Ultrasound-guided infraclavicular brachial plexus block

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Background. Peripheral nerve blocks are almost always performed as blind procedures. The purpose of this study was to test the feasibility of seeing individual nerves of the brachial plexus and directing the block needle to these nerves with real time imaging.

Methods. Using ultrasound guidance, infraclavicular brachial plexus block was performed in 126 patients. Important aspects of this standardized technique included (i) imaging the axillary artery and the three cords of the brachial plexus posterior to the pectoralis minor muscle, (ii) marking the position of the ultrasound probe before introducing a Tuohy needle, (iii) maintaining the image of the entire length of the needle at all times during its advancement, (iv) depositing local anaesthetic around each of the three cords and (v) placing a catheter anterior to the posterior cord when indicated.

Results. In 114 (90.4%) patients, an excellent block permitted surgery without a need for any supplemental anaesthetic or conversion to general anaesthesia. In nine (7.2%) patients local or perineural administration of local anaesthetic, and in three (2.4%) conversion to general anaesthesia, was required. Mean times to administer the block, onset of block and complete block were 10.0 (SD 4.4), 3.0 (1.3) and 6.7 (3.2) min, respectively. Mean lidocaine dose was 695 (107) mg. In one patient, vascular puncture occurred. In 53 (42.6%) patients, an indwelling catheter was placed, but only three required repeat injections, which successfully prolonged the block.

Conclusion. The use of ultrasound appears to permit accurate deposition of the local anaesthetic perineurally, and has the potential to improve the success and decrease the complications of infraclavicular brachial plexus block.

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During infraclavicular approach to the brachial plexus block, electrical stimulation is employed to ensure close proximity of the needle to the nerves. The success of this method depends on a good understanding of anatomy and strong reliance on landmarks which may be obscured by obesity or anatomical variations. In addition, this technique requires eliciting twitches of muscles distal to the wrist; a proximal response may be obtained in as many as 21% of patients in whom the failure rate may be as high as 66%.[1] Because of the blind nature of this technique, unintentional puncture of blood vessels or nerve injury may also occur.[2 3] By providing precise control of needle placement, ultrasound may improve the success rate of the block and minimize vascular and neurological complications. However, previous studies using ultrasound with different techniques in various approaches to the brachial plexus reported mixed results regarding the success rate, onset time and complications of this method.[4–8] We have developed a standardized, ultrasound-guided infraclavicular brachial plexus block technique that involves injections of local anaesthetic around each cord. In this report we describe the technique and present its performance characteristics.

Methods

After obtaining Institutional Review Board approval, 126 consecutive consenting patients were included in this prospective study. Children aged below 18 yr, adults over 80 yr and patients with pre-existing neurological disorders were excluded. Routine monitors, including pulse oximeter, electrocardiogram and blood pressure cuff were used, and an i.v. line was inserted. Each patient, except one who weighed 225 kg and had obstructive sleep apnea, received midazolam 2 mg and fentanyl 50 µg prior to the procedure.

Technique

With a patient in the supine position, the arm was abducted to 90°. The deltopectoral region was scanned with a 2.5 MHz probe of a Hewlett-Packard 77020A ultrasound monitor (Andover, MA, USA). A transverse image of the second part of the axillary artery and vein, and of the three cords of the brachial plexus, was obtained posterior to the pectoralis minor muscle. The outline of the ultrasound probe was marked on the skin. The area was prepared with betadine and draped. Figure 1 depicts the location of the probe and a diagrammatical representation of the sonographic image. The probe was covered with a sterile sheath (Microtech Medical Inc., Columbus, MS, USA) after applying a liberal amount of gel (Aquasonic, Parker Laboratories, Fairfield, NJ, USA), and placed over the previously marked area which was covered with another layer of sterile gel. Depending on availability, a 17- or 18-gauge Tuohy needle without a stylet was connected to sterile extension tubing attached to a stopcock and two 20-ml syringes, and flushed with local anaesthetic until the air in the system was completely removed. An 18-gauge needle was used to puncture the previously anaesthetized skin. The Tuohy needle was then introduced and advanced until it was imaged. The needle tip was first directed to the medial cord between the axillary artery and vein (Fig. 2). One or 2 ml of 2% lidocaine, with epinephrine 1:200 000, and sodium bicarbonate (0.9 mEq/10 ml), was injected to ensure that the needle tip was within the neurovascular bundle, behind the posterior fascia of the pectoralis minor muscle; local anaesthetic would distribute within the muscle if the needle bevel did not completely penetrate the fascia. After confirming satisfactory spread of lidocaine, an additional 7–11 ml of local anaesthetic was injected around the medial cord. The needle was partially withdrawn and redirected between the lateral cord and the superior aspect of the axillary artery (Fig. 3). Again, after 1–2 ml lidocaine injection to ensure satisfactory spread, 7–11 ml of anaesthetic solution was injected. The needle was then advanced slightly deeper than the posterior aspect of the artery, and its shaft was brought into a more horizontal position to place its tip between the artery and the posterior cord. Then an additional 7–11 ml of lidocaine was deposited (Fig. 4). The spread of lidocaine around the cords was observed sonographically during each injection. During all manoeuvres the image of the entire needle was kept in view. When the image was lost because of misalignment between the probe and the needle, further manipulation or injection was carried out only after obtaining the image of the entire needle by realignment. Gentle in-and-out jiggling of the needle was also used to help regain the image.

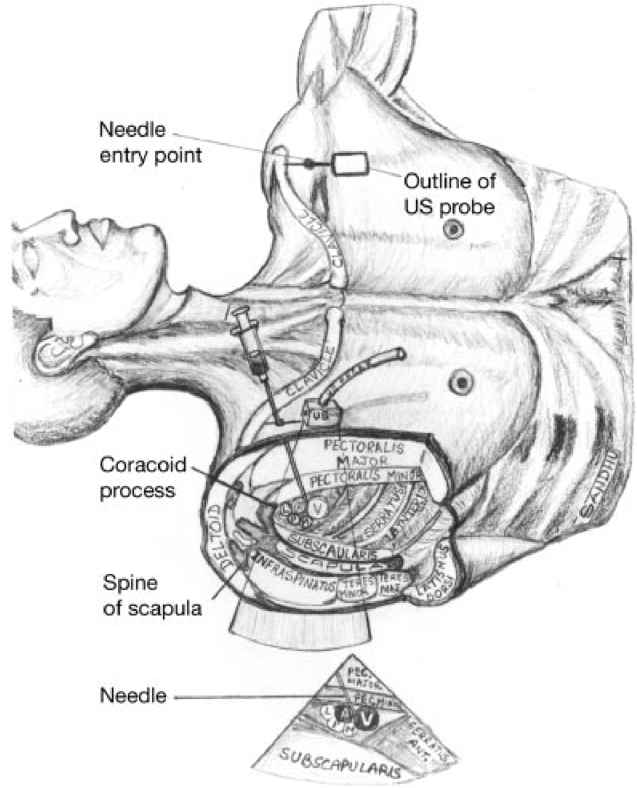

Fig 1 Sagittal section of the right deltopectoral region with corresponding diagrammatical representation of the ultrasound image obtained by an anteriorly placed transducer. Location of the ultrasound probe and the needle entry point are depicted on the left chest. Note that the block needle reaches the neurovascular region after traversing the pectoralis major and minor muscles. US, ultrasound probe; A, axillary artery; V, axillary vein; L, P and M are lateral, posterior and medial cords, respectively.

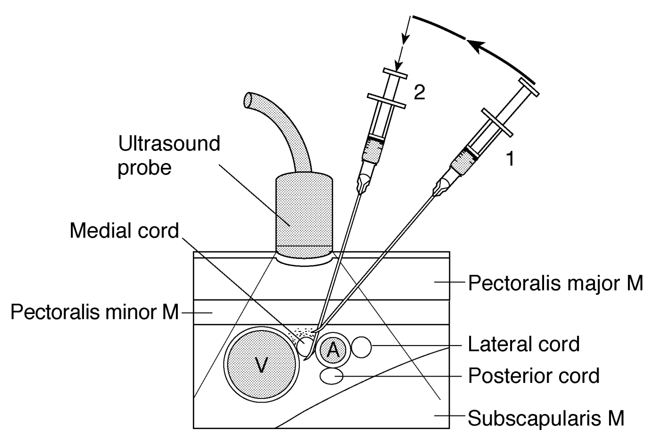

Fig 2 Diagram representing infraclavicular region and advancement of block needle towards the medial cord of the brachial plexus with ultrasound guidance. A, axillary artery; V, axillary vein. 1 is the initial direction of needle advancement and 2 is the final direction.

In 53 patients in whom surgery was expected to last longer than 2 h, a single-hole, 19-gauge Flexitip (Arrow International, Reading, PA, USA) or 20-gauge epidural

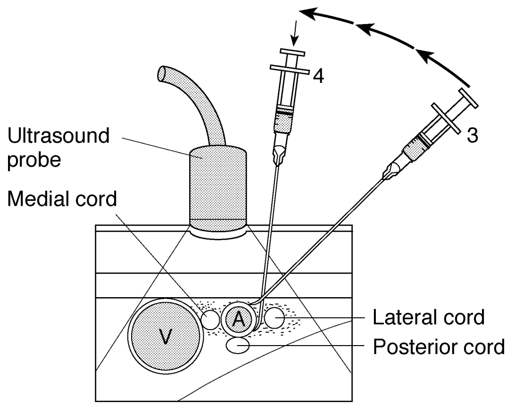

Fig 3 The needle is withdrawn into pectoralis minor muscle from its final position shown in Figure 2, and redirected towards the antero-superior aspect of the axillary artery (position 3). Then the needle is advanced further in a more vertical direction to place its tip between axillary artery and the lateral cord (position 4). A, axillary artery; V, axillary vein.

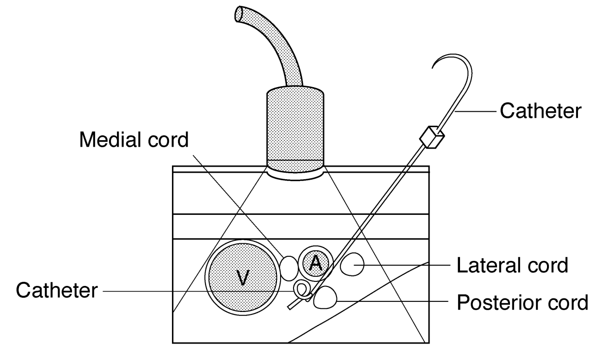

Fig 5 Catheter placed between the axillary artery and the posterior cord. In the real-time imaging, the catheter is easily recognized by motion artefact produced by gentle traction. The final location of the catheter tip is confirmed by injection of 1 ml air and observing a hyperechoic image in the region of cords. A, axillary artery; V, axillary vein.

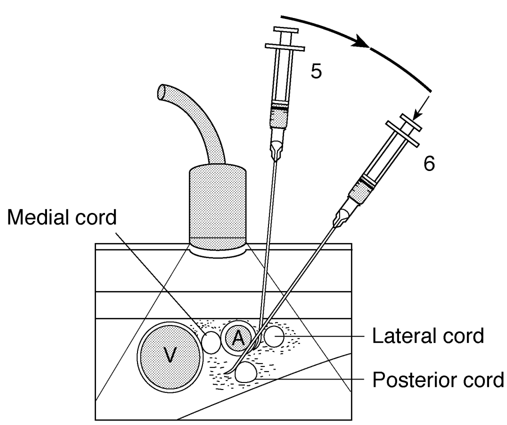

Fig 4 The block needle is advanced further posteriorly just beyond the axillary artery (position 5). Then the needle tip is redirected in a more horizontal manner to bring up its tip between the posterior wall of the axillary artery and the posterior cord (position 6). A, axillary artery; V, axillary vein.

catheter (Sims Portex Inc., Keene, NH, USA) was passed through the needle and placed 4–5 cm beyond the needle tip between the posterior cord and the axillary artery (Fig. 5). Multiorifice catheters were avoided to prevent escape of local anaesthetic into unintended areas. The position of the catheter tip was confirmed by injecting 1–2 ml of air and observing its echodense spread around the posterior cord. The catheter was secured with a transparent adhesive dressing.

Assessment of block

Sensory block was initially tested by pinching the skin of the hand and arm at the following areas innervated by individual nerves: the thenar eminence, the hypothenar region, the dorsum of the hand, the lateral aspect of the forearm and the area overlying the insertion of the deltoid muscle, for median, ulnar, radial, musculocutaneous and axillary nerves, respectively. When a decreased response to pinch was noted, a 22-gauge needle was used to evaluate the sensory block in the tested area. The motor block was evaluated by asking the patient to flex the arm (musculocutaneous), extend the flexed arm and wrist (radial), abduct the shoulder (axillary), sustain elevation of the arm (axillary), and adduct the arm (medial and lateral pectoral nerves and thoracodorsal nerve). Onset of the block was defined as the time from the last injection to diminished response to pinch and motor weakness. Anaesthesia was considered to be at surgical level when the patient could not feel pain from the needle in tested areas of the upper extremity and was unable to move the shoulder, elbow and/or wrist. Time to perform the block included the time needed to image and mark the area, prepare and drape the field, insert the needle, inject the local anaesthetic, and in 53 patients, place the catheter.

Results

Patients' characteristics are shown in Table 1. One patient weighed 225 kg and had obstructive sleep apnea, hypertension, and diabetes mellitus. All patients with end-stage renal disease received the block for the creation of an arteriovenous fistula or for the placement of a graft for haemodialysis. In the remaining patients, the block was given for surgery of the hand, including tendon, vessel and nerve repair, and external fixation or open reduction of fractures of the digits, hand or forearm. The insertion and manipulations of the needle were well tolerated by all patients. The neurovascular structures were easily imaged in all patients. In three patients (2.4%) the block was incomplete, necessitating conversion to general anaesthesia with tracheal intubation. Nine patients (7.2%) required augmentation of the block; two patients each received local infiltration, median nerve or ulnar nerve block at the wrist,

Table 1 Patient characteristics (n=126). Many patients had more than one pre-existing condition

	n	Percentage
Mean age (range) (yr)	42.9 (18–79)	–
Mean weight (SD) (kg)	76.5 (24.3)	–
Male/female	93/33	–
Mean ASA status (SD)	1.8 (0.8)	–
Patients without history of pre-existing conditions	69	54.7
Patients with history of pre-existing conditions	57	45.2
Hypertension	25	19.8
End-stage renal disease	18	14.2
Bronchospastic disease	9	7.2
Coronary artery disease	7	5.5
Cardiac valvular disease	1	0.8
Dysrhythmias	4	3.1
Morbid obesity	4	3.1
Sleep apnea	1	0.8
Cardiomyopathy	2	1.6
Chronic alcoholism	1	0.8
Diabetes mellitus	7	5.5
Hypothyroidism	2	1.6
Hepatitis	4	3.1
Human immunodeficiency virus	2	1.6
Pregnancy	1	0.8

one was given a radial nerve block at the wrist and two received digital nerve blocks. One of the patients who required local infiltration had a complete block of the upper extremity, but surgery involved a region of the axilla and torso that is not innervated by the brachial plexus. Patients with incomplete blocks also received additional doses of fentanyl (50–150 μg). Despite excellent sensory and motor block in six patients, additional doses of midazolam 2–4 mg and/or propofol, either a bolus 20–70 mg or infusion 10–25 $\mu g\ kg^{-1}\ min^{-1}$, were administered because of anxiety in two, agitation in one, back pain secondary to prolonged surgery in two, and frequent movement of the torso causing an unstable field under the microscope in one. Mean surgical duration was 117 (SD 58) min; the longest operation was 300 min. Mean time to administer the block was 10 (4.4) min. The onset of anaesthesia was 3.0 (1.3) min. Complete block occurred in 6.7 (3.2) min in 114 (90.5%) patients who did not require general anaesthesia or additional augmentation with local anaesthetic. An upper arm tourniquet was used in 96 patients, none of whom developed tourniquet pain. Mean lidocaine dose was 695 (107) mg. An indwelling catheter was placed in 53 patients, but it was used in only three patients for prolonging the anaesthesia because the initial injection provided a sufficiently long duration of anaesthesia for completion of surgery in the rest of the patients. In all three instances, these repeat injections relieved the surgical pain and discomfort caused by dissipation of the initial dose.

In one patient (0.8%) blood was aspirated prior to injection, necessitating withdrawal of the needle and application of pressure to the area. Ultrasound examination prior to removal of the needle in this patient did not suggest puncture of the axillary artery or vein, nor was haematoma seen around these vessels with ultrasound examination. A successful block was subsequently administered. Paraesthesias occurred in three patients during manipulation of the block needle from the lateral to the posterior cord, probably as a result of stretching of the lateral cord with the shaft of the needle rather than by direct contact of either cord with the needle tip. Patients were followed for 24 h after surgery, either by visiting them in the hospital or by telephoning them at home. No immediate complications related to the block occurred. We did not follow these patients thereafter. However, their surgeons saw them in their offices and did not report any neurological complications. Blood lidocaine concentrations were not monitored, but no patient developed signs or symptoms of local anaesthetic toxicity.

Discussion

The present work is the largest prospective series published on ultrasound-guided brachial plexus block. The results of our study suggest that this technique has the potential to improve success rate, time of onset and of performance of the block, and to decrease complications such as vascular puncture. The original study by Raj and colleagues[9] reported a success rate of 95% and an onset time of 20 min for infraclavicular block. The time required to perform the procedure and the complication rate were not addressed. Coracoid block, a variant of the infraclavicular block developed by Whiffler[2] had a success rate of 92.5%, onset time of 10–20 min and axillary artery puncture rate of 50%. With the recently reported modified Raj technique,[1] the success rate was improved to 97% when a twitch response could be obtained at the wrist or fingers. However, the rate was only 44% when a proximal response was obtained. Their overall success rate was 86%. Indeed, in practice it is not uncommon to obtain a proximal response and to experience difficulty in stimulating the hand in a timely manner. This leads to reduced success and/or prolonged time to perform the block. Our results with ultrasound guidance compare favourably with those mentioned above. Nevertheless, a rigorously performed randomized prospective comparative study will be needed to establish the superiority of our technique.

To our knowledge, only two previous studies used ultrasound imaging as a guide for infraclavicular brachial plexus block. Wu and colleagues[5] reported eight successful blocks in nine patients, but three were complicated by subclavian artery puncture. (Based on their landmarks they were probably describing the axillary artery; the subclavian becomes the axillary artery at the lateral border of the first rib.[10]) These authors did not attempt to identify the echodense cords; instead they deposited the local anaesthetic at the lateral border of the subclavian artery. Furthermore, they used a thin (23-gauge) spinal needle that we find difficult to see sonographically. To reach the target, they calculated the maximum allowable depth of penetration at the angle at which the needle was introduced. The needle then was advanced based on this calculation rather than by following it with real time imaging. In addition to testing the technique in a substantially greater number of patients, we directed our block needle to each of the cords individually. The entire length of the needle was seen at all times. We believe this simple measure was a major factor in obtaining the higher success rate and substantially lowering the rate of vascular puncture (0.8% *vs* 33%) in our study. Several investigators have already emphasized the importance of depositing local anaesthetic around each nerve in the brachial plexus as a factor in improving success rate.[11 12] Using a 17- or 18-gauge Tuohy needle and aligning it with the probe enabled us to follow its image and to direct it to each cord. In addition, the rigidity of a large bore needle provides better control of its tip during manipulations than a thinner needle that bends easily. We believe that use of a Tuohy needle with its blunt tip also helped avoid vascular puncture by pushing away vessels and nerves, although we recognize that vascular puncture with this type of needle may produce greater damage than with a smaller gauge needle. Finally, a large bore Tuohy needle permits easy placement of a catheter for continuous use.

A recent study by Ootaki and colleagues,[8] reported 100% success rate with the use of ultrasound guidance in infraclavicular block. Of their 60 patients, in whom blocks were performed by the principal author, 57 did not require any additional local anaesthetic or opioid supplementation. Two patients were given additional infiltration of local anaesthetic and one received analgesia with fentanyl. Although not recorded, the time to perform the block was estimated as 5 min. While they claimed an overall success rate of 100%, the ulnar, radial and median nerves were spared in 10%, 6.7% and 3.3% of patients, respectively, 30 min after injection. Thus we believe their actual success rate is comparable to ours. The onset time in their study appears to be 30 min; it was 6.7 (3.2) min in our series. This delay can be attributed to the fact that no attempt was made to observe the nerve trunks or cords. Consequently, the anaesthetic was deposited on all sides of the subclavian artery to surround it like a doughnut with the expectation that it would spread around the nerves. Incidentally, it appears from their diagram and sonographic image that, like Wu and colleagues,[5] they also called the axillary artery the subclavian. More importantly, at their midclavicular needle entry point the divisions of the brachial plexus are all closely apposed posterosuperiorly to the axillary artery.[13] Depositing local anaesthetic in a doughnut-like fashion around the artery at this level limits the quantity that diffuses into the nerves, which are located only on one side of the vessel.[13] With our technique, the needle entry point is more lateral, at the level of the coracoid process, where the cords of the plexus are not close together, but lie on three sides of the axillary artery. Thus, the anaesthetic can easily be deposited around each cord. We strongly believe that the rapid onset and reliability of the block depends on perineural rather than perivascular spread. Another reason for the slow onset in the study of Ootaki and colleagues[8] may be related to the use of a slightly lower concentration of lidocaine (1.5%) without sodium bicarbonate. Sodium bicarbonate is used routinely in our institution to hasten the onset of block irrespective of the technique used for nerve blocks.

The approximately 9.3 mg kg^{-1} dose of lidocaine (average 700 mg) used in our study (similarly to Wu and colleagues[5]) may appear large as compared with that used by Ootaki and colleagues[8] (7.3 mg kg^{-1}). Previous studies using 900 mg and up to 18 mg kg^{-1} have demonstrated the safety of larger doses of lidocaine.[14 15] Nevertheless, we have recently been able to produce successful infraclavicular blocks with comparable onset time using ultrasound guidance at substantially reduced doses (4.3 mg kg^{-1}) and low volume (13–15 ml) of 2% lidocaine.[16]

We used a 2.5 MHz transthoracic echocardiography probe which gives a grainy image. This was the only probe available for this study. At present we use a 3.5–7 MHz probe that provides substantially better imaging. Ootaki and colleagues[8] used a 7 MHz probe, whereas Wu and colleagues[5] did not specify the frequency of their probe.

An advantage of ultrasound guidance is that the block may be repeated at the same site when it begins to dissipate; this is not feasible with the nerve stimulator technique. Similarly, a successful block can be administered with this technique in patients with amputated distal upper extremities. Ultrasound guidance also provides an excellent educational tool; more than 90% of the blocks in this study were performed by approximately 20 residents at different levels of training, with no prior experience of peripheral nerve blocks. They were all supervised by an attendant who also held the ultrasound probe in place. It is highly probable that our success rate could have reached 100% if all the blocks had been performed by the authors, as in the study of Ootaki and colleagues.[8] Although we did not specifically focus our study to determine the learning curve for this procedure, we feel that approximately 20 procedures under direct supervision of an expert may enable an operator to be proficient.

In conclusion, ultrasound-guided infraclavicular block appears to be associated with a high success rate, short onset time, easy placement of catheter, low complication rate, and excellent analgesia even when a tourniquet is used. It is well tolerated by patients. The cost of the ultrasound device may be considered a limiting factor. However, it represents a one-time capital expense that, if prorated over a large number of patients, may become cost effective, especially when the time saved for each procedure is taken into account.

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References

1 Borgeat A, Ekatodramis G, Dumont C. An evaluation of the infraclavicular block via a modified approach of the Raj technique. *Anesth Analg* 2001; **93**: 436–41
2 Whiffler K. Coracoid block—a safe and easy technique. *Br J Anaesth* 1981; **53**: 845–8
3 Urban MK, Urquhart B. Evaluation of brachial plexus anesthesia for upper extremity surgery. *Reg Anesth* 1994; **19**: 175–82
4 Ting RL, Sivagnanaratnam V. Ultrasonographic study of the spread of local anaesthetic during axillary brachial plexus block. *Br J Anaesth* 1989; **63**: 326–9
5 Wu T-J, Lin S-Y, Liu C-C, Chang H-C, Lin C-C. Ultrasound imaging aids infraclavicular brachial plexus block. *Acta Anaesthesiol Sin* 1993; **31**: 83–6
6 Kapral S, Krafft P, Eibenberger K, Fitzgerald R, Gosch M, Weinstabl C. Ultrasound-guided supraclavicular approach for regional anesthesia of the brachial plexus. *Anesth Analg* 1994; **78**: 507–13
7 Yang WT, Chui PT, Metreweli C. Anatomy of the normal brachial plexus revealed by sonography and the role of sonographic guidance in anesthesia of brachial plexus. *AJR Am J Roentgenol* 1998; **171**: 1631–6
8 Ootaki C, Hayashi H, Amano M. Ultrasound guided infraclavicular brachial plexus block: an alternative technique to anatomical landmark-guided approaches. *Reg Anesth Pain Med* 2000; **25**: 600–4
9 Raj PP, Montgomery SJ, Nettles D, Jenkins MT. Infraclavicular brachial plexus block: a new approach. *Anesth Analg* 1973; **52**: 897–904
10 Gabella G. Cardiovascular section. In: Williams PL, ed. *Gray's Anatomy*, 38th Edn. New York: Churchill Livingstone, 1995; 1537
11 Lavoie J, Martin R, Tetrault J-P, Cote DJ, Colas MJ. Axillary plexus block using a peripheral nerve stimulator: single or multiple injections. *Can J Anaesth* 1992; **39**: 583–6
12 Baranowski AP, Pither CE. A comparison of three methods of axillary brachial plexus anaesthesia. *Anaesthesia* 1990; **45**: 362–5
13 Moore KL. The upper limb. In: Moore KL, ed. *Clinical Oriented Anatomy*, 3rd Edn. Baltimore: Williams and Wilkins, 1992; 510–23
14 Aantaa R, Kirvela O, Lahdenpera A. Transarterial brachial plexus anesthesia for hand surgery: a retrospective analysis of 346 cases. *J Clin Anesth* 1994; **6**: 189–92
15 Palve H, Kirvela O, Olin H, Syvalahti E, Kanto J. Maximum recommended doses of lignocaine are not toxic. *Br J Anaesth* 1995; **74**: 704–5
16 Sandhu NS, Bahniwal CS, Capan LM. Ultrasound guidance reduces local anesthetic requirements for infraclavicular block. *Anesthesiology* 2001; **95**: A851