39 ± 7
Range 45° abduction	3–13	10–36	13–38	55–77	13–42	30–53	81–98	16–30
Range 90° abduction	0–7	5–29	5–29	41–77	18–43	33–51	95–114	28–54
P	0.033*	0.239	0.042*	0.814	0.731	0.076	0.001*	0.001*

Target deviation = the distance in mm between the needle trajectory and the target, as seen in three different planes; the true deviation/distance is found in the sagittal plane through the target, Target angle = the needle angle to the skin to touch the target (the optimal angle to the skin), in the axial plane through the point of needle insertion, Needle depth (mm)/Before and After = the needle depth before and after redefining the optimal angle to the skin, Pleura angle = the needle angle to the skin to touch the pleura, in the axial plane through the point of needle insertion, Pleura-Target angle = the angle difference between the described pleura and target angles.

[a] With 45° abduction of the arm, the simulated needle trajectory was caudad to the target in all volunteers. With 90° abduction, the trajectory was cephalad to or corresponding to the target in all volunteers except for Volunteer 3. He had a 1-mm caudad deviation of the simulated needle from the target.

[b] With 45° abduction of the arm, the needle trajectory was anterior to the target in all volunteers. With 90° abduction, the trajectory was anterior to the target in all volunteers except for Volunteer 3. He had a 5-mm posterior deviation of the needle from the target.

* Significant difference between the results in the two arm positions by using Student's paired *t*-test, when $P < 0.05$.

that the other details of the technique and the configuration of the thoracic cage are recognized.

The selection of our target on the cords may be controversial. With a more proximal target on the cords, the needle angle to the skin necessary to hit this target would increase, increasing the risk of contacting the pleura. A more distal target would reduce this angle, but could end in an area more easily reached by an axillary approach (10). Taken together, we think that our chosen target is appropriate.

In conclusion, our MR study demonstrates that the 45°-needle angle to the skin recommended by the lateral approach of the infraclavicular brachial plexus block is often too shallow to contact the cords of the brachial plexus, with both 45° and 90° arm abduction. By using 90° abduction, a 65°-needle angle to the skin appears optimal, still with a minimal risk of penetrating the pleura. However, this needs to be confirmed by a clinical study.

For better understanding of the brachial plexus anatomy, parallel to our MRI studies, we performed human cadaver dissections on the brachial plexus. We thank Professor Per Brodal, at the Department of Anatomy, University for Oslo for encouraging discussions and cooperation by the dissections. We thank Terje Tillung (The Interventional Center) for processing the images and Per Øyvind Hvidsten (The Norwegian Defense Research Establishment) for developing the three-dimensional visualization software.

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