Educational and clinical aspects of peripheral nerve blockade

Wegener, Jessica

Link to publication

Citation for published version (APA):
Wegener, J. T. (2013). Educational and clinical aspects of peripheral nerve blockade

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Chapter 1
General introduction

Historical technical developments in peripheral nerve blockades

During the times of progress in medicine, the discoveries of new techniques and pharmacological developments of the vibrant 19th century, it was Sir Francis Rynd who performed the first documented nerve block with morphine in 1845.\[1\] Alexander Wood followed this example with better equipment, consisting of a syringe and a needle, to inject morphine close to the nerve in 1855. In the same period, cocaine, derived from the leaves of Erythroxylon coca, was introduced into clinical practice for its systemic effects.\[2\] Karl Koller, a Viennese ophthalmologist, searched for agents with local insensitivity capacities for eye surgery, and by chance he found the ideal agent. A small sample of cocaine, given by his friend Freud, numbed his tongue. Experiments with cocaine followed successfully, after which Koller instilled cocaine to the eye of patients for local anesthesia prior to eye surgery. The preliminary results of Koller’s clinical trial with cocaine were presented during a meeting of ophthalmologists in Heidelberg (1884). In the same year William S. Halsted, a surgeon in New York, experimented with cocaine after reading Koller’s report and performed the first axillary nerve block by injecting cocaine under direct vision near the nerves. Later, other local anesthetics were developed, because of the addictive and toxic side effects of cocaine. Hirshel (1911) and Kuhlenkampff (1928) refined the techniques to a percutaneous axillary block of the brachial plexus.\[3\] These pioneers gave rise to the development of a plethora of unprecedented approaches and new nerve block techniques, often associated with incomplete anesthesia and unexpected failures or complications.

In contrast to general anesthesia, the use of peripheral nerve blocks in regional anesthesia became less popular due to the moderate success rates. The site of needle insertion was defined upon the basis of external anatomical landmarks, and eliciting paresthesia of the nerve with the needle subsequently localized the nerve. Although Perthes had already described the technique of electrical nerve stimulation in 1912, it took half a century before an electrical stimulator suitable for clinical application in localizing a nerve was available.\[4\] Using this method, corresponding motor contractions are elicited by electrical stimulation when the needle is advanced into the vicinity of the nerve or neural plexus. The current of the
nerve stimulator should be reduced to the threshold at which minimal motor responses are still observed. The quantity of the threshold would be proportional to the distance between the needle tip and the nerve according to the law of Coulomb. A minimum of 0.3-0.5 mA was advised as a safe and effective threshold. Standard needles were soon replaced by specially designed needles with an isolated shaft and blunt tip. This method was believed to contribute to patient safety by reducing the risk of nerve damage, which, however, has never been proved. Although the axillary block was the most commonly used technique for anesthesia of the upper limb, even with guidance by an electrical nerve stimulator the success rates were still around 80-90%.\(^5\)\(^6\) On basis of anatomical studies, incomplete anesthetic blocks were attributed to uneven spread of local anesthetics as a consequence of variable presence of interneural fascial septa.\(^7\)\(^8\) In 2002, a percutaneous variant of the invasive nerve stimulation technique was developed. This technique was used for pre-locating the nerves by indenting the skin with an electrical stimulation pen to elicit accompanying motor and sensory responses.\(^9\) The stimulation pen was believed to assist in determining the optimal puncture site for superficial nerve blocks. After evaluation of the value of the electrical stimulation pen in a volunteer study this technique proved to be unreliable. At the same time, high resolution ultrasonography was introduced that almost revolutionized the field of regional anesthesia. Now pre-location of the nerve was possible by direct visualization of the nerve using ultrasound imaging. The first study of ultrasound-guided supraclavicular nerve block of the brachial plexus was published by Kapral in 1994.\(^10\) Earlier, Ting and Sivagnanaratham reported the use of ultrasonography just to identify the axillary artery for surrounding it with local anesthetics as a new kind of nerve block technique of the brachial plexus.\(^11\) From this time on use of ultrasound guided peripheral nerve blocks accelerated rapidly. Ongoing technological advancements in ultrasound equipment such as higher frequency and high resolution, together with other technical innovations in software made the performance of ultrasound-guided nerve blocks increasingly more accessible. Many advantages of ultrasonography-guidance have been found, such as shortened performance and onset time, improved quality of the block, and the ability to reduce the minimum effective volume of local anesthetic required.\(^12\)\(^-\)\(^15\) Possibly, reduction of volumes of local anesthetics ends in adverse shortening of the duration of action. Ultrasound might support in optimizing patient’s position for applying a specific peripheral nerve block. Adjusting the arm position prior to the performance of an axillary brachial plexus block could change ultrasonic visibility and locations of nerves.
However, the value of nerve stimulation remains evident, and this technique is often used in combination with ultrasound to identify the nerves with more safety and reliability. Nerve stimulation provides functional information to the inexperienced user of ultrasonography in addition to the ultrasonography images of the targeted nerves.

**Education**

The training of peripheral nerve blocks has always been a point of discussion, and has been a shortcoming in many educational programmes. Up to now, no academic center in the Netherlands has a residency program containing a well-defined curriculum for ultrasound-guided regional anesthesia. Inadequate exposure to these techniques during training results in a lack of confidence and competence. Current training methods are still based on ‘trial and error’, which implies acquiring skills through practice in patients under supervision. This process conflicts with ambitions of providing consistently high levels of patient safety and comfort.

The introduction of high-resolution ultrasound to regional anesthesia asks for new skills that must be trained by the anesthesiologist. Anesthesiologists have never used before real-time imaging techniques or ultrasound. For example, the use of ultrasound reveals the immense importance of a thorough knowledge of anatomy. In addition to classical systematic anatomy a more topographic anatomy is required and knowledge of sono-anatomy, which means that the appearance of different tissues on an ultrasound image has to be identified for interpreting the internal anatomical structures. The mastering of new skills requires appropriate training strategies that include the use of ultrasound equipment, handling of the ultrasound probe, identification of sono-anatomy and improved hand-eye coordination to enable advancement of the needle tip to close proximity of the target nerve whilst avoiding surrounding vital structures. There is a growing interest in new training methods, such as simulation training systems for the tuition of unknown techniques to novices. Current learning methods involving ‘trial and error’ techniques in patients are increasingly regarded as unethical. Therefore, the need for sufficient suitable simulation facilities increases.

**Clinical developments**

Since the 1990’s, renewed interests in the clinical application of peripheral nerve blockades have accompanied technical developments. Peripheral nerve blockades were no longer considered as an alternative intraoperative anesthesia technique, but
were increasingly used for improved postoperative analgesia by continuous infusion of local anesthetics instead of single injections. The first provisional catheter technique for continuous administration of local anesthetics was performed by Ansbro long time ago (1946). This unstable construction, consisting of a blunt needle to a rubber tube and a piece of cork with adhesive stripping for fixation, was not worth following. Years later the technique was adjusted by percutaneous insertion of an intravenous catheter adjacent to the plexus. Later on, special nerve catheter sets for continuous infusion were developed by pharmaceutical and medical companies and became widely available. Continuous nerve block techniques offer more site specific pain therapy with fewer side effects and fewer serious complications compared to systemic opioids and epidural analgesia in the management of postoperative pain for patients undergoing surgery of their limbs. Still, general anesthesia followed by postoperative intravenous opioid patient-controlled-analgesia is more widely accepted by surgeons, anesthesiologists and patients and is less dependent on specific technical skills. However, patients suffer from more side effects such as nausea, vomiting, headache, dizziness and fatigue, resulting in prolonged recovery times and significant discomfort. Epidural anesthesia offers excellent postoperative analgesia, but its use is becoming increasingly restricted, mainly due to safety concerns regarding perioperative anticoagulation and the risk of serious neuraxial complications. In addition, the potential side effects of epidural analgesia such as bilateral motor blockade, bradycardia, hypotension and urinary retention might limit postoperative convalescence and mobilization.

A faster recovery and improved pain control with fewer side effects after regional anesthesia compared to systemic and epidural analgesia can be of great advantage in the well-being of patients, especially in the elderly. Thus, the anesthetic management of patients requiring major orthopedic surgery favors a peripheral nerve block as main part of a multimodal postoperative analgesia package.

Another reason of growing interest of peripheral nerve blocks is in the field of chronic pain. Persistent surgical pain is recognized as a major health problem. Unrelieved severe postoperative pain is one of the most important predictors for the development of chronic surgical pain. The prevalence of persistent knee pain following total knee arthroplasty has been reported to occur from 5% to as many as 44% of patients. Use of regional anesthesia for postoperative pain relief may reduce the risk of chronic surgical pain. In this context, more attention is paid for use of peripheral nerve blocks in treatment of severe pain following total knee arthroplasty.
An additional reason for interest in peripheral nerve blocks is related to health economics. In recent years there has been an extensive search for the best methods of postoperative analgesia management for reaching a discharge condition of the patient much faster. Savings in hospital stay are urgently needed in the light of cost explosion in health care inflicted by advances in medical technology and demographic changes of an aging population. Notably, the increasingly large number of older patients undergoing total knee replacement asks for increased use of methods supporting an accelerated recovery.28-31 Hence, peripheral nerve blocks play an important role in the postoperative pain management and functional outcome of patients undergoing total knee arthroplasty and are one of the fundamental elements of a successful pathway for shortened hospital stay in the respective patient population.

**Aims of this thesis**

The aim of this thesis was to elucidate important clinical and educational aspects of peripheral nerve blockades, especially ultrasound-guided regional anesthesia (UGRA).

The following questions were answered in the course of this investigation:

– How to learn a new technique? What methods are available to learn ultrasound-guided regional anesthesia? (Chapter 2). The standard technique of learning manual skills in anesthesia has been ‘learning by doing’. The literature was reviewed and future directions in education in UGRA and research in education in UGRA outlined. The following chapter discusses an example to improve education by technical aids.

– Does a tutorial help to improve the training of ultrasound-guided regional anesthesia for novices in the identification of sono-anatomy? (Chapter 3) Here the value of an onboard tutorial for self-education of trainees in UGRA was evaluated. The tutorial improved the identification of sono-anatomy, however the effect was small and many more training tools than a tutorial are needed to learn UGRA. Probably, transcutaneous nerve stimulation is a potential tool for the trainee to identify superficial nerves that cannot be recognized from the sono-anatomical image. Therefore, in the following study the correlation of sono-anatomy and stimulation-thresholds of transcutaneous nerve stimulation were investigated.
– Does the level of nerve stimulation correlate with the distance between the stimulation electrode and the nerve stimulated as measured by ultrasound? (Chapter 4) Unfortunately, there was no correlation of the depth and position of the nerves seen by ultrasound and the observed excitability and thresholds of transcutaneous electrical stimulation. Another aspect of regional anesthesia has been the best positioning of the patient for a specific block. Thus, for an axillary plexus block the patient has traditionally been positioned on his back with shoulder and elbow 90 degree flexed. Therefore, we investigated systematically in volunteers whether this traditional positioning is actually also for UGRA the best position to visualize the plexus with ultrasound.

– Does traditional patient positioning used for landmark techniques also guarantee the best nerve visibility when using ultrasound? (Chapter 5) Overall the positioning had no great effect on nerve visibility in the axilla. Especially, the visibility of the radial nerve, which is most difficult to identify being often hidden behind the axillary artery, could not be improved. The visibility of two other nerves could be improved by positioning. However, their visibility is usually not a problem during UGRA of the axillary brachial plexus. UGRA enables to reduce volumes of local anesthetics for peripheral nerve blocks. In the next step we evaluated the effect of a reduced volume of local anesthetics on the duration of its action.

– What is the effect of reduced volumes of local anesthetics on the duration of sensory and motor block in ultrasound guided axillary brachial plexus block (Chapter 6). Reduction of volume of local anesthetics restricted the duration of sensory and motor block of individual nerves significantly and time to first request of postoperative analgesia was also significantly reduced. After investigating the education of UGRA and technical aspects, in the last two chapters improvement in postoperative pain therapy, length of hospital stay and long-term pain and functional outcome were investigated.

– Does effective perioperative pain management provided by peripheral nerve blockades in patients undergoing total knee arthroplasty (TKA) shorten hospital stay? (Chapter 7) To what extent is peripheral nerve blocking of the leg needed in patients undergoing TKA? Although the quality of pain therapy was significantly different it did not influence the length of hospital stay

– Does improved postoperative pain therapy result in improved long-term
functional outcome and less chronic postsurgical pain? (Chapter 8). No significant differences could be demonstrated in functional outcomes and pain scores after one year, whereas significant differences were found in immediate postoperative pain scores among different types of peripheral nerve blocks for TKA. Mode of postoperative analgesia management affects functional outcome in the first period following total knee replacement. Some analgesia techniques and medications have beneficial effects on functional outcome after TKA.
References

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