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Overview of Total Knee Arthroplasty and Modern Pain Control Strategies

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Abstract Perioperative pain management of total knee arthroplasty (TKA) remains a challenge for physicians and anesthesiologists. Reducing postoperative pain is an essential component of patient satisfaction, functional outcomes, and hospital length of stay. Multimodal pain management regimens have been demonstrated to be superior to monotherapy in achieving adequate pain control, as well as an effective method of limiting side effects of analgesics. In the present investigation, we present literature published over the last year relating to new advancements in perioperative pain management for TKA. While it is widely accepted that methods including peripheral nerve blocks and local anesthetic injections are essential to pain protocols, there is still conflicting evidence over what modalities provide superior relief. The incorporation of cryoneurolysis preoperatively is a new modality which has been incorporated and has been shown to improve pain control in patients undergoing TKA.

Keywords Total knee arthroplasty · Multimodal pain management · Femoral nerve block · Adductor canal block · Local infiltrative analgesia · Pain management · Periarticular injection · Cryoneurolysis

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Introduction

Total knee arthroplasty (TKA) has proven to be a successful treatment to improve mobility and pain for patients suffering from end-stage osteoarthritis. Despite advances in TKA management, postoperative pain control still remains suboptimal [1–3]. The downfall to suboptimal pain control postoperatively is that it can delay recovery and mobility, thus leading to immobility-related complications and poor outcomes [1, 2]. As fast-track recovery protocols evolve, focusing on early mobility and hospital discharge, controlling pain in the postoperative period has become a primary focus of research. Improved pain control correlates with decreased recovery time including decreased hospital length of stay, faster rehabilitation, and improved outcomes [1, 3]. Furthermore, patient perception of postoperative pain has been shown to affect patient satisfaction with their surgical outcome and overall surgical experience, including their perception of the treating orthopedist [4]. Pain management is a continuously evolving field in total knee arthroplasty as orthopedic surgeons and anesthesiologists aim to minimize postoperative pain and improve functional outcomes in patients.

Traditionally, opioid analgesics have been the mainstay of pain control in operative patients. Unfortunately, opioid analgesia is associated with several adverse side effects including constipation, nausea, urinary retention, respiratory depression, and dependence. Secondary to their side effect profile, clinicians have driven the focus towards multimodal analgesic protocols. Multimodal pain protocols focus on combining drugs that act through different mechanisms to optimize analgesia, decrease pain perception, and reduce adverse side effects [1, 3, 5•]. By using various medications, clinicians target several biological pain pathways to provide optimal relief. It employs different routes of drug administration preoperatively, intraoperatively, and postoperatively. Although there is a wide variation in perioperative pain control protocols across the USA, current analgesic regimens include combinations of continuous epidurals, regional anesthesia via peripheral nerve blocks, oral analgesics, and local infiltrative analgesia including intraarticular and periarticular injections [1, 3, 6, 7]. The 2012 American Society of Anesthesiologists practice guidelines promote multimodal pain management with NSAIDs, acetaminophen, and COXIBs dosed to optimize efficacy while minimizing side effects [5•]. The efficacy of postoperative pain control is generally assessed with two variables: (1) visual analog score (VAS), a standard self-reported pain scale, and (2) consumption of narcotics. This article will review the latest literature on two key components of the multimodal approach, local infiltrative analgesia and peripheral nerve blockade, and discuss a new modality in perioperative pain management, cryoneurolysis.

Local Anesthetic Injections

Local infiltrative analgesia (LIA) was described in 2008 as a technique to control acute postoperative pain following joint replacement through infiltration of a local anesthetic ketolorac and epinephrine around the surgical site [8]. Since its introduction, LIA has been used by surgeons to control pain in the acute postoperative period in order to facilitate early mobilization and hospital discharge. Other advantages of LIA are that it can be administered directly by the orthopedic surgeon and it does not cause a motor blockade [7]. Modern periarticular injections typically consist of a corticosteroid, NSAID, local anesthetic, and an opioid [4]. There still remains little scientific data to delineate the most effective drug combination for LIA, but multiple randomized control trials continue to show lower VAS pain scores, decreased narcotic consumption, and enhanced mobility in the postoperative period with the use of intraoperative periarticular injections [1, 7, 9, 10].

Lamplot et al. compared, in a randomized controlled trial, patients undergoing TKA with intraoperative periarticular injections containing bupivacaine, morphine, and ketolorac versus a control group without intraoperative intervention. They found that patients receiving periarticular injections reported overall lower VAS scores, decreased narcotic consumption, and significantly fewer adverse effects [1].

In 2016, Barrington et al. compared the effectiveness of liposomal bupivacaine-based periarticular injections, ropivacaine-based injections, and morphine-based spinal anesthesia in controlling postoperative pain. They showed a transient positive effect of liposomal bupivacaine periarticular injection and spinal morphine groups on postoperative pain at 6 and 12 h with lower VAS pain scores compared to the ropivacaine periarticular injection group. The incidents of pruritus were higher in those receiving morphine spinal anesthesia, but they found no differences in other adverse reactions or total narcotics consumed [11].

However, there remains conflicting evidence regarding the benefit of corticosteroids in the injection. The latest study addressing the efficacy of corticosteroids in periarticular injections was a double-blinded randomized control by Tsukada et al. comparing patients who received periarticular injections plus methylprednisolone to those who received periarticular injections without methylprednisolone. They demonstrated that by adding 40 mg methylprednisolone to a periarticular injection with ropivacaine, morphine, epinephrine, and ketoprofen, postoperative pain in the first 24 h was significantly lower than the control. Patients receiving methylprednisolone also required less rescue analgesia to achieve pain control. Patients receiving injections containing the corticosteroid reported less pain during activity 24 h postoperatively, but there was no difference at rest [9].

Regional Anesthesia

Regional anesthesia via a continuous femoral nerve block (FNB) is a common intervention used in TKA to achieve adequate intraoperative and postoperative analgesia of the operative limb. However, the efficacy of FNB in achieving pain control versus using local infiltrative analgesia (LIA) has remained controversial. Disadvantages of FNB include increased risk of falls and prolonged quadriceps weakening secondary to the combined sensory and motor blockade. Adductor canal block (ACB) has been implemented in order to selectively block the sensory nerves without a resulting decrease in motor function and strength [2, 10, 12].

Kurosaka et al. measured VAS scores and opioid consumption in a randomized clinical control trial to compare the efficacy of LIA, using periarticular injection of ketoprofen, ropivicaine, and epinephrine to continuous FNB. The LIA group had a statistically significant decrease in VAS score 4 h after surgery and 1 day postoperatively versus the continuous FNB group. Opioid consumption, measured as the total volume of morphine over the first 24 h after surgery, was also lower in the LIA group. No significant difference in complication rates or medication side effects was detected [13].

A systemic review by Dong et al. evaluated the efficacy of pain management in several randomized control trials using an ACB versus FNB measured by VAS scores and rescue opioid consumption. They showed no statistical difference in VAS pain scores at 4, 24, and 48 h postoperatively during rest or mobilization. They concluded ACB and FNB are equally safe and effective means of pain control, and the intervention performed should be based on anesthesiologist preference [2].

A similar study by Ludwigson et al. compared functional outcomes, patient-reported VAS scores, and opioid consumption between patients receiving ACB versus FNB. Patients receiving

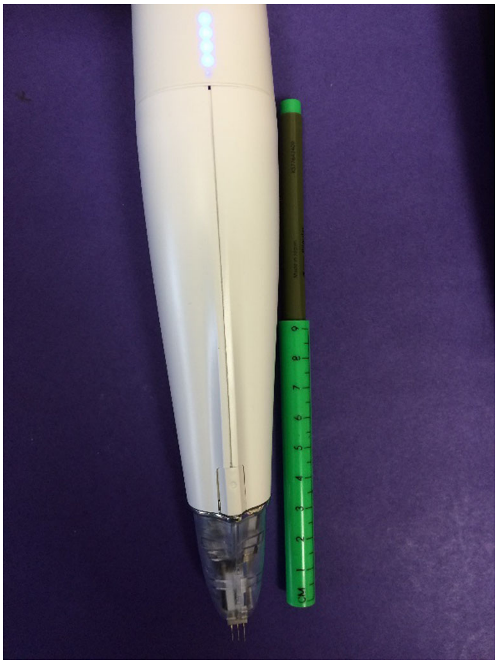

Fig. 1 Iovera device (reproduced with permission from Dasa et al. [15••]

ACB demonstrated greater improvements in mobility and were discharged home sooner than patients receiving continuous FNB. However, they demonstrated equivalency in regard to pain control. There was no significant difference in VAS scores or opioid administration between the two groups [12].

In 2015, Auyong et al. showed decreased pain scores and opioid consumption on postoperative day 1 and 2 in patients undergoing an enhanced recovery protocol where patients received a 48 h ACB compared to an intermittent FNB. Patients receiving ACB had significantly higher maximum pain scores but similar opioid consumption to those receiving an intermittent FNB in the first 24 h postoperatively [14].

Cryoneurolysis

A new modality for perioperative pain management is cryoneurolysis. Cryoneurolysis is a form of cryotherapy that involves freezing peripheral sensory nerves for perioperative pain control. Percutaneous cryoneurolysis aims to decrease neuropathic knee pain in the postoperative period by targeting cutaneous nerves of the knee. By cooling the nerves to low temperatures, axon and myelin degradations occur while the epineurium and perineurium resist freeze damage. This allows normal axonal regeneration and remyelination to occur. A cryoneurolysis device, Iovera, was developed for percutaneous freezing of superficial sensory nerves (Fig. 1). The device treats the nerves with low temperatures through three small needles producing a localized cold zone. Cryoneurolysis is performed in the office with only minimal bruising or tenderness. In a retrospective study comparing preoperative

Table 1 Perioperative and postoperative pain protocols after total knee arthroplasty

Medication/procedure	Dose	Route	Frequency	Notes
Preoperative				
Cryoneurolysis		Percutaneous	1 dose	Procedure performed with Iovera device in the office 5 days prior to surgery
Decadron	10 mg	IV	1 dose	
Regional anesthesia			1 dose	Given as Adductor Canal Block
Intraoperative				
0.25 % Marcaine 1 % Epinephrine	20 mL 30 mL 20 mL	Periarticular injection		3 doses of LIA administered: 1.Prior to incision (targeting ISN/AFCN) 2.along medial parapatella arthrotomy and geniculate nerves 3.After transection of cruciate ligaments (posterior compartment and meniscal attachment)
Postoperative				
Acetaminophen	650 mg	Oral	1 dose every 6 h	For 24 h
Celecoxib	200 mg	Oral	1 dose every 12 h	For 24 h
Pregablin	75 mg	Oral	1 dose every 12 h	For 24 h
Hydrocodone/acetaminophen	10/325 mg	Oral	1 dose every 4 h	As needed
Discharge				
Oxycodone/acetaminophen	10/325 mg	Oral	1 dose every 4–6 h	As needed; 2-week supply provided
Tramadol	50 mg	Oral	1 dose every 8 h	As needed only if additional medication requested following 2-week visit

cryoneurolysis as adjunctive therapy to standard multimodal pain management to standard multimodal pain management alone, the cryoneurolysis arm showed significant benefits. When cryoneurolysis was administered by the handheld Iovera device targeting the infrapatellar branch of the saphenous nerve (ISN) and anterior femoral cutaneous nerve (AFCN) 5 days before planned TKA, patients showed significantly less opioid consumption during the first 12 weeks postoperatively, a decrease of 45 % compared to the control. Patients receiving cryoneurolysis had a shorter inpatient hospital stay with the majority discharged within 2 days of surgery. Additionally, the patients had significantly reduced Patient Reported Outcomes Measurement Information System (PROMIS) pain scores measured at the 2 weeks postoperative visit [15••, 16].

Discussion

The senior author's multimodal pain regimen for patients undergoing TKA includes preoperative cryoneurolysis 5 days prior to surgery. On the day of surgery in the preoperative holding area, all patients are given 10 mg IV dexamethasome and an ACB is performed by the anesthesiology team.

Intraoperatively, patients receive three periarticular injections of bupivicaine with epinephrine administered at different points during surgery: prior to incision, prior to medial parapatella arthrotomy, and lastly after transection of the cruciate ligaments. Postoperatively, patients receive scheduled acetaminophen, celecoxib, pregablin, and hydrocodone/acetaminophen. All stable patients are discharged within 24 h with a 2 weeks supply of hydrocodone/acetaminophen (Table 1).

Conclusion

Multimodal pain management, focused on decreasing usage of opioids and their side effects, is an important component of patient perioperative care. While opioids are still commonly incorporated into postoperative pain regimens, the advancements in adjuvant therapies have shown to be effective at decreasing patient use of rescue opioids. Despite advances, there is still controversy on the most optimal method for achieving postoperative pain control, the lowest rescue opioid usage, and the greatest patient satisfaction. The addition of peripheral nerve blocks and local anesthetic injections has all decreased patient-reported pain scores and opioid consumption in the postoperative period. Incorporating cryoneurolysis into the preoperative regimen has shown promising results with great clinical utility to further improve pain management. Patient comorbidities, anesthesiology staff, and facility type are all factors that should be considered when selecting what modality is ultimately incorporated into patient management [6]. Patient and physician factors must be also taken into consideration when perioperative pain management is planned [1].

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Compliance with Ethical Standards

Conflict of Interest Lacey Giambelluca Lavie and M. Patricia Fox declare that they have no conflict of interest.

Vinod Dasa declares consultancy fees from Myoscience.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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- •• Of major importance

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