

# Ultrasound-guided peripheral nerve blocks: What are the benefits?

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**Background:** Use of ultrasound by anaesthesiologists performing regional blocks is rapidly gaining popularity. The aims of this review were to summarize and update accumulating evidence on ultrasound-guided nerve blocks, with an emphasis on the clinical relevance of the results and to critically appraise changing standards in regional anaesthesia.

**Methods:** A search of MEDLINE and EMBASE (1966 to 31 December 2007) was conducted using the following free terms: 'ultrasound and regional anaesthesia', 'ultrasound and peripheral block' and 'ultrasound and nerve and block'. These were combined with the MESH terms 'nerve block' and 'ultrasonography'. The following limits were applied: studies with abstracts, only in humans, published in core clinical journals. Trial type: meta-analysis, randomized-controlled trial and clinical trial.

**Results:** When peripheral nerves are adequately imaged by ultrasound, the concomitant use of nerve stimulation offers no further advantage. However, several studies reported problems with obtaining satisfactory images in some patients. Ultrasound guidance significantly shortened the block performance time and/or reduced the

number of needle passes to reach the target in all comparative studies. The occurrence of paraesthesia during block performance was also reduced, but not the incidence of short-lasting post-operative neuropraxia. The frequency of accidental vascular punctures may be lower, but the data are contradictory. Block onset time was significantly shortened. Block duration was longer in children, but not in adults. Ultrasound also allowed dose reduction of the local anaesthetic (LA).

**Conclusions:** Ultrasound guidance shortens the block performance time, reduces the number of needle passes and shortens the block onset time. Blocks may be performed using lower LA doses.

Accepted for publication 16 February 2008

**Key words:** Ultrasonography; nerve block; regional anaesthesia.

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THE popularity of peripheral nerve blocks for orthopaedic surgery has increased dramatically in the last 10 years. Many anaesthesiologists use anatomical landmarks, elicitation of paraesthesia and/or electrical nerve stimulation in order to place the needle as close as possible to the target nerve. If local anaesthetic (LA) injection is guided by these methods, it is assumed that all fascicles containing neurons will be exposed to a sufficient number of LA molecules. However, nowadays, we realize that the only information provided by paraesthesia or by nerve stimulation is needle-nerve proximity. The needle tip may be located intravascularly, intra-neurally, or on the other side of the fascia (1). Moreover, any part of the axon may be depolarized and may propagate an action potential. Hence, it is not possible to decide with certainty where the LA is being injected. Worrying case reports about intraspinal injections during

interscalene brachial plexus block (2), intraneural injections during sciatic nerve block (3) and a large multicentre study (4) show that neither paraesthesia nor nerve stimulator is foolproof and that the generally accepted current threshold of 0.5 mA, indicating needle proximity to the nerve, may be too high. In some patients, it is not possible to elicit muscle twitches (5–8), even when using high currents. Electrical stimulation may be unpleasant (9) and elicitation of mechanical paraesthesia may be harmful (10). Besides, upon a visually confirmed needle-nerve contact, paraesthesia is felt by only 38% of the patients and an electrical stimulation of  $\leq 0.5$  mA elicits a visible muscle twitch only in 75% of them (11). Therefore, a visual control of needle advancement in real time should improve our practice and increase both patients' comfort and safety.

We are all interested in providing to our patients fast, effective and safe regional anaesthesia without

discomfort. Ultrasound guidance is a method that may help us reach this goal. However, it requires both personal skills, which are not so easy to learn, and high-quality, expensive ultrasound machines. Even if these machines are available, the inter-individual variability in patients' anatomy and the echographic appearance of the nerves can make the ultrasound-guided block a challenge for both the patient and the anaesthesiologist. Hence, it is prudent to elucidate the value of this increasingly popular method. The aims of this review are to summarize rapidly accumulating knowledge on the ultrasound-guided nerve blocks, with an emphasis on the clinical relevance of the results and to critically appraise changing standards in regional anaesthesia.

In the review published over 3 years ago, Marhofer et al. (12) suggested that ultrasound guidance offers several potential advantages:

1. *Direct visualization of nerves*: This may replace other methods of nerve localization, such as electrical stimulation or paraesthesia.
2. *Direct visualization of anatomical structures: vessels, muscles, bones, fascias, tendons*: This may help assess individual variations in anatomy and facilitate identification of nerves.
3. *Real-time control of needle advancement*: This may reduce the number of needle passes, shorten the block performance time and lower the risk of complications caused by a needle e.g., vascular puncture, neuropraxia or pneumothorax.
4. *Assessment of LA spread around the nerves and immediate supplementary injections in case of insufficient spread*: This may improve block effectiveness, shorten latency, prolong duration, allow LA dose reduction and lower the risk of overdose.
5. *Avoidance of muscle twitches*: This may reduce block discomfort.

These suggestions were based on the vast experience of Viennese colleagues and on the limited number of clinical studies. Since then, the number of clinical studies using ultrasound guidance for peripheral nerve blocks have increased substantially. This review sought to validate these potential advantages.

## Methods

The author searched the MEDLINE and EMBASE (1966 to 31 December 2007) using the following free terms:

1. 'ultrasound and regional anaesthesia',
2. 'ultrasound and nerve and block',
3. 'ultrasound and peripheral block'.

These terms were then combined with the MESH terms 'nerve block' and 'ultrasonography'.

The following limits were applied:

- Studies with abstracts.
- Humans only.
- Published in: Core clinical journals.
- Trial type: meta-analysis, randomized-controlled trial (RCT) and clinical trial.

The electronic search was expanded to related articles. Abstracts were scanned for relevance to peripheral nerve blocks. Relevant studies published in English, German, French and Spanish were printed out in full text and their reference lists were checked manually. Reports of case series were included. However, solitary case reports, editorial views, letters to editor, expert reviews and descriptions of sonoanatomy on cadavers were excluded.

## Results

The search gave 60 hits. Twenty were relevant to peripheral nerve blocks. One of them was a meta-analysis of coeliac plexus block in cancer pain (13). Eight of the studies were RCTs comparing ultrasound with other methods and eight were non-randomized studies either on patients or volunteers in which ultrasound was used to identify the nerves. The remaining three studies did not use ultrasound guidance. However, check of related articles and reference lists of these 20 studies resulted in 59 more papers. Three of them (14–16) were irrelevant to the aims of this review, because ultrasound was used either to assess blood flow or diaphragmatic function after the brachial plexus block. The meta-analysis (13) was also considered to be irrelevant, because <1% of all the blocks were performed using ultrasound. Seventy-nine reports (11, 13–90) were further scrutinized.

### *Ad.1 Direct visualization of nerves*

In five imaging articles on healthy subjects, all the target nerves were visualized by ultrasound (17–21). However, in a study of posterior lumbar plexus block, Kirchmair et al. (22) were unable to identify individual nerves and used an alternative reference point. In two out of 21 of his volunteers, the

sonography failed at all examined levels because of obesity. Perlas et al. (23) could not visualize individual cords of the brachial plexus in the infraclavicular area in 11 out of 15 volunteers. Likewise, Wang et al. (24) could not identify all three cords and the pleura in 21, 26 and 35 out of 40 volunteers, depending on the degree of arm abduction. Chan et al. (25) could not identify the sciatic nerve in two out of 15 subjects. Also, Soong et al. (26) failed to identify anterior divisions of the obturator nerve in six, and the posterior division in five out of 20 volunteers, respectively, and Lundblad et al. (27) did not find the infra-patellar branch of the saphenous nerve in one out of 10 volunteers.

Clinical studies have shown that for superficial locations, e.g., interscalene, supraclavicular, axillary, inguinal, popliteal, elbow/forearm and in paediatric patients, ultrasound allows direct visualization of nerves and is a main method of both needle guidance and LA injection (28–50). In obese patients, the ultrasound-guided interscalene block yields similar results as in patients with normal weight (29). Moreover, one study of an interscalene block (30) has shown that after positioning the needle tip between C5 and C6 nerve roots using ultrasound, the onset and quality of anaesthesia for ambulatory shoulder surgery was similar regardless of the amplitude of stimulating current above or below 0.5 mA (range 0.1–1.7). In a similar study of supraclavicular block (50), a lack of motor response to a stimulating current of 0.5 mA did not affect the success rate. Both these reports suggested that search of muscle twitch in adequately imaged nerves may have a limited role. However, in the later study, adequate images were obtained in only 79% of the patients. In the infraclavicular block of the brachial plexus, only one group consequently reported visualization of the three cords in all their patients (51–53). Others were unable to do so in 8–18% of their patients, depending on the arm position and ultrasonic beam direction (54). Marhofer et al. (55) could not identify the femoral nerve in 15% of patients. The uncertainty of the ultrasonographic findings may be the reason for the concomitant use of electrical stimulation in many clinical studies (22–26, 31, 33, 56–62, 73, 80, 81). Electrical stimulation is also popular for nerve image verification in training of anaesthesia residents (63, 64). Other methods were also used to confirm the ultrasonographic findings. In one older study of continuous brachial plexus, block radiography was used to verify the position of the catheters (65). In another, a ‘fascial click’ was

used to place the cannula inside the axillary sheath and ultrasonography to confirm the correct placement and the spread of injectate (66).

*Summary and comments:* The results of two controlled studies suggested that the concomitant use of nerve stimulation offers no further advantage. However, most clinical studies reported problems with obtaining satisfactory nerve images in some of their patients. Confirmation of images by electrical stimulation was also beneficial for specialist training. Therefore, it is probably still advisable to use a nerve stimulator as a back-up.

### *Ad.2 Direct visualization of anatomical structures*

In several clinical studies, the blood vessels, being the most easily distinguishable structures, were used to determine the end-points for LA injection. The axillary artery was the most common landmark, which was visualized during infraclavicular and axillary approaches to the brachial plexus (39, 56, 67–72). Older studies of infraclavicular approaches used the circumferential spread of LA around the artery as the end-point for injections (67, 68). Spread of injectate posterior, posterolateral or U-shaped posterolateromedial to the artery is considered to be a sufficient predictor of an effective block in newer studies (56, 62, 70–72). In the axillary approach, a full circumferential spread of LA was considered to be necessary for success (69, 73). Sonograms of the femoral vessels were also used to map the position of the femoral nerve on the skin, which was then identified with a nerve stimulator (61).

Few studies used the images of anatomical structures other than vessels to facilitate block performance. In the volunteer study of posterior lumbar plexus block, the images of psoas – , quadratus lumborum – and erector spinae muscles were considered to be the feasible end-points (22). In an ultrasonographically guided paravertebral block for breast surgery, the transverse process and the parietal pleura were used to estimate the depth of needle insertion (74). The space between anterior scalene and the sternocleidomastoid muscles, at the level of carotid bifurcation, was the target for LA injection to block the C2–C4 nerve roots (75) and the space below the Scarpa’s fascia for the dorsal penile nerve block in children (76). The posterior m. rectus abdominis sheath was used by Willschke et al. (77) to guide LA injection for an umbilical hernia repair in small children.

*Summary and comments:* The axillary artery was frequently used as a surrogate target in infraclavicular and axillary approaches to the brachial plexus. LA spread posterior, posterolateral or posterolateromedial to the artery was the indicator of a successful infraclavicular block. In axillary block, a full circumferential LA spread around the artery plus a separate injection of the musculocutaneous nerve were necessary for success. Solitary studies of posterior lumbal plexus, thoracic paravertebral, stellate ganglion blocks in adults, as well as rectus abdominis and penis blocks in children used other landmarks as targets for LA injection.

*Ad.3 Real-time control of needle advancement*

*Block performance time.* The numerical data are presented in Table 1. In a randomized study of a supraclavicular block comparing ultrasound guidance with nerve stimulation, Williams et al. (78) shortened the block performance time almost by half. Similar results were obtained by Schwemmer et al. (79) in a retrospective study of 130 consecutive axillary blocks. Casati et al. (80), in a study of a multiple-injection axillary block, required four-needle passes to block four terminal nerves in the ultrasound group, compared with eight in the nerve stimulator group. Two other RCTs (81, 85) showed statistically significant reductions in time necessary to perform the axillary block. Similar results were obtained by Sites et al. (72), who compared the transarterial approach in axillary block with ultrasound guidance, and by Dingemans et al. (62) in a study of an infraclavicular block. Domingo-Triadó et al. (82) did not shorten the performance time of the sciatic nerve block, but significantly reduced the number of needle passes in the ultrasound group compared with the nerve

stimulator group. Orebaugh et al. (63), in a retrospective analysis of various blocks performed by anaesthesia residents in 124 consecutive patients, showed significant reductions in both the block performance time and the number of needle insertions. In the last two studies (63, 82), a nerve stimulator was used as a back-up to verify the echographic findings, which probably prolonged the procedure time of block in the ultrasound groups.

*Summary and comments:* Ultrasound significantly shortened the block performance time and/or reduced the number of needle passes to reach the target in all comparative studies with other methods.

*Complications*

*Vessel puncture.* Several studies assessed the incidence of accidental vascular punctures. In one older report of axillary block in 10 patients, none had an arterial puncture (66). In a similar report of infraclavicular block in 10 patients, three had an accidental arterial puncture (67). Larger, prospective or retrospective studies of ultrasound-guided peripheral nerve blocks reported accidental vessel punctures or bruising between 0% and 4% of patients (38, 48, 51, 53, 54, 63, 80, 83). However, an initial report of hydrolocalization (ultrasonographic recognition of the needle tip during advancement by repetitive 1 mL injections of LA) reported a 5.5% incidence of vessel punctures during an axillary block (84). Three studies comparing nerve stimulator guidance with either ultrasound alone or backed by a nerve stimulator showed significantly fewer vessel punctures in the ultrasound-guided groups (32, 63, 85). The differences in other studies did not reach statistical

Table 1

Comparative studies assessing block performance time and/or number of needle passes needed to find the target nerve.

Authors	Study type	Block type	Control group	Patient no.	Block performance	P-value
Williams et al. (78)	RCT	SC	Nerve stimulation	80	5.0 vs. 9.8 min	0.0001
Dingemans et al. (62)	RCT	IC	Nerve stimulation	72	5.2 vs. 3.1 min	0.006
Chan et al. (81)	RCT	AX	Nerve stimulation	188	11.2 vs. 9.3 min	<0.01
Liu et al. (85)	RCT	AX	Nerve stimulation	90	8.2 vs. 6.7 min	<0.01
Domingo-Triadó et al. (82)	RCT	Sciatic	Nerve stimulation	61	5.0 vs. 5.0 min	NS
Sites et al. (72)	RCT	AX	Transarterial	56	2 vs. 1 passes	0.001
Schwemmer et al. (79)	Retr.	AX	Nerve stimulation	130	11.1 vs. 7.9 min	<0.05
Orebaugh et al. (63)	Retr.	Varia	Nerve stimulation	124	10.0 vs. 5.0 min	<0.001
					6.5 vs. 1.8 min	<0.001
					6 vs. 2 passes	<0.001
Casati et al. (80)	RCT	AX	Nerve stimulation	60	8 vs. 4 passes	0.002

RCT, randomized-controlled trial; Retr., retrospective; SC, supraclavicular; IC, infraclavicular; AX, axillary; Varia, different peripheral blocks.

significance (55, 80). No permanent sequelae of vessel punctures during ultrasound-guided blocks have been reported as yet.

*Summary and comments:* The data are inconclusive. Three RCTs found a significantly lower frequency of accidental vascular punctures compared with nerve stimulation, and the others two did not.

*Paraesthesia.* Five studies assessed the incidence of paraesthesia. In one randomized study of 40 patients (34), the frequency of unintentional paraesthesia during performance of interscalene and axillary blocks was significantly lower when using ultrasound guidance compared with the landmarks-based method. Needle paraesthesia was experienced by one patient (5%) in the ultrasound group, compared with five patients (25%) in the landmark group. The corresponding figures for pressure paraesthesia during LA injection were nine (45%) and 13 (65%) of patients. In a prospective study of an ultrasound-guided supraclavicular block in 200 patients, 28% experienced paraesthesia during needle advancement and 71.5% during LA injection (48). A randomized study of an axillary block (85) has shown a 10% incidence of paraesthesia in a nerve stimulator-guided group and none in the ultrasound-guided group. In another randomized study of an axillary block on 188 patients (80), post-block paraesthesia lasting <5 days was observed in 13 patients (21%) in both ultrasound- and nerve stimulator-guided blocks. Dingemans et al. (62) recorded paraesthesia after an ultrasound-guided infraclavicular block in one patient out of 36 that lasted 7 days. Only one paper reported nerve damage lasting 2 months after an ultrasound-guided interscalene block for total

shoulder replacement (83). The patient, however, had multiple sclerosis, the plexus was adequately imaged and the post-operative EMG and MRI studies suggested stretch injury. This reviewer did not find any reports of permanent nerve injuries after using ultrasound guidance.

*Summary and comments:* The data are scarce. Ultrasound reduced the incidence of paraesthesia during block performance compared with the landmarks-based method. However, the incidence of paraesthesia and of short-lasting post-operative neuropraxia was similar when compared with the nerve stimulator.

*Pneumothorax.* The author of this review is unaware of any literature reports of pneumothorax after ultrasound-guided blocks. However, recently, there has been a case of a large pneumothorax in our hospital, which was diagnosed 16h after an infraclavicular block. This case report is submitted for publication.

*Ad.4 Assessment of LA spread around the nerves Success rate.* Most randomized studies compared ultrasound guidance with nerve stimulation (Table 2). The ultrasonographic guidance did not significantly increase the surgical effectiveness of a supraclavicular brachial plexus block compared with nerve stimulation (78), but improved the quality of an ulnar nerve block. Block effectiveness was also similar in studies of axillary blocks (80, 85), as well as in the studies of lower extremity blocks in adults (55, 82) and in children (45). However, other researchers reported significantly better success rates in nerve blocks guided either

Table 2

Comparative studies assessing block success rate (anaesthesia sufficient for surgery without supplements).

Authors	Study type	Block type	Control group	Patient no.	Success rates (% of patients vs. controls)	P-value
Williams et al. (78)	RCT	SC	Nerve stimulation	80	85 vs. 78	NS
Dingemans et al. (62)	RCT	IC	Nerve stimulation	72	92 vs. 74	0.049
Soeding et al. (34)	RCT	IS/AX	Landmarks	40	95 vs. 90	NS
Chan et al. (81)	RCT	AX	Nerve stimulation	188	95 vs. 86	0.07
Liu et al. (85)	RCT	AX	Nerve stimulation	90	90 vs. 90	NS
Casati et al. (80)	RCT	AX	Nerve stimulation	60	94 vs. 97	NS
Sites et al. (72)	RCT	AX	Transarterial	56	100 vs. 71	<0.001
Schwemmer et al. (79)	Retr.	AX	Nerve stimulation	130	96 vs. 80	0.014
Willschke et al. (46)	RCT	II+IH	Fascial click	100	96 vs. 74	0.004
Domingo-Triadó et al. (82)	RCT	Sciatic	Nerve stimulation	61	90 vs. 97	NS
Marhofer et al. (55)	RCT	3-in-1	Nerve stimulation	40	95 vs. 85	NS
Oberndorfer et al. (45)	RCT	Sc+Fe	Nerve stimulation	46	100 vs. 91	NS
Orebaugh et al. (63)	Retr.	Varia	Nerve stimulation	124	97 vs. 93	NS

RCT, randomized-controlled trial; Retr., retrospective; SC, supraclavicular; IC, infraclavicular; IS, interscalene; AX, axillary; II+IH, ilioinguinal and iliohypogastric; Sc+Fe, combined sciatic and femoral; Varia, different peripheral blocks.

Table 3

Comparative studies assessing onset time of sensory block, frequency of complete sensory block or sensory scores at pre-determined time intervals.

Authors	Study type	Block type	Control group	Patient no.	Block onset time, frequency of complete block or sensory scores	P-value
Marhofer et al. (55)	RCT	3-in-1	Nerve stimulation	40	16 vs. 27 min	<0.05
Marhofer et al. (86)	RCT	3-in-1	Nerve stimulation	60	13 vs. 27 min	<0.01
Casati et al. (80)	RCT	AX	Nerve stimulation	60	14 vs. 18 min	0.01
Schwemmer et al. (79)	Retr.	AX	Nerve stimulation	130	5 vs. 20 min	<0.01
Marhofer et al. (44)	RCT	IC	Nerve stimulation	40	9 vs. 15 min	<0.001
Dingemans et al. (62)	RCT	IC	Nerve stimulation	72	86% vs. 57%	0.007
Domingo-Triadó et al. (82)	RCT	Sciatic	Nerve stimulation	61	97% vs. 71%	0.01
Soeding et al. (34)	RCT	IS/AX	Landmarks	40	5.3 vs. 6.4–10 min 6.3 vs. 7.3–20 min	0.011

RCT, randomized-controlled trial; Retr., retrospective; IS, interscalene; IC, infraclavicular; AX, axillary.

by ultrasound alone, or in combination with the nerve stimulation (62, 81). In a study of infraclavicular block (62), the differences between the ultrasound group and nerve stimulation groups just reached statistical significance. In a randomized study of axillary block (81), comparing three groups of patients, ultrasound guidance alone or combined with nerve stimulation resulted in significantly better success rates than nerve stimulation.

Schwemmer et al. (79), in a retrospective study of axillary block on 130 consecutive patients, reported a significantly lower failure rate in the ultrasound group compared with the nerve stimulator group. The differences reported by Orebaugh et al. (63) in the analysis of 124 various peripheral blocks performed by residents did not reach statistical significance.

Three randomized studies compared block effectiveness using ultrasound guidance with methods of nerve blocks other than electrical stimulation. Sites et al. (72) reported a high failure rate of the transarterial axillary block and no failures in the ultrasound-guided technique. Success rates in the landmarks-guided interscalene and axillary blocks compared with the ultrasound-guided blocks (34) were not significantly different. In children, Will-schke et al. (46) reported a significantly higher failure rate of the intraoperative analgesia in a 'facial click'-guided ilioinguinal/iliohypogastric nerve block, compared with the ultrasound-guided group.

*Summary and comments:* Block success rates were not significantly different in six out of eight RCTs comparing ultrasound with nerve stimulation. The results of two large retrospective studies are contradictory. Therefore, the potential advantage of higher block effectiveness using an ultrasound compared with a nerve stimulator has not yet been proved.

However, ultrasound is more successful than the anatomical landmarks, transarterial or fascial click methods.

*Block onset.* Onset time was assessed in seven RCTs and one retrospective study (Table 3). In two reports of a three-in-one block, Marhofer et al. (55, 86) found significantly shorter mean block onset times in patients allocated to the ultrasound groups compared with neurostimulator-guided groups. Similarly, Casati et al. (80) found a significantly shorter onset of analgesia in the ultrasound group. Soeding et al. (34) showed significantly higher scores for sensory and motor blocks after 10 and 20 min in the ultrasound group compared with the landmark-based axillary and interscalene blocks. In Dingemans' et al. (62) study of an infraclavicular block, the number of patients with a complete sensory block after 30 min was significantly higher in the ultrasound group than in the nerve stimulator group. A similarly designed study of sciatic nerve block by Domingo-Triadó (82) showed similar results. In children (44), ultrasound guidance resulted in a significantly shorter onset of analgesia after an infraclavicular block, compared with nerve stimulator guidance. In a large retrospective study of axillary blocks in adults, Schwemmer et al. (79) reduced the time from insertion of the blocking needle to the patient's transfer to the operating room from 20 min in the nerve stimulator group to 5 min in the ultrasound group. These results were, however, biased, because the researchers, having observed the spread of LA around the nerves, did not wait for the onset of analgesia in the latter group.

*Summary and comments:* Block onset time was significantly reduced in all RCTs (six comparing an ultrasound with a nerve stimulator and one

with the landmarks-based method). Block duration was longer in children (two RCTs) but not in adults (two RCTs).

*Block duration.* The duration of analgesia after ultrasound or nerve stimulator guidance was compared by three randomized studies. Sensory and motor block durations of the sciatic nerve block in adult patients were similar (82). In children, however (44), ropivacaine-induced analgesia lasted significantly longer after an ultrasound-guided infraclavicular block (median 384 min) than after a nerve-stimulator guided block (median 310 min). In a similar study of sciatic and femoral blocks in older children (45), the corresponding times were 508 min in the ultrasound group and 335 min in the nerve stimulator group ( $P < 0.05$ ) after levobupivacaine injections. This difference was observed despite the significantly lower LA volumes used in the ultrasound-guided blocks. In an RCT, comparing ultrasound with a landmarks-based approach in adult patients (34), the differences were not significant: 11.2 vs. 10.3 h.

*Summary and comments:* Block duration was longer in children, but not in adults.

*LA doses.* Two randomized studies in adults (86, 87) and two in children (45, 46) compared the LA doses for ultrasound-guided blocks with conventional methods. In the older study of a three-in-one block (86), 20 ml of 0.5% bupivacaine injected under ultrasonic guidance resulted in faster onset and better quality of a sensory block than either 20 or 30 ml of the same LA injected under nerve stimulator guidance. However, the overall block success was not significantly different between the three groups. Casati et al. (87) assessed the minimum effective LA volume required to block the femoral nerve with either an ultrasound or a nerve stimulator. Using an up-and-down staircase method, they found that the mean volumes of 0.5% ropivacaine necessary to block the nerve in 95% of patients were 22 ml in the ultrasound group and 41 ml in the nerve stimulator group ( $P = 0.002$ ). In children, the volume of LA used for sciatic and femoral blocks was significantly lower with ultrasound guidance: 0.2 and 0.15 ml/kg, respectively, than with nerve stimulator guidance: 0.3 and 0.3 ml/kg, respectively (45). Similarly, the amount of LA used for ultrasound-guided ilioinguinal/iliohypogastric blocks was significantly lower than in blocks guided by 'fascial-click', 0.19 vs. 0.3 ml/kg b.w. (46). The same authors used the

up-and-down staircase method to determine the minimum effective volume of 0.25% levobupivacaine for an ultrasound-guided iliohypogastric/ilioinguinal nerve block in children (88). They found that 0.075 ml/kg b.w. is sufficient, which was less than half of the dose used in the previous study (46). Also, case series in adult patients confirmed the feasibility of low-dose LA for ultrasonographically guided infraclavicular blocks. In eight patients, Sandhu et al. (89) performed bilateral blocks using 20 ml of 2% lignocaine on each side and in 14 other patients, the same authors (52) obtained successful blocks using only 14 ml of the same LA.

*Summary and comments:* All four RCTs comparing the LA doses showed that ultrasound allows significant dose reduction compared with other methods. Also, two case series suggested that smaller doses of lignocaine than usually recommended are sufficient for the infraclavicular brachial plexus block.

#### *Ad.5 Avoidance of muscles twitches*

Only four randomized studies of ultrasound-guided blocks assessed block discomfort/patients' satisfaction. Significantly fewer adults in the ultrasound-guided group reported procedure-related pain during an axillary block than in the nerve stimulator group (80). However, patients' acceptance of the block was similar. Concordant results on patients' acceptance were obtained for ultrasound- vs. landmarks-guided axillary and interscalene blocks (34). The intensity of block discomfort on visual analogue scale (VAS) 0–10 was not significantly different in a study of an infraclavicular block: 2.8 for ultrasound and 2.5 for nerve stimulator guidance (62). In a study of an infraclavicular block in children with upper extremity trauma (44), ultrasound guidance resulted in significantly lower block discomfort (VAS) compared with nerve stimulator guidance. None of these studies answered the question as to whether avoidance of muscle twitches in the ultrasound-guided blocks had any effect on procedure-related pain.

*Summary and comments:* One RCT in adults and one in children suggested that ultrasound reduces VAS-measured block discomfort compared with the nerve stimulation. The other two RCTs did not find significant differences. Patient's acceptance of the block was similar in the three studies

on adults. There may be a tendency towards lower block discomfort, but the data are inconclusive.

### Limitations of this review

This expert review is an effort to summarize clinically important data on ultrasound-guided peripheral blocks. However, it has several limitations. The electronic literature search with the proposed terms revealed only one-third of the included studies and the manual search of the related articles and reference lists may have missed some relevant publications. Numerous solitary case reports, cadaver studies, editorial views and letters to editor were excluded despite their potential clinical importance, e.g., infrequent complications. Publications in languages other than English, German, French and Spanish e.g., Taiwanese were only reviewed as abstracts. Also, this review does not include unpublished data and clinical studies not accepted for publication. Therefore, important data may have been missed. The methodological quality of the included studies varied from very good, in double-blinded RCTs with a clear hypothesis and sample size calculation, to descriptions of short case series. Primary endpoints were variable: for instance, block onset time was defined as anaesthesia of two, four or five terminal nerves of the brachial plexus, loss of pin-prick sensation in the sensory distribution of the sciatic nerve, number of patients with a complete sensory block at the pre-determined time intervals, percentage sensory loss measured on VAS and time from block start to making a 'ready for surgery' decision. Most ultrasound-guided blocks were performed or supervised by the experts and the results obtained are therefore not necessarily applicable to all anaesthesiologists. Also, the reviewer did not make any effort to perform a meta-analysis, qualify the results according to the strength of evidence or to the number of patients. Hence, the following comments and conclusions may be biased and should be viewed with caution.

### Conclusions

The literature indicates that in adequately imaged peripheral nerves, ultrasound may replace other methods. However, satisfactory images are difficult to obtain in all patients. Hence, most studies used a nerve stimulator as a back-up. Ultrasound guidance shortens the block performance time, reduces the

number of needle insertions and shortens the block onset time. It also allows reduction of the LA dose. Block effectiveness is not significantly better than when using a nerve stimulator, but ultrasound is probably more effective than other methods on nerve localization. Block duration is prolonged in children, but not in adults. There may be fewer accidental vascular punctures and paraesthesia during ultrasound-guided blocks, but the incidence of short-term post-operative complications like bruising or neuropraxia is similar. Whether avoidance of muscle twitches reduces block discomfort is not sufficiently elucidated. In adult patients, the acceptance of the block procedure is comparable with other methods. Further clinical studies are needed to answer the remaining questions posed in this review and confirm the superiority of ultrasound over other methods of nerve localization.

### Acknowledgements

This work did not receive any financial support from any source. The author would like to thank Ass. Prof. Lars S. Rasmussen MD, PhD, DMSc, and Prof. Jørgen Viby Mogensen, both from Rigshospital, Copenhagen, Denmark, for their valuable comments and critical appraisals of this review.

### References

1. Thompson GE. The Labat lecture 1997. From Pauchet to today. The French connection. *Reg Anesth Pain Med* 1998; **23**: 126–33.
2. Benumoff JL. Permanent loss of cervical spinal cord function after interscalene block performed under general anesthesia. *Anesthesiology* 2000; **93**: 1541–4.
3. Sala Blanch X, Pomés J, Matute P et al. Intra-neural injection during anterior approach for sciatic nerve block. *Anesthesiology* 2004; **101**: 1027–30.
4. Auroy Y, Benhamou D, Bagues L et al. Major complications of regional anesthesia in France: the SOS Regional Anesthesia Hotline Service. *Anesthesiology* 2002; **97**: 1274–80.
5. Plunkett AR, Brown DS, Rodgers JM et al. Supraclavicular continuous peripheral nerve block in a wounded soldier: when ultrasound is the only option. *Br J Anaesth* 2006; **97**: 715–7.
6. Assmann N, McCartney CJL, Tumber PS et al. Ultrasound guidance for brachial plexus localization and catheter insertion after complete forearm amputation. *Reg Anesth Pain Med* 2007; **32**: 93.
7. Van Geffen JG, Tielen L, Gielen M. Ultrasound-guided interscalene brachial plexus block in child with femur fibula ulna syndrome. *Paediatr Anaesth* 2006; **16**: 330–2.
8. Sites BD, Gallagher J, Sparks M. Ultrasound-guided popliteal block demonstrates an atypical motor response to nerve stimulation in 2 patients with Diabetes Mellitus. *Reg Anesth Pain Med* 2003; **28**: 479–82.
9. Koscielniak-Nielsen ZJ, Rotbøll-Nielsen P, Rasmussen H. Patients' experiences with multiple stimulation axillary block for fast-track ambulatory hand surgery. *Acta Anaesthesiol Scand* 2002; **46**: 789–93.

10. Selander D, Edshage S, Wolff T. Paresthesiae or no paresthesiae? Nerve lesions after axillary blocks. *Acta Anaesthesiol Scand* 1979; **3**: 27–33.
11. Perlas A, Niazi A, McCartney C et al. The sensitivity of motor response to nerve stimulation and paresthesia for nerve localization as evaluated by ultrasound. *Reg Anesth Pain Med* 2006; **31**: 445–50.
12. Marhofer P, Greher M, Kapral S. Ultrasound guidance in regional anaesthesia. *Br J Anaesth* 2005; **94**: 7–17.
13. Eisenberg E, Carr DB, Chalmers TC. Neurolytic coeliac plexus block for treatment of cancer pain: a meta-analysis. *Anesth Analg* 1995; **80**: 290–5.
14. Iskandar H, Wakim N, Benard A et al. The effect of interscalene brachial plexus block on humeral blood flow: a Doppler ultrasound study. *Anesth Analg* 2005; **101**: 279–81.
15. Shemesh D, Olsha O, Orkin D et al. Sympathectomy-like effects of brachial plexus block in arteriovenous access surgery. *Ultrasound Med Biol* 2006; **32**: 817–22.
16. Cornish PB, Leaper CJ, Nelson G et al. Avoidance of phrenic nerve paresis during continuous supraclavicular regional anaesthesia. *Anaesthesia* 2007; **62**: 354–8.
17. Fornage BD. Peripheral nerves of the extremity: imaging with ultrasound. *Radiology* 1988; **167**: 179–82.
18. Graif M, Seton A, Nerubai J et al. Sciatic nerve: sonographic evaluation and anatomic-pathologic considerations. *Radiology* 1991; **181**: 405–8.
19. Greher M, Retzl G, Niel P et al. Ultrasonographic assessment of topographic anatomy suggests a modification of the infraclavicular vertical brachial plexus block. *Br J Anaesth* 2002; **88**: 632–6.
20. Retzl G, Kapral S, Greher M et al. Ultrasonographic findings of the axillary part of the brachial plexus. *Anesth Analg* 2001; **92**: 1271–5.
21. Schwemmer U, Marcus CK, Greim CA et al. Sonographic imaging of the sciatic nerve in the popliteal fossa. *Ultraschall Med* 2005; **26**: 496–500.
22. Kirchmair L, Entner T, Wissel J et al. A study of the paravertebral anatomy for ultrasound-guided posterior lumbar plexus block. *Anesth Analg* 2001; **93**: 477–81.
23. Perlas A, Chan VW, Simons M. Brachial plexus examination and localization using ultrasound and electrical stimulation: a volunteer study. *Anesthesiology* 2003; **99**: 429–35.
24. Wang FY, Wu SH, Lu IC et al. Ultrasonographic examination to search out the optimal upper arm position for coracoid approach to infraclavicular brachial plexus block – a volunteer study. *Acta Anaesthesiol Taiwan* 2007; **45**: 15–20.
25. Chan VWS, Nova H, Abbas S et al. Ultrasound examination and localization of the sciatic nerve. A volunteer study. *Anesthesiology* 2006; **104**: 309–14.
26. Soong J, Schaffhalter-Zoppoth I, Gray AT. Sonographic imaging of the obturator nerve for regional block. *Reg Anesth Pain Med* 2007; **32**: 146–51.
27. Lundblad M, Kapral S, Marhofer P et al. Ultrasound-guided infrapatellar nerve block in human volunteers: description of a novel technique. *Br J Anaesth* 2006; **97**: 710–4.
28. Roessel T, Wiessner D, Heller AR et al. High-resolution ultrasound-guided high interscalene plexus block for carotid endarterectomy. *Reg Anesth Pain Med* 2007; **32**: 247–53.
29. Schwemmer U, Papenfuss T, Greim C et al. Ultrasound-guided interscalene brachial plexus anaesthesia: differences in success rates between patients of normal and excessive weight. *Ultraschall Med* 2006; **27**: 245–50.
30. Sinha SK, Abrams JA, Weller RS. Ultrasound-guided interscalene needle placement produces successful anesthesia regardless of motor stimulation above or below 0.5 mA. *Anesth Analg* 2007; **105**: 848–52.
31. Van Geffen GJ, Rettig HC, Koornwinder T et al. Ultrasound-guided training in the performance of brachial plexus block by the posterior approach: an observational study. *Anaesthesia* 2007; **62**: 1024–8.
32. Kapral S, Krafft P, Gosch M et al. Ultrasound imaging for stellate ganglion block: direct visualization of puncture site and local anesthetic spread. *Reg Anesth* 1995; **20**: 323–8.
33. Kapral S, Krafft P, Eibenberger K et al. Ultrasound-guided supraclavicular approach for regional anesthesia of the brachial plexus. *Anesth Analg* 1994; **78**: 507–13.
34. Soeding PF, Sha S, Royse CF et al. A randomized trial of ultrasound-guided brachial plexus anaesthesia in upper limb surgery. *Anaesth Intensive Care* 2005; **33**: 719–25.
35. Blaiwas M, Lyon M. Ultrasound-guided interscalene block for shoulder dislocation reduction in the ED. *AJEM Am J Emergency Med* 2006; **24**: 293–6.
36. Stone MB, Price DD, Wang R. Ultrasound-guided supraclavicular block for the treatment of upper extremity fractures, dislocations and abscesses in the ED. *AJEM Am J Emergency Med* 2007; **25**: 472–5.
37. Schwemmer U, Markus CK, Greim C et al. Ultrasound-guided anaesthesia of the axillary brachial plexus: Efficacy multiple injection approach. *Ultraschall Med* 2005; **26**: 114–9.
38. Kefalianakis F, Spohner F. Ultraschallgestützte Blockade des axillären Plexus brachialis in der Handchirurgie. *Handchir Mikrochir Plast Chir* 2005; **37**: 344–8.
39. Su HH, Lui PW, Yu CL et al. The effects of continuous axillary brachial plexus block with ropivacaine infusion on skin temperature and survival of crushed fingers after microsurgical replantation. *Chang Gung Med J* 2005; **28**: 567–74.
40. Spence BC, Sites BD, Beach ML. Ultrasound-guided musculocutaneous nerve block: A description of a novel technique. *Reg Anesth Pain Med* 2005; **30**: 198–201.
41. Gray AT, Schaffhalter-Zoppoth I. Ultrasound guidance for ulnar nerve block. *Reg Anesth Pain Med* 2003; **28**: 335–9.
42. Liebmann O, Price D, Mills C et al. Feasibility of forearm ultrasonography-guided nerve blocks of the radial, ulnar and median nerves for hand procedures in the emergency department. *Ann Emerg Med* 2006; **48**: 558–62.
43. Hurdle MF, Weingarten TN, Crisostomo RA et al. Ultrasound-guided blockade of the lateral femoral cutaneous nerve: technical description and review of 10 cases. *Arch Phys Med Rehab* 2007; **88**: 1362–4.
44. Marhofer P, Sitzwohl C, Greher M et al. Ultrasound guidance for infraclavicular brachial plexus anaesthesia in children. *Anaesthesia* 2004; **59**: 642–6.
45. Oberndorfer U, Marhofer P, Bosenberg A et al. Ultrasonographic guidance for sciatic and femoral blocks in children. *Br J Anaesth* 2007; **98**: 797–801.
46. Willschke H, Marhofer P, Bosenberg A et al. Ultrasonography for Ilioinguinal/iliohypogastric nerve blocks in children. *Br J Anaesth* 2005; **95**: 226–30.
47. Willschke H, Bosenberg A, Marhofer P et al. Ultrasonographic-guided Ilioinguinal/iliohypogastric nerve block in pediatric anesthesia: what is the optimal volume? *Anesth Analg* 2006; **102**: 1680–4.
48. Sáinz López J, Prat Vallribera A, Seguí Pericas M et al. Bloqueo supraclavicular del plexo braquial con bajos volúmenes de anestésico y dirigido por ecografía. Descripción

- de la técnica y análisis de resultados. *Rev Esp Anesthesiol Reanim* 2006; **53**: 400–7.
49. Swenson JD, Bay N, Loose E et al. Outpatient management of continuous peripheral nerve catheters placed using ultrasound guidance: an experience in 620 patients. *Anesth Analg* 2006; **103**: 1436–43.
  50. Beach ML, Sites BD, Gallagher JD. Use of a nerve stimulator does not improve the efficacy of ultrasound-guided supraclavicular nerve blocks. *J Clin Anesth* 2006; **18**: 580–4.
  51. Sandhu NS, Capan LM. Ultrasound-guided infraclavicular brachial plexus block. *Br J Anaesth* 2002; **89**: 254–9.
  52. Sandhu NS, Bahival CS, Capan LM. Feasibility of infraclavicular block with a reduced volume of lidocaine with sonographic guidance. *J Ultrasound Med* 2006; **25**: 51–6.
  53. Sandhu NS, Manne JS, Medabalmi PK et al. Sonographically guided infraclavicular brachial plexus block in adults. A retrospective analysis of 1146 cases. *J Ultrasound Med* 2006; **25**: 1555–61.
  54. Bigeleisen P, Wilson M. A comparison of two techniques for ultrasound guided infraclavicular block. *Br J Anaesth* 2006; **96**: 502–7.
  55. Marhofer P, Schrögendorfer K, Koining H et al. Ultrasonographic guidance improves sensory block and onset time of three-in-one blocks. *Anesth Analg* 1997; **85**: 854–7.
  56. Bloc S, Garnier T, Komly B et al. Bloc infraclaviculaire sous contrôle échographique: une étude préliminaire de faisabilité. *Ann Fr Anesth Reanim* 2007; **26**: 627–32.
  57. Helayel PE, da Conceição DB, Pavei P et al. Ultrasound-guided obturator nerve block: a preliminary report of a case series. *Reg Anesth Pain Med* 2007; **32**: 221–6.
  58. Arcand G, Williams SR, Chouinard P et al. Ultrasound-guided infraclavicular versus supraclavicular block. *Anesth Analg* 2005; **101**: 886–90.
  59. Spence BC, Sites BD, Beach ML. Ultrasound-guided musculocutaneous nerve block: a description of novel technique. *Reg Anesth Pain Med* 2005; **30**: 198–201.
  60. Sinha A, Chan VWS. Ultrasound imaging for popliteal sciatic nerve block. *Reg Anesth Pain Med* 2004; **29**: 130–4.
  61. Sites BD, Beach M, Gallagher JD et al. A single injection ultrasound assisted femoral nerve block provides side effect-sparing analgesia when compared with intrathecal morphine in patients undergoing total knee arthroplasty. *Anesth Analg* 2004; **99**: 1539–43.
  62. Dingemans E, Williams SR, Arcand G et al. Neurostimulation in ultrasound-guided infraclavicular block: a prospective randomized trial. *Anesth Analg* 2007; **104**: 1275–80.
  63. Orebaugh SL, Williams BA, Kentor ML. Ultrasound guidance with nerve stimulation reduces the time necessary for resident peripheral nerve blockade. *Reg Anesth Pain Med* 2007; **32**: 448–54.
  64. Van Geffen GJ, Rettig HC, Koornwinder T et al. Ultrasound-guided training in the performance of brachial plexus block by the posterior approach: an observational study. *Anaesthesia* 2007; **62**: 1024–8.
  65. Yang WT, Chui PT, Metreweli C. Anatomy of the normal brachial plexus revealed by sonography and the role of sonographic guidance in anesthesia of the brachial plexus. *AJR Am J Roentgenol* 1998; **171**: 1631–6.
  66. Ting PL, Sivagnanaratnam V. Ultrasonographic study of the spread of local anaesthetic during axillary brachial plexus block. *Br J Anaesth* 1989; **63**: 326–9.
  67. Wu TJ, Lin SY, Liu CC et al. Ultrasound imaging aids infraclavicular brachial plexus block. *Ma Zui Xue Za Zhi* 1993; **31**: 83–6.
  68. 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.
  69. Liu FC, Lee LI, Liou JT et al. Ultrasound-guided axillary brachial plexus block in patients with chronic renal failure: a report of sixteen cases. *Chang Gung Med J* 2005; **28**: 180–5.
  70. Porter JM, McCartney CJL, Chan VWS. Needle placement and injection posterior to the axillary artery may predict successful infraclavicular brachial plexus block: a report of three cases. *Can J Anaesth* 2005; **52**: 69–73.
  71. Slater M-E, Williams SR, Harris P et al. Preliminary evaluation of infraclavicular catheters inserted using ultrasound guidance: through-the-catheter anesthesia is not inferior to through-the-needle blocks. *Reg Anesth Pain Med* 2007; **32**: 296–302.
  72. Sites BD, Beach ML, Spence BC et al. Ultrasound guidance improves the success rate of a perivascular axillary block. *Acta Anaesthesiol Scand* 2006; **50**: 678–84.
  73. Bloc S, Garnier T, Komly B et al. Spread of injectate associated with radial or median nerve-type response during infraclavicular brachial plexus block: an ultrasound evaluation. *Reg Anesth Pain Med* 2007; **32**: 130–5.
  74. Pusch F, Wildling E, Klimscha W et al. Sonographic measurement of needle insertion depth in paravertebral blocks in women. *Br J Anaesth* 2000; **85**: 841–3.
  75. Kefalianakis F, Koeppl T, Geldner G et al. Ultraschallgestützte Blockade der Regio colli lateralis zur Karotis-Chirurgie-eine Fallserie. *Anaesthesiol Intensivmed Notfallmed Schmerzther* 2005; **40**: 576–81.
  76. Sandeman DJ, Dilley AV. Ultrasound guided dorsal penile nerve block in children. *Anaesth Intensive Care* 2007; **35**: 266–9.
  77. Willschke H, Bosenberg A, Marhofer P et al. Ultrasonography-guided rectus sheath block in paediatric anaesthesia – a new approach to an old technique. *Br J Anaesth* 2006; **97**: 244–9.
  78. Williams SR, Chouinard P, Arcand G et al. Ultrasound-guidance speeds execution and improves the quality of supraclavicular block. *Anesth Analg* 2003; **97**: 1518–23.
  79. Schwemmer U et al. Prozessmanagement bei axillären Plexusblockade: Vergleich von Ultraschall und Nervenstimulation. *Anaesthesist* 2006; **55**: 451–6.
  80. 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.
  81. Chan VWS, Perlas A, McCartney CJL et al. Ultrasound guidance improves success rate of axillary brachial plexus block. *Can J Anaesth* 2007; **54**: 176–82.
  82. Domingo-Triadó V, Selfa S, Martinez F et al. Ultrasound guidance for lateral midfemoral sciatic nerve block: a prospective, comparative, randomized study. *Anesth Analg* 2007; **104**: 1270–4.
  83. Sites B, Spence BC, Gallagher JD et al. Characterizing novice behaviours associated with learning ultrasound-guided peripheral regional anesthesia. *Reg Anesth Pain Med* 2007; **32**: 107–15.
  84. Garnier T, Bloc S, Mercadal L et al. Hydrolocalization during ultrasound guided regional anesthesia. *Anesthesiology* 2007; **107**: A639.
  85. Liu FC, Liou JT, Tsai YF et al. Efficacy of ultrasound-guided axillary brachial plexus block: a comparative study with a nerve stimulator-guided method. *Chang Gung Med J* 2005; **28**: 396–402.

86. Marhofer P, Schrögenderfer K, Wallner T et al. Ultrasonographic guidance reduces the amount of local anaesthetic for 3-in-1 blocks. *Reg Anest Pain Med* 1998; **23**: 584–8.
87. Casati A, Baciarello M, Di Cianni S et al. Effect of ultrasound guidance on the minimum effective anaesthetic volume required to block the femoral nerve. *Br J Anaesth* 2007; **98**: 823–7.
88. Willschke H, Bosenberg A, Marhofer P et al. Ultrasonographic-guided Iliioinguinal/iliohypogastric nerve block in pediatric anesthesia: what is the optimal volume? *Anesth Analg* 2006; **102**: 1680–4.
89. Sandhu NS, Maharlouei B, Patel B et al. Simultaneous bilateral infraclavicular brachial plexus block with low-dose lidocaine using ultrasound guidance. *Anesthesiology* 2006; **104**: 199–201.
90. Bigeleisen P. Nerve puncture and apparent intraneural injection during ultrasound guided axillary block does not invariably result in neurologic injury. *Anesthesiology* 2006; **105**: 779–83.

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