14 Perioperative Analgesia for Orthopedic Surgery

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Introduction

Orthopedic surgical procedures are often some of the most painful procedures performed in medicine. In 2001, treatment of patients' pain became a significant focus in healthcare, and thereafter, pain was considered the "fifth vital sign" [1–3]. This created a new priority of aggressively treating pain symptoms with narcotics, which unfortunately resulted in increasing rates of narcotic dependence and addiction. The heavy reliance on narcotic pain medications developed into widespread use. This lead to a dramatic increase in opioid related complications, such as addiction, diversion, and fatal overdose. Thus, the modern-day "opioid epidemic" is a national issue that stresses the need for appropriate and responsible pain treatment. There is a delicate balance between managing a patient's pain and creating an overreliance on narcotic pain medication. In an effort to reduce the use of narcotic medications for perioperative pain control, there has been an increased focus on alternative methods of pain control for all surgical procedures. The Centers for Disease Control (CDC) has already man-

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dated regulations on the number of narcotics given by day or oral morphine equivalent (OME) [4, 5]. However, it is also the surgeon's responsibility to understand the many options available to aid in reduction of postoperative discomfort.

Orthopedics is a broad, comprehensive surgical specialty, and procedures are quite diverse in how invasive and/or painful they can be. Classically, we categorize orthopedic surgeries into major and minor procedures, depending on the extent of soft tissue dissection or osseous manipulation, need for inpatient stay, overall morbidity to the patient, complexity of postoperative rehabilitation, and the level of pain expected after surgery.

Major orthopedic surgeries are usually performed under general anesthesia or monitored anesthesia with or without regional anesthesia. Examples include total joint arthroplasty/replacement (hip, knee, ankle, elbow, and shoulder), most periarticular fracture care, long bone or pelvic trauma, spinal surgery, tumor and limb salvage procedures, and major ligament repairs or reconstructions (rotator cuff, labrum, anterior cruciate ligament, etc.) including those performed arthroscopically. Any of these surgeries may involve aggressive manipulation of the bones and/or ligaments/soft tissues with associated violation of joint space and deep fascial compartments. They tend to cause significant pain postoperatively, and patients usually need to spend at least one night in the hospital after surgery.

Alternatively, minor orthopedic procedures can be performed under general anesthesia and monitored anesthesia care with local or by a technique referred to as "wide awake local anesthesia no tourniquet", more commonly known as WALANT. These cases tend to be outpatient surgeries and generally do not result in the same level of postoperative discomfort as major surgeries. Examples of minor orthopedic procedures include closed fracture reductions, nerve decompressions, laceration repairs, wound debridement, biopsies, or tendon releases.

Regardless if a surgeon is performing a major or minor procedure, it is extremely important to have a discussion with the patient about pain control strategies and expectations throughout the entire perioperative period [6]. There are many options for multimodal pain control preoperatively, intraoperatively, and postoperatively depending on the location and the nature of

surgery. This chapter is designed to outline the numerous options a surgeon has to choose from when considering perioperative pain control in the orthopedic patient.

Preoperative

During more invasive or extensive surgeries, the patient may be "pre-medicated" with IV or PO medications upon arrival to the pre-op suite. These most commonly include IV or oral acetaminophen, nonsteroidal anti-inflammatory drugs (NSAIDs), or oral neuromodulating agents such as gabapentin or pregabalin [7–9]. There are many studies supporting the use of preemptive multimodal analgesia [10].

However, the most frequently utilized adjunct to major orthopedic surgery is a regional nerve block with the use of short-, intermediate-, and/or long-acting local anesthetics. These are usually administered by the anesthesiologist prior to surgery under the assistance of neurostimulation or ultrasound guidance. The use of peripheral nerve blocks has generally led to better postoperative pain control with reduced narcotic requirement [11–16]. Depending on the location of the procedure, many different options or combination of blocks exists. Blocks can be performed as a "single shot" or employed as a continuous nerve catheter. A single-shot block is a one-time dose of local analgesic medication that is injected around the nerves that usually lasts for 12 hours or more. Alternatively, a continuous nerve catheter is a medication pump that is temporarily implanted, allowing a slow and steady infusion of anesthetic during and after the procedure.

Upper Extremity Nerve Blocks

Brachial plexus blocks are the mainstay of regional anesthesia for many major upper extremity procedures, especially about the shoulder. The most commonly performed blocks in the upper limb are interscalene, supraclavicular, infraclavicular, and suprascapular/axillary nerve blocks [11, 17, 18].

Interscalene

Interscalene blocks are administered between the anterior and posterior scalene muscles, just posterior to the sternocleidomastoid. This provides blockade of most of the brachial plexus (C5–C8 dermatomes) and however often inadequately covers the inferior trunk, including C8. This is called ulnar sparing and can lead to difficulty with procedures requiring coverage to the C8 distribution along the axilla, medial arm, elbow, and forearm [11, 17]. Therefore, interscalene blocks are generally preferred for procedures of the clavicle, shoulder, or proximal humerus. If an interscalene block is chosen for a more distal procedure, it is often necessary to supplement with an additional ulnar nerve block.

Complications of an interscalene block are primarily related to unintended extravasation of the local medication to surrounding nerves, as is the case with many regional blocks. Often, this leads to temporary paralysis of motor nerves necessary for diaphragmatic function (phrenic nerve) or vocal cord function (recurrent laryngeal nerve). The phrenic nerve (C3–5) is temporarily affected in 70–100% of interscalene blocks [18, 19]. Vocal cord dysfunction may present with hoarseness and difficult phonation, whereas phrenic nerve paralysis will present with varying degrees of shortness of breath as well as hemidiaphragm elevation on chest radiograph. Interscalene nerve blocks are generally avoided in patients with baseline severe respiratory disease as it can lead to further respiratory decline.

Supraclavicular

Supraclavicular nerve blocks are performed with injection of local anesthetic just superior to the clavicle around the level of the first rib. This allows for more coverage of distal nerve distributions but sacrifices more proximal and superior shoulder anesthetic coverage. For this reason, supraclavicular blocks are commonly used for procedures involving the distal humerus, elbow, forearm, wrist, and hand.

Complications of supraclavicular blocks also include paralysis of the phrenic nerve, albeit much less commonly than an interscalene block. Studies show that phrenic nerve paralysis occurs in 17–50% of supraclavicular nerve block procedures [20]. Given the anatomic

proximity, however, supraclavicular injections do carry risks of pneumothorax as well as injury to the subclavian artery [17].

Infraclavicular

Infraclavicular blocks are administered below the clavicle at the level of the brachial plexus cords. The shoulder is not well covered with an infraclavicular block, so it is not recommended for clavicle, shoulder, or most humerus procedures. This block provides the best analgesia for the distal two-thirds of the arm, elbow, forearm, wrist, and hand [11, 17]. Complications of the infraclavicular block are low especially with regard to pneumothorax, where the risk is less than 1% [21].

Suprascapular and Axillary

Suprascapular nerve blocks are rarely used in isolation but rather are commonly combined with an axillary block. This combination is excellent for shoulder procedures, particularly in patients with respiratory disease, COPD, and sleep apnea or those at high risk for pulmonary complications. The suprascapular and axillary nerve block combination has similar analgesic profile in the shoulder but fewer respiratory complications than a more proximal block [22, 23]. Typical shoulder procedures ideal for this block combination include arthroscopic vs open rotator cuff repair, biceps release and/or tenodesis, labral repairs, and acromioclavicular resections/distal clavicle resections. Complication rates are quite low and include inadvertent intraneural infiltration or prolonged motor deficits postoperatively [24].

Lower Extremity Nerve Blocks

Blocks of the lower extremity have a variety of applications, with the majority being employed distal to the lumbosacral plexus. In addition, neuraxial blocks also have utility in many patient populations. Commonly used regional blocks in orthopedics include the lumbar plexus block, femoral nerve block, sciatic nerve block, saphenous nerve block, and popliteal block. Neuraxial blocks include spinal or epidural anesthesia. These blocks are

incorporated in the perioperative care of patients undergoing elective joint replacement, soft tissue repair and/or reconstruction, and certain fracture care.

Lumbar Plexus/Psoas Block

Also referred to as a psoas block, the lumbar plexus block is directed into the psoas muscle compartment usually via a paravertebral approach just lateral to the L4 spinous process. It is particularly useful for anterior hip, thigh, and anterior knee procedures and may be paired along with sciatic nerve blocks to augment total analgesic effect in the lower extremity [25, 26]. Like in upper extremity blocks, side effects and complications are commonly a result of inadvertent diffusion of analgesic medication. Epidural dispersion is observed in 3–27% of cases, and a complete spinal block can result from direct intrathecal injection [27–30]. Other complications are often related with intravascular injection with possibility of an associated retroperitoneal hematoma, as well as fall risk if patients attempt ambulation without assistance prior to resolution of the block or residual motor deficits remain due to nerve damage [31].

Femoral Nerve Block

Femoral nerve blocks are widely used for elective surgeries of the knee, both open and arthroscopic procedures [32]. Femoral nerve blocks are administered within the femoral (Scarpa's) triangle, just lateral to the femoral artery. There is some debate in the literature with regard to how significant the improvements in pain control are with femoral nerve blocks performed in isolation. There are several studies that demonstrate significant improvement in pain scores and lower narcotic use; however, some research reveals only a modest effect postoperatively [33–36]. Femoral nerve blocks can be performed in combination with sciatic blocks, which has been shown to be beneficial for pain control in complex knee surgeries [37, 38].

While complications are uncommon, femoral blocks carry a risk profile that can result in significant challenges for patients. The close proximity of the femoral artery exposes injections to misdirection intravascularly at a rate of 5.7% [39]. Intraneural

injection can result in toxicity or increased risk of falls related to prolonged or even permanent quadriceps weakness [39, 40].

Sciatic Block

As discussed above, sciatic nerve blocks can often be combined with femoral nerve or psoas blocks for procedures of the thigh or knee. However, when used alone, sciatic nerve blocks can provide adequate coverage for surgery involving only the lower leg, ankle, or foot [26, 36]. Similar to femoral nerve blocks, complications are rare but quite serious. These include direct nerve injury, intravascular injection, or vascular puncture/injury (6.6%). Prolonged nerve blockade without expected timely resolution can lead to ulceration of the heels and motor deficits such as foot drop [31, 39].

Saphenous Nerve Block

This block is often combined with a popliteal or sciatic block for more acral procedures of the leg. Saphenous nerve block can be performed at the mid-thigh in the adductor canal or just below the knee depending upon the desired area of anesthesia [15, 26, 32, 41]. Innervating only sensory nerves, this block is particularly effective for medial leg soft tissue procedures, including arthroscopic partial meniscectomies. In these patients, saphenous nerve blocks were reported to improve pain at rest, pain with activity, and weight-bearing pain [42].

Popliteal Block

As stated above, this block is often combined with a saphenous nerve block for procedures of the knee, foot, and ankle [15, 26, 43]. Injection is performed at the level of the popliteal fossa [44]. Noted complications include intraneural or intravascular injections and associated damage, local abscess, hematoma formation, and persistent foot drop and risk for latent plantar pressure necrosis [15, 45].

Epidural/Spinal Anesthesia

Neuraxial anesthesia, which refers to spinal and epidural anesthetics, has been widely implemented in elective lower extremity

total joint arthroplasties, particularly of the hip and knee. Given the magnitude of total hip and total knee arthroplasties being performed annually, large cohorts of patients have been available to study the outcomes of neuraxial anesthesia as compared with general anesthesia. While implementation is variable by surgeon and anesthesiologists, neuraxial anesthesia has largely been considered equivalent to general anesthesia in both efficacy and safety [46].

Although the literature has demonstrated appropriate safety and/or at least equivalence to general anesthesia, not all studies have been able to delineate which patients may particularly benefit. A large cohort of over 18,000 patients undergoing primary and revision total joint arthroplasty was studied between 2005 and 2016, with subgroups identified as "frail," "vulnerable," and "non-frail," as based on a preoperative frailty index [47–51]. No difference in risk between general or neuraxial anesthesia was found in the "non-frail" or "frail" patients; however, there was significantly decreased mortality and wound complications in the "vulnerable" patient population. Other studies have shown similar conclusions, with at least equivalent and often improved outcomes among TKA and THA patients [46, 47].

Complications of neuraxial anesthesia include infection, dural leak, postdural headache, epidural and spinal hematoma, nerve damage, or neuropraxia [52]. These can render significant morbidity to the patient during a postoperative period characterized by difficult mobility and function. Furthermore, patients on anticoagulation, those who have suffered prior spine trauma or have underlying neurologic deficits or disorders (e.g., multiple sclerosis), have undergone spinal fusion, or have advanced degenerative disease of the spine, may be contraindicated from attempts at neuraxial anesthesia [53].

Intraoperative

As patients are almost always intubated or sedated during orthopedic procedures, pain control relies heavily on intravenous medications provided by our anesthesia colleagues. Narcotics such as

Dilaudid or fentanyl are often employed to provide adequate pain control during major orthopedic procedures. However, there are many adjuncts, such as IV acetaminophen and ketorolac, that are used to supplement or reduce the need for high doses of narcotics.

Ketorolac is a nonsteroidal anti-inflammatory drug (NSAID) analgesic that is available in oral, intravenous, and intramuscular forms. It is effective in providing excellent pain control and decreasing morphine requirements for both adult and pediatric patients undergoing major and minor orthopedic procedures. It is a good alternative or adjunct medication for use in patients without contraindications such as underlying renal disease or increased risk of bleeding [54–57].

There are some concerns in the orthopedic community about the use of ketorolac and other NSAIDs during or after surgery, as there are reports of higher rates of nonunion in certain procedures, such as lumbar spinal fusion [58–60]. There is no strong consensus on whether or not NSAIDs and ketorolac should be avoided in situations where bony healing is of utmost importance. This is generally left to the discretion of the surgeon and often is a decision made on the patient's risk of nonunion, depending on their unique biology, smoking status, and other comorbidities. As mentioned previously, IV acetaminophen is also employed as an adjunct medication to reduce narcotic use for patients without significant liver disease or other contraindications [61].

Single nerve blocks, field blocks, or periarticular injections can also be administered intraoperatively to augment pain control and decrease postoperative narcotic requirements if a block was not given before surgery. For example, a median nerve block can be administered by the surgeon after a distal radius fracture fixation for postoperative pain control. There is evidence that surgeon-administered local blocks given intraoperatively are as effective as preoperative anesthesiologist-administered nerve blocks [62]. Field blocks, with or without epinephrine, are especially prevalent in orthopedic procedures where the surgical field is smaller, such as hand cases or single-level spine surgery.

Periarticular injections or "joint cocktails" are also an increasingly popular and effective way to manage postoperative pain. The location, technique, and "recipe" for these injections are

highly variable. The base ingredient often consists of a local anesthetic which is then mixed with opioids, neuromodulators, and anti-inflammatory medications, including steroids. A multimodal drug mixture has been shown to be superior in reduction of narcotic requirements and pain control when compared with an injection of a single medication in the same region [9, 63]. There is evidence to support the use of periarticular joint injections in many settings, like joint arthroplasty or hip fracture fixation, to allow patients earlier joint mobility and rehabilitation, in addition to reducing the need for pain medications [64, 65].

Postoperative

The use of narcotic pain medications in the postoperative setting is ubiquitous after nearly any orthopedic procedure. Patients and providers consider this the primary method of pain control after surgery until a patient can transition to non-opioid medications such as acetaminophen or NSAIDs. As has been championed during prior phases of an orthopedic case, postoperative multimodal analgesia has demonstrated superior outcomes when paired against single medication choices [65]. Postoperative pain protocols today can offer a wide integration of narcotics with NSAIDs, acetaminophen, topical anesthetics, muscle relaxants, and post-procedural regional infusions.

Most surgeons have adopted the prescription of narcotic painkillers as a significant facet of medical care over the past decades, with rising concerns that this has been mostly used to enhance patient satisfaction scores. Many studies have investigated not only the relationship of narcotics and their comorbidities but also the general prescribing practices in the postoperative period. There is evidence that many providers may be "defensively" prescribing an abundance of pills to avoid postoperative emergency visits or calls as well as readmissions for pain control [66–68]. A recent study demonstrated that patients are being prescribed about three times the necessary amount of opioids [69].

With this in mind, the diversion of these leftover narcotic pills has grown, and their use for recreation, self-treatment, or sales has

been an evolving focus. Goyal et al. demonstrated the efficacy of preoperative instructions on decreasing the consumption of narcotic pain medications in the postoperative period while maintaining patient outcome scores. The authors studied a cohort of 305 patients undergoing upper extremity surgery and identified risk factors for increased opioid consumption. This data was then used to develop an "opioid calculator" to determine the necessary number of narcotic pills to implement for a second cohort of 221 patients undergoing a similar distribution of surgeries. This calculated regimen was also combined with a standardized pre- and postoperative surgical instruction set that included instructions for disposal of extra pills. As a result, 63% fewer opioids were prescribed, and 58% fewer opioids were consumed leading to 62% less opioid waste/diversion. These results underscore the growing need to approach postoperative pain management with careful judgment, patient education, and an armamentarium of non-opioid adjuvants [70].

Extensive research focusing on objective and subjective outcome scores has influenced every level of physician care, particularly during the postoperative phase of care. Depending on the magnitude of surgery, patients may expect pain requiring this multimodal approach with narcotic integration to continue for several days to weeks postoperatively. It is very important for patients to be well informed by their surgical team regarding the anticipated pain course and management once they are home on their own. Usually, a course of narcotic weaning is incorporated per the surgeon's preference, and the use of therapies and modalities such as ice, heat, elevation, compression, and early range of motion (when appropriate) can be added for optimization of comfort and swelling.

Conclusion

Orthopedics is a broad surgical subspecialty covering everything from extensive spinal fusions and limb reconstructions to ankle fractures and trigger finger releases. There is enormous variability in the level of pain that is experienced after orthopedic surgery, as

each procedure is vastly different and every patient is unique in their reaction to and tolerance for pain. It is essential that healthcare providers at every level understand the nearly limitless combinations of analgesics available to alleviate discomfort after orthopedic surgery while minimizing reliance on narcotic pain medications with informed patient education and guidance.

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Works Cited

1. Phillips DM. JCAHO pain management standard are unveiled. J Am Med Assoc. 2000;284(4):428–9.
2. Baker D. The Joint Commission's pain standards: origins and evolution. Oakbrook Terrace: The Joint Commission; 2017.
3. VHA. Pain as the 5th vital sign toolkit. Washington, DC: Veterans Health Administration; 2000.
4. Wyles CC, Hevesi M, Ubl DS, et al. Implementation of procedure-specific opioid guidelines. JBJS Open Access. 2020;5(1):e0050.
5. Dowell D, Haegerich TM, Chou R. CDC guideline for prescribing opioids for chronic pain-United States, 2016. JAMA. 2016; https://doi.org/10.1001/jama.2016.1464.
6. Syed UAM, Aleem AW, Wowkanech C, et al. Neer award 2018: the effect of preoperative education on opioid consumption in patients undergoing arthroscopic rotator cuff repair: a prospective, randomized clinical trial. J Shoulder Elb Surg. 2018;27(6):962–7.
7. Chakravarthy V, Yokoi H, Manlapaz MR, Krishnaney AA. Enhanced recovery in spine surgery and perioperative pain management. Neurosurg Clin N Am. 2020;31(1):81–91. https://doi.org/10.1016/j.nec.2019.08.010
8. Nir RR, Nahman-Averbuch H, Moont R, Sprecher E, Yarnitsky D. Preoperative preemptive drug administration for acute postoperative pain: a systematic review and meta-analysis. Eur J Pain (United Kingdom). 2016;20(7):1025–43.
9. Summers S, Mohile N, McNamara C, Osman B, Gebhard R, Hernandez VH. Analgesia in total knee arthroplasty. J Bone Joint Surg Am. 2020;102-A(8):719–27.
10. Il KS, Ha KY, Oh IS. Preemptive multimodal analgesia for postoperative pain management after lumbar fusion surgery: a randomized controlled trial. Eur Spine J. 2016;25(5):1614–9.
11. Srikumaran U, Stein BE, Tan EW, Freehill MT, Wilckens JH, Henze EP. Upper-extremity peripheral nerve blocks in the perioperative pain management of orthopaedic patients: AAOS exhibit selection. J Bone Joint Surg Am. 2013;95(24):1–13.

12. Hughes M, Marava M, Wright R, Brophy R, Smith M. Interscalene brachial plexus block for arthroscopic shoulder surgery: a systematic review. J Bone Joint Surg Am. 2013;95-A(14):1318–24.
13. Brown AR, Weiss R, Greenberg C, Flatow EL, Bigliani LU. Interscalene block for shoulder arthroscopy: comparison with general anesthesia. Arthroscopy. 1993;9(3):295–300.
14. Garlich J, Pujari A, Debbi E, et al. Time to block: early regional anesthesia improves pain control in geriatric hip fractures. J Bone Joint Surg Am. 2020;102(10):866–72.
15. Stein BE, Srikumaran U, Tan EW, Freehill MT, Wilckens JH. Lower-extremity peripheral nerve blocks in the perioperative pain management of orthopaedic patients: AAOS exhibit selection. J Bone Joint Surg Am. 2012;94(22):1–13.
16. Borgeat A, Ekatodramis G, Schenker C. Postoperative nausea and vomiting in regional anesthesia: a review. Anesthesiology. 2003;98:530–47.
17. Mian A, Chaudhry I, Huang R, Rizk E, Tubbs RS, Loukas M. Brachial plexus anesthesia: a review of the relevant anatomy, complications, and anatomical variations. Clin Anat. 2014;27(2):210–21.
18. Jones MR, Novitch MB, Sen S, et al. Upper extremity regional anesthesia techniques: a comprehensive review for clinical anesthesiologists. Best Pract Res Clin Anaesthesiol. 2019;34(1):e13–29.
19. Urmey WF, Talts KH, Sharrock NE. One hundred percent incidence of hemidiaphragmatic paresis associated with interscalene brachial plexus anesthesia as diagnosed by ultrasonography. Anesth Analg. 1991;72(4):498–503.
20. Mak PHK, Irwin MG, Ooi CGC, Chow BFM. Incidence of diaphragmatic paralysis following supraclavicular brachial plexus block and its effect on pulmonary function. Anaesthesia. 2001;56(4):352–6.
21. Desroches J. The Infraclavicular brachial plexus block by the coracoid approach is clinically effective: an observational study of 150 patients. Can J Anesth. 2003;50(3):253–7.
22. Chang K-V, Wu W, Hung C-Y, Han D, Yang R, Chang C. Comparative effectiveness of Suprascapular nerve block in the relief of acute postoperative shoulder pain: a systematic review and meta-analysis. Pain Physician. 2016;19:445–56.
23. Hussain N, Goldar G, Ragina N, Banfield L, Laffey JG, Abdallah FW. Suprascapular and Interscalene nerve block for shoulder surgery. Anesthesiology. 2017;127(6):998–1013.
24. Kay J, Memon M, Hu T, et al. Suprascapular nerve blockade for postoperative pain control after arthroscopic shoulder surgery: a systematic review and meta-analysis. Orthop J Sports Med. 2018;6(12):1–17.
25. De Leeuw MA, Zuurmond WWA, Perez RSGM. The psoas compartment block for hip surgery: the past, present, and future. Anesthesiol Res Pract. 2011;2011:1–6.
26. Murray JM, Derbyshire S, Shields MO. Lower limb blocks. Anaesthesia. 2010;65(Suppl 1):57–66.

27. Touray ST, De Leeuw MA, Zuurmond WWA, Perez RSGM. Psoas compartment block for lower extremity surgery: a meta-analysis. Br J Anaesth. 2008;101(6):750–60.
28. Capdevila X, Macaire P, Dadure C, et al. Continuous psoas compartment block for postoperative analgesia after total hip arthroplasty: new landmarks, technical guidelines, and clinical evaluation. Anesth Analg. 2002;94(6):1606–13.
29. Cram P, Lu X, Kaboli P, et al. Clinical characteristics and outcomes of Medicare patients undergoing total hip arthroplasty, 1991–2008. J Am Med Assoc. 2011;305(15):1560–7.
30. Biboulet P, Morau D, Aubas P, Bringuier-Branchereau S, Capdevila X. Postoperative analgesia after total-hip arthroplasty: comparison of intravenous patient-controlled analgesia with morphine and single injection of femoral nerve or psoas compartment block. A prospective, randomized, double-blind study. Reg Anesth Pain Med. 2004;29(2):102–9.
31. Jeng C, Torrillo T, Rosenblatt M. Complications of peripheral nerve block. Br J Anaesth. 2010;105(51):i97–i107.
32. Enneking FK, Chan V, Greger J, Hadžić A, Lang SA, Horlocker TT. Lower-extremity peripheral nerve blockade: essentials of our current understanding. Reg Anesth Pain Med. 2005;30(1):4–35.
33. Wulf H, Löwe J, Gnutzmann KH, Steinfeldt T. Femoral nerve block with ropivacaine or bupivacaine in day case anterior crucial ligament reconstruction. Acta Anaesthesiol Scand. 2010;54(4):414–20.
34. Iskandar H, Benard A, Ruel-Raymond J, Cochard G, Manaud B. Femoral block provides superior analgesia compared with intra-articular ropivacaine after anterior cruciate ligament reconstruction. Reg Anesth Pain Med. 2003;28(1):29–32.
35. Mall NA, Wright RW. Femoral nerve block use in anterior cruciate ligament reconstruction surgery. Arthroscopy. 2010;26(3):404–16.
36. Hunt KJ, Bourne MH, Mariani EM. Single-injection femoral and sciatic nerve blocks for pain control after total knee arthroplasty. J Arthroplast. 2009;24(4):533–8.
37. Williams BA, Kentor ML, Vogt MT, et al. Femoral-sciatic nerve blocks for complex outpatient knee surgery are associated with less postoperative pain before same-day discharge: a review of 1,200 consecutive cases from the period 1996–1999. Anesthesiology. 2003;98(5):1206–13.
38. Zorrilla-Vaca A, Li J. The role of sciatic nerve block to complement femoral nerve block in total knee arthroplasty: a meta-analysis of randomized controlled trials. J Anesth. 2018;32(3):341–50.
39. Wiegel M, Gottschaldt U, Hennebach R, Hirschberg T, Reske A. Complications and adverse effects associated with continuous peripheral nerve blocks in orthopedic patients. Anesth Analg. 2007;104(6):1578–82.
40. Brull R, McCartney CJL, Chan VWS, El-Beheiry H. Neurological complications after regional anesthesia: contemporary estimates of risk. Anesth Analg. 2007;104(4):965–74.

41. Kim CW, Hong JP. Lower extremity reconstruction under popliteal sciatic nerve (tibioperoneal trunk) and saphenous nerve block. Plast Reconstr Surg. 2005;115(2):563–6.
42. Akkaya T, Ersan O, Ozkan D, et al. Saphenous nerve block is an effective regional technique for post-meniscectomy pain. Knee Surg Sports Traumatol Arthrosc. 2008;16(9):855–8.
43. Grosser DM, Herr MJ, Claridge RJ, Barker LG. Preoperative lateral popliteal nerve block for intraoperative and postoperative pain control in elective foot and ankle surgery: a prospective analysis. Foot Ankle Int. 2007;28(12):1271–5.
44. Fraser TW, Doty JF. Peripheral nerve blocks in foot and ankle surgery. Orthop Clin North Am. 2017;48(4):507–15. https://doi.org/10.1016/j.ocl.2017.06.008.
45. Anderson JG, Bohay DR, Maskill JD, et al. Complications after popliteal block for foot and ankle surgery. Foot Ankle Int. 2015;36(10):1138–43.
46. Memtsoudis SG, Cozowicz C, Bekeris J, et al. Anaesthetic care of patients undergoing primary hip and knee arthroplasty: consensus recommendations from the international consensus on anaesthesia-related outcomes after surgery group (ICAROS) based on a systematic review and meta-analysis. Br J Anaesth. 2019;123(3):269–87.
47. Johnson RL, Abdel MP, Frank RD, Chamberlain AM, Habermann EB, Mantilla CB. Impact of frailty on outcomes after primary and revision total hip arthroplasty. J Arthroplast. 2019;34(1):56–64.e5.
48. Chamberlain AM, Rutten LJF, Manemann SM, et al. Frailty trajectories in an elderly population-based cohort. J Am Geriatr Soc. 2016;64(2):285–92.
49. McNallan SM, Chamberlain AM, Gerber Y, et al. Measuring frailty in heart failure: a community perspective. Am Heart J. 2013;166(4):768–74.
50. Johnson RL, Kopp SL, Burkle CM, et al. Neuraxial vs general anaesthesia for total hip and total knee arthroplasty: a systematic review of comparative-effectiveness research. Br J Anaesth. 2016;116(2):163–76.
51. Rockwood K, Andrew M, Mitnitski A. A comparison of two approaches to measuring frailty in elderly people. J Gerontol A Biol Sci Med Sci. 2007;62(7):738–43.
52. Memtsoudis SG, Sun X, Chiu YL, et al. Perioperative comparative effectiveness of anesthetic technique in orthopedic patients. Anesthesiology. 2013;118(5):1046–58.
53. Olawin A, Das J. Spinal anesthesia. Treasure Island: StatPearls Publishing; 2020. p. 1–6.
54. Pichard CP, LaPorte DM. Use of ketorolac (toradol) in hand surgery. J Hand Surg Am. 2009;34(8):1549–50.
55. Kinsella J, Moffat AC, Patrick JA, Prentice JW, Mcardle CS, Kenny GNC. Ketorolac trometamol for postoperative analgesia after orthopaedic surgery. Br J Anaesth. 1992;69(1):19–22.

56. Mcnicol ED, Rowe E, Cooper TE. Ketorolac for postoperative pain in children. Cochrane Database Syst Rev. 2018;7(7):CD012294.
57. Anthony D, Jasinski DM. Postoperative pain management: morphine versus ketorolac. J Perianesth Nurs. 2002;17(1):30–42.
58. Kurd MF, Kreitz T, Schroeder G, Vaccaro AR. The role of multimodal analgesia in spine surgery. J Am Acad Orthop Surg. 2017;25(4):260–8.
59. Glassman S, Rose M, J D, Puno R, Campbell M, Johnson J. The effect of postoperative nonsteroidal anti-inflammatory drug administration on spinal Fusion. Spine (Phila Pa 1976). 1998;23:834–48.
60. Li Q, Zhang Z, Cai Z. High-dose ketorolac affects adult spinal fusion: a meta-analysis of the effect of perioperative nonsteroidal anti-inflammatory drugs on spinal fusion. Spine (Phila Pa 1976). 2011;36(7):461–8.
61. Huang PS, Gleason SM, Shah JA, Buros AF, Hoffman DA. Efficacy of intravenous acetaminophen for postoperative analgesia in primary Total knee Arthroplasty. J Arthroplast. 2018;33(4):1052–6.
62. Greenky MR, McGrath ME, Levicoff EA, et al. Intraoperative surgeon administered Adductor Canal blockade is not inferior to anesthesiologist administered Adductor Canal blockade: a prospective randomized trial. J Arthroplast. 2020;35(5):1228–32.
63. Tammachote N, Kanitnate S, Manuwong S, Panichkul P. Periarticular multimodal drug injection is better than single anesthetic drug in controlling pain after total knee arthroplasty. Eur J Orthop Surg Traumatol. 2018;28(4):667–75.
64. Koehler D, Marsh JL, Karam M, Fruehling C, Willey M. Efficacy of surgical-site, multimodal drug injection following operative management of femoral fractures: a randomized controlled trial. J Bone Joint Surg Am. 2017;99(6):512–9.
65. Milani P, Castelli P, Sola M, Invernizzi M, Massazza G, Cisari C. Multimodal analgesia in total knee arthroplasty: a randomized, double-blind, controlled trial on additional efficacy of periarticular anesthesia. J Arthroplast. 2015;30(11):2038–42.
66. Shrank WH. Our bulging medicine cabinets – the other side of medication nonadherence. N Engl J Med. 2011;364(17):1591–3.
67. Rodgers J, Cunningham K, Fitzgerald K, Finnerty E. Opioid consumption following outpatient upper extremity surgery. J Hand Surg Am. 2012;37(4):645–50.
68. Bates C, Laciak R, Southwick A, Bishoff J. Overprescription of postoperative narcotics: a look at postoperative pain medication delivery, consumption and disposal in urological practice. J Urol. 2011;185(2):551–5.
69. Kim N, Matzon JL, Abboudi J, et al. A prospective evaluation of opioid utilization after upper-extremity surgical procedures: identifying consumption patterns and determining prescribing guidelines. J Bone Joint Surg Am. 2016;98-A(20):1–9.
70. Jamieson MD, Everhart JS, Lin JS, Jain SA, Awan HM, Goyal KS. Reduction of opioid use after upper-extremity surgery through a predictive pain calculator and comprehensive pain plan. J Hand Surg Am. 2019;44(12):1050–1059.e4.