Health Sciences Review 4 (2022) 100031

Contents lists available at ScienceDirect

Health Sciences Review

journal homepage: www.elsevier.com/locate/hsr

Regional anesthesia for acute and subacute orthopedic trauma: A review

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ARTICLE INFO

Keywords:
Regional anesthesia
Orthopedic trauma
Fracture care
Perioperative pain management

ABSTRACT

Pain management in the setting of acute and subacute orthopedic trauma can be challenging. Due to the recent focus on the rising opioid epidemic, as well as the adverse side of effects of opioid pain medication, multimodal pain control has become the standard of care for management of orthopedic trauma, particularly during operative fixation. The purpose of this paper is to report on the use of regional anesthesia for surgical intervention of extremity fractures in patients who present following traumatic injury as part of a multimodal pain management protocol. Types of, indications for, and outcomes of both upper and lower extremity peripheral nerve blocks will be reviewed.

Introduction

The management of pain in the setting of acute orthopedic trauma can be challenging. With a primary focus on the acute resuscitation, assessment, and treatment of life-threatening injuries, the provision of analgesia can often be delayed. Situational factors including confusion or dementia in the elderly, head injury and or hypotension in the high energy patient, patient refusal, and provider-patient communication issues have also been shown to limit the delivery of timely and adequate analgesia [1]

Although intravenous opioid therapy is the most common modality of analgesia in the acute trauma setting given ease of administration, fast onset, and excellent analgesia, opioid analgesia places the patient at risk for significant adverse effects including respiratory depression, vasodilation and hypotension, delirium, nausea or vomiting, and the inability to take oral medication [2] The resultant pain in acute orthopedic trauma often requires significant amounts of opioids to provide adequate pain relief. Given the recent focus on the rising opioid epidemic, a multimodal analgesic approach is now often the standard of care to both decrease opioid requirements and opioid-related adverse effects as well as to better address patient and trauma-specific factors for which opioids may poorly or adversely treat.

Even with the addition of multimodal agents, there is still widespread undertreatment of pain in orthopedic trauma patients. In a study of patients presenting to the emergency department with predominantly extremity injuries, 91% had pain on admission and 86% still had pain upon discharge with pain increasing in 17% of patients at the time of discharge [3] Such data speaks to the need for improved pain management and introduces a role for regional anesthesia techniques to improve pain relief in the acute orthopedic trauma setting. The purpose of this paper is to report on the use of regional anesthesia for surgical intervention of extremity fractures in patients who present following traumatic injury as part of a multimodal pain management protocol.

Upper extremity blocks

There are several peripheral nerve blocks (Fig. 1) that can be implemented in the setting of upper extremity orthopedic trauma, with their specific utility determined by the specific nerve distribution along the brachial plexus (Table 1).

Interscalene block

Indications

For injuries of the shoulder, proximal humerus, and distal clavicle, the interscalene block targeting the roots as well as the suprascapular and supraclavicular nerves has been shown to be effective in providing prolonged pain relief, reducing length of stay in the emergency department and one-to-one monitoring requirements.8 Possible side effects of the interscalene block include phrenic nerve blockade, sympathetic chain blockade, and recurrent laryngeal nerve blockade. A rare complication of the interscalene block is spinal cord root injury [5]

Technique and clinical efficacy

An interscalene block of the brachial plexus is performed by injecting local anesthetic in the interscalene groove between the anterior and middle scalene muscles (Fig. 2). It targets the C5, C6, and C7 nerve roots

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https://doi.org/10.1016/j.hsr.2022.100031
Received 21 May 2022; Accepted 18 June 2022

Table 1
Regional anesthesia blocks by sensory coverage and fracture patterns.

Block	Nerve Distribution Coverage	Fractures
Upper Extremity		
Interscalene	Suprascapular nerve Supraclavicular nerve C5–7 nerve roots	Proximal humerus fractures Clavicle fractures
Supraclavicular	C5-T1 nerves – targets brachial plexus divisions	Fractures of the humerus Fractures about the elbow Forearm fractures Fractures about the wrist (i.e. distal radius fractures) Fractures about the hand
Infraclavicular	C5-T1 nerves – targets brachial plexus cords	Midshaft and distal humerus fractures Fractures about the elbow Forearm fractures Fractures about the wrist (i.e. distal radius fractures) Fractures about the hand
Axillary	Terminal branches of brachial plexus	Fractures about the Wrist (i.e. distal radius fractures) Fractures about the Hand
Lower Extremity		
Fascia Iliaca	Femoral nerve Lateral femoral cutaneous Obturator nerve	Fractures about the hip
Femoral Nerve Block	Femoral nerve	Fractures about the hip Femur fractures Peri-articular fractures about the knee
Sciatic Nerve Block	Motor and sensory innervation to posterior aspect of knee, hamstrings and entire leg below knee (except medial lower leg and foot)	Tibia fractures Fractures about the ankle Fractures about the foot
Popliteal Sciatic Nerve Block	Motor and sensory innervation to lower limb below the knee (except medial lower leg and foot)	Fractures about the ankle Fractures about the foot
Saphenous Nerve block	Sensory innervation to medial leg and foot	Fractures about the ankle Fractures about the foot
IPACK	Articular branches of the obturator and tibial nerves	Peri-articular fractures about the knee

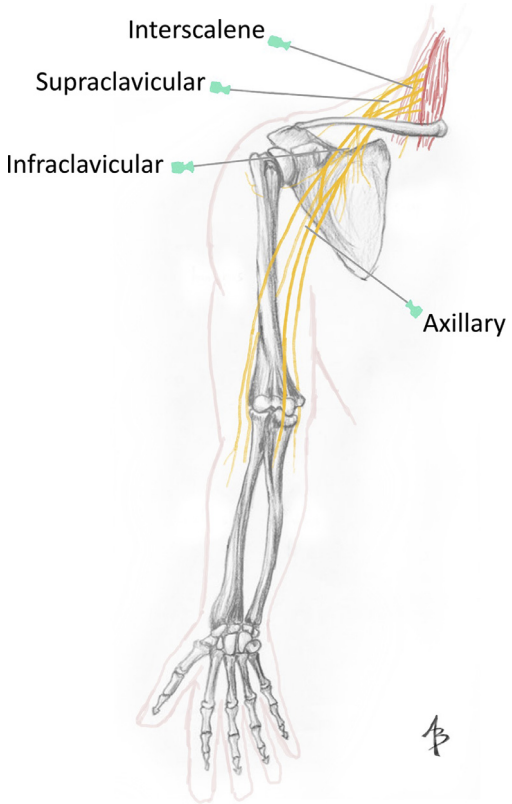

Fig. 1. Sites of Regional Blocks of the Upper Extremity.

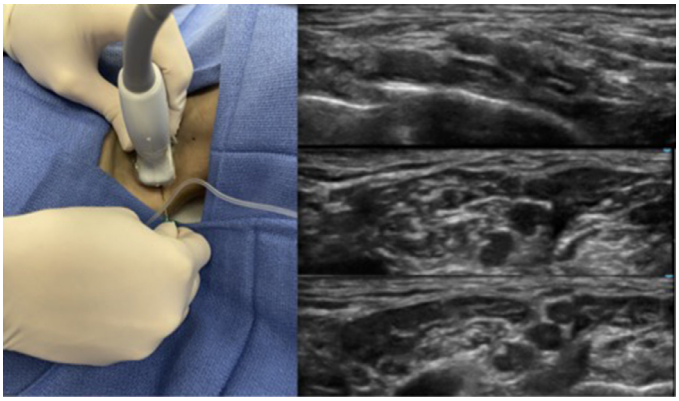

Fig. 2. Interscalene Nerve Block Technique.

as well as the suprascapular and supraclavicular nerves. The lower parts of the brachial plexus originating from C8 and T1 are generally spared.

The nerves that are covered are both motor and sensory and cover the region of the shoulder and upper arm. The area under the T2 distribution (intercostobrachial nerve) which is the axilla and the medial part of the upper arm is spared in all brachial plexus techniques and needs to be blocked separately if required for the surgical procedure.

Outcomes

For clavicle fractures, interscalene brachial plexus blocks should be supplemented with modified superficial cervical plexus block in order to provide adequate regional anesthesia coverage of the surgical field and obviate the need for general anesthesia. A study of 110 patients randomized to combined interscalene brachial plexus block and modified superficial cervical plexus block without general anesthesia versus general anesthesia with interscalene brachial plexus block demonstrated higher

intra-operative fentanyl requirements in the general group with no intra-operative conversions of the combined blocks to general [6] Furthermore, total anesthesia time and overall case time were significantly longer in the general anesthesia group. Interscalene blocks have also demonstrated good clinical efficacy for use in proximal humerus fractures. A systematic review by Iliaens et al. included 9 studies utilizing interscalene block, which all showed that regional anesthesia was efficacious for management of post-operative pain [7]

Supraclavicular block

Indications

The supraclavicular block targets the divisions of the brachial plexus. This block is suitable for injuries of the humerus, elbow, forearm, wrist, and hand as it includes C8 and T1 nerve roots, which are most often spared by the interscalene block.

Technique and clinical efficacy

The supraclavicular block is performed by placing a linear ultrasound probe above the clavicle. The key anatomical features to identify are the subclavian artery, first rib, lung, and the divisions of the brachial plexus which appear as a "bunch of grapes" at this level. 20–30 mL of local anesthetic are injected to surround the plexus, providing both motor and sensory blockade to the arm. Just as with the interscalene block, the area of the T2 distribution would need to be blocked separately if indicated for the surgical procedure.

Some side effects of this block are similar to that of the interscalene and include hoarse voice (recurrent laryngeal nerve), hemidiaphragmatic paralysis (phrenic nerve), and Horner's syndrome (cervicothoracic ganglion sympathetic fibers). In addition to the risk of vascular injury, there is also the risk of pneumothorax given the close proximity of the lung.

Outcomes

A randomized control trial comparing general anesthesia versus supraclavicular block for operative repair of distal radius fractures demonstrated lower post-operative pain and opioid consumption in the regional anesthesia group [8] In a study by Stone et al., patients who received a supraclavicular block for upper extremity fractures, dislocations, and/or abscesses experienced a shorter length of stay without any adverse effect on patient safety or satisfaction [9]

Infraclavicular block

Indications

The infraclavicular block targets the cords of the brachial plexus. This block is suitable for injuries of the mid to distal humerus, elbow, forearm, wrist, and hand as it includes C8 and T1 nerve roots, which are most often spared in by interscalene block.

Technique and clinical efficacy

The infraclavicular block is performed by placing a linear or high frequency curved ultrasound probe inferior to clavicle and medial to the coracoid process (Fig. 3). The medial, lateral, and posterior cords of the brachial plexus are identified as three hyperechoic structures surrounding the axillary artery, which lies deep the pectoralis major and minor muscles. Other anatomical structures to identify include lung and the axillary vein. 20–30 mL of local anesthetic are injected to surround the axillary artery in a U shape, providing both motor and sensory blockade to the arm [10]

In addition to the risk of vascular injury, there is also the risk of pneumothorax given the close proximity of the lung. Furthermore, as with the interscalene and supraclavicular blocks, the area of the T2 distribution (intercostobrachial nerve) would need to be blocked separately if indicated for the surgical procedure.

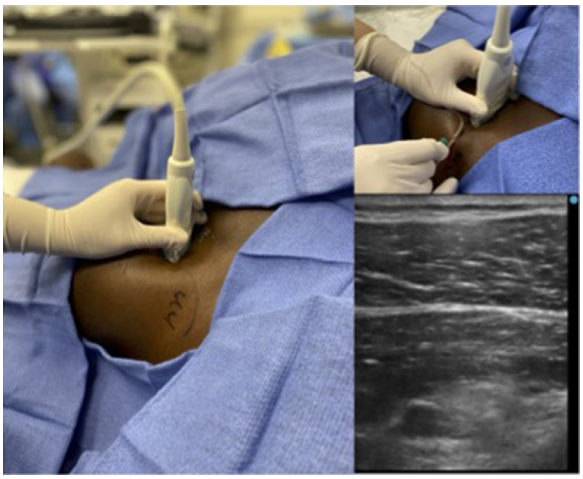

Fig. 3. Infraclavicular Nerve Block Technique.

Outcomes

A retrospective review of 187 consecutive patients who underwent open reduction and internal fixation of a distal radius fracture under general versus regional anesthesia with an infraclavicular block showed decreased post-operative pain, increased wrist and finger range of motion and higher functional outcome scores at 3 and 6 months post-surgery in the regional anesthesia group [11] A recent prospective randomized control trial demonstrated significantly lower pain scores for up to 48 h post-operatively as well as significantly decreased post-operative morphine consumption compared to general anesthesia for patients undergoing distal radius fracture fixation [12] Regional anesthesia also was associated with a lower incidence of nausea and vomiting, and higher patient satisfaction [12] Additionally, for patients undergoing distal radius fractures, there is no difference in continuous versus single shot infraclavicular block with respect to post-operative pain or narcotic use [13] Infraclavicular blocks are associated with a greater degree of sensory block in axillary nerve and medial cutaneous brachial nerve distributions compared to axillary nerve block for patients undergoing orthopedic surgery distal to the elbow [14] Infraclavicular blocks have also been shown to be effective in controlling procedural pain for pediatric patients undergoing closed reduction of forearm fractures in the emergency department setting [15]

Axillary block

Indications

Axillary nerve blocks target the terminal branches of the brachial plexus and may be used for injuries involving the distal regions of the arm. This nerve block may be useful in situations where the upper portions of the plexus may not be accessible such as in the case of burns. Also given the superficial location of the plexus in this technique, it may be useful in morbidly obese patients.

Technique and clinical efficacy

The axillary nerve block is performed by placing a linear ultrasound probe distal to where the pectoralis major muscle inserts onto the humerus. The radial, ulnar, and median nerves can be identified as three hyperechoic structures surrounding the axillary artery. These nerves are blocked with 1–3 injections of local anesthetic. The musculocutaneous nerve must be identified and blocked separately; it lies either within or between coracobrachialis and biceps muscles. A total of 20 mL of local anesthetic may be used to perform the block [16]

Outcomes

A randomized control trial showed high rates of patient satisfaction in patients undergoing surgery for hand or forearm trauma with both

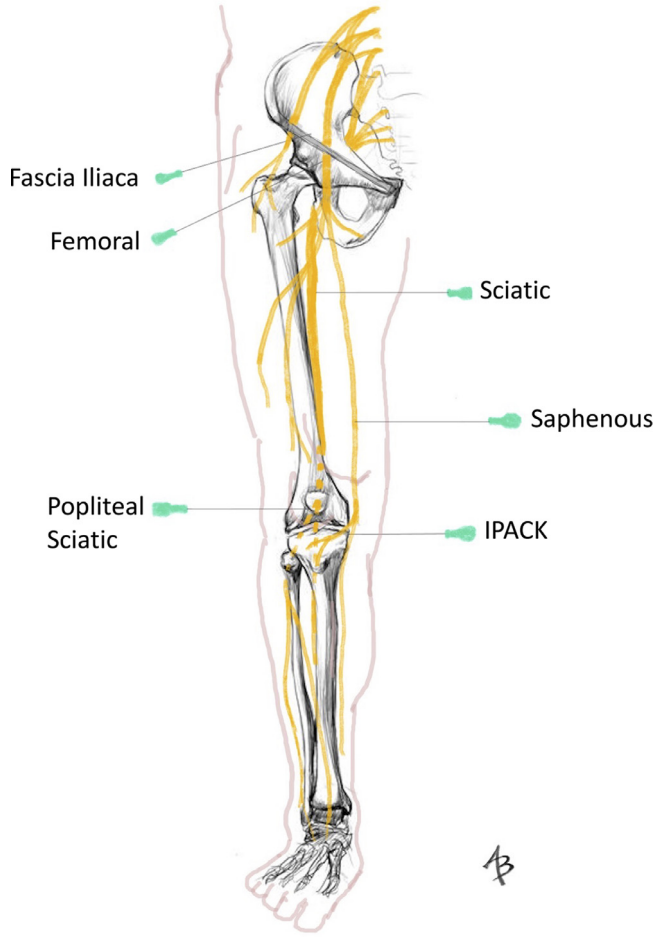

Fig. 4. Sites of Regional Blocks of the Lower Extremity.

electrical nerve stimulation and fascial pop techniques, although better efficacy is seen with fentanyl as an adjunct compared to ketamine [17,18] In the emergency department setting, axillary nerve blocks can be used successfully in lieu of intravenous sedation for reduction or immobilization of upper extremity fractures [19] Axillary nerve blocks are also effective in the emergency department setting for pediatric patients undergoing closed reduction for forearm fractures [20]

Lower extremity blocks

There are several peripheral nerve blocks (Table 1) that can be implemented in the setting of lower extremity orthopedic trauma with positive outcomes (Fig. 4).

Fascia iliaca block

Indications

The fascia iliaca block targets the femoral, lateral femoral cutaneous, and obturator nerves simultaneously. Although technically less demanding than femoral nerve blocks, fascia iliaca blocks may not be as effective in their pain relief properties [21] However, these blocks are typically used for hip and femur fractures.

Indications

The fascia iliaca block or fascia iliac compartment nerve block targets the femoral nerve and often the lateral femoral cutaneous nerve [22] Therefore, it is indicated in injuries of the anterior thigh or knee; it may also be integrated as part of multimodal analgesia following hip or knee procedures, such as femur neck fracture repairs and above the knee amputations. Though complication rates are low, they can include hematoma and nerve transection as with all regional blocks. An extremely rare side effect is perforation of the peritoneal cavity organs and bladder puncture.

Technique and clinical efficacy

The fascia iliaca block can be performed with either a landmark technique or an ultrasound-guided infra-inguinal approach. Using the landmark approach, the femoral artery is palpated along an imaginary line connecting the anterior superior iliac spine and pubic tubercle. A needle is inserted approximately 1.5 cm lateral to the artery along the same imaginary line; two “pops” are frequently felt with puncture through the fascia lata and fascia iliaca. Following negative aspiration, local anesthesia is deposited into this potential space. With ultrasound guidance, the femoral artery and iliopsoas muscle (lateral and deep to the artery) are identified. The iliopsoas is covered by the hyperechoic fascia with the femoral nerve between the two layers; the goal of the block is to deposit a large volume (20–40cc) of local anesthetic underneath the fascia and observe the hydro-dissection of the fascia from the underlying muscle planes [23,24]

Outcomes

A study by Castillon et al. described a cohort of 216 patients with hip fractures who received a fascia iliac block for pain control in the emergency department, and demonstrated a significant reduction in patient-reported pain following the block, with only approximately a quarter of the patients requiring morphine as rescue medication in the first 8 h after diagnosis [25] Another more recent study by Thompson et al. also demonstrated in a prospective study that pre-operative fascia iliaca blocks significantly decreased post-operative opioid consumption in geriatric hip fracture patients [26] Additionally, multiple systematic reviews of randomized controlled trials have reported that fascia iliac blocks provide significant pain relief during perioperative management of geriatric patients with hip fractures, and reduces the need for narcotic pain medication [27,28]

Femoral nerve block

Indications

Both the femoral nerve block and fascia iliaca block target the femoral nerve. The fascia iliaca block is a volume-block; therefore, surgical anesthesia is difficult to achieve. The femoral nerve block is more suited for hip, femur, and knee injuries, particularly patellar and tibial plateau fractures. Unlike the fascia iliaca block, the femoral nerve block does not reliably cover the lateral femoral cutaneous nerve. As with most lower extremity blocks, a rare complication is femoral artery puncture.

Technique and clinical efficacy

Femoral nerve blocks are accomplished with the patient positioned supine with mild external rotation of the lower extremity. A linear probe is oriented perpendicular to the inguinal ligament to identify the hyperechoic femoral nerve lateral to the iliopsoas and the femoral artery immediately medial to the nerve (same as with fascia iliaca block). The block needle is then inserted in plane and advanced through the fascia iliaca to the superior surface of the femoral nerve. Injection of 10–20cc local anesthetic should demonstrate spread below the fascia iliaca line with steady enlargement of the femoral nerve [29,30]

Femoral nerve block results in sensory deprivation to the anterior and medial thigh, as well as the medial leg and foot (saphenous nerve distribution). Because the femoral nerve also carries motor function, a frequently encountered side effect is quadriceps weakness. The obturator and sciatic nerves are spared.

Outcomes

Several studies have proved the efficacy of femoral nerve blocks in the management of acute hip fractures, leading to earlier patient mobility, improved respiratory function, and decreased overall complications including pneumonia, confusion, and opioid requirement [31,32] One retrospective study even found a significantly decreased mortality rate in community dwelling patients with hip fracture who received indwelling catheters for prolonged femoral nerve blockade [33]

Sciatic nerve block

Indications

The sciatic nerve provides both sensory innervation to the posterior aspect of the knee, hamstrings, and entire leg below the knee (with the exception of the medial lower leg and foot). This block is indicated for foot and ankle surgeries, as well as below-the-knee amputations; additionally, it is incorporated as part of multimodal analgesia following knee surgery involving the posterior compartment. A rare complication is femoral artery puncture with the anterior approach.

Technique and clinical efficacy

There are several approaches for performing the sciatic nerve block – anterior, transgluteal, subgluteal, parasacral, lateral and the more distal popliteal fossa approach (discussed later). The approach depends on patient characteristics and provider preference. For an ultrasound-guided transgluteal technique, the sciatic nerve can be visualized as a hyperechoic structure deep to the gluteus maximus muscle lying between the ischial tuberosity and greater trochanter. The subgluteal approach may be easier to perform as it done a few centimeters distally where the nerve lies more superficially. Successful blockade typically entails injection of 10–20 mL of local anesthetic. [34,35]

Although the sciatic nerve provides motor and sensory innervation to most of the lower leg, sciatic nerve block does not cover the posterior aspect of thigh, which derives sensory innervation from the posterior femoral cutaneous nerve.

Outcomes

In a study by Elkassabany et al., patients who underwent general anesthesia with sciatic nerve blocks for operative repair of tibia and ankle fractures reported significantly higher satisfaction scores at 24 h postoperatively as compared to those who exclusively received general anesthesia.7 Sciatic nerve blocks have also recently been reported to successfully control intra-operative pain when used in conjunction with other blocks in order to perform awake surgery for hip fracture patients with significant medical co-morbidities, in order to avoid receiving general anesthesia [37,38]

Popliteal sciatic nerve block

Indications

Popliteal sciatic blocks are indicated for foot and ankle injuries as well as Achilles tendon ruptures. These blocks are often preferred over more proximal sciatic nerve blocks because they only anesthetize distal to the hamstring muscles, thereby preserving knee flexion. Popliteal sciatic blocks are often combined with saphenous blocks, discussed later, to adequately cover the entire lower leg. Complications are minimal with this block. Although intra-arterial injection is a risk for most blocks, it is uncommon in popliteal blocks given the superficial location of the nerve relative to the artery.

Technique and clinical efficacy

To perform an ultrasound-guided popliteal block, the transducer is placed in the transverse position at the popliteal crease (Fig. 5). The popliteal artery and vein are identified, with the biceps femoris at either side of the artery. The tibial nerve is located lateral to the vein and the common peroneal nerve is identified lateral to the tibial nerve. At this point, the transducer is slowly directed proximally to visualize the joining of these two nerves to form the sciatic nerve. Around 15–20 mL of local anesthetic is deposited into this epineural sheath to allow for adequate block [39]. Sciatic nerve blocks result in sensory and motor anesthesia below the knee, sparing only the medial lower leg and foot (innervated by saphenous nerve).

Outcomes

A randomized control trial of 150 patients undergoing ankle fracture surgery compared combined popliteal and saphenous blocks with spinal anesthesia, and demonstrated superior post-operative pain control with popliteal and saphenous blocks, despite potential for rebound pain after peripheral nerve block [40] Furthermore, continuous local anesthetic infusion in popliteal sciatic block has been shown to decrease rebound pain and need for narcotic pain medication compared to single-shot popliteal sciatic block for operative repair of ankle fractures (Ding et al.). Preoperative popliteal sciatic blocks have also been shown to be more effective in controlling post-operative pain compared to post-operative blocks or no block in patients undergoing ankle fracture surgery [41] A recent randomized control trial also demonstrated that post-operative popliteal sciatic nerve blocks are effective in controlling post-operative pain following operative repair of calcaneus fractures [42]

Saphenous nerve block

Indications

Saphenous nerve blocks (also referred to as adductor canal blocks) often supplement sciatic nerve blocks,. Most commonly they are used for patients undergoing ankle fracture surgery or saphenous vein harvesting. Adverse effects include pain on injection, vascular injection, bleeding, and allergic reactions, as with all regional blockade; more specific to saphenous nerve blocks, however, complication includes quadriceps weakness (discussed below).

Technique and clinical efficacy

With the transducer in transverse position along the distal aspect of the anteromedial thigh, the sartorius muscle is identified as a trapezoid-appearing structure (Fig. 6). Deep to the sartorius, the femoral artery and vein are surrounded by the vastus medialis and adductor magnus. Adjacent to the femoral artery, the hyperechoic saphenous nerve can be visualized at a depth of 2–3 cm and about 5–10 mL of local anesthetic is injected [43]

The saphenous nerve is the terminal sensory branch of the femoral nerve, providing innervation below the medial aspect of the knee. Although the saphenous nerve block is a sensory block, injection of large volumes of local anesthetic can result in a motor blockade of the nerve to the vastus medialis which may present clinically as mild quadriceps weakness.

Outcomes

Although not often used in isolation, when saphenous nerve blocks are used in combination with popliteal sciatic nerve blocks as opposed to popliteal block alone, there is significant reduction in post-operative pain in patients undergoing ankle fracture surgery [44] A recent case report by Darling et al. described the use of a saphenous nerve block alone for medial foot surgery, with the patient reporting 0/10 pain post-operatively [45]

IPACK block

Indications

IPACK is an acronym for Infiltration between the Popliteal Artery and Capsule of the Knee. This field block targets the articular branches of the obturator and tibial nerves, thereby providing sensory blockade to the posterior aspect of the knee. This block may be useful for knee

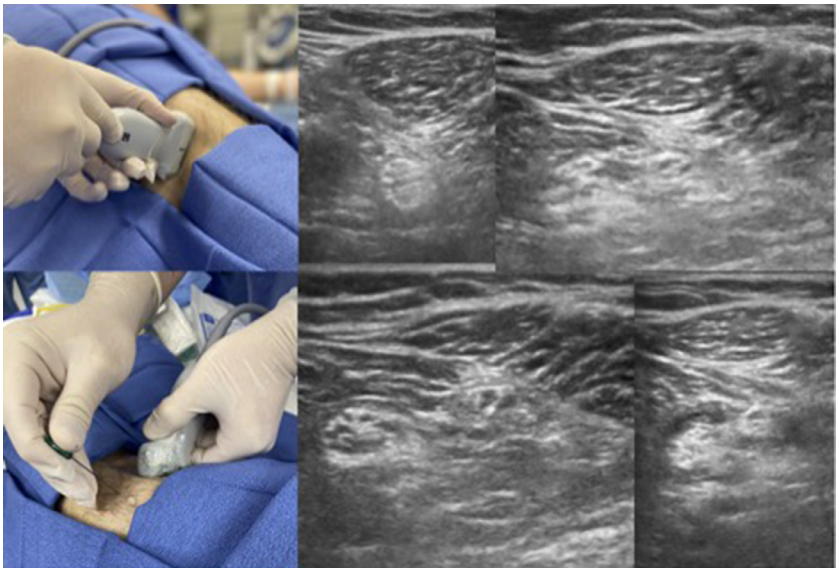

Fig. 5. Popliteal Sciatic Nerve Block Technique.

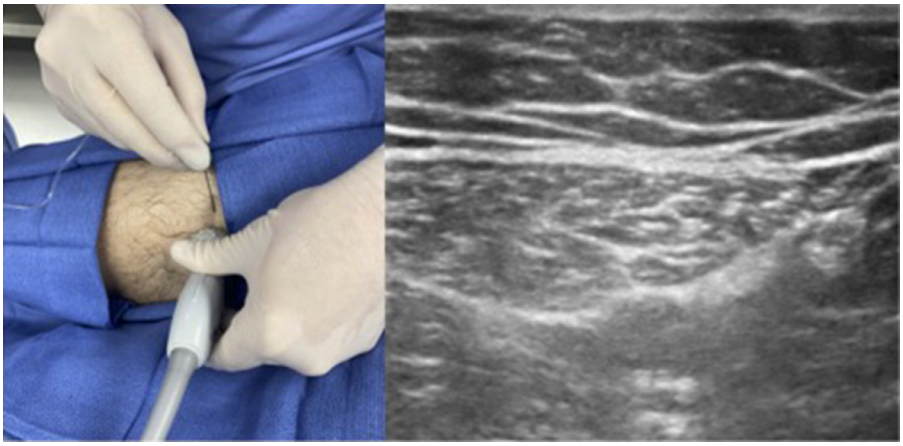

Fig. 6. Saphenous (Adductor Canal) Nerve Block Technique.

arthroplasty, cruciate ligament repairs or reconstructions and other procedures involving the posterior aspect of the knee.

Technique and clinical efficacy

With the leg in the frog-leg position, a low frequency curved ultrasound probe is placed behind the distal femur. Once the popliteal artery and femoral condyles are identified the probe is moved cephalad until the condyles appear to flatten. A needle is then inserted from the medial side of the leg and advanced between the posterior femur and popliteal artery. 10–20 mL of local anesthetic are injected in this plane. It is important to identify the sciatic nerve lateral to the popliteal artery and ensure that the local anesthetic does not spread to that nerve. The goal of this block is provide sensory blockade to the posterior aspect of the knee. A possible complication of this block is inadvertent blockade of the sciatic nerve in the popliteal fossa. If the sciatic nerve in advertently blocked, the patient will also have motor blockade below the knee and could present with a foot drop clinically.

Outcomes

Given that the IPACK block is a relatively new form of regional anesthesia, there are currently no studies demonstrating its efficacy in fracture care. However, multiple studies have shown that the IPACK block significantly decreases pain in the immediate post-operative period when used as an adjunctive block following total knee arthroplasty and anterior cruciate ligament reconstructions, and thus should be investigated as an adjunct for peri-articular knee fractures [46–48]

Risks of regional anesthesia

There are minimal risks associated with regional anesthesia, with less than 1% of patients experiencing neurologic symptoms after both upper and lower extremity blocks, with the majority of neurologic symptoms due to causes unrelated to the block [49] Supraclavicular blocks involve a risk for pneumothorax given their proximity to the apical pleura, however studies have shown that such risk is significantly diminished with ultrasound guidance [50]

For injuries below the knee, the saphenous and the sciatic nerve at the popliteal fossa are most frequently targeted. A known complication of tibial fractures is acute compartment syndrome (ACS), particularly the proximal and middle third of the diaphysis secondary to bulky muscle mass. Given that paresthesia and pain are recognized as early indicators of developing ACS, many clinicians avoid nerve blocks due to the risk of masking these symptoms. However, the sensitivity and positive predictive value of these signs are only 11–19%; the specificity and negative predictive value are 97–98% for lower extremity trauma [51] While the data on peripheral blocks and ACS is sparse, most case reports suggest neural blockade may aid in the diagnosis and treatment of ACS as breakthrough pain from the newly ischemic limb can alert physicians to a change in the patient's clinical status and prompt an assessment. Most data linking regional anesthesia to missed ACS events involved epidural block as opposed to peripheral nerve blocks. Additionally, although some case reports have implicated femoral nerve blocks during tibia intramedullary nailing with missed diagnoses of ACS, these authors fail

to recognize that the anterior compartment is primarily supplied by the deep peroneal nerve and thus a femoral nerve block is unlikely to mask symptoms [52]

Benefits of regional anesthesia

Regional anesthesia limits exposure to the effects of general anesthesia and its associated complications, including nausea or vomiting, immunosuppression, cognitive dysfunction or delirium, and hemodynamic instability. It has been associated with a decreased opioid requirement and opioid-related adverse events, such as dependence and tolerance [31] Regional anesthesia may also decrease the incidence of chronic pain syndromes. Risk factors for the development of chronic pain include age, medical comorbidities, mental health disorders (particularly anxiety and depression), alcohol and tobacco consumption, and most importantly, high intensity acute pain at the time of the insult [53] Given that regional anesthesia provides excellent site-specific analgesia, it may have a role in preventing post-traumatic chronic pain. Multimodal analgesia with adjunctive regional anesthesia incurs economic advantages as well. The economic burden of the opioid crisis in the United States is an estimated $50 billion annually [54] By minimizing narcotic administration during surgery, regional anesthesia offers a more accessible approach to analgesia. Furthermore, regional anesthesia can lead to a shorter length of stay which reduces the cost of care and increases patient safety and satisfaction [4,36]

Conclusion

This review highlights the types of upper and lower extremity peripheral nerve blocks in the setting of orthopedic trauma, and presents strong evidence that supports their use for patients undergoing operative management of acute orthopedic injuries.

Funding

There was no source of funding for this paper.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests.

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