Ultrasound-Guided Supraclavicular Block

Outcome of 510 Consecutive Cases

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Introduction: Supraclavicular brachial plexus block provides consistently effective anesthesia to the upper extremity. However, traditional nerve localization techniques may be associated with a high risk of pneumothorax. In the present study, we report block success and clinical outcome data from 510 consecutive patients who received an ultrasound-guided supraclavicular block for upper extremity surgery.

Methods: After institutional review board approval, the outcome of 510 consecutive patients who received an ultrasound-guided supraclavicular block for upper extremity surgery was reviewed. Real-time ultrasound guidance was used with a high-frequency linear probe. The neurovascular structures were imaged on short axis, and the needle was inserted using an in-plane technique with either a medial-to-lateral or lateral-to-medial orientation.

Results: Five hundred ten ultrasound-guided supraclavicular blocks were performed (50 inpatients, 460 outpatients) by 47 different operators at different levels of training over a 24-month period. Successful surgical anesthesia was achieved in 94.6% of patients after a single attempt; 2.8% required local anesthetic supplementation of a single peripheral nerve territory; and 2.6% received an unplanned general anesthetic. No cases of clinically symptomatic pneumothorax developed. Complications included symptomatic hemidiaphragmatic paresis (1%), Horner syndrome (1%), unintended vascular punctures (0.4%), and transient sensory deficits (0.4%).

Conclusions: Ultrasound-guided supraclavicular block is associated with a high rate of successful surgical anesthesia and a low rate of complications and thus may be a safe alternative for both inpatients and outpatients. Severe underlying respiratory disease and coagulopathy should remain a contraindication for this brachial plexus approach.

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Peripheral nerve blocks are an excellent anesthetic option for upper limb surgery, providing long-lasting pain relief; lower incidence of nausea, vomiting, and sore throat than general anesthesia; and expedited hospital discharge.[1]

Initially described by Kulenkampff and Persy[2] in the early 20th century, the supraclavicular approach to the brachial plexus provides more consistent and effective regional anesthesia to the upper extremity than other approaches to brachial plexus blockade.[3] As originally described, this technique requires the insertion of a needle toward the first rib where the brachial plexus lies in close proximity to the subclavian artery. After an initial period of popularity, the use of this approach declined significantly because of an unacceptably high incidence of pneumothorax (0.6%–6.1%), although this may be higher than actually seen in contemporary practice.[4] Other complications of supraclavicular block include vascular punctures, unintended intravascular injection with resulting local anesthetic systemic toxicity, Horner syndrome, recurrent laryngeal nerve blockade, and phrenic nerve blockade with transient hemidiaphragmatic paresis.[4]

Several alternative supraclavicular approaches were described in the second half of the 20th century, in an attempt to minimize the risk of pneumothorax.[5–8] More recently, it has been suggested that real-time ultrasonographic guidance for supraclavicular block may potentially help avoid this complication, because the pleura and the lung can be imaged simultaneously with needle advancement.[9,10] However, previous reports of ultrasound-guided supraclavicular block include only a limited number of patients, and larger-scale clinical outcome data are missing at this time. In the present study, we report block success and clinical outcome data from 510 consecutive patients who received an ultrasound-guided supraclavicular block.

MATERIALS AND METHODS

After University Health Network institutional review board approval, all patients who received an ultrasound-guided supraclavicular block for upper extremity surgery in the period from May 2005 to May 2007 were included in this review. Data for this review were gathered both prospectively and retrospectively. Data on patient demographics, block technique including local anesthetic solution and dose, identity and level of training of the performing physician, success rates, need for supplementation, and immediate complications were prospectively entered by the physician performing the block into a specially designed database on the day of surgery. In addition, information on intraoperative medications, need for general anesthesia (either planned or unplanned), maximum visual analog scale scores and need for analgesics in the postanesthetic care unit (PACU), incidence of hospital admission (both planned and unplanned), and delayed complications was obtained retrospectively through an electronic patient chart review, surgeon's follow-up clinic note, and a follow-up telephone interview (from 2 to 12 months postoperatively).

During this follow-up telephone interview, performed by 1 of 3 coinvestigators (A.P., G.L., or R.K.), patients were asked a set of standardized questions as follows:

1. After your surgery, did you notice any new weakness of the arm or hand that was not present before?

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2. After your surgery, did you notice any new numbness or lack of sensation in the arm or hand that was not present before?
3. In the days after your surgery, did you have any breathing difficulties?
4. In the days after your surgery, did you have to seek emergency medical attention?

If patients answered *yes* to any of the above questions, a thorough history of the event(s) was taken.

All data (both prospectively and retrospectively gathered) were entered into a database specifically designed for the purpose of this review. Data were summarized using SPSS 11.0 for Windows (SPSS Inc., Chicago,Ill) and reported as mean ± SD, rates, and percentages, as appropriate; χ^2 was used to compare success rates and event incidences, as appropriate.

Block Technique

All block procedures were performed ahead of surgery in a dedicated regional anesthesia room. Patients were positioned supine, with the head turned to the contralateral side. Routine electrocardiogram, noninvasive blood pressure, and pulse oximetry monitors were applied. Intravenous access was established in the nonoperative limb, and an infusion of normal saline was started at a maintenance rate. Anxiolysis was established with 1 to 3 mg midazolam intravenously as required. A time-out procedure was performed according to hospital policy to ensure correct block sidedness. The skin was disinfected with 2% chlorhexidine in 70% isopropyl alcohol. Various ultrasound equipment was used including Philips HDI 5000 and Philips HD11 Xe (Philips Ultrasound, Bothell, Wash), GE logiq E (GE Health Care Canada, Mississauga, Ontario, Canada), and SonoSite MicroMaxx (SonoSite, Bothell, Wash). A linear high-frequency probe (5–12 or 6–13 MHz) covered with a sterile adhesive dressing (3M Tegaderm; 3M Health Care, St. Paul, Minn) was used to scan the supraclavicular fossa in a coronal-oblique plane, parallel and immediately posterior to the clavicle, to obtain a short-axis view of the neurovascular structures. The brachial plexus was identified as a compact group of nerves (trunks and/or divisions) located over the first rib, laterally and posterior to the subclavian artery (Fig. 1). The rib and pleura were identified before needle insertion. A 2-in, 22-gauge insulated needle (Stimuplex; B. Braun Medical, Bethlehem, Pa) was advanced in-plane with the ultrasound beam, from either end of the probe, in either a medial-to-lateral (Fig. 2) or lateral-to-medial (Fig. 3) direction, depending on the provider's preference. The needle was advanced in-plane with the ultrasound beam until the brachial plexus sheath was penetrated, and the needle tip was positioned within the sheath compartment among the nerves (Fig. 1). The first rib was not intentionally contacted during the block procedure. At this point, electrical nerve stimulation was used if desired (mostly for teaching purposes) to demonstrate a distal motor response in the hand. However, the primary method of guidance was imaging of the needle and local anesthetic spread. If no motor response was obtained, the block was performed under ultrasound guidance alone. After a negative aspiration, the local anesthetic solution was administered incrementally, ensuring expansion of the brachial plexus sheath. We found that it is often necessary to make small readjustments of needle tip position to ensure local anesthetic spread to the 3 trunks. These readjustments tend to be subtle, and the needle does not usually need to be removed from

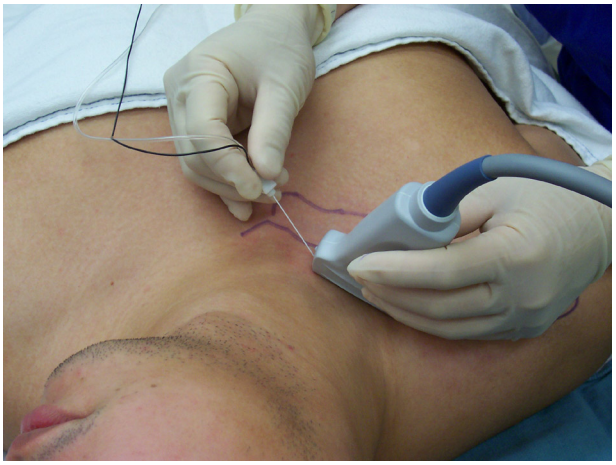

FIGURE 2. In plane approach, medial-to-lateral needle orientation.

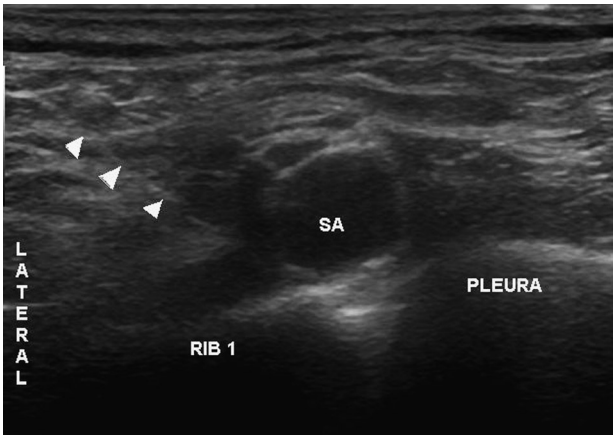

FIGURE 1. Ultrasound image of the brachial plexus in the supraclavicular area. Arrowheads show blocking needle. SA indicates subclavian artery; RIB 1, first rib.

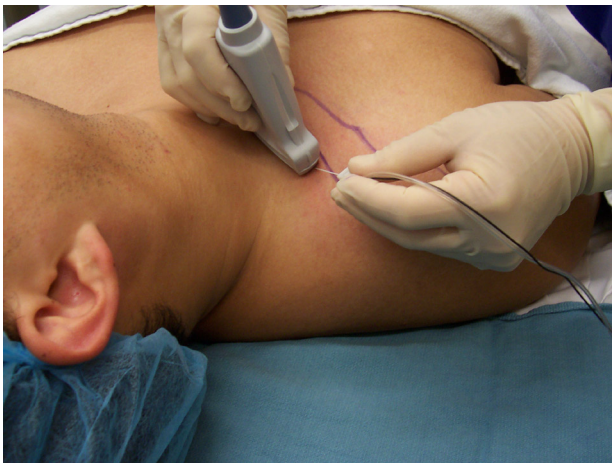

FIGURE 3. In plane approach, lateral-to-medial needle orientation.

TABLE 1. Demographics (N = 510)

Male-female ratio	1.6:1
Age, mean ± SD, y	46 ± 16
BMI, mean ± SD, kg/cm^2	28 ± 10
Height, mean ± SD, cm	169 ± 11
Weight, mean ± SD, kg	77 ± 17
ASA I, % (n)	32.0% (163)
ASA II, % (n)	55.1% (281)
ASA III, % (n)	12.6% (64)
ASA IV, % (n)	0.4% (2)
Outpatients, n	460
Inpatients, n	50

within the plexus compartment until the full desired dose is administered. If an initial 1 to 2 mL of local anesthetic spreads outside the sheath, the needle is readjusted until proper local anesthetic spread is visualized.

Patients were closely monitored in the perioperative period for any symptoms and signs of respiratory difficulty. Upright inspiratory/expiratory chest radiographs were obtained if respiratory symptoms or chest pain was reported. Patients were evaluated after block performance for block success. If a single nerve territory failed to be anesthetized, it was supplemented distally in the arm or forearm. If the block was considered to be unsuccessful, with extensive areas of preserved sensation beyond a single nerve territory, or there was no sufficient time for supplementation before the surgical procedure, a general anesthetic was administered at the discretion of the attending anesthesiologist. In all other cases, intraoperative anxiolysis was achieved with low-dose midazolam (1–3 mg), fentanyl (1–2 μg/kg), and/or propofol at conscious sedation doses (25–75 μg/kg per min).

RESULTS

Five hundred ten consecutive patients received an ultrasound-guided supraclavicular block for elective upper extremity surgery between May 2005 and May 2007. Demographic data are presented in Table 1. Most patients (90%) underwent hand or wrist surgery, with the remaining undergoing forearm, elbow, or arm surgery. Fifty patients underwent a concomitant iliac crest bone graft and were admitted to the hospital overnight as planned. The remaining 460 were outpatients. Blocks were performed by 47 different physicians consisting of staff anesthesiologists (36%), regional anesthesia fellows (51%), and residents under staff supervision (13%).

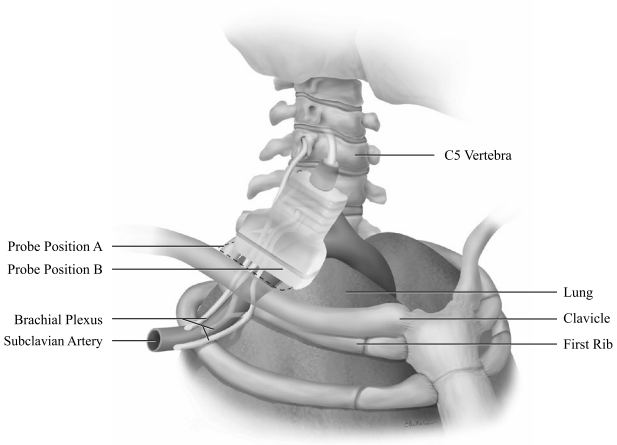

FIGURE 4. Probe position relative to the first rib and the pleura.

Concomitant nerve stimulation was used in 246 patients (48% of cases). The minimum stimulating current was 0.58 ± 0.23 mA. The local anesthetic solution used in 94% of patients was a 50:50 mixture of 2% lidocaine with 1:200,000 epinephrine and 0.5% bupivacaine with 1:200,000 epinephrine. The remaining patients received either lidocaine 2% with 1:200,000 epinephrine or bupivacaine 0.5% with 1:200,000 epinephrine. The mean volume used was 33 ± 8 mL.

Block Outcome and Need for Supplementation

Fifty patients (9.8%) received a planned general anesthetic because the surgery also included an iliac crest bone graft. For

TABLE 2. Block Outcome and Complications by Needle Orientation

	All Patients	Medial-to-Lateral	Lateral-to-Medial
	N = 510	n = 361	n = 149
Planned general anesthetic	9.8% (50)	9.1% (33/361)	11.4 (17/149)
Unplanned general anesthetic	2.6% (12)	3.1% (10/328)	1.3% (2/132)
Local anesthetic supplementation	2.8% (13)	2.4% (8/328)	3.4% (5/132)
Success after 1 attempt	94.6% (435/485)	94.5% (310/328)	94.7% (125/132)
Pneumothorax	0	0	0
95% CI	0%–0.6%		
Symptomatic diaphragmatic paresis	1% (5)	0.8% (3)	1.3% (2)
95% CI	0.4%–2.3%		
Horner syndrome	1% (5)	1.4% (5)	0.7% (1)
95% CI	0.4%–2.3%		
Vascular puncture	0.4% (2)	0.6% (2)	0
95% CI	0.1%–1.4%		
Neurological deficits	0.4% (2)	0.6% (2)	0
95% CI	0.1%–1.4%		

All differences between groups are not significant (χ^2 or Fisher exact test $P > 0.05$).

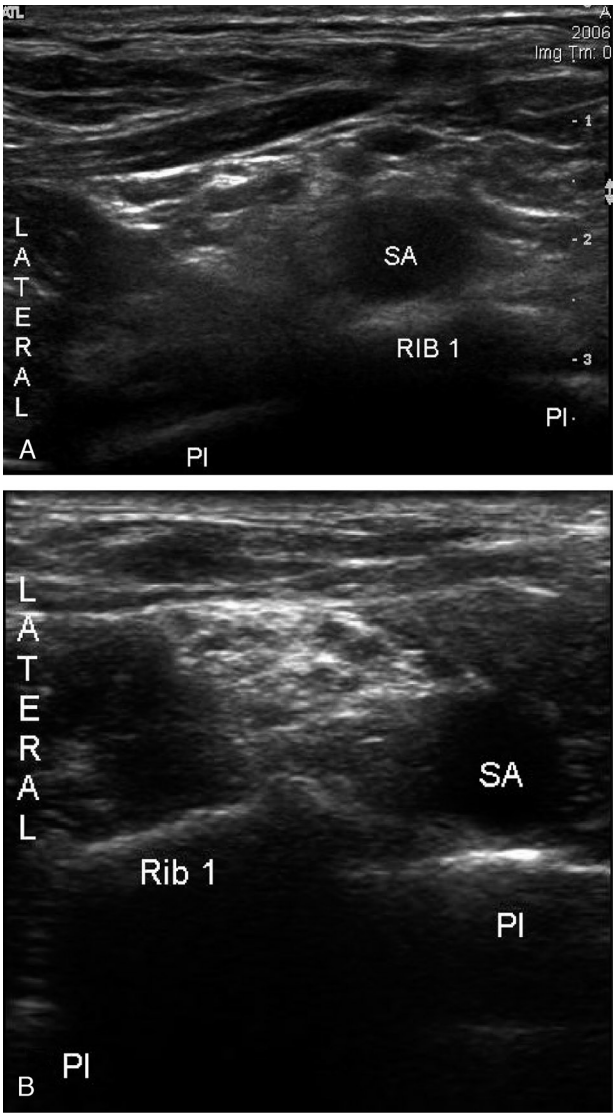

FIGURE 5. A, Ultrasound image corresponding to probe position A. Note the subclavian artery and brachial plexus on the first rib. B, Ultrasound image corresponding to probe position B. Note the subclavian artery and brachial plexus on the pleura. SA indicates subclavian artery; PL, pleura.

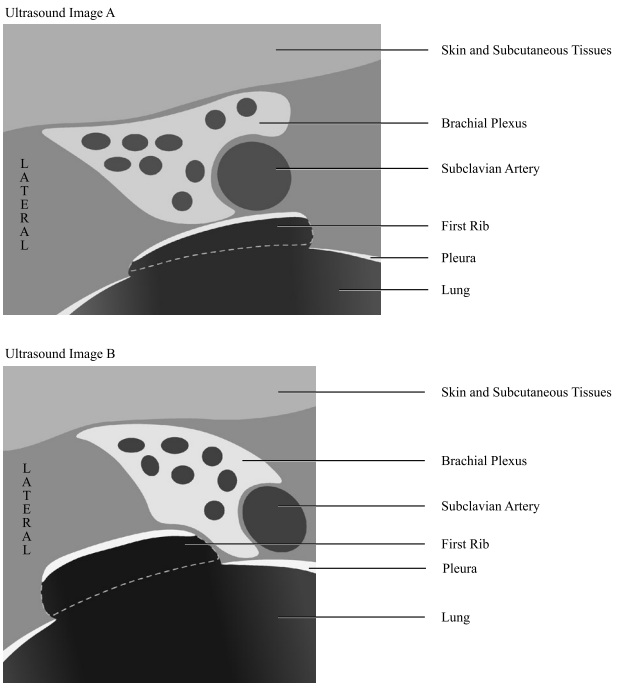

FIGURE 6. A, Schematic representation of image in probe position A. B, Schematic representation of image in probe position B.

TABLE 3. Ultrasound Characteristics of the First Rib and Pleura/Lung Interface

	1st Rib	Pleura
Echogenicity	Hyperechoic	Hyperechoic
Appearance of area immediately deep to it	Anechoic shadow	Shimmering quality ± comet's tail sign
Sliding sign	No	Yes
Movement with normal tidal volume breathing	No	Yes
Movement with arterial pulsation	No	Yes

the remaining 460 outpatients, 13 (2.8%) required a supplemental distal block of a single peripheral nerve, and 12 patients (2.6%) received an unplanned general anesthetic because of incomplete blockade. The peripheral nerves that required supplementation were ulnar in 6 cases, median in 5 cases, radial in 1 case, and musculocutaneous in 1 case. Four hundred thirty-five patients (94.6%) had successful surgical anesthesia after the initial block.

The median visual analog scale pain score in the PACU was 0 (range, 0–10). Forty-five patients (8.8%) required short-acting analgesics in the PACU, 31 of whom had had a concomitant iliac crest bone graft.

Complications and Side Effects

Six patients complained of shortness of breath or chest pain within 1 hr of the block procedure. Upright inspiratory/expiratory radiographs in these patients excluded a diagnosis of pneumothorax. In 5 (1%; 95% confidence interval [CI], 0.4%–2.3%) of these patients, a diagnosis of ipsilateral hemidiaphragmatic paresis was made, based on clinical symptoms of dyspnea and the presence of an elevated hemidiaphragm on the operative side in the inspired chest radiograph. Symptoms were mild in all 5 patients, with resolution before discharge. A diagnosis of acute angina was made in the remaining patient who had a pre-existing coronary artery disease with frequent anginal episodes. Her chest radiograph was normal. She was admitted to the hospital for medical management of her angina without surgery and discharged home in stable condition after 3 days. This was the only unanticipated admission to the hospital in this case series. Other complications included 2 (0.4%, 95% CI, 0.1%–1.4%) vascular punctures recognized by aspiration of blood. The identity of the punctured vessel was not recorded. The needle was repositioned in both cases, and no symptoms of local anesthetic toxicity ensued. Horner syndrome was noticed

in 5 patients (1%; 95% CI, 0.4%–2.3%) with spontaneous resolution.

During the telephone interview, 2 patients (0.4%; 95% CI, 0.1%–1.4%) reported transient postoperative numbness in the fingers of the operative hand that subsided without intervention within several weeks. No new neurological deficits were reported at the time of the first postoperative surgical follow-up.

Needle Orientation

All blocks were performed with a needle-in-plane approach. A medial-to-lateral orientation was used in 361 cases, and a lateral-to-medial orientation was used in the remaining 149 cases at the discretion of the attending anesthesiologist. The 2 groups had similar block success rates after the initial attempt and similar complication rates (Table 2).

DISCUSSION

The present study describes the outcome of 510 consecutive ultrasound-guided supraclavicular blocks for upper extremity surgery, performed at a single academic institution over 2 years by 47 different anesthesiologists at different levels of training. There were no cases of clinically evident pneumothorax. Using the widely accepted method reported by Hanley and Lippman-Hand,[11] we estimated that the upper limit of the 95% CI for the incidence of pneumothorax would be 0.6%. A key step for preventing pneumothorax is to consistently and unequivocally identify the first rib and differentiate it from the pleural surface before needle advancement. Both the soft tissue–rib interface and the soft tissue–pleura interface appear on ultrasound as intensely hyperechoic linear structures because of a marked mismatch in acoustic impedance at the tissue interface (a marked increase in acoustic impedance from the soft tissues to the first rib and a marked decrease in acoustic impedance from the soft tissue to the pleura and air-containing lung).[12] To the inexperienced user of ultrasound imaging, the pleura may look similar to the first rib. Most publications to date report imaging the subclavian artery and the brachial plexus as they lie directly on the first rib (Figs. 4, 5A, and 6A). However, if the probe is tilted only slightly posteriorly and medially, the artery and plexus will be seen typically in direct contact with the pleural surface, as they lie over the cervical portion of the pleura before crossing over the first rib (Figs. 4, 5B, and 6B). There are a number of differences that may help to distinguish the pleura-lung surface from the first rib (Table 3). First, nearly all the ultrasound beam is attenuated on the surface of the first rib, casting a dark, anechoic "shadow" deep to the first rib (Fig. 5A). In contrast, some of the ultrasound beam penetrates through the pleura, with the air-containing lung visualized as having a "shimmering" quality (Fig. 5B). Occasionally, a "comet's tail sign" may be seen (Fig. 7). Second, the first rib has no appreciable movement either during normal tidal volume respiration or secondary to arterial pulsation. In contrast, the pleural surface often moves with subclavian artery pulsation and respiratory movements. Third, a "pleural sliding sign" can often be seen as the 2 layers of the pleura slide over one another during respiration. Finally, the first rib is located over the pleura, so a "step-down" can often be identified on both sides of the first rib, signaling the interface between first rib and pleura. All these elements help define the regional anatomy of the supraclavicular area, in particular the relative position of the subclavian artery in relation to the first rib and pleura, and help decide on the most suitable site for block placement.

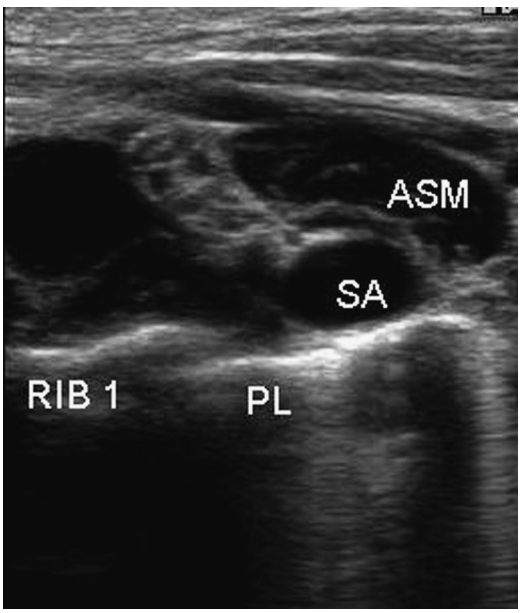

FIGURE 7. Notice comet tail's sign underneath the pleural surface. PL indicates pleura; SA, subclavian artery; ASM, anterior scalene muscle; RIB 1, first rib.

Regarding the scanning plane and needle approach, different techniques have been reported. Kapral et al[9] imaged the brachial plexus 3 cm superior to the clavicle in a sagittal plane. The needle orientation relative to the scanning plane was undisclosed. De Andres and Sala-Blanch[13] scanned in a sagittal plane at the level of the first rib, and "the needle advanced to the deeper part of the plexus along its vertical axis, to avoid medial angulation." This seems to describe an out-of-plane approach and was also used by other authors.[3,14] In contrast, we use a coronal oblique plane for imaging, parallel and immediately posterior to the clavicle, to obtain a short-axis view of the subclavian artery and brachial plexus (Fig. 4).[10] We use an in-plane approach for needle advancement to facilitate needle tip imaging and needle guidance in real time. A medial-to-lateral or lateral-to-medial needle trajectory may be used. In the present review, block success rate after a single attempt and rates of unplanned general anesthesia and local supplementation were similar with either needle orientation (Table 2). The traditional teaching during blind supraclavicular block is to avoid a lateral-to-medial needle orientation to reduce the possibility of pleural puncture. However, under ultrasound guidance, if the pleural surface is properly identified, the blocking needle should be safely kept away from the pleura while advancing in either direction. Conversely, pleural puncture may conceivably occur with either needle direction if the pleura is not properly identified, or if the needle is advanced but not seen on the screen.

One limitation of the medial-to-lateral direction is that one has to "negotiate" the subclavian artery to be able to approach the most dependent components of the brachial plexus, usually the inferior trunk. This may be ergonomically more challenging and may possibly increase the risk of a vascular puncture. In the present series, there were 2 vascular punctures in the medial-to-lateral group and none in the lateral-to-medial group (0.4% of all patients). However, the low incidence of this event precludes drawing any meaningful conclusion as to a cause-and-effect association. The identity of the punctured vessel was not recorded. Possibilities include the subclavian artery itself and the transverse cervical artery and dorsal scapular artery, 2 smaller vessels of variable origin and trajectory, which often cross the

supraclavicular area in the vicinity of the brachial plexus. These 2 smaller vessels and their venous counterparts may be easily "missed" unless identified with color Doppler.

In this series, 5 patients without pre-existing respiratory disease (1%) developed symptomatic hemidiaphragmatic paresis. Symptoms subsided by the time of discharge, and no medical intervention was necessary. However, it is very likely that the true incidence of hemidiaphragmatic paresis is much higher, because it is often asymptomatic in healthy patients.[15] This implies that a supraclavicular block as performed in this series should remain contraindicated in patients with significant underlying respiratory disease or pre-existing contralateral hemidiaphragmatic paresis (and underscores the importance of patient selection).

Other complications occurred with a low incidence (1% Horner syndrome and 0.4% transient neurological deficits) and are comparable with other series.[16]

The use of supraclavicular blocks in an outpatient population has been controversial because of the possibility of delayed onset of symptoms after an initially "silent" pneumothorax. The results of the present study suggest that, with the technique described, the incidence of pneumothorax may be minimized, and ultrasound-guided supraclavicular block may become a safe technique for outpatients. However, this study has insufficient patient numbers to make a definitive recommendation on this topic. The possibility of a pneumothorax, however rare, will always be present regardless of the technique used because of the close anatomic relationship between the brachial plexus and the pleura in the supraclavicular fossa.

The most important limitation to this study is that some of the data were gathered retrospectively, which carries an inherent possibility of bias. We attempted to eliminate selection bias by including all patients who received a supraclavicular block within the study period. The incidence of recall bias cannot be completely eliminated and may underestimate the incidence of some of the events studied. We attempted to minimize recall bias by checking symptoms of respiratory difficulty and new neurological deficits from 3 different sources (patient hospital chart, follow-up telephone interview, and surgeons' follow-up notes). Also, the reported rates of both pneumothorax and hemidiaphragmatic paresis refer to clinically symptomatic cases. The possibility of asymptomatic cases cannot be excluded.

CONCLUSIONS

Ultrasound-guided supraclavicular block was associated with a high success rate and low complication rate, with no pneumothorax in a series of 510 consecutive patients. Ultrasound-guided supraclavicular block as described may be a safe technique for outpatients, although larger numbers of subjects will be required to make this statement with certainty. Pre-existing significant respiratory impairment or contralateral hemidiaphragmatic paresis, as well as coagulopathy, should remain as contraindications to ultrasound-guided supraclavicular brachial plexus anesthesia.

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