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TOPIC HIGHLIGHT

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Perioperative pain control after total knee arthroplasty: An evidence based review of the role of peripheral nerve blocks

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Abstract

Over the last decades, the number of total knee arthroplasty procedures performed in the United States has been increasing dramatically. This very successful intervention, however, is associated with significant postoperative pain, and adequate postoperative analgesia is mandatory in order to allow for successful rehabilitation and recovery. The use of regional anesthesia and peripheral nerve blocks has facilitated and improved this goal. 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; this is important as hospital rankings and advertisement have become more common worldwide and many patients use these factors in order to choose a certain institution for a specific procedure. This review provides a short overview of currently used regional anesthetic and analgesic techniques focusing on related implications, considerations and outcomes.

Key words: Regional anesthesia; Peripheral nerve blockade; Total knee arthroplasty; Perioperative pain control; Postoperative outcome

Core tip: Over the last decades, the number of total knee arthroplasty procedures performed has increasing dramatically. This very successful intervention, however, is associated with significant postoperative pain, and adequate postoperative analgesia is mandatory in order to allow for successful rehabilitation and recovery. The use of regional anesthesia and peripheral nerve blocks has facilitated and improved this goal. In contrast to patient controlled analgesia using opioids, patients with a regional anesthetic technique suffer from fewer adverse events and show higher patient satisfaction. This review provides a short overview of currently used regional anesthetic and analgesic techniques focusing related implications, considerations and outcomes.

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INTRODUCTION

Over the last decades, major orthopedic procedures have been increasingly performed throughout the United

States. Specifically, total knee arthroplasties (TKA) have risen in volume by 154% between 1993 and 2011[1]. Projections suggest that the same trend will continue over the next decades, resulting in a demand of 3.48 million TKAs in 2030[2]. In order to appropriately meet this demand and provide comprehensive patient care physicians performing TKA need to keep in mind that this procedure is associated with severe postoperative pain and effective postoperative analgesic care is therefore mandatory. Regional anesthesia, and specifically the application of peripheral nerve blocks, has undergone significant developments over the last decade while proving its effectiveness and superiority over other traditional techniques. In this context it must be mentioned that the use of peripheral nerve blocks for TKAs remains underutilized[3], thus pointing to a significant potential for growth and expansion. Most recently, the use of ultrasound guidance has become more popular, resulting in the refinement of many nerve block techniques and more expansive utilization. Numerous publications have documented advances in respect to increases in safety, the use of decreased volumes of local anesthetics as well as improved onset times, prolonged duration of the blockade and/or a reduced length of stay[4-8]. Moreover, imaging technique and other necessary resources such as needles, catheters or infusion pumps have been improved in regard of their design as well as the material used[9-11].

Despite this progress, there is an ongoing discussion in the literature which type of block (or combinations thereof) is best for preventing postoperative pain, while facilitating rehabilitation and postoperative mobilization, reducing time to hospital discharge, enhancing cost effectiveness, and reducing the risk for complications (*e.g.*, inpatient falls) in TKA patients[12-14]. Various approaches to the performance of peripheral nerve blocks for postoperative pain control in patients undergoing TKA have been described in the literature; this includes the lumbar plexus block, the femoral nerve block, with or without a concomitant sciatic nerve block and the saphenous nerve block[12,15-19]. In addition, there is still a conflicting discussion in the regional anesthesia community whether a peripheral nerve block should be performed as a single-shot or as a continuous peripheral nerve block using a catheter.

This review aims to give an overview of peripheral nerve blocks currently used for postoperative analgesia in patients undergoing TKA, while assessing their impact on various outcomes. While some variations of the blocks discussed in this article exist; this review will focus on the most commonly used block techniques. Furthermore, we may summarize benefits and drawbacks for different approaches (*e.g.*, single shot *vs* continuous approach) in regard of side effects, complications and economic factors, such as cost effectiveness. In order to provide a focused discussion on the topic, the article, will only focus on peripheral blocks and not engage the field of neuraxial anesthesia and analgesia, which is also considered a regional anesthetic approach, but is more commonly although not exclusively used for effective intraoperative anesthesia.

PERIPHERAL NERVE BLOCKS USED FOR TKA

Lumbar plexus block

In the early 1970s, Winnie and colleagues introduced 2 different approaches to the lumbar plexus[20,21]. While the anterior approach failed to provide blockade of the obturator or lateral cutaneous femoral nerve, the posterior approach provided sufficient analgesia of the lumbar plexus[18]. The latter approach has been modified using various lumbar levels as a landmark for needle insertion as well as different distances from the spinous process[22]. Moreover, the use of ultrasound for regional anesthesia has become more widely available, thus providing and alternative to the traditional landmark guided approach towards the lumbar plexus block[23].

Technique: The L4 approach was described by Capdevila *et al*[24] and modified by the New York School of Regional Anesthesia, and includes the following landmarks: the spinous processes serve to define the midline at the level of the iliac crest (intercristal line, level of L4), the needle is inserted 4 cm lateral to the intersection of the midline and the iliac crest using nerve stimulation. A successful block will be achieved when local anesthetic is injected in the fascial plane of the psoas compartment; twitches of the quadriceps muscle using the nerve stimulator indicate the appropriate depth[25]. In 2001, Kirchmair *et al*[23] published a detailed description of the sonoanatomy of the lumbar plexus. They introduced a paramedian sagittal scan technique to identify the psoas muscle between L3-5. The needle is again inserted approximately 4 cm from the midline. The ultrasound guided technique described above, thus uses a similar approach as the landmark guided technique; it does, however, provide the benefits of ultrasound guidance including visualization of the needle as well as of the local anesthetic spread during injection.

Implications, considerations and outcomes: In regard to the use of a lumbar plexus block for total knee arthroplasty, some drawbacks have to be considered (Table 1). The block represents a clinically advanced technique with the potential for serious complications[26]. The main risk is derived from the close relation of important anatomical structures to the lumbar plexus, *i.e.*, proximity of the epidural space, the retroperitoneum or the kidney. Epidural spread leading to high neuraxial anesthesia, mislead catheters (epidural space) as well as kidney injuries have been reported[26-28]. Moreover, this technique should be avoided in anticoagulated patients to the lumbar plexus' location within the psoas muscle and risk of hematoma formation and subsequent nerve injury[29,30]. A large volume of local anesthetic is needed to provide sufficient anesthesia and postoperative analgesia; this fact may be one reason for reports of local anesthetic toxicity associated with lumbar plexus blocks[31]. Furthermore, when using ultrasound guidance, the user should have advanced skills as it may be challenging to obtain optimal images according to the

Table 1 Overview of block characteristics

Block	Landmarks	Ultrasound guidance	Catheter technique	Benefits
Lumbar plexus block	Spinous process iliac crest (L4) needle insertion 4 cm from midline	Paramedian sagittal L3-L5 identification of psoas muscle needle insertion 4cm from midline	Not widely used not practical	Some evidence for benefit in regard of early recovery and opioid consumption
Femoral nerve block	Inguinal ligament inguinal crease femoral artery	Transverse direction femoral crease identification of femoral artery and femoral nerve	Superior to single shot after 24 h	Easy to learn safe to use
Saphenous nerve block	United States guidance preferred	Midthigh identifying sartorius muscle anteromedial to femoral artery		Easy to learn safe to use
Sciatic nerve block	Classic approach: greater trochanter posterior superior iliac spine needle insertion 4 cm distal to the mid of the drawn line	Anterior approach: proximal end of medial thigh nerve beneath aducctor magnus muscle and femur	FNB catheter neccesary classic approach not well suited for catheters	Classic approach - easy to perform - high success rate

depth of the plexus and the anatomical structures in the neighboring area.

Following TKA, early remobilization and physiotherapy is a crucial part of the recovery process. The downside of this practice still lies in dreaded complications like inpatient falls. Therefore, the goal of regional anesthesia in this context must be a balance between the most effective pain relief and-at the same time–a minimal amount of motor blockade. In terms of postoperative outcomes, only very limited data for lumbar plexus blocks for total knee arthroplasty are available[32,33]. There is at least some evidence that the use of a continuous lumbar plexus blockade may be beneficial for early recovery. Watson *et al*[32] reported improved early recovery of patients receiving a continuous lumbar plexus block while simultaneously achieving a reduction in morphine consumption when compared with a single shot blockade. Lee *et al*[33] provided similar results; they compared pain scores over 48 h [continuous lumbar plexus block *vs* intravenous patient controlled analgesia (Ⅳ PCA)]. There were no differences in the first 6 h, whereas significant lower pain scores were found at 24 and 48 h, respectively. Consequently, nausea and sedation occurred more frequently in the Ⅳ PCA group. A difference in rescue analgesic consumption was however not observed. Indeed, lumbar plexus block might be used as an approach for regional anesthesia in patients undergoing TKA; there is however a potential for serious complications, moreover, advanced skills to perform the block are necessary. As a consequence, this block is not widely used.

Femoral nerve block

The femoral nerve block (FNB) is currently deemed to be the analgesic of choice when used for postoperative analgesia in patients undergoing TKA. It was first described in the 1920's by Labat[15]. FNBs are well studied and used in patients undergoing TKA to provide sufficient postoperative analgesia; this may be due to some advantages of this technique. Regardless if a single shot or continuous approach is chosen, a FNB is relatively simple to perform and therefore easy to learn; it has shown to have high success rates and carries a low risk for complications. FNBs can be performed using either nerve stimulator technique or ultrasound guidance; the latter technique has evolved over the last decade and is gaining popularity rapidly.

Technique: In contrast to lumbar plexus blocks, there is a well-defined insertion site for the FNB[34]: it is based on 3 landmarks: inguinal ligament, inguinal crease, and femoral artery. Using a nerve stimulator, the needle is inserted at the lateral margin of the artery in a sagittal, slightly cephalad plane; patella twitches, indicating quadriceps muscle stimulation and consequently the correct injection site, must be obtained before administrating the local anesthetic. For placing a nerve catheter, the technique is similar; however, a reduced insertion angle of the needle may facilitate advancement of the catheter. Using ultrasound guidance, it is however not necessary to palpate the femoral pulse as the artery needs to be visualized[35]. The transducer is positioned in a transverse direction, close to the femoral crease. After identifying the femoral artery and the femoral nerve using an in-plane technique, the needle is advanced towards the nerve. As soon as the needle tip is adjacent to the nerve, a small dose is administered to confirm the correct position by visualization of adequate spread. If the spread of local anesthetic is confirmed surrounding the nerve, the complete volume can be injected. A nerve stimulator may be used in addition to ultrasound guidance. Inserting a nerve catheter in the ultrasound guided setting, may be facilitated through a helper, as the catheter position should be visualized during advancement.

Implications, considerations and outcomes: An abundant amount of literature is available on the use of FNBs, for both regarding single shot blockade and continuous catheter techniques. Much of the literature suggests that a FNB facilitates recovery, improves early mobilization and reduces morphine consumption during the perioperative period when compared with other approaches[19,36]. It has shown that a single shot FNB can provide sufficient analgesia for pain with activity during the first 24 h, thereafter a continuous catheter technique is of advantage if prolonged analgesia is desired compared to a single shot blockade[37]. The use of an indwelling catheter in an inpatient setting after TKA has been well described while it may be challenging to provide continuous FNB catheters in an outpatient setting[38,39]. More resources, such as a well-trained acute pain team or on call anesthesiologists are needed. One of the major drawbacks may consist in a belated awareness of complications[40]; moreover falls may occur more frequently if the patient is discharged home early. Some institutions, including leading centers for regional anesthesia, do not provide such services on an ambulatory basis due to those limitations. In contrast, the use of FNB catheters in an inpatient setting is well established. However, catheter dislodgment, nerve injury or prolonged motor weakness resulting in falls may also occur during the course of the patient's recovery[13,41,42]. Although exceedingly rare and with limited consequences if treated, an increased infection rate for catheters may be of concern; bacterial contamination is common 48 h after placement[43].

In terms of block safety, FNB is associated with a low complication rate and a low incidence of related long-term adverse effects. In general, neurologic complications after peripheral nerve blocks are low with a range reported between 0.3% and 2.07%[44-47]. Data on long-term outcomes beyond 6 mo are very limited, mainly due to limitations in study design (*i.e.*, follow up period) and high numbers needed to identify these already rarely occurring adverse effects. Moreover, neurological complications, which are attributable to the peripheral nerve block, are likely to be resolved within one year after the procedure. Recently, Widmer *et al*[41] reported an incidence of nerve injury of 1.94% in a retrospective analysis, ranging in the upper zone, which was previously described for femoral nerve blocks. The neurological symptoms lasted on average longer (25 mo) than previous studies have suggested. Interestingly, patients receiving a nerve catheter reported significantly fewer neurological adverse events than those receiving a single shot technique (0.93% *vs* 2.66%, P = 0.01). There are, however, some limitations to this study (retrospective, small sample size to determine rare adverse events) and data therefore have to be interpreted with caution. As an additional consequence of a FNB, a reduction in the quadriceps muscle strength of up to 80% can be observed[48]. Various attempts to counteract this effect, including a reduction in volume and/or dose of local anesthetic administered, blockade on a more distal level (saphenous nerve, see below) or manipulation of the location of the catheter tip have been performed with variable success[49-51]. Ilfeld *et al*[13] re-analyzed and pooled the data of three separate trials, which have – analyzed independently–not shown a significant difference between sham FNB and active FNB in regard to inpatient fall risk, which is viewed as a major complication associated with potential quadriceps weakness. However, in the pooled analysis a significantly higher fall rate for active FNB has been encountered. It remains, however, the subject of current research if a peripheral nerve block indeed is a strong contributor to inpatient falls. In a recent population based analysis including more than 190000 patients, Memtsoudis *et al*[52] did not find an increase in the odds for inpatient falls when a peripheral nerve block was placed, suggesting that in real world practice with the existence of fall prevention programs and other precautionary measures the reduction in muscle strength may be adequately considered and managed. One can conclude that a careful choice of the anesthetic technique is always warranted and the decision has to be made after carefully weighing pro/contra of each technique.

Saphenous nerve block

The saphenous nerve block (SaphNB, also referred to as adductor canal block) is a modification of the FNB discussed above[53]. The SaphNB has been gaining popularity in the anesthesia community over the last few years, particularly supported by the increased use of ultrasound. The saphenous nerve is the terminal sensory branch of the femoral nerve. It is located within the adductor canal in conjunction with a branch of the femoral artery; it further divides into two branches, the infrapatellar branch supplies the anteromedial area of the knee, the sartorial branch travels further distally and provides innervation of the medial area of the leg and ankle[54]. Motor weakness, which has been traditionally linked with regional anesthesia with FNB, is still under suspicion to contribute to dreaded complications like inpatient falls[13]. Therefore, a more sensory specific approach may have its advantages provided the analgesic potency is equally comparable to other block techniques. Mansour provided one of the first descriptions for a more sensory specific block (rather than a FNB) for orthopedic surgery using the subsatorial approach in the 1990ies[55]. He described a landmark technique including the use of a nerve stimulator. The development of the technique and the success rate of the SaphNB were facilitated through the emerging use of ultrasound.

Technique: The SaphNB is typically performed using ultrasound guidance[56]; higher success rates and better performance measures have been reported[57]. Nerve stimulation may be used in addition to confirm the correct needle position, by showing absence of motor activity. The transducer is placed on the mid-thigh identifying the sartorius muscle. It is then moved to an anteromedial position with the goal of identifying the branch of the femoral artery. As soon as the course of the femoral artery is confirmed, the needle is advanced towards the femoral artery using an in-plane technique. The needle tip should be visualized right next to the femoral artery. After careful aspiration, a small amount of local anesthetic is injected to confirm the correct needle location. As the saphenous nerve is rarely visualized, the local anesthetic solution is administered periarterially.

Implications, considerations and outcomes: The SaphNB provides some advantages over a conventional

FNB (Table 1). If performed at the proper level, motor weakness of the quadriceps muscle, *i.e.*, vastus medialis muscle, might be reduced or even be non-existent. The branch of the femoral nerve innervating the vastus medial muscle lies, however, also within the adductor canal[58]; it exits the canal more proximally. The correct needle insertion site as well as low volume of local anesthetic is therefore mandatory to avoid motor weakness. By using ultrasound guidance, the SaphNB has a low complication rate[59]; the block itself is relatively easy to learn and shows a high success rate. It is however not yet clear if the SaphNB has the equal anesthetic potency compared with a FNB; moreover, the theoretically possible reduction in motor weakness is not yet confirmed. A recent clinical trial by Jaeger *et al*[51] shows however promising results. More randomized controlled clinical trials are needed to determine whether those advantages may be provided through the SaphNB.

Sciatic nerve block

The sciatic nerve block (SNB) has undergone a controversial debate in the literature in regard of its usefulness for patients undergoing TKA. It is most commonly considered to treat posterior knee pain after TKA. The posterior approach to the sciatic nerve was first described by Labat[15]. Since then, it has been modified multiple times, however, the clinical impact of those modifications remains uncertain[60-63]. Nonetheless, the classic posterior approach remains to be used most commonly and will be referred to for the purposes of the review.

Technique: The landmark guided approach for the classic SNB includes the greater trochanter and the posterior superior iliac spine[64]. The needle insertion point may be found approximately 4 cm distal to the mid of a line drawn between the two anatomic landmarks. The needle is inserted perpendicular to the skin and advanced slowly. Twitches of the gluteal muscle are observed first; as soon as a response to the sciatic nerve (hamstring, calf, foot or toes) is obtained, the current is decreased. After negative aspiration, the local anesthetic may be injected slowly. Similar to most other nerve blocks, the posterior approach to the sciatic nerve may also be performed using ultrasound guidance[65]. Alternatively, the anterior approach using ultrasound guidance can be used[65]. This technique may be advantageous when the patient cannot be positioned in the lateral position. The ultrasound probe is positioned on the proximal end of the medial thigh. The sciatic nerve can be visualized as a hyperechoic structure beneath the adductor magnus muscle medially to the femur. Nerve stimulation can be used to further confirm the needle position. A different approach of blocking the sciatic nerve would be a high popliteal sciatic block. Perlas[66] recently showed that an ultrasound-guided block through the paraneural sheath at the site of the bifurcation of the sciatic nerve is a simple and safe alternative compared to 2 single injections; moreover block onset times were reduced by approximately 30% compared to the conventional technique. However, it has to be determined in randomized controlled clinical trials if this would be a feasible approach for postoperative analgesia in TKA patients.

Implications, considerations and outcomes: The SNB itself, especially the posterior approach, is relatively simple to perform. Moreover, it has shown a high success rate (Table 1). In terms of a continuous blockade, the SNB in addition to a FNB nerve catheter can be challenging for patients. First, managing two different pumps may be logistically difficult; second, the needle insertion site, especially within the classic approach for the SNB, is not well suited for a nerve catheter, and third, the anterior approach to the sciatic nerve is an advanced technique and is therefore not widely available. However, Morin *et al*[67] reported reduced opioid consumption with a combined FNB and SNB catheter technique compared to a continuous FNB alone. The authors used the anterior approach for the SNB resulting in a relatively high failure rate, which may be in part attributable to the lack of ultrasound guidance as well as to the approach chosen in general. Of even higher concern may have been the fact that physiotherapists reported "…active exercise was more difficult to perform and walking were more insecure with patients who had the combined FEM/SCI catheter because of more pronounced motor weakness...". There was no measurement for motor strength of the quadriceps muscle; therefore one can only hypothesize on the impact on recovery. A systematic review article by Abdallah *et al*[12] found no evidence for a beneficial analgesic effect of a SNB beyond 24 h. This was also true when a continuous nerve catheter was used. They concluded that the area innervated by the sciatic nerve might be of minor importance in contributing to postoperative pain following TKA. Of note, within 24 h after TKA, a SNB has provided better pain relief and has reduced the opioid consumption within the majority of the trials that have been included into the systematic review. Therefore the question arises if a continuous catheter technique is (still) needed at times when the analgesic duration achieved with a single shot of local anesthetics tends to be prolonged, either through the choice of long acting anesthetic or the addition of additives.

Patient satisfaction and cost effectiveness

Peripheral nerve blocks in general have contributed to improving patient satisfaction, shortening length of stay in the recovery unit and while remaining cost effective.

Patient satisfaction: Hospital rankings and advertisement have become more common worldwide; especially in the United States many patients use these factors in order to choose a certain institution for a specific procedure. A similar trend has started and is expected to continue in many other countries over the next years as well. However, these rankings seem to always include some measure of patient satisfaction. High levels in patient satisfaction might resemble an institution's ability to meet the patient's needs and meet or even exceed the patient's expectations. This is important, as with a change in the reimbursement policy, the Centers for Medicare and Medicaid will account for patient satisfaction rating when reimbursing hospitals for their expenses[68]. In this context it is important to note that regional anesthesia and peripheral nerve blocks have shown the potential to significantly contribute to a higher overall level of patient satisfaction[69]. In the successful multimodal analgesic model, regional anesthesia plays one of the most important roles. Therefore, it seems prudent that when medically indicated peripheral nerve blocks should be considered whenever possible in TKA patients.

Cost effectiveness: Cost-effectiveness has become a major factor in most health care systems around the world when providing medical care. In this regard, it has been shown that peripheral nerve blocks are associated with cost savings when used for postoperative pain management after TKA. In a retrospective analysis, Ilfeld *et al*[70] demonstrated a 34% reduction in hospital cost for patients receiving continuous FNB after conventional TKA. Regarding the use of ultrasound guidance, it has been shown to be a cost-effective alternative compared to a nerve stimulator technique for a continuous sciatic nerve block despite initially high acquisition costs[71]. A limitation for this and all other studies evaluating the costs for ultrasound usage are overhead costs which are not reflected within these trials. This includes the cost for education and training for users. Moreover, most trials do not take multiple clinical applications of ultrasound machines into account which may have a cost sparing effect as well.

CONCLUSION

Regional anesthesia, in specific the use of peripheral nerve blocks, has significantly improved the perioperative (pain) management of patients undergoing TKA. Early mobilization and rehabilitation, improved patient satisfaction and a reduced length of stay have been accomplished by using regional anesthesia and therefore peripheral nerve blocks are becoming ever more popular. The providers' skill as well as the institution's resources might however influence the specific choice of the peripheral nerve block used. It must be stressed, that health care providers utilizing peripheral nerve blocks need to be knowledgeable regarding possible complications such as risk nerve damage, bleeding, infection and inpatient falls, and take precautions to reduce such risk.

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