Chapter

Regional Analgesia for Knee Surgeries: Thinking beyond Borders

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Abstract

Knee surgeries are the most commonly performed joint surgeries in the modern world, which help maintain the quality of life by improving joint functions. These include open trauma, sports injury, or joint replacement surgeries. Among various available regional analgesia options for knee surgeries, the goal is to choose motor-sparing, opioid-sparing, and procedure-specific modalities. Therefore, it is essential to know the complex anatomy of the knee joint, essential steps of various surgical procedures, and innervations of the pain-generating structures for a particular surgery. Background knowledge of all these essentials helps select the most appropriate regional analgesia technique for knee surgeries.

Keywords: Knee joint analgesia, Total knee replacement, Total knee arthroplasty, Procedure-specific anesthesia, Motor sparing analgesia, Opioid sparing analgesia, Subsartorial blocks

1. Introduction

The knee is the biggest and the most complicated joint of the human body. Being a most stressed joint subject to enormous pressure while providing flexible movement, it is vulnerable to injury. During walking and jumping, it is loaded with 7-fold body weight. The attached muscles and ligaments provide stability and flexibility to the knee joint. The most important structure of the knee joint is its cartilage surface which might get damaged due to trauma, overload, and genetic disorders. As a result, the patient experiences pain, inflammation, and a limitation of the range of motion, finally leading to an impaired gait.

Knee surgeries are one of the most commonly performed, life-changing surgical procedures of the modern world, leading to improved health-related quality of life and functional status [1, 2]. Knee surgeries vary from minimally-invasive arthroscopic procedures (in relatively younger populations) to open arthroplasty procedures (in the elderly populations).

Before deciding the analgesia techniques for the postoperative period, knowledge of functional anatomy, surgical steps, pain generation, pain generators, and innervation of the pain generators is essential. A multidisciplinary approach with multimodal analgesia is the demand of time for successful surgical outcomes. Regional analgesia (RA) is an important component of multimodal analgesia to deal with perioperative pain. Among many available RA options, challenges include selecting more procedure-specific, motor-sparing, and opioid-sparing options suitable for enhanced recovery after surgeries (ERAS) protocols. A properly planned procedure-specific RA technique provides optimal analgesia without any motor effects, which helps in early mobilization and discharge, reducing opioid consumption and their side effects significantly.

2. Functional anatomy of the knee joint

The knee joint is the largest synovial-type and most-stressed joint in the body. This modified hinge joint is composed of two articulations; the **tibiofemoral** and patellofemoral. The structural and functional stability of the knee joint comes from the muscles and ligaments attached, which also helps to bear considerable biomechanical stress brought upon the joint. Furthermore, the patella acts as an anatomical pulley for the quadricep muscles [3], which enhances knee joint extension by allowing frictionless movements, stabilizes and protects the knee joint. In addition, the joint cartilage and the menisci provide intraarticular flexibility, cushioning, and shock absorption.

2.1 Ligaments of the knee joint

Ligaments provide stability and strength to the knee joint along with bones and cartilage. These include joint capsule, **extracapsular,** and **intracapsular ligaments**.

2.1.1 Joint capsule

It is a thick, fibrous structure mainly formed by muscle tendons and their expansions that wrap around the knee joint. It forms a thick ligamentous sheath around the knee joint. The synovial membrane lying inside the outer fibrous layer lubricates the articular surfaces, reduces friction, and nourishes the joint cartilage. It also has several fluid-filled pouches called bursae that also reduce friction within the knee joint. The folds of the synovium within the joint are called plicae [4].

The synovial fluid in the soaked cartilage (like water in a sponge) squeezes out when the knee bends or bears weight. The osteoarthritic changes in the joint lead to a decrease in synovial fluid that exacerbate joint friction. The anterior capsule has an opening for the attachment to the patella. Similarly, the posterior capsule has an opening for the passage of the popliteus tendon.

2.1.2 Extracapsular ligaments

Extracapsular ligaments include the patellar, popliteal (oblique and arcuate), and collateral (medial and lateral) ligaments.

- **Patellar ligament (Ligamentum patellae)** is a strong, thick fibrous band and a distal continuation of the quadriceps femoris tendon extending from the apex of the patella to the tibial tuberosity. It blends with the medial and lateral patellar retinacula along with the overlying fascia. It stabilizes the patella and prevents its displacement.

- **Popliteal ligaments prevent hyperextension** of the knee joint.

    a. Oblique popliteal ligament (Bourgery ligament) connects the medial tibial condyle with the lateral femoral condyle. It is an expanded portion of the semimembranosus tendon that spans the intercondylar fossa. It reinforces the posterior capsule by blending with it in the central portion.

b. Arcuate popliteal ligament is a thick, fibrous band arising on the posterior aspect of the fibular head. It arches superiorly and medially to attach to the posterior side of the joint capsule of the knee. Thus, it reinforces the posterolateral part of the joint capsule.

- **Collateral ligaments** are two strap-like ligaments providing side-to-side stability of the knee joint and preventing excessive medial or lateral movement.

  a. Medial (tibial) collateral ligament (MCL) is a broad and flat ligament that lies on the medial side of the knee joint. It attaches proximally to the medial femoral epicondyle and distally to the medial tibial condyle. It prevents excessive sideways movement by restricting external and internal rotation of the extended knee.

  b. Lateral (fibular) collateral ligament (LCL) is thin and rounder than MCL that attaches proximally to the lateral femoral epicondyle and distally to the lateral fibular head splitting the biceps femoris tendon. It lies deep to the lateral patellar retinaculum and superficial to the popliteal tendon.

2.1.3 Intracapsular ligaments

Intracapsular ligaments include cruciate (anterior and posterior) ligaments. The paired cruciate ligaments crisscross each other obliquely like a letter “X” within the knee joint. They prevent the femur and tibia from sliding too far forward or backward.

- Anterior cruciate ligament (ACL) arises from the anterior intercondylar area of the tibia and attaches to the posterior part of the lateral femoral condyle (medial surface). It prevents anterior dislocation of the tibia onto the femur by limiting the forward motion of the tibia. It also prevents hyperextension of the knee joint and limits rotation and sideways movement of the knee joint. A newly discovered anterolateral ligament (ALL) works in conjunction with ACL. However, the ACL can get torn by sudden pivoting motions of the knee.
- Posterior cruciate ligament (PCL) arises from the posterior intercondylar area of the tibia and attaches to the anterior part of the medial femoral condyle (lateral surface). It is stronger and more vascular than ACL. It prevents posterior dislocation of the tibia onto the femur by limiting the backward motion of the tibia. It also prevents hyperflexion of the knee joint and limits rotation and sideways movement of the knee joint. However, the PCL can get torn with a forceful landing on the shin.

2.2 Menisci

These are thick pads of fibrocartilaginous crescent-shaped plates found between the articular surfaces of the femur and tibia. By deepening the articular surface, they increase joint stability; and by increasing surface area to dissipate forces further, they act as a shock absorber during weight-bearing and joint movements.

They are highly vascular and thicker in the outer one-third than the inner two-third [5]. The outer one-third contains larger circumferentially arranged bundles whereas, the inner two-thirds contain radially organized collagen bundles. This makes the outer portion of the menisci suitable for resisting tensional forces and the inner portion for adaptation for weight-bearing. The anterior horn of both the menisci attaches to the anterior tibial intercondylar area and blends with ACL. The posterior horn of both the menisci attaches to the posterior tibial intercondylar area. The lateral meniscus is more mobile and smaller than the medial meniscus. The menisci are held in place by other ligaments like transverse ligament, meniscofemoral ligaments, meniscotibial (coronary) ligaments, and patellomeniscal ligament (medial and lateral). All these ligaments indirectly prevent displacement of the knee joint. Surgical removal of the meniscus can lead to osteoarthritic changes in the underlying cartilage.

2.3 Bursae

A bursa is a tiny, slippery, fluid-filled sac located between a bone and soft tissue to reduce friction between them. Arthritis of the knee joint leads to alteration into the joint biomechanics leading to irritation of the bursa. This irritation leads to inflammation called bursitis. Among various types of bursae around the knee, the notable bursae include [6],

- Suprapatellar bursa lies between the quadriceps femoris and the femur
- Prepatellar bursa lies between the apex of the patella and the skin
- Infrapatellar bursa splits into superficial (between the patellar ligament and the skin) and deep (between the tibia and the patellar ligament)
- Semimembranosus bursa lies between the semimembranosus muscle and the medial head of the gastrocnemius

2.4 Muscles around the knee

The muscle groups attached to the knee joint provide strong support and keep the joint stable, well-aligned, and moving. These groups include,

- Quadriceps over the anterior aspect of the thigh
- Hamstrings over the posterior aspect of the thigh
- Adductors over the medial aspect of the thigh
- Lower leg muscles, including the gastrocnemius at the back of the calf

The four movements (**Table 1**) that occur at the knee joint are flexion, extension, lateral and medial rotation. With the flexed knee joint, the lateral and medial rotations occur at the hip joint and vise versa. The hamstrings are responsible for both the hip extension and knee flexion. The knee flexion ranges from 120 degrees to 140 degrees (with the extended hip), increasing 160 degrees with the passive flexion [7, 8].

Movements	Primary muscles	Secondary muscles
Flexion	Adductors (biceps femoris, semitendinosus, and semimembranosus)	Initiated by popliteus Assisted by gracilis and sartorius
Extension	Quadriceps (rectus femoris, vastus medialis, vastus lateralis, and vastus intermedialis)	Tensor fascia latae
Medial rotation	Popliteus Semimembranosus Semitendinosus	Sartorius Gracilis
Lateral rotation	Biceps femoris	

Table 1.
Muscles responsible for various movements in the knee joint.

2.5 Neurovascular supply

The knee joint has a rich vascularization from the genicular anastomosis around the knee (**Figure 1**) formed by genicular branches from femoral and popliteal arteries [9]. There are approximately ten arteries involved in the formation of genicular anastomosis:

- Descending branches from the femoral artery: Lateral circumflex femoral artery and descending genicular branch.
- Ascending branches from the tibial artery: The posterior tibial artery (circumflex fibular branch) and the anterior tibial artery (anterior and posterior tibial recurrent branches).
- Branches of the popliteal artery: Lateral genicular arteries (superior and inferior), the medial genicular arteries (superior and inferior), and the middle genicular arteries.

The nerve supply of the knee joint follows Hilton's law, as innervations of the muscles which cross joints also innervate the knee joint. The knee joint receives all its

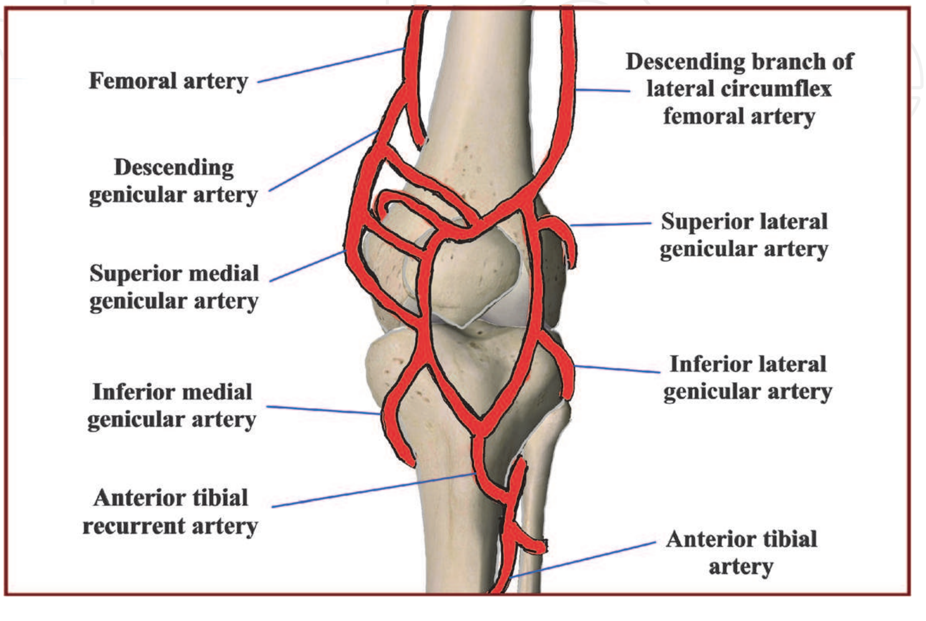

Figure 1.
Genicular anastomosis around the knee joint.

innervation from the branches of the lumbar and sacral plexus. The knee joint innervations need detailed considerations before planning procedure-specific RA techniques.

3. Innervation of the knee joint

A dermatome is an area of skin supplied by the dorsal (sensory) root of the spinal nerve. A myotome is the segmental innervations of skeletal muscle by the ventral (motor) root. An osteotome is the innervation of bone that does not follow a segmental pattern. Various branches (from the lumbar and sacral plexus) innervating the knee joint include the femoral nerve (anterior knee), obturator nerve (posteromedial knee), and sciatic nerve (posterior knee). These nerves have cutaneous branches

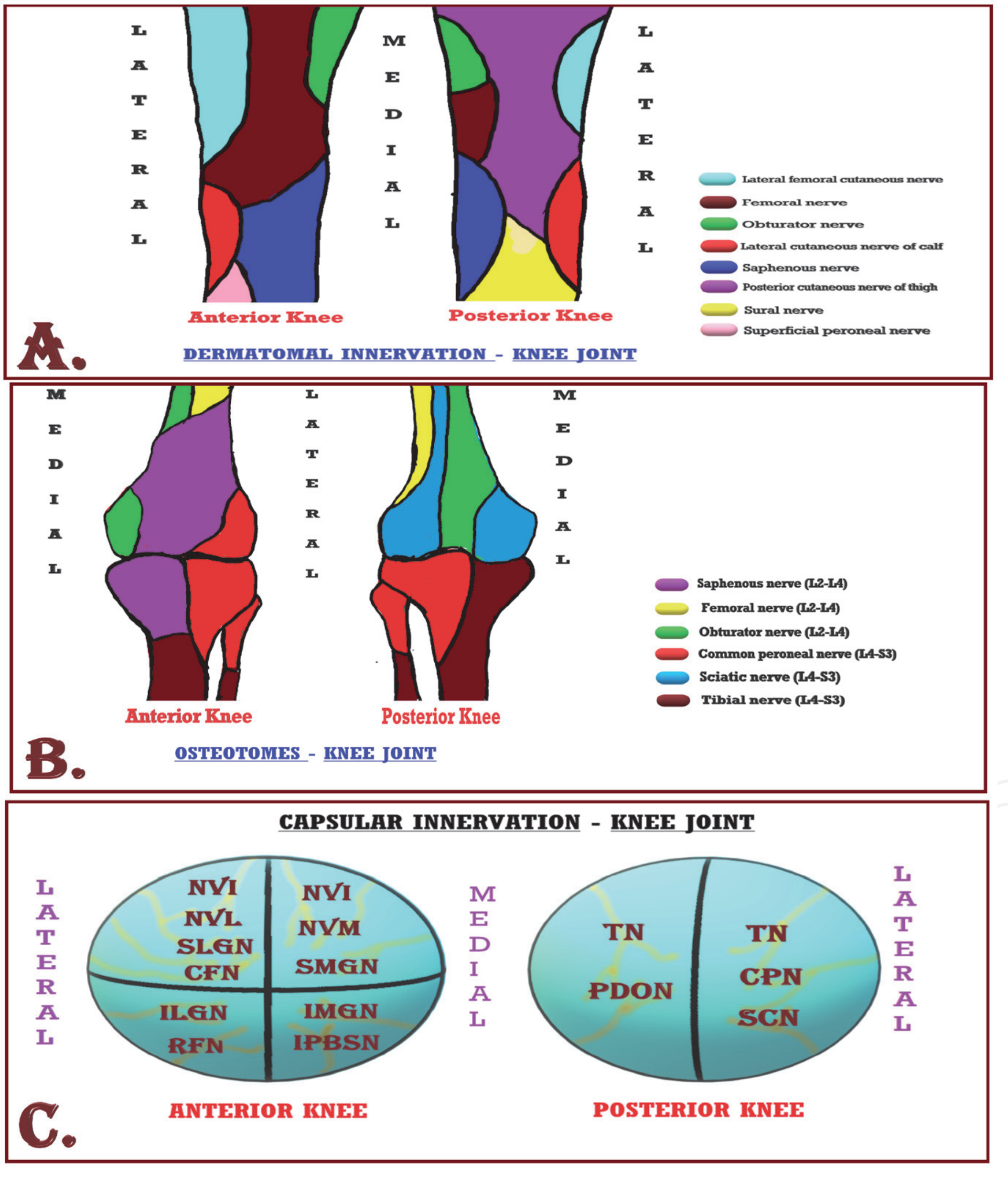

Figure 2.
Dermatomal, osteotomal, and capsular innervation of the knee joint.
***A**: Dermatomal innervations, **B**: Osteotomal innervations, **C**: Capsular innervation.*
*(**NVI**: Nerve to vastus intermedialis, **NVM**: Nerve to vastus medialis, **NVL**: Nerve to vastus lateralis, **SMGN**: Superomedial genicular nerve, **SLGN**: Superolateral genicular nerve, **IMGN**: Inferomedial genicular nerve, **ILGN**: Inferolateral genicular nerve, **IPBSN**: Infrapatellar branch of saphenous nerve, **RFN**: Recurrent fibular nerve, **TN**: Tibial nerve, **CPN**: Common peroneal nerve, **SCN**: Sciatic nerve, **PDOB**: Posterior division of obturator nerve).*

Muscles attached to knee		Innervations
Anterior knee		
1.	Sartorius	Femoral Nerve (L2-L3)
2.	Quadriceps Femoris Rectus Femoris Vastus Medialis Vastus Intermedialis Vastus Lateralis	Femoral Nerve (L2-L4)
Medial knee		
3.	Semitendinosus	Tibial Nerve (L5-S2)
4.	Semimembranosus	Tibial Nerve (L5-S2)
5.	Gracilis	Obturator Nerve (L2-L4)
6.	Adductor Magnus	Obturator Nerve (L2-L4) Sciatic Nerve (L4)
Lateral knee		
7.	Tensor Fasciae Latae	Superior Gluteal Nerve (L4-L5)
Posterior knee		
8.	Biceps Femoris	Sciatic Nerve (L5-S1)
9.	Gastrocnemius	Tibial Nerve (S1-S2)
10.	Popliteus	Tibial Nerve (L4-S1)

Table 2.
Myotomal innervation of the knee joint.

supplying skin (**Figure 2A**), muscular branches supplying muscles (**Table 2**), and articular or genicular branches supplying knee joint or joint capsule (**Figure 2B** and **C**). Before supplying the knee joint, these nerves contribute to the formation of 3 different plexuses (**Table 3**); Subsartorial plexus, Peripatellar plexus, and Popliteal plexus [10–13].

The anterior capsule [14, 15] of the knee joint is innervated,

- Superomedially by the nerve to vastus medialis (NVM), nerve to vastus intermedialis (NVI), superior medial genicular nerve (SMGN)
- Superolaterally by the nerve to vastus lateralis (NVL), NVI, superior lateral genicular nerve (SLGN), common fibular nerve (CFN)
- Inferomedially by Infrapatellar branch of the saphenous nerve (IPBSN), inferior medial genicular nerve (IMGN)
- Inferolaterally by inferior lateral genicular nerve (ILGN), recurrent fibular nerve (RFN)

The posterior capsule [16] of the knee joint is innervated,

- Medially by tibial nerve (TN) and posterior division of obturator nerve (PDON)
- Laterally by tibial nerve, common peroneal nerve, and sciatic Nerve (SCN)

Plexus	Location	Contributing nerves	Innervations
Subsartorial plexus	Medial knee under the sartorius	• Infrapatellar branch of saphenous nerve • Anterior division of obturator nerve • Medial femoral cutaneous nerve • Nerve to vastus medialis	• Skin over the medial aspect of the knee • Medial retinaculum • Medial collateral ligaments • Anterior capsule of the knee joint
Peripatellar plexus	Around the patella	• Medial femoral cutaneous nerve • Intermediate femoral cutaneous nerve • Lateral femoral cutaneous nerve • Infrapatellar branch of the saphenous nerve • Nerve to vastus medialis (NVM) • Medial retinacular nerve (terminal branch of NVM) • Lateral retinacular nerve (terminal branch of the sciatic nerve)	• Skin over the anterior, superior, inferior, medial, and lateral to the patella • Retinacula • Collateral ligaments • Anterior capsule of the knee joint
Popliteal plexus	Posterior aspect of the knee joint	• Articular branches from the tibial nerve, common peroneal nerve, and sciatic nerve • Posterior division of the obturator nerve	• Posterior capsule of the knee joint • All intraarticular structures • Retinacula • Collateral ligaments

Table 3.
Various plexuses innervating the knee joint.

4. Knee joint injuries

The injuries to the knee joint are not uncommon due to associated biomechanical stress during routine activities. Any unnatural joint movement (twisting, pivoting, sudden change of direction, or a forceful blow) leads to injury to the structures stabilizing the knee joint. Common conditions include:

- **Jumper's knee is** an inflammation of the patellar ligament due to overuse stress on it like sudden impact on the joint during landing after a jump in the sports activity. It is also common in overweight individuals due to significant stress on the joint.

- **Anterior cruciate ligament (ACL) injury** is caused by the hyperextension of the knee joint or by the application of large force over the posterior knee. This injury is common among athletes such as football, occurring due to a sudden change of direction or improper landing after a jump. The ACL injury causes pain, swelling, and instability of the knee joint.

- **Posterior cruciate ligament (PCL) injury** is caused by the hyperextension of the knee joint commonly seen in car dashboard injury that causes posterior displacement of the tibia due to significant force over the flexed knee and shin.

- **Collateral ligament tears** occur most commonly in contact sports due to a blow on the side of the knee. The MCL can be injured by a direct blow to the lateral knee, whereas the LCL can be injured by a direct blow to the medial knee.

- **Terrible/unhappy triad** consists of injury to the cruciate ligament, MCL ligament, and the medial meniscus commonly caused by a lateral blow to the extended knee associated with sports like rugby or football.

- **Housemaid's knee** is inflammation of the prepatellar bursa, causing swelling on the anterior knee caused due to friction between skin and the patella.

- **Clergyman's knee** is inflammation of the infrapatellar bursa caused due to friction between skin and the tibia during kneeling on hard surfaces.

5. Symptoms of the knee joint injury

Knee joint symptoms are variable depending on the injury pattern or disease extent.

- **Pain** over the knee joint can be dull, sharp, constant, or on-and-off type.

- **Unstable knee/Increased range of motion** is due to ligamentous injuries.

- **Decreased range of motion** is due to arthritis changes in the knee joint.

- Immediate **swelling** is usually due to hemarthrosis (bleeding into the joint). Delayed **swelling** or on-and-off swelling is due to the irritation and inflammation of the structures inside the joint, causing excess production of synovial fluid.

- **Locking (or catching)** occurs due to a loose body or a torn meniscus in the knee joint.

- **Giving Way** is due to injuries to ligaments, a loose body, or a torn meniscus.

- **Snaps, crackles, and pops** occur due to osteoarthritis and chondromalacia patella, where the cartilage under the patella starts to wear down.

6. Pain generation and pain generators

Diseases or injuries that affect the knee joint cause biochemical reactions leading to the stimulation of pain receptors present on various structures that contribute to developing significant pain. Nociception is the normal body response to subthreshold noxious stimuli. In comparison, the pain generation process results from the interplay between noxious stimuli, nociceptors, and the central nervous system (CNS). It involves four major processes: transduction, transmission, modulation, and perception [17].

a. **Transduction** is the conversion of suprathreshold noxious stimuli into an electrical signal (action potentials) by the nociceptors - first-order neurons.

b. **Transmission** is the conduction of action potential through nociceptive specific neurons (lamina I, II) and wide dynamic range neurons (lamina III-VI) – second-order neurons.

c. **Modulation** is an augmentation or attenuation of afferent transmission by spinal and supraspinal centers.

d. **Perception** is the subjective awareness produced by integrating inputs in the somatosensory cortex and limbic system – third-order neurons. It is a complex function of several processes, including attenuation, expectation, and interpretation.

6.1 Knee joint nociceptors

Knee joint nociceptors are of two types, slow conducting C-fibers and fast conducting A-delta fibers. They are scattered in the skin, subcutaneous tissue, muscles, joint capsule, intraarticular structures, periosteum of the bone, infrapatellar fat pad, and extra-articular retinacular ligament. The joint cartilages with adjacent cortical and trabecular bone contain no nociceptors.

These nociceptors get activated by mechanical (pressure, pinch), heat, and chemical stimuli. The mechanical and heat stimuli are shorter (fast pain) than the chemical stimuli (slow pain). Chemicals activating or sensitizing primary afferent nociceptors include potassium, histamine, serotonin, bradykinin, prostaglandins, leukotrienes, and substance P [18, 19]. These chemicals are released from damaged tissues and circulating blood cells (migrated to the damaged area). For this reason, the concentration of these chemicals increases in regions of inflammation as well as pain.

6.2 Causes of knee joint pain

The knee joint pain arises due to joint-related and non-joint-related causes [20]. Joint-related causes include infections/inflammation (osteoarthritis), instability (ligament injury or malalignment/loosening of the implant), fractures, femoropatellar problems, and damage to the structures responsible for knee joint stability. Non-joint causes include soft tissue irritation (impingement due to oversize implants and muscle/tendon overuse during aggressive physiotherapy), neurological disease (neuropathies and spine disorders), hip disease (osteoarthritis and hip necrosis), vascular disease (aneurysm and thrombosis), and reflex sympathetic dystrophy.

6.3 Perioperative knee pain

The injury or pathology in the knee joint mainly initiates the pain generation process. Before surgery, the pain usually arises from the damaged or diseased tissues that stimulate free nerve endings and nociceptors. Postsurgical pain is mainly due to surgical insult leading to tissue damage, nerve irritation, microfractures, tendinitis, and inflammation. Postoperative knee pain is of 2 types:

a. **Musculoskeletal pain:** It arises due to damage to the soft tissues and muscles. The nature of this pain is usually aching, dull, and throbbing type. Postoperative tourniquet pain is also a musculoskeletal type of pain that arises after regression of spinal level. This pain arises due to the irritation of nociceptors by various inflammatory mediators released due to muscle ischemia.

b. **Neuropathic pain:** The mechanisms for neuropathic pain are more complex than nociceptive pain. The nature of this pain is usually sharp, electric shooting, and stabbing type. It results from the injury to the nerves involved in the pain pathway, leading to an alteration in the pain processing. The hypersensitivity and hyperexcitability of the neurons result in dysesthesia, allodynia, and hyperalgesia. In addition, psychological factors like stress, fear, and anxiety can influence the experience and extent of pain, known as modulatory influences prolonging the pain episodes in susceptible individuals.

7. The pain management strategies

Pain is "*an unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage [21].*"

The components of pain assessment include history and physical assessment, functional assessment, psychosocial assessment, and multidimensional assessment. All kinds of pain are associated with stress, which is an essential factor in pain management. Thus, the psychological component of pain is crucial in determining the patient's treatment protocols and promoting active involvement in self pain control. In addition, the pain perceptions may vary among individuals depending upon types of injuries/pathology, duration of pain, and associated psychosocial backgrounds. Therefore, the ABCDE of pain management (**Figure 3**) is essential to deal with any pain [22].

The pain management strategies have been evolving and ever-changing. With the introduction of a new effective protocol every decade, the approach to handle pain has become more comprehensive and target-specific. This evolution in the management strategies resulted in more effective and focused results with reduced complications.

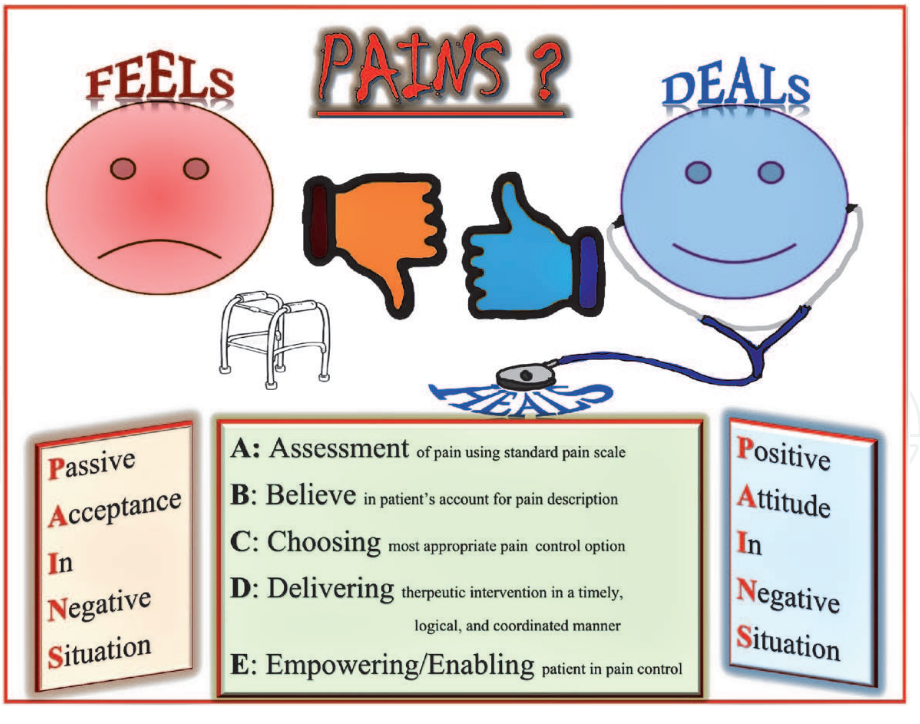

Figure 3.
Perceptions of pain and ABCDE of pain management.

7.1 Evolution of pain management

- **1980**: Pain was underrated and usually treated with intravenous/intramuscular narcotics. Due to fear of the side effects of narcotics (opioid phobia), the pain remained undertreated (oligoanalgesia) in this decade.

- **1990**: The American Pain Society declared pain as the 5th Vital Sign in this decade [23, 24]. Significant efforts by pharmaceutical companies were made in developing new products and aggressive marketing of opioids. In the same decade, Patient Controlled Analgesia (PCA) was also introduced as a mode of delivery of narcotics.

- **2000–2010:** This decade was known as 'The Decade of Pain Control and Research [25].' The concepts of Pre-emptive analgesia and Multimodal Analgesia were introduced to shift focus on reducing narcotic consumption.

- **2010:** Multimodal analgesia became an essential cornerstone of the strategy in this decade. The use of regional techniques (PNB/LIA) was introduced as an essential component of MMA.

- **2020:** Now, the pendulum has begun to swing back from the era of less opioid use, then aggressive use, and now no opioid use. The concept of "Opioid Free Anaesthesia/Analgesia" was introduced. On the same ground, a non-profit organization like the Society of Opioid Free Analgesia (SOFA) was formed to research, promote & educate anesthesia professionals and the general public on opioid-free pain management techniques in Hudson, US.

- **2030 onwards:** Researchers will likely focus more on detailing the innervations and achieving more target-specific blocks. In this decade, new techniques will probably be introduced to replace existing conventional blocks (**Figure 4**).

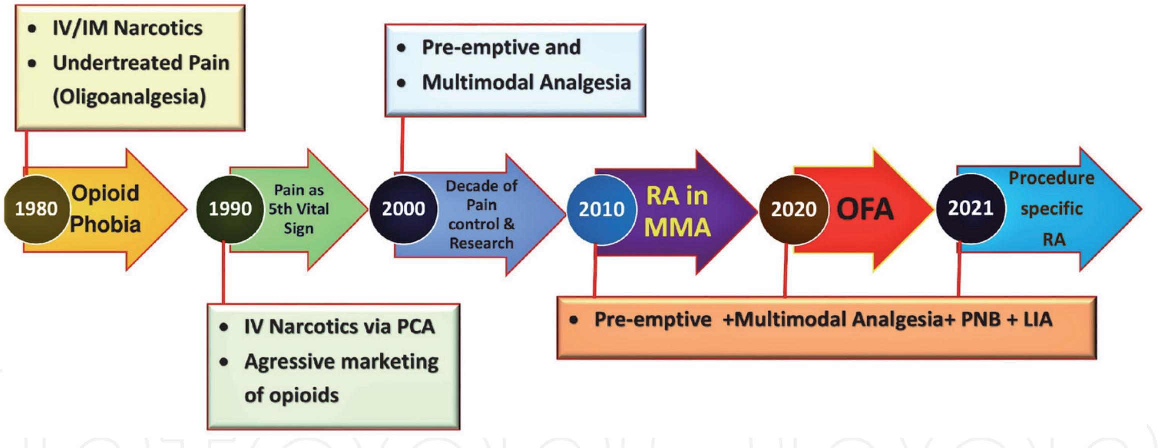

Figure 4.
Evolution of pain.
*(**IV/IM**: Intravenous/intramuscular, **PCA**: Patient-controlled analgesia, **RA**: Regional analgesia/anesthesia, **MMA**: Multimodal analgesia, **OFA**: Opioid-free anesthesia, **PNB**: Peripheral nerve block, **LIA**: Local infiltration analgesia).*

8. Analgesia protocols

The pain generation is a continuous process due to the nonadaptive property of the nociceptors. It depends on transforming the continuous noxious stimuli into the pain signals, transmitting the pain signals through pain pathways, and perceiving actual pain at the central level. Thus, pain treatment protocols should reduce noxious stimuli, interrupt pain pathways, and modify pain perception at the central level. Reduction in noxious stimuli generation is possible by addressing causative factors like inflammations and nerve injuries. Interruption of pain pathways is possible by blocking the transmission using the local anesthetic solution in RA techniques. Finally, modification of pain perception is possible using various analgesic drugs mainly acting on the CNS level. A combination of various pharmacological agents, nonpharmacological techniques, and RA techniques constitutes the concept of multimodal analgesia. The components of MMA act on various levels of pain pathways.

8.1 Multimodal analgesia

Multimodal analgesia (MMA) includes more than one pain-control modality (pharmacological and nonpharmacological)(**Figure 5**) to achieve optimal analgesia [26]. The additive or synergistic effects of these modalities act on various sites of the pain pathways to enhance pain control. It also helps to minimize any side effects that are associated with a single agent. Pharmacological agents include acetaminophen, nonsteroidal anti-inflammatories, steroids, narcotics, N-methyl-D-aspartate (NMDA) receptor antagonists (ketamine or dextromethorphan), and antiseizure medications (gabapentinoids, particularly gabapentin and pregabalin). Nonpharmacological adjuncts include immersive virtual reality, acupuncture, injections (trigger point injections and epidural steroid injections), other neuroexperimental modalities, cryotherapy, transcutaneous electrical nerve stimulation units, and various regional analgesia techniques.

The regional analgesia (RA) techniques play an essential role as an adjunct to MMA by interrupting pain transmission and sensitization (central and peripheral) processes. MMA also includes pre-emptive analgesia, which also plays an essential role in decreasing peripheral and central sensitization. Various studies recommend the MMA as the best approach for any postsurgical pain. Unaddressed postsurgical

Figure 5.
Multimodal analgesia components.

pain initiates several neuroendocrine stress responses - leading to secretion of various hormones [27] like ACTH, catecholamines, and ADH - resulting in an increase in blood pressure, heart rate, prolonged recovery, and infections.

9. Enhanced recovery after surgery (ERAS)

ERAS is one of the leading examples of pathway-based perioperative care (**Figure 6**). It provides a structured mechanism to improve the quality of care, reduce variation in surgical care, minimize complications, and improve outcomes of surgeries [28]. ERAS also controls perioperative physiology to optimize the patient by minimizing the stress response to surgery and anesthesia [29, 30]. The key elements of ERAS protocol include patient education, expectation setting, aggressive optimization of comorbidities, standardized anesthetic and surgical techniques, early mobilization, early oral nutrition, early discharge, and effective pain management using MMA. ERAS decreases postoperative complications and costs, shortens hospital stay, and enhances patient satisfaction [31]. Rapid recovery in knee surgeries is possible because of less invasive surgical procedures, more selective soft tissue balancing, improved patient education, meticulous instrumentation, selecting suitable implant design, and improved analgesia options.

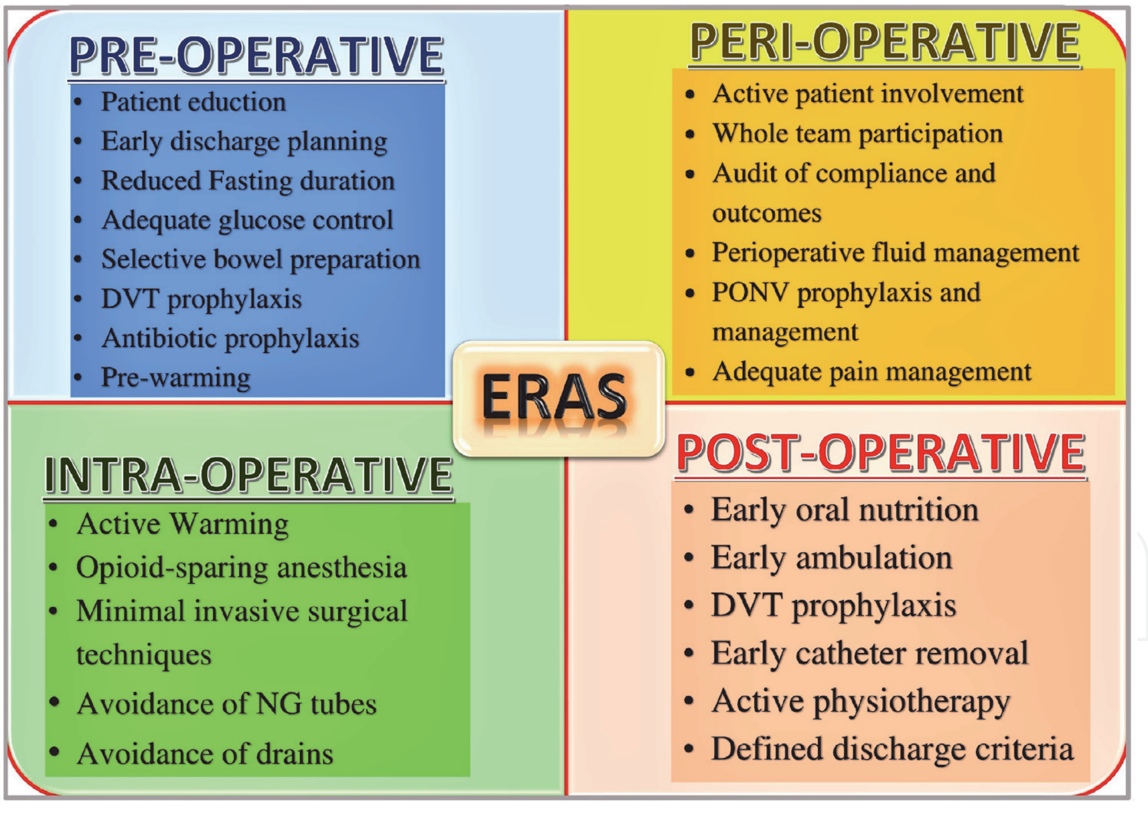

Figure 6.
Enhanced recovery after surgery protocol.
*(**DVT**: Deep venous thrombosis, **PONV**: Postoperative nausea and vomiting, **NG**: Nasogastric).*

10. RA options for knee surgeries

The regional anesthesia or analgesia techniques for knee surgeries have been evolving to improve procedural outcomes, reduce complications and improve patient satisfaction [32]. With the introduction of ultrasound into the RA practice, the perioperative analgesic strategies for knee surgeries have undergone a conceptual revolution in the last decade.

Apart from providing optimal analgesia and intraoperative clear surgical field, RA also helps in the reduction of major postoperative complications like deep venous thrombosis, pulmonary embolism, requirements of blood transfusion, pneumonia, and respiratory depression [33, 34]. RA options available for knee surgeries from center-to-periphery include (**Figure 7**).

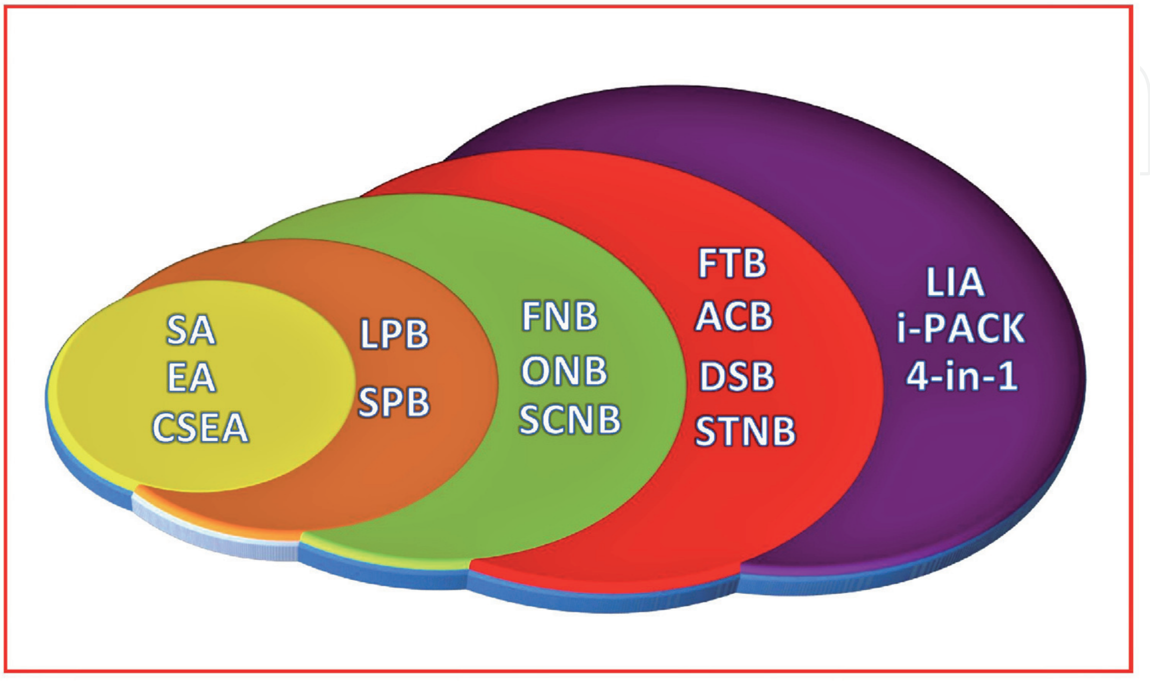

Figure 7.
Regional analgesia options from 'Centre-to-periphery' for knee surgery.
*(**SA**: Spinal analgesia, **EA**: Epidural analgesia, **CSEA**: Combined spinal-epidual analgesia, **LPB**: Lumbar plexus block, **SPB**: Sacral plexus block, **FNB**: Fenoral nerve block, **ONB**: Obturator nerve block, **SCNB**: Sciatic nerve block, **FTB**: Femoral triangle block, **ACB**: Adductor canal block, **DSB**: Dual subsartorial block, **STNB**: Selective tibial nerve block, **LIA**: Local infiltration analgesia, **i-PACK**: Infiltration between popliteal artery and capsule of knee joint).*

A. **Neuraxial blocks**:

- Subarachnoid block (SAB)
- Epidural analgesia (EA)
- Combined spinal + epidural analgesia (CSEA)

B. **Plexus block**:

- Lumbar plexus block (LPB)
- Sacral plexus block (SPB)

C. **Non-motor-sparing peripheral nerve blocks**:

- Femoral + sciatic + obturator nerves block
- Selective tibial nerve block (STNB)

D. **Motor-sparing blocks**:

I. **Subsartorial blocks**:

a. Femoral triangle block (FTB)

b. Adductor canal block (ACB)

c. Dual subsartorial block (DSB)

II. **High volume blocks**:

a. Hi-Volume Proximal Adductor Canal (Hi-PAC) block

b. 4-in-1 block/modified 4-in-1 block.

c. Ultrasound-guided Hamstring block

III. **Infiltrations techniques**:

a. Infiltration between Popliteal Artery and Capsule of Knee (IPACK) block

b. Local Infiltration Analgesia (LIA)

c. Ultrasound-guided LIA or Ring block

A. **Neuraxial blocks**: Neuraxial blocks were considered the gold standard option in providing postoperative analgesia in knee surgeries. However, due to unwanted side effects (like urinary retention, delayed mobility, blocking of other limbs, chances of epidural hematomas in patients on anticoagulants), they lost their popularity [35, 36].

B. **Lumbosacral plexus block**: The lumbar plexus mainly contributes to the anterior knee innervations, whereas the sacral plexus contributes to posterior knee innervations. Thus, both the plexuses need to be blocked to provide complete postoperative analgesia. However, the lumbosacral plexus block remains unsuitable for patients on anticoagulants due to its deeper location and rich vascularity around it. It also results in muscle weakness, causing delayed recovery, mobility, and discharge - Exclusion from the ERAS protocol.

C. **Non-motor-sparing blocks**:

- **Femoral nerve block**: Femoral nerve contributes to the anterior knee innervations. Its blockade provides excellent pain relief, especially over the anterior and medial compartments of the knee. However, due to associated quadriceps muscle weakness, it is not recommended in ERAS protocol.

- **Obturator/Sciatic nerve block**: Due to associated muscle weakness of adductors and hamstrings with obturator and sciatic nerve block, respectively, they are not recommended in ERAS protocol. The sciatic nerve blockade also causes foot drop, which may mask the surgically injured common peroneal nerve in severe valgus deformity.

- **Selective tibial nerve block***: The tibial nerve can be selectively blocked in the popliteal region to avoid unwanted foot drop due to the common peroneal nerve (CPN) blockade. It* presents a viable alternative to sciatic *nerve block.* However, the proximal spread of local anesthetic (LA) showed involvement of CPN, which is unwanted and not solving the purpose. This block is given as an adjunct to the femoral nerve block to provide analgesia for total knee replacement surgeries.

D. **Motor-sparing blocks**:

Due to associated motor weakness with the techniques mentioned above, further leading to the risk of falls, delayed mobility, and delayed discharge, the following alternatives (**Figure 8**) can be considered suitable for ERAS protocols.

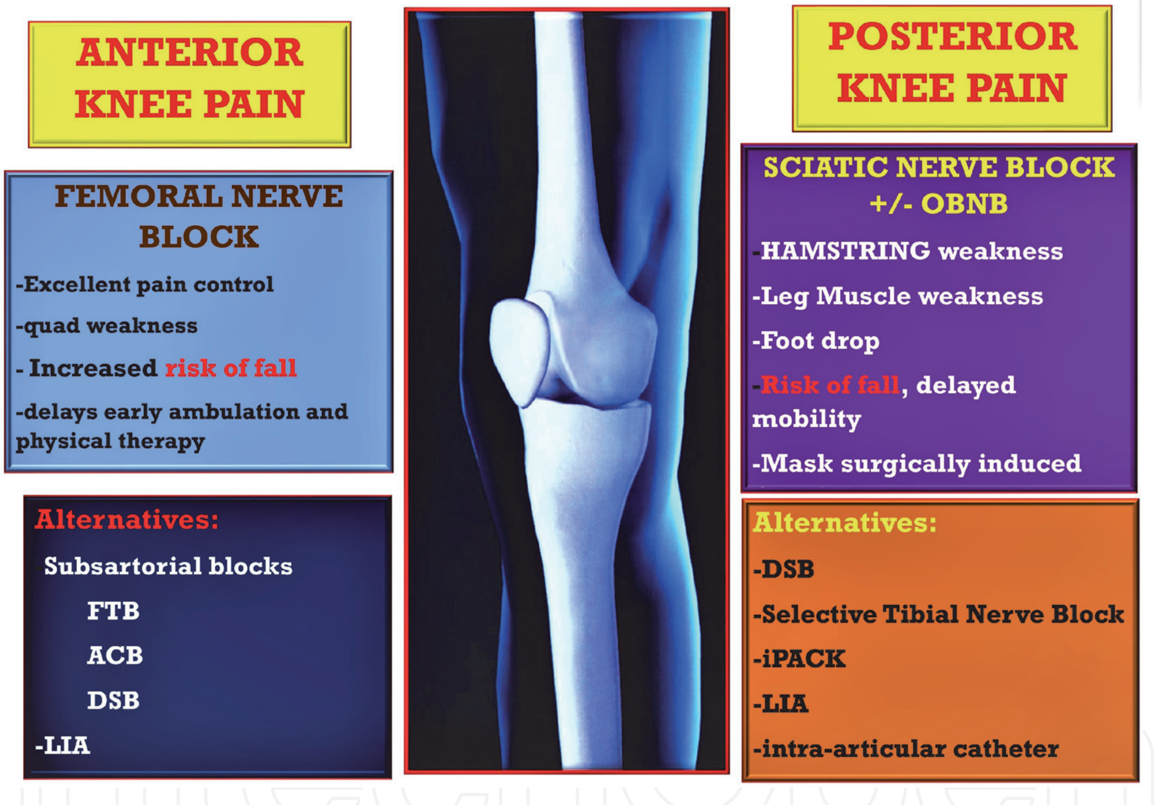

Figure 8.
Regional analgesia option for anterior and posterior knee pain.
*(**FTB**: Femoral triangle block, **ACB**: Adductor canal block, **DSB**: Dual subsartorial block, **LIA**: Local infiltration analgesia, **iPACK**: Infiltration between popliteal artery and capsule of knee joint).*

I. **Subsartorial blocks**: For all the blocks in the thigh for knee surgeries, the sartorius muscle is a familiar muscular landmark in the sonoanatomy. The LA solution is deposited below the sartorius muscle during these blocks, hence the name "subsartorial blocks [37, 38]." The subsartorial blocks include femoral triangle block, adductor canal block, and dual subsartorial block (**Figure 9**).

a. **Femoral triangle block**:

The femoral triangle (FT) is a subfascial space in the upper third of the thigh bounded by the inguinal ligament (base), medial

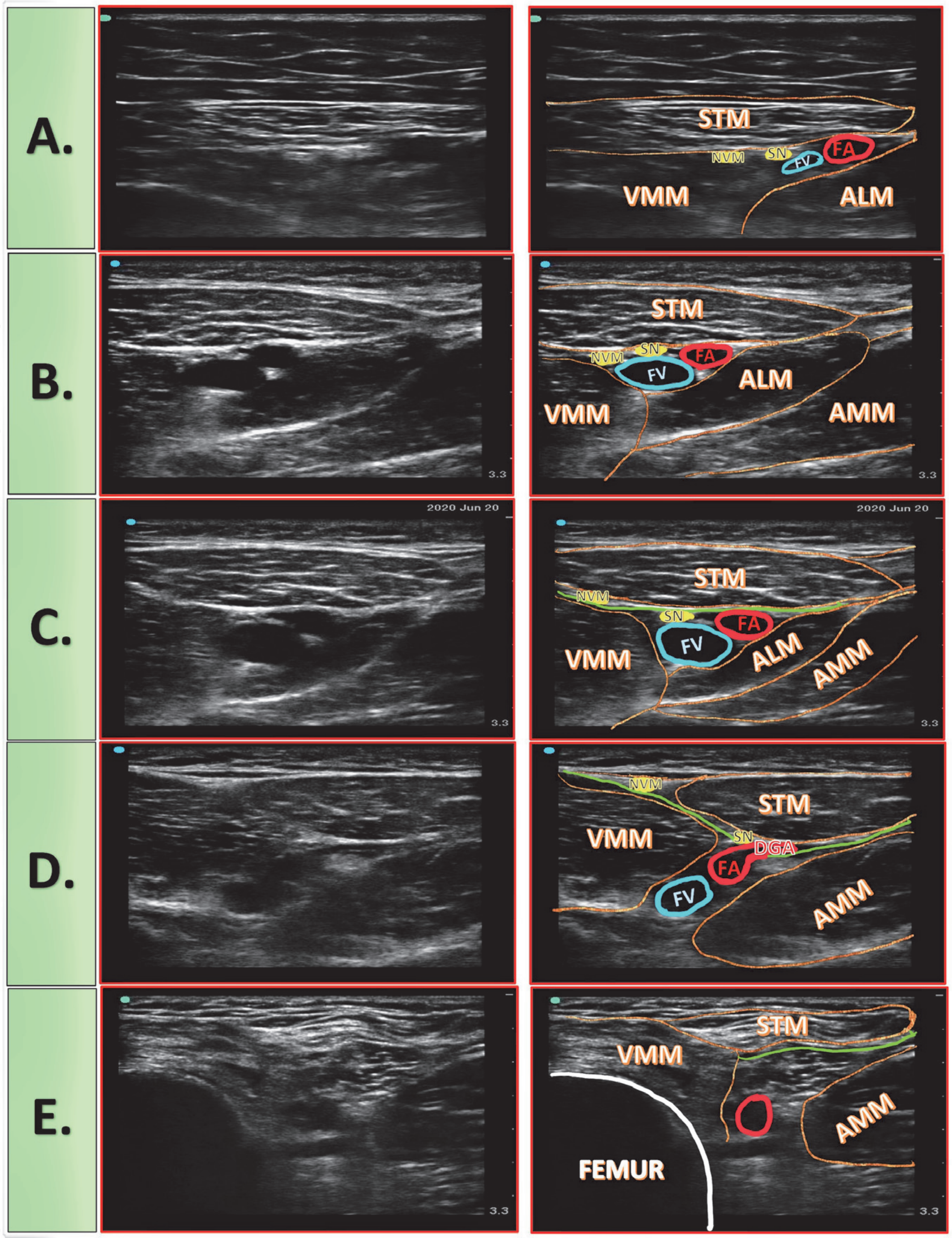

Figure 9.
Sonoanatomy of subsartorial regions.
***A**: Distal femoral triangle, **B**: Apex of the femoral triangle, **C**: Proximal adductor canal, **D**: Mid-adductor canal, **E**: Distal adductor canal.*
*(**STM**: Sartorius muscle, **ALM**: Adductor longus muscle, **VMM**: Vastus medialis muscle, **AMM**: Adductor magnus muscle, **SN**: Saphenous nerve, **NVM**: Nerve to vastus medialis, **FA**: Femoral artery, **FV**: Femoral vein, **DGA**: Descending genicular artery, **Yellow color**: Nerves, **Red color**: Artery, **Blue color**: Vein, **Brown color**: Muscles).*

border of the adductor longus muscle (medial border), and the medial border of the sartorius muscle (lateral border). Femoral triangle block can be given at the distal-most part of FT, just (1–2 cm) proximal to the apex of FT. Sonoanatomy of this location includes posteromedial adductor longus muscle (ALM), anterolateral vastus medialis muscle (VMM), and medial sartorius muscle (STM). The saphenous nerve (SN) and nerve to vastus medialis (NVM) appear as hyperechoic structure lying lateral to the femoral artery (FA) in the fascial plane between STM and VMM. This analgesic block requires diluted (low concentration) local anesthetic solution with the volume of 10-20 ml. A higher volume (more than 40 ml) or higher concentrated LA may cause proximal spread and include the femoral nerve and its branches, causing unwanted motor weakness. The drug injected into the distal FT spreads distally above and below the vasoadductor membrane (VAM) in the adductor canal region [39, 40]. Due to drug spread between STM and VAM, the subsartorial plexus also gets blocked, providing an additional and required analgesic coverage. The FT block mainly addresses anterior knee pain.

b. **Adductor canal block**:

The adductor canal (AC) is a musculoaponeurotic tunnel extending from the FT apex above to the adductor hiatus below. It is triangular in a cross-section bounded anterolaterally by VMM, posteromedially by ALM proximally and adductor magnus muscle (AMM) distally, and medially by the vasoadductor membrane (VAM). The presence of VAM is the peculiarity of the AC region. Due to VAM, the lower border of the sartorius muscle appears bilayered under ultrasound.

Initially, the adductor canal block (ACB) was considered a saphenous nerve block [41, 42]. Later, various dye studies demonstrated the spread of the dye into the popliteal region when injected in the AC below the VAM. Therefore, the injection at any point distal to the FT apex below VAM can be considered an ACB. However, the involvement of neuronal components will be varied, depending upon the proximal or distal location of ACB. The required LA volume for the ACB is 10–20 ml.

Three critical events occur in the AC [41, 42]:

- Entry of SN along with the femoral vessels from the FT into the AC - in the proximal part of AC
- Exit of SN along with descending genicular artery (a branch from FA) by piercing VAM and leaving AC- in the middle-third part of AC
- Entry of the femoral vessels (with the posterior division of the obturator nerve) into the opening of the AMM (adductor hiatus) - in the distal part of AC.

Due to these events, it is essential to divide ACB into three subdivisions: Proximal, mid, and distal AC. However, in all three locations, a drug injected into the AC below the VAM tracks along with the femoral vessels towards the adductor hiatus (involving the posterior division of the obturator nerve) and enters the backside of the knee (involving the popliteal plexus) [43, 44].

The SN enters the AC in the proximal part but leaves the AC in the middle part, where it lies between STM and AMM above the VAM [41]. Later, it crosses the thigh from the anterior to the medial side and becomes superficial by piercing the deep fascia of the thigh, where it lies between STM and gracilis muscles [41].

So, SN is not the content of mid-to-distal AC. The NVM always lies above the VAM with an additional fascial covering, so not the content of the entire AC [41, 45]. Thus, the analgesic coverage of the AC varies as per the involvement of the neuronal components at different locations.

Proximal adductor canal block is given in the proximal third of AC, just (1–2 cm) distal to the apex of FT. Sonoanatomy includes ALM posteromedially, VMM anterolaterally, VAM medially, and SM above VAM. The hyperechoic SN lies into the adductor canal lateral to the FA.

Mid-adductor canal block is given in the middle third of AC, distal to the proximal AC, where the ALM is replaced by AMM posteromedially.

Distal adductor canal block is given in the lower third of AC, where the femoral vessels enter into the adductor hiatus to become popliteal vessels. Sonoanatomy includes AMM posteromedially, VMM anterolaterally, and VAM (with SM above) medially. No nerves lie in this part of the adductor canal.

c. **Dual subsartorial block (DSB)**:

Dual subsartorial block (DSB) is described as opioid-sparing, motor-sparing, and procedure-specific RA technique for total knee replacement (TKR) surgeries, mainly with medial incisions. It is a hybrid form of subsartorial block combining two subsartorial blocks (distal FT and AC block) to cover all procedure-specific innervations of pain generators involved in TKR surgery [46]. It is given immediately after the surgery with two different injections at two different locations below the sartorius muscle, hence termed a "dual subsartorial block" (**Figure 10**).

The first injection (distal FT block) targets SN and NVM directly and subsartorial plexus indirectly due to the distal spread of the drug under SM but above the VAM [43]. The subsartorial plexus lies between VAM and SM in the AC region. In the second injection (adductor canal block), no nerves are targeted. Simply depositing the drug perivascularly (around FA) under the VAM is sufficient to obtain the desired outcome. A drug injected into the AC below VAM will travel along the femoral vessels and enter the adductor hiatus to reach the posterior aspect of the knee joint [44]. Thus, the second injection indirectly targets the popliteal plexus formed by the articular branches from the posterior division of the obturator nerve, tibial, common peroneal, and sciatic nerve.

Thus, DSB involves blockade of SN, NVM, subsartorial plexus, the medial half of the peripatellar plexus, and the popliteal plexus. It results in sensory blockade over the anteromedial aspect of the knee up to the tibial tuberosity, medial retinacular complex, and intraarticular region (popliteal plexus). It will not cover the skin over the anterolateral (supplied by lateral half of peripatellar plexus) and posterior aspect (supplied by the posterior femoral cutaneous nerve of the thigh) of the knee.

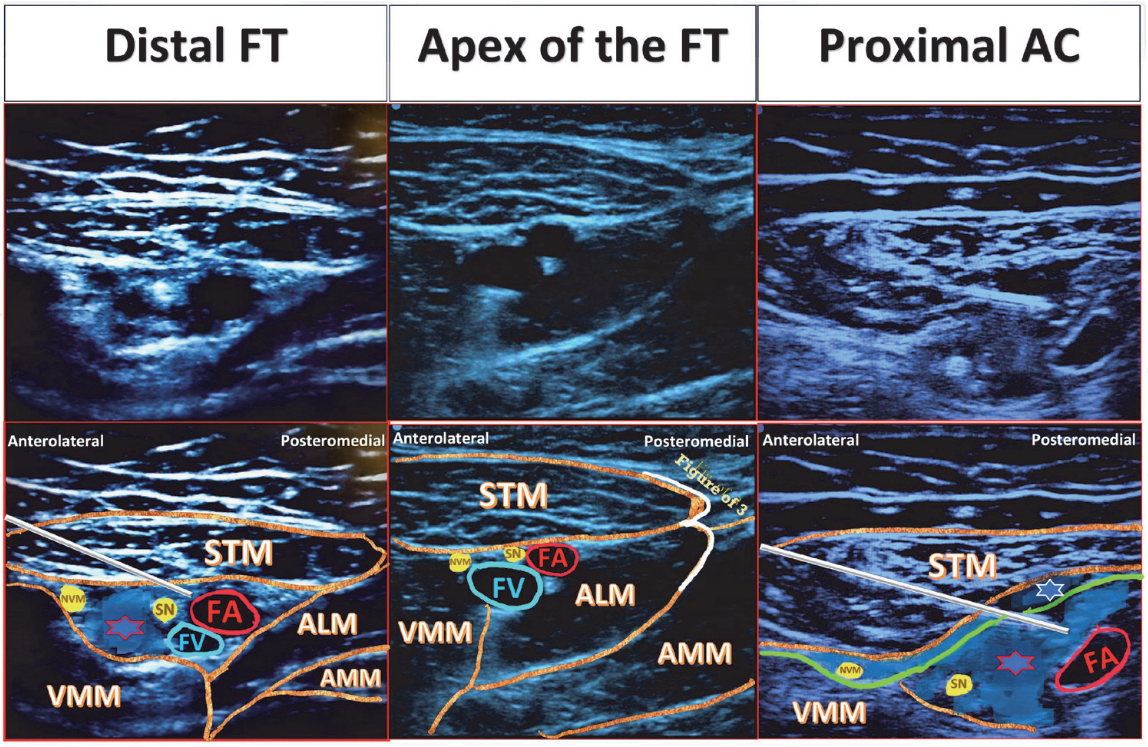

Figure 10.
Sonoanaltomy of dual subsartorial block.
*(**STM**: Sartorius muscle, **ALM**: Adductor longus muscle, **VMM**: Vastus medialis muscle, **AMM**: Adductor magnus muscle, **SN**: Saphenous nerve, **NVM**: Nerve to vastus medialis, **FA**: Femoral artery, **FV**: Femoral vein, **DGA**: Descending genicular artery, **Yellow color**: Nerves, **Red color**: Artery, **Blue color**: Vein, **Brown color**: Muscles, **Green line**: Vasoadductor membrane, **White line**: Needle track, **Blue star with red border**: Drug spread, **Blue star with white border**: Drug spread above vasoadductor membrane).*

These uncovered areas are not included in the total knee replacement surgeries with medial approaches, so the lack of analgesia in the spared region is of little clinical consequence. If given precisely with recommended LA concentration and volumes, the DSB does not cause any motor blockade and involves all target procedure-specific innervations.

II. **High-volume blocks**:

a. **Hi-Volume Proximal Adductor Canal (Hi-PAC) block**:

Hi-PAC block is described recently as an indirect anterior approach of popliteal sciatic nerve block [47]. In this block, high-volume (30–40 ml) and low-concentration LA (0.2% ropivacaine) with an adjuvant (8 mg dexamethasone) is injected in the proximal adductor canal just below the VAM. The probe position and injection technique are the same as the second injection of DSB into the proximal AC, except for higher volume LA in the Hi-PAC block. The analgesic coverage of this block involves territory of the saphenous nerve, posterior division of obturator nerve, popliteal plexus, tibial, common peroneal, and finally popliteal sciatic nerve. Although this block provides analgesic coverage as adductor canal block, it is mainly described for below-knee surgeries due to wide coverage involving all innervations below the knee.

b. **4-in-1 block/ modified 4-in-1 block**: (**Figure 11**)

Unlike the Hi-PAC block (given in proximal AC), the 4-in-1 block [48] is given into the distal AC. The important landmark for this block is descending genicular artery to identify the block site, whereas the landmark for the Hi-PAC block is the apex of the femoral triangle. The volume and type of LA required for this block are 35 ml of 0.2% ropivacaine. It is described to provide analgesia for knee surgeries as well as below-knee surgeries. Due to injection into the distal AC below VAM, there is a possibility of the saphenous nerve and nerve to vastus medialis sparing. The saphenous nerve leaves AC in the mid-adductor canal location and becomes superficial, whereas the NVM always lies above the VAM (thus, not the content of AC). Considering the sparing of NVM, which is an important nerve for knee surgeries, a modified 4-in-1 block was described mainly for knee surgeries.

The modified-4-in-1 block [49] involves two injections: The first injection (5–7 ml of 0.2% ropivacaine) above VAM around the NVM after stimulating it, and the second injection (20–25 ml of 0.2% ropivacaine) below VAM perivascularly. The possibility of the saphenous nerve-sparing remains the same in this block.

Due to the distal spread of injected LA through the adductor hiatus into the popliteal region, both blocks involve posterior division of obturator nerve, tibial, common peroneal, and sciatic nerves.

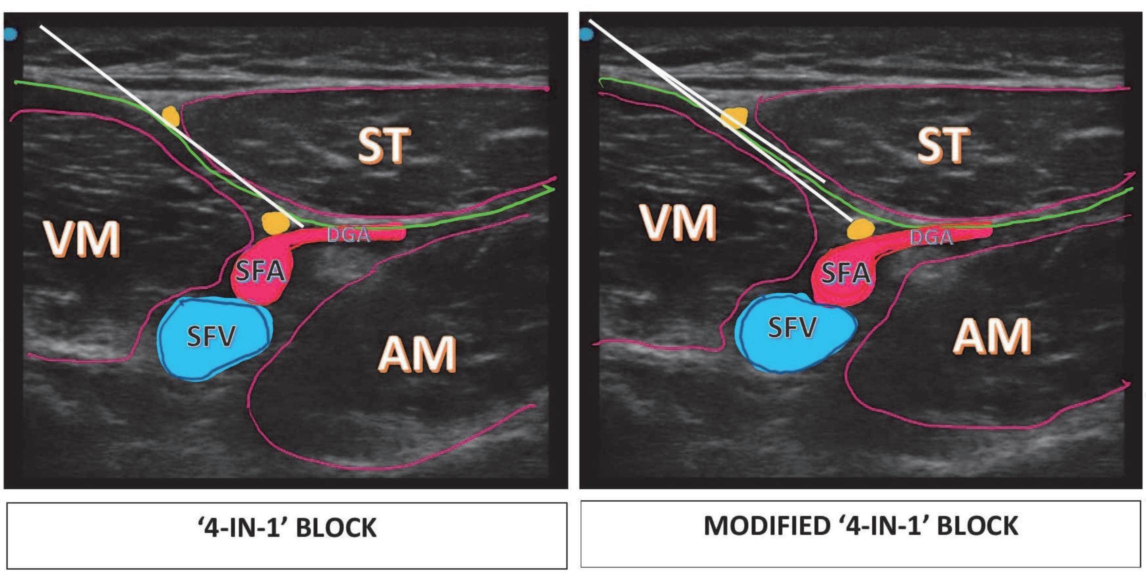

Figure 11.
Sonoanaltomy of 4-in-1 and modified 4-in-1 block.
*(**ST**: Sartorius muscle, **VM**: Vastus medialis muscle, **AM**: Adductor magnus muscle, **SFA**: Superficial femoral artery, **SFV**: Superficial femoral vein, **DGA**: Descending genicular artery, **Yellow dots**: Nerves, **Red color**: Artery, **Blue color**: Vein, **Green line**: Vasoadductor membrane, **White lines**: Needles track).*

c. **Ultrasound-guided Hamstring block** [50, 51]**: (Figure 12)**

- Initially described in 2012 mainly to cover hamstring graft harvesting site
- Reduces pain following hamstring graft harvest for ACL reconstructions

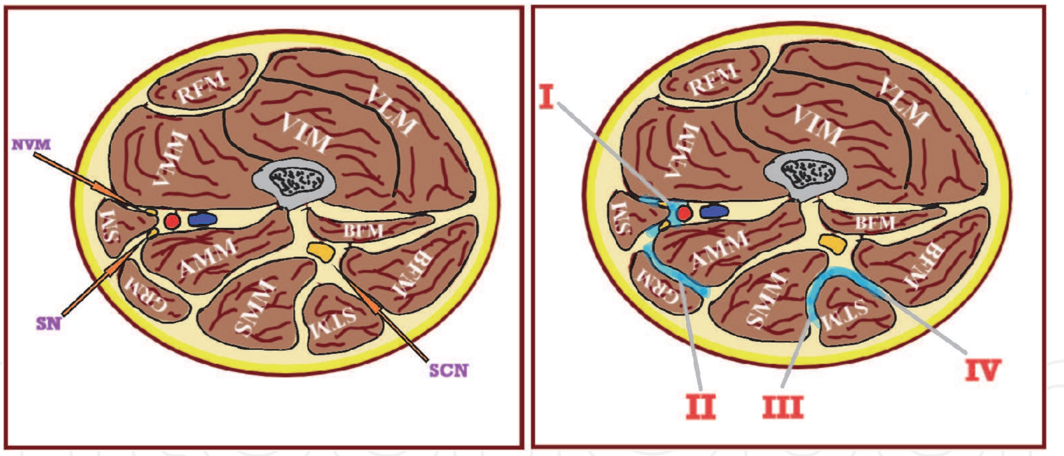

Figure 12.
Hamsting block injection sites.
***I**: First injection under the sartorius muscle in the adductor canal. **II:** Second injection below gracilis muscle. **III & IV**: Third and fourth injections around semotendinosus muscle. (**SM**: Sartorius muscle, **VMM**: Vastus medialis muscle, **AMM**: Adductor magnus muscle, **RFM**: Rectus femoris muscle, **VIM**: Vastus intermedialis muscle, **VLM**: Vastus lateralis muscle, **BFM**: Bicep femoris muscle, **STM**: Semitendinosus muscle, **SMM**: Semimembranosus muscle, **GRM**: Gracilis muscle, **SN**: Saphenous nerve, **NVM**: Nerve to vastus medialis, **SCN**: Sciatic nerve, **Yellow color**: Nerves, **Red color**: Artery, **Blue color**: Vein, **Brown color**: Muscles, **Gray color**: Femoral bone, **Light blue area:** Drug spread).*

- **Needle**: 10–15 cm block needle
- **LA volume:** 30–40 ml

    i. 5–7 ml below the sartorius in the adductor canal

    ii. 10–15 ml below gracilis muscle with probe over the posteromedial aspect of the distal thigh

    iii. 15–20 ml around the semitendinosus muscle (above and below) with probe over the posterior aspect of the distal thigh

III. **Infiltration techniques**:

a. **I-PACK Block**:

The term i-PACK is described as a motor-sparing RA technique that consists of an infiltration of local anesthetic into the interspace between the popliteal artery and the posterior capsule of the knee [52–54]. It can be used as an adjunct to the femoral nerve or adductor canal blocks to cover the posterior knee pain. It creates field block (**Figure 13**), causing blockade of articular branches arising of the tibial, common peroneal, and obturator nerves in the popliteal region. Indications of I-PACK include postop analgesia for TKR surgeries, ACL repairs, and procedures involving the posterior aspect of the knee. The required LA volume for this block is 15–20 ml. This block needs to be given preoperatively due to loss of anatomical landmarks after surgery. It can be given using two approaches: medial approach and popliteal approach, as shown in **Figure 14**.

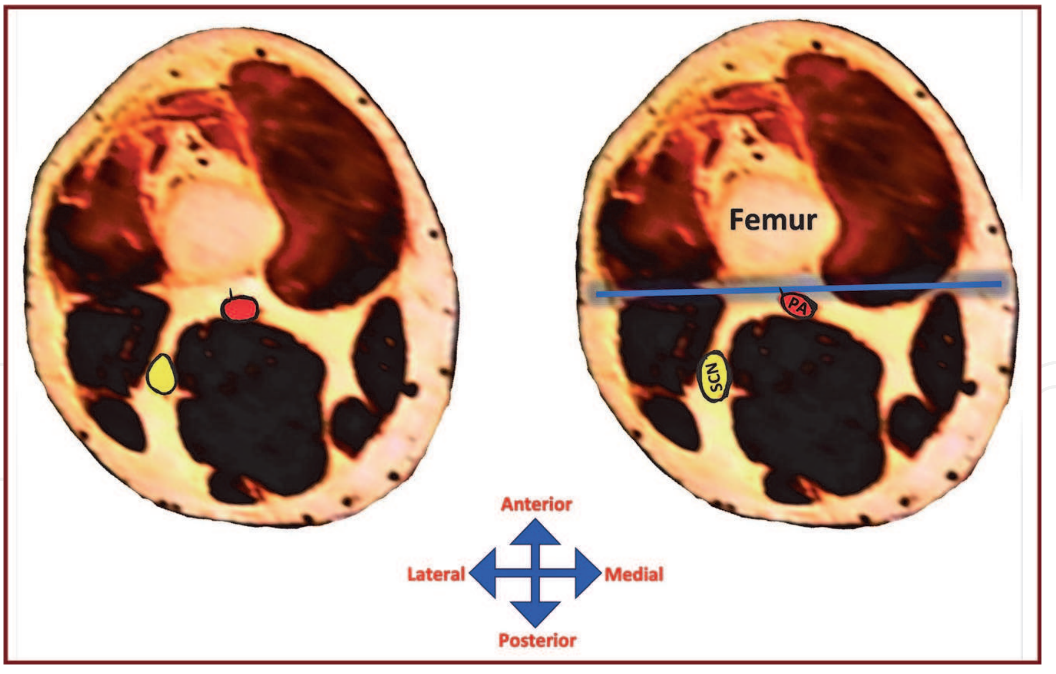

Figure 13.
Needle track and drug spread of i-PACK block.
*(**PA**: Popliteal artery, **SCN**: Sciatic nerve, **Blue color**: Needle track and drug spread between PA and femur).*

b. **Local infiltration analgesia (LIA)**:

Kohan and Kerr repopularized the concept of local infiltration analgesia (LIA) in 2008 for postoperative analgesia for knee surgery [55]. It is mainly given by the operating surgeon during surgery using various drug combinations and volumes.
The cocktail combination used for LIA includes LA (ropivacaine 2 mg/ml or bupivacaine 2.5 mg/kg), NSAIDs (ketorolac 30 mg), adrenaline (10 micrograms/ml), opioids (morphine 5–10 mg), and steroids (dexamethasone 8 mg). The total volume of cocktail combination used for LIA may go up to 100–170 ml. For LIA, the surgeon mainly targets the anterior and posterior capsule of the knee, intercondylar area, collateral ligaments, tissue along the femur and tibia, and subcutaneous tissue.

The analgesic effect of the LIA technique depends on the involved injection sites by the surgeon and used drug combinations. However, the drawbacks of single-shot LIA include its limited duration of analgesia (12–18 hours), chances of infection if sterility is not maintained while loading drugs [56, 57], and chondrotoxicity [58] (due to agents used) that may cause loosening of the implants in the long-term followups. Indwelling LIA catheter is usually avoided due to the fear of infection.

c. **Ultrasound-guided Ring block**:

Ultrasound-guided Ring block is nothing but the LIA technique given by an anesthesiologist under direct vision using ultrasound

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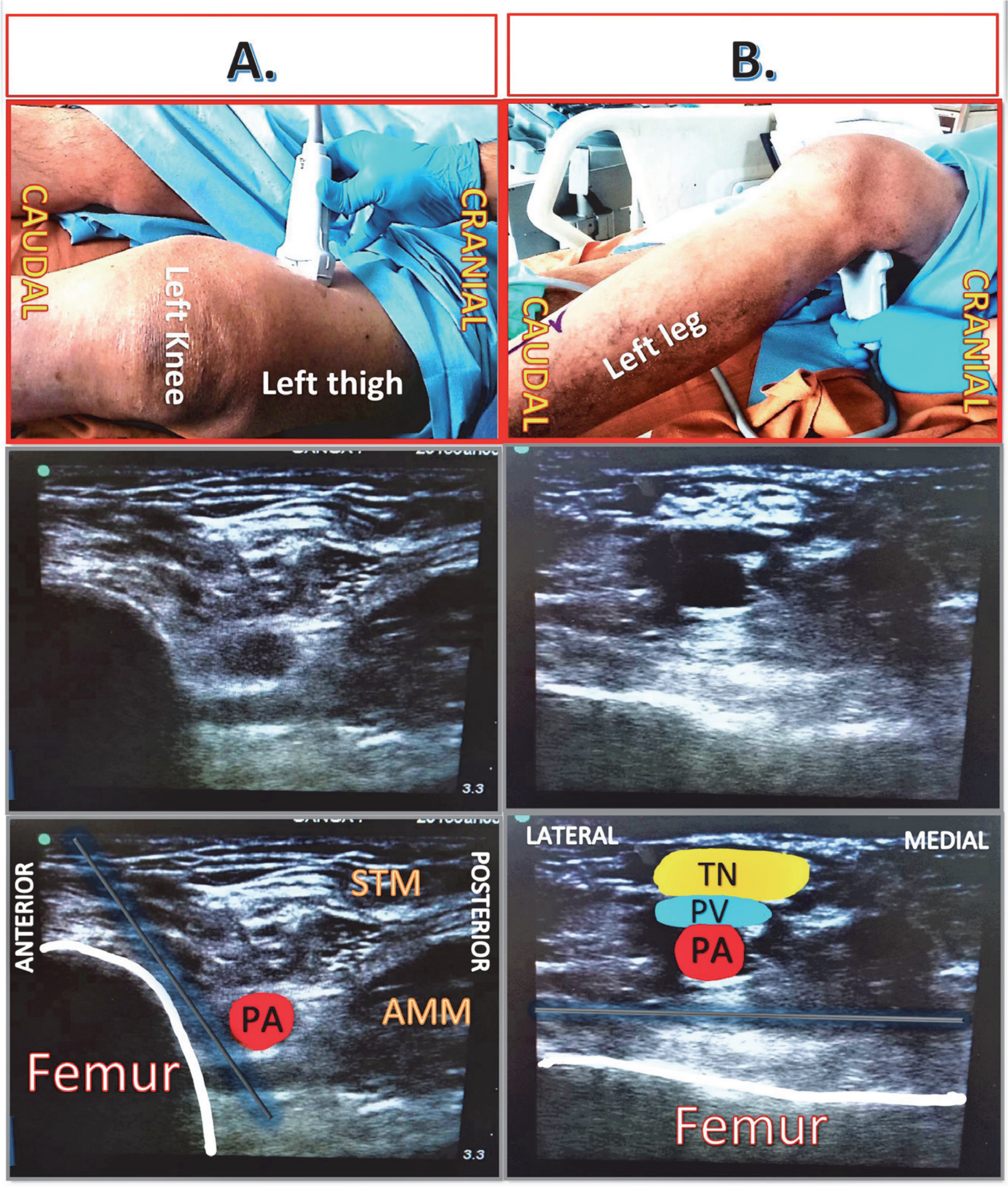

Figure 14.
Probe position and sonoanatomy of various apporaches of i-PACK block.
A*: Anteromedial approach of i-PACK,* ***B****: Popliteal approach of i-PACK.*
*(****STM****: Sartorius muscle,* ***AMM****: Adductor magnus muscle,* ***PA****: Popliteal artery,* ***PV****: Popliteal vein,* ***TN****: Tibial nerve,* ***Gray line with blue glow****: Needle track and drug spread between PA and femur).*

[59–61]. It targets all innervations responsible for postoperative pain generations. Like conventional LIA, it is also given preoperatively before the beginning of the surgery after the primary mode of anesthesia (neuraxial or GA). This block consists of multiple injections around the knee joint (**Table 4**) except for the lateral spared area of the common peroneal nerve territory (**Figure 15**).

Since this block is given under ultrasound guidance targeting almost all of the innervations of the knee joint, the precision with this block is greater than the LIA given by the surgeon. Surgeons sometimes are reluctant to infiltrate near the popliteal artery in fear of injuring it.

Injections	Probe location	LA volume	Pattern of injection	Target innervations
First	Medial aspect of the mid-thigh	10–20 ml	LA injected into the intermuscular plane between the sartorius and vastus medialis muscles	• Saphenous nerve • Nerve to vastus medialis • Subsartorial plexus
Second	Anterior aspect of the distal thigh	10–20 ml	LA infiltrated into the belly of the vastus intermedialis muscle through multiple passes	• Nerve to vastus intermedialis
Third	Lateral aspect of the distal thigh	10–20 ml	LA infiltrated into the belly of the vastus lateralis muscle through multiple passes	• Nerve to vastus lateralis
Fourth	Posterior aspect of the distal thigh	15–20 ml	LA injected between the popliteal artery and hyperechoic femoral condyle creating a field block	• Popliteal plexus
Fifth	Lateral to the tibial tuberosity in the leg	5–10 ml	LA injected after hitting the bone.	• Inferior lateral genicular nerves
Sixth	Medial to the tibial tuberosity in the leg	5–10 ml	LA injected after hitting the bone.	• Inferior medial genicular nerves

*(**LA**: Local anesthetic)*

Table 4.
Injections sites of ultrasound-guided LIA or Ring block.

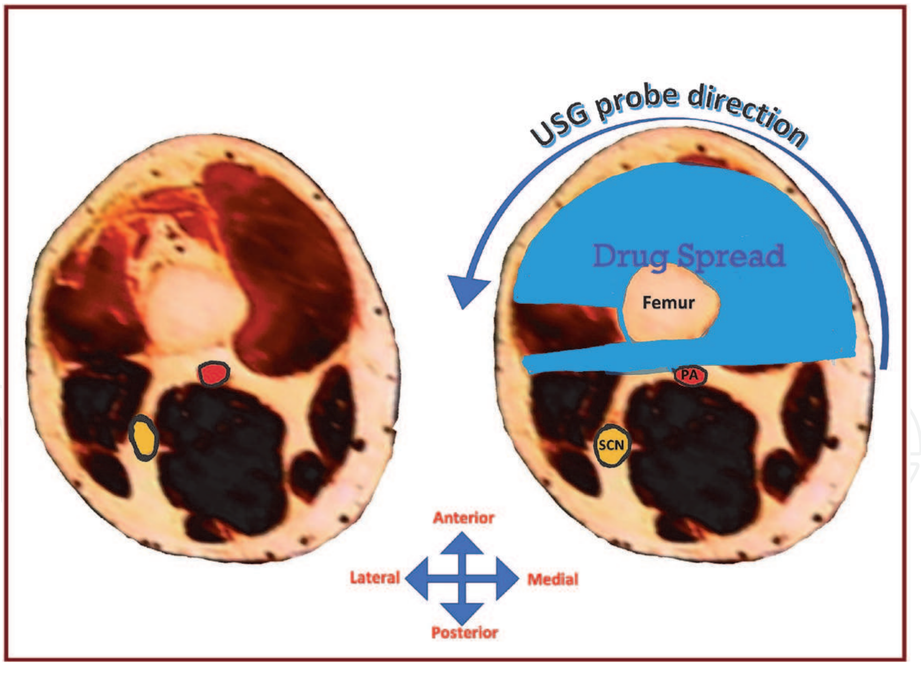

Figure 15.
Field block created by ultrasound-guided LIA or Ring block.
*(**PA**: Popliteal artery, **SCN**: Sciatic nerve, **Blue area**: Field block due to drug spread).*

11. Procedure- specific RA

Sometimes standard regional blocks fail in providing expected analgesia. Block failure may be due to the sparing of some of the innervations of pain-generating structures involved in the surgery. For this reason, understanding surgical steps, innervations of pain-generating structures, and customizing standard RA techniques to make them suitable for the surgery is essential. The standard procedures performed in the knee joint include joint replacement surgery and arthroscopic surgery.

11.1 Knee joint replacement surgery

Knee joint replacement is one of the best treatments available for end-stage osteoarthritis, wherein the damaged cartilages are replaced with an implant, allowing patients to regain joint function. This life-changing procedure improves health-related quality of life and functional status by providing optimal analgesia and near-normal joint function [1, 2].

Depending upon the extent of the disease, joint replacement surgeries can be divided into the following types.

1. Total knee replacement (TKR), where the whole joint (femoral and tibial component with patella) is replaced with implants,

2. Unicondylar knee replacement or patellofemoral replacement where a single component of joint is replaced.

3. Computer-assisted navigation systems (CAS) or robotic surgery allow surgeons to perform many complex procedures with more precision, flexibility, and control than conventional techniques.

Surgical Steps involved in such surgery include,

- **Incision:** TKR can be performed by various approaches (**Figure 16**) like medial parapatellar, lateral parapatellar, Sub-vastus, Mid-vastus, and midline.6Medial parapatellar/longitudinal incision (From 5 cm proximal to

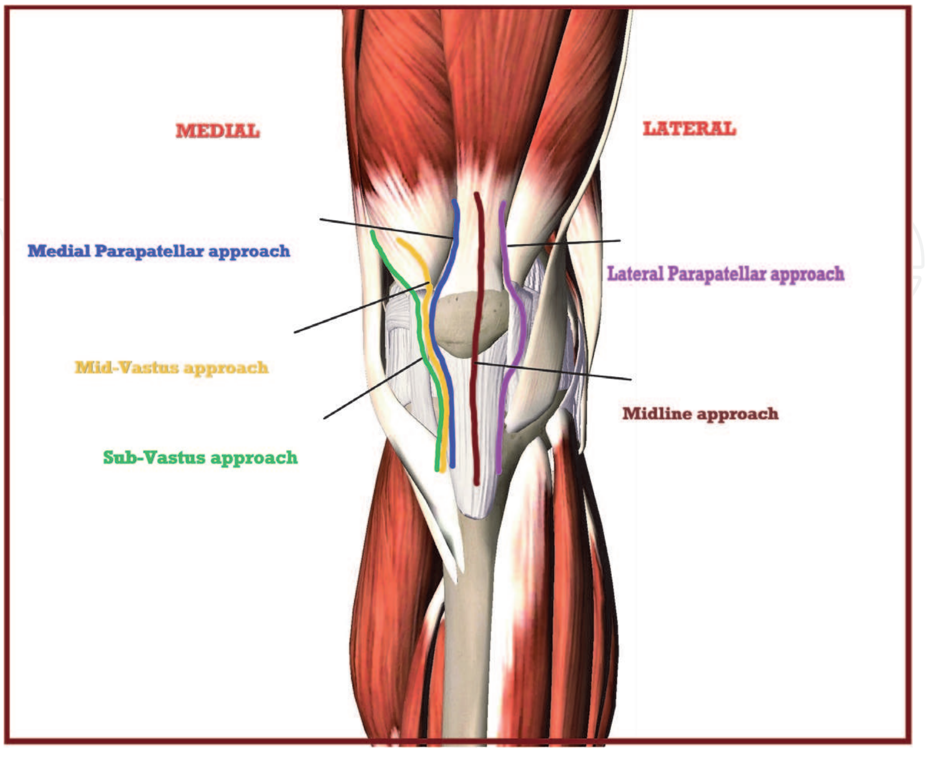

Figure 16.
Various approaches of knee replacement surgeries.
*(**Source**: Images is courtesy of 3D4Medical's essential anatomy).*

the superior pole of the patella to tibial tuberosity) is most commonly performed, especially for varus knees. For this reason, it is called a workhorse of the Varus knee.

- **Dissection** through the medial retinacular complex (Deep fascia + retinacular ligament and fibrous capsule) along the medial border of the quadriceps tendon, patella, and patellar ligament.

- **The knee joint is accessed** by opening synovial membrane to allow removal of menisci, cruciates and transverse ligaments, infrapatellar fat pads, and osteophytes.

- **Resection** of Cartilage of femoral and tibial condyles along with the back of the patella.

- **Shaping** of femoral and tibial bony surfaces to fit metal components of knee prosthesis.

The total duration of surgery is 1–2 hours. The majority of the patients begin physiotherapy within 24 hours of surgery. The patients are usually discharged within 3–5 days post-surgery.

Post-surgery complications include infection, nerve damage, increased risk of fall, bone fractures, persistent/chronic pain, deep venous thrombosis, joint stiffness, prosthesis-related complications (loosening/fracture of prosthesis components, joint instability, and dislocation, component misalignment, and breakdown.

11.1.1 RA options for knee joint replacement surgery

- CSEA: It provides excellent analgesia but is associated with delayed mobility as discussed before, also not recommended for ERAS

- FTB with LIA

- ACB with LIA

- Dual subsartorial block

- Local infiltration analgesia (LIA)

- Ultrasound-guided ring block

11.2 Bilateral TKR

Bilateral TKR, either staged or single-staged (simultaneous), is also a commonly performed joint surgery in relatively younger and healthy patients. Patient selection is very crucial in bilateral TKR as it is associated with advantages as well as disadvantages.

The **advantages** of bilateral TKR surgeries include [62],

- Single event (surgical and anesthesia) with bilateral functional recovery.

- Relatively shorter hospital stay.

- Reduced pain intensity, better functional recovery, and general health due to correction of the pathology of both knees simultaneously.
- The possibility of rehabilitating the patient symmetrically.
- Lower cost as estimated medical care costs savings of 18–26% [63]. An estimated cost of simultaneous TKR is almost half compared to staged bilateral TKR [64–66].
- Reduced risk of mechanical malfunction and periprosthetic joint infection [67–70].

The **disadvantages** of bilateral TKR surgeries include,

- Higher risk of pulmonary embolism (about 80%) in the three months than after a single procedure [71].
- Higher mortality and morbidity risk.
- Higher risk of cardiac complications.
- Associated with relatively more blood loss and need for blood transfusion.
- Increased risk of overall complications (pulmonary embolism, wound infections, and need for the second operation).

11.2.1 RA options for bilateral TKR

- CSEA: It provides excellent analgesia but is associated with delayed mobility as discussed before, also not recommended for ERAS.
- Bilateral FTB with LIA.
- Bilateral ACB with LIA.
- Bilateral dual subsartorial block.
- Bilateral local infiltration analgesia (LIA): Required volume of LA may cross maximum allowable dose.

11.3 Arthroscopic knee surgeries

Knee arthroscopy, also called knee scoping, is a minimally invasive procedure to diagnose and treat joint pathologies or injuries. It is performed using an arthroscope inserted into the knee joint through various portal sites (**Figure 17**).

11.3.1 Type of arthroscopic knee surgeries

- Meniscal repair or removal
- ACL, MCL, or PCL rapair or reconstruction
- Synovectomy

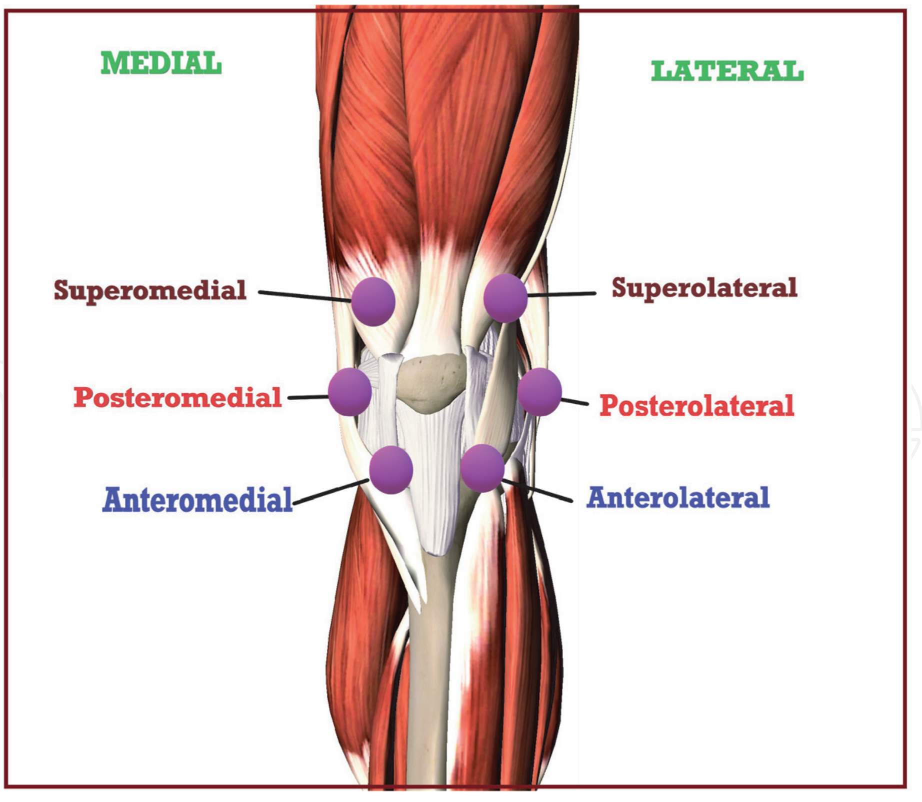

Figure 17.
Various portal sites for arthroscopic knee surgeries.
*(**Source**: Images is courtesy of 3D4Medical's essential anatomy app).*

- Trimming of damaged articular cartilage
- Removal of loose fragments of bone or cartilage
- Treatment of patella (kneecap) problems
- Knee debridement

11.3.2 Arthroscopic portal insertion sites

1. Primary portal sites:
    a. Anterolateral/Anteromedial
    b. Superomedial/Superolateral
2. Secondary portal sites:
    a. Posteromedial/ posterolateral portal
    b. Transpatellar portal
    c. Proximal supoeromedial portal
    d. Far medial or far lateral portal

Duration of surgery is usually <1 hrs (ranging from 30 min to 45 min). Arthroscopic surgeries are minimal-invasive surgeries associated with less severe postoperative pain. The postoperative pain generators include the intraarticular components, portal entry sites, and a hamstring graft-harvesting site in such surgeries. Most of the innervations of the postoperative pain generators involved popliteal plexus and saphenous nerve. So, RA techniques involving these innervations can provide optimal analgesia along with multimodal analgesics.

11.3.3 RA options for arthroscopic knee surgeries

- Adductor canal block as it covers saphenous nerve directly and popliteal plexus indirectly.
- iPACK mainly covers the popliteal plexus.
- Intraarticular administration of LA or morphine or cocktail mixture.
- Ultrasound-guided Hamstrings block

11.4 Postoperative pain generators

The postoperative pain of any surgery depends on the number of pain generators removed and retained after surgery (**Figure 18**). The TKR surgery involves removing many pain generators (like anterior capsule, synovium, meniscus,

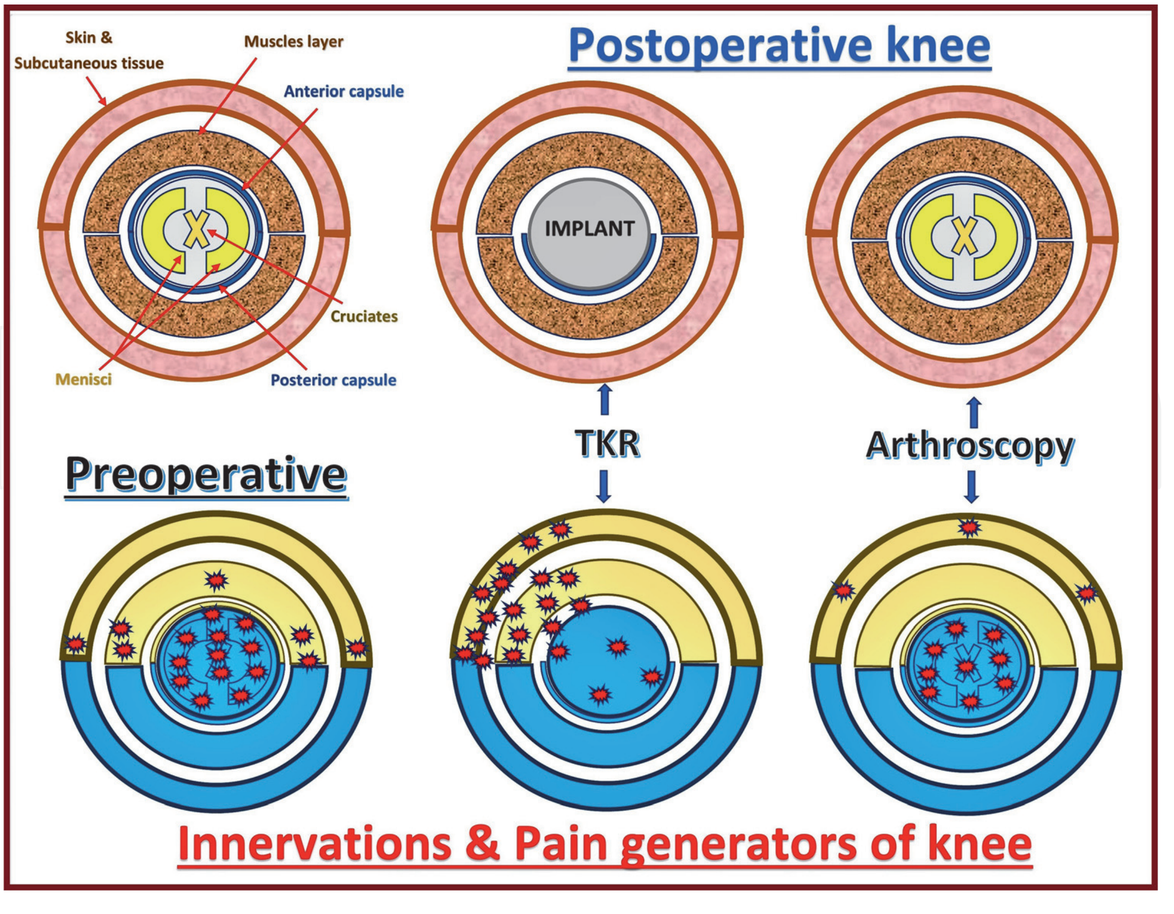

Figure 18.
Preoperative and postoperative pain generating structures of knee surgeries.
***Yellow colored area in circles**: Anterior knee innervations. **Blue colored area in circles**: Posterior knee innervations. **Red star-like dots**: Pain generating area. **TKR**: Total knee replacement.*

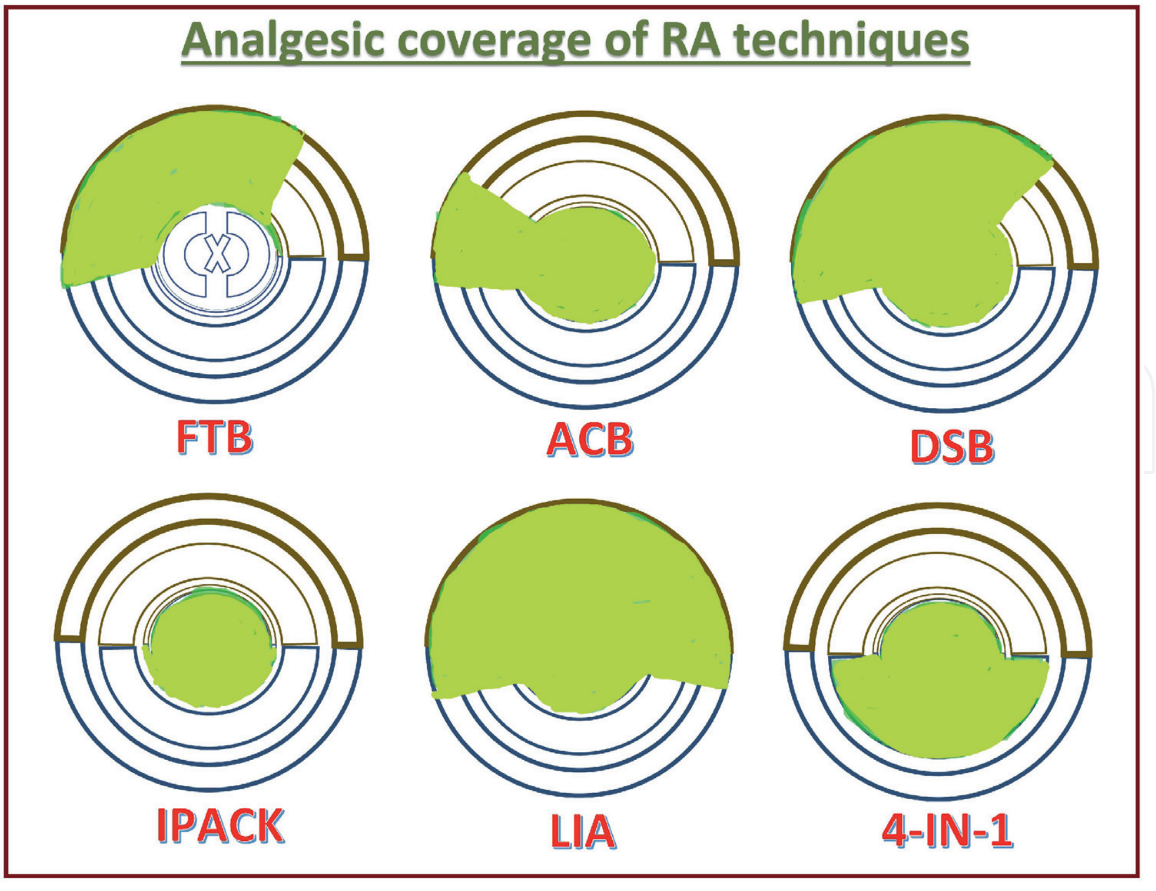

Figure 19.
Analgesic coverage of various regional techniques for knee surgeries.
Green colored area in circles: *Analgesic covered regions. (**FTB:** Femoral triangle block, **ACB:** Adductor canal block, **DSB:** Dual subsartorial block, **IPACK:** Ilfiltration between popliteal artery and capsule of knee joint, **LIA:** Local infiltration analgesia).*

cruciates, intraarticular ligaments, periosteum of the knee joint, and prepatellar fat pads) [11, 72–77]. The retained pain-generating components responsible for post-TKR pain include skin/subcutaneous tissues over the incision area, medial retinaculum, periosteal rim of the cut bones, remnant of the anterior joint capsule, cut nerves along the surgical dissection area, microfractures, and inflammation. For arthroscopic knee surgery, the pain-generating components are mainly intra-articular. Therefore, the innervations of these retained components are essential targets for any procedure-specific RA techniques.

The analgesic coverage of each RA technique is different, as shown in **Figure 19**. The choice of RA techniques depends on the procedure performed and its associated innervations.

An “identify-select-combine” approach [78, 79] is beneficial to obtain procedure-specific RA techniques for knee surgery (**Table 5**). This approach includes identifying target innervations, selecting target blocks involving most of the target nerves, and combining all target blocks to cover innervations of all the pain generators.

12. Conclusion

Background knowledge of the knee joint and its components is essential to achieve the best surgical and analgesic outcomes. Perioperative pain management of the patient undergoing any knee surgery is a complex and challenging task. Therefore, the holistic approach is required considering the patient’s age, comorbid

Surgical Steps	Approaches	Target innervations	Target blocks	Procedure-specific RA options
Incision	**Medial**	• Subsartorial plexus	• Subsartorial blocks	• **Medial approach:** • FTB + ACB • DSB • FTB + i-PACK • LIA • **Lateral approach:** • FNB + ACB infiltration over incision • FNB + i-PACK + infiltration over incision • LIA • **Anterior approach:** • FNB + ACB • FNB + i-PACK • LIA • **Posterior approach:** • ACB + infiltration over incision site • Popliteal sciatic nerve block + infiltration over the incision site • i-PACK + infiltration over incision site
	Lateral	• Peripatellar plexus	• FNB • LFCN block • Lateral cutaneous nerve of calf block	
	Midline	• Peripatellar Plexus	• FNB	
	Posterior	• PCNT	• Infiltration over the incision site	
Superficial + Deep dissection	**Medial**	• Subsartorial plexus	• Subsartorial blocks	
	Lateral	• Peripatellar plexus	• FNB	
	Midline	• Peripatellar plexus	• FNB	
	Posterior	• Popliteal plexus • Sciatic nerve	• ACB • i-PACK • Popliteal SCN block • LIA	
Joint Access	**Anterior capsule**	• Subsartorial plexus • Peripatellar plexus	• Subsartorial blocks • FNB	
	Posterior capsule	• Popliteal plexus	• ACB • i-PACK • LIA	
Intraarticular dissection		• Popliteal plexus	• ACB • i-PACK • LIA	

*(**FNB:** Femoral nerve block, **LFCN:** Lateral femoral cutaneous nerve, **FTB:** Femoral triangle block, **ACB:** Adductor canal block, **DSB:** Dual subsartorial block, **SCN:** Sciatic nerve, **i-PACK:** Ilfiltration between popliteal artery and capsule of knee joint, **LIA:** Local infiltration analgesia)*

Table 5.
Procedure-specific regional analgesia options for knee.

factors, psychological components, complex innervations, multifactorial pain generations, surgery type, and demand for the best analgesic options suitable for ERAS protocol.

Optimum perioperative analgesia reduces the stress response of the surgery or pain. It hastens early mobilization and discharge, reduces hospital stay and associated complications, controls treatment costs, most importantly, improves patient satisfaction. A well-functioning knee joint is essential to improve quality of life and reduce perioperative morbidity and mortality. Multimodal analgesia for multifactorial pain should be the ideal protocol for knee surgeries. The regional analgesia, an essential component of MMA, should be motor-sparing, opioid-sparing, and procedure-specific.

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Conflict of interest

The authors declare no conflict of interest.

Contribution statement

Both the authors contributed equally to design and complete this manuscript.

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