REVIEW ARTICLE

Does the use of ultrasound guidance improve the safety and efficacy of placing peripheral nerve blocks?

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ABSTRACT

Objectives: Peripheral nerve blocks have traditionally been administered using anatomical landmarks or peripheral nerve stimulation to locate the nerve. The use of ultrasound technology has led to a paradigm shift in practice in the placement of these blocks.

Methods: A literature search was performed using the Cochrane Database of Systematic Reviews and PubMed to locate evidence from peer-reviewed journals comparing the efficacy and safety of using ultrasound technology for placing peripheral nerve blocks.

Results: Five evidence sources met the inclusion criteria including 2 systematic reviews with meta-analysis, 2 systematic reviews without meta-analysis and 1 randomized controlled trial. The evidence reviewed indicated that block success rate was at least as good as with other methods and the incidence of some minor complications reduced. Larger studies are needed to evaluate its effect on major complications. Ultrasound may improve the quality of sensory and motor block, onset time and duration of the block. The success of this particular technique may depend on the expertise of the provider. Future studies should include a larger sample size and adopt a consistent method to assess block success, accuracy and competency of the provider.

Conclusions: Providers should consider adopting ultrasound technology when placing peripheral nerve blocks provided they have adequate education and training with the technology.

Key Words: *Regional anesthesia; Ultrasound; Peripheral nerve block*

INTRODUCTION

Anesthesia providers have the option of administering general anesthesia, a peripheral nerve block or a combination when caring for patients undergoing extremity surgery. A nerve block has several advantages compared to general anesthesia including increased hemodynamic stability, avoidance of the manipulation of the airway and increased intraoperative and postoperative analgesia [1].

For a peripheral nerve block to be effective the local anesthetic has to be injected in close proximity to the nerve, therefore locating the nerve is key to the success of the procedure. Various techniques have been used to establish the needle's location close to the nerve. Easily identifiable surface landmarks can be used to guide the point of needle insertion, followed by the distinctive feel of the needle as it passes through various layers of tissue and the elicitation of paresthesia as the needle nears the nerve [2]. Low current electrical stimulation of the nerve has become a popular method of identifying nerve structure; muscles supplied by the nerve can be seen to twitch when the electrical current stimulates the nerve [3].

Ultrasound guidance is increasingly used to facilitate the placement of peripheral nerve blocks. This allows the anesthesia provider to visualize the nerves, blood supply, needle tip and anatomy in real time. Direct visualization of the spread of the local anesthetic should decrease the risk of intravascular injection and local anesthetic toxicity, pneumothorax and failed block [4].

This review will examines the safety and efficacy of using ultrasound guidance for the placement of peripheral nerve blocks

The history of regional anesthesia dates back to 1884 when Karl Koller used a regional block for eye surgery in Vienna, Austria [4]. Between 1884 and the late 1970's regional nerve blocks using anatomical landmarks were developed and became mainstream practice. The pioneers of regional anesthesia used a strict landmark technique to administer their nerve blocks. This technique did not account for abnormal anatomy in patients and therefore led to inconsistent results in the efficacy of the block along with patient discomfort. This led to an aversion of regional anesthesia by practitioners [4].

In 1955, it was demonstrated that when an insulated regional anesthesia needle was attached to a nerve stimulator, an electrical current could elicit a twitch in the muscle innervated by the stimulated nerve. When a muscle twitch is elicited with a current of 0.3 - 0.5mA, the needle is deemed to be in the correct position and local anesthesia is injected. This technique has been widely used in clinical practice since the 1970s and is commonly used to place peripheral nerve blocks [5]. Criticism of the nerve stimulation technique include failure of electrical stimulation to elicit muscle response in all patients [6] and false negative results leading to unnecessary manipulation of the needle [7].

The use of ultrasound to guide the placement of a peripheral nerve block was first describe in 1978 when ultrasound was used to locate the subclavian vasculature during a supraclavicular brachial plexus nerve block [8]. Ultrasound probes both transmit and receive sound waves. They are classified as high (10-15 MHz), midrange (5-10MHz), or low (<5MHz) frequency. High-frequency probes provide high-resolution images but reduced depth penetration when compared to low-frequency probes. High-resolution linear transducers are most suitable when imaging superficial structures, as when performing nerve blocks at the brachial plexus in the supraclavicular, interscalene and axillary regions. The lower frequency curved transducer is better at visualizing structures deeper than 4 cm, such as the infraclavicular area. The success of an ultra-sound guided nerve block is dependent on the skill and experience of the person placing it [1].

The pico question

A common method used to develop an appropriate clinical question is the PICO (patient or population, intervention, comparison, outcome) approach. This mnemonic describes the key components required to construct a good question: patient or population, intervention, comparison and outcome; not all questions have a comparison [9]. The PICO question developed to guide the literature search was: "In the adult patient (patient) does the use of ultrasound guidance (intervention) when placing a peripheral nerve block increase the efficacy and safety of the procedure (outcome)?"

METHOD

Searchstrategy

The search for the evidence was conducted using Cochrane Database of Systematic Reviews and PubMed, 2003 to 2014. The American Society of Regional Anesthesia and Pain Medicine website was also examined for professional practice guidelines. The specific search terms were "regional anesthesia", "ultrasound", and "peripheral nerve block". Evidence was restricted to full text systematic reviews with or without meta-analysis,

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evidence-based clinical practice guidelines (CPGs) and randomized controlled trials (RCTs) not included in the systematic reviews. Further restrictions included evidence written in English and published in peer reviewed journals or appearing on websites of professional organizations. The reference lists from reviewed articles were examined for relevant evidence. The "related links" tool in PubMed was also used to locate sources. Evidence included in systematic reviews was not individually appraised.

The titles for all the sources of evidence were reviewed for relevancy. Then, the abstracts of sources meeting inclusion criteria based on their title were examined. Finally, the full text of relevant sources was reviewed for inclusion. The number of sources meeting the inclusion criteria at each level is described in the Figure 1.

RESULTS

Critical appraisal of the literature

The search revealed 5 evidence sources meeting the inclusion criteria consisting of 2 systematic reviews with meta-analysis [10-12] systematic reviews without meta-analysis and 1 randomized controlled trial (RCT) not included in the systematic reviews. One of the systematic reviews without meta-analysis was a Cochrane Review [13]. Studies included in the systematic reviews with or without meta-analysis were not appraised separately. Of the 4 systematic reviews included 4 shared 3 studies, 3 shared 11 studies and 2 shared 7 studies. Systematic reviews overcome some of the limitations of individual studies and are considered the strongest form of evidence [14]. The studies were critiqued by the method proposed by Melnyk and Fineout-Overholt [15] and presented in the Table 1.

One of the systematic reviews with meta-analysis compared peripheral nerve blocks performed using ultrasound guidance with those administered using electrical neuro stimulation [11]. Full text copies of all relevant articles were obtained and 2 authors independently assessed whether each article met the inclusion criteria (perspective data collection, randomization, and comparison of ultrasound and peripheral nerve stimulation guidance for peripheral nerve blocks in humans). This resulted in 13 randomized controlled trials involving a total of 946 subjects being included in the meta-analysis.

All studies that were included in this systematic review with meta-analysis, 11 were independently rated for methodological quality using a 9 item scoring system. There was no discussion of how the validity of this tool was assessed or if it had been used in previous reviews. Six studies were rated as good quality and 7 as fair quality studies. For binary outcomes, pooled risk ratio was calculated and standard errors were calculated for continuous outcomes. Interpretation of results may be limited due to the small number of studies included in each meta-analysis.

Another systematic review with meta-analysis addressed the analgesic efficacy of ultrasound-guided regional anesthesia and included 16 randomized controlled studies that compared ultrasound-guided nerve blocks to those performed using surface landmarks or nerve stimulation techniques [10]. Interestingly, methodological quality assessment of the constituent studies was not performed. The authors suggested that the failure to completely report methodology does not necessarily imply inadequacy of a specific study. Statistical analysis, including assessment of heterogeneity was performed using software available from the Cochrane Collaboration. Relative risk ratios with confidence intervals were calculated to measure outcome differences. Limitations of this meta-analysis included a small number of subjects in the meta-analysis, the ability to generalize the results to anesthesia providers who are less skilled with ultrasound and the heterogeneity of the data sources.

Two systematic reviews without meta-analysis 3, 12 were appraised and 1 was performed by the Cochrane Collaboration.3 One of the systematic reviews 3 included 18 trials containing data from 1344 subjects assessing whether the use of ultrasound to guide peripheral nerve blocks is advantageous over other methods. The inclusion criteria for this review stipulated that the

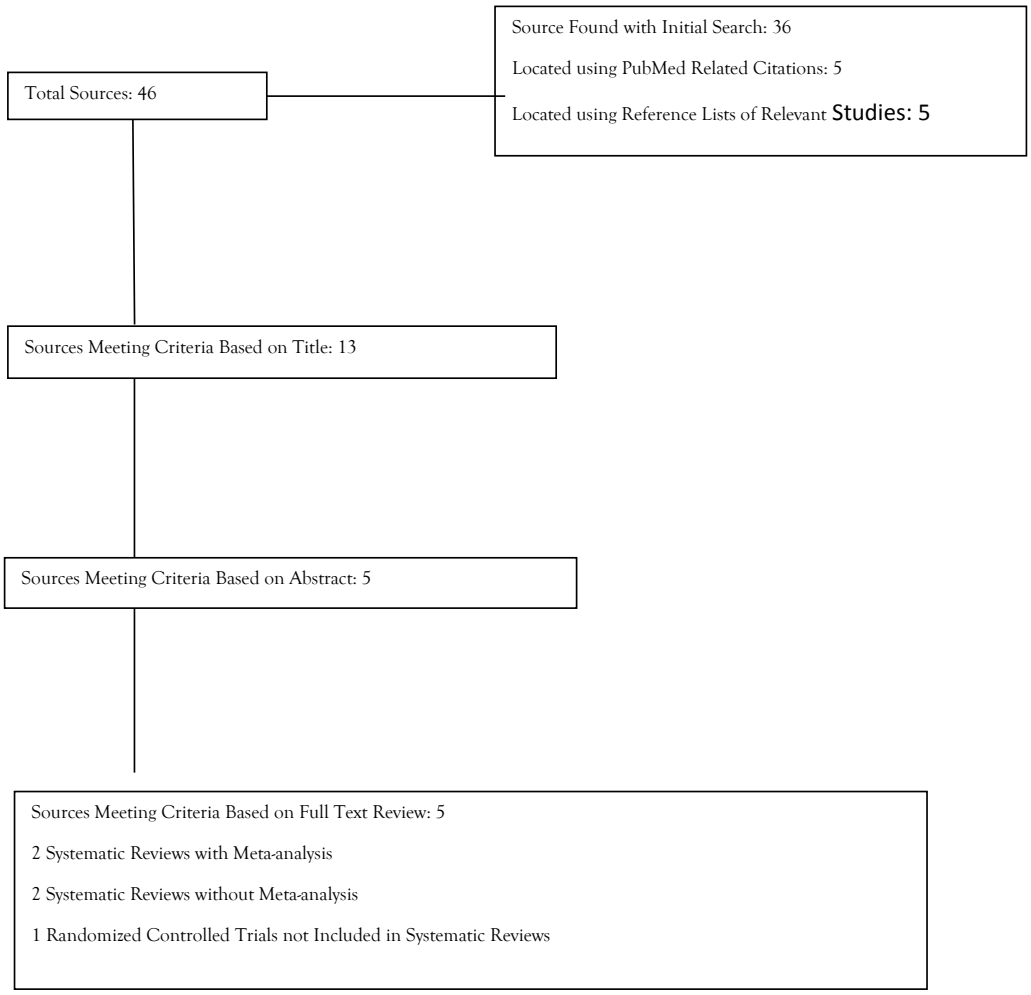

Figure 1: Flow diagram of the search for evidence examining if ultrasound guidance improves the safety and efficacy of placing peripheral nerve blocks

TABLE 1

Evidence evaluating if ultrasound guidance improves the safety and efficacy of placing peripheral nerve blocks

Evidence source	Evidence type, level, subjects	Outcomes	Comments
Abrahams, et al.	Systematic review with meta-analysis Level 1 13 trials 964 subjects	Blocks performed using US guidance versus PNS more likely to be successful, shorter performance time, shorter mean onset time, longer block duration, reduced risk of vascular puncture Block failure (RR 0.41, [95% CI 0.26-0.66, p<.0001]) Mean performance time: 1 min less, [95% CI 0.4-1.7 min, p=.003] Mean onset time: 29% faster with US, [95% CI 45-12%, p=.001] Block duration: 25% longer duration, [95% CI 12-38%, p<.001]. Risk of vascular puncture: (RR 0.16, [95% CI 0.05-0.47, p=.001])	· Rigorous review method 6 good quality, 7 fair quality studies. · Possible risk of publication bias · Interpretation of results may be limited due to small number of studies in each meta- analysis
Sites, et al.	RCT; level 2 107 subjects	Blocks performed using USNS versus US showed no significant difference in the partial or complete blocks, more redirections required in the USNS group with a higher percentage requiring more than 2 needle attempts, more time performing the blocks in the USNS group. No significant differences in the proportion of patients with partial or complete block (OR 2.97, p=.19). More needle redirections in the USNS group (4.1 *vs.* 1.1, p<.001), with higher percentage requiring more than 2 needle attempts (44.2% *versus* 18.9%), p<.01. More time performing block in USNS (188 *vs* 148 secs, p=.01)	· Power analysis performed. · Patient, operator and sedation nurse not blinded. · The blocks were recorded and the videos reviewed increasing the risk of reviewer bias
Walker, et al.	Systematic review; level 1 18 trials and 1344 subjects	Blocks performed using US provided similar block success rate as peripheral nerve stimulation, appeared to improve the quality of both sensory and motor block, reduced insertion times and onset times, reduced the number of needle passes and attempts. No differences in complication rates were found Success rates: range US 72% to 98.8%; PNS 58% to 93.1%. Insertion time: mean difference 2-5 mins Onset time: mean difference 4-14 mins	18 trials including 1344 patients were included in the systematic review. The methodology was assessed using criteria outlined in the Cochrane Handbook for Systematic Reviews of Interventions and most were found to be of moderate quality. All trials deemed to have a moderate risk of bias due to inability to blind the practitioner.
Liu, et al.	Systematic review: level 1 16 trials and 778 subjects	Blocks performed using US resulted in a faster initial onset, modestly improved the quality especially in the lower extremities, but did not increase the duration of the block For upper extremity blocks with US: 9/15 (60%) studies reported a faster onset of block. 4/16 (25%) reported better quality of block. 1/6 (17%) reported longer duration of blocks. Only 1 RCT reported US to be inferior in any outcome. For lower extremity blocks with US: 5/7 (71%) reported faster onset. 5/8 (63%) reported better quality 0/3 (0%) reported longer duration of blocks. No RCT reported that US was inferior in any outcome.	Sixteen RCTs for upper extremity blocks and 8 RCTs for lower extremity blocks included. Quality was assessed using a Jadad score. The average Jadad score was 2 which would indicate a moderate risk of bias Interpretation of results may be limited due to RCTs having small sample sizes.
Gelfand, et al.	Systematic review with meta-analysis; level 1 16 trials and 622 subjects	Blocks performed using US resulted in an increased success rate with the exception of infraclavicular nerve blocks. US *versus* all non US techniques: associated with an increase in the success rate (RR = 1.11 [95% CI 1.06 to 1.17, p<.0001)] US *versus*. NS: US associated with an increased success rate (RR = 1.11 [95% CI: 1.05 to 1.17, p=.0001]). For specific blocks: US versus all non-US techniques increased success with US with: Brachial plexus blocks (all) (RR = 1.11 [95% CI: 1.05 to 1.20, p=.0001]). Sciatic popliteal block (RR = 1.22 [95% CI: 1.08 to 1.39, P=.002]). Brachial plexus axillary block (RR = 1.13 [95% CI: 1.00 to 1.26, p=.05]). No difference found with infraclavicular block (RR=1.25 [95% CI: 0.88 to 1.76, p=.22])	16 RCTs met the inclusion criteria. All statistical analyses, including assessment of heterogeneity, were performed with RevMan (The Nordic Cochrane Center, The Cochrane Collaboration) Interpretation of results may be limited due to small number of studies in each meta-analysis. Unable to comment on the quality of constituent studies as methodological quality assessment was not performed. Studies performed at center where providers likely to be highly skilled with ultrasound technology limiting the generalization of finding.

PNS, peripheral nerve stimulator; US, ultrasound; RR, risk ratio; CI, confidence interval; RCT, randomized control trial; USNS, ultrasound with nerve stimulator; OR, odds ratio.

study must be an RCT comparing ultrasound guided peripheral nerve blocks with at least 1 other method of nerve location; most compared ultrasound with peripheral nerve stimulation. The trials were assessed for quality using established criteria and were deemed to have a moderate risk of bias due to the inability to blind the provider. The results may not be reproducible when ultrasound is used by less skilled providers.3

Another systematic review without meta-analysis included 24 RCTs looking at the onset, quality and duration of peripheral nerve blocks. The quality of the studies was rated using a Jadad score with a median score of 2 on a scale of 0-5. The inability to blind the provider during the administration of a peripheral nerve block typically reduced this score [12]. Another potential weakness of this review was the small sample size of the RCTs.

The RCT was single-blinded and compared sensory and motor loss after a femoral nerve block performed with ultrasound versus ultrasound with PNS.13 Approximately 37 patients per group were required to obtain a power of 0.80. The authors examined 170 subjects undergoing unilateral total knee arthroplasty. The effects size was measured using odds ratio (OR). A limitation of the study was that the patient, operator and sedation nurse were not blinded, increasing the risk of bias in the study.

DISCUSSION

Two of the reviews and the RCT measured complication rates. No differences were found in complication rates when using ultrasound versus other techniques to place peripheral nerve blocks. When comparing ultrasound to peripheral nerve stimulation a statistically significant incidence of vascular

puncture was observed [11]. Authors of only 1 study concluded that they had insufficient power to reach any conclusions related to complications. Efficacy was measured using 4 different outcomes: success rates, onset, quality and duration. Three of the reviews measured success rates found an increased success rate when using ultrasound and found no difference. Three of the reviews and the RCT measured onset of the block when using ultrasound with the 3 reviews finding faster onset and the RCT finding no difference. Two reviews and the RCT addressed quality of the block when using ultrasound with both of the reviews reporting a better quality of block and the RCT finding no difference [13]. Duration was found to be prolonged in 1 review 11 with no difference reported in the second [12].

Safety Complication rates were evaluated by the authors of the Cochrane systematic review of the systematic reviews with meta-analysis and the RCT [13]. In the systematic review with meta-analysis of the studies compared the risk ratio between the ultrasound and peripheral nerve stimulation group. Complications assessed were vascular puncture, postoperative bruising at the site of the block, and persistent neurological symptoms in the distribution of the nerves blocked. No major complications such as systemic local anesthetic toxicity, pneumothorax or persistent neurological damage were reported.

Four of the systematic review with meta-analysis reported an increase in the incidence of vascular puncture with peripheral nerve stimulation compared with ultrasound. No statistical difference was reported between the 2 groups in the incidence of paresthesia during block placement or persistent neurological symptoms after the blocks resolution. The authors recommended that larger studies are needed to determine whether the use of ultrasound decreases the incidence of local anesthetic toxicity [11].

In the Cochrane systematic review trials recorded complication rates. There was no report of major complications in any included study. One trial found a significant reduction in complications in the US group although no differences were found in the incidence of individual complications. Eight trials had a lower incidence of hematoma or vascular puncture in the ultrasound group. There were no adverse effects reported related to use of the ultrasound. The RCT found no complications in either group but stated that their study was not sufficiently powered to detect this [13].

Success rate

When evaluating the success rate of peripheral nerve blocks both the systematic reviews with meta-analysis concluded that the use ultrasound when placing the blocks increased the likelihood that the blocks were successful. Success was defined as anesthesia sufficient for surgery without supplementation either with additional nerve blocks or general anesthesia [10].

Ultrasound guidance was also associated with a greater success rate when used for all the brachial plexus blocks except for the infraclavicular block [10]. There was an increased risk of patients requiring conversion to general anesthetic or spinal anesthetic in the non-ultrasound group, although no difference was found in the need for rescue blocks.

The authors of the Cochrane systematic review assessed block success defined as achieving surgical anesthesia without supplementary pain relief or conversion to general anesthesia. The results of 3 of the 14 trials suggested a significant improvement with ultrasound compared to peripheral nerve stimulation. One trial showed a significant improvement when ultrasound was compared to the transarterial method for axillary blocks. Ten studies showed no difference in block success rates. Overall, block success rates were similar for ultrasound and peripheral nerve stimulation (range 72% - 98.8% with ultrasound and 58% to 93.1% with peripheral nerve stimulation).

Onset time

Onset time of the block was measure by both the systematic reviews of the systematic reviews with meta-analysis and the RCT. In the Cochrane systematic review studies measured onset time of the blocks. Six found that onset times were significantly improved with ultrasound, 1 reported a faster onset with US in only 1 of 4 measured components, 2 showed no difference between the 2 groups and 1 showed a longer onset in the ultrasound group. In the other systematic review 6 of 16 RCTs reported onset time for nerve blocks in the upper extremities. Two reported a faster onset for the block of 4 to 12 minutes, 3 of the 6 reported no difference and 1 of 6 reported a slower onset by 2 minutes. For lower extremity blocks, 3 of 5 RCTs reported a faster onset of the block by 11-14 minutes with the remaining 2 reporting no difference [12].

In the meta-analysis 8 studies compared the onset time for nerve blocks using PNS or US. The US group had a 29% faster onset time when compared to the peripheral nerve stimulation group 11 The RCT showed no statistically significant difference in onset time when ultrasound alone was compared to ultrasound in conjunction with peripheral nerve stimulation [13].

Duration of the block

Duration of block was reported in 1 of the systematic review the meta-analysis 11 and both of the systematic reviews without meta-analysis. In the systematic reviews without meta-analysis only 1 of 8 RCTs 12 and 1 of 6 RCTs 3 noted a prolonged duration of nerve block when performed using ultrasound. In the systematic review with meta-analysis 5 studies examined the duration of block and found a 25% increase in duration when ultrasound was used [11].

Quality

The quality of the block was reported in both of the systematic reviews without meta-analysis. In 1 of the reviews, the authors reported that in 15 studies assessments were made of the quality of the nerve blocks. Six of these studies found statistically improved quality of sensory block with ultrasound, 1 study found this improvement was restricted to a single dermatome and 6 studies found no statistical difference between the 2 groups.3 Another of the systematic review found that only 4 of 16 RCTs that looked at upper extremity blocks reported superiority in at least 1 measure of block quality; 5 of 8 RCTs that looked at lower extremity blocks reported superiority in some quality measures [12].

Summary

The use of ultrasound for invasive procedures is common practice in many institutions. While this review revealed some contradictory evidence as to the effects on efficacy and safety of using ultrasound when placing peripheral nerve blocks, individual studies included in the reviews suggested that with the use of ultrasound success rates was at least as good as with other methods 3,10,11 and the incidence of some complications reduced. Ultrasound may improve the quality of sensory and motor block onset time and duration of the block. Some authors noted that the success of this particular technique may depend on the expertise of the provider administering it. This can make it difficult to generalize the findings to populations at large.

A common weakness in the studies reviewed was small sample sizes 10-12 along with the lack of consistency in the methods used to assess block success and accuracy. The use of ultrasound for placing nerve blocks is still relatively new and recommendations about how to record block performance and success may aid in study designs and allow for more comparable results. Providers must consider obtaining appropriate training before using ultrasound.

Future 1 studies should continue to measure the effect of ultrasound on the efficacy and safety of placing peripheral nerve blocks. Larger studies with consistent methods of measuring block performance and success rate as well as the skill level of the anesthesia providers administering the block will strengthen the validity and reliability of future studies.

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