Current concepts and future trends in ultrasound-guided regional anesthesia

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Current Opinion in Anaesthesiology 2010, 23:632–636

Purpose of review

Ultrasound guidance for regional anesthesia has gained enormous popularity during the past several years. This review article highlights the importance of acquiring an understanding and knowledge of human anatomy for well tolerated and effective performance of regional anesthesia; includes description of some of the major principles of ultrasound-guided regional anesthesia techniques (adequate identification of neuronal and adjacent anatomical structures along with the procedure needle); use of adequate volumes of local anesthetic and the proper administration of local anesthetic; and discusses economical along with educational aspects of ultrasound-guided regional blocks.

Recent findings

Recent studies by various authors have indicated that ultrasound-guided regional blocks can be performed by using smaller volumes of local anesthetics. Such findings will further contribute to the safety of regional anesthesia in daily clinical practice. Additional positive economical aspects associated with regional anesthesia have also been described in the recent literature.

Summary

With little reservation, it is anticipated that ultrasound-guided regional anesthesia will become the 'GOLD' standard for performance of regional anesthesia. Excellent science and educational concepts will continue to be required with the continued increase in popularity of this exciting specialty of anesthesia.

Keywords

economy, nerve blockade, regional anesthesia, ultrasound

Curr Opin Anaesthesiol 23:632–636

0952-7907

Introduction

Ultrasound guidance for various regional anesthesia blocks has gained enormous popularity during the past 10 years. An increasing number of anesthesiologists use these techniques in their daily clinical practice. Some of the many prerequisites for implementation of ultrasound in regional anaesthesia include excellent understanding and knowledge of human anatomy, understanding of the principles related to ultrasound-guided blocks such as good hand skills and excellent hand–eye coordination.

The importance of anatomical knowledge

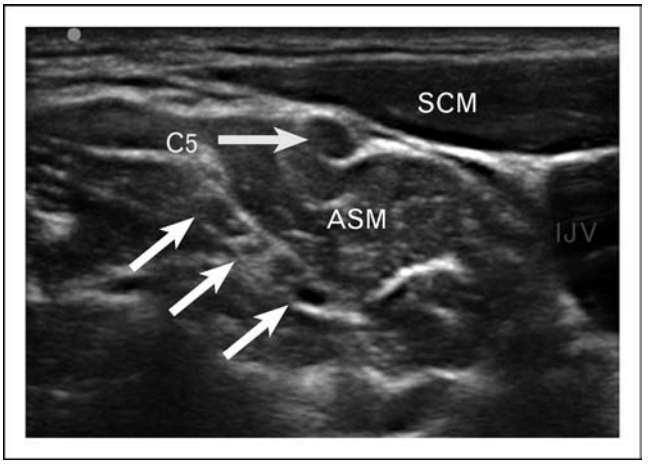
'Regional anesthesia is applied anatomy': this statement reflects clinical reality. Appropriate anatomical knowledge was always a major prerequisite for successful performance of regional anesthesia, and this has not changed due to direct visualization techniques provided with the introduction and incorporation of ultrasound into regional anesthesia practice. Although it is true that correct identification of neuronal and adjacent anatomical structures enables effective and well tolerated block performance; anaesthesiologists have to accept that the first step for successful implementation for all kinds of regional anesthesia techniques remains the requirement of profound topographical knowledge of human anatomy. The performance of regional blocks without this common anatomical understanding of how to apply anatomy is considered substandard and unsafe patient care (bordering close to malpractice) and should be avoided.

Identification of anatomical structures with ultrasound is the next sequential step to acquiring the knowledge and skill sets necessary to improve upon safety and efficacy of regional anesthesia. Use of ultrasound has been an important diagnostic and therapeutic tool in anesthesia and intensive care medicine. Therefore, the subsequent transition from cardiac anesthesia to anatomical small-part sonography (as required for regional block techniques) proved to be both a simple and easy next step. Anesthesiologists have learned and maintained a profound technical knowledge and understanding of high-end equipment implementation within clinical

practice on a daily basis that it is now standard care in both the operating room environment and intensive care unit. Thus, incorporation of ultrasound technology into daily clinical practice by anesthesiologists will become an uncomplicated evolution of continuing patient care. However, special education and training are required to make the transition toward incorporation of ultrasound technology into daily practice (visualize neuronal structures in an optimal manner). Another important consideration is the appropriate identification of variables and artifacts (e.g. mirroring, reverberations, etc.) that can frequently be discovered and encountered during the use of ultrasound to guide regional anesthesia.

Successful implementation of regional anesthesia and peripheral nerve block performance is gained by an appreciation and knowledge of 'normal' anatomy and for a recognition and awareness of anatomical variations. Anatomical variables may be partially responsible for regional anesthesia block failures and implementation of ultrasound technology will enable direct visualization for the correct diagnosis and detection of these anatomical variations. It remains intuitive that landmark-based techniques for performance of regional anesthesia or indirect procedures of nerve identification using parasthesia or nerve stimulators have proven to be poor methods of differentiating between normal anatomy and 'variations' of human anatomy. Figure 1 serves as an example of anatomical variation in which the nerve roots of the entire brachial plexus are not located between the anterior and medial scalene muscles. Consequently, for successful interscalene brachial plexus blockade in this patient, the chosen regional anesthetic technique would have to be modified so that local anesthetic could be properly placed in order to prevent a partial or incomplete peripheral nerve block. Consideration and identification of these potential variables of human anatomy may minimize regional anesthesia failures.

Figure 1 Variation of the brachial plexus relative to the posterior interscalene groove, in which the C5 root is located between the sternocleidomastoid and anterior scalene muscles



The white arrows indicate the other roots of the brachial plexus inside the posterior interscalene groove. ASM, anterior scalene muscle; IJV, internal jugular vein; SCM, sternocleidomastoid muscle; right side, medial.

Figure 2 Out-of-plane needle guidance technique for interscalene brachial plexus blockade (simulated technique)

Human anatomy knowledge and understanding may also serve as the basis to electively deviate from 'classical' regional anesthesia techniques and for the performance of less commonly performed approaches of regional anesthesia placement. For example, the posterior approach to the brachial plexus at the interscalene level is a technique that may lend to possible injury of the dorsal scapular and thoracic longus nerves that pass through and pierce the middle scalene muscle. Therefore, an out-of-plane approach, as illustrated in Fig. 2, may prove to be a better tolerated technique application of this particular nerve block.

Major principles of ultrasound-guided regional anesthetic techniques

During the last 16 years, numerous techniques for describing and explaining successful performance of regional anesthetic procedures have been described in several anesthesia and scientific journals. It should be clear that a particular description of some major principle(s) of ultrasound-guided regional anesthetic techniques in a review article may only reflect one author's opinion. It should also be understood that described regional anesthesia methods according to scientific contributions in the literature are to apply to clinical practice and that it is without much value to describe sophisticated regional anesthesia techniques which can only be performed and used by a few of the world's leading experts. Routine ultrasound-guided regional anesthesia protocols require theoretical knowledge along with an ability to perform adequate hand skills and concepts of

regional anesthesia that are based on substantial scientific experience and accomplishment. A continuing discussion and current controversy in the UK addresses the concept of whether regional anesthesia and peripheral nerve blocks should be performed or placed by nurse anesthetists. The debate should be based on practitioner training, educational background, foundation and knowledge of human anatomy, along with medical expertise and judgement that remains as some of the necessary prerequisites. This solution will help to insure that proper and well tolerated implementation of regional anesthesia is performed with medical expertise as well as a profound pharmacological understanding and a host of other specific medical (physiology) education developments that can be acquired through the discipline of medical school preparation. Therefore, an important principle of ultrasound-guided regional anesthesia is its continued and expanded clinical use practiced by physicians (i.e. anesthesiologists).

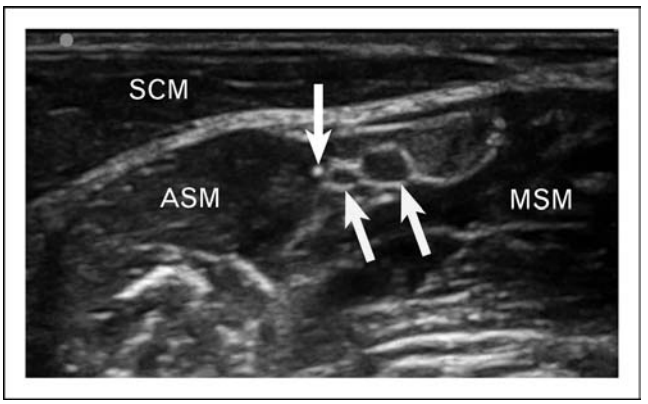
Identification of neuronal and adjacent anatomical structures (blood vessels) along with the procedure needle is another important concept in the application of ultrasound-guided regional anesthesia. The present era of ultrasound manufacturers provide excellent equipment for small-parts sonography that yields adequate visualization and image quality. As an analogy, the best golf clubs are worthless in the hands of an inexperienced or unskilled player, yet this is the situation that can frequently be observed with ultrasound-guided regional anesthesia. Therefore, both proper and adequate experience, education and training remain as some of the major prerequisites for successful implementation of ultrasound-guided regional anesthesia techniques into daily clinical practice.

Throughout much of the preceding literature regarding sonography and regional anaesthetic techniques, there was a foundation based on indirect methods of nerve visualization and injection of large volumes of local anesthetics to compensate for the rather inexact ultrasound guidance methods [1]. Large volumes of local anesthetics could be potentially harmful due to systemic toxic effects from the local, adverse neurological effects associated with the drugs used, and concerns of nerve compression from the large volume of local injected. Recent studies show that complex nerve plexus as well as single nerve block techniques can be successfully performed with lower volumes of local anesthetics than used previously [2–5]. O'Donnell and Iohom [4] describe the successful blockade of the brachial plexus at the axillary level with 1 ml of local anesthetic per nerve branch. Riazi and colleagues [5] identified similar findings of adequate and complete nerve blockade by administering 5 ml of local anesthetic for interscalene brachial plexus blocks. Local anesthetic volume reduction studies while performing single nerve blocks have been published by Eichenberger and colleagues [2] and also by Latzke and colleagues [3] for ulnar and sciatic nerve blocks, respectively. Both studies have incorporated novel methods of calculation for local anesthetic volumes based on cross-sectional nerve areas and both studies identified approximately 0.10 ml/mm^2 of cross-sectional nerve area as being sufficient for successful nerve blockade. Larger volumes (2–3 increase) of local anesthetic than those described in these volume-reduction studies are typically used in daily clinical practice. Even with a 2–3-fold local anesthetic volume reduction as described in these studies, well tolerated and effective low-volume blocks can be realized. In almost every clinical case situation of regional anesthesia, using a multi-injection technique and low volume of local anesthetic is often all that is required to appreciate optimal peripheral nerve block results.

Another important concept regarding ultrasound-guided regional anesthesia specific to performing peripheral nerve blocks is related to the optimal site of local anesthetic administration relative to targeted nerve structures. It has been advocated by many experts and is also our strict opinion that all peripheral nerve blocks should be performed with an extra-epineural needle tip position and subsequent extra-epineural administration of local anesthetic. Some authors favor intra-epineural injections [6,7] that may predispose or potentially lead to nerve damage from the procedure needle or during drug injection. Figure 3 illustrates the suggested correct position of the procedure needle tip relative to a neuronal structure.

Improved and elaborate ultrasound technology along with optimal and best ultrasound technique modalities, are

Figure 3 Extra-epineural position of the tip of the needle (white arrow) for interscalene brachial plexus blockade



The C5 and 6 nerve roots are indicated by the yellow arrows. ASM, anterior scalene muscle; MSM, middle scalene muscle; right side, lateral; SCM, sternocleidomastoid muscle.

useless if they are unaffordable. An argument often stated against ultrasound for regional anesthesia and peripheral nerve block procedures are the high equipment-related costs. High-end ultrasound equipment can be expensive, but a more open view is required for sufficient discussion regarding this important topic. Most studies in the field of ultrasound-guided regional anesthetic techniques illustrate improved success rates, faster regional anesthesia-onset times and longer duration from regional anesthesia procedures when using ultrasound. Therefore, a reduced need and less reliance on alternative perioperative options (switching to general anesthesia) would be necessary and the clinical production times which are influenced by anesthesia induction and emergence from general anesthesia can be significantly reduced. These economical aspects have been recently described by Gonano and colleagues [8], when a specific workflow is suggested which considers the above described factors. In summary, an ultrasound-guided regional anesthesia program incorporating practiced and efficient ultrasound techniques are highly cost-effective when all cost factors are considered together.

How to achieve necessary hand skills for performing ultrasound-guided regional anesthesia

One of the most important prerequisites for well tolerated and effective implementation of ultrasound-guided regional anesthesia remains adequate education and training. Theoretical knowledge in the field (topographic anatomy, pharmacology, etc.) can be acquired by anesthesiologists and is usually just a matter of personal interest fueled by the intensity of occupation with this exciting anesthesia subspecialty. Otherwise, hand skills are highly individual and specific coordination training may therefore be much more difficult to realize. Similar to almost all techniques in medicine, adequate hand skills can be acquired through practice by most anesthesiologists and ultrasound-guided regional simulation may serve as a valuable option in this endeavor.

Grau and colleagues [9] and Dessieux and colleagues [10] describe steep learning curves during training on patients and with a phantom ultrasound model, respectively. Baranauskas and colleagues [11] highlight the importance of theoretical education prior to practical training. Most ultrasound novices seem to have problems with exact ultrasound probe position and imaging of the procedure needle and needle tip during advancement [12]. The American and European Societies of Regional Anesthesia (ASRA and ESRA) recently published guidelines for training in ultrasound-guided regional anesthesia, highlighting the encouragement of individual institutions to support a quality-improvement process [13]. We suggest a combination of basic and advanced workshops for the well tolerated and effective performance of ultrasound-guided regional anesthetic techniques [1].

Have we achieved a 'golden standard' in ultrasound-guided regional anesthesia?

Ultrasound guidance during performance of regional anesthesia for peripheral nerve block procedures may be a great way to formulate the 'golden standard(s)' for regional anesthesia. It remains important to highlight limitations associated with ultrasound-guided regional anesthesia procedures including issues such as: why blockade of the final target structures may not always be successful (optimal block success), or why such regional methods and techniques are still confounded by various complications and side-effects (ultrasound-guided regional anesthesia and peripheral nerve block procedures are still challenged and confronted with potential for patient morbidity). One of the key issues and reasons for this ongoing dilemma could be the fact that there are far too many descriptions for any particular ultrasound scanning method and explanations of 'best' means to perform a particular regional anesthetic technique. Quality of the science for ultrasound-guided regional anesthesia is still not optimal and there remains room for improvements, but the scientific quality of ultrasound research in regional anesthesia is in close context with the broad use of the techniques in daily clinical practice. To achieve a 'golden standard' in any particular technique requires both excellent science along with responsible and careful implementation into clinical practice. Analyzed retrospectively, a 'golden standard' in regional anaesthesia has not yet been reached since current ultrasound-guided techniques described with an average success rate of 80% cannot be depicted as the 'golden standard' [14]. Use of ultrasound during performance of regional blocks may provide, for the first time, the establishment of potential 'standards' in this subspecialty provided a responsible, scientific, structured and careful implementation of such techniques are performed.

Associated within the area(s) of optimal regional anesthesia performance and closely tied to the importance of this topic is patient satisfaction that remains a driving force necessary to continue the growth of the subspecialty. Ultimately, it is our patients who will decide if regional anesthesia techniques achieve the many criteria necessary to be considered as a 'golden standard'. Patient needs should be satisfied with any anesthetic technique that provides a predictable outcome and ideally an optimal and pain-free experience following their surgical intervention. Anesthesiologists (like other physicians) may tend to overestimate their own clinical performance expertise and should therefore provide all medical procedures based upon proven and scientific evaluation.

It should be remembered that the best techniques are without any longstanding value without first achieving global acceptance. More than one billion people do not have access to modern medicine and the lack of anesthesia to enable surgery remains a key issue in the context of this bigger problem. Ultrasound for regional anesthesia may provide a significant input for various surgical procedures in remote areas or where the economical situations are less than optimal. Thus, anesthesia opinion leaders in the field, healthcare companies and governments of first and second world countries are depended upon to find adequate solutions for this situation. The 'golden standard' in regional anaesthesia is only achieved when this most important first target has been realized.

A major drawback in the continued quest for the development of any 'golden standard' in ultrasound-guided regional anesthesia is the lack of large outcome studies regarding patient safety. Considering reliable quantifications of regional anesthesia-related nerve injury is 3.5/10 000 (0.00035%) [15], performing such needed patient safety outcome studies may prove extremely difficult to perform due to large numbers of study patients needed. Thus, traditional 'evidence-based' level studies conducted in this particular field of anesthesia will perhaps never be achieved.

Expectations for the future

Standardization of ultrasound-guided regional block techniques based on anatomical factors and an educational concept that is applicable all over the world would be extremely helpful for the implementation of this technique in our daily clinical practice. The triumphal procession of ultrasound-guided regional anesthesia has already started, and it is the responsibility of opinion leaders to provide both excellent science and useful descriptions of individual regional techniques.

Conclusion

Ultrasound guidance in regional anesthesia continues to be an exciting subspecialty and some of the major principles of ultrasound guidance in regional anesthesia include:

(1) Profound understanding and knowledge of human anatomy in order to perform well tolerated and effective ultrasound-guided regional anesthesia.
(2) The aim is to broaden (globally) the use of ultrasound technology, to synthesize it with regional anesthesia techniques, and to then apply the science gained into anesthesia clinical practice by physicians.
(3) Education and training will remain important prerequisites for the continued growth of ultrasound-guided regional anesthesia.
(4) Only adequate volumes of local anesthetics via multi-injection techniques should be used instead of compensation for inadequate techniques and inexact administration of local anesthetic relative to nerve structures with large volumes of local anesthetic.
(5) An extra-epineural needle tip position and subsequent extra-epineural administration of local anesthetic should be considered as the proper peripheral nerve block technique that will continue to provide well tolerated methods of regional anesthesia success.
(6) Regional anesthesia techniques should remain economical to perform and implement when an emphasis on efficiency and improved success is directed toward the anesthesia workflow (fast onset times and high success rates of ultrasound-guided regional anesthesia).

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