Ultrasound Examination of Peripheral Nerves in the Forearm

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Background and Objectives: We examined in a volunteer population whether nerves in the forearm could be seen consistently using ultrasound imaging and whether this new information could have implications for the way we perform regional anesthesia of the median, radial, and ulnar nerves.

Methods: Eleven volunteers underwent ultrasound examination of both forearms. The median, ulnar, and radial nerves were followed and images were obtained at the elbow, proximal forearm, mid forearm, distal forearm and wrist levels. In addition the radial nerve was followed proximally to a point 5 cm above the elbow. Images were compared for consistency of location of the nerves and depth from skin and width was calculated for each nerve at each level.

Results: Anatomy of each nerve was consistent except for one forearm where the median nerve was lateral to the brachial artery at the elbow and one forearm where a superficial ulnar artery only joined the ulnar nerve at the wrist. A convenient location for blockade of both median and ulnar nerves is the midforearm combining ease of visualization, ability to block all terminal branches and minimal potential for vascular injury. The radial nerve is seen most easily at the elbow although blockade of the superficial radial nerve may spare radial motor function.

Conclusions: Nerves in the forearm are consistently located using ultrasound. Further confirmation in clinical practice is required. *Reg Anesth Pain Med 2007;32:434-439.*

Key Words: Regional anesthesia, Nerve block, Forearm, Median, Radial, Ulnar.

Brachial plexus blocks provide many advantages for patients yet even in the most experienced hands are only completely effective in 85% to 90% of patients. Rescue blocks of the median, radial, and ulnar nerves are often performed at the elbow or wrist yet these techniques in themselves can fail. Traditional techniques rely on surface landmarks to guide the needle insertion point and subsequent paresthesia or nerve stimulation to indicate the needle tip is adjacent to the nerve. This restricts the regional anesthesiologist to sites at the elbow or wrist where surface landmarks are readily identifiable.[1,2] However injection at these levels has potential for neurological (median nerve at the wrist, ulnar nerve at the elbow) and vascular (median nerve at the elbow, ulnar nerve at the wrist) injury. Blocks at the wrist can fail because the median and ulnar nerves divide into branches proximal to the wrist and after wrist block some components of the nerve may not be anesthetized. Existing studies document the incidence of block failure after wrist block as 9% to 15% for the median nerve and 15% to 32% for the ulnar nerve at the wrist.[1,2]

Because the use of ultrasound allows direct visualization of anatomical structures it may be possible to choose alternative sites where all components of each nerve can be blocked allowing improvement of success rate and potentially reducing risk of neurovascular injury.

This study sought to confirm that it is possible to consistently identify the median, radial, and ulnar nerves in the forearm and to determine optimal sites for needle insertion during ultrasound-guided block.

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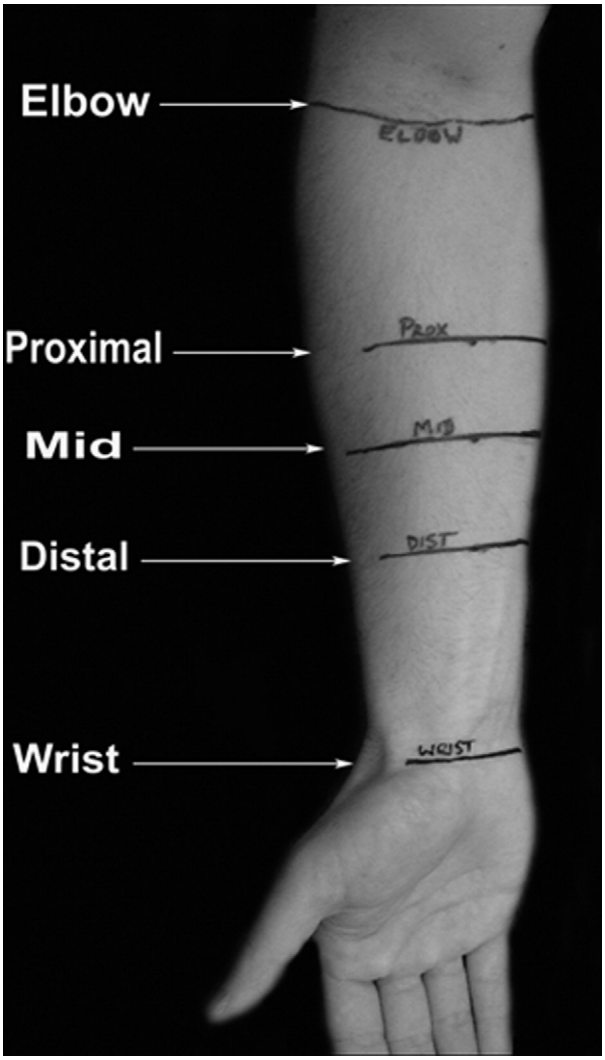

Fig 1. Markings indicate the 5 levels at which attempt was made to visualize median, radial, and ulnar nerves in the forearm.

Methods

After University Health Network Research Ethics Board approval and informed consent 11 healthy American Society of Anesthesiologists I or II adult volunteers were recruited to this observational study. Each volunteer had both arms scanned with ultrasound so that 22 series of images were collected in total. The scans were performed using a Philips HDL5000 ultrasound machine (Philips Medical Systems, Bothell, Washington) with a 5 MHz to 12 MHz probe in the transverse plane at 5 different levels. The median and ulnar nerves were visualized at the elbow, mid forearm, and distal wrist crease and at 2 points in between called proximal and distal forearm (Fig 1). The radial nerve was identified at the elbow and followed proximally to a point 5 cm above the elbow. The nerve was then followed distal to the elbow as far as possible towards the radial styloid.

Static ultrasound images were saved and visualized using E-film software version 1.2.1 (Merge Healthcare, Milwaukee, WI). The images were calibrated and at each point the distance from skin to nerve was measured to the nearest mm and data are presented as mean ± SD. Width of the nerve at each location was also measured and presented as mean ± SD. Anatomical variants were also noted. For each nerve a point was chosen that combined ease of visualization, proximity to skin, and be as far as possible from vascular structures or from areas where the nerve could be exposed to pressure injury (for example when adjacent to bony structures).

Results

Eleven volunteers were recruited and had bilateral arm examinations giving 22 series of images. Characteristics of volunteers are shown in Table 1.

The median nerve was consistently found medial to the brachial artery at the elbow as a hyperechoic structure (Fig 2A) although in one forearm the nerve was lateral to the artery and was hypoechoic. The nerve was difficult to visualize as it passed distal to the elbow between the heads of pronator teres and flexor digitorum superficialis (FDS) because of the change in angle of the nerve in relation to the ultrasound probe, the loss of vascular association, and change in shape of the nerve as it is compressed between the 2 muscles. In the proximal forearm the nerve became easier to identify under FDS and remained easily visible through the mid forearm (Fig 2B) until the distal forearm was reached (Fig 2C). A useful method for identifying the median nerve is to identify the ulnar nerve and artery under FDS in the mid forearm and then follow the muscle layer (seen as a hyperechoic band) laterally until the median nerve is reached. In the wrist the nerve was visible but could be easily confused with the multiple tendons in the area (Fig 2D).

The ulnar nerve was consistently seen posterior to the medial epicondyle at the elbow level (Fig 3A). The

Table 1. Characteristics of Volunteers

Demographic Information	n	Mean ± SD	Minimum	Maximum
Height (cm)	11	170.6 ± 6.1	163.0	180.0
Weight (kg)	11	70.2 ± 14.6	50.0	91.0
BMI	11	23.9 ± 3.8	18.6	30.1
Length of forearm (cm)	22	25.6 ± 2.1	22.5	28.0

Abbreviation: BMI, body mass index.

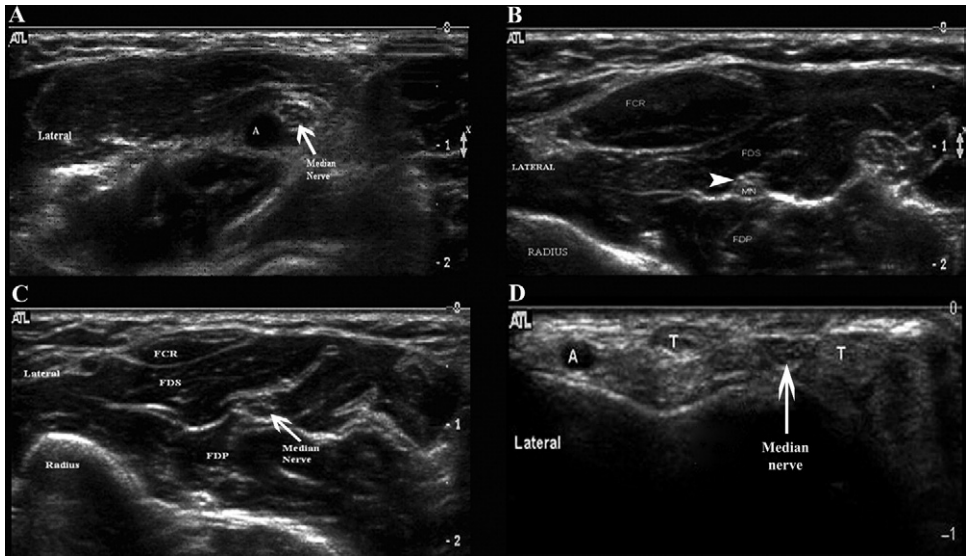

Fig 2. Ultrasound images of the median nerve in (A) elbow, (B) mid forearm, (C) distal forearm, and (D) wrist. Arrowhead indicates median nerve. A, artery; FCR, flexor carpi radialis; FDP, flexor digitorum profundus; FDS, flexor digitorum superficialis; t, tendons.

nerve was most easily seen from proximal to mid forearm where the ulnar artery moves medially from the division of the brachial artery to meet with the hyperechoic ulnar nerve at mid forearm level (Fig 3B). In the distal forearm (Fig 3C) the nerve is smaller and seen as a hypoechoic structure (but with a visible fine honeycomb pattern of the fascicular contents) and less easily seen although it can be tracked all the way to the wrist where it lies very superficial and medial to the ulnar artery (Fig 3D). The position of the nerve was consistent in all cases with no deviation in anatomy between volunteers except in one forearm where a superficial ulnar artery did not join the nerve in the mid forearm as is typical but remained superficial until it reached the proximal wrist and joined the nerve before passing under the flexor retinaculum.

The radial nerve is easily seen as the deep and superficial branches between the brachioradialis and brachialis muscles at the elbow (Fig 4A) and was consistent across all volunteers. From the elbow level the nerve can be easily followed proximally up the arm where it usually divides approximately 2 cm to 3 cm proximal to the elbow. The single radial nerve can be easily visualized 5 cm proximal to the elbow lateral to the humerus (Fig 4B). Traveling distal from the elbow it was only possible to follow the superficial branch of the radial nerve as far as the mid forearm in 65% of volunteers (Fig 4C) and as far as the distal forearm (5 cm proximal to radial styloid where the nerve crosses anterior to the radius and then splits into small terminal branches) in 55% of volunteers. Distance from skin to target nerve and width of the nerve at each level is presented in Tables 2 and 3.

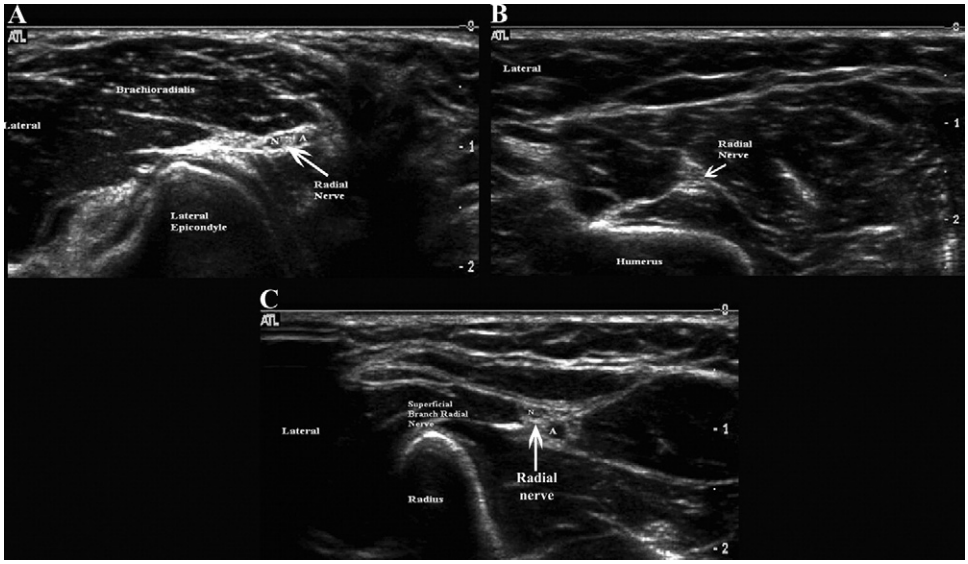

Fig 3. Ultrasound images of the ulnar nerve in (A) elbow, (B) mid forearm, (C) distal forearm, and (D) wrist. A, ulnar artery; FCU, flexor carpi ulnaris; FDP, flexor digitorum profundus; FDS, flexor digitorum superficialis.

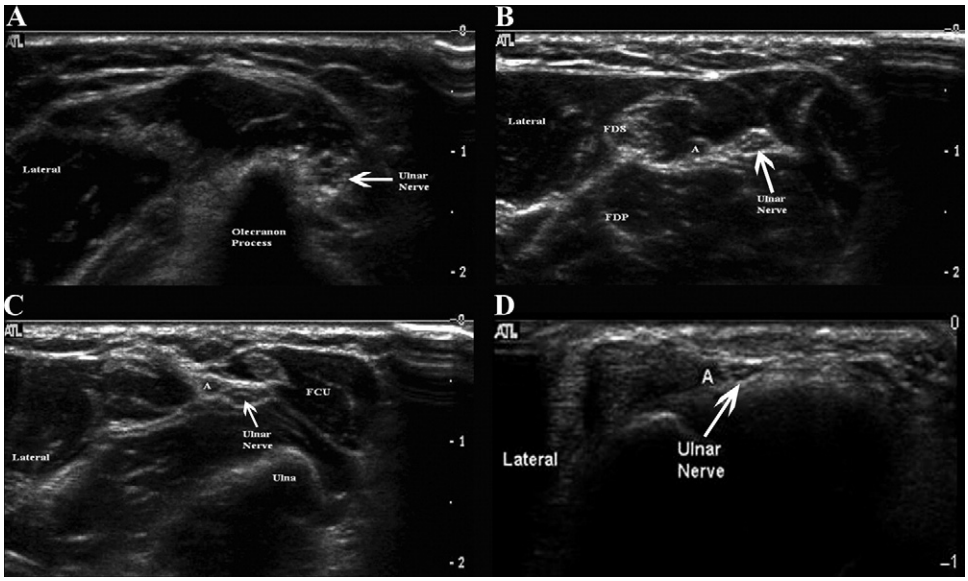

Fig 4. Ultrasound images of the radial nerve in (A) elbow, (B) 5 cm proximal to the elbow, and (C) mid forearm. (A) A, recurrent radial artery; N, radial nerve. (C) A, radial artery; N, superficial branch radial nerve.

Discussion

This study determined that in our 11 volunteers it is consistently possible to visualize the median and ulnar nerves from the elbow down to the wrist with the aid of ultrasound imaging. This study adds to the work of Heinemeyer et al.[3] who determined the feasibility of visualization of the radial, median, and ulnar nerves in the forearm at limited levels for each nerve namely radial nerve at the elbow, median nerve in the mid forearm and wrist and ulnar nerve distal to the cubital tunnel. Peeters et al. also determined the feasibility of visualization of the ulnar nerve at Guyon's canal with a 5 MHz to 12 MHz linear transducer.[4] This is in contrast to the present study where we have determined the feasibility of visualization of each nerve throughout the length of the forearm rather than at 1 level alone.

Table 2. Distance (mm) Between Skin and Target Nerve (N = 22)

Target Nerve	n	Mean ± SD	Minimum	Maximum
Radial Nerve				
Distal forearm	12	4.0 ± 1.3	2	6
Middle forearm	14	7.6 ± 1.7	5	10
Proximal forearm	18	10.8 ± 2.5	7	16
Elbow	22	12.3 ± 4.4	4	21
Above elbow 5 cm	22	15.6 ± 2.9	10	21
Median Nerve				
Wrist	22	2.1 ± 0.5	1	3
Distal forearm	22	8.5 ± 1.9	6	13
Middle forearm	22	12.4 ± 2.2	10	18
Proximal forearm	22	16.8 ± 2.7	13	23
Elbow	22	7.1 ± 2.7	3	12
Ulnar Nerve				
Wrist	21	3.2 ± 0.8	2	5
Distal forearm	22	5.7 ± 0.9	4	8
Middle forearm	22	8.5 ± 1.7	6	12
Proximal forearm	21	11.3 ± 2.0	8	15
Elbow	21	10.1 ± 3.6	6	17

NOTE. n value represents number of occasions where the nerve could be visualized and measured at each level.

The 2 branches of the radial nerve can be consistently seen at the elbow but are less easy to follow distal to the elbow. Minimal variation in anatomical position of the nerves occurred although the median nerve lay lateral to the artery in 1 volunteer. The median and ulnar nerves are both easily found with ultrasound guidance throughout the length of the forearm. An observed variation of ulnar artery anatomy was noted in 1 forearm in this series where the artery did not pass through the forearm with the ulnar nerve but remained superficial until it joined the radial artery at the elbow. This variation occurs in up to 3.75% of patients[5] and may make the ulnar nerve more difficult to identify in the forearm because of the lack of an associated vascular landmark.

The radial nerve is easy to visualize both above and at the elbow. Distal to the elbow the deep branch of the radial nerve passes under extensor carpi radialis brevis to supply the extensor muscles of the forearm. The sensory superficial branch of the radial nerve can be followed more easily but only down as far as the distal forearm (5 cm proximal to radial styloid) in 55% of cases.

Existing techniques for blockade of the median, radial, and ulnar nerves at the wrist or the elbow are used because anatomical surface landmarks allow approximate nerve location to be determined. However with the use of ultrasound the practitioner is no longer limited to surface landmarks and can choose the most convenient and potentially safest position for forearm block that may not be at

Table 3. Transverse (Medial-Lateral) Width (mm) of Target Nerve (N = 22)

Target Nerve	n	Mean ± SD	Minimum	Maximum
Radial Nerve				
Distal forearm	13	3.2 ± 0.7	3	5
Middle forearm	14	3.8 ± 0.6	3	5
Proximal forearm	17	4.4 ± 1.3	3	8
Elbow	20	5.3 ± 1.6	3	8
Above elbow 5 cm	20	4.3 ± 0.9	3	6
Median Nerve				
Wrist	22	4.3 ± 1.0	3	6
Distal forearm	22	4.1 ± 0.8	3	6
Middle forearm	22	4.2 ± 0.5	3	5
Proximal forearm	22	4.4 ± 0.8	3	6
Elbow	22	4.5 ± 1.1	2	7
Ulnar Nerve				
Wrist	21	3.6 ± 0.9	2	5
Distal forearm	22	4.0 ± 0.8	3	6
Middle forearm	22	4.4 ± 0.7	3	5
Proximal forearm	21	4.2 ± 0.7	3	6
Elbow	22	4.6 ± 1.0	3	7

NOTE. n value represents number of occasions where the nerve could be visualized and measured at each level.

the elbow or the wrist. The ulnar nerve may have a higher risk of neurological injury at the elbow because of proximity to bone and at the wrist, puncture of the ulnar artery is possible. Block of the median nerve at the elbow risks brachial artery puncture and at the wrist neurological injury is possible. Unfortunately there are no data in the literature that allow determination of the frequency of vascular or neurological injury following blockade of the nerves in the forearm, or whether ultrasound guidance can reduce injury in these circumstances.

Ultrasound-guided blockade of the ulnar nerve is easiest at the mid forearm level where the ulnar artery lies close to the nerve (which facilitates echolocation) but is starting to move laterally away from the nerve (theoretically reducing the risk of arterial puncture). Blockade at this level may also improve chances of providing anesthesia of the dorsal branch of the ulnar nerve that arises 5 cm above the wrist.

The median nerve is most easily seen at the mid distal forearm where it lies more superficially under FDS. Anesthesia at this level may also increase the chance of anesthetizing the palmar branch that may be missed by blockade at the wrist. Finally block of both the median and ulnar nerves at this level may preserve forearm muscle function compared with block at the elbow.

One criticism of this technique may be that the needle path is through muscle and this may produce more pain than necessary. However in our early experience with the use of these techniques patient discomfort has not been noted. The lack of patient discomfort may be related to the narrow gauge needle used (25-gauge) and the reduced needle passes required with direct visualization of the nerve by ultrasound.

The deep and superficial branches of the radial nerve are most easily seen at the elbow level lying deep under brachioradialis and superficial to the radial head and brachialis muscle (Fig 4A). The small radial recurrent artery is also visible at this level. Because of the difficulty in tracking the small superficial branch distal to the elbow it would seem most logical to anesthetize this nerve at the elbow level using ultrasound guidance. The use of ultrasound facilitates anatomical determination and single pass of the needle to reach the nerve. With practice it is possible to visualize the superficial radial nerve and if anesthetized separately will spare motor function for the extensor muscles in the forearm. Although the radial nerve can be seen easily above the elbow blockade at this level may be more difficult because in our experience the ultrasound probe is less easily held at this level while needle insertion is performed. Table 4 gives recommendations for performance of ultrasound-guided nerve blocks in the forearm.

Use of forearm techniques for rescue of inadequate proximal techniques is relatively common in our practice given a success rate of approximately

Table 4. Recommendations for Performing Ultrasound-Guided Nerve Blocks in the Forearm

Nerve	Optimal Position for Block	Advantages
Median	Mid distal forearm	Easily seen between FDS and FDP. Proximal to origin (and therefore ensures block) of palmar branch. Also avoids brachial artery at elbow level and tendons (easy to confuse with nerve) at wrist level. Possible to block both median and ulnar nerves with one needle insertion. Peripheral nerve stimulator can be used to confirm nerves.
Radial	Elbow	Easily seen in fascia deep to brachioradialis. Blocks both deep and superficial branch in one injection. Easy position to hold ultrasound probe.
Ulnar	Mid forearm	Easily seen medial to the ulnar artery but separated from artery at this level avoiding vascular injury. Proximal to origin of dorsal branch and therefore ensuring blockade. Possible to block both median and ulnar nerves with one needle insertion.

Abbreviations: FDP, flexor digitorum profundus; FDS, flexor digitorum superficialis.

90% for many of our brachial plexus blocks. The use of ultrasound to visualize the needle tip may be reassuring when attempting to place local anesthetic around an already partially anesthetized nerve. The use of an in-plane technique with the needle in line with the ultrasound probe may be necessary to optimally visualize the needle tip.

Forearm blocks may be especially useful in isolation for minor surgery such as carpal tunnel release and procedures in the emergency department. Liebmann et al. studied the feasibility and success of ultrasound-guided forearm blocks in the emergency department in a cohort of 11 patients and found that practitioners can perform these techniques successfully and after minimal training.[6] Another useful technique could include the use of a longer acting local anesthetic or a continuous catheter to block a single nerve in the forearm for postoperative analgesia combined with a short-acting proximal block for surgery. This could create ideal conditions of a generalized block for surgery while providing specific and long-lasting postoperative analgesia (e.g., isolated ulnar block for Dupuytren's contracture release).

Limitations of this study include the small sample size and the lack of any clinical data confirming the usefulness of the suggested points for blocking individual forearm nerves. We are currently assessing results of performing these techniques in clinical practice. In this study we did not attempt to visualize the lateral cutaneous nerve of the forearm.

In summary we found that the median, ulnar, and radial nerves can be consistently seen in the forearm using ultrasound imaging. The ease of visualizing the median and ulnar nerves in the mid forearm would suggest an advantage in performing the injections at this level and this may improve efficacy and potentially decrease adverse effects although this remains to be determined in future studies. The radial nerve can be easily seen both immediately superior to and at the elbow. Although visualization of the superficial radial nerve distal to the elbow may be more challenging, isolated anesthesia of this branch may be advantageous with regard to reduction in motor block of the forearm extensor muscles.

Further evidence of the benefit of these approaches in clinical practice is needed.

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