Can J Anesth/J Can Anesth (2009) 56:109–114
DOI 10.1007/s12630-008-9024-3

REPORTS OF ORIGINAL INVESTIGATIONS

Ultrasound-guided block of the brachial plexus at the humeral canal

Bloc par échoguidage du plexus brachial au niveau du canal huméral

Emmanuel Guntz, MD · Vanessa Van den Broeck, MD · Etienne Dereeper, MD · Walid El Founas, MD · Maurice Sosnowski, MD, PhD

Received: 30 May 2008 / Revised: 1 December 2008 / Accepted: 3 December 2008 / Published online: 13 January 2009

Abstract

Purpose *Conduction block of the brachial plexus block at the humeral canal, as described by Dupre, has certain clinical indications. The aim of this preliminary study was to assess the feasibility of this technique under ultrasound guidance.*

Methods *After ultrasound evaluation of the brachial plexus at the humeral canal in 61 adult volunteers, we performed ultrasound-guided blocks in another 20 adult patients. A linear 38 mm probe, 13–6 MHz, and a 50-mm insulated block needle were used to guide injection of lidocaine 1.5% with epinephrine.*

Results *Ulnar and median nerves are superficial and located at similar depths. Ultrasound imaging showed the musculocutaneous nerve to be located dorsally. The radial nerve is dorsal to the plane of the musculocutaneous nerve. Relative to the brachial artery, the median nerve is situated between 12 and 1 o'clock in 66% of the cases. Relative to the basilic vein, the ulnar nerve is situated at 3 o'clock in 46% of the cases. The evaluated block sequence was radial, ulnar, musculocutaneous and median nerve; two points of puncture were mandatory, and 6.85 ± 0.37 min were required to perform the blocks. Sensory onset times were similar for the four nerves. Injectate volume was lower for the musculocutaneous nerve compared to other nerves ($P < 0.05$). All 20 patients experienced complete sensory and motor blocks.*

E. Guntz, MD (✉) · V. Van den Broeck, MD ·
E. Dereeper, MD · W. El Founas, MD ·
M. Sosnowski, MD, PhD
Department of Anesthesiology, Hôpital Universitaire Saint-Pierre, Université Libre de Bruxelles, Rue Haute, 322, 1000 Brussels, Belgium
e-mail: eguntz@ulb.ac.be

Conclusion *We describe an approach to, and the feasibility of ultrasound-guided block of the brachial plexus at the humeral canal. Further study will be required to establish the effectiveness and the safety of this technique.*

Résumé

Objectif *Les blocs de conduction du plexus brachial au niveau du canal huméral tels que décrits par Dupre ont certaines indications cliniques. L'objectif de cette étude préliminaire était d'évaluer la faisabilité de cette technique par échoguidage.*

Méthode *Après une évaluation ultrasonographique du plexus brachial au niveau du canal huméral chez 61 volontaires adultes sains, nous avons réalisé des blocs par échoguidage chez 20 autres patients adultes. Une sonde linéaire de 38 mm, 13–6 MHz, et une aiguille de bloc isolée de 50 mm ont été utilisées pour guider l'injection de lidocaïne 1,5% avec épinéphrine.*

Résultats *Les nerfs cubital et médian sont superficiels et situés à des profondeurs similaires. L'imagerie par ultrason a montré que le nerf musculocutané était situé en position dorsale. Le nerf radial est dorsal au plan du nerf musculocutané. Par rapport à l'artère brachiale, le nerf médian se situe entre midi et une heure dans 66% des cas. Par rapport à la veine basilique, le nerf cubital se situe à 3 heures dans 46% des cas. La séquence de bloc évaluée se situait au niveau des nerfs radial, cubital, musculocutané et médian; deux points de ponction étaient requis, et 6,85 ± 0,37 min ont été nécessaires pour réaliser les blocs. Les délais d'action sensitifs étaient semblables pour les 4 nerfs. Le volume de la dose injectée était plus bas pour le nerf musculocutané comparativement aux autres nerfs ($P < 0,05$). Des blocs sensori-moteurs complets ont été réalisés chez les 20 patients.*

Conclusion *Nous décrivons une approche ainsi que la faisabilité d'un bloc échoguidé du plexus brachial au niveau du canal huméral. Des études plus poussées seront nécessaires afin de déterminer l'efficacité et l'innocuité de cette technique.*

Introduction

Ultrasound-guided brachial plexus blocks have been described for interscalene,[1] supraclavicular,[2] infraclavicular,[3] and axillary approaches.[4] However, there is no description of ultrasound-guided brachial plexus block at the humeral level.

The humeral approach, as described by Dupre, allows a multi-injection technique to be performed at the level of the junction between the proximal and the middle third of the arm.[5] At this level, the four main branches of the brachial plexus, the radial, the ulnar, the median, and the musculocutaneous nerves, are anatomically separated from each other. At the axillary level, multiple injections of the brachial plexus under ultrasound guidance are superior to nerve stimulation techniques in terms of the success rates of sensory blocks and their onset times.[6] An ultrasound-guided approach provides an opportunity for the anesthesiologist to visualize the needle position relative to the vascular structures and the spread of local anesthetic. At the humeral canal level, the location of the nerves in relation to blood vessels is less variable than at the axillary level.[7] These characteristics should favor nerve identification and selective injection under ultrasound guidance. Nevertheless, Retzl et al. showed that the nerves of the brachial plexus do not appear together on the same ultrasound screen[8] at the level of the humeral canal. Consequently, a blockade of these nerves with the classical single point of puncture is technically difficult.

In this preliminary study, we first described the ultrasound anatomy of the brachial plexus at the level of the humeral canal. From these clinical observations, we designed an approach to plexus block at this level, and we assessed the feasibility of performing this block under ultrasound guidance.

Methods

Ultrasound description of the brachial plexus at the humeral canal

The Medical Ethics Committee of Hôpital Universitaire Saint-Pierre approved this prospective study, and the volunteers gave written informed consent without any financial compensation. Ultrasound-guided characterization of the brachial plexus was performed at the level of the humeral canal on volunteers who were ASA physical status I to III. During their preoperative evaluations, the patients were invited to participate in the first part of our study. Ultrasound-guided characterization was performed during the preoperative period inside the operating room. The volunteers were placed in the supine position with one arm in abduction (90°) and externally rotated and the corresponding forearm flexed (90°) (Fig. 1a). Ultrasound guidance was performed with a Micromaxx (Sonosite, Bothell, WA, USA) equipped with a linear 38 mm probe, 13–6 MHz. The ultrasound probe was placed at the junction of the proximal and the middle third of the arm, perpendicular to the brachial artery, and was moved in a caudal-cephalad axis along this landmark in order to image the four main nerves (Fig. 1a, b). The sequence of visualization was radial, ulnar, musculocutaneous, and median nerve, respectively. We recorded the skin-to-nerve distances, the distance from the cephalad side of the probe to the radial nerve, the intersection of this line with the humerus, the position of the median nerve relative to the brachial artery, and the position of the ulnar nerve relative to the basilic vein. The distance from the cephalad side of the probe to the radial nerve was measured at the point where the position of the probe provided optimal visualization of the nerve. Regarding the location of nerves relative to vessels, we defined four pie chart sectors focused on vessels (1a, 2a, 3a, 4a around the humeral artery; 1v, 2v, 3v, 4v around the basilic vein) and classified the position of the nerves in each of these sectors (Fig. 2). A first evaluation was performed on a convenience sample of 61 volunteers who agreed to participate in the study. The skin-to-nerve distances, expressed as mean $\pm$ SEM, were compared using ANOVA for repeated measurements. Multiple comparisons were performed with the Sidak test. P values <0.05 were considered significant.

Block of the brachial plexus under ultrasound guidance at the humeral canal

Following the ultrasound evaluation of the brachial plexus at the humeral canal, we designed an approach to targeting the blockade of the brachial plexus through the humeral canal under ultrasound guidance. After providing their written informed consent, we recruited a second group of 20 patients who were ASA physical status I, II, or III, were without preexisting neurological illness, and were scheduled for either wrist and/or hand surgery. All 20 patients received standard monitoring and were sedated with midazolam 1–2 mg i.v. Patient positioning was identical to that described above and as shown in Fig. 1a. The US probe was covered with a sterile sheath (Tegaderm, Saint

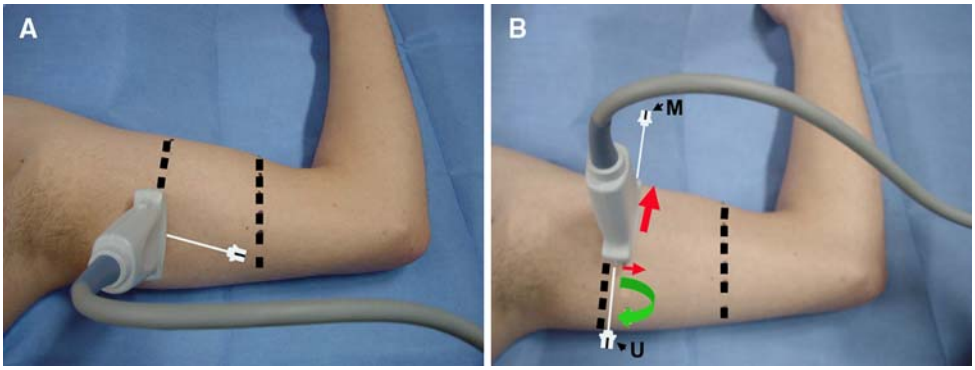

Fig. 1 **a** Position of the patient, the probe, and the needle during block of the radial nerve. The radial nerve is blocked through an out-of-plane approach. **b** Position of the patient, the probe, and the needle during block of the ulnar (*U*), the median (*MN*), and the musculocutaneous nerves (*MCN*). The probe is repositioned more cephalad and slightly laterally compared to the position of the probe described in Fig. 1a (*red arrows*); for the block of the ulnar nerve, the needle is re-orientated in an in-plane position (*green arrow*). A second point of puncture is performed on the cephalad side of the probe in order to block the musculocutaneous nerve and the median nerve through an in-plane approach

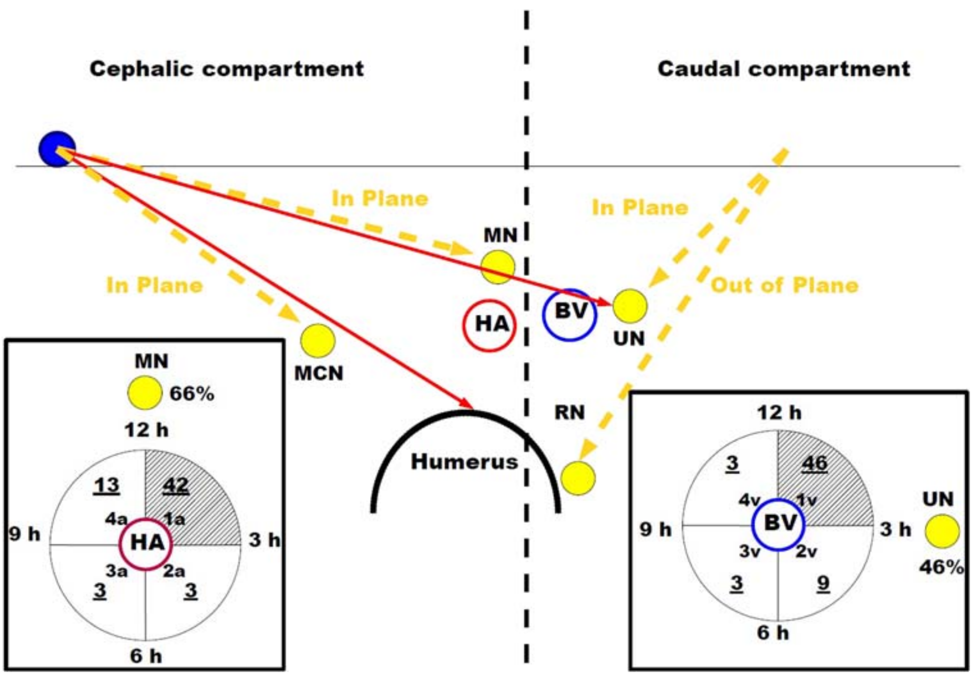

Fig. 2 Graphical synthesis of the brachial plexus at the level of the humeral canal under ultrasound description. *RN* radial nerve, *UN* ulnar nerve, *MCN* musculocutaneous nerve, *MN* median nerve, *HA* humeral artery, *BV* basilic vein, *HB* humerus. The *dotted line* separates the caudal compartment from the cephalic compartment. The *underlined* numbers correspond to volunteers. The MN is between 12 and 1 o'clock in 66% of the cases. The UN is situated at the 3 o'clock position in 46% of the cases. The UN and the RN cannot be blocked from a single point of puncture located on the cephalic side of the probe (*red arrows*). The 2 points of puncture inside the 2 compartments are mandatory (*yellow arrows*)

Paul, MN, USA) and with an abundance of sterile gel (Aquasonic, Parker, Laboratories, Fairfield, NJ, USA). Under sterile technique, the probe was placed over the described landmarks in order to image nerves in the short axis (Fig. 1a, b). The nerves were visualized and blocked in the following sequence: radial, ulnar, musculocutaneous, and median nerves, respectively. A 22-gauge insulated 50-mm needle (Stimuplex A Braun, Melsungen, Germany) was used; nerve stimulation was not performed. After gentle aspiration, lidocaïne 1.5% with epinephrine 1: 200,000 was injected when both the nerve and the needle were imaged. The volume of local anesthetic necessary to surround the nerve determined the injectate volume. Nerve stimulation was not performed. The volume of injected local anesthetic and the time to perform the block were recorded. Sensory block onset times were recorded at 5, 10, 20, and 30 min thereafter, as evaluated by a pinprick test (needle of a Dejerine's reflex hammer, neurologicals 5038) and a cold test in the four nerve territories. The tests were performed on the dorsal first web space for the radial nerve, on the pulp of the fifth finger for the ulnar nerve, on the pulp of the first finger for the median nerve, and on the lateral aspect of the forearm for the musculocutaneous nerve. Motor block onset times were recorded at the same corresponding time intervals as follows: extension of the fingers (radial nerve), flexion of the fifth finger (ulnar nerve), thumb opposition (median nerve), and flexion of the forearm on the arm (musculocutaneous nerve). Two experienced anesthesiologists (E.G. and V.V.B) performed the blocks; a blinded observer recorded the data. Patients were asked to classify their experience into one of three categories: no discomfort, unpleasant, or painful.

The volume of local anesthetic that was required to surround each nerve, the corresponding sensory onset times, and the motor block onset times are expressed as mean ± SEM. Summary results for each of the nerves were compared using ANOVA for repeated measurements. Multiple comparisons were performed with the Sidak test. P values <0.05 were considered significant.

Results

Ultrasound description of the brachial plexus at the humeral canal

Evaluation of the 61 volunteers involved 39 women and 22 men, ASA physical status I ($n = 32$), II ($n = 25$), and III ($n = 4$). The mean age was 45.0 ± 1.8 years; the mean weight was 73.0 ± 1.5 kg; and the mean height was 167.0 ± 0.9 cm. The mean skin-to-nerve distance was 2.67 ± 0.05 cm for the radial nerve (Fig. 3a), 0.98 ± 0.03 cm for the ulnar nerve, 0.95 ± 0.03 cm for the median nerve (Fig. 3b), and 1.44 ± 0.03 cm for the musculocutaneous nerve (Fig. 3c). There were no differences between the average depths of the ulnar and the median nerves ($P > 0.05$); however, the average depth of the musculocutaneous nerve, located between the coracobrachialis and the biceps muscles, was greater than the average depths of both the ulnar and the median nerves ($P < 0.001$). At the point of examination, the radial nerve was located beside the humerus and deeper than the musculocutaneous nerve ($P < 0.001$). Finally, the distance from the cephalad side of the probe to the radial nerve was 3.59 ± 0.06 cm. This line intersected the humerus in 58% of the patients.

The median nerve was situated in sector 1a in 69% of the cases and between 12 and 1 o'clock in 66% of the cases. The ulnar nerve was situated in sector 1v in 76% of the cases and at the 3 o'clock position in 46% of the cases (Fig. 2). In cases where the variability of the location of the

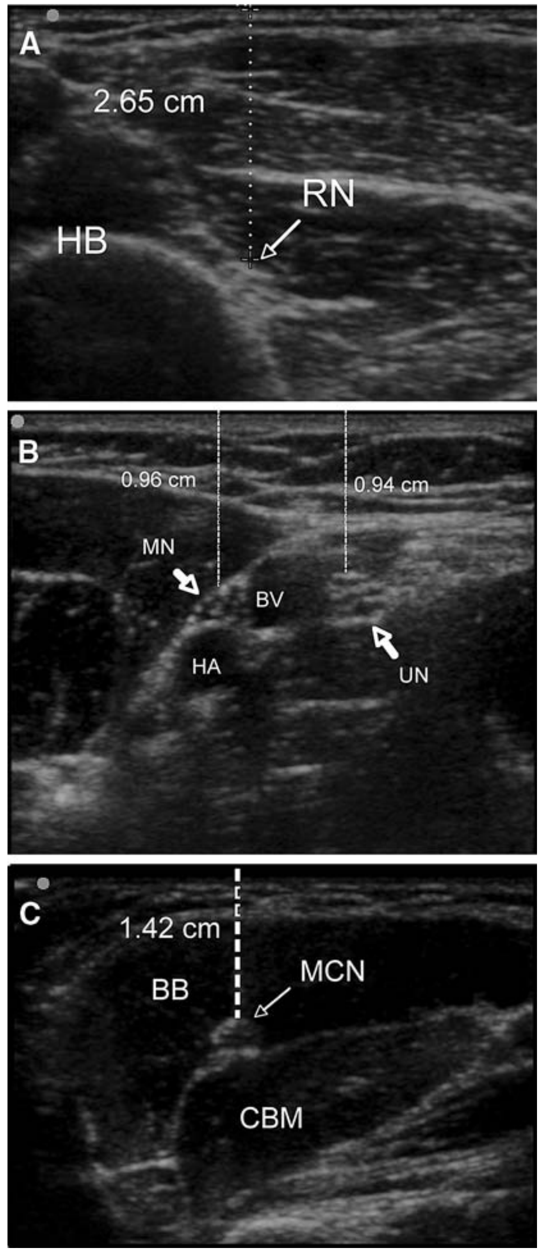

Fig. 3 **a** Ultrasound description of the radial nerve. The *blue point* is situated at the cephalic side of the probe. The skin is located on the top of the image. *RN* radial nerve, *HB* humerus. In this picture, the distance skin-to-nerve is 2.65 cm. **b** Ultrasound description of the median and ulnar nerve. The *blue point* is situated at the cephalic side of the probe. The skin is located on the top of the image. *UN* ulnar nerve, *MN* median nerve, *HA* humeral artery, *BV* basilic vein. The distance skin-to-median nerve is 0.96 cm. In this picture, the distance skin-to-ulnar nerve is 0.94 cm. **c** Ultrasound description of the musculocutaneous nerve. The *blue point* is situated at the cephalic side of the probe. The skin is located on the top of the image. *MCN* musculocutaneous nerve, *CBM* coracobrachialis muscle, *BB* biceps brachialis muscle. In this picture, the distance skin-to-nerve is 1.42 cm

median and ulnar nerves was associated with a difficult ultrasound examination, these nerves were imaged at the level of the elbow and followed until the level of the humeral canal.

Block of the brachial plexus under ultrasound guidance at the humeral canal

An initial evaluation of the sample of 20 patients was performed. This involved 14 women and 6 men whose mean age was 50 ± 4.58 years, mean weight was 67.9 ± 2.49 kg, and mean height was 168 ± 2.31 cm.

Surgeries for carpal tunnel syndrome (6 patients), wrist fracture (12 patients), and cyst resection of the wrist (2 patients) were performed under regional anesthesia with mild sedation and with a tourniquet positioned on the upper arm. With due consideration of the anatomic findings from the ultrasound investigations, the patients were placed in the position described above, and the nerves were blocked in the following sequence: radial, ulnar, musculocutaneous, and median nerve, respectively. The radial nerves were blocked through an out-of-plane approach (Fig. 1a). The probe was repositioned in front of the brachial artery and slightly laterally, in order to image the ulnar nerve and place the point of puncture on the caudal side of the probe. Therefore, the ulnar nerves were blocked through the same point of puncture and through an in-plane approach (Fig. 1b). A second point of puncture was performed on the cephalad side of the probe; the musculocutaneous nerve and the median nerves were blocked sequentially through an in-plane approach (Fig. 1b).

The blocks were performed within 6.85 ± 0.37 min. The injected volume was less on the musculocutaneous nerve than that required on the other three nerves (musculocutaneous nerve vs. median nerve: $P = 0.006$; musculocutaneous nerve vs. ulnar nerve: $P = 0.02$; musculocutaneous nerve vs. radial nerve: $P < 0.001$). Nerve sensory onset times were similar for the 4 nerves ($P > 0.05$); however, motor onset times were shorter for the musculocutaneous nerve than for the median nerve and the ulnar nerves ($P < 0.001$ and $P = 0.019$, respectively). Motor onset times for the radial nerve were also shorter than the onset times for the median nerve ($P = 0.019$) (Table 1). Complete sensory and motor blocks were obtained for all 20 patients. No vessels were punctured in any patient, and no patients reported pain during the procedure.

Discussion

Ultrasound examinations of the brachial plexus through the humeral canal show that ulnar and median nerves are located superficially under the skin. The radial nerve, located beside the humerus, is the most dorsally located nerve of the plexus. The musculocutaneous nerve is situated midway between these two nerves.

Images obtained from ultrasound examinations of the brachial plexus through the humeral canal can be illustrated on a graphical synthesis and can be divided into two compartments. A superficial and a dorsal nerve can be found within each compartment. Median and musculocutaneous nerves are located inside the cephalic compartment; whereas the musculocutaneous nerve is located dorsally. Ulnar and radial nerves are located inside the caudal compartment; the radial nerve is located dorsally (Fig. 2).

In half of the cases, when the point of puncture is situated cephalic to the probe (superior left corner of the screen), the needle crosses the basilic vein in order to reach the ulnar nerve. Similarly, the radial nerve cannot be blocked through this pathway because the humerus is situated on the pathway of the needle in 58% of the cases (Fig. 2). It would be possible to introduce the needle on the caudal side of the probe, but in this configuration, movements of the needle are impeded by the upper limb layout. Consequently, we advocate two points of puncture: the first is dedicated to the blockade of radial and ulnar nerves; and the second is dedicated to the blockade of musculocutaneous and median nerves. Perlas et al. emphasized that the four main nerves of the brachial cannot be imaged together at the level of the humeral canal, and that the radial nerve is difficult to visualize.[9] Therefore, we proposed to position the probe more caudally. This technique allows a reduction of the skin-to-radial nerve distance to facilitate visualization of the radial nerve otherwise hidden by the humerus. In this configuration, the radial nerve is initially blocked through an out-of-plane approach. After the probe has been

Table 1 Clinical data

	Radial nerve	Ulnar nerve	Musculocutaneous nerve	Median nerve
Volume of local anesthetics (ml)	9.75 ± 0.25	9.05 ± 0.40	7.60 ± 0.38	9.35 ± 0.36
Sensory block onset				
Negative cold test (min)	6.50 ± 0.67	6.50 ± 0.57	5.50 ± 0.38	7.75 ± 1.08
Negative pin-prick (min)	7.25 ± 0.82	7.94 ± 1.05	5.58 ± 0.38	11.76 ± 1.70
Motor block onset (min)	10.75 ± 1.16	13.68 ± 1.88	7.5 ± 0.72	17.63 ± 2.23

re-directed anterior to the vessels, the ulnar nerve is blocked within the same point of puncture through an in-plane approach (Fig. 1b).

Nerves from the cephalic compartment are both blocked through an in-plane approach. The deepest nerve is always blocked first; otherwise the injected local anesthetic impedes location of the deepest structures. In a previous study, we suggested blocking the deepest nerves before the superficial ones in order to improve the safety of the technique.[10] Our results confirm the efficacy of this sequence for rather different reasons.

We decided not to perform nerve stimulation evaluation for two reasons. First, we wanted to avoid potential bias, particularly regarding the assessment of the time required to locate the nerves and the time required to obtain complete nerve blocks. Both can be modified, whether the block is performed under ultrasound guidance alone or under ultrasound guidance combined with nerve stimulation.[11] Second, when blocking patients for open reduction and fixation of wrist fractures, we considered the potential confounding influence of pain that might be related to nerve stimulation. The mean time to perform the block was 6.85 ± 0.37 min, including the time necessary to visualize the nerves. This length of time is similar to that observed during the neurostimulation of the brachial plexus block at the humeral canal level.[12,13]

We defined the injected volume as the volume necessary to surround the nerve. Interestingly, these volumes are similar to those reported and recommended during neurostimulation blockades.[13,14] Moreover, with respect to the musculocutaneous nerve, a smaller volume of injectant was needed, and the onset time of the motor block was shorter than for the other nerves, as suggested by the results from the neurostimulation techniques.[13,15]

Vessels are superficial and easily imaged; consequently, we did not observe any vascular puncture. Similarly, the ulnar and median nerves, being the more superficial nerves, can be located quite easily around the vessels. Furthermore, the musculocutaneous nerve has a bright echogenic texture between the coracobrachialis and the biceps brachialis muscles and a specific triangular shape at the level of the humeral canal.[15] These three nerves are blocked through an in-plane approach. This configuration provides a high quality image of the nerves, the needle, and the injected local anesthetics. Finally, it is an important observation that no patient reported pain while the blocks were performed, which is of clinical relevance for patients suffering from wrist and hand fractures.

This preliminary study is novel with regard to a description of blocking the brachial plexus at the level of the humeral canal under ultrasound guidance. This technique offers an additional opportunity to block the nerves of the brachial plexus proximally. At this level, the nerves are anatomically separated. Consequently, a multi-injection technique could be performed with different local anesthetics. For instance, short-acting local anesthetics can be injected on the musculocutaneous nerve, whereas long-acting local anesthetics can be injected on the other nerves. In the case of hand and wrist surgery, this technique allows the patient to recover the flexion of the forearm while providing effective post-operative analgesia. Further studies will be required to compare this approach to other proximal approaches, to define clinical situations in which the anesthesiologist should favor this approach, and to further explore the technique's efficiency and overall safety.

Conflicts of interest None declared.

References

1. *Chan VW*. Applying ultrasound imaging to interscalene brachial plexus block. Reg Anesth Pain Med 2003; 28: 340–3.
2. *Chan VW, Perlas A, Rawson R, Odukoya O*. Ultrasound-guided supraclavicular brachial plexus block. Anesth Analg 2003; 97: 1514–7.
3. *Sandhu NS, Capan LM*. Ultrasound-guided infraclavicular brachial plexus block. Br J Anaesth 2002; 89: 254–9.
4. *Reed J, Leighton S*. Ultrasound facilitation of brachial plexus block. Anaesth Intensive Care 1994; 22: 499.
5. *Dupre LJ*. Brachial plexus block through humeral approach. Cah Anesthesiol 1994; 42: 767–9.
6. *Casati A, Danelli G, Baciarello M, et al.* A prospective, randomized comparison between ultrasound and nerve stimulation guidance for multiple injection axillary brachial plexus block. Anesthesiology 2007; 106: 992–6.
7. *Partridge BL, Katz J, Benirschke K*. Functional anatomy of the brachial plexus sheath: implications for anesthesia. Anesthesiology 1987; 66: 743–7.
8. *Retzl G, Kapral S, Greher M, Mauritz W*. Ultrasonographic findings of the axillary part of the brachial plexus. Anesth Analg 2001; 92: 1271–5.
9. *Perlas A, Chan VW, Simons M*. Brachial plexus examination and localization using ultrasound and electrical stimulation: a volunteer study. Anesthesiology 2003; 99: 429–35.
10. *Guntz E, Herman P, Delbos A, Sosnowski M*. The radial nerve should be blocked before the ulnar nerve during a brachial plexus block at the humeral canal. Can J Anesth 2004; 51: 354–7.
11. *Dingemans E, Williams SR, Arcand G, et al.* Neurostimulation in ultrasound-guided infraclavicular block: a prospective randomized trial. Anesth Analg 2007; 104: 1275–80.
12. *Bouaziz H, Narchi P, Mercier FJ, et al.* Comparison between conventional axillary block and a new approach at the midhumeral level. Anesth Analg 1997; 84: 1058–62.
13. *Carles M, Pulcini A, Macchi P, Duflos P, Raucoules-Aime M, Grimaud D*. An evaluation of the brachial plexus block at the humeral canal using a neurostimulator (1417 patients): the efficacy, safety, and predictive criteria of failure. Anesth Analg 2001; 92: 194–8.
14. *Dupre LJ*. Block of the branches of the brachial plexus and brachial canal. Ann Fr Anesth Reanim 2006; 25: 237–41.
15. *Schafhalter-Zoppoth I, Gray AT*. The musculocutaneous nerve: ultrasound appearance for peripheral nerve block. Reg Anesth Pain Med 2005; 30: 385–90.