SPECIAL ARTICLE

The ASRA Evidence-Based Medicine Assessment of Ultrasound-Guided Regional Anesthesia and Pain Medicine

Executive Summary

Joseph M. Neal, MD,* Richard Brull, MD,† Vincent W. S. Chan, MD,† Stuart A. Grant, MBChB,‡
Jean-Louis Horn, MD,§ Spencer S. Liu, MD,|| Colin J.L. McCartney, MBChB,¶
Samer N. Narouze, MD, MSc,# Anahi Perlas, MD,† Francis V. Salinas, MD,*
Brian D. Sites, MD,** and Ban Chi-ho Tsui, MD††

Objectives: The American Society of Regional Anesthesia and Pain Medicine charged an expert panel to examine the evidence basis for ultrasound guidance as a nerve localization tool in the clinical practices of regional anesthesia and interventional pain medicine.

Methods: The panel searched, examined, and assessed the literature of ultrasound-guided regional anesthesia (UGRA) from the past 20 years. The qualities of studies were graded using the Jadad score. Strength of evidence and recommendations were graded using an accepted rating tool.

Results: The panel made specific literature-based assessments concerning the relative advantages and limitations of UGRA relative to traditional nerve localization methods as they pertained to block characteristics and complications. Assessments and recommendations were made for upper and lower extremity, neuraxial, and truncal blocks and include pediatrics and interventional pain medicine.

Conclusions: Ultrasound guidance improves block characteristics (particularly performance time and surrogate measures of success) that are often block specific and that may impart an efficiency advantage depending on individual practitioner circumstances. Evidence for UGRA impacting patient safety is currently limited to the demonstration of improvements in the frequency of surrogate events for serious complications.

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We are approaching 2 decades since the first descriptions of using ultrasound as a tool for nerve localization, which were first published in this[1,2] and other journals.[3,4] The first decade of ultrasound-guided regional anesthesia (UGRA) largely established its feasibility and described approaches to common peripheral nerve blocks (PNBs). As ultrasound technology improved, investigators began to experiment with deeper blocks and perineural catheter placement, and anesthesiologists started to appreciate the advantages and limitations of this new localization tool. Perhaps most important in this evolution is the beginning of efforts to critically compare UGRA to other forms of nerve localization—the building of an evidence base for potentially improving effectiveness and enhancing patient safety. From these foundations comes a body of literature that enables practitioners to assess the role for UGRA in their practice. Although the rapidity of these formative stages is encouraging, the effort to scientifically assess what is arguably one of the most exciting periods in the history of regional anesthesia is in its adolescence.

This executive summary represents an overview of the assessments and recommendations that are detailed and defended within the individual supporting articles contained within this supplement. Clinicians are encouraged to read these supporting articles for a more robust understanding of the evidence base for UGRA.

METHODS

In April 2008, the Board of Directors of the American Society of Regional Anesthesia and Pain Medicine (ASRA) commissioned a group of UGRA experts to review, critically assess, and present in evidence-based medicine (EBM) format the scientific underpinnings of ultrasound guidance as a tool for nerve localization. Of interest to the panel was published evidence that related to 3 general areas pertinent to UGRA: (1) block-related outcomes such as improvements in onset, duration, or patient satisfaction; (2) process-related outcomes such as reduction in block performance time; and (3) safety-related outcomes. The board's charge was issued in concert with its partnering with the European Society of Regional Anaesthesia and Pain Therapy to develop a suggested learning curriculum for UGRA.[5] Panelists were chosen based on demonstrated expertise in UGRA research, clinical care, and/or education. Primary

TABLE 1. Key to Evidence Statements and Grades of Recommendations

Statements of evidence

Ia   Evidence obtained from meta-analysis of RCTs

Ib   Evidence obtained from at least 1 RCT

IIa   Evidence obtained from at least 1 well-designed controlled study without randomization

IIb   Evidence obtained from at least 1 other type of well-designed quasi-experimental study

III   Evidence obtained from well-designed nonexperimental descriptive studies, such as comparative studies, correlation studies, and case reports

IV   Evidence obtained from expert committee reports or opinions and/or clinical experiences of respected authorities

Grades of recommendations

A   Requires at least 1 prospective, randomized controlled trial as part of a body of literature of overall good quality and consistency addressing the specific recommendation (evidence levels Ia and Ib)

B   Requires the availability of well-conducted clinical studies, but no prospective, randomized clinical trials on the topic of recommendation (evidence levels IIa, IIb, III)

C   Requires evidence obtained from expert committee reports or opinions and/or clinical experiences of respected authorities; indicates an absence of directly applicable clinical studies of good quality (evidence level IV)

Source: US Department of Health and Human Services Agency for Health Care Policy and Research.[17]

participants in the evidence-based medicine program are listed as authors of this article. Panelists were charged with evaluating the evidence for their assigned topic and presenting it on May 2, 2009 at the ASRA spring meeting in Phoenix, Ariz, then creating manuscripts that were internally peer reviewed by fellow panelists before undergoing external peer review in accordance with the standards of this journal.

This project was designed to accomplish several goals. First was to directly compare UGRA to other nerve localization tools with regard to block- and performance-related outcomes (block performance time, onset, success, and duration) and patient safety issues (2 global issues: postoperative neurologic symptoms (PONSs) and local anesthetic systemic toxicity (LAST); and 2 block-specific issues: hemidiaphragmatic paresis [HDP] and pneumothorax). These parameters were evaluated separately for upper and lower extremity, truncal, and neuraxial blocks. Second, the project assessed the role of ultrasound guidance in special patient populations, notably pediatrics and interventional pain medicine. Third, related topics such as education, scope of practice, ultrasound physics, ultrasound machine function, and billing were presented at the symposium, some of which are presented in this supplement or related articles.[5–8]

Specific methodologies for the various components of this project are detailed in the accompanying individual articles.[9–16] In brief, putative evidence was gathered using a variety of standard electronic search engines to identify relevant literature from the early 1990s through fall 2009. Specific search engines used, language limitations, and MeSH (medical subject headings) are described in the individual articles. Central to our collective search criteria was the inclusion of only randomized controlled trials (RCTs), systematic reviews, meta-analyses, comparative studies, or case series of at least 10 subjects. Case reports and letters-to-the-editor were used only to document rare complications. Cadaver or imaging studies, or case series of less than 10 subjects, were used to demonstrate feasibility, but not to determine comparative attributes of UGRA.

Evidence-based statements are constructed from a common schema developed by the US Department of Health and Human Services Agency for Health Care Policy and Research[17] for evaluating strength of evidence and grades of recommendation (Table 1). To further evaluate the quality of studies from which these assessments were made, we graded scientific quality using the Jadad score[18] (Table 2). This numerical score (from 0 = weakest to 5 = strongest) is a validated measure of study design and quality of reporting.

RESULTS

As detailed within the supporting articles, our literature search terms identified up to 211 articles. After exclusion of those articles that did not fit inclusion criteria or were related to ultrasound uses other than regional anesthesia, most individual topic assessments were based on less than 25 applicable studies. In this executive summary article, pertinent results are summarized as a prelude to individual subtopics within the discussion.

Because study design and definitions of block characteristics vary widely among studies, we made no attempt to pool results for further statistical analysis. Useful information can be gleaned from case series and studies that compare various block approaches that use ultrasound guidance. However, the most

TABLE 2. Jadad Score

Study Characteristic	Score
Was the study described as randomized (this includes words such as randomly, random, and randomization)?	0/1
Was the method used to generate the sequence of randomization described and appropriate (table of random numbers, computer generated, etc)?	0/1
Was the study described as double blind?	0/1
Was the method of double blinding described and appropriate (identical placebo, active placebo, dummy, etc)?	0/1
Was there a description of withdrawals and dropouts?	0/1
Deduct 1 point if the method used to generate the sequence of randomization was described and it was inappropriate (patients were allocated alternately, or according to date of birth, hospital number, etc).	0/−1
Deduct 1 point if the study was described as double-blind but the method of blinding was inappropriate (eg, comparison of tablet vs injection with no double dummy).	0/−1

The first 5 items are indications of good study quality; a point is added for each criteria met. The last 2 items indicate poor study quality; a point is subtracted for each criteria met. The Jadad score therefore ranges from 0 to 5.[18]

TABLE 3. Topics Assessed by Studies Comparing UGRA With Another Nerve Localization Technique

Author, Year	Jadad Score	Comparative Technique			Block Characteristics					Complications			
		Peripheral Nerve Simulation	Other Localization Technique	Pediatric	Block Performance Time	Block Onset	Block Success	Block Duration	Hemidiaphragmatic Paresis	Local Anesthetic Toxicity	Neurologic Symptoms	Pneumothorax	Vascular Puncture
Antonakakis et al,[62] in press	5	•			•						•		•
Barrington et al,[46] 2009	N/A	•			•					•	•		
Brull et al,[25] in press	5	•			•		•						•
Casati et al,[19] 2007	3	•			•	•	•				•		•
Casati et al,[26] 2007	4	•			•	•	•				•		•
Chan et al,[20] 2007	5	•			•		•				•		
Danelli et al,[63] 2009	3	•			•	•	•						
Dhir and Ganapathy,[64] 2008	2	•			•		•						•
Dingemans et al,[65] 2007	2	•			•		•				•		
Dolan et al,[66] 2008	4	•	•					•					
Dolan et al,[28] 2009	2	•	•										
Domingo-Triado et al,[67] 2007	3	•			•	•	•	•			•		
Dufour et al,[68] 2008	4	•			•		•	•					
Fredrickson and Kilfoyle,[69] 2009	N/A	•									•		
Fredrickson et al,[70] 2009	3	•			•	•	•						•
Gurkan et al,[22] 2008	2	•			•	•	•						•
Kapral et al,[71] 2008	2	•			•	•	•	•			•		•
Liu et al,[72] 2005	2	•			•								
Liu et al,[23] 2009	3	•			•	•	•				•		
Macaire et al,[21] 2008	2	•			•	•	•						•
Marhofer et al,[73] 1997	1	•			•	•	•						•
Marhofer et al,[74] 1998	2	•			•	•	•						•
Marhofer et al,[31] 2004	3	•		•	•	•	•						
Mariano et al,[75] 2009	3	•			•	•	•	•					•
Morros et al,[76] 2009	1	•			•	•	•	•					•
Oberndorfer et al,[32] 2007	4	•		•				•			•		•
Orebaugh et al,[47] 2009	N/A	•			•	•	•			•	•		•
Perlas et al,[77] 2008	4	•											•
Ponde and Diwan,[78] 2009	3	•		•	•		•	•					•
Redborg et al,[79] 2009	5	•			•		•				•		•
Redborg et al,[80] 2009	5	•			•		•				•		•

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TABLE 3. *(Continued)*

Author, Year	Jadad Score	Comparative Technique			Block Characteristics				Complications				
		Peripheral Nerve Simulation	Other Localization Technique	Pediatric	Block Performance Time	Block Onset	Block Success	Block Duration	Hemidiaphragmatic Paresis	Local Anesthetic Toxicity	Neurologic Symptoms	Pneumothorax	Vascular Puncture
Renes et al,[52] 2009	2	•							•				
Renes et al,[53] 2009	4	•							•				
Sauter et al,[24] 2008	3	•			•	•	•					•	•
Sites et al,[81] 2006	3		•		•	•	•				•	•	
Soeding et al,[82] 2005	1				•		•	•			•		
Taboada et al,[83] 2009	3	•	•		•	•	•	•			•		
Tedore et al,[84] 2009	2									•	•		•
Van Geffen et al,[27] 2009	3	•	•		•	•	•						
Weintraud et al,[29] 2009	5	•		•						•			
Williams et al,[55] 2003	2	•					•	•			•	•	•
Willschke et al,[30] 2005	3			•	•			•					•
Willschke et al,[36] 2006	2		•	•									•
Yu et al,[85] 2007	3		•	•									

N/A indicates not applicable.

valuable information for this project came from studies that compared specific block characteristics or complications as a function of UGRA versus another form of nerve localization. Studies that satisfied those criteria and their Jadad scores are listed in Table 3.

DISCUSSION

The literature of UGRA is a heterogeneous mix of generally small studies that compare ultrasound guidance with another form of nerve localization, usually peripheral nerve stimulation (PNS). Direct comparison of outcomes between studies is impossible because of variability in their chosen definitions for outcomes such as block performance time or success. Some studies compared the relative attributes of 2 or more approaches to a nerve or plexus block, all performed under ultrasound guidance. Other studies examined the ability to achieve neural blockade using differing volumes of local anesthetics. Although the latter 2 study methodologies contributed to our analysis, they were not used to infer any advantage or limitation of UGRA versus another form of nerve localization. What follows is a block-specific summary of results, discussion, and listing of recommendations when appropriate.

Upper-Extremity Blocks

Nineteen studies met inclusion criteria for comparing UGRA to other methods of nerve localization for upper-extremity block; most of these comparisons were made with PNS. Although these studies represent level Ib evidence, their quality varied widely (Jadad score, 1–5; median, 3). We qualitatively defined a study as "positive" if any measure of UGRA block characteristic was statistically superior to the compared technique, "negative" if the compared technique was statistically superior to ultrasound, or "no net difference" if the techniques were statistically indistinguishable or split between comparison groups. This distinction is important in that we did not quantify the magnitude of time difference for a specific block characteristic. Thus, the clinician is left to decide, for example, whether a 4- to 12-min faster onset time is relevant to their practice, particularly if equipment setup time was not included or if overall block success was not different between techniques.[19,20] Of the 19 studies, 15 were positive for ultrasound, 3 showed no net difference,[21] and 1 demonstrated faster block performance time in the PNS group.[22] Tables within the supporting articles detail the myriad comparisons that were made by individual studies, thereby giving readers a sense of the actual time advantage within the context of other measures of success. In addition to time-related block characteristics, 3 studies[19,23,24] reported a reduced number of needle passes in the ultrasound group, yet this potential advantage did not consistently translate to improved patient satisfaction or block-related complication rates. Six upper-extremity UGRA studies compared 2 or more ultrasound-guided approaches. The results of these studies were mixed, with most but not all reporting higher success rates and lower complication rates (Horner syndrome and HDP) with infraclavicular or axillary block versus supraclavicular block. Lower success rates with the supraclavicular approach were consistently related to failure to anesthetize the lower trunk.[11]

Under the conditions of our analysis, there is level Ib, grade A evidence that ultrasound guidance results in faster sensory block onset and higher surrogate rates of block success, based on 6 of 7 conclusive studies for onset and 8 of 8 conclusive studies for success. Successful block, variously defined as sensory or motor anesthesia of 1 or more nerves, was reported positive for ultrasound as compared with the control technique: 75%

to 86% versus 47% to 63%, respectively.[10] Although higher success rates were shown for block onset and success when defined by nerves anesthetized, there was less distinction between groups when block success was defined by perhaps more clinically relevant measures such as readiness for surgery or the ability to complete surgery without block supplementation or provision of general anesthesia. When analyzed by these "block quality" indicators, about 20% of RCTs reported less need for rescue block, and ~10% found less need for supplemental analgesia in the ultrasound study groups.[10] Specific recommendations cannot be made for other block characteristics such as performance time or duration—most studies represent Ib evidence, but are either conflicting in their results or too few in numbers to justify definitive recommendations. Block performance time is noteworthy in that earlier studies often failed to include time for prescanning or equipment setup. However, 2 recent high-quality (Jadad score, 5) studies[20,25] have shown shorter block performance times that include ultrasound prescanning and setup as compared with PNS.

Lower-Extremity Blocks

The effect of ultrasound guidance on lower-extremity block characteristics has been evaluated in fewer studies as compared with the upper extremity; these studies support slightly more patients benefiting from the use of ultrasound guidance in terms of block success. Inclusion criteria were met by 4 RCTs (240 patients) that evaluated 3-in-1, femoral, and fascia iliaca blocks; 5 RCTs examined popliteal sciatic nerve block (214 patients); and 2 RCTs assessed combined ultrasound and PNS. Median Jadad score was 3 (range, 1–4). Perhaps reflecting the primarily analgesic use of these blocks in clinical practice, success of surgical anesthesia was rarely measured.[15]

The same criteria as described for upper-extremity block were used to judge lower-extremity UGRA as being positive, negative, or no difference compared with other localization techniques. Using these qualitative criteria to describe the superiority of ultrasound guidance to traditional techniques, 5 of 7 studies supported faster block onset, whereas 1 of 7 reported slower onset using ultrasound. Regarding block quality, there was no difference in the need for rescue anesthesia or supplemental analgesia, but 5 of 8 studies documented more complete block of all studied nerves in the ultrasound groups (97%–100% with ultrasound vs 71%–75% with other techniques). Three of 3 studies reported no difference in lower-extremity block duration.[10] Two studies demonstrated the ability of UGRA to reduce the amount of local anesthetic necessary to achieve adequate block as compared with PNS guidance (absolute mean reductions of 9 mL for femoral block[26] and 20 mL for sciatic block[27]). These data support level Ib, grade A recommendations in favor of ultrasound for increasing sensory block success and allowing a reduced volume of local anesthetic to achieve adequate block. Similar evidence (Ib, A) supports the use of ultrasound to decrease sensory block onset time by an average of 11 to 14 mins. Catheter placement block performance times were faster in the ultrasound groups for popliteal sciatic nerve block. Investigations of lower-extremity blocks lacked sufficient power to allow definitive recommendations regarding quality of sensory block, number of needle punctures and redirections, patient discomfort during the block, or block duration.[15]

Truncal Blocks

Truncal blocks include paravertebral, intercostal, transversus abdominis plane (TAP), rectus sheath, and ilioinguinal/iliohypogastric (II/IH) blocks. The literature of ultrasonically guided truncal blocks largely consists of case series, audits, or anatomic studies that establish feasibility. Three RCTs compare rectus sheath[28] or II/IH blocks[29,30] to landmark-based techniques.

There currently are insufficient data to address the usefulness of ultrasound guidance for intercostal nerve block. Several case series and an anatomic study establish the feasibility of using ultrasound for paravertebral blocks (IIb, B), but there are no data available from which to compare the success or safety of paravertebral blocks using ultrasound versus traditional techniques (IV).[9] Ultrasound guidance might be expected to reduce the incidence of visceral organ injuries and intraperitoneal needle placements linked to TAP blocks. However, the evidence for ultrasound-guided TAP blocks is limited to cadaver studies, retrospective audits, and noncomparative opioid-sparing studies. Although these studies establish feasibility and high success rates, there are no level I or II data that address the relative benefit of ultrasound-guided TAP to traditional approaches.[9]

Two small case series of pediatric patients established feasibility of ultrasound-guided rectus sheath block. A recent RCT compared the performance of trainees using ultrasound versus loss-of-resistance (LOR) technique. Given the inexperience of trainees with both approaches, it is notable that the needle was placed twice in the correct tissue plane as often using ultrasound. Intraperitoneal needle placement occurred in 21% of the LOR subjects[28] (Ib, A). An RCT that compared ultrasound-guided to landmark-based II/IH block reported higher success for anesthesia and analgesia in those children randomized to ultrasound.[30] Although there is insufficient evidence to demonstrate increased safety with ultrasound, this study establishes a limited (Ib, A) recommendation for ultrasound-guided II/IH block in children.

In summary for truncal blocks, limited RCT evidence supports the recommendation for ultrasound as the preferred localization technique for rectus sheath and II/IH blocks (Ib, A). There is insufficient evidence from which to judge the relative contributions of ultrasound to TAP, intercostal, and paravertebral blocks.[9]

Neuraxial Blocks

The body of literature examining the role of ultrasound in neuraxial anesthetic techniques is smaller than that for PNBs. Seventeen studies met inclusion criteria and can be generally categorized as addressing (1) ultrasound-assisted techniques or (2) real-time ultrasound-guided techniques.

Ultrasound-assisted neuraxial techniques involve preprocedural scanning to determine midline, targeted interspace, or depth from skin to the epidural or subarachnoid spaces before performing the procedure using traditional methods. In adults, these basic measurements are often difficult to obtain because of intervening soft tissues or acoustic shadowing from bone and/or calcification. Nevertheless, ultrasound is superior to physical examination, but inferior to radiologic imaging, for correctly identifying spinal interspace levels (IIa). Ultrasound is highly accurate for predicting skin-to-epidural space depth in the cervical spine (adults) and the lumbar spine (adults and children) (Ib). The clinical relevance of these findings is uncertain. For instance, when ultrasound was compared with landmark-based examination before placement of labor epidurals, the anesthesiologist using ultrasound was able to complete epidural placement using fewer attempts at fewer interspaces, yet the success rate for labor analgesia was no different. Higher success was achieved if the operator was a trainee[14] (Ib).

A single real-time ultrasound-guided neuraxial study of combined spinal epidural anesthesia in obstetric patients noted

fewer attempts to successfully place the needle in the ultrasound group, but equal block success (Ib). There are no safety studies of ultrasound-facilitated versus traditional neuraxial techniques. Unfortunately, ultrasound guidance is likely to be most useful in patients who present challenging neuraxial anatomy secondary to obesity, spinal deformity, or previous spine surgery. However, there is often more difficulty obtaining images on these groups of patients, and data are still lacking at this early stage.[14]

Pediatrics

The use of UGRA in pediatrics is of particular interest because children are often anesthetized before block placement and therefore unable to provide feedback related to needle-to-nerve contact or symptoms of local anesthetic intravascular injection. Existing studies are too small to address these patient safety issues. Twelve studies (6 RCTs and 6 case series) have assessed pediatric ultrasound-guided PNB, and 12 others (1 RCT, 1 comparative study, and 10 case series) have evaluated pediatric neuraxial block. The median Jadad score for these studies was 3 (range, 2–5).[16]

For PNB, a single study of infraclavicular block showed that the onset of sensory block was, on average, 6 mins faster with UGRA versus PNS,[31] but the success of surgical anesthesia was not different (Ib, B). Conversely, ultrasound improved block success for pediatric anterior truncal blocks, which are typically performed using tactile or landmark-based techniques[29,30] (Ib, A). Ultrasound guidance modestly prolonged neural blockade, as measured by duration time or decreased pain scores, in infraclavicular, sciatic, and/or femoral block models[31,32] (Ib, A). Three studies demonstrated that ultrasound reduced the volume of local anesthetic required for various pediatric blocks, but limited duration of follow-up (4 hrs) and instances of early presentation of pain confound interpretation of these results with regard to whether reduced volumes can maintain or improve block quality and duration[33–35] (Ib, A).

Real-time ultrasound-guided neuraxial blocks have proven valuable in pediatric patients whose smaller body mass allows the use of high-resolution linear transducers to image neuraxial structures. Feasibility studies demonstrate real-time observation of injectate spread through epidural needles, epidural catheter insertion, and final catheter position (III).[14] Several investigations confirm the usefulness of UGRA for visualizing the ligamentum flavum and particularly the dura mater in neonates, infants, and children up to 12 years of age (Ib, A). Preprocedural scanning offers a moderate prediction of depth from skin to expected LOR.[16] A comparison of ultrasound guidance to LOR for epidural placement found that ultrasound reduced the number of bone contacts and facilitated faster placement of the catheter, but did not affect analgesia or complications[36] (Ib, B).

In summary, a modest body of literature addresses UGRA in the pediatric population. Similar to adults, studies show that sensory block onset is often faster, but ultrasound equipment setup time is typically not reported. Feasibility studies demonstrate the ability of ultrasound to identify dura mater and ligamentum flavum, particularly in neonates and young children, but to date there are little data linking this to actual clinical advantage in terms of improved block success or safety. The ability to use smaller volumes of local anesthetic is particularly appealing in children because of their small-size–related susceptibility to local anesthetic toxicity. Although smaller local anesthetic volumes are indeed possible in these patients, there is limited evidence regarding how this might affect block quality and no evidence regarding serious complications such as seizure. The common practice of placing blocks in anesthetized or heavily sedated children[37,38] is another instance where neural

visualization presents a theoretical advantage of ultrasound guidance, but nerve injury has not been studied in this group.

Chronic Pain Medicine: Interventional Procedures

Ultrasound guidance might offer similar benefits to pain physicians as it does for surgical and acute pain medicine practice,[39] but acoustic shadowing and obesity make neuraxial imaging particularly difficult in adults. Compared with fluoroscopy or other radiographic imaging techniques, ultrasonography reduces radiation exposure to the patient and operator. The evidence base for interventional pain medicine is quite limited, with most reports classified as feasibility studies; that is, cadavers and/or noncomparative patient models are used to explore the potential for ultrasound guidance to facilitate block procedures. Preliminary feasibility studies support the use of ultrasound guidance for cervical selective nerve root block[40] and stellate ganglion block.[41] No data exist to compare the efficacy of ultrasound to fluoroscopic guidance for lumbar facet injection, lumbar nerve root injection, or cervical selective nerve root injection.

The single RCT within this topic area compared ultrasound with computed tomography guidance for lumbar facet joint intra-articular injection. Ultrasound was superior to computed tomography with regard to time for block placement and less radiation exposure, but there was no difference in pain relief between groups[42] (Ib). A nonrandomized crossover trial of lumbar facet medial branch blocks noted that ultrasound-guided blocks (administered 1 month after a fluoroscopically guided block) were 95% successful for establishing proper needle placement. This study may not be applicable to Western populations because of the small physical stature (mean, 51 kg) of its subjects.[43]

Patient Safety

As compared with other nerve localization methods, UGRA has the advantage of directly visualizing the target nerve, surrounding tissues, and injectate spread. It is reasonable to speculate that these advantages might reduce complications such as nerve injury, LAST, pneumothorax, or HDP. Unfortunately, the most serious of these complications (permanent nerve injury and severe LAST) are so rare as to defy statistical proof that ultrasound might affect their occurrence.[13]

Twenty-two RCTs and 4 large case series that together encompass ~17,000 patients showed no difference in the frequency of PONSs as a function of localization technique. This finding is supported by a recent meta-analysis and systematic review.[44,45] Two large audits found no statistical difference in the incidence of PONSs regardless of nerve localization by ultrasound or PNS.[46,47] Importantly, the frequency of PONSs after UGRA (0.4/1000; 95% confidence interval [CI], 0.08–1.1/1000)[46] does not appear to be significantly different from historical frequencies reported using PNS techniques. However, cases of peripheral nerve injury have been reported after ultrasound-guided PNB.[13,48]

Seventeen RCTs and 2 large case series (~15,000 patients) showed a reduction in the incidence of vascular puncture when ultrasound guidance was used. However, data are conflicting with regard to subsequent reduction in the occurrence of LAST—one audit showed no reduction as a function of localization technique,[46] whereas another audit[47] noted fewer seizures in the ultrasound group. Case reports[49,50] describe seizures despite the use of ultrasound. The overall frequency of LAST after UGRA (95% CI, 0.42–1.9/1,000) is remarkably similar to that previously reported using PNS guidance.[13,51]

Three RCTs[52–54] evaluated the potential for UGRA to reduce the incidence of HDP after above-the-clavicle block. Ultrasound-facilitated local anesthetic volume reduction caused less frequent and intense HDP, but HDP still occurred unpredictably (95% CI, 0.00%–0.14% for supraclavicular block[53]), which likely limits absolute reliance on small-volume, ultrasound-guided blocks in those patients for whom a potential 30% reduction in pulmonary function would be relatively contraindicated. Three RCTs[24,53,55] and a case series[56] report no pneumothoraces associated with UGRA (upper limit 95% CI, 0.5%), although pneumothorax associated with UGRA has been reported after single-injection and continuous techniques.[57,58]

In summary, there is no evidence that UGRA results in less frequent peripheral nerve injury than that historically reported using PNS guidance. Because of the extreme rarity of this complication, a statistically significant difference between nerve localization techniques, if indeed any difference exists, will likely never be realized (III). Ultrasound reduces the frequency of vascular puncture (Ia), but there is conflicting evidence whether this results in true reduction of LAST (III). Although the use of ultrasound and low local anesthetic volume reduces the frequency and intensity of HDP (Ia), it does so unpredictably, which may limit the usefulness of this technique in those patients most likely to benefit from it (IV). Finally, pneumothorax has been reported despite the use of ultrasound guidance (III).

Concluding Comments

The evidence base for UGRA as a nerve localization tool is expanding rapidly. Although existing studies are hampered by small numbers of subjects and varying definitions of block characteristics and success, their quality has improved substantially over the past 5 years. Current assessments of the advantages and limitations of ultrasound are hampered by (often unavoidable) methodological limitations. For instance, most studies were performed by ultrasound experts, which may limit the ability to generalize results to less experienced practitioners. Conversely, these same investigators are often highly skilled in the comparator technique, which should promote fairer comparison. More problematic are those studies that compare ultrasound to a less-than-ideal version of the comparator, such as not using the optimal number of PNS-guided injections or motor responses.[59]

Despite the literature's limitations, several general conclusions can be made. First, most studies found UGRA to be superior or equal to the comparator technique, and none showed that ultrasound guidance was clearly inferior or dangerous. Second, ultrasound offers statistically, but perhaps not clinically, proven advantages in block characteristics, particularly reduced onset time and improved intermediate measures of success. These advantages need to be qualified in that they are often block specific, and surrogate measures of block success are more likely to favor ultrasound guidance than do those measures that rely on supplement-free surgical anesthesia. Third, there is no evidence that ultrasound eliminates complications; indeed, the limited existing data suggest that complication rates are similar to historical norms reported using traditional nerve localization tools. There is reason to at least consider that poorly performed ultrasound guidance, such as failure to image the needle, misinterpretation of artifacts,[7,8] or novice behavior,[60,61] might actually increase the risk of injury. Furthermore, ultrasound is but another form of nerve localization, all having a potential role in the multifactorial process of nerve injury, which is also affected by local anesthetic neurotoxicity, underlying patient conditions, and surgical-related insults. The literature is silent with regard to patient- or situation-specific safety outcomes where ultrasound may prove to be particularly useful. For example, there is reason to suspect that UGRA may reduce the frequency of LAST more in children than in adults, or that preventing nerve injury may be more relevant in patients at increased risk for nerve injury (diabetes, chemotherapy-induced neuropathy, etc) as compared with the overall population.

In closing, the panel wishes to emphasize its belief that ultrasound guidance is a significant advance in the practice of regional anesthesia and pain medicine. At this early stage, the volume of evidence-based UGRA literature has already matched or arguably exceeded that for transesophageal echocardiography. Future studies will most certainly improve our understanding of its strengths and weaknesses. However, the use of ultrasound is but a single component of the practice of regional anesthesia. Ultrasound guidance does not remove traditional requirements for physician judgment, training, anatomic knowledge, and experience. Most importantly, ultrasound does not lessen the practitioner's responsibility for using time-proven strategies to improve block quality and patient safety—including proper anesthetic selection and dosing, aspiration for blood, appropriate test dosing, patient- and procedure-appropriate sedation, and vigilant intrablock and postblock monitoring.

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