An Evaluation of the Infraclavicular Block via a Modified Approach of the Raj Technique

Alain Borgeat, MD, Georgios Ekatodramis, MD, and Charles Dumont, MD*

Departments of Anesthesiology and *Orthopedic Surgery, University Hospital of Zurich/Balgrist, Zurich, Switzerland

Infraclavicular plexus block has recently become a technique of increasing interest. However, no approach has provided easily identifiable landmarks, good conditions for catheter placement, and lack of complications (mainly pneumothorax). We describe a modified approach of the Raj technique based on the identification of the anterior acromial process, jugular notch, and emergence of the axillary artery within the axillary fossa, with the arm abducted to 90° and elevated by approximately 30°. We evaluated the clinical characteristics of this approach by injecting 40 to 50 mL of ropivacaine 0.6% in 150 patients scheduled for elective surgery of the forearm, wrist, or hand. Success was defined as a sensory block of the 5 nerves with territories distal to the elbow within 30 min after performing the block. The success rate was 97% when a distal response (flexion or extension of the wrist or fingers) was elicited and 44% when a proximal (contraction of the triceps, biceps) was obtained using a nerve stimulator. Complications were rare: aspiration of blood was seen in 2% of patients and hematoma was seen at the puncture site in 0.6%; no pneumothorax occurred. Eleven patients (7%) complained of some pain during the procedure. We conclude that the modified approach of the Raj technique for infraclavicular block is very effective when a distal nerve stimulator response is obtained with a small complication rate and a high degree of patient satisfaction.

(Anesth Analg 2001;93:436–41)

Regional anesthesia is appropriate for surgery of the upper limb. Different sites may be chosen to perform a brachial plexus block. Infraclavicular block is indicated for surgery of the forearm, wrist, and hand because it is possible to cover all sensory territories of the distal part of the upper limb with only one puncture. To perform an infraclavicular block it is desirable to have identifiable landmarks, good conditions for the placement of a catheter, and the avoidance of pneumothorax. The infraclavicular approach to the brachial plexus was first described by Labat (1) in 1922. The technique was later modified by Raj et al. in 1973 (2) and Sims (3) in 1977 to improve the reliability of the landmarks. The latter technique is based on the localization of the coracoidopectoral depression, which is not always easily palpable. Whiffler (4) described the coracoid block in 1981, which is not well suited for the insertion of a catheter. In 1995 Kilka et al. (5) described a new technique, the infraclavicular vertical brachial plexus block. This approach carries a risk of pneumothorax and of technical difficulties in the placement of a catheter. More recently Kapral et al. (6) described the lateral infraclavicular plexus block, in which the main landmark is the coracoid process. The main disadvantage of this technique is related to the difficulty in catheter placement. We have modified the approach described by Raj et al. (2) for the infraclavicular block to use easily identifiable surface anatomy landmarks, to provide an easy way to insert a catheter, and to minimize the risk of complications, mainly pneumothorax (7). The aims of our study are to evaluate the feasibility and efficacy of this modified approach to the infraclavicular block.

Methods

After obtaining institutional and ethical committee approval and patient consent, 150 patients of ASA physical status I–III scheduled for elective surgery of the forearm, wrist, and hand, under infraclavicular plexus block, were prospectively included in the trial. Patients with previous neurological damage of the operated limb, with neuropathy or history of drug abuse, and pregnant women were excluded from the study.

The following landmarks were identified to perform the modified approach of the Raj technique. A point bisecting a line joining the ventral acromial process of the scapula (lateral landmark) and the jugular notch

Accepted for publication April 10, 2001.
Address correspondence and reprint requests to Alain Borgeat, MD, Chief-of-Staff Anesthesia, Orthopedic University Clinic Zurich/Balgrist, Forchstrasse 340, CH-8008 Zurich/Switzerland. Address e-mail to aborgeat@balgrist.unizh.ch.

0003-2999/01

(medial landmark) is marked (Fig. 1). To identify these landmarks, the patient lies supine with the arm in a neutral position along the body. The point of emergence of the axillary artery at the fossa axillaris is next identified (Fig. 1). To perform the block, the patient's head is slightly turned away from the arm to be anesthetized, the arm being abducted to 90° and elevated by approximately 30°. The whole length of the clavicle is marked after palpation. A skin wheal is raised 1 cm caudal below the inferior border of the clavicle at its central point. The needle is directed laterally at between 45° and 60° to the skin toward the emergence of the axillary artery in the fossa axillaris as close as possible to the lateral border of the pectoralis major muscle (Fig. 2). All the blocks were performed according to a standardized procedure by using a nerve stimulator (Stimuplex® HNS 11; B. Braun Melsungen AG, Melsungen, Germany) connected to the proximal end of the metal inner of a short bevel needle (Stimuplex® A 21 gauge stimulation needle; B. Braun Melsungen AG). The placement of the needle was judged to be successful when a muscle distal to the deltoid was stimulated with a threshold intensity of the current <0.5 mA and an impulse duration of a 0.1 m/s. A response was considered proximal if contraction of the triceps, biceps, flexor carpi radialis, or flexor carpi ulnaris was elicited and distal if flexion or extension of the wrist or the fingers was obtained. Each time flexion or extension of the fingers or the wrist was part of the response, the response was considered as distal (contraction of the flexor carpi and flexion of the fingers, for example).

For the catheter placement, the cannula over needle technique was used with a plastic cannula (Polymedic®, Polyplex N 50-T, external diameter 20 gauge; Te me na, Bondy, France) and a catheter with a stylet (Polymedic®, Polyplex N 50-T, internal diameter 23 gauge; Te me na). The catheter was pushed 1 cm distal to the end of the cannula. All catheters were fixed with adhesive tape after subcutaneous tunneling, as described for the interscalene catheter (8). All patients were premedicated with midazolam 0.1 mg/kg *per os* 1 h before the block. The blocks were performed with ropivacaine 0.6% 50 mL for patients weighing more than 60 kg and 40 mL for those weighing <60 kg. In patients with a catheter, the initial block was performed through the catheter. A successful block was defined as the abolition of cold and pinprick response in all 5 nerve territories of the forearm (radial, ulnar, median, musculocutaneous, and median antebrachial cutaneous) within 30 min after the injection of the drug. The block was considered to have failed if anesthesia was not present in one or more of the nerve distributions within 30 min. The appearance of sensory block was evaluated every 5 min. Motor block was assessed 30 min after giving the local anesthetic and graded as follows: grade 1 = ability to flex and extend the forearm; grade 2 = ability to flex or extend only the wrist and fingers; grade 3 = ability to flex or extend only the fingers; grade 4 = inability to move the forearm, wrist, and fingers. Duration of the block was assessed as the time interval between the administration of local anesthetic and the first demand for analgesics (patients with an infraclavicular catheter were not considered). Immediate and late complications were noted. Patient satisfaction was assessed 6 h after the initial block or 6 h after the end of the infusion on a visual analog scale where 10 = entirely satisfied and 0 = entirely dissatisfied. Axial computer tomography image of the shoulder was performed to check the placement of the tip of the needle (Somaton Plus 4, Siemens Medical Systems, Erlangen, Germany).

Results

One-hundred-fifty-one patients were included in the study. One patient was excluded because of an inability to localize the infraclavicular brachial plexus. This patient had a history of severe trauma with a double clavicular fracture necessitating surgical repair. Among the 150 patients included, 37 had catheters that remained in place for an average of 3 days. In this group, 14 patients had an articulation arthrolysis of 1 or 2 fingers, 10 had flexor or extensor finger tenolysis, 9 had complex radius and ulnar osteotomy, and 4 had vascularized flaps of the forearm. One catheter associated with a proximal response was unsuccessful and was withdrawn. A distal response was elicited in 118 patients and associated with a success rate of 97% (115 patients). In two patients, extension of the fingers and the wrist was elicited but an insufficient sensory block of the territories of the median and musculocutaneous nerves was obtained. One patient who had flexion of the fingers and the wrist had insufficient sensory block of the radial nerve territory. Details of the "distal response" are summarized in Table 1. A proximal response was elicited in 32 patients with a success rate of 44% (14 patients). Among the failures, contraction of the triceps was elicited in 13 patients; in 10, the median and musculocutaneous nerves were not blocked and in the other 3 patients, the ulnar and median antebrachial cutaneous nerves were not reached. In two patients, who had a stimulation of the flexor carpi radialis, the ulnar and median antebrachial cutaneous nerves were not blocked. In three patients with a flexor carpi ulnaris response, one had an insufficient radial nerve block and two had no median and musculocutaneous block. Details of the "proximal responses" are summarized in Table 1.

The onset time of the block (loss of cold and pinprick sensation) and the duration of the block (first patient call for pain) are reported in Table 2. All patients tolerated a tourniquet. The plexus was reached at a mean depth of 4.5 cm (range, 3.0–7.0); the median

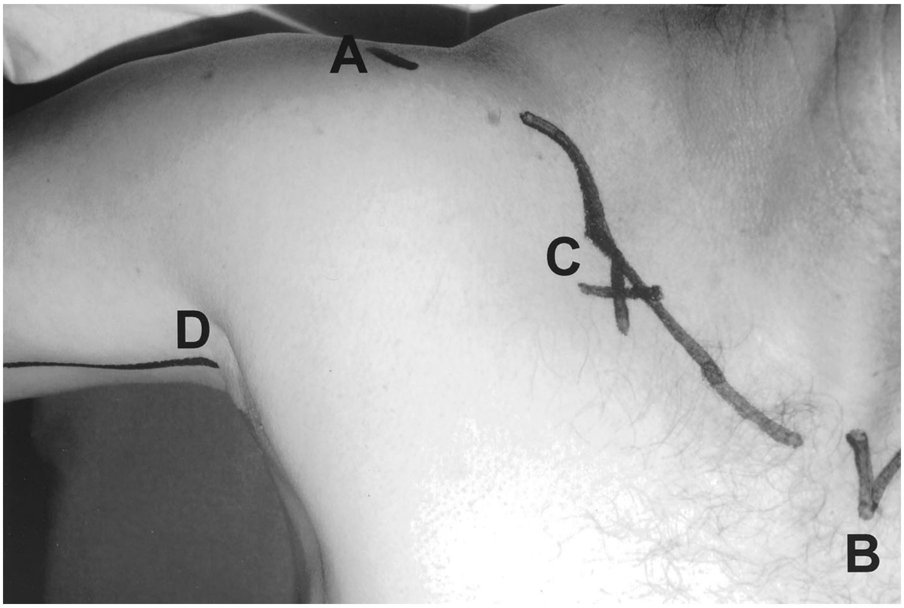

Figure 1. Landmarks for the modified approach of the Raj technique. A, ventral acromial process of scapula; B, jugular notch; C, midpoint between A and B; D, point of emergence of the axillary artery.

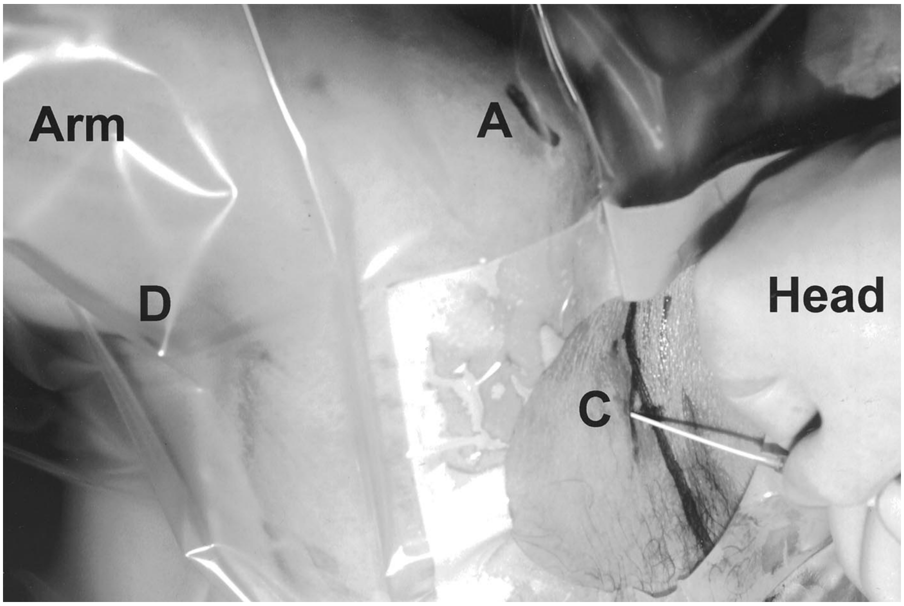

Figure 2. Performance of the modified approach of the Raj technique. The needle is introduced at an angle of 60° 1 cm below the clavicle exactly at a midpoint (C) between the ventral acromial process of the scapula (A) and the jugular notch (not visible on this picture) in a direction toward the point of emergence of the axillary artery in the fossa axillaris (D), the arm being abducted to 90° and elevated by approximately 30°.

nerve was slightly more superficial 4.1 cm (range, 3.0–6.0) than the radial or ulnar 4.8 cm (range, 3.5–7.0) nerves. An adequate response was obtained in 39% of the cases after the first attempt. The needle had to be redirected once in 33%, twice in 19%, three times in 7%, and more than three times in 2%.

Seventy-two percent of the patients with a successful block had a grade 4 motor block after 30 min (fingers + wrist + forearm completely blocked). Grades 2 and 3 motor block were noted in 28% of the cases (slight movements of the wrist and fingers). No patient of the successful group needed supplementary analgesics during surgery. Seven patients requested sedation (target-controlled infusion propofol titrated between 0.5 to 1 μg/mL) for their own comfort. Among the 21 failures, 10 received general anesthesia and 11 had an additional block performed in the axilla. Among the 10 who had general anesthesia when in the recovery room, 4 had a complete block involving the 5 nerves. Fifteen patients had an axial computed tomography image of the shoulder to check the position of the needle after eliciting a distal response (Fig. 3). All the images were similar.

Observed complications and side effects were venous blood aspiration during performance of the block in 3 patients (2%) and hematoma at the puncture site in 1 (0.6%), and 11 (7%) reported pain during the procedure. Among the 37 patients who had an infraclavicular catheter, 28 (75%) reported paresthesias in the fingers at the end of the infusion, 4 (11%) reported

Table 1. Extension of Anesthesia in 150 Patients with a "Distal" or "Proximal" Response to Nerve Stimulation

Sensory territory	Success rate distal response	Success rate proximal response
All 5 nerves	115 (97%)	14 (44%)
Median nerve	116 (97%)	17 (53%)
Ulnar nerve	118 (100%)	27 (84%)
Radial nerve (distal)	117 (99%)	29 (91%)
Musculocutaneous nerve	116 (98%)	17 (53%)
Median antebrachial cutaneous nerve	118 (100%)	27 (84%)

Radial nerve was tested distal to the elbow.

Table 2. Onset Time and Duration of the Infraclavicular Block in 129 Successful Blocks

Median nerve	16 ± 9 min
Ulnar nerve	20 ± 7 min
Radial nerve	19 ± 9 min
Musculocutaneous nerve	18 ± 10 min
Median antebrachial cutaneous nerve	22 ± 6 min
Duration of the block	853 ± 202 min

Data presented as mean ± SD.

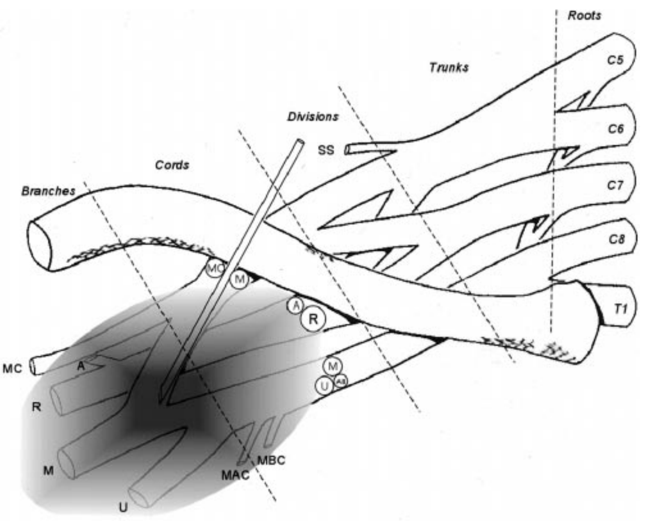

Figure 3. Schematic representation of the ideal placement of the needle eliciting flexion of the fingers through the direct stimulation of the median nerve. Diffusion gradient centered about the needle tip targeting all the peripheral nerve branches. C5 to T1 = cervical root; SS = suprascapular nerve; MC = musculocutaneous nerve; M = median nerve; A = axillary nerve; U = ulnar nerve; R = radial nerve; MAC/AB = medial antebrachial cutaneous nerve; MBC = medial brachial cutaneous nerve.

paresthesias in the fingers 24 h later, and none reported paresthesias in the fingers 1 wk after the initial block. Among the patients who had a single shot, 90 (79%) had paresthesias in the fingers the day after surgery that disappeared completely within a week.

The successfully blocked patients rated their satisfaction at 9.7 ± 0.4. The satisfaction rate was similar among patients with or without a catheter. Results are presented as mean ± SD

Discussion

In this study we demonstrated that the Raj modified technique for infraclavicular block was associated with a very high success rate when a distal nerve stimulator response was obtained (97%) with rapid onset of the block, an infrequent incidence of complications and a high degree of patient satisfaction. Conversely, the success rate was infrequent when a proximal response was elicited (44%).

The high success rate observed among the patients with a distal response is comparable to those found after the lateral infraclavicular plexus block (6), the vertical infraclavicular plexus block (5), and the axillary block (7), although these success rates are higher than reported by others (9–11). After the first 50 infraclavicular blocks, analysis clearly showed that a proximal response was associated with a frequent failure rate. We have no clear explanation for these differences. Indeed, Fitzgibbon et al. (12) were the first to suggest in a case report in 1995 that a proximal stimulation was associated with the occurrence of failure of the block when performing the infraclavicular technique as described by Raj et al. (2). However, the concept of a neurovascular sheath at the infraclavicular level, as described by Raj et al. (2), has to be challenged according to our results. No sheath surrounding the nerves has been described by surgeons during brachial plexus surgery (13) or by our own surgeons carrying out surgical dissection of the brachial plexus. Only the presence of some disorganized fibrous tissue surrounding each nerve has been described by Bonnel and Canovas (14).

Our results may be explained by the anatomical approach (15). The best results were observed when stimulation of the median nerve with a distal response (flexion of the fingers) was obtained. Stimulation of the median nerve indicated that the needle was placed approximately at the center of the region where the nerves emerge (Fig. 3). Moreover, the somatotopic arrangement of fibers in the trunks of the brachial plexus shows that fibers in the core (or central) bundles innervate the distal arm (16). This spatial arrangement may explain better diffusion of the solution to the radial and ulnar nerves, when it is applied on the median nerve after eliciting a distal response of this nerve (Fig. 3) and is in agreement with the concept of a diffusion space as described by Capdevila et al. (17). These anatomical considerations may also explain the 40% delayed success rate among the patients in whom the blocks failed who had general anesthesia.

The tourniquet was well tolerated by all patients without any supplementary injection, suggesting good analgesia of the axillaris and medial brachial

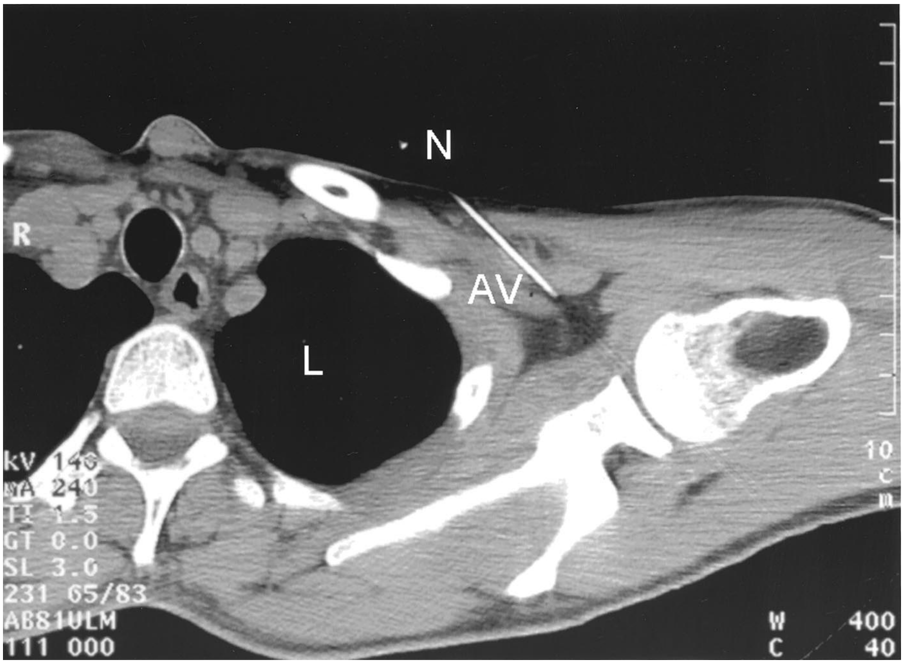

Figure 4. Axial computed tomography image of left shoulder with arm in abduction after eliciting a distal response (flexion of the fingers). This picture shows the relationships between the needle (N), the lung (L), and the subclavian vein and artery (AV). With this approach the needle remains away from the lung at any depth. Note the vicinity between the tip of the needle and the subclavian vessels.

cutaneous nerves. We did not check these sensory territories systematically because they were not included as an outcome in the design of this trial.

The success rate of this modified approach of the Raj technique, when a distal response was obtained, is comparable to that reported by Kilka et al. (5) or Kapral et al. (6). Our approach is based on reliable and constant bony landmarks and one rather constant vascular reference, the point of emergence of the brachial artery from the axillary fossa. Klaastad et al. (18) described a technique that has some similarities to our technique, although the landmarks are not comparable. Indeed, by magnetic resonance imaging the authors demonstrated that an abducted arm of 90° and needle angle of approximately 60° were the best requirements for reaching the brachial plexus cords. These conditions match almost exactly those used in our technique. On the contrary, the approach described by Raj et al. (2) uses the Chassaignac tubercle and a landmark found by palpation of the subclavian artery at the midclavicle. These landmarks are not always easily located and the relationship between the subclavian artery and the clavicle may greatly vary (19). The coracoidopectoral groove, the main landmark of the Sims (3) technique may also be difficult to identify. The direction of the needle in our approach, tangential to the cords, permits an easy placement of a catheter. The vertical as well as the lateral vertical technique (5,6) conveys the risk of pneumothorax. A recent case report (20) describes such a complication after a vertical infraclavicular block despite the fact that the procedure strictly followed the guidelines recommended by Kilka et al. (5). The occurrence of venous puncture was infrequent in our trial (2%) in contrast to the 10.5% (5) to 30% (21) reported with the vertical infraclavicular technique. A very frequent incidence of vascular puncture (up to 50%) was observed with the application of the coracoid block according to Whiffler (4). The infrequent occurrence of this complication in our study may be explained first by the angle of the needle (60° to 45°) giving a tangential approach to the vessels together with the use of a short beveled needle (30°). Despite the vicinity of the vessels to the plexus (Fig. 4), we believe the approach needle angle and the short beveled needle will push the vessels away rather than perforating them. Of the different techniques used, only the vertical lateral technique is associated with a similar infrequent incidence of venous puncture (6). The use of a catheter was not associated with any particular complications but these considerations are limited by the small number of patients. The pharmacokinetics of ropivacaine (onset time and duration of action) were comparable to those found after interscalene brachial plexus block (22).

Mastering this technique is simple; indeed, in more than 90% of the patients the needle had to be redirected only 2 times to localize the plexus. The most difficult part of the technique is the correct location of the anterior part of the acromial process, which requires some training, particularly in muscular patients.

The disadvantages of the technique are the positioning of the arm (90° abduction), which can be painful for patients with a traumatized limb, and the elicitation of pain in some patients when the needle goes through the pectoralis muscle. Light sedation may be helpful for these patients.

In conclusion, the modified approach of the Raj technique for the infraclavicular brachial plexus block is an easy technique to learn, is based on reliable landmarks, offers good conditions for the placement of a catheter, minimizes complications such as pneumothorax, and is associated with a very frequent rate of success if a distal response, particularly of the median nerve, is elicited.

References

1. Winnie AP II. Historical considerations. In: Winnie AP, Hakansson L, eds. Plexus anesthesia. Philadelphia: WB Saunders, 1993: 67–116.
2. Raj PP, Montgomery SJ, Nettles D, Jenkins MT. Infraclavicular brachial plexus block: a new approach. Anesth Analg 1973;52: 897–904.
3. Sims JK. A modification of landmarks for infraclavicular approach to brachial plexus block. Anesth Analg 1977;56:554–5.
4. Whiffler K. Coracoid block: a safe and easy technique. Br J Anaesth 1981;53:845–8.
5. Kilka HG, Geiger P, Mehrkens HH. Die vertikale infraclaviculäre blockade des plexus brachialis. Anesthesist 1995;44:339–44.
6. Kapral S, Jandrasits O, Schabernig C, et al. Lateral infraclavicular plexus block versus axillary block for hand and forearm surgery. Acta Anesthesiol Scand 1999;43:1047–52.
7. Urban MK, Urquhart B. Evaluation of brachial plexus anesthesia for upper extremity surgery. Reg Anesth 1994;19:175–82.
8. Ekatodramis G, Borgeat A. Subcutaneous tunneling of the interscalene catheter: a simple and effective method to prevent interscalene catheter dislocation. Can J Anaesth 2000;47:716–7.
9. Davis WJ, Lennon RL, Wedel DJ. Brachial plexus anesthesia for outpatient surgical procedures on an upper extremity. Mayo Clin Proc 1991;66:470–3.
10. Selander D. Axillary plexus block: paresthetic or perivascular. Anesthesiology 1987;66:726–8.
11. Conn RA, Cofield RH, Byer DE, Linstromberg JW. Interscalene block anesthesia for shoulder surgery. Clin Orthop 1987;216: 94–8.
12. Fitzgibbon DR, Debs AD, Erjavec MK. Selective musculocutaneous nerve block and infraclavicular brachial plexus anesthesia. Reg Anesth 1995;20:239–41.
13. Slingluff C, Terzis J, Edgerton M. Anatomie chirurgicale du plexus brachial humain. In: Alnot JY, Narakas A, eds. Les paralysies du plexus brachial. Paris: Expansion Scientifique Française, 1995:14–8.
14. Bonnel F, Canovas F. Anatomie du plexus brachial chez le nouveau-né et l'adulte. In: Alnot JY, Narakas A, eds. Les paralysies du plexus brachial. Paris: Expansion Scientifique Française, 1995:3–13.
15. Kerr AT. The brachial plexus of nerves in man, the variations in its formation and branches. Am J Anat 1918;23:285–395.
16. Williams MJ. Pharmacology for regional anesthetic techniques. In: Hahn MB, McQuillan PM, Sheplock GJ, eds. Regional anesthesia: an atlas of anatomy and techniques. St. Louis: Mosby, 1996:3–17.
17. Capdevila X, Biboulet P, Bouregba M, et al. Comparison of the three-in-one and fascia iliaca compartment blocks in adults: clinical and radiographic analysis. Anesth Analg 1998;86: 1039–44.
18. Klaastad O, Lilleas FG, Rotnes JS, et al. A magnetic resonance imaging study of modifications to the infraclavicular brachial plexus block. Anesth Analg 2000;91:929–33.
19. Tountas CP, Bergman RA. Arteries. In: Tountas CP, Bergman RA, eds. Anatomic variations of the upper extremity. New York: Churchill Livingstone 1993:187–92.
20. Neuburger M, Landes H, Kaiser H. Pneumothorax bei der vertikalen infraklavikulären Blockade des Plexus brachialis. Anaesthesist 2000;49:901–4.
21. Neuburger M, Kaiser H, Rembold-Schuster I, Landes H. Vertical infraclavicular block of brachial plexus: a clinical study of the reliability of a new method for plexus anaesthesia of the upper extremity. Anaesthesist 1998;47:595–9.
22. Borgeat A, Tewes E, Biasca N, Gerber C. Patient-controlled interscalene analgesia with ropivacaine after major shoulder surgery: PCIA vs PCA. Br J Anaesth 1998;81:603–5.