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Local Anesthesia/Peripheral Nerve Block with Monitored Anesthesia Care (LPMAC) for Peripheral Vascular Surgery: Review Article

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1. Abstract

Chronic limb threatening ischemia (CLTI) is associated with high morbidity and mortality. The 5 year survival for patients with CLTI is 50 - 60%, with 1 year perioperative mortality rate as high as 17-25%. General and regional anesthesia techniques have both been used successfully for patients with CLTI requiring endovascular revascularization interventions, open surgical bypass surgery and major lower limb amputations, however current evidence is insufficient to favour one technique over the other in terms of mortality and cardiac morbidity benefits. This article discusses the utility of Local anesthesia/Peripheral nerve block with monitored anesthesia care in lower extremity endovascular revascularization (LER) with a description of the commonly performed lower limb nerve blockades. It discusses the techniques, distribution of anesthesia, the advantages and disadvantages of these nerve blocks and touches on the minimum peri-procedural monitoring required and what to watch out for in case of local anesthetic toxicity.

2. Introduction

Chronic limb threatening ischemia (CLTI) represents the most severe manifestation of peripheral arterial disease (PAD) and is defined by the presence of obstructive arterial disease caused by atherosclerosis, associated with tissue ulceration and gangrene that fails to heal within 2 weeks. This disease process is associated with high morbidity and mortality. The 5 year survival for patients with CLTI is 50 - 60%, with 1 year perioperative mortality rate as high as 17-25% and 1 year major lower extremity amputation rate of 25% [1-4]. CLTI patients usually present with multi-level infra-inguinal PAD and tibial arterial occlusions (3). An endovascular-first revascularization policy using percutaneous angioplasty (PTA) is currently preferred to re-establish straight-line blood flow to the foot necessary for wound healing and limb salvage because of its minimal therapeutic footprint [4]. General and regional anesthesia techniques have been used successfully for patients with CLTI requiring endovascular revascularization interventions, open surgical bypass surgery and major lower limb amputations, however current evidence is insufficient to favour one technique over the other in terms of mortality and cardiac morbidity benefits [2,5,6]. There have been increasing reports of successful use of local anesthesia and peripheral nerve blocks combination with monitored anesthesia care (LPMAC) to facilitate lower extremity revascularization (LER), particularly for patients with high burden of comorbidities [5,7], which is usually the case in these patients. This article will discuss considerations and utility of LPMAC in lower extremity endovascular revascularization (LER) with a focus on the evaluation for suitability of MAC and description of the commonly performed lower limb nerve blockades including femoral, adductor canal (saphenous), proximal sciatic, popliteal-sciatic and ankle nerve block techniques.

3. Considerations for LPMAC Technique

Selection of anesthetic technique, local, regional, neuraxial, or general anesthesia [GA] depends on procedure-specific factors such as anticipated duration of the procedure and patient-specific factors like recent administration of anticoagulant drugs.

Surgical techniques for PAD therapy, which are amenable to LP-

MAC include:

- Endovascular techniques; including angioplasty and stenting (LA at puncture site is adequate +/- sedation).
- Surgical bypass grafting, endarterectomy (infrainguinal).
- Hybrid revascularization procedure (dual technique utilizing endovascular methods and open surgical revascularization for femoral or infrainguinal disease).
- Lower limb and foot wound debridement.
- Amputations including digital ray, forefoot, below and above knee amputations (requires femoral/obturator/lateral femoral cutaneous and sciatic nerve blockade performed at same setting) [9,10].

4. Evaluation for Suitability of MAC

As sedation can be associated with potential complications such as cardiorespiratory compromise, patients who are planned for LA and/ or regional anesthesia must be evaluated for suitability of MAC including:

- Airway evaluation: Ensure that conversion to GA can be easily done and access is unimpeded during lower limb vascular surgery.
- Lie motionless in the position required for the procedure – MAC may not be appropriate for procedures that require immobility in patients who may not be able to remain still in supine position without excessively deep sedation or general anesthesia (e.g. essential tremor, persistent cough, orthopnea).
- Cooperation /Communication with care providers – Verbal communication is required during MAC for assessment of the depth of sedation, explanation, and reassurance. Patients with cognitive dysfunction, dementia, extreme anxiety, and barriers to communication during the procedure may make general anesthesia a better choice than MAC.
- Management of patient expectations — Patients should be counselled that they have awareness and can recall the procedure performed under sedation.

5. Peripheral Nerve Blocks for LER

5.1. Femoral Nerve Block

The femoral nerve block is a simple procedure, which can be performed under ultrasound guidance. Classically, this blockade is used for anesthesia and postoperative analgesia for knee (arthroplasty, reconstruction of the anterior and posterior cruciate ligament, tibial plateau fracture, and patella fracture), hip (arthroplasty, femoral neck fracture), and thigh (transtrochanteric and femoral condyle fractures) surgeries. This blockade is also useful (in combination with sciatic nerve block) for above and below knee amputations.

5.1.1. Anatomy

Femoral nerve is formed by the roots of L2-L4, enters the thigh posterior to the inguinal ligament and passes laterally to the femoral vessels. It is located in a slightly deeper position (0.5-1.0 cm) and lateral to the femoral artery (about 1.5 cm). There are two fascias: fascia lata, which passes over the nerve and over the vessel, and iliac fascia that passes over the nerve, but below the femoral vessels.

5.1.2. Distribution of Anesthesia

Femoral nerve block results in anesthesia of the anterior and medial thigh down to and including the knee, as well as a variable strip of skin on the medial leg and foot (saphenous nerve). It also innervates the hip, knee, and ankle joints in a variable percentage of patients, this blockade also extends to the thigh - lateral cutaneous nerve of the thigh (analgesia of the skin on the lateral side of the thigh) and obturator nerves (medial thigh and adductor muscles of the thigh), and thus contributes to analgesia of hip and knee joints.

5.1.3. Technique

The skin over the femoral groin crease is disinfected with the patient in a supine position with the ipsilateral hip slightly externally rotated (Figure 1). The femoral artery and nerve are identified with the linear ultrasound transducer. Image acquisition of femoral nerve can be improved with tilting the transducer proximally or distally to identify the hyperechoic nerve from iliacus muscle (posteriorly), superficial adipose tissue and fascia iliaca (anteriorly) (Figure 2). Once the femoral nerve is identified, local anesthetic is administered 1 cm away from the lateral edge of the transducer. The needle is advanced toward the femoral nerve in a lateral to medial orientation using an in-plane approach. If nerve stimulation is used (0.5 mA, 0.1 msec), the passage of the needle through the fascia iliaca and contact of the needle tip with the femoral nerve usually is associated with a motor response of the quadriceps muscle group and patella ("dancing patella"). The volume of local anesthetic used is 10- 20 mL after negative aspiration. Choice of LA used would be dependent on institutional practice, desired speed of onset and duration of analgesia/ anesthesia (Table 1). The presence of femoral vascular graft is a relative contraindication to this technique. Furthermore, there may be important anatomical variations, such as femoral nerve located at a distance from the femoral artery, difference in depth/ femoral nerve, which can hamper the blockade.

5.2. Saphenous (Adductor Canal) Nerve Block

The saphenous nerve innervates the medial aspect of leg, knee joint, ankle and foot. Can provided anesthesia and analegesia for saphenous vein stripping, harvesting and can supplement a sciatic nerve block in operations involving the medial aspect of ankle and foot including big toe and forefoot amputations

Table 1: Onset and duration of 20mls of local anesthetic in femoral block (Reference from NYSORA: https://www.nysora.com/techniques/lower-extremity/femoral/femoral-nerve-block/).

	Onset (min)	Anesthesia (h)	Analgesia (h)
3% 2-Chloroprocaine	10–15	1	2
3% 2-Chloroprocaine (+ HCO3 + epi)	10–15	1.5–2	2–3
1.5% Mepivacaine	15–20	2–3	3–5
1.5% Mepivacaine (+ HCO3 + epi)	15–20	2–5	3–8
2% Lidocaine	10–20	2–5	3–8
0.5% Ropivacaine	15–30	4–8	5–12
0.75% Ropivacaine	10–15	5–10	6–24
0.5 Bupivacaine	15–30	5–15	8–30

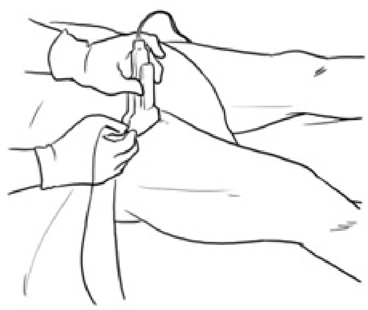

Figure 1: Positioning of US probe and patient in supine position for right femoral nerve block.

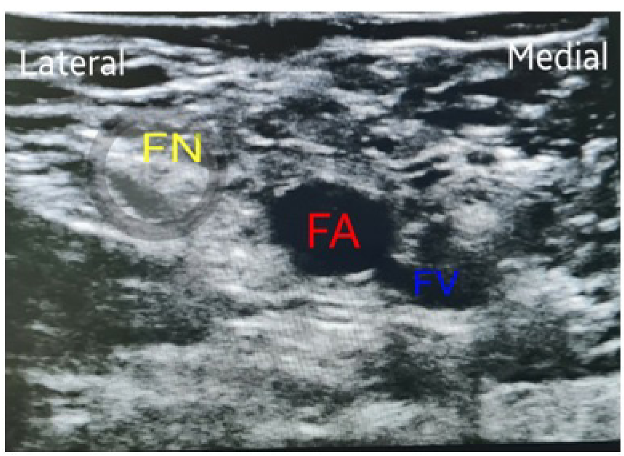

Figure 2: Ultrasound image of right femoral nerve with manual annotations, From lateral to medial, FN: Femoral Nerve, FA: Femoral artery FV: Femoral vein

5.2.1. Anatomy

Saphenous nerve is the terminal sensory branch of the femoral nerve. It originates from the posterior division of the femoral nerve when it converges with femoral artery. It lies in front of femoral artery in the adductor canal where it passes beneath the sartorius muscle. It lies in proximity of the femoral artery above knee, descending genicular artery and saphenous vein in the lower leg and ankle

5.2.2. Distribution of Anesthesia

The saphenous nerve innervates the medial aspect of leg, knee joint, ankle and foot

5.2.3. Technique

This block is done with patient in supine position with leg abducted and externally rotated. skin is disinfected depending on the approach the linear transducer is positioned on the anteromedial thigh between middle and distal third of thigh (proximal approach) or bellow knee at the level of tibial tuberosity (distal approach). Sartorius muscle forms the roof over the adductor canal in the lower thigh and the medial side of the canal is formed by adductor longus or magnus and the lateral side of the canal is formed by vastus medialis. Long acting local anesthetic 10-15mls is deposited lateral to the femoral artery deep to the sartorius muscle (proximal) or near saphenous vein below knee (distal). The use of ultrasound has increased the success of this block compared to filed blocks done on tibial tuberosity below knee.

5.3. Sciatic Nerve Block

Sciatic nerve blocks can be performed under ultrasound guidance and/or with a nerve stimulator. It offers good lower limb anesthesia, analgesia and has low complication rates. With a combined femoral nerve block, it provides knee, leg, and foot analgesia to allow for virtually any surgical procedure to be performed below the knee. When combined with a posterior lumbar plexus block, it provides femur, thigh, knee, leg, and foot analgesia.

5.3.1. Anatomy

The sciatic nerve is the largest peripheral nerve and is formed by the union of the lumbosacral trunk L4-L5 and anterior branches of the S1-S3 roots. It emerges from the greater sciatic notch below the piriformis muscle, then descends between the greater trochanter of the femur and the ischial tuberosity. The nerve then runs along the posterior thigh to the lower third of the femur, where it diverges into two large branches, the tibial and common peroneal nerves.

5.3.2. Distribution of Anesthesia

The sciatic nerve, through its collateral branches, provides sensory and motor innervation to the muscles of the entire posterior surface of the thigh, leg, and foot, except the anterior-inner leg, whose innervation is made by the saphenous nerve, sensory terminal branch of femoral nerve. The posterior tibial nerve gives rise to the sural nerve, medial and lateral plantar branches which are responsible for sensory and motor innervation throughout the plantar foot (plantar flexion). The common peroneal nerve divides into the superficial and deep peroneal nerve and is responsible for sensory and motor innervation of the anterolateral shin and dorsum of the foot (dorsiflexion).

Figure 3: Positioning of US probe and patient in supine position and the leg abducted and externally rotated.

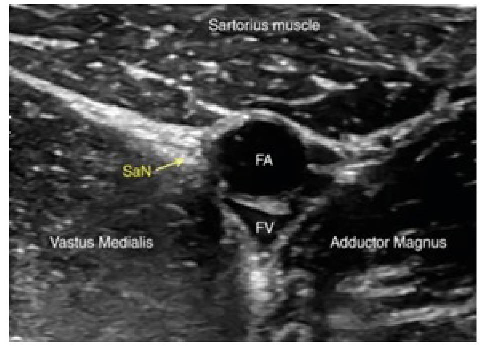

Figure 4: Ultrasound image of saphenpous nerve SaN with manual annotations, From lateral to medial, VM: Vastus Medialis, FA: Femoral artery FV: Femoral vein, SM: Sartorious m, AM: Adductor Magnus.

5.3.3 Technique

Several approaches have been reported for sciatic nerve block. Due to its great length, it can be blocked at virtually any point. With the transgluteal or subgluteal approach under US guidance, the patient is placed in a lateral decubitus position (Figure 5). The limbs are flexed at the hip and knee. When nerve stimulation is used simultaneously, (1.0 mA, 0.1 msec), exposure of the hamstrings, calf, and foot is required to detect and interpret motor responses. As the sciatic nerve is a deep structure, the curvilinear transducer is typically deployed. The reference points are the greater trochanter and the ischial tuberosity (ischium). The initial transducer position is in the depression between the two bony structures. Tilting the transducer slightly proximal or distal can improve the visualization of sciatic nerve which is located between the gluteus maximus superiorly and quadratus femoris inferiorly (Figure 6). Once the sciatic nerve is identified, local anesthetic wheal is administered 1 cm away from the lateral edge of the transducer. The needle is advanced toward the sciatic nerve in a lateral to medial orientation using an in-plane approach. After aspiration to rule out intravascular needle placement, 1-2 mL of LA is deposited to improve visualization of the sciatic nerve suitable injection site. Additional adjustment of needle direction towards sciatic nerve is made. A single injection of 15-20 mL of local anesthetic is conventionally adequate, however distinct spread of LA around the sciatic nerve can also be improved with injections of two to three smaller aliquots at different locations. Similar to the femoral nerve block, choice LA for sciatic nerve block would affect the speed of onset and duration of anesthesia/ analgesia (Table 2).

Figure 5: Positioning of curvilinear ultrasound probe and patient in left lateral position for right proximal sciatic nerve block.

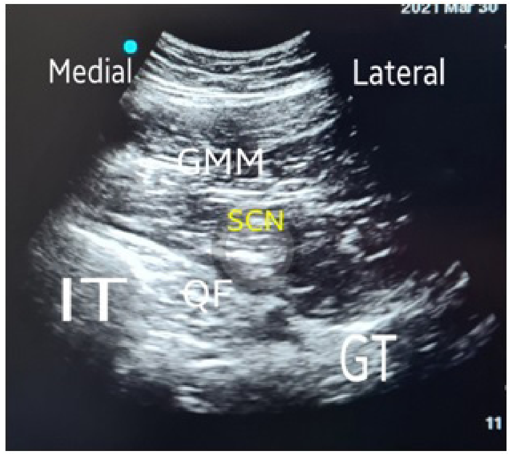

Figure 6: Ultrasound image of right proximal sciatic nerve with annotations. SCN: Sciatic Nerve, GMM: Gluteus maximus muscle QF: Quadratus femoris IT: Ischial tuberosity GT: Greater trochanter.

Table 2: Onset and duration of 20mls local anesthetic in sciatic nerve block (reference from NYSORA: https://www.nysora.com/techniques/lower-extremity/sciatic-nerve-block/).

	Onset (min)	Anesthesia (h)	Analgesia (h)
3% 2-Chloroprocaine	10–15	2	2.5
1.5% Mepivacaine	10–15	4–5	5–8
2% Lidocaine	10–20	5–6	5–8
0.5% Ropivacaine	15–20	6–12	6–24
0.75% Ropivacaine	10–15	8–12	8–24
0.5% Bupivacaine	15–30	8–16	10–48

5.4. Popliteal- Sciatic Nerve Block

5.4.1. Distribution of Anesthesia

Distal sciatic nerve block (popliteal fossa block) is an indispensable technique for anesthesia below the knee. Popliteal fossa block results in anesthesia of the entire distal two thirds of the lower extremity, with the exception of the medial aspect of the leg (covered by saphenous nerve; a superficial sensory terminal extension of the femoral nerve).

5.4.2. Technique

Our instituition commonly performs the popliteal fossa block from the lateral approach under in-plane US guidance (Figure 7). A skin wheal is made on the lateral aspect of the thigh 2–3 cm above the lateral edge of the transducer, and the needle is inserted in plane in a horizontal orientation from the lateral aspect of the thigh and advanced toward the sciatic nerve. The transducer is positioned to identify the sciatic nerve at around 6- 7 cm above the popliteal crease; lateral and superior to the popliteal artery. The quality of the image and better visualization can be improved with sliding transducer probe proximally and distally. The nerve block is performed at the level where tibial nerve (TN) and common peroneal nerve (CPN) start diverging but are still in the common sciatic nerve sheath (Figure 8).

Long-acting local anesthetics such as ropivacaine 0.5% 15- 20mls are injected to provide 12–24 hours of analgesia after foot / below knee vascular surgery. As opposed to the more proximal block of the sciatic nerve, popliteal fossa block anesthetizes the leg distal to the hamstring muscles, allowing patients to retain knee flexion. When used as a sole technique popliteal fossa block provides excellent anesthesia and postoperative analgesia, allows use of a calf tourniquet, and avoids the disadvantages of neuraxial blockade. Analgesia with popliteal fossa blocks lasts significantly longer than with ankle blocks.

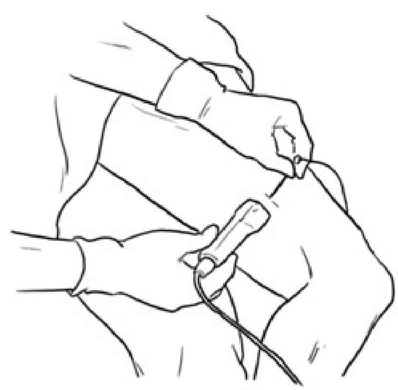

Figure 7: Positioning of Ultrasound probe and patient in left lateral position for right popliteal sciatic nerve block.

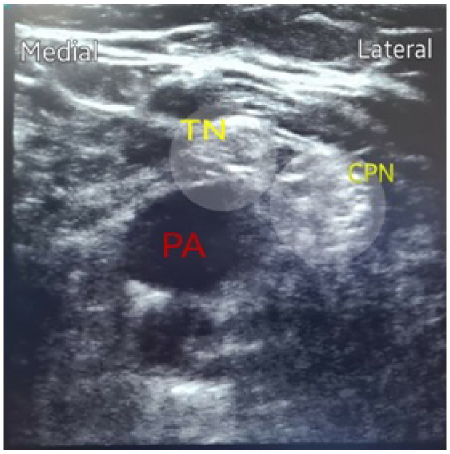

Figure 8: Ultrasound image of right sciatic nerve at popliteal level with annotations, TN**:** Tibial nerve , CPN: Common peroneal nerve: PA: Popliteal artery.

5.5. Ankle Nerve Block

5.5.1. Distribution of Anesthesia

Anesthesia of the foot can be accomplished by blocking the five peripheral nerves that innervate the area at the level of the ankle. The ankle block can be used for all types of foot surgery and is safe and reliable, and has a high success rate.

The medial aspect is innervated by the saphenous nerve, a terminal branch of the femoral nerve. The rest of the foot is innervated by branches of the sciatic nerve (Figure 9 & 10):

- The lateral aspect is innervated by the sural nerve arising from the tibial and communicating superficial peroneal branches.
- The deep ventral structures, muscles, and sole of the foot are innervated by the posterior tibial nerve, arising from the tibial branch.
- The dorsum of the foot is innervated by the superficial peroneal nerve, arising from the common peroneal branch.
- The deep dorsal structures and web space between the first and second toes are innervated by the deep peroneal nerve.

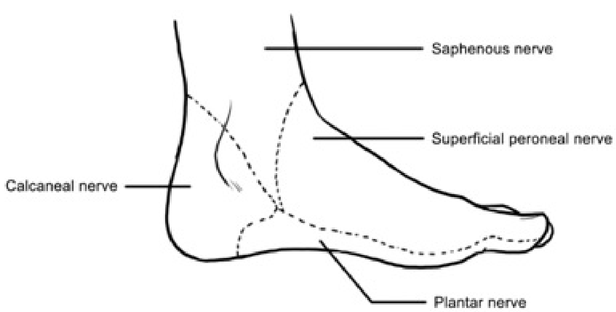

Figure 9: Sensory innervation of the medial aspect of the foot.

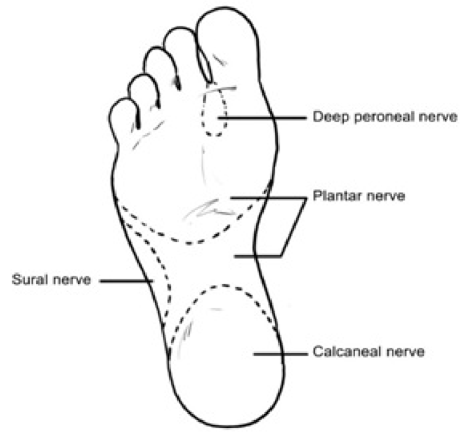

Figure 10: Sensory innervation of the plantar aspect of foot.

5.5.2. Technique

This technique can be done both under anatomic landmarks and/or US guidance. The goal is to place the needle tip immediately adjacent to each of the five nerves and deposit local anesthetic until the spread around each nerve is accomplished. With the patient in the proper position, the skin is disinfected. For each of the nerve blocks, the needle can be inserted either in-plane or out-of-plane. Ergonomics often dictate which approach is most effective. A successful nerve block is predicted by the spread of local anesthetic immediately adjacent to the nerve. Redirection to achieve circumferential spread is not necessary because these nerves are small, and the local anesthetic diffuses quickly into the neural tissue. A 3–5 mL of local anesthetic per nerve is typically sufficient for an effective nerve block. In patients with CTLI, ankle block can be performed for foot surgeries include forefoot amputation, osteotomy, wound debridement. It is also able provide analgesia for soft tissue injuries. Ankle block is preferable to sciatic/ femoral (saphenous) nerve block for outpatient forefoot as it impairs ambulation on the affected leg to a lesser degree than sciatic or popliteal block and patients can be discharged home before the block wears off. Long-acting local anesthetics with ankle block can provide excellent postoperative analgesia. Ankle block should be avoided in patients with local infection, oedema, burn, soft tissue trauma, or distorted anatomy with scarring in the area of block placement.

5.6. Digital Nerve Block

Digital blocks are relatively easy to perform by injection over the base of the toe at the dorsal and plantar aspect of both medial and lateral side to provide regional anesthesia. The advantages of this technique are [1] rapid onset of action, [2] only a small volume of anesthetic solution is required, [3] absence of risk of direct trauma to the neurovascular bundles. One specific complication of digital blocks is vascular insufficiency and gangrene. This catastrophe is a result of digital artery occlusion together with collateral circulation insufficiency. The use of epinephrine-containing solutions for this block is avoided by many as the safety of its use is controversial.

6. Monitoring for Local Anesthetic Systemic Toxicity (LAST)

Recognition of mechanisms, risk factors, prevention and therapy of LAST is particularly important in the subset of patients with PAD. Common comorbidities seen including elderly, End Stage renal disease (ESRD), hepatic dysfunction and cardiac disease may reduce LA plasma clearance and increase susceptibility to LA –induced systemic toxicity (LAST) as potentially large doses of LA may be used for LPMAC. Doses should not be exceeding 3mg/kg of ropivacaine, 5mg/kg of lignocaine, 2mg/kg of bupivacaine) [13].

Practitioners should have a high index of suspicion for LAST by monitoring for manifestations affecting:

- CNS: seizures, perioral paresthesia, confusion, audio-visual disturbances, double vision. dygeusia, agitation or reduced level of consciousness
- CVS: dysrhythmias, conduction defects, hypotension and eventually cardiac arrest (commonly of an asystolic nature)

Mainstay of treatment includes prompt administration of lipid emulsion therapy, expedient seizure management, and selective use of cardiovascular supportive drugs [13].

7. Peri- Procedural Monitoring

To ensure provision of safe LPMAC care, standard ASA monitoring including pulse oxygen saturation (SpO2), Heart rate (HR), Blood pressure (BP) and Electrocardiogram (ECG) are applied to every patient at the start of the procedure and continued in the Post-Anesthetic Care Unit (PACU).

In our institution, patients are monitored in recovery for at least 30 minutes with extended monitoring as required depending on underlying medical history, intra and post-operative revascularization complications such as reperfusion syndrome, compartment syndrome, vascular access bleeding etc.

Specific handover related to LPMAC should be given to the PACU nurse including:

- Type of sedative used, need for supplemental oxygen to maintain saturations of > or = to 94%.
- Type and dose of LA given, and other intra-op analgesics given.
- Vigilance regarding LA toxicity: CNS symptoms such as perioral numbness, tingling, metallic sensation, dysguesia, CVS symptoms such as dysrhythmia, conduction blocks, hypotension.
- Precautions for insensate lower limb and falls.

The acute pain team service would initiate a follow-up post LPMAC the next day to identify potential complications related to peripheral nerve block such as haematoma at injection site, infection and residual blockade after 24 hours. In event of such complications, patients would be offered appropriate relevant advice, management and follow-up. At the same setting, patients' feedback and overall satisfaction with LPMAC can be gauged opportunistically.

8. Discussion

Peripheral nerve blockade (combined femoral/ sciatic nerve block) for lower limb revascularisation should be considered in the following circumstances:

- In patients with multiple comorbidities (high risk for GA and central neuraxial block) undergoing lower extremity revascularization which may favour peripheral lower limb blockade
- Contraindication to GA: pre-existing difficult airway, recent MI, severe pulmonary disease.
- Contraindications to central neuraxial block: Coagulopathy, on antiplatelets/ anticogulant, spinal deformity, patient refusal.
- Also indicated in patients requiring superior analgesia and for reduction of stress response and haemodynamic stability.

Peripheral nerve blocks have the following advantages:

- It reduces postoperative cognitive dysfunction (POCD) while providing good quality postoperative analgesia which can be extended up to 24 hours.
- It reduces respiratory morbidity. As airway instrumentation or the use of inhaled agents or neuromuscular blockers is not required, it is a good option for patients with significant pulmonary disease.
- It avoids rare but serious central neuraxial complications such as spinal/ epidural haematomas, spinal cord injury, paralysis specially as these patients often have deranged clotting due to being on antiplatelets and anticoagulants.

Peripheral nerve blocks have the following disadvantages:

- It may be unsuitable for patients who are unable to lie flat due to cardiac, respiratory, or musculoskeletal problems and for prolonged procedures.
- Relative contraindication: Coagulopathy, risk vs benefits must be carefully considered for patients on dual anti-platelet therapy. Particularly if the nerve to be blocked is close to deep or major vascular structures (femoral artery/ vein).
- Systemic toxicity related to high doses of LA, usually required for multiple lower limb blockades.
- Possible other adverse events include neurological damage by intraneural injection, , local and/or systemic infection and hematoma at the puncture site.
- Caution with falls risk due to transient loss of motor function.
- Absence of pain may mask compartment syndrome.

Various authors have reported that LA and/or peripheral nerve block with sedation are effective techniques in high-risk patients undergoing revascularization and amputations including above knee amputations [7- 9]. Fereydooni et al demonstrated, LPMAC was associated with significantly lower overall morbidity and shorter operating time compared with GA for hybrid lower extremity revascularization. There was a trend towards lower rate of myocardial infarction (1.1% vs 2.4%) and less post-op ventilator use for >48 hours (0.4% vs 2.6%) for LPMAC patients, but this was not found to be statistically significant [7]. Peripheral nerve blockade should also theoretically confer an improvement in lower limb graft patency similar to central neuraxial techniques. In older studies, central neuraxial anesthesia were found to improve lower limb graft patency of up to 5 times in the post-operative period compared to GA [11,12]. Two postulation for these findings are that spinal/ epidural induces a sympathectomy to promote blood flow to improve patency of lower limb graft and may avoid a GA-associated hypercoagulable state postoperatively (hyperfibrinogenemia and increased platelet reactivity) [5]. This finding was however not demonstrated in more recent studies likely due to advances in anesthetic techniques and improved medication safety profile [2]. Postoperative analgesia and anxiety are important aspects to be considered, as response to surgical stress and risk of MIs are highest that period [10] Effective peripheral nerve blockade even as a single shot (may last for up to 12 to 36 hours) can reduce post-op pain and surgical stress coupled with perioperative use of anxiolytics [5].

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