Evidence-Based Approach of Treatment Options for Postoperative Knee Pain

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Jack Farr, MD[1]
Ryan Jaggers, MD[2]
Hal Lewis, BS[3]
Andreas Plackis, BS[3]
Seung B. Sim, MD[4]
Seth L. Sherman, MD[3]

[1]Cartilage Restoration Center of Indiana, Greenwood, IN; [2]Methodist Sports Medicine, Indianapolis, IN; [3]University of Missouri, Columbia, MO; [4]Anesthesiology and Pain Medicine, OrthoIndy and Indiana Orthopaedic Hospital, Indianapolis, IN

Abstract: Optimal pain management is critical after knee surgery to avoid adverse events and to improve surgical outcomes. Pain may affect surgical outcomes by contributing to limitations in range of motion, strength, and functional recovery. The causes of postoperative pain are multifactorial; therefore, an appropriate pain management strategy must take into account preoperative, intraoperative, and postoperative factors to create a comprehensive and individualized plan for the patient. Preoperative assessment includes management of patient expectations, recognition of conditions and early counseling for high-risk patients (ie, opioid dependence, psychiatric comorbidities), and use of preemptive analgesia techniques (ie, preoperative IV medications, peripheral nerve blocks, incisional field blocks). Intraoperative strategies include meticulous surgical technique, limiting the use of tourniquets (ie, duration and pressure), and using preventive analgesia methods (ie, postoperative field block, continuous nerve catheters, intra-articular injection). Postoperative analgesia may be facilitated by cryotherapy, early mobilization, bracing, and rehabilitation. Certain modalities (ie, continuous passive motion devices, transcutaneous electrical nerve stimulation units, iontophoresis) may be important adjuncts in the perioperative period as well. There may be an evolving role for alternative medicine strategies. Early recognition and treatment of exaggerated postoperative pain responses may mitigate the effects of complex regional pain syndrome or the development of chronic pain.

Keywords: knee pain; analgesia; postoperative; treatment

Introduction

Some degree of pain is expected after knee surgery. Without adequate pain control, there may be adverse effects on surgical outcome, including limited range of motion, strength, and functional recovery. In some instances, the pain may become the major focus and take on a life of its own, as in the cases of sympathetically mediated pain (ie, complex regional pain syndrome) and chronic pain.[1] Understanding and using effective pain management strategies are a critical component of optimal recovery from knee surgery.

Pain is the central perception of a peripheral noxious stimulation or, as the International Association for the Study of Pain defines it: "an unpleasant sensory or emotional experience associated with actual or potential tissue damage, or described in terms of such damage."[2] In either case, it is imperative to develop a comprehensive plan for postoperative knee pain control. To begin planning this approach, it is useful to divide the problem into 2 broad categories: a) intrinsic knee factors that activate nerve fiber impulses which cause pain, and b) factors that alter the brain receptors and the patient's cognition sensitivity (eg, personality, mental status, and emotional overlay) to the received peripheral pain signals. Within these 2 broad categories, pain management

Correspondence: Jack Farr, MD, Cartilage Restoration Center of Indiana, 1260 Innovation Parkway, Ste 100, Greenwood, IN 46143.
Tel: 317-884-5200
Fax: 317-884-5360
E-mail: indyknee@hotmail.com

can be further subdivided into preoperative, intraoperative, and postoperative factors.

Materials and Methods

We searched all published literature in the English language in PubMed by using the keywords *knee pain* AND *post-operative* (1329 articles) OR *pre-operative* (165 articles) OR *intraoperative* (345 articles). We preliminarily excluded all articles that did not discuss knee operations. In addition, to further broaden the scope of the nonmedicinal aspects of postoperative pain, we used the keywords *knee pain* AND *physical therapy* AND *post-operative* (112 articles) OR *pre-operative* (17 articles). Further exclusion of articles occurred based on a hierarchy of evidence, beginning with randomized controlled trials. Abstracts of the remaining articles were reviewed and selected based on their relative contributions to our current understanding of the basic science and clinical evidence for preoperative, intraoperative, and postoperative treatment modalities.

Preoperative Pain Management

Setting Expectations

An important part of postoperative pain control begins well before surgery. Preoperative counseling regarding postoperative pain expectations, rehabilitation, and healing can help alleviate stressful anxiety and fear, which can increase the cognitive and emotional sensitivity to painful stimuli. A prospective study showed that those patients who were shown videos describing treatment preoperatively and at 6 weeks postoperatively had significantly less pain than those who were not.[3] Encouraging a calming and healing environment, stress modulation, distraction therapy, and biofeedback training can help alleviate the pain experience. Additionally, preoperative recognition and treatment of anxiety and depression is important because it is well established that these conditions can amplify pain perception.[4] Several psychosocial predictors of chronic postsurgical pain include preoperative anxiety, introverted personality, less catastrophizing, and less social support. Early recognition may lead to treatment that includes counseling and medication to manage these factors before proceeding with the operation. In a subset of patients, the fear-avoidance model may also be pertinent. This approach can be preoperatively identified with a Fear Avoidance Beliefs Questionnaire, which can allow both preoperative and postoperative planning.[2,5] As Crombrez has pointed out, "the fear of pain is more disabling than the pain itself."[6] The importance of preoperative identification of risk factors for an exaggerated pain response cannot be overemphasized. Adequate preoperative counseling and emotional guidance may benefit patients substantially in decreasing pain-related complications.

Chronic Narcotic Use

Several studies indicate that the level of preoperative pain is correlated with the development of early postoperative pain and the subsequent development of chronic pain, which may persist for months or years after surgery.[7–9] Chronic narcotic use changes the central perception of pain not only emotionally but also physiologically. That is, the central opioid receptors develop drug tolerance. These pain receptor and pain pathway tolerances necessitate a higher level of postoperative opiate drugs to effect the same degree of pain relief. Unfortunately, because the amount of opiate medication needs to be increased to address the pain, the untoward side effects are also increased. These side effects include depression, constipation, and psychosocial maladaptive behaviors. The chronic use of opioid medications may lead to hyperalgesia, which adversely affects perioperative and postoperative pain management, rehabilitation, and clinical outcomes.[10] In potential knee surgery candidates, narcotic medications should be avoided if at all possible before surgery to preserve their postoperative benefits.[11] In cases of preoperative opiate medication use, the pain management specialist should use a multimodal approach to manage the patient with a minimal amount of narcotics, which ideally will allow some degree of CNS adjustment of opiate sensitivity prior to surgery. The benefits of this approach are cited as improved efficacy, lower doses, and fewer side effects.[12] Even with these measures, however, there may be chronic alteration of the pain response in these patients.

Preemptive Analgesia

Acute surgical pain is—directly and indirectly—the result of peripheral noxious stimuli from the surgery itself and how it is processed centrally. Blocking the initial surge of pain signals is important when trying to decrease both the magnitude and duration of pain response. A multimodal approach in using both preemptive and preventive strategies may lead to optimal perioperative pain control.[13] Pre-emptive analgesia is defined as the administration of a pharmacologic agent before the perception of pain, or an effect lasting beyond the time that the agent is clinically active. This time is defined as > 5.5 half-lives of the drug. It is directed both centrally and peripherally. Pre-emptive analgesia can neither change the noxious stimuli of the surgery nor the postsurgical tissue sequelae. It does, however, decrease the pain signals that reach the brain

and modulates how the brain processes the signals that do reach it. Depending on the length and mode of action of the anesthetic, it does this both during surgery and in the early postoperative period. Theoretically, the anesthetic prevents the cortical and subcortical (eg, thalamus) regions of the brain from experiencing the intense pain signals of the surgical procedure. It also may alter the neural connections related to sensitivity and the learning component of pain. To address the central components of pain, early administration of preoperative pharmacologic agents is important in addition to noting that some agents may also act in peripheral modulation of nociceptive fiber activation (eg, anti-inflammatory medications). These medications are complementary and include central-acting medications, anti-inflammatory medications, narcotic analgesics, and neuropathic adjuvant pain relievers (Tables 1 and 2). All of these medications further diminish brain receptor sensitivity and decrease the contributors of painful impulses in the knee.

Central nerve blocks include spinal and epidural injections. For unilateral knee surgery, it is typically not recommended to block the entire lower body due to the resultant secondary effects of loss of bladder control, hypotension, and contralateral limb control (thus limiting ambulatory surgery with release on crutches). Select cases, however, may warrant consideration for spinal/epidural anesthesia to facilitate aggressive postoperative range of motion (ie, knee lysis of adhesions). Paralumbar sympathetic blockade is also useful in unique cases for patients with a history of sympathetically mediated pain. Here, the goal is to block sympathetic afferent impulses in an attempt to prevent reactivation of the sympathetically mediated pain.

In the most general sense, peripheral nerve blockade includes all techniques distal to the brain and spinal cord. Nerves that innervate the area around the knee joint include the femoral, sciatic, obturator, and lateral femoral cutaneous nerves. Femoral nerve blocks and blocks of the tibial branch of the sciatic nerve are usually sufficient to provide analgesia to the knee joint in most patients. Some patients may need an obturator or lateral femoral cutaneous nerve block for additional relief from medial or lateral knee pain, respectively. The femoral nerve is the major nerve that covers the knee. Femoral nerve block is typically performed by using ultrasound or peripheral nerve stimulation. The block is administered just lateral to the femoral artery, along the femoral crease. The sciatic nerve can be blocked in various locations. A single or continuous block can be placed in the subgluteal area. Usually, a single-shot nerve block is placed in the popliteal fossa to avoid catheters around the surgical field. Both subgluteal and popliteal sciatic nerve blocks can be performed with either ultrasound or peripheral nerve stimulation. Peripheral nerve blocks are planned to block the typical pain fibers of the regions within the surgical field (Table 3). It must be appreciated that, even though these blocks address major nerves in the field of surgery, there may be vascular, unmyelinated nerves that are not blocked. In addition, knee effusions may activate nerves remote from the surgical site postoperatively. An example would be an incision that is well blocked with a femoral nerve block, yet the patient experiences pain from fibers within the posterior capsule that are stretched with postoperative effusion.

Table 1. Oral Agents That Modify Central and Peripheral Pain

Agent Type	Specific Examples	Peripheral	Central	Notes
NA	Acetaminophen		x	
NSAIDs	Ibuprofen	x	x	May want to avoid because of bleeding risk
	Toradol			
Corticosteroid	Decadron	x	x	
Central signal	Gabapentin		x	
Narcotic	Oxycodone		x	
Cox-2 inhibitor	Celebrex	x	x	

Abbreviations: NA, not applicable; NSAID, nonsteroidal anti-inflammatory drug.

Table 2. Example of a Preoperative "Cocktail"

NA	Acetaminophen, 500 mg IV
	Acetaminophen, 500 mg po
Cox-2 inhibitor	Celebrex, 200 mg po
Corticosteroid	Decadron, 10 mg IV
Central	Pregabapentin, 75–150 mg po
	Gabapentin, 400–600 mg po
Narcotic	Oxycontin, 20 mg (off-label usage)

Abbreviation: NA, not applicable.

Table 3. Common Regional Blocks for Knee Surgery

Nerve	Distribution	Advantages
Femoral	Anteromedial knee	
Fascia iliaca block		Minimizes quadriceps weakness
Adductor canal block		
Common sciatic	Posterior knee joint	
Tibial branch of sciatic nerve just proximal to the popliteal fossa	Posterior knee joint	Preserves the hamstring function. Dorsiflexion may be preserved
Obturator	Medial knee joint	
Lateral femoral cutaneous	Lateral and some anterior knee	Sensory only
Lumbar plexus block		Blocks the femoral, obturator, and lateral femoral cutaneous

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Physical Therapy

Preoperative knee strength is an important factor that can influence postoperative outcomes. At 1, 2, and 3 months after anterior cruciate ligament (ACL) reconstruction, patients with preoperative strength > 90% had significantly better strength than patients with a preoperative strength < 75%.[14] In addition, delaying ACL reconstruction until full range of motion is established reduces the risk of postoperative arthrofibrosis.[15] Level 1 evidence has shown that preoperative rehabilitation can facilitate postoperative recovery.[14–16] In addition, there is considerable evidence showing that exercise can help reduce pain in the population of patients with osteoarthritic knees.[17–20] Therapy in combination with exercise has been shown to be more effective in improving pain, stiffness, and function compared with a home-based exercise program alone.[21] The role of physical therapy can go beyond relief of pain postoperatively. Physical therapy combined with exercise may reduce the need for total joint replacement and medication injections in this population.[18]

Intraoperative Pain Management

Preventive Analgesia

In contrast to preemptive analgesia, which begins before noxious surgery stimuli are encountered, preventive analgesia is used to attenuate these stimuli intraoperatively or perioperatively. Examples include postoperative surgical field blocks, intra-articular injection, and continuous peripheral nerve blockade. Note that the field block—defined as local anesthetic infiltration of the surgical site—may also be considered preemptive if administered prior to the initial skin incision. Multiple cocktails have been investigated. In general, a combination of short- and long-acting local anesthetics may be the best choice given their onset of action and duration of effect (Table 4). Intra-articular knee injection of local anesthetics or morphine derivatives is also a popular method of preventive analgesia (ie, 0.2% ropivacaine). Caution should be used in this pain management approach, because there is an increasing body of evidence[22,23] suggesting the risk of in vitro and in vivo chondrotoxicity due to the use of several common local anesthetic agents. Key points when considering injection include the use of low-toxicity anesthetics (ie, ropivacaine) at diluted concentrations (0.2%) with short duration of exposure. Although peripheral nerve blocks are a common form of preemptive analgesia, continuous infusion of the peripheral nerve block postoperatively is also a preventive strategy that can help to minimize the transmission of painful nerve impulses from the knee to the brain in the early recovery period.

Table 4. Examples of Incisional Injection Cocktails

Lidocaine	Short duration of action, quick onset of effect
Bupivacaine	Longer duration of action, slower onset of effect
Ropivacaine	Similar effect to bupivacaine but less CNS and CV toxicity

Abbreviations: CNS, central nervous system; CV, cardiovascular.

Tourniquet

Tourniquet effect has been investigated as playing a role in postoperative pain. The primary variables are duration and tourniquet pressure.[24] Ischemia leads to tissue hypoxia and acidosis that is proportional to duration. Clinically, tourniquet times ≤ 2 hours are considered safe and are commonly used in extremity surgery.[25] Tourniquet times exceeding 2 hours may result in post-tourniquet syndrome featuring edema, stiffness, pallor, weakness, and subjective numbness, which typically resolves within 1 week.[26] Lesser complications can also be seen, such as quadriceps weakness, which is likely multifactorial, but possibly due to components of ischemic myopathy and compressive neurapraxia.[27] Tourniquet use may have more detrimental effects on pain relief after longer procedures (eg, total knee arthroplasty [TKA]) vs shorter ones. For routine arthroscopy, recent evidence[29–30] suggests no difference in pain scores, analgesic requirements, serum creatine phosphokinase levels, and even return to work and jogging between tourniquet vs no-tourniquet groups.[30] Regarding tourniquet pressure, it has been shown that use of a wider cuff can arrest blood flow at lower pressures.[31] A promising new technology uses a pulse oximeter to calculate the cuff pressure that is required to achieve blood occlusion, rather than relying on a standard pressure setting. Further investigation is needed to determine the potential benefits of these kinds of devices for postoperative analgesia.

Surgical Technique

Tissue trauma from poor surgical technique can significantly influence postoperative pain. Aggressive or traumatic soft tissue handling ignites a more rigorous inflammatory repair process. This cascade both activates and sensitizes nociceptive nerve endings. Postoperative bleeding causes both increased pain due to pressure effect and an increased and prolonged inflammatory response. For optimal analgesia, surgical principles of meticulous hemostasis and careful soft tissue handling are critical to a successful outcome.

Postoperative Pain Management

Cryotherapy, Elevation, Compression

Rest, ice, compression, and elevation (RICE) is a mainstay of initial treatment of both acute knee injury and postoperative pain. Ice, compression, and elevation all help to decrease

swelling, which at minimum may diminish nerve fiber stretch and painful impulse transmission to the brain. This technique may also help to limit the inflammatory component of pain. Cryotherapy has a long anecdotal history. The science behind cryotherapy is based on controlling blood vessel engorgement, limiting the inflammation response, possibly slowing nerve conduction, and decreasing nerve ending sensitivity. This approach may also decrease pain by lowering cellular metabolism. Cryotherapy has been shown to be effective in either preventing a rise in temperature or lowering the intra-articular temperature.[32–34] The effect of decreased blood flow and cellular metabolism with cryotherapy has been demonstrated by using a bone scan.[35] Its effect on inflammation has also been studied objectively with prostaglandin E2 and lactate concentrations after knee arthroscopy. Compared with controls, those patients treated with cryotherapy had a lower lactate concentration and a lower prostaglandin E2 concentration—but not to a significant degree.[36] The literature is somewhat mixed on the efficacy of cryotherapy and specific delivery devices. Studies show no apparent difference in those patients who were treated with cryotherapy and those who were not.[37–39] Patients treated with cryotherapy after ACL reconstruction, however, have less pain and less analgesic requirements.[40,41] Studies have even looked to compare specific devices such as the Cryo/Cuff (Aircast, DJO Global, Vista, CA) with conventional ice therapy, with overall evidence leaning toward less analgesic requirements.[42–44] A 2005 meta-analysis supports the findings of significantly lower postoperative pain with the use of cryotherapy.[45] As with any intervention, the potential exists for complications of cryotherapy, including frostbite leading to skin compromise or, more rarely, injury to the peroneal nerve has been reported.[46–48]

There is a paucity of literature looking at the efficacy of compressive therapy and elevation. One study did not find a significant benefit of postoperative use of medical compression stockings on postoperative knee pain and swelling.[49] Another study showed that the use of combined compression and cryotherapy after ACL reconstruction resulted in improved short-term pain relief and a greater likelihood of independence from narcotic use compared with cryotherapy alone.[43] Further studies investigating the use of compression therapy in postoperative care are warranted.

Bracing

Knee immobilizers are commonly used after peripheral nerve block to protect the patient until quadriceps function returns. Aside from that purpose, the use of postoperative knee bracing is controversial. One level 1study showed no difference in pain scores or analgesic use in the first 14 days when comparing the use of an immobilizer with no brace.[50] Other studies have rendered similar findings in examining the use of a neoprene sleeve and functional braces compared with no brace.[51–53] The role of functional knee bracing after ACL reconstruction has been extensively studied in the literature. Only 1 study suggests that the brace may improve pain scores at 2 weeks.[54] The overwhelming majority of these studies show no effect of a brace on pain control, re-injury, range of motion, or knee stability at final follow-up.[55]

Continuous Passive Motion Devices

The use of continuous passive motion devices (CPM) for postoperative pain relief is controversial. There are studies demonstrating a decreased narcotic use in patients treated with CPM,[56,57] and another that showed no effect on analgesic use.[58] Multiple studies have shown that the use of a CPM does not affect range of motion or anterior laxity after ACL reconstruction.[57,59–61] Given the cost associated with CPM and the lack of effect on overall functional outcomes, it is hard to justify their use as purely an adjunct to pain control without definitive level 1 supportive evidence.[62]

Mobilization and Rehabilitation

In general, clinical trials have shown that physical therapy exercise programs help improve pain, swelling, and knee function postoperatively.[14,16,63,64] Early mobilization and accelerated rehabilitation after knee surgery continues to evolve, following suit with many other postoperative protocols in orthopedics. Research has demonstrated that these protocols are not only safe but also beneficial regarding postoperative pain and function. A randomized clinical trial showed that initiating rehabilitation within 24 hours after TKA for osteoarthritis compared with 48 to 72 hours reduced the number of sessions needed to regain normal gait and balance, in addition to a reduced mean hospital stay.[65]

Another level 1 study showed that although there was no difference in anterior knee laxity, pain, and functional improvement after ACL reconstruction in a group of patients with an early start of open kinetic chain exercises (week 4 postoperatively) compared with a group with a late start (week 12 postoperatively), the early group showed a faster recovery in quadriceps strength.[66] Immediate weight bearing compared with a 2-week delay showed decreased anterior knee pain for the patients with no deleterious effects.[67] Concerning closed- compared with open-chain exercises, a long-term study showed increased pain and laxity in those patients

who underwent open-chain exercises. This finding has since served as the basis for many closed–chain-based protocols.[68] However, several studies with short-term follow-up (6–14 weeks) have showed no significant differences in pain, laxity, range of motion, and functional movements in comparing these 2 groups of exercises.[69–73] In other studies looking at progressive early eccentric exercises and early quadriceps and hamstring strengthening showed no deleterious effects of accelerated protocols on knee pain or laxity measures.[74–76] Level 1 evidence shows that neuromuscular training that includes dynamic joint stabilization, plyometrics, agility drills, balance, and sport-specific exercises resulted in significant improvement in Cincinnati Knee Scores and VAS scores for global knee function when compared with traditional strength training at the 6-month follow-up period following ACL reconstruction. In addition, subjects who developed pain, swelling, or decreased range of motion underwent specific interventions until the problems were resolved.[63] Specific targeting of key muscle groups (ie, quadriceps femoris, hamstring, gluteus medius, and gastrocnemius muscles) is critical to improved function and decreased postoperative pain following knee surgery. Neuromuscular training activities are performed without significant pain and swelling to ensure their effectiveness. Early aggressive activity can result in inflammation, a range of motion deficit, and chronic pain. These factors can have detrimental effects on postoperative recovery. One study showed that early return to physical activity after ACL reconstruction can decrease intermediate postsurgical stability and 24-month stability.[77]

Analgesics

Postoperative pharmacologic medications decrease brain receptor sensitivity to pain impulses and decrease factors in the knee that contribute to the impulses. Centrally acting agents, such as acetaminophen, opioids, and neuropathic agents, act at the brain receptors to decrease sensitivity to the impulses. Anti-inflammatory medications reduce inflammatory cytokine production and swelling at the knee level to diminish pain impulses from the knee. Pharmacologic strategies often include acetaminophen, nonsteroidal anti-inflammatory drugs (NSAIDs), injections of cortisone or viscosupplementation, and, less commonly, tramadol or other pain relievers.[11]

Topical Agents

Topical agents formulated with local anesthetics, neuropathic adjuvant pain relievers, anti-inflammatories, and antispasmodic muscle relaxant medications may prove helpful in the postoperative knee by diminishing nerve fiber impulse transmission. Short-term use of topical NSAIDs, diclofenac sodium 1% gel, and diclofenac sodium 1.5% in 45.5% dimethylsulfoxide solution, has shown safety and efficacy in the treatment of knee pain.[11] These topical agents may also be most useful in treating patients with lower pain thresholds or patients with persistent pain after healing. Additionally, topical analgesics provide a beneficial treatment alternative to the elderly population at risk of systemic toxicity to oral NSAIDs because they offer better tolerability.[11,78]

Transcutaneous Electrical Nerve Stimulation

Transcutaneous electrical nerve stimulation (TENS) is another adjunctive modality for pain control. In the central nervous system, TENS activates areas in the brainstem and spinal cord that contain serotonin, muscarinic, and opioid receptors. At the region of TENS administration in the periphery, α-2 noradrenergic receptors and opioid receptors are activated.[79] After knee arthroscopy, those patients who used TENS for an average of 4 days had decreased postoperative pain that was statistically significant on day 2 and regained preoperative motion, isokinetic strength in flexion and extension, and leg volume 1 month sooner than those patients who were treated with placebo.[80] Another study that examined open knee surgery reported that high-frequency TENS given for 15 to 20 minutes decreased pain perception by 50% at rest and 11% after quadriceps contraction. It also increased muscle contraction ability by 305%, compared with the initial contraction before treatment. This finding is in contrast to placebo TENS, which had no effect on either parameter.[81]

Iontophoresis

Iontophoresis is a method of transdermal administration of ionized drugs in which electrically charged molecules are propelled through the skin by an external electrical field. In 1 study regarding pain management of TKA patients, iontophoresis devices were attached for 6 hours to patients who received either morphine HCl or lactated Ringer's solution. Pain levels were measured by use of a patient-controlled analgesia device, with the group who received iontophoresis using the patient-controlled analgesia device considerably less than the control group.[82]

Pulsed Electromagnetic Field Therapy

Pulsed electromagnetic field therapy (PEMF) directs a series of magnetic pulses through injured tissue, whereby small

Table 5. Summary of Physical Postoperative Pain Management Interventions

Study	Study Type	Treatment Group (n)	Control Group (n)	Outcome Measured	Results	Operation
Cryotherapy, Elevation, Compression						
Cohn et al[39]	Prospective RCT	Use of hot/ice thermal blanket post op (26)	No blanket use post op (28)	Pain, pain medication required, physical therapy, length of hospital stay	Less pain, pain medication, and more compliant to physical therapy compared with controls. No difference in length of hospital stay	ACL reconstruction
Daniel et al[35]	Prospective RCT	Cooling pads incorporated into the dressing (89)	No cooling pads (42)	Pain, pain medication use, limb swelling, knee ROM	No difference in hospital stay, pain medication use, pain, knee girth, or ROM	ACL reconstruction
Martin et al[31]	Prospective RCT	Treated with ice post op for 2 hours (12)	Treated without ice post op for the first hour (5)	Intra-articular knee temperature	Significantly decreased temperature compared with controls	Routine knee arthroscopy
Munk et al[47]	Prospective RCT	Post op compression stocking for 4 wks	No stocking for 4 wks	Swelling, knee flexion, pain, and function	No difference in swelling, knee flexion, pain level, and function	TKA
Ohkoshi et al[30]	Prospective RCT	Joint cooling at 4° post op (7)	No joint cooling (7)	Pain score, analgesia required, blood loss	Improved pain score and decreased blood loss and analgesia administration compared with controls	ACL reconstruction
Schröder et al[40]	Prospective RCT	Cold-compression system post op (23)	Traditional ice therapy post op (21)	Girth, ROM, pain score, pain medication consumption, function	Increased ROM, function, less pain, and swelling compared with controls	ACL reconstruction
Stalman et al[34]	Prospective RCT	Post op cooling and compression (20)	No cooling and compression post op (20)	PGE2, glucose, lactate, glycerol, glutamate, ethanol exchange ratio, pain	Decreased PGE2, blood flow compared with controls. No difference in pain.	Knee arthroscopy
Waterman et al[41]	Prospective RCT	Cryotherapy/ compression device post op	Standardized ice pack post op	Edema, pain (using VAS), Lysholm knee score, SF-36, SANE	Decreased VAS compared with controls. No difference in Lysholm, SF-36, SANE, or swelling	ACL reconstruction
Bracing						
Brandsson et al[52]	Prospective RCT	Brace use for 3 weeks post op	No brace use	Tegner activity level, Lysholm score, hop test, knee laxity, and isokinetic torque, complications, and pain	Less pain and complications compared with controls. No difference in other findings.	ACL reconstruction
Hiemstra et al[48]	Prospective RCT	Immobilizer after wound closure (44)	No immobilizer (44)	Pain, pain medication use, complications, ROM	No difference in pain, pain medication use, complications and ROM	ACL reconstruction
CPM						
McCarthy et al[54]	Prospective RCT	CPM use for post op rehab	No CPM use	Pain, pain medication use	Decreased pain medication use compared with controls. No difference in pain.	ACL reconstruction
Richmond et al[57]	Prospective RCT	14-day CPM use post op	4-day CPM use post op	Girth (swelling), knee ROM, knee laxity	No difference	ACL reconstruction
Rosen et al[58]	Prospective RCT	Group 1: Early active motion (25), Group 2: CPM and active motion (25)	CPM 30 days post op (25)	Pain medication use, hospital stay length, knee laxity, knee ROM	No difference between any of the groups	ACL reconstruction

(*Continued*)

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Table 5. (*Continued*)

Study	Study Type	Treatment Group (n)	Control Group (n)	Outcome Measured	Results	Operation
Analgesics						
Tiso et al[76]	Prospective RCT	Ibuprofen tid daily for 2 wks (10)	4% topical gel 4 times daily for 2 wks (10)	WOMAC, SF-12v2, satisfaction questionnaire	No difference	NA (chronic knee pain)
TENS						
Arvidsson et al[79]	Prospective RCT/ Comparative Study	High frequency TENS given for 15–20 min post op	Placebo TENS	Quadriceps contraction (via EMG), pain perception	Decreased pain perception and increased muscle contraction ability compared with control	Open knee surgery
Jensen et al[78]	Prospective RCT	Group 3: "live" TENS unit post op (30)	Group 1: No TENS unit post op (30)	Pain medication use, pain, isokinetic strength, ROM, leg volume	TENS improved post op pain, pain medication use, strength, ROM, and leg volume compared with control groups	Arthroscopic knee surgery
Iontophoresis						
Ashburn et al[80]	Prospective RCT	1: iontophoresed morphine for 6 hrs on post op morning (17), 2: iontophoresed lactated Ringer's for 6 hrs on post op morning (21)	No iontophoresis post op	PCA analgesia	Morphine group utilized PCA significantly less than control group	TKA
PEMF						
Benazzo et al[84]	Prospective RCT	PEMF use for 4 hr/day for 60 days	No PEMF use	Function via IKDC, use of NSAIDs	Faster recovery, improved joint swelling, ROM compared with controls at 1 year but no difference at 2 years	ACL reconstruction
Fini et al[82]	Prospective RCT	PEMFs 6 hr/day for 6 mo in guinea pigs	No PEMF use	Histomorphometric measurement of cartilage thickness, fibrillation index, subchondral bone thickness and epiphyseal bone microarchitecture, bone density via dual x-ray absorbtiometry	PEMF reduced progression of osteoarthritic lesions compared with controls	NA

Abbreviations: ACL, anterior cruciate ligament; CPM, continuous passive motion; EMG, electromyography; IKDC, International Knee Documentation Committee Form; NA, not available; NSAIDs nonsteroidal anti-inflammatory drug; PCA, patient controlled analgesia; PEMF, pulsed electromagnetic field therapy; PGE2, prostaglandin E2; postop, postoperatively; RCT, randomized controlled trial; ROM, range of motion; SF-36, Short Form-36; SANE, single assessment numerical evaluation; SF-12v2, The Medical Outcomes Study 12-item Short Form Health Survey; TENS, transcutaneous electrical nerve stimulation; TKA, total knee arthroplasty; VAS, visual analogue scale; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

Table 6. The Effects of Physical Therapy and Early Mobilization on Postoperative Knee Pain

Study	Study Type	Treatment Group (n)	Control Group (n)	Outcome Measured	Results	Operation
Beynnon et al[72]	Prospective RCT	Accelerated rehab	Nonaccelerated rehab	Knee laxity, function, cartilage metabolism, patient satisfaction, activity level	At 2-yr follow-up, no difference in knee laxity, patient satisfaction, activity level, function, and cartilage metabolism	ACL reconstruction
Deyle et al[21]	Prospective RCT	Manual therapy in clinic and home exercise (42)	US to knee (41)	Distance walked in 6 min and WOMAC score	Improvement of walking distance and WOMAC score at 4 and 8 wks	None (therapy may prevent surgery in OA)
Fukuda et al[64]	Prospective RCT	EOKC began exercises at 4 wks post op (25)	LOKC began exercises at 12 wks post op (24)	Quad and hamstring strength, NPRS, hop tests, anterior knee laxity, Lysholm knee scoring	EOKC had improved muscle strength at 19 wks, 25 wks, and 17 mo. No difference in pain or functional assessment	ACL reconstruction
Gerber et al[74]	Prospective RCT	12 wks of eccentric exercise starting 3 wks post op (20)	12 wks of standard rehab starting 3 wks post op (20)	Quadriceps, hamstring, gluteus maximus, and gracilis structure	Increased volume and area of quadriceps and gluteus maximus compared with controls. No difference in hamstring and gracilis	ACL reconstruction
Labraca et al[63]	Prospective RCT	Rehab initiated 24 hrs post op (153)	Rehab initiated 48–72 hrs post op (153)	Joint ROM, strength, gait and balance, length of hospital stay, rehab sessions	Decreased pain, greater ROM, improved strength, gait balance, and decreased hospital stay and rehab sessions compared with controls	TKA
Matassi et al[16]	Prospective RCT	6 wks home exercise before surgery (61)	No home exercise before surgery (61)	Knee ROM, length of hospital stay, post op duration before achieving 90° knee flexion	Achieved 90° flexion faster, shorter hospital stay, improved knee ROM compared with controls	TKA
Osteras et al[62]	Prospective RCT	Exercise therapy for 4 mo (36)	No exercise (34)	Pain (VAS), muscle strength, function (KOOS)	Improved pain and function compared with controls	Degenerative meniscus damage
Risberg et al[61]	Prospective RCT	NT (39)	ST (35)	Cincinnati Knee Score, VAS, hop tests, muscle strength, proprioception, balance	High Cincinnati Knee Scores, VAS scores compared with controls. No difference in hop tests, balance, proprioception, and strength	ACL reconstruction
Sekir et al[73]	Prospective RCT	Isokinetic exercise at 3 wks post op	Isokinetic exercise at 9 wks post op	Strength, knee function	Greater strength and knee function compared with controls	ACL reconstruction
Tyler et al[65]	Prospective RCT	Immediate weight bearing as tolerated (25)	Non-weight bearing for 2 wks (20)	Vastusmedialis oblique function, knee extension ROM, knee stability, anterior knee pain, Lysholm score	No effect on knee extension ROM, vastusmedialis oblique function, knee stability. Also decreased pain at an averageof 7.3 mo follow-up compared with control	ACL reconstruction

Abbreviations: ACL, anterior cruciate ligament; EOKC, early open kinetic chain group; KOOS, functional assessment questionnaire; LOKC, late open kinetic chain group; NPRS, numerical pain rating scale; NT, neuromuscular training; postop, postoperatively; ROM, range of motion; ST, strength training; TKA, total knee arthroplasty; VAS, visual analog scale; US, ultrasound; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

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electrical signals are induced to stimulate cellular repair. Electromagnetic fields in vivo prevent degeneration of articular cartilage and down-regulate the synthesis and release of proinflammatory cytokines in the synovial fluid. These findings suggest that electromagnetic fields may be used to control joint inflammation and to stimulate cartilage anabolic activities, ultimately resulting in chondroprotection.[83–85] The use of a pulsed electromagnetic field after ACL reconstruction has also been examined. Those patients who received it for 4 hours daily for 60 days showed less NSAID use at 1 year compared with placebo, but showed no difference at 2 years.[86]

Psychological Techniques

Regarding psychopathology and its relation to pain levels following TKA, 1 study showed that patient-perceived outcome scores were lower for patients with psychological disorders at the 1 year mark compared with those with no psychopathology. However, even though outcome scores may be worse for patients with psychopathology, the same study found that these patients still benefit—and with the same degree of improvement in function.[87] Therefore, to decrease pain complications related to psychological status, a relaxation and guided-imagery psychological program may be beneficial in the postoperative period. Cupal et al[88] showed that patients who had 10 individual sessions of guided imagery and listened to audiotapes daily thereafter had increases in isokinetic strength and decreases in pain and reinjury anxiety.

Avoidance of Pain Modulate Dysfunction

Recognizing risk factors for potential exaggerated pain responses in the postoperative period is important to prevent hypersensitivity pain states and complex regional pain syndrome. Several psychosocial predictors of chronic postsurgical pain include preoperative anxiety, introverted personality, less catastrophizing, and less social support.[13] Early intervention with neuropathic medications, physical therapy, and sympathetic nerve blocks is helpful in reversing the effects of complex regional pain syndrome and the development of chronic painful states. Even if this approach fails to alleviate the pain, then it can be a helpful way to rule out pain modulation dysfunction as a cause and help to better focus the investigation on other potential causes.

Alternative Medicine Approaches

Acupuncture, cupping, and moxibustion have been standard treatments in Asian medicine for centuries. They often serve as the only sources of operative and postoperative pain control in the setting of Asian medicine, but they are now receiving increased attention in the West. Studies have shown acupuncture and moxibustion to be effective treatments for knee pain.[89,90] In 1 study on the efficacy of acupuncture following TKA, acupuncture was found to be a highly effective treatment with in pain relief, reduction of swelling around the knee, and early recovery of range of motion.[91] Even difficult cases of phantom limb pain had been treated with acupuncture.[92] It can ease the discomfort some subjects feel while waiting for knee surgery, and it may even be considered as an alternative to surgery in some cases. As with any other form of health care, however, one needs to remember that not all patients will respond to acupuncture. Likewise, mental preoperative and intraoperative suggestive therapy, short of hypnosis, has experienced increased interest in the healthcare community.

Summary

Prevention of knee pain following surgery requires a multimodal approach. An effective pain management strategy includes preoperative, intraoperative, and postoperative considerations. Preoperative management of patient expectations, recognition of condition and early counseling for high-risk patients (ie, opioid-dependent, psychiatric comorbidities), and use of preemptive analgesia (ie, preoperative intravenous medications, peripheral nerve blocks, and incisional field blocks) is critical. In addition, preoperative physical therapy is important in facilitating postoperative recovery. Intraoperative strategies include meticulous surgical technique, limitation of the duration and pressure of tourniquet use, and use of preventive analgesia methods (ie, post-operative field block, continuous nerve catheters, intra-articular injection). Postoperative analgesia may be facilitated by cryotherapy, early mobilization, and rehabilitation (Tables 5 and 6). Immediate postoperative rehabilitation, including exercise in conjunction with manual physical therapy, is important in controlling effusion and improving pain, knee movement, gait, strength, and flexibility.[62,93] Analgesics and modalities may be important adjuncts in the perioperative period. There may be an evolving role for alternative medicine strategies. Early recognition and treatment of exaggerated postoperative pain responses may mitigate the effects of complex regional pain syndrome or the development of chronic pain.

Conflict of Interest Statement

Jack Farr, MD, Ryan Jaggers, MD, Hal Lewis, BS, Andreas Plackis, BS, Seung B. Sim, MD, and Seth L. Sherman, MD, disclose no conflicts of interest.

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