

Novel Methodologies in Regional Anesthesia for Knee Arthroplasty

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KEYWORDS

- Knee arthroplasty • Cryoanalgesia • Cryoneurolysis • Neuromodulation
- Peripheral nerve stimulation

KEY POINTS

- Combined with the rising expertise of ultrasound imaging among anesthesiologists, ubiquitous availability of ultrasound devices, and availability of portable cryodevices, cryoanalgesia is now a realistic intervention for acute pain management.
- Although a single application of ultrasound-guided percutaneous cryoneurolysis provides weeks to months of analgesia, careful selection of candidates is required given the potential prolonged motor block if mixed motor-sensory nerves are targeted.
- Ultrasound-guided percutaneous peripheral nerve stimulation offers a novel intervention to provide post-knee arthroplasty analgesia without the major limitations of opioids and continuous peripheral nerve blockade.
- Before ultrasound-guided percutaneous cryoanalgesia and percutaneous peripheral nerve stimulation may be routinely practiced, robust clinical trials documenting their risks and benefits in managing acute and subacute postoperative pain should be conducted.

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INTRODUCTION

Maximizing analgesia is critical following joint arthroplasty because postoperative pain is a major barrier to adequate participation in physical therapy, which is in itself central to optimizing functional recovery. Both single-injection and continuous peripheral nerve blocks (PNB) provide pain control following knee arthroplasty¹ and are often considered the gold standard for postoperative analgesia.² However, limitations of these techniques have limited their general use,^{3,4} and alternatives could improve the risk-benefit ratio and increase their application worldwide following knee arthroplasty.

One of the major issues of local anesthetic-based analgesics is their duration measured in only a few hours or days. The pain following total knee arthroplasty (TKA) usually far outlasts this analgesic duration. The duration of continuous PNB catheters is limited by the risk of infection and dislodgement.⁵ Perineural infusions also induce motor, sensory, and proprioception deficits that potentially increase the risk of falling.⁴ A further disadvantage of continuous PNB in ambulatory patients is the burden of carrying an infusion pump and local anesthetic reservoir bag. Percutaneous cryoneurolysis and peripheral nerve stimulation (PNS) are two modalities approved by the Food and Drug Administration (FDA) for use in treating acute pain; yet they have been nearly absent from the acute pain literature.^{6–8} This article reviews these analgesic methods and their application to acute pain states, specifically for knee arthroplasty.

CRYOANALGESIA

Cryoanalgesia, also termed cryoablation, cryoneuroablation, or cryoneurolysis, is a method in which peripheral nerves are reversibly ablated by extremely cold temperatures leading to analgesia in the distribution of the nerve for multiple weeks to months. It was first reported in 1961 using liquid nitrogen to create temperatures at -190°C to ablate nerves.^{9,10} Lloyd and colleagues¹¹ coined the term “cryoanalgesia” 15 years later after describing its use for the management of pain. Since then, its clinical application expanded mainly to treat various chronic pain conditions.¹² In the few cases cryoneurolysis was used to treat acute pain, it was almost exclusively applied intraoperatively by surgically exposing the target nerves and applying the cannula under direct visualization.^{13–25} More recently, cryoneurolysis was administered using a blind percutaneous approach using landmarks,¹⁸ and subsequently using a percutaneous ultrasound-guided approach.^{6,7} Most studies have involved application to sensory-only nerves. Although mixed sensory-motor nerve treatment was reported without negative sequelae in preclinical^{26,27} and clinical²⁸ settings, its safety and therapeutic profile have yet to be determined with adequately designed and powered trials.

Mechanism of Action

The modern cryoprobe consists of a hollow tube with a smaller inner tube. Highly pressurized gas (usually nitrous oxide or carbon dioxide) travels from the proximal part of the tube to its distal portion where it is released from a larger outer tube through a narrow annulus, allowing the gas to rapidly expand in the closed tip (**Fig. 1**). Because of the Joule-Thompson effect, a drop of temperature to approximately -70°C accompanies the drop in pressure, creating an ice ball at the tip of the probe.²⁹ The gas itself is vented back proximally through the outer tube. This mechanism ensures that no gas enters or remains in the patient's tissues.

Wallerian degeneration (a breakdown of the axon) occurs distal to the point of treatment, resulting in a complete sensory, motor, and proprioception conduction block.

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