

We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

3,900

Open access books available

116,000

International authors and editors

120M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com



Ultrasound-Guided Peripheral Nerve Block Anesthesia with Emphasis on the Interscalene Approach to Brachial Plexus Blockade

James C. Krakowski and Steven L. Orebaugh

Additional information is available at the end of the chapter

<http://dx.doi.org/10.5772/56645>

1. Introduction

Epidemiologic data has revealed a progressive rise in the aggregate number of patient surgical visits with an increasing number occurring within the ambulatory setting [1]. Accompanying this rise has been a growing need for adequate, efficient patient anesthesia and analgesia [2]. With a significant proportion of procedures involving focal orthopedic interventions of the knee and shoulder, peripheral nerve blockade has become an increasing trend in anesthetic practice while neuraxial blockade use has decreased [2]. The popularity of peripheral nerve blockade may stem from its demonstrated effectiveness with studies showing improved analgesia and recovery during the postoperative period versus opioids [3] or general anesthetic [4]. In this chapter, we will review ultrasonography and its application to a commonly employed peripheral nerve block, namely, the interscalene block.

2. Ultrasound guidance for peripheral nerve blockade

2.1. A brief history

The first published account of ultrasound use with peripheral nerve blockade occurred in 1978 when Doppler sonography assisted blood flow detection during supraclavicular brachial plexus block [5]. Although the initial technology did not allow for direct nerve visualization, this was later rectified in 1994, when advancements in technology allowed the first documented use of ultrasound to visually facilitate supraclavicular brachial plexus block [5]. Since this time, ultrasound use for regional anesthesia has shown increasing popularity, and ultrasound

technology has mirrored practitioner demand with machines possessing greater portability, simplicity, and image resolution [5]. Literature regarding the utility of ultrasound for a variety of peripheral nerve blocks continues to emerge.

2.2. Advantages

The rising popularity of ultrasound guidance for peripheral nerve blockade (PNB) stems from numerous described advantages supporting its use [6], [7], [5]. Perhaps the principal benefit of ultrasound resides in the technology's inherent ability to directly visualize peripheral nerves and tissue planes in real-time, allowing for optimal injectate or catheter placement with the ultimate goal of optimizing neural blockade [7]. Today's ultrasound machines are equipped with high-frequency probes capable of imaging the majority of nerves necessary for a wide array of regional blocks, and also their oblique course as they traverse the body [7]. This imaging modality permits the identification of relatively diminutive 2 mm diameter digital nerves [7], as well as differentiation of complex neurovascular nuances as found within the brachial plexus [8]. Additional benefit is conveyed in the ability to reposition one's needle in assessing for adequate local anesthetic spread, fascial plane movement, or lack thereof with intravascular injection [7]. The idea of preemptively scanning patient anatomy for neurovascular variations or abnormalities has been suggested as a means of improving patient safety by preventing block complication [9].

A number of objective evaluations have supported the efficacy of ultrasound guidance during PNB. When compared with performance via peripheral nerve stimulation (PNS), PNB executed using ultrasound guidance has been shown to require less time to perform, possesses more rapid onset and longer duration of anesthesia, and is more likely to be successful (less block failure) [6]. The use of ultrasound rather than PNS has also been shown to decrease the risk of vascular puncture [6], [10], and demonstrate improved quality of sensory block [11]. The use of ultrasonography does not exclude the use of PNS for PNB, and the combination for brachial plexus block was shown to have decreased risk of central nervous system toxicity secondary to local anesthetic versus a PNS-landmark technique [12]. Another study demonstrated high rates of success with axillary brachial plexus block using sonography regardless of concurrent PNS use [13]. Compared with PNS for femoral nerve block, ultrasound guidance also provides a reduction in the minimum effective anesthetic volume (MEAV50) [14], and has allowed reduced dosing for many blocks, with a potential impact on local anesthetic systemic toxicity and therefore patient safety [15]. Lastly, given the steady rise in yearly surgical procedures [1], findings such as decreased time to perform PNB [6], [7] and recent demonstration of cost-effectiveness in clinical practice [5] will likely support the role of ultrasound guidance in regional anesthesia's future.

2.3. Disadvantages

Despite many reported advantages to ultrasound guidance during PNB, several barriers to implementation and training have been described. One such limitation arises from peripheral nerve anatomical variation leading to difficulty in regional pattern recognition [16]. Difficulty to trainees may arise from the necessary knowledge of cross-sectional anatomy, terminology,

appropriate local anesthetic spread, as well as an understanding of novel probe operating mechanics and regular needle tip visualization [7], [17], [18]. As a result, images may appear ambiguous to the novice operator [19], and identifying the intricate neurovascular anatomy of a common PNB structure as the brachial plexus may prove formidable [20]. Inexperience leading to inability to recognize common on-screen artifacts stemming from image processing may also skew interpretation [21]. In contrast to a definitive motor response end-point elicited with nerve stimulator, the optimal pattern of local anesthetic deposition and distribution continues to be investigated [22], [18].

Ultrasonography may also prove challenging as a result of current technological limitations. For example, discriminating neuronal tissue and its epineurium from that of connective tissue or tendons may prove difficult due to the similar hyperechoicity, or echotexture [7], [20]. Furthermore, ultrasound imaging has been shown to underrepresent the total number of neuronal fascicles as compared to light microscopy, and the possibility of intraneural injection (a topic of controversy with respect to morbidity) exists [23], [20].

3. The interscalene brachial plexus block

3.1. Block description

Upper extremity peripheral nerve blocks account for the majority of performed regional anesthesia techniques in most anesthesia practices [24]. Of the upper extremity PNBs, the interscalene block (ISB) is the most commonly applied block for patients undergoing shoulder surgery [25], [26], [8], imparting both anesthesia and analgesia with adequate coverage of the shoulder, lateral arm, and lateral forearm [27]. The ISB was first described in 1970 by Winnie, who noted based on anatomic and radiographic imaging that the interscalene space allowed for a novel, percutaneous approach to anesthetizing the proximal brachial plexus [28]. This approach allowed for brachial plexus anesthesia of similar quality to that of thoracic epidural anesthesia [28]. Compared to the previously described axillary and subclavian approaches prior to this time, the ISB was quickly favored for its ease of execution due to readily palpable landmarks in patients with large body habitus, no requirement for unique upper extremity positioning, and ability to readily repeat the block during protracted surgical procedures [28]. Both single-shot and continuous catheter placement have been successfully performed with ISB via landmark-paresthesia, nerve stimulator, or ultrasound-guided technique [8].

3.2. Anatomy

With the exception of the supraclavicular nerves, the brachial plexus is responsible for all motor and sensory innervation to the shoulder area [8]. The brachial plexus is an intricate neuronal network originating as ventral rami from cervical nerve roots, C5-8, and initial thoracic nerve root, T1 [24]. Together, these roots within the neck further subdivide into trunks, divisions, cords, and, ultimately, peripheral branches traveling distally into the upper arm [29]. After exiting the vertebral column, the roots become trunks as they traverse through the apposition of the anterior and middle scalene muscles, or interscalene groove [24]. Beyond the distal first

rib, the trunks divide into divisions. At the distal clavicle and latter portion of the axillary artery, the divisions combine to form cords, which further subdivide into terminal branches at the level of the humerus [24].

Winnie described three anatomical spaces comprising the fascial sheath-enveloped area, cradling the neurovasculature of the brachial plexus along its course from the proximal, cervical vertebral bodies distally toward the axilla [28]. These regions included the axillary, subclavian, and interscalene spaces [28]. The interscalene space describes the contiguous area enveloped posteriorly by the fascial sheath covering of the middle scalene muscle and anteriorly by that of the anterior scalene fascia [28]. The interscalene space was noted to be continuous with both the axillary and subclavian spaces, thereby allowing appropriate peripheral nerve blockade introduction at this site [28].

In order to provide effective analgesia for shoulder surgery, one must anesthetize the nerves supplying all of the muscle, ligamentous, and osseous tissues of the shoulder joint and surrounding area [8]. Properly performed interscalene blockade provides anesthesia to the superior and middle trunks of the brachial plexus with C5-7 coverage, while also blocking the supraclavicular nerves arising from C3-4 [26]. The C3-4 blockade of the superficial cervical plexus is both fortunate and necessary as this innervation lies outside of the brachial plexus while supplying cutaneous sensation to the rostral shoulder [24].

3.3. Indications

Since its initial description, the interscalene block has been met with widespread acceptance, demonstrating effective [30], [31], [26], [8] and reliable perioperative analgesia for shoulder surgery [27], [26]. The interscalene block is suitable for a wide array of surgical procedures involving the shoulder with coverage including the shoulder joint, proximal humerus, as well as distal clavicle [8].

ISB offers several advantages afforded by regional anesthesia [8]. ISB may be used as an adjuvant to general anesthesia or as solitary anesthetic technique for shoulder surgery [8]. As a primary anesthetic, ISB may thereby reduce the risk of adverse events associated with general anesthesia, including time to ambulation secondary to impaired motor function, postoperative nausea and vomiting, and prolonged length of stay [4]. ISB also allows for a reduction in opioid analgesics and their consequential ill-effects [27], [8]. Additionally, ISB may prove more cost-effective as solitary anesthetic when compared to general anesthesia [8].

Although ISB has proved well-suited for shoulder surgery, it lacks coverage of C8 and T1 distribution, and so it has not been routinely used for surgeries involving the hand or elbow without supplying additional peripheral nerve block technique [30].

3.4. Landmark and nerve stimulator techniques

Prior to the advent of ultrasound imaging guidance, the primary methods for performing brachial plexus blockade included landmark and peripheral nerve stimulator (PNS) techniques [32], [33]. Both methods of nerve localization involve non-visualization of internal

structures, and instead rely on either paresthesias or muscle twitch responses for landmark and PNS, respectively [32]. Originally described by Winnie in 1970, the ISB landmark technique entails localizing the interscalene groove lateral to the cricoid cartilage at approximate C6 level, needle advancement until elicitation of paresthesias along the shoulder and upper arm distribution, and completion with deposition of local anesthetic [28].

After its introduction in performing regional anesthesia, PNS later overcame landmark/paresthesia technique as the method of choice for performing ISB [6], [34]. A common method for performing PNS guidance involves applying a current, ranging from 0.2 to 0.5 mA, at a frequency of 2 Hz while observing for muscle twitch with needle advancement [35]. Specifically, a contraction of the biceps or triceps may be appreciated, corresponding to cervical nerve stimulation at levels C5-6 and C6-8, respectively, at which point local anesthetic is deposited [35]. Of note, PNS may hold limited effectiveness in diabetic patients complicated by neuropathy, as motor response may not be elicited despite application of a standard stimulus [36]. Despite a theoretical advantage in determining needle tip proximity to neuronal tissue with greater precision using PNS as compared to paresthesia elicitation, both techniques have shown similar efficacy for peripheral nerve blockade [24]. In addition, ultrasound studies have revealed that the 0.2 to 0.5 mA range of current has limitations in predicting the accuracy of needle tip placement [37].

3.5. Ultrasonography for interscalene block

In contrast to prior methods of nerve localization, ultrasound guidance provides visualization of the block needle, neurovascular structures and their anatomical course, and the spread of local anesthetic injectate in real-time [38], [7], [5], [24], [39], [8]. Ultrasound guidance has been implemented both with and without concomitant nerve stimulator for the performance of regional anesthesia [10], although no added benefit has been proven with the addition of PNS [24], [40].

Typical sonoanatomy seen while performing the interscalene block has been described. Application of an ultrasound probe in the vicinity of interscalene groove allows for direct visualization of the C5-7 nerve roots exiting their corresponding intervertebral foramina and subsequently passing between the anterior and middle scalene muscles [20]. One may reliably differentiate the seventh cervical nerve root, as the C7 transverse process possesses no anterior tubercle [24]. Elements of the brachial plexus appear characteristically as a cluster of hypoechoic, or comparably dark, bodies on ultrasound imaging, while surrounding fascial layers appear hyperechoic, or comparably white [20]. Of note, numerous variations of the brachial plexus have been characterized, and these subtle deviations may be appreciated with ultrasonography [24].

Reliable brachial plexus blockade via ISB and ultrasonography has been described using a consistent method [38], [41] (Table 1). Patients undergoing ISB should have routine monitoring and supplemental oxygen in place prior to beginning the PNB, with low dose anxiolytic premedication administered when appropriate. Head positioning away from the intended block site may facilitate probe placement (Figure 1). Antiseptic technique including cleansing solution, drape, transducer dressing, gel, and standard practitioner barriers should be

implemented. In order to assist avoidance of initial vascular trauma or injection, the subclavian artery is first visualized in cross-sectional view within the supraclavicular region. Color Doppler mode may assist in identifying additional vasculature surrounding the plexus [9]; [42]. Translation of the transducer probe medially reveals the characteristic hypoechoic cluster of brachial plexus fascicles located between the anterior and middle scalene muscle bellies [38] (Figure 2).



Figure 1. Typical ultrasound probe placement on a patient's neck while performing the interscalene block. Note positioning of the patient's head to the contralateral side of the intended nerve block may facilitate ultrasound probe placement and visualization of brachial plexus anatomy.

Subcutaneous local anesthetic is often administered for patient comfort prior to block needle insertion. Optimally, the entire length of block needle is maintained on-screen during advancement, with particular emphasis on visualizing its tip [7] (Figure 3).

Direct needle tip visualization in relation to neuronal structures allows for repositioning prior to injection while also permitting monitoring of live local anesthetic spread within the interscalene groove [30] (Figure 4). The desired volume of local anesthetic is deposited in 5 cc or less increments following aspiration with each injection [15].

The block needle may be equipped with a PNS for further confirmation of appropriate plexus proximity before deposition of local anesthetic [38]. For example, stimulating with settings of 0.7 to 0.8 mA for 0.1 ms at 2 Hz while approaching the plexus allows for monitoring of desired motor twitch response, which includes contraction of the ipsilateral pectoralis, deltoid, biceps, and triceps muscle groups. These responses indicate adequate proximity to the brachial plexus

1. Apply routine patient monitors and supplemental oxygen
2. Adjust patient bed to comfortable height for block placement
3. Position ultrasound machine with screen readily visible and probe accessible to practitioner
4. Position patient head away from intended block site to facilitate block placement (Figure 1)
5. Provide anxiolytic and/or sedative premedication as necessary
6. Verify patient monitors and vital signs
7. Choose ultrasound probe¹
8. Prepare ultrasound probe in sterile fashion
9. Prepare patient's skin with antiseptic solution
10. Verify block needle is of appropriate type² and primed with selected local anesthetic³
11. Verify patient and procedure
12. Verify probe anatomical orientation on patient matches orientation displayed on ultrasound screen
13. Adjust ultrasound machine depth and gain parameters to enhance displayed image
14. Identify subclavian artery at the supraclavicular area
15. Identify brachial plexus lateral/dorsal to subclavian artery
16. Scan with probe to interscalene groove in order to identify optimal local anesthetic injection site (consider ultrasound Doppler function to scan for vessels at chosen injection site)
17. Warn patient of local anesthetic skin infiltration and provide skin wheel
18. Warn patient of needle insertion and insert block needle
19. Visualize block needle tip prior to advancing to desired position within interscalene groove
20. Instruct assistant to provide negative-pressure syringe aspiration to rule out intravascular needle placement
21. Warn patient of possible discomfort and instruct assistant to inject local anesthetic in small (3 – 5 ml) increments (aspirate prior to injecting each aliquot)
22. Assess local anesthetic spread on ultrasound screen for adequacy and reposition block needle if necessary
23. Remove block needle and clean patient's skin at site of insertion
24. Follow-up block adequacy via patient physical exam assessment

¹Typical ultrasound probe selection for the performance of interscalene block includes a straight, linear array probe due to its higher operating frequencies (5 - 13 MHz), providing increased resolution at the expense of decreased penetration. This probe type facilitates superficial imaging optimal for visualizing the brachial plexus.

²Typical block needle selection may include a 22 gauge, beveled needle 5 cm or greater in length. Greater length may allow for superior ultrasound needle visualization due to its ability to provide a less acute angle of approach and thus increased right-angle ultrasound beam reflection.

³Local anesthetic choice is typically dependent on desired anesthetic duration. For example, 10 – 12 h of shoulder anesthesia may be elicited when 20 cc of ropivacaine 0.75% is administered via ultrasound-guided interscalene blockade.

Table 1. Routine clinical procedure in performance of the single shot, ultrasound-guided interscalene block



Figure 2. Ultrasound view of the interscalene region demonstrating hypoechoic nerve cross sections of the brachial plexus (N), lying between the middle scalene (MS) and anterior scalene (AS) muscle bellies.

prior to local anesthetic delivery, if consistent with appropriate deposition of local anesthetic solution in the interscalene groove as visualized with real-time ultrasound imaging [41].

Physical examination is used to evaluate for brachial plexus block success. Just as Winnie noted maximal anesthetic effect within 15 min of landmark ISB technique [28], physical examination to assess for appropriate motor and sensory block after ultrasound-guided ISB should be conducted after this timeframe. Examination may include the patient's ability to abduct the arm, assessing deltoid function; flex at the elbow, assessing biceps function; as well as discrimination of pain by prick and temperature by alcohol swab of the shoulder and arm surfaces, or C4 and C5, respectively [38], [30], [41].

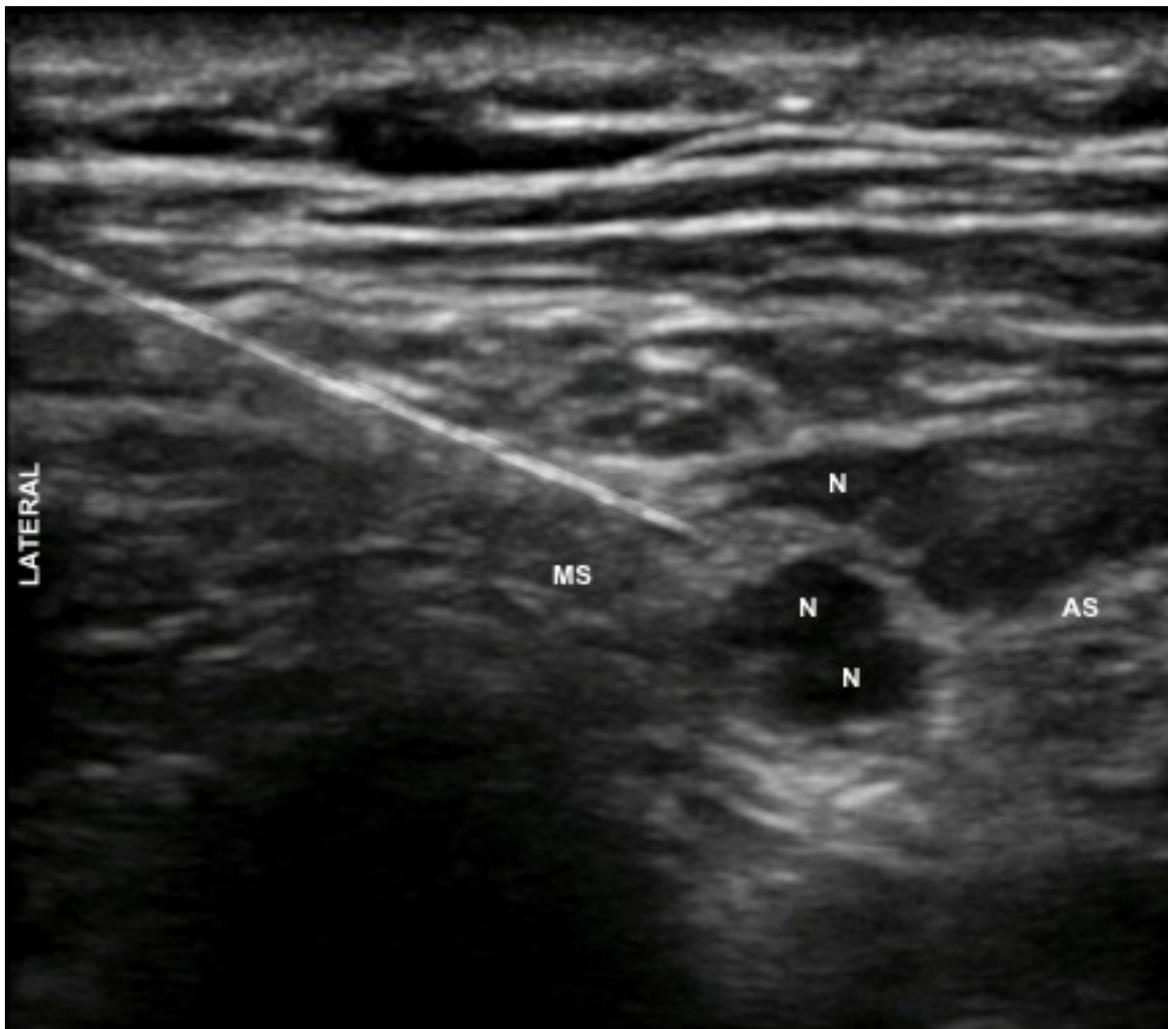


Figure 3. Ultrasound view demonstrating typical lateral approach of a peripheral nerve block needle within the interscalene groove. N: nerve cross sections of the brachial plexus; MS: middle scalene muscle belly; AS: anterior scalene muscle belly.

3.6. Efficacy of ultrasound guidance for interscalene block

The successful implementation of ultrasonography for interscalene block has been well-documented with a variety of studies citing its efficacy [6]. Regarding imaging sensitivity, Muhly et al compared ultrasound imaging with cadaveric dissections of ISB anatomy and found that ultrasound was successfully able to detect vasculature branching as well as its course closely bordering nerves of the brachial plexus [42]. Due to individual variation in the neurovasculature surrounding the brachial plexus, one may appreciate the utility of directly visualizing such discrepancies from typical anatomy that might otherwise remain undetected using prior forms of PNB guidance [42].

Several studies have examined the effect of ultrasound with respect to quality of ISB anesthesia. Kapral et al compared performance of ISB using ultrasound versus peripheral nerve stimulation in a randomized trial, finding a significantly greater motor, sensory, and extent of brachial



Figure 4. Ultrasound view of areas of local anesthetic (LA) volume deposition surrounding the brachial plexus at the level of the interscalene groove. Note the circumferential enhancement of the brachial plexus nerves (N) after local anesthetic deposition. The peripheral block needle is seen here as a hyperechoic linear structure positioned above the brachial plexus.

plexus blockade while using ultrasound [30]. Similarly, a randomized study by Liu et al, examining ultrasound versus nerve stimulator for ISB in randomized patients, revealed increased motor blockade assessed after five minutes as well as a decreased number of needle attempts for the ultrasound group [25]. McNaught et al also noted decreased needle attempts using ultrasound for ISB, while showing a significant decrease in the minimum effective analgesic volume (MEAV) of local anesthetic, and decreased pain 30 min postoperatively when compared to a nerve stimulator group [27]. When examining ultrasound placement versus nerve stimulator placement of ISB catheters in randomized patients, Fredrickson et al demonstrated greater effectiveness in the ultrasound group, requiring less local anesthetic boluses and tramadol use in addition to fewer needle attempts [43]. Additionally, examination of ISB performance among supervised resident trainees at a large academic center has shown a significant decrease in needle attempts, time required for block completion, and incidence of needle perforation of vasculature [44].

3.7. Revelations with ultrasound and interscalene block

Unexpected findings have been revealed when utilizing ultrasound guidance for interscalene block since the technique's initial application. One such revelation includes the cervical level of block performance. Plante et al carried out a study comparing ultrasound-guided ISB performed at the C5 versus C6 anatomical level in randomized patients undergoing shoulder surgery [39]. This study revealed ISB performed at both levels possessing similar efficacy, however the C6 level resulted in significantly greater block success of the distal brachial plexus, including the ulnar, radial, and medial nerves [39].

Needle proximity and neuronal tissue microanatomy with regard to ISB have also been examined. Spence et al sought to determine the ideal location of local anesthetic deposition for ISB [18]. When comparing needle tip and injection superficial to the brachial plexus sheath versus penetration deep to this plexus covering in randomized patients, both positions showed comparable times to block onset, yet the deeper injection resulted in longer mean block duration [18]. In examining ultrasound-guided needle tip placement relative to the nerve roots of the brachial plexus epineurium in the interscalene groove, using india ink staining in a cadaveric study, it was demonstrated that subepineural injection occurred more often than anticipated despite ultrasound guidance [45].

Although the middle scalene muscle itself was largely thought devoid of neuronal structures, the continued use of ultrasound guidance in performance of the interscalene block has indeed proven useful in both identifying and localizing brachial plexus nerves within this area. In conducting an observational study in 50 adult patients receiving ultrasound-guided, posterior approach interscalene block prior to shoulder surgery, Hanson and Auyong identified the dorsal scapular nerve and/or long thoracic nerve in 90% of these patients (verified with peripheral nerve stimulator twitch monitoring). These nerves were found to occur at a depth approximating the C6 nerve root level and less than 1 cm posterior to the larger brachial plexus with the dorsal scapular nerve identified more commonly than the long thoracic nerve (77% versus 23%, respectively) [46]

Local anesthetic volume and concentration necessary for successful ISB have also been studied. Riazi et al compared the use of 5 ml versus 20 ml ropivacaine 0.5% with ultrasound-guided ISB for randomized patients receiving shoulder surgery [26]. The lower volume group was shown to provide equivalent analgesia to the 20 ml group while resulting in a significant decrease in respiratory complications, including diaphragmatic or phrenic nerve paralysis, declines in oxygen saturation, and reduced function on spirometry testing [26]. A later study by Renes et al examined the minimum effective volume (MEV) of ropivacaine 0.75% necessary to provide successful analgesia for elective shoulder surgery when deposited at the C7 level via ultrasonography [31]. This study revealed the MEV to be 2.9 ml and 3.6 ml for 50% and 95% of patients, respectively [31]. Fredrickson et al compared varying ISB bolus ropivacaine concentrations and volumes for preoperative PNB in randomized patients undergoing shoulder surgery and also receiving postoperative 0.2% ropivacaine infusions [47]. The larger volume, 30 ml of 0.5% ropivacaine demonstrated no significant increase in anesthesia duration as compared to 20 ml of

ropivacaine 0.375% [47]. Of note, local anesthetic concentration was shown to be the principle determinant of motor blockade [47].

Goebel et al conducted a randomized trial examining the use of ultrasound-placed ISB catheters in managing postoperative pain for major shoulder surgery [48]. Patient controlled infusions of ropivacaine 0.2% resulted in less concomitant pain medication administration in the first 24 h postoperatively as compared to catheter infusions of normal saline [48].

3.8. Adverse effects with interscalene block

With the performance of interscalene block over the past four decades, notable adverse effects have been established. Perhaps most notable, phrenic nerve (C3-5) paralysis occurs in nearly all patients receiving ISB that may lead to significant decline respiratory function, particularly in patients with underlying pulmonary disease [26], [31]. One ultrasound study found the anatomical separation between the brachial plexus and phrenic nerve lateral to the cricoid cartilage to be as little as 2 mm [49]. Other undesirable effects of regional anesthesia at this site may include blockade of the recurrent laryngeal nerve causing hoarseness, stellate ganglion causing Horner's syndrome, and increased local anesthetic spread rarely causing elements of epidural or spinal quality anesthesia [27]. Inadvertent needle placement during ISB performance may lead to vasculature puncture and direct nerve injury, including reported cases of spinal cord injury [50]. As with other forms of regional anesthesia, systemic local anesthetic toxicity as well as block failure may occur [51]. Failure to anesthetize the distribution of the ulnar nerve is of particular propensity with ISB, as the lower trunk is often spared [24].

3.9. Impact of ultrasound on adverse effects

With the inclusion of ultrasound guidance for interscalene block, several studies have demonstrated an impact on previously reported adverse effects. Renes et al conducted a randomized trial in patients undergoing shoulder surgery, comparing general anesthesia combined with ISB performed with 10 ml ropivacaine deposited via ultrasound versus peripheral nerve stimulator technique [35]. The ultrasound group showed a significantly decreased incidence of diaphragmatic hemiparesis [35]. In addition, the use of ultrasound technique has allowed ISB studies that have revealed decreased incidence of phrenic nerve blockade and respiratory complications based on level of block performance (C7) and reduced volume of local anesthetic [27], [26]. Abrahams et al conducted a systematic review and meta-analysis of randomized trials for a variety of peripheral nerve blocks [6]. When comparing ultrasound guidance versus peripheral nerve stimulation, ultrasound guided blocks were shown to have significantly less risk of vascular puncture [6]. Despite direct visualization when using ultrasound-guidance for PNB, no significant difference in the incidence of neuronal injury or neurologic symptoms postoperatively has been shown [25], [24]. With regard to failure to anesthetize the brachial plexus inferior trunk with ISB, Kapral et al demonstrated improved ulnar nerve and median nerve blockade 30 min post-block when compared to PNS guidance [30].

Perhaps the most important impact of ultrasound guidance during performance of peripheral nerve blockade to date has been related to an increase in patient safety via a decrease in local anesthetic systemic toxicity (LAST). Over a hundred cases of severe toxicity have been described in the medical literature, including some that have resulted in fatality, though the incidence of actual cases are likely much more numerous [15]. Most such cases involve toxicity to the central nervous system, including loss of consciousness, agitation, or, most commonly, seizure. Fifty percent of reported cases showed some evidence of cardiovascular toxicity, for which resuscitation may prove quite challenging [15]. Several studies have recently been published which strongly support the idea that ultrasound imaging has reduced the incidence of serious LAST. Sites, et al, reported over 12,000 cases of ultrasound-guided nerve blocks, with only one case of LAST [52], which compares quite favorably to reports of this complication during the era of nerve stimulator guidance, with rates of 1/1000 to 1/3000. In another large database report from a single site summarizing experience at a single teaching institution, Orebaugh, et al, reported a significant reduction in LAST episodes over a six-year period as the practice transitioned from nerve stimulator to ultrasound guidance—there were no such complications in over 9000 cases in which ultrasound was utilized [53]. Finally, Barrington, et al, reported from a large, multicenter, international database on complications related to peripheral nerve blockade, that the risk of LAST was significantly lowered when ultrasound guidance was utilized (relative risk 0.25-0.31), compared to blocks guided by nerve stimulation alone [54]. These reports have allowed the regional anesthesiologist, using ultrasound guidance, to approach his/her patients with greater certainty, confidence and safety.

4. Conclusions

Peripheral nerve blockade has become an ever-increasing tool in providing analgesia for patients undergoing focal surgical interventions. Advancements in ultrasound guidance for performance of these peripheral nerve blocks have allowed a parallel increase in this technology's utilization. The interscalene approach to brachial plexus blockade is a commonly employed peripheral nerve block that has demonstrated effectiveness in providing perioperative analgesia for patients undergoing shoulder surgery. The use of ultrasound guidance in performing the interscalene block has been shown to be effective in providing postoperative analgesia while decreasing specific respiratory side-effects [26], [27], [35], vascular puncture [6], and local anesthetic toxicity [53] as compared to non-ultrasonographic, blind techniques. These benefits likely stem from the direct visualization of anatomical structures afforded by ultrasound implementation during block performance. Ultrasound guidance for peripheral nerve blockade remains an exciting advancement in caring for patients during the perioperative period, and this technology will likely continue to become commonplace with an increasing patient population and demonstrated effectiveness.

Author details

James C. Krakowski and Steven L. Orebaugh

Department of Anesthesiology, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania, USA

References

- [1] Cullen KA, Hall MJ, Golosinskiy A. Ambulatory surgery in the United States, 2006. *Natl Health Stat Report* 2009 Jan 28;(11)(11):1-25.
- [2] Memtsoudis SG, Kuo C, Ma Y, Edwards A, Mazumdar M, Liguori G. Changes in anesthesia-related factors in ambulatory knee and shoulder surgery: United States 1996-2006. *Reg Anesth Pain Med* 2011 Jul-Aug;36(4):327-331.
- [3] Hadzic A, Arliss J, Kerimoglu B, Karaca PE, Yufa M, Claudio RE, et al. A comparison of infraclavicular nerve block versus general anesthesia for hand and wrist day-case surgeries. *Anesthesiology* 2004 Jul;101(1):127-132.
- [4] Hadzic A, Williams BA, Karaca PE, Hobeika P, Unis G, Dermksian J, et al. For outpatient rotator cuff surgery, nerve block anesthesia provides superior same-day recovery over general anesthesia. *Anesthesiology* 2005 May;102(5):1001-1007.
- [5] Marhofer P, Harrop-Griffiths W, Kettner SC, Kirchmair L. Fifteen years of ultrasound guidance in regional anaesthesia: part 1. *Br J Anaesth* 2010 May;104(5):538-547.
- [6] Abrahams MS, Aziz MF, Fu RF, Horn JL. Ultrasound guidance compared with electrical neurostimulation for peripheral nerve block: a systematic review and meta-analysis of randomized controlled trials. *Br J Anaesth* 2009 Mar;102(3):408-417.
- [7] Gray AT. Ultrasound-guided regional anesthesia: current state of the art. *Anesthesiology* 2006 Feb;104(2):368-73, discussion 5A.
- [8] Sripada R, Bowens C, Jr. Regional anesthesia procedures for shoulder and upper arm surgery upper extremity update--2005 to present. *Int Anesthesiol Clin* 2012 Winter; 50(1):26-47.
- [9] Manickam BP, Perlas A, Chan VW, Brull R. The role of a preprocedure systematic sonographic survey in ultrasound-guided regional anesthesia. *Reg Anesth Pain Med* 2008 Nov-Dec;33(6):566-570.
- [10] Barrington MJ, Watts SA, Gledhill SR, Thomas RD, Said SA, Snyder GL, et al. Preliminary results of the Australasian Regional Anaesthesia Collaboration: a prospective audit of more than 7000 peripheral nerve and plexus blocks for neurologic and other complications. *Reg Anesth Pain Med* 2009 Nov-Dec;34(6):534-541.

- [11] Marhofer P, Schrogendorfer K, Koinig H, Kapral S, Weinstabl C, Mayer N. Ultrasonographic guidance improves sensory block and onset time of three-in-one blocks. *Anesth Analg* 1997 Oct;85(4):854-857.
- [12] Orebaugh SL, Williams BA, Vallejo M, Kentor ML. Adverse outcomes associated with stimulator-based peripheral nerve blocks with versus without ultrasound visualization. *Reg Anesth Pain Med* 2009 May-Jun;34(3):251-255.
- [13] Swenson JD, Bay N, Loose E, Bankhead B, Davis J, Beals TC, et al. Outpatient management of continuous peripheral nerve catheters placed using ultrasound guidance: an experience in 620 patients. *Anesth Analg* 2006 Dec;103(6):1436-1443.
- [14] Casati A, Baciarello M, Di Cianni S, Danelli G, De Marco G, Leone S, et al. Effects of ultrasound guidance on the minimum effective anaesthetic volume required to block the femoral nerve. *Br J Anaesth* 2007 Jun;98(6):823-827.
- [15] Neal JM, Bernardis CM, Butterworth JF, 4th, Di Gregorio G, Drasner K, Hejtmanek MR, et al. ASRA practice advisory on local anesthetic systemic toxicity. *Reg Anesth Pain Med* 2010 Mar-Apr;35(2):152-161.
- [16] Orebaugh SL, Pennington S. Variant location of the musculocutaneous nerve during axillary nerve block. *J Clin Anesth* 2006 Nov;18(7):541-544.
- [17] Sites BD, Spence BC, Gallagher JD, Wiley CW, Bertrand ML, Blike GT. Characterizing novice behavior associated with learning ultrasound-guided peripheral regional anesthesia. *Reg Anesth Pain Med* 2007 Mar-Apr;32(2):107-115.
- [18] Spence BC, Beach ML, Gallagher JD, Sites BD. Ultrasound-guided interscalene blocks: understanding where to inject the local anaesthetic. *Anaesthesia* 2011 Jun;66(6):509-514.
- [19] Sites BD, Beach ML, Spence BC, Wiley CW, Shiffrin J, Hartman GS, et al. Ultrasound guidance improves the success rate of a perivascular axillary plexus block. *Acta Anaesthesiol Scand* 2006 Jul;50(6):678-684.
- [20] Van Geffen GJ, Moayeri N, Bruhn J, Scheffer GJ, Chan VW, Groen GJ. Correlation between ultrasound imaging, cross-sectional anatomy, and histology of the brachial plexus: a review. *Reg Anesth Pain Med* 2009 Sep-Oct;34(5):490-497.
- [21] Antonakakis JG, Sites B. The 5 most common ultrasound artifacts encountered during ultrasound-guided regional anesthesia. *Int Anesthesiol Clin* 2011 Fall;49(4):52-66.
- [22] Brull R, Macfarlane AJ, Parrington SJ, Koshkin A, Chan VW. Is circumferential injection advantageous for ultrasound-guided popliteal sciatic nerve block?: A proof-of-concept study. *Reg Anesth Pain Med* 2011 May-Jun;36(3):266-270.
- [23] Silvestri E, Martinoli C, Derchi LE, Bertolotto M, Chiaramondia M, Rosenberg I. Echotexture of peripheral nerves: correlation between US and histologic findings and criteria to differentiate tendons. *Radiology* 1995 Oct;197(1):291-296.

- [24] Neal JM, Gerancher JC, Hebl JR, Ilfeld BM, McCartney CJ, Franco CD, et al. Upper extremity regional anesthesia: essentials of our current understanding, 2008. *Reg Anesth Pain Med* 2009 Mar-Apr;34(2):134-170.
- [25] Liu SS, Zayas VM, Gordon MA, Beathe JC, Maalouf DB, Paroli L, et al. A prospective, randomized, controlled trial comparing ultrasound versus nerve stimulator guidance for interscalene block for ambulatory shoulder surgery for postoperative neurological symptoms. *Anesth Analg* 2009 Jul;109(1):265-271.
- [26] Riazi S, Carmichael N, Awad I, Holtby RM, McCartney CJ. Effect of local anaesthetic volume (20 vs 5 ml) on the efficacy and respiratory consequences of ultrasound-guided interscalene brachial plexus block. *Br J Anaesth* 2008 Oct;101(4):549-556.
- [27] McNaught A, Shastri U, Carmichael N, Awad IT, Columb M, Cheung J, et al. Ultrasound reduces the minimum effective local anaesthetic volume compared with peripheral nerve stimulation for interscalene block. *Br J Anaesth* 2011 Jan;106(1):124-130.
- [28] Winnie AP. Interscalene brachial plexus block. *Anesth Analg* 1970 May-Jun;49(3):455-476.
- [29] 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 Dec;171(6):1631-1636.
- [30] Kapral S, Greher M, Huber G, Willschke H, Kettner S, Kdolsky R, et al. Ultrasonographic guidance improves the success rate of interscalene brachial plexus blockade. *Reg Anesth Pain Med* 2008 May-Jun;33(3):253-258.
- [31] Renes SH, van Geffen GJ, Rettig HC, Gielen MJ, Scheffer GJ. Minimum effective volume of local anesthetic for shoulder analgesia by ultrasound-guided block at root C7 with assessment of pulmonary function. *Reg Anesth Pain Med* 2010 Nov-Dec;35(6):529-534.
- [32] Chan VW, Perlas A, Rawson R, Odukoya O. Ultrasound-guided supraclavicular brachial plexus block. *Anesth Analg* 2003 Nov;97(5):1514-1517.
- [33] Perlas A, Chan VW, Simons M. Brachial plexus examination and localization using ultrasound and electrical stimulation: a volunteer study. *Anesthesiology* 2003 Aug;99(2):429-435.
- [34] Tsui B, Hadzic A. Peripheral nerve stimulators and electrophysiology of nerve stimulation. In: Hadzic A, editor. *Textbook of Regional Anesthesia and Acute Pain Management* New York: McGraw-Hill; 2007. p. 93-104.
- [35] Renes SH, Rettig HC, Gielen MJ, Wilder-Smith OH, van Geffen GJ. Ultrasound-guided low-dose interscalene brachial plexus block reduces the incidence of hemidiaphragmatic paresis. *Reg Anesth Pain Med* 2009 Sep-Oct;34(5):498-502.
- [36] Byrne K, Tsui BC. Practical concepts in nerve stimulation: impedance and other recent advances. *Int Anesthesiol Clin* 2011 Fall;49(4):81-90.

- [37] Bigeleisen PE, Moayeri N, Groen GJ. Extraneural versus intraneural stimulation thresholds during ultrasound-guided supraclavicular block. *Anesthesiology* 2009 Jun; 110(6):1235-1243.
- [38] Chan VW. Applying ultrasound imaging to interscalene brachial plexus block. *Reg Anesth Pain Med* 2003 Jul-Aug;28(4):340-343.
- [39] Plante T, Rontes O, Bloc S, Delbos A. Spread of local anesthetic during an ultrasound-guided interscalene block: does the injection site influence diffusion? *Acta Anaesthesiol Scand* 2011 Jul;55(6):664-669.
- [40] Sites BD, Beach ML, Chinn CD, Redborg KE, Gallagher JD. A comparison of sensory and motor loss after a femoral nerve block conducted with ultrasound versus ultrasound and nerve stimulation. *Reg Anesth Pain Med* 2009 Sep-Oct;34(5):508-513.
- [41] Orebaugh SL, Williams BA, Kentor ML, Bolland MA, Mosier SK, Nowak TP. Interscalene block using ultrasound guidance: impact of experience on resident performance. *Acta Anaesthesiol Scand* 2009 Nov;53(10):1268-1274.
- [42] Muhly WT, Orebaugh SL. Sonoanatomy of the vasculature at the supraclavicular and interscalene regions relevant for brachial plexus block. *Acta Anaesthesiol Scand* 2011 Nov;55(10):1247-1253.
- [43] Fredrickson MJ, Ball CM, Dalgleish AJ. A prospective randomized comparison of ultrasound guidance versus neurostimulation for interscalene catheter placement. *Reg Anesth Pain Med* 2009 Nov-Dec;34(6):590-594.
- [44] 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 Sep-Oct;32(5):448-454.
- [45] Orebaugh SL, McFadden K, Skorupan H, Bigeleisen PE. Subepineurial injection in ultrasound-guided interscalene needle tip placement. *Reg Anesth Pain Med* 2010 Sep-Oct;35(5):450-454.
- [46] Hanson NA, Auyong DB. Systematic ultrasound identification of the dorsal scapular and long thoracic nerves during interscalene block. *Reg Anesth Pain Med*. 2013 Jan-Feb;38(1):54-7.
- [47] Fredrickson MJ, Smith KR, Wong AC. Importance of volume and concentration for ropivacaine interscalene block in preventing recovery room pain and minimizing motor block after shoulder surgery. *Anesthesiology* 2010 Jun;112(6):1374-1381.
- [48] Goebel S, Stehle J, Schwemmer U, Reppenhagen S, Rath B, Gohlke F. Interscalene brachial plexus block for open-shoulder surgery: a randomized, double-blind, placebo-controlled trial between single-shot anesthesia and patient-controlled catheter system. *Arch Orthop Trauma Surg* 2010 Apr;130(4):533-540.

- [49] Kessler J, Schafhalter-Zoppoth I, Gray AT. An ultrasound study of the phrenic nerve in the posterior cervical triangle: implications for the interscalene brachial plexus block. *Reg Anesth Pain Med* 2008 Nov-Dec;33(6):545-550.
- [50] Benumof JL. Permanent loss of cervical spinal cord function associated with interscalene block performed under general anesthesia. *Anesthesiology* 2000 Dec;93(6):1541-1544.
- [51] Neal JM, Brull R, Chan VW, Grant SA, Horn JL, Liu SS, et al. The ASRA evidence-based medicine assessment of ultrasound-guided regional anesthesia and pain medicine: Executive summary. *Reg Anesth Pain Med* 2010 Mar-Apr;35(2 Suppl):S1-9.
- [52] Sites BD, Taenzer AH, Herrick MD, Gilloon C, Antonakakis J, Richins J, et al. Incidence of local anesthetic systemic toxicity and postoperative neurologic symptoms associated with 12,668 ultrasound-guided nerve blocks: An analysis from a prospective clinical registry. *Reg Anesth Pain Med*. 2012 Sep-Oct;37(5):478-82.
- [53] Orebaugh SL, Kentor ML, Williams BA. Adverse Outcomes Associated with Nerve Stimulator-Guided and Ultrasound-Guided Peripheral Nerve Blocks by Supervised Trainees: Update of a Single-Site Database. *Reg Anesth Pain Med* 2012 (in press).
- [54] Barrington MJ, Kluger R. Use of ultrasound guidance for peripheral nerve blockade is associated with a reduced incidence of local anesthetic systemic toxicity [abstract]. American Society of Anesthesiologists Annual Meeting. October 16, 2012. BOC12.