Update in Anesthesia of Joint Arthroplasty

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Abstract: Ultrasound Guided has had a profound effect on regional anesthesiology and acute pain medicine. Despite the heterogeneity in the design of multiple RCTs, USG has consistently provided improved outcomes regarding block procedure time, block onset time, and (depending on the varying definitions) increased block success for single-injection and CPNBs. More recent data support a role for preprocedural USG in patients with predictors of technically difficult spinal anesthesia. Although the evidence for decreasing the risk of peripheral injury is currently lacking, accumulating evidence confirms that USG decreases but (just as important) does not eliminate the risk of LAST. Finally, the focus of research has appropriately changed to investigating the optimal USG techniques for specific nerve blocks and emerging data should further expand the applications and benefits of regional anesthesia.

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Introduction

Preoperative optimization is mandatory as the chances of serious complications within 30 days of joint replacement surgery is as high as 2.2%. In addition to established protocol for age and co morbidities, an elaborate pre-anesthetic check up should include rheumatoid arthritis, cardiovascular morbidity and assessment of co-morbidities Renal function may be impaired owing to age, hypertension or chronic use of non-steroidal anti inflammatory drugs (NSAIDs). Musculoskeletal other joint involvement is common. The range of limb and neck movements should be noted. Obesity may be a cause or consequence of degenerative joint disease. Assessment for positioning on the table and for regional blockade should be made. In patients with metastatic disease, the bone scan should be checked to ensure there are no spinal deposits that may interfere with regional anaesthesia. **(Kakar et al, 2012)**

Patients undergoing total joint arthroplasty (TJA) experience high levels of pain after surgery that often interferes with their functional recovery and sleep patterns in the postoperative period. In one study, patients undergoing total hip arthroplasty (THA) and total knee arthroplasty (TKA) reported mean worst pain severities of 7.6 and 8.1 on a 10-point scale, respectively. Numerous techniques have been developed for anesthesia and analgesia in an effort to optimize perioperative pain control, patient satisfaction, and functional recovery. Each method for pain control is associated with specific benefits, risks, side effects, economic implications, patient satisfaction levels, and labor requirements for the health care team. **(Webster et al, 2010)**

The use of regional anesthesia and peripheral nerve blocks has facilitated and improved the perioperative pain. Many different approaches and techniques for peripheral nerve blockades, either landmark or, more recently, ultrasound guided have been described over the last decades. This includes but is not restricted to techniques discussed in this review. The introduction of ultrasound has improved many approaches to peripheral nerves either in success rate and/or time to block. Moreover, ultrasound has enhanced the safety of peripheral nerve blocks due to immediate needle visualization and as consequence needle guidance during the block. In contrast to patient controlled analgesia using opioids, patients with a regional anesthetic technique suffer from fewer adverse events and show higher patient satisfaction. **(Danninger et al, 2014)**

Clinical pathways for total joint arthroplasty have been shown to reduce costs and significantly impact perioperative outcomes mainly through reducing provider variability. Effective clinical pathways link evidence to individual practice and balance costs with local experience, outcomes, and access to resources for responsible perioperative management. Common components of clinical pathways with major impact on perioperative outcomes are: 1) implementing pathways designed to include multimodal analgesia with regional anesthesia, 2) use of tranexamic acid to reduce blood loss, and 3) preconditioning followed by participation in early, accelerated rehabilitation programs to prevent postoperative complications related to immobility. **(*Johnson & Kopp, 2014)***

Several important concepts had been demonstrated in acute perioperative pain medicine. First, preoperative multimodal medications are paramount to effective postsurgical pain control. Second, interruption of pain pathways at multiple anatomic levels is optimal. In this case, peripheral nociceptors, spinal pathways, supraspinal signaling centers, and systemic anti-inflammatories all contributed to providing analgesia for this patient. Finally, the opioid-tolerant patient requires special consideration, as her analgesic needs are increased while her opioid safety margin is diminished. **(Fisher et al, 2012)**

Aim of Work

To focus on recent literature about anesthesia Of joint arthroplasty. Special features of regional anesthesia in joint Arthroplasty, recent studies about ultrasound guided regional anesthesia for joint Arthroplasty, and acute pain management, and success rates and risk profiles in this setting are presented.

Evidence Based Medicine in Ultrasound Guided Regional Anesthesia in Joint Arthroplasty

Ultrasound guidance (USG) has gained widespread acceptance in anesthesiology and perioperative medicine. ***(Terkawi et al, 2013).*** Evidence strongly supports increased safety, effectiveness, and efficiency of vascular access with USG compared with anatomic landmark-based techniques. ***(Lamperti et al, 2012)***

In 2010, The American Society of Regional Anesthesia and Pain Medicine published an executive summary and accompanying series of articles, providing evidenced-based recommendations on the use of USG for regional anesthesia. ***(Neal et al, 2010)***. This series of articles critically appraised outcomes comparing USG to traditional landmark-based techniques (predominantly peripheral nerve stimulation [PNS]) as a nerve localization tool. Central to this series was the inclusion of only randomized controlled trials (RCTs), systematic reviews, meta-analyses, comparative studies, and large case series investigating the specific primary outcomes. Overall, these articles demonstrated that, for PNBs, USG provided a more rapid onset of sensory and/or motor block, increased block success, improved block quality (sensory and/or motor), decreased block performance time, and decreased local anesthetic dose requirements. ***(McCartney et al, 2010).*** Almost all studies did not specifically investigate or were not powered for success of surgical anesthesia as the primary outcome. At that time, there was insufficient evidence demonstrating a decrease in the incidence of clinically relevant patient-safety outcomes of peripheral nerve injury (PNI), local anesthetic systemic toxicity (LAST), or pneumothorax. Notably, there was a lack of published data directly comparing USG to traditional landmark-based techniques for central neuraxial anesthesia. ***(Salinas, 2010).*** Two subsequent meta-analyses specifically investigated the primary outcome measure of anesthesia sufficient for surgery without supplementation (additional nerve blocks or exceeding a predetermined amount of intravenous systemic analgesia) or conversion to general anesthesia. The pooled data from these 2 meta-analyses showed that USG was associated with an increased success rate of surgical block. ***(Gelfand et al, 2011).***

After this series of articles, there has been a few RCTs directly comparing USG to PNS for PNBs. There are several reasons:

1. USG has rarely been found to be inferior to PNS, so perhaps there is less interest in adding additional data regarding the benefits of USG compared with PNS; ***(Liu et al, 2010)***
2. With the rapid improvement (increased image quality and portability) and decreased cost of ultrasound (US) technology, the cost-benefit argument against USG continues to decrease in terms of economic relevance; ***(Perlas, 2010)***
3. The widespread adoption of USG as the dominant technique of peripheral nerve localization. ***(Helwani et al, 2012)***
4. A shift in the emphasis on future research defining the optimal techniques for USG regional anesthesia. ***(Choquet et al, 2102).***

Recent evidence comparing ultrasound guidance to peripheral nerve stimulation for peripheral nerve blocks

Two recent RCTS examined block performance times directly comparing USG to PNS in anesthesia trainees. In a study of 41 subjects undergoing preoperative interscalene block before arthroscopic shoulder surgery, USG resulted in a statistically significant decrease in block performance time of 57% and sensory block onset time of 37%. There was no difference in block success for surgical anesthesia, which was similarly high in both groups (95% vs 91%), most likely due to the large mass of local anesthetic used in this protocol. ***(Cataldo et al, 2012).***

In a study of 71 subjects undergoing hallux valgus repair using popliteal sciatic nerve block (PSNB), USG did not provide any increase in onset time or surgical block success within 30 minutes compared with PNS. USG decreased block performance time by 20% (82 seconds), although this was a secondary outcome. **(Trabelsi et al, 2013)**

In 60 subjects scheduled for upper limb surgery undergoing preoperative infraclavicular block (ICB), subjects were randomized to either USG or PNS. This was powered to detect a 10-minute difference in complete sensory and motor block onset. There was no significant difference in block procedure time or block onset time. Although, it was a secondary outcome, USG resulted in a 100% block success at 30 minutes compared with 74% with PNS. ***(Sala-Blanch et al, 2012).***

In a study of 52 subjects undergoing PSNB block before hallux valgus repair, subjects were randomized to either USG or PNS with 20 mL mepivacaine 1.5%. The proportion of subjects with a complete sensory (80% vs 4%) and motor block (60% vs 8%) at 15 minutes was significantly higher with USG, although by 30 minutes all subjects had adequate sensory block to allow surgery without supplementation. In 39 subjects undergoing interscalene block with ropivacaine 0.5% before arthroscopic shoulder surgery under general anesthesia, the minimum effective anesthetic volume (MEAV) required to achieve a postoperative verbal rating scale of 0 was compared for USG and PNS. The MEAV required to provide effective analgesia was lower with USG. Despite this difference, it is notable that the MEAV for effective postoperative analgesia was relatively low in both groups. ***(McNaught et al, 2011).***

In another recent RCT directly comparing USG to PNS in subjects receiving interscalene block for shoulder surgery, there was no difference in sensory block onset time using 20 mL of ropivacaine 1%. Because studies have shown that successful interscalene brachial plexus block with USG may be achieved with much lower doses of ropivacaine (7 mL ropivacaine 0.75%), **(Gautier et al, 2011).**

recent evidence for ultrasound guidance in central neuraxial anesthesia

Based on the limited evidence available at the time of the initial evidence-based review, ***(Perlas, 2010)*** no firm recommendations were provided, although it was suggested that USG for central neuraxial anesthesia may be a useful adjunct to traditional landmark-based physical examination. The current application of USG for central neuraxial block may be classified into 2 categories: (1) US-assisted technique and (2) real-time USG technique.

[1] Ultrasound-Assisted Technique

Two complementary scanning planes are used to identify acoustic windows for subsequent needle insertion and advancement: a transverse-midline (TM) plane and a paramedian sagittal-oblique (PSO) plane. A standardized preprocedural scan can be used to identify the specific intervertebral space, the estimated US depth to either the epidural space or the subarachnoid space, and, most important, the initial needle insertion site. ***(Chin et al, 2013).*** Both the TM and PSO imaging planes can potentially identify the posterior complex and the anterior complex (***Figures. 1 and 2***). The ability to visualize the anterior and/or posterior complex through these open acoustic windows suggests an unobstructed path to the targeted central neuraxial space between either the adjoining spinous processes or the adjoining lamina. ***(Karmakar et al, 2012)***

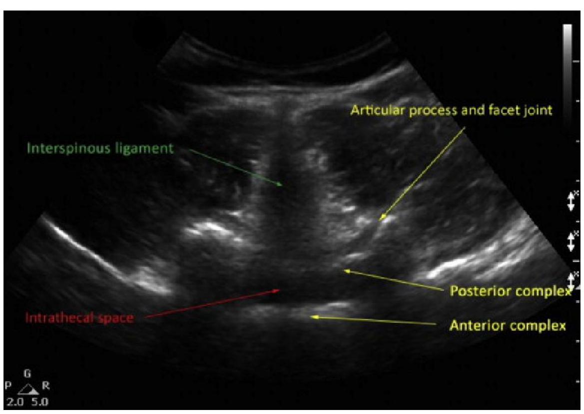

Figure-1: Transverse midline interlaminar view of the lumbar spine.

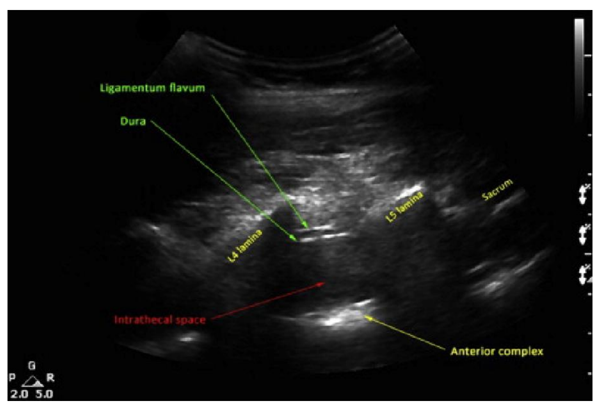

Figure- 2: Paramedian sagittal oblique of the L4-L5 intervertebral space through the interlaminar window.

[2] Real-Time Ultrasound-Guided Technique

The real-time USG technique requires maintaining the desired imaging plane with one hand while advancing the spinal needle in real time with the other hand. Otherwise, a second operator would be required to either hold the US transducer or advance the needle. This has been described in recent case series, ***(Brinkmann et al, 2013),*** but direct comparative studies to either landmark techniques or preprocedural US-assisted technique are notably lacking.

After the Perlas review, ***(Perlas, 2010),*** in a quantitative systematic review of central neuraxial analgesia in obstetric subjects, USG was associated with significant reductions in both needle puncture attempts and fewer punctures levels. ***(Schnabel et al, 2012).*** More specifically, in subjects in whom it was presumed that central neuraxial blocks would be potentially difficult, the success rate with USG was 71% compared with only 20% with conventional landmark techniques. That 84% of the data came from a single institution suggests a potential for publication or selection bias, which limits generalizability of the results. ***(Vallejo et al, 2010)***

Since 2010, there have been 5 RCTs that have directly compared US-assisted spinal anesthesia and lumbar epidural analgesia to landmark-based techniques. ***(Ansari et al, 2014), (Sahin et al, 2013), (Chin et al, 2011), (Lim et al, 2014).*** All 5 trials were adequately powered to detect a significant difference in the primary outcomes of interest: successful dural puncture on the first attempt, time required to perform successful block, or success rate of epidural labor analgesia. In all 5 trials, the USG group had a standard preprocedural TM and/or PSO scan to determine the initial needle puncture site, whereas the needle puncture site in the landmark groups was identified by palpation lumbar spinous processes and estimation of the intercristal line.

In an RCT of 150 obstetric spinal anesthetics with easily palpable landmarks in all subjects, USG failed to show a significant difference in procedure time, number of skin punctures, or needle passes compared with a landmark technique. ***(Ansari et al, 2014).***

In contrast, USG significantly improved the first-pass success rates in a study stratifying subjects as either nonobese or obese. In this study, the first-pass success rate in both nonobese and obese subjects with USG was 92% compared with a first-pass success rate of 72% in nonobese and only 44% in obese subjects without USG. ***(Sahin et al, 2013).***

A recent RCT has evaluated the usefulness of US-guided spinal anesthesia in nonobstetric subjects. In this RCT of 170 subjects scheduled for orthopedic, general surgical, and urologic procedures, USG failed to demonstrate a significant difference in either first-pass success rate or number of needle redirections. ***(Lim et al, 2014).***

An RCT investigated the impact of preprocedural USG on the efficiency of spinal anesthesia in subjects with (1) BMI greater than 35 kg/m^2, (2) moderate-to-severe lumbar scoliosis, or (3) previous lumbar spinal surgery. In this study, the average BMI (39 vs 41 kg/m^2) and percentage of subjects with difficult-to-impossible surface landmarks (61% and 75%) was similarly high in both the US and landmark groups. USG provided an advantage in the primary outcome of first-pass success rate (65% vs 32%), as well decreases in mean number of needle insertion attempts and mean number of total needle passes. ***(Chin et al, 2013)***

Although the single RCT looking at a clinically relevant outcome of failed labor epidural analgesia demonstrated an advantage with USG, not unexpectedly, ***(Vallejo et al, 2010)*** none of the 4 RCTs investigating spinal anesthesia failed to demonstrate an increase in success of surgical anesthesia once cerebrospinal fluid was obtained. ***(Ansari et al, 2014), (Sahin et al, 2013), (Chin et al, 2011), (Lim et al, 2014).***

In a prospective observational study of 60 subjects presenting for lower extremity orthopedic surgery, a standard PSO view of the lumbar spine (see ***Figure 2***) was performed by operators with extensive experience in central neuraxial US. They rated the ability to see the anterior complex and quality of image as either absent, hazy, or clear. Subsequently, another anesthesiologist, blinded to the preprocedural US scan, performed spinal anesthesia. Technically difficult spinal anesthesia was defined as greater than or equal to 10 needle passes and a duration greater than 400 seconds. Poor US visualization of the anterior complex was associated with a 50% rate of difficult spinal anesthesia, whereas the ability to clearly see the anterior complex was associated with only a 9% rate of technical difficulty. ***(Weed et al, 2011)***

recent evidence for ultrasound guidance and patient safety

Three recently published studies that provide newer data on the incidence of PNI and LAST, with and without USG are summarized.

In a prospective single-center clinical registry of 12,668 USG PNBs over an 8-year period (2003–2011), the reported incidence of long-term PNI was found to be 0.9 per 1000 blocks. There was 1 case of LAST (seizure) for a reported incidence of 0.08, highlighting that the incidence is very low. There were no cases of pneumothorax in 1508 USG supraclavicular (SCB) blocks. ***(Sites et al, 2012)***

In a recent update of a single-center quality assurance database, the incidence of PNI and LAST was reviewed in 9062 PNBs using combined USG with PNS and in 5436 blocks with landmark-based PNS alone. There was no difference in the incidence of long-term PNI between the USG-PNS technique and the landmark-PNS technique. In contrast, there was a statistically-significant difference in the incidence of LAST between US-PNS and landmark-PNS. It was notable that the historical incidence of LAST at this single center was 1 to 3 seizures per year when landmark-PNS was the dominant nerve localization technique. However, over the 6-year study period, the use of USG-PNS increased from approximately 10% to approximately 90%, suggesting that adoption of USG decreased the risk of LAST during this transition period. ***(Orebaugh et al, 2012)***

The most recent update of Australian and New Zealand Registry of Regional Anesthesia (AURORA) further expands the evidence regarding the role of USG in reducing the risk of LAST. The study population of 20,021 subjects who received 25,336 PNBs at 20 hospitals is the largest prospective database to date. There were 22 reported episodes of LAST for an overall incidence of 0.87 per 1000 blocks. ***(Mulroy & Hejtmanek, 2010).***

However, there were 10 cases of LAST in the 4745 PNBs without USG for an incidence of 2.1 per 1000 blocks. In contrast, there were 12 cases of LAST in 20,401 USG PNBs for an incidence of 0.59 per 1000 blocks. The primary finding of this study is that when compared with PNS alone, USG reduced the likelihood of LAST by greater than 65%. However, an accompanying editorial highlighted that USG did not completely eliminate the incidence of LAST, and that USG does not eliminate the need for using the minimum effective local anesthetic dose, judicious use of intravascular markers, incremental aspiration and injection, and availability of lipid emulsion and checklists when LAST does occur. ***(Weinberg et al, 2010)***

Pneumothorax is a potential complication commonly associated with either SCB or ICB approaches to the brachial plexus. Recently published large case series do provide updated point estimates of risk. There have been 2 cases of symptomatic pneumothorax in a total of 4736 ICBs, with the most recent prospective observational study providing an estimated risk of 0.7 per 1000 blocks. ***(Gauss et al, 2014).***

A prospective registry did not report a single case of pneumothorax in 654 USG-SCBs, ***(Liu et al, 2010),*** and in more than 3000 USG-SCBs, a group with substantial experience reported only 1 case of symptomatic pneumothorax over a 4-year period. ***(Brull & Chan, 2011).***

More recently, 2 large prospective observational studies of USG-SCBs have reported an incidence of 0.06 in 3403 blocks or 0.6 per 1000 blocks, ***(Gauss et al, 2014),*** and 0.4 in 2384 blocks or 0.4 per 1000 blocks. ***(Abell & Barrington, 2014).*** The reported cases had either immediate or delayed onset of symptoms subsequently confirmed by chest radiography. Because routine chest radiography is typically not performed after either ICB or SCB, there is likely a higher incidence of asymptomatic pneumothorax that can spontaneously resolve without sequelae.

Evidence for ultrasound guidance and continuous peripheral nerve blocks

CPNBs have been consistently shown to provide superior postoperative pain control and decreased opioid-related side effects compared with both systemic opioid analgesia and single-injection PNBs. ***(Richman et al, 2006), (Bingham et al, 2012).*** A recent meta-analysis reviewed 977 subjects in 15 RCTs comparing USG with PNS. The primary outcome was defined as perioperative successful catheter placement (defined primarily as successful peripheral nerve catheter placement within a defined time period but also included successful surgical block when investigated). ***(Schnabel et al, 2013).*** Overall, USG provided a modest but statistically significant benefit for successful catheter placement with the most benefit occurring with popliteal sciatic and ICB perineural catheter placement, as well as lower risk of accidental vascular puncture. In contrast, postoperative pain scores with movement were comparable between USG versus PNS-guided peripheral nerve catheters. In a unique cost-effectiveness analysis, the incremental cost-effectiveness ratio was calculated using 4000 nonparametric bias-corrected bootstrap replicates for USG continuous sciatic nerve block. ***(Ehlers et al, 2012).*** The mean ICER was negative, indicating that USG leads to better effect and lower cost compared with PNS guidance alone. Subsequent RCTs of CPNBs have focused on comparing 2 primary techniques for USG peripheral perineural catheter placement: short-axis imaging of the target nerve with in-plane (SAX-IP) needle and catheter insertion versus long-axis imaging of the target nerve with in-plane (LAX-IP) needle and catheter insertion; with the primary outcomes investigating either quality of postoperative analgesia or block procedure time. ***(Wang et al, 2010), (Mariano et al, 2013).*** Overall, there was no difference in the quality of postoperative analgesia and, not surprisingly, SAX-IP techniques provided a 33% to 45% reduction in the time required for successful catheter placement compared with LAX-IP. Despite the heterogeneity of the study designs within the meta-analyses and RCTs, it seems that USG provides advantages in terms of decreased block procedure time, without advantages in terms of quality of postoperative analgesia. When using USG, the evidence supports that the SAX-IP technique provides advantages in block procedure–related outcomes when compared with alternative approaches. ***(Fredrickson et al, 2013)***

Evidence for optimal ultrasound-guided local anesthetic distribution

One of the unique advantages of USG for PNBs is the ability to adjust the needle tip location in real time to optimize local anesthetic distribution either around a nerve or plexus, or within the desired fascial plane or compartment. Several RCTs have been published investigating the optimal LA distribution for successful surgical brachial plexus block and surgical sciatic nerve block.

The most common technique for USG SCB block targets local anesthetic distribution at the intersection of the first rib and subclavian artery in an attempt to anesthetize the inferior trunk (divisions) of the brachial plexus. Described as the *corner pocket technique*, this single-injection technique (SIT) may potentially decrease local anesthetic spread to the more superior aspects of the trunks-divisions. ***(Soares et al, 2007)***

Two RCTs compared SIT *corner pocket technique* to a double-injection technique (DIT) in subjects undergoing surgery of the elbow, forearm, or hand. In both studies, DIT provided a more rapid onset of complete sensory block only at 15 minutes but required more needle passes and longer block procedure time. ***(Tran et al, 2009), (Roy et al, 2011).***

In a more recent study comparing SIT to a triple-injection technique (TIT) for hand, wrist, or elbow surgery. TIT provided a more rapid onset of complete sensory block at 20 minutes but also took longer to perform, with no advantage in rates of successful surgical anesthesia 30 minutes after block completion. ***(Desgagnes et al, 2009)***

For brachial plexus infraclavicular block, local anesthetic distribution posterior to the axillary artery (AA) in the sagittal plane appears to be closet to all three 3 cords. ***(Fredrickson et al, 2010)***

Targeting the 4 terminal nerves of the axillary brachial plexus may potentially provide a more rapid block onset but, intuitively, also requires at least 4 needle passes. A DIT specifically targeting the musculocutaneous nerve in conjunction with circumferential AA local anesthetic spread has been found to be equally effective. ***(Imasogie et al, 2010).***

A recent RCT compared DIT, followed by perivascular (PV) injection either anterior (12 o'clock) or posterior (6 o'clock) to the AA. Interestingly, block performance time, block onset time, and overall block success rate (84%) were comparable in both groups. ***(Cho et al, 2014).***

USG for PNB is an effective and efficient technique for providing surgical anesthesia for major foot and ankle surgery. An USG technique that provides the best balance between rapid and predictable onset of sensory block for surgical anesthesia while minimizing the risk for nerve injury requires an understanding of the complex tissue layers that comprise the popliteal sciatic nerve. The sciatic nerve is formed from 2 nerves: the tibial nerve (TN) and common peroneal nerve (CPN). They are independent anatomic structures that do not share their respective sensorimotor fibers. The bifurcation (the TN and CPN physically separate) may occur in a range of locations as proximal as the gluteal compartment to as far distal as the popliteal crease; however, it most commonly occurs 5 to 10 cm cephalad to the popliteal crease. ***(Cho et al, 2014).***

Three RCTs have investigated circumferential local anesthetic injections either proximal to the sciatic nerve bifurcation or distal to the sciatic nerve bifurcation. All 3 trials consistently demonstrated a more rapid onset of sensory block with separate injections around the smaller TN and CPN components, yet both techniques required multiple needle redirections to achieve circumferential local anesthetic distribution. ***(Andersen et al, 2012), (Karmakar et al, 2013), (Abdallah et al, 2013)***

Two RCTs recently shed light on the potential advantages of injections within the paraneural compartment**.** In these 2 trials, USG was used to direct a needle tip just beyond the bifurcation of the sciatic nerve deep to paraneural sheath, followed by a single injection of local anesthetic. The trials compared block onset time and successful PSNB with the conventional circumferential local anesthetic injection around the TN and CPN. Injections resulted in significantly more rapid onset of sensory block, increased percentage of complete blocks, and shorter procedure-related block times. ***(Tran et al, 2011), (Perlas et al, 2013)***

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