Systematic Review

Postoperative Multimodal Pain Management and Opioid Consumption in Arthroscopy Clinical Trials: A Systematic Review

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Purpose: To provide an updated review of multimodal pain management in arthroscopic surgery by evaluating pain and opioid consumption after shoulder, knee, and hip arthroscopy. **Methods:** A comprehensive literature search was performed to identify randomized controlled trials (RCTs) investigating multimodal pain management after shoulder, knee, and hip arthroscopy. Articles were identified from January 2011 through December 2020 using various databases. As the primary outcome variables of this study, differences in postoperative pain and opioid consumption volumes were summarized from all reported postoperative time points. **Results:** 37 shoulder, 28 knee, and 8 hip arthroscopy RCTs were included in the study. The most frequent bias present in the included RCTs was incomplete outcome data (58%), while group allocation concealment was the least frequent bias (15%). Qualitative analysis of rotator cuff repair ($n = 12$), anterior cruciate ligament reconstruction ($n = 11$), meniscectomy ($n = 5$), femoroacetabular impingement ($n = 2$), oral medications ($n = 8$), postoperative interventions ($n = 10$), and nonpharmacological interventions ($n = 6$) was performed. **Conclusions:** Many multimodal pain management protocols offer improved pain control and decreased opioid consumption after arthroscopic surgery. On the basis of the current literature, the evidence supports an interscalene nerve block with a dexamethasone-dexmedetomidine combination for rotator cuff repair, a proximal continuous adductor canal block for anterior cruciate ligament reconstruction, and local infiltration analgesia (e.g., periacetabular injection with 20 mL of .5% bupivacaine) for hip arthroscopy. When evaluating oral medication, the evidence supports 150 mg Pregabalin for shoulder arthroscopy, 400 mg Celecoxib for knee arthroscopy, and 200 mg Celecoxib for hip arthroscopy, all taken preoperatively. There is promising evidence for the use of various nonpharmacological modalities, specifically preoperative opioid education for rotator cuff repair patients; however, more clinical trials that evaluate nonpharmacological interventions should be performed. **Level of Evidence:** Level II, systematic review of Level I and II studies.

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Introduction

As pain became the "fifth vital sign" and sustained-release OxyContin (Purdue Pharma, Stamford, CT) was approved for use, opioids were marketed aggressively as an effective treatment for noncancerous pain.[1,2] However, excessive opioid usage is associated with increased mortality[3,4] and addiction,[5] which have been implicated in the current opioid epidemic. In 2020, there were nearly six times more opioid-related overdose deaths than there were in 1999.[6] With patient-reported pain remaining unchanged while opioid prescription rates continued to increase,[7] research has been increasingly focused on nonopioid pain management techniques.

Optimal management of postoperative pain is associated with decreased morbidity and faster recovery times, as well as improved physical function and quality of life.[8] Despite efforts to minimize postoperative pain, 61% of outpatients still experience moderate/extreme pain after discharge.[9] Some of the most painful surgeries are orthopedic procedures, with arthroscopic surgeries, such as cruciate ligament reconstruction[10] and rotator cuff repair,[11] considered among the most painful outpatient orthopedic surgical procedures. Because of the pain associated with these procedures, orthopedic surgeons were the third highest prescribers of opioids based on specialty in the United States, behind only primary care physicians and internists.[12] The American Society of Anesthesiologists recommends the use of multimodal pain regimens to minimize opioid use and improve pain control.[13] Multimodal pain management uses combinations of opioid prescriptions, nonopioid prescription, regional and local anesthesia, and nonpharmacological therapy. An effective multimodal pain management protocol should limit both postoperative pain and opioid consumption.

Four systematic reviews have evaluated randomized controlled trials (RCTs) within knee,[14] hip,[15] and shoulder[16,17] arthroscopy. Warrender et al.[17] suggests that the interscalene nerve block is the most effective analgesic for arthroscopic shoulder surgery, while Hurley et al.[16] recommend nerve block adjuncts to improve pain control. In hip arthroscopy, Kunze et al.[15] similarly recommend adjunct analgesia, and they suggest that local infiltration analgesia may optimize postoperative pain and opioid consumption. In knee arthroscopy, Secrist et al.[14] did not determine an optimal multimodal management protocol for anterior cruciate ligament reconstruction.

In order to optimize postoperative care, treatment plans should minimize both pain and opioid consumption after arthroscopic surgery. However, few reviews have focused on postoperative opioid consumption along with pain management in arthroscopic surgery. The purpose of the study was to provide an updated review of multimodal pain management in arthroscopic surgery by evaluating pain and opioid consumption after shoulder, hip, and knee arthroscopy.

Methods

Study Selection

This systematic review was performed according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines.[18] A comprehensive literature search was performed to identify all RCTs regarding pain management after arthroscopic surgeries of the shoulder, hip, and knee. Articles were identified from a 10-year period ranging from January 1st, 2011 through December 31st, 2020 by using the PubMed, Ovid, and CINAHL databases. The following keywords were used: opioid, pain management, multimodal, sports medicine, shoulder, hip, knee, surgery, surgical, and arthroscopy. Screening of RCTs by title and abstract was performed by two independent researchers, R.W.P. (research fellow) and P.S. (orthopaedic surgery resident), with disagreements settled by K.B.F. (attending orthopaedic surgeon).

Inclusion and Exclusion Criteria

Only RCTs that 1) were related to arthroscopic surgery of the shoulder, hip, and knee, 2) reported both postoperative pain and volume of postoperative opioid consumption, and 3) had a dependent variable focusing on multimodal pain management, were included. Interventions provided preoperatively, intraoperatively, and postoperatively were all included as well. Multimodal pain management was considered any combination of at least two of the following: education, exercise interventions, pharmaceutical medications, regional anesthesia, rehabilitative interventions (exercise, manual therapy, physical modalities), and workplace intervention. Combinations of varying medications were also considered multimodal, as has been done in several other systematic reviews and meta-analyses.[19–22] Studies that 1) were not randomized controlled trials focusing on arthroscopic surgery of the shoulder, hip, and knee, 2) did not report both postoperative pain scores and postoperative opioid consumption, and 3) did not have an intervention regarding multimodal pain management, were excluded.

Assessment of Study Quality

Included studies were evaluated for bias using the Cochrane Risk of Bias tool.[23] Six categories of bias assessment were used from the Cochrane Risk of Bias tool: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, and selective reporting. Bias in each category was classified as high, low, or unclear.

Data Collection and Abstraction

Surgical category (shoulder, hip, knee arthroscopy), pain management intervention, descriptions of treatment groups, details regarding treatment dosages, and demographic data (age, sex, and BMI) were collected from each included study. As the primary outcome variables of this study, postoperative pain scores and volume of postoperative opioid consumption were collected from all reported postoperative time points. Statistically significant differences in postoperative pain scores and opioid consumption were noted within each included study.

Statistical Analysis

Because of differences in study intervention, patient populations, and surgical procedure, postoperative pain scores and opioid consumption were not pooled. Summary data regarding the postoperative pain scores and opioid consumption from all time points were presented.

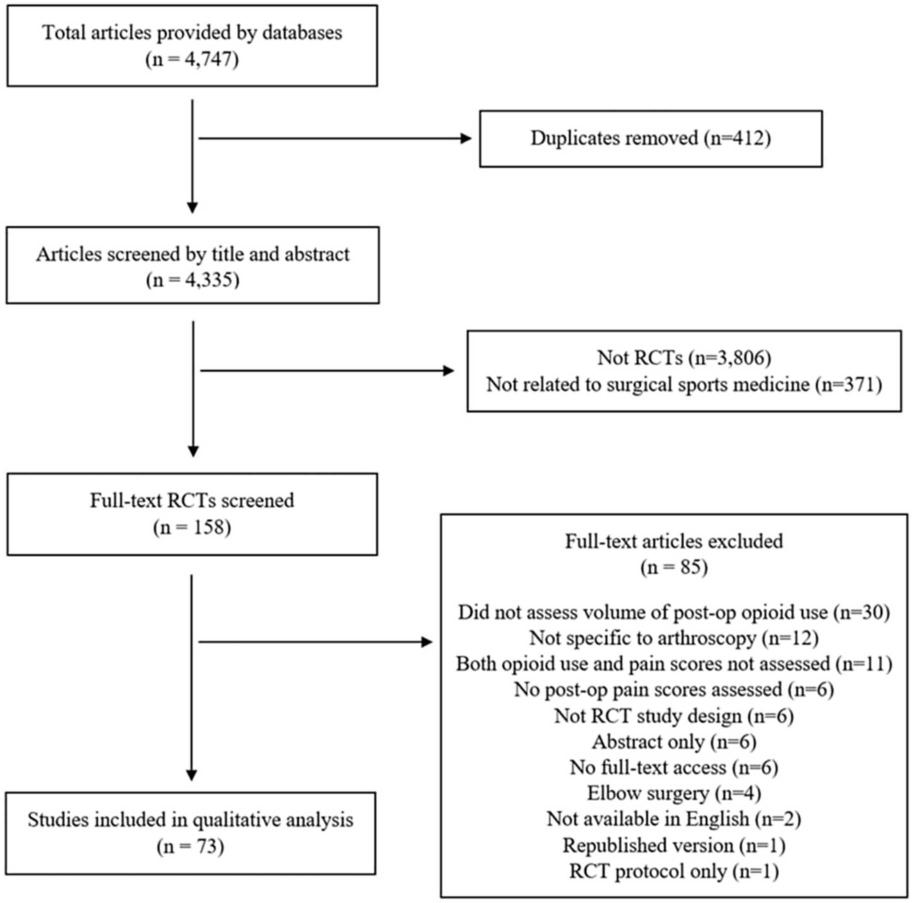

Fig 1. Flowchart of randomized controlled trial (RCT) screening process, with 73 final studies included, and the reasons for excluding 85 other articles are noted.

Results

Overall, 4,335 nonduplicate articles were screened by title and abstract for inclusion. After excluding 3,806 studies that were not RCTs and 371 that were not related to arthroscopy, 158 studies were screened by full text. Eighty-five articles were excluded based on full text, with exclusion reasons available in Fig 1. Seventy-three RCTs assessed both postoperative pain and postoperative opioid consumption after arthroscopic procedures and were included in the final qualitative analysis.

Study Quality

The most frequent bias present in the included RCTs was incomplete outcome data, as 42 out of the 73 included RCTs (58%) either did not provide data for all variables or did not provide adequate statistics, such as standard deviations and exact *P* values (Table 1, Fig 2). Group allocation concealment was the least frequent bias, as 62 of the 73 included studies (85%) concealed participants' group allocations, often by using sealed opaque envelopes. The rest of the average Cochrane Risk of Bias tool data is available in Fig 2, with individual studies' bias scores available in Table 1.

Shoulder Arthroscopy

There were 37 RCTs that assessed pain and opioid consumption after shoulder arthroscopy (Table 2); 18 of the RCTs assessed nerve blocks, while 3 evaluated localized injections, 3 assessed oral medications, and 3 evaluated nonpharmacological interventions. Also, 12 RCTs isolated patients that underwent rotator cuff repair, 2 RCTs isolated patients that underwent subacromial decompression, and 1 RCT isolated patients that underwent Bankart repair. Finally, 20 studies showed significant differences in postoperative pain, and 21 studies found significant differences in opioid consumption.

Rotator Cuff Repair

Four studies evaluated nerve blocks for rotator cuff repair specifically.[32,37,44,87] Cabaton et al.[37] found that a supraclavicular nerve block with 100 mg levobupivacaine and clonidine provided similar pain management but much less opioid consumption from 0 to 48 hours postoperatively compared to an ultrasound-guided interscalene nerve block with the same dosages. Wong et al.[87] shows that an interscalene block with 20 mL of .2% ropivacaine decreases opioid consumption at

Table 1. Cochrane Risk of Bias Data for all Included Studies

Author	Publication Year	Random Sequence Generation	Allocation Concealment	Incomplete Outcome Data	Blind of Participants and Personnel	Blinding of Outcome Assessment	Selective Reporting
Abdallah et al.[24]	2016 (knee)	High	Low	High	Low	Low	Low
Abdallah et al.[24]	2016 (shoulder)	Low	Low	Low	Low	Low	Low
Abdallah et al.[25]	2019	Low	Low	Low	Low	Low	Low
Abdallah et al.[26]	2020	Unclear	Low	High	Low	Low	Low
Ahn et al.[27]	2016	Low	Low	Low	Low	Low	Low
Aksu et al.[28]	2015	Low	Unclear	Low	High	Low	High
Amin et al.[29]	2011	Low	High	High	Unclear	Unclear	High
Arti and Mehdinasab[30]	2011	High	Low	High	Low	Low	Low
Auyong et al.[31]	2018	Low	Low	Low	Low	Low	Low
Baessler et al.[32]	2020	Low	Low	Low	High	Unclear	Low
Bailey et al.[33]	2019	Low	Unclear	Low	High	Low	Low
Behrends et al.[34]	2018	Low	Low	High	Low	Low	High
Bengisun et al.[35]	2014	Low	Low	High	Low	Low	Low
Bjørnholdt et al.[36]	2014	Unclear	Low	High	Low	Low	Low
Cabaton et al.[37]	2019	Low	Low	High	High	Low	Low
Choromanski et al.[38]	2015	Low	Low	Low	Low	Low	Low
Cho et al.[39]	2011	Low	High	High	High	Unclear	High
Cogan et al.[40]	2020	Low	Low	High	Low	Low	High
DeMarco et al.[41]	2011	Low	Low	High	Low	Low	Low
Espelund et al.[42]	2014	Low	Low	High	Low	Low	Low
Espelund et al.[43]	2014	Low	Low	High	Low	Low	Low
Faria-Silva et al.[44]	2016	Low	Unclear	High	High	Low	Low
Glomset et al.[45]	2020	Low	Unclear	Low	High	Unclear	Low
Hanson et al.[46]	2013	Low	Low	High	Low	Low	Low
Hartwell et al.[47]	2020	High	High	Low	High	High	Low
Hsu et al.[48]	2013	Low	Low	Low	Low	Low	Low
Jeske et al.[49]	2011	Low	Low	High	Low	Low	High
Kager et al.[50]	2011	Low	Low	High	Low	Unclear	Low
Kahlenberg et al.[51]	2017	Unclear	Low	High	Low	Unclear	Low
Kahn et al.[52]	2018	Low	Low	Low	Low	Low	Low
Kang et al.[53]	2018	Low	Low	High	Low	Low	Low
Kang et al.[54]	2019	Low	Low	High	Low	Low	Low
Kataria et al.[55]	2019	Low	Low	High	Low	Low	Low
Keller et al.[56]	2019	Low	Low	Unclear	Low	Low	Unclear
Khashan et al.[57]	2016	Low	Low	Low	Low	Low	Low
Kim et al.[58]	2019	Low	Low	Low	Low	Low	Low
Ko et al.[59]	2013	Low	Low	High	Low	Low	Low
Koltka et al.[60]	2011	Low	Unclear	High	High	Low	High
Kraeutler et al.[61]	2015	Unclear	High	High	High	High	Low
Lee et al.[62]	2015	Low	Low	High	Unclear	Unclear	Low
Lee et al.[62]	2012	Low	Low	High	Low	Low	High
Lierz et al.[63]	2012	Low	Low	High	Low	Low	Low
Lu et al.[64]	2017	Low	Low	Low	Low	Low	Low
Lynch et al.[65]	2019	Low	Low	Low	Low	Low	Low
Mahure et al.[66]	2017	Low	Low	Low	Low	Low	Low
Mardani-Kivi et al.[67]	2016	Low	Low	Low	Low	Low	Low
Mardani-Kivi et al.[68]	2013	Low	Low	Low	Low	Low	Low
Marinković et al.[69]	2016	Unclear	Unclear	High	Unclear	Unclear	High
McHardy et al.[70]	2020	Low	Low	Low	Low	Low	Low
Merivirta et al.[71]	2012	Low	Low	High	Low	Low	Low
Merivirta et al.[71]	2013	Low	Low	High	Low	Unclear	Low
Mitra et al.[72]	2011	Low	Low	Low	Low	Low	High
Moyano et al.[73]	2016	Low	Low	Low	Low	Low	Low
Neuts et al.[74]	2018	Low	Low	High	Low	Low	Low
Oh et al.[75]	2018	Low	Low	High	Low	Low	Low
Premkumar et al.[76]	2016	Low	Low	High	Low	Low	Low
Purcell et al.[77]	2019	High	Low	Low	High	Low	Low
Reda et al.[78]	2016	Low	Low	High	High	Low	Low
Sanel et al.[79]	2016	Unclear	High	Low	Low	Low	Low
Saritas et al.[80]	2015	Low	Low	High	Low	Low	Low
Sayin et al.[76]	2015	Low	Low	Low	Unclear	Unclear	High

(continued)

Table 1. Continued

Author	Publication Year	Random Sequence Generation	Allocation Concealment	Incomplete Outcome Data	Blind of Participants and Personnel	Blinding of Outcome Assessment	Selective Reporting
Schwartzberg et al.[81]	2013	Low	Low	High	Low	Low	Low
Shlaifer et al.[82]	2017	Low	Low	High	High	Low	Unclear
Spence et al.[83]	2011	Low	Low	Low	Low	Low	Low
Syed et al.[84]	2018	Low	Low	Low	Low	Low	Unclear
Thapa et al.[66]	2016	Unclear	Low	High	Low	Low	High
Tompkins et al.[85]	2011	Low	Low	High	Low	Low	High
Westergaard et al.[86]	2014	Unclear	Low	High	Low	Low	Low
Wong et al.[87]	2016	High	Low	Low	Low	Unclear	Low
Xing et al.[88]	2015	Low	Low	Low	Low	Low	Low
Yun et al.[89]	2012	Low	Low	High	High	High	High
Zhang et al.[90]	2014	Low	Low	High	Low	Low	High
Zhou et al.[91]	2017	Low	Low	Low	Low	Low	Low

72 hours postoperatively compared to the same block with only .1% ropivacaine. Faria-Silva et al.[44] found that adding .15 mg clonidine to a brachial plexus block with .33% ropivacaine does not affect pain or opioid consumption within the first day postop. Lastly, Baessler et al.[32] found that the addition of liposomal bupivacaine in an interscalene nerve block leads to less opioid consumption for several days after surgery. Baessler et al.[32] also showed that providing dexamethasone with liposomal bupivacaine and conventional bupivacaine may decrease postoperative pain, while providing comparable opioid consumption. However, this difference in pain was only observed at postoperative day 3, and not on days 1, 2, or 4.

Three studies evaluated injections for rotator cuff repair.[57,62,80] Khashan et al.[57] found that adding 50 mg ketamine to a preoperative intra-articular injection of morphine provided worse pain relief than morphine alone from 0-2 weeks postoperatively, while morphine also provides better pain relief than a saline control from 0 to 2 weeks. However, all three groups had comparable pain relief at 3 months, and no differences in opioid consumption. Saritas et al.[80] found that an intra-articular injection with 1,000 mg of magnesium sulfate decreases pain from postoperative hours 1-12, while also significantly decreasing opioid consumption. Lastly, Lee et al.[62] showed that local analgesic injections of bupivacaine and lidocaine used in the glenohumeral joint, in the subacromial space, and in both spaces all provide similar pain relief and opioid consumption.

Knee Arthroscopy

Twenty-eight RCTs assessed pain and opioid consumption after knee arthroscopy (Table 3). Eleven studies evaluated various types of nerve blocks, while 8 compared local injections and 2 assessed non-pharmacological intervention. Eleven RCTs isolated patients that underwent anterior cruciate ligament (ACL) reconstruction, and 5 isolated patients that underwent meniscectomy. Of these studies, 19 studies

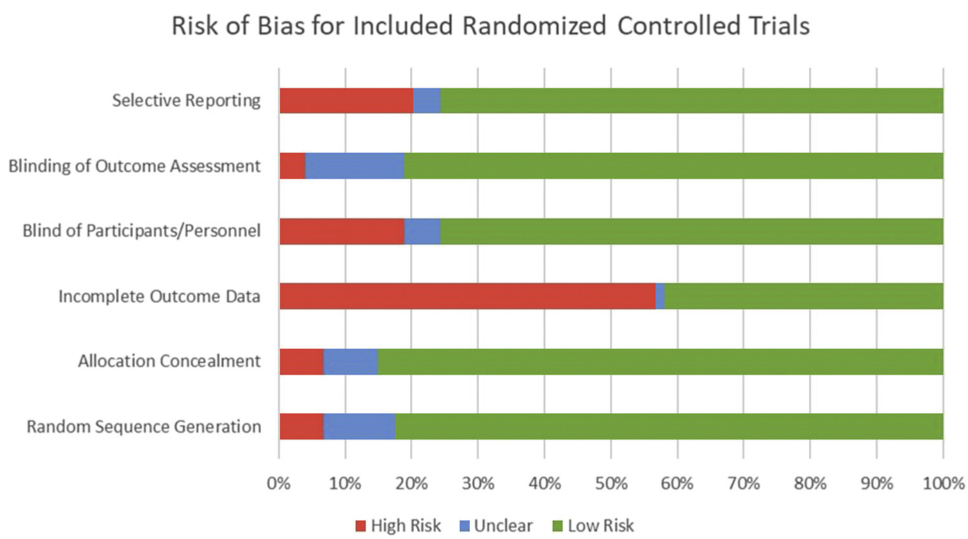

Fig 2. Cochrane Risk of Bias tool categorical scores of all included randomized controlled trials (RCTs). Red denotes high risk. Blue denotes unclear. Green denotes low risk.

Table 2. Treatment Provided, Patient Population, Postoperative Pain, and Postoperative Opioid Consumption Summarized from all Included RCTs Regarding Shoulder Arthroscopy

Author, Publication Year	Level of Evidence	Surgical Procedure	Intervention	Treatment Groups	Dosage	Patients (*n*)	Age (years)	Post-Op Pain Differences	Post-Op Opioid Consumption Differences
Cabaton et al., 2019[37]	1	Rotator cuff repair	Nerve block	SCB: Supraclavicular nerve block	100 mg levobupivacaine with clonidine	52	57	NRS scale: SCB = ISB, from 0 to 48 hours	Total morphine consumed: SCB < ISB, from 0 to 48 hours
				ISB: Ultrasound-guided interscalene nerve block	100 mg levobupivacaine with clonidine	51	58		
Wong et al., 2016[87]	2	Rotator cuff repair	Nerve Block	.1%: Phrenic nerve block, .1% ropivacaine	Ultrasound-guided interscalene block with 20 mL of .1% ropivacaine	18	48.3	DVPRS: .1% = .2%, at 30 min and 1 hour	PACU fentanyl consumption, and codeine equivalents at 72 hours: .1% = .2%, in PACU. .1% > .2%, at 72 hours post-block
				.2%: Phrenic nerve block, .2% ropivacaine	Ultrasound-guided interscalene block with 20 mL of .2% ropivacaine	19	40.5		
Faria-Silva et al., 2016[44]	1	Rotator cuff repair	Nerve block	LA + CL: Brachial plexus block with ropivacaine and clonidine	30 mL of .33% ropivacaine and .15 mg clonidine	26	52 ± 11	NRS: LA+CL=LA, from 6-24 hours	Doses of rescue analgesic: LA+CL=LA, total consumption
				LA (local anesthetics): Brachial plexus block with ropivacaine	30 mL of .33% ropivacaine	24	54 ± 10		
Auyong et al., 2018[31]	1	Rotator cuff repair (90%) or Bankart repair (10%)	Nerve block	ISB: Interscalene nerve block	15 mL of .5% ropivacaine	63	54 ± 13	NRS: ISB = SCB = SSB, in PACU and at 1 hour	Fentanyl consumption: ISB = SCB = SSB, in PACU and at 1 hour
				SCB: Supraclavicular nerve block	15 mL of .5% ropivacaine	63	53 ± 14		
				SSB: Suprascapular nerve block	15 mL of .5% ropivacaine	63	55 ± 14		
Kang 2018[53]	2	85% rotator cuff repair, 11% Bankart repair, 4% other	Nerve block	Control	50 mL of .9% normal saline	18	47.8 ± 14.4	VAS: DEX 2.0 < control only, at 12 hour. All groups are equal at 6 hours and 24 hours	Opioid Consumption: *DEX 2.0 < DEX 1.0, DEX .5, and control, at 24 hour. All groups are equal at 6 hour and 12 hour
				DEX .5: Dexmedetomidine (DEX), .5 μg/kg	IV DEX .5 μg/kg added to 50 mL of .9% normal saline	18	53.7 ± 13.6		
				DEX 1.0: DEX- 1.0 μg/kg	IV DEX 1.0 μg/kg added to 50 mL of .9% normal saline	18	49.7 ± 12.5		
				DEX 2.0: DEX- 2.0 μg/kg	IV DEX 2.0 μg/kg added to 50 mL of .9% normal saline	18	52.9 ± 10.5		
Kataria 2019[55]	1	73% Bankart repair, 27% rotator cuff repair	Nerve block	A: Ultrasound-guided interscalene block (ISB) with dexmedetomidine (DXM)	20 mL .5% ropivacaine + 2 mL saline containing DXM .5 mcg/kg	30	30.1 ± 10.9	VAS: DXA < DXM, at 24 hours DXM = DXA at 30 minutes, 1 hour, 2 hours, 3 hours, 6 hours, and 12 hours	Analgesic consumption: DXA < DXM, total consumption
				A: Ultrasound-guided interscalene block (ISB) with dexamethasone (DXA)	20 mL .5% ropivacaine + 2 mL saline containing DXA .5 mcg/kg	30	30.2 ± 11.7		
Neuts 2018[74]	1	Rotator cuff repair + decompression (38%) and subacromial decompression (31%), other (31%)	Nerve block	Interscalene brachial plexus nerve block (ISBPNB)	20 mL .75% ropivacaine	50	54 ± 10	NRS: ISBPNB < SSB/AX, from 0-8 hours ISBPNB = SSB/AX from 8-24 hours	Oxycodone Equivalents: ISBPNB < SSB/AX, from 0-8 hours ISBPNB = SBB/AX from 8-24 hours
				Suprascapular + axillary nerve bock (SSB/AX)	10 mL .75% ropivacaine	48	51 ± 10		
Kim 2019[58]	1	Rotator cuff repair (48%), other (52%)	Nerve Block	Superior trunk block (STB)	15 mL .5% bupivicaine	62	51.5	NRS: STB = ISBPNB, from 1-48 hours	Morphine Equivalents: STB = ISBPNB, from 0-48 hours
				Interscalene brachial plexus nerve block (ISBPNB)	15 mL .5% bupivicaine	63	50		

(continued)

Table 2. Continued

Author, Publication Year	Level of Evidence	Surgical Procedure	Intervention	Treatment Groups	Dosage	Patients (*n*)	Age (years)	Post-Op Pain Differences	Post-Op Opioid Consumption Differences
Choromanski 2015[38]	2	Bankart repair (17%), superior labrum anterior and posterior repair (30%), arthroscopic rotator cuff repair (30%), other (23%)	Continuous Nerve Block	Continuous interscalene nerve block catheter with .125% bupivacaine	400 mL .125% bupivacaine @ 6 mL/h	14	54 ± 18.8	VAS: Ropivacaine = bupivacaine, on postop day 1	Oxycodone Equivalents: Ropivacaine = Bupivacaine, from 0 to 24 hours
				Continuous interscalene brachial plexus nerve block catheter with .2% ropivacaine	400 mL .2% ropivacaine @ 6 mL/h	16	48.2 ± 17.7		
Abdallah et al., 2020[26]	1	Acromioplasty (29%), rotator cuff repair (22%), biceps tenodesis (11%), other (37%)	Nerve block	Interscalene block (ISB)	15 mL .5% ropivacaine with epinephrine 1:200,000	69	40 ± 15	VAS: ISB = SASB, from 0 to 24 hours	Morphine Equivalent Consumption: ISB < SASB, in PACU. ISB = SASB, until 24 hours
				Subomohyoid anterior suprascapular block (SASB)	15 mL .5% ropivacaine with epinephrine 1:200,000	67	46 ± 15		
Baessler et al., 2020[32]	1	Rotator cuff repair, with frequent concomitant biceps tenodesis (46%) and biceps tenotomy (46%)	Nerve block	LBD group: Liposomal bupivacaine (LB) + dexamethasone + conventional bupivacaine	15 mL .5% bupivacaine, 10 mL (133 mg) LB, .4 mL (4 mg) dexamethasone, and 5 mL saline solution	26	57.5 ± 8.8	VAS: LBD<LB, day 3. All groups were similar at all other time points, days 1-4	Oral Morphine Milligram Equivalents: LB = LBD, days 1-4. *LB < Control, day 2. LB < Control, day 3. LB < Control, day 2. *LB < Control, day 3
				LB group: Liposomal bupivacaine + conventional bupivacaine	15 mL .5% bupivacaine, 10 mL (133 mg) LB, and 5.4 mL saline	24	56.9 ± 9.6		
				Control group: Conventional bupivacaine + dexamethasone	30 mL .5% bupivacaine and .4 mL (4 mg) of preservative-free dexamethasone	26	59.1 ± 9.0		
DeMarco 2011[41]	1	83% bursectomy, 79% subacromial decompression, 32% rotator cuff repair, and other concomitant procedures	Nerve block	ISB: Preoperative interscalene nerve block	30 mL of .5% ropivacaine	28		VAS: *ISB < Placebo, at 6 hr. ISB = Placebo, from 12-80 hours	Narcotic Pills Used: ISB = Placebo, from 6-80 hours
				Placebo	100 mL saline solution	25			
Ko 2013[59]	2	Acromioplasty	Nerve block	UG SSB: Ultrasound-guided suprascapular nerve block	10 mL of .375% ropivacaine	15	42.8 ± 14.3	VAS: UG SSB < EG SSB + Blind SSB, at 4 hours. UG SSB = EG SSB = Blind SSB, from 24-72 hours	Morphine Consumption: EG SSB + UG SSB < Blind SSB, from 0 to 72 hours
				EG SSB: Electrophysiology-guided suprascapular nerve block	10 mL of .375% ropivacaine	18	39.3 ± 15.3		
				Blind SSB: Suprascapular nerve block using anatomic landmarks	10 mL of .375% ropivacaine	19	40.8 ± 15.8		

(continued)

Table 2. Continued

Author, Publication Year	Level of Evidence	Surgical Procedure	Intervention	Treatment Groups	Dosage	Patients (n)	Age (years)	Post-Op Pain Differences	Post-Op Opioid Consumption Differences
Bengisun et al., 2014[35]	1	Subacromial decompression	Nerve block	LE: Levobupivacaine + epinephrine	Interscalene block with 20 mL of 100 mg levobupivacaine (.5%) + 50 µg epinephrine	25	50.4 ± 12.9	VAS: *LED < LE, from 2 to 24 hours	Lornoxicam consumption: *LED < LE, at 24 hours
				LED: Levobupivacaine + epinephrine + dexmedetomidine	Interscalene block with 20 mL of 100 mg levobupivacaine (.5%) + 50 µg epinephrine + 10 µg dexmedetomidine	23	55.9 ± 8.5		
Jeske et al., 2011[49]	2	Subacromial decompression	Nerve Block vs. Subacromial injection	SSN: Suprascapular nerve block	10 mL of 1% ropivacaine	15	59.1 ± 6.1	VAS: SSN < SAI + Placebo, at 6 hours. *SSN < SAI, from 24 to 48 hours. SSN = Placebo, from 24 to 48 hours. Placebo = SAI, at 6 hours. *Placebo < SAI, from 24 to 48 hours	Total analgesic consumption: SSN < SAI + Placebo, from 0 to 24 hours. SSN < Placebo, from 0 to 48 hours. SSN = Placebo, from 0 to 48 hours
				SAI: Subacromial infiltration	20 mL of 1% ropivacaine, soon after end of surgery	15	62.9 ± 6.9		
				Placebo	10 mL of .9% saline solution	15	63.6 ± 9.0		
McHardy et al., 2020[70]	1	Subacromial decompression or rotator cuff repair	Perineural vs intravenous nerve block	PN: Interscalene nerve block with perineural (PN) dexamethasone	Injectate mixture, 3 mL 1% ropivacaine, 1 mL .4% dexamethasone, 2 mL .9% saline	90	51.6	NRS: PN = IV, at 12 hours, 24 hours, and 7 days	Oral Morphine Equivalents: PN = IV, at 12 hours, 24 hours, and 7 days
				IV: Interscalene nerve block with intravenous (IV) dexamethasone	IV infusion, 50 mL .9% saline (infusion bag), 1 mL .4% dexamethasone	89	52.8		
Abdallah et al., 2016[24]	1	Rotator cuff repair + acromioplasty (35%), acromioplasty (24%), Bankart repair (23%), other (18%)	IV vs Perineural vs Placebo nerve block	PN: Perineural dexmedetomidine with single-injection interscalene nerve block	.5 µg/kg dexmedetomidine + 15 mL ropivacaine .5%	33	42	VAS: PN < IV < Placebo, at 30 min. PN = IV from 60 min to 14 days	Morphine Equivalents: PN and IV < Placebo, at 8 hours, and for cumulative 24-hour consumption. PN and IV = Placebo from 24 hours to 14 days. PN = V, at all time points
				IV: Intravenous Dexmedetomidine with single-injection interscalene nerve block	.5 µg/kg dexmedetomidine IV	34	36.1		
				Placebo: Saline with single-injection interscalene nerve block	Saline	32	38		
Kahn et al., 2018[52]	1	Shoulder Arthroscopy	IV vs. Perineural nerve block	IV: Dexamethasone with interscalene nerve block	1 mg IV dexamethasone	62	47 ± 15	NRS: IV=PN for ISBPNB, in PACU and on days 2 and 3	Morphine Equivalents: IV=PN for ISBPNB, on days 0, 2, and 3
				PN: Perineural dexamethasone with interscalene nerve block	30 mL bupivacaine .5% and 2 mL (2 mg) dexamethasone	63	50 ± 14		
Aksu et al., 2015[28]	1	Rotator cuff repair and acromioplasty (67%), Bankart repair (20%), other (13%)	Nerve block vs. local analgesic injection	IBSP: Interscalene brachial plexus nerve block	20 mL of .25% bupivacaine	20	45.1 ± 15.5	VAS: IBSP < Ia < Control, from 0 to 6 hours. All groups are equal from 12 to 24 hours	Morphine Equivalents: IBSP < Ia < Control, from 0 to 24 hour
				Ia: Intra-articular injection	20 mL of .25% bupivacaine, at the end of surgery	20	44.2 ± 15.9		
				Control: No block or intra-articular injection		20	43.4 ± 13.5		

(continued)

Table 2. Continued

Author, Publication Year	Level of Evidence	Surgical Procedure	Intervention	Treatment Groups	Dosage	Patients (*n*)	Age (years)	Post-Op Pain Differences	Post-Op Opioid Consumption Differences
Merivirta et al., 2013[71]	1	54% acromioplasty, 46% rotator cuff repair	Subacromial Catheter	Bupivacaine	Continuous infusion of 5 mg/mL bupivacaine, at 2 mL/hr	39	53 ± 9	NRS: Bupivacaine = Saline, from 0 to 12 hours. Bupivacaine < Saline, at 18 hours. Bupivacaine = Saline, on days 1 and 3	Opioid and codeine consumption: Bupivacaine < Saline, on days 0 and 1. *Bupivacaine < Saline, on day 2. Bupivacaine = Saline, on day 3
				Saline	Continuous infusion of 9 mg/mL saline, at 2 mL/hr	43	55 ± 6		
Schwartzberg and Reuss 2013[81]	1	Rotator cuff repair	Subacromial Catheter	Catheter with bupivacaine	Postoperative infusion catheter with 200 mL of .5% bupivacaine without epinephrine	32	56	VAS: No catheter < Catheter with saline solution, immediately after surgery. No catheter = Catheter with bupivacaine, and Catheter with bupivacaine = No catheter, immediately after surgery. All groups are equal, from 1 to 12 hour	Oxycodone consumption: All groups are equal, days 0-4
				Catheter with saline solution	Postoperative infusion catheter with 200 mL of sterile saline solution	29	56		
				No catheter		27	58		
Kang et al., 2019[54]	1	73% rotator cuff repair, 20% Bankart repair, 8% other	IV Injection	Control: saline	Intravenous .9% saline injection with interscalene nerve block, prior to surgery	22	46.3 ± 16.6	VAS: Control = D1 = D2, at 6 hours. D1 + D2 < Control, at 12 hours. D2 < Control + D1, from 18 to 24 hours	Morphine Equivalents: D1 and D2 < Control, from 12-24 hours. D2 < D1 from 18 to 24 hours. Control = D1 and D2, at 6 hours
				D1: Dexamethasone	Intravenous dexamethasone .11 mg/kg with interscalene nerve block, prior to surgery	22	46.1 ± 17.0		
				D2: Dexamethasone + dexmedetomidine	Coadministered intravenous dexamethasone .11 mg/kg + intravenous dexmedetomidine, with interscalene nerve block, prior to surgery	22	47.4 ± 13.5		
Bjørnholdt et al., 2014[36]	2	Subacromial decompression and/or acromioclavicular joint resection	Intravenous medication	D40: 40 mg Dexamethasone	40 mg dexamethasone intravenously, preoperatively	25	53 ± 10	NRS: D40 = D8 = Placebo, from surgery until day 3	Total analgesic consumption: D40 = D8 = Placebo, from surgery until day 3
				D8: 8 mg dexamethasone	8 mg dexamethasone intravenously, preoperatively	26	55 ± 11		
				Placebo	Placebo infused, preoperatively	22	49 ± 11		
Oh et al., 2018[75]	1	Shoulder Arthroscopy	Intravenous Patient-Controlled Analgesia (PCA)	Nefopam	PCA provided once awake, of 120 mg nefopam, 20 μg/kg fentanyl, and 16 mg ondansetron	46	53.3 ± 12.8	VAS and NRS: Nepofam = Ketorolac, from 10 min to 48 hours	Total PCA: Nepofam = Ketorolac, from 10 min to 24 hours
				Ketorolac	PCA provided once awake, of 2 mg/kg ketorolac, 20 μg/kg fentanyl, and 16 mg ondansetron	46	51.9 ± 11.5		

(continued)

Table 2. Continued

Author, Publication Year	Level of Evidence	Surgical Procedure	Intervention	Treatment Groups	Dosage	Patients (n)	Age (years)	Post-Op Pain Differences	Post-Op Opioid Consumption Differences
Yun et al., 2012[89]	1	Rotator cuff repair, with SLAP lesion in 62% and biceps tear in 17%	IV PCA vs. Subacromial PCA	SA-PCA: Subacromial patient-controlled analgesia	150 mL of .5% ropivacaine, infused at 2 mL/hour, for hours 0-48 postoperatively	30	54.1 ± 11.6	VAS: *SA-PCA < IV-PCA, at 1 hour. SA-PCA = IV-PCA, from 4 to 48 hours	Rescue boluses received: SA-PCA = IV-PCA, from 1 to 48 hours
				IV-PCA: Intravenous patient-controlled analgesia	Fentanyl (.3-.5 µg/kg/mL), keterolac (.03-.05 mg/kg/mL), and ondansetron (.08 mg/mL), infused at 1 mL/hr	30	51.5 ± 17.4		
Merivirta et al., 2013[71]	1	50% acriomioplasty, 50% rotator cuff repair	Patch vs infusion	Fentanyl	12 µg/hour fentanyl patch for 72 hours, with 4 mL/hr saline infusion in a subacromial manner, for 72 hours	30	52 ± 9	NRS: Fentanyl = Bupivacaine, from immediately after surgery to day 90	Rescue Analgesics Used: Fentanyl = Bupivacaine, from recovery room to day 3
				Bupivacaine	2.5 mg/mL bupivacaine infusion in a subacromial manner, with placebo patch, for 72 hours	30	54 ± 9		
Khashan et al., 2016[57]	2	Rotator cuff repair	Intra-articular injection	M: Morphine	20 mg/10 mL morphine, 20 minutes before surgery	15	50.7 ± 2.4	NRS: M < KM + S, on ward. M + S < KM, in PACU. M < KM < S. from 1 to 2 weeks. All groups are equal at 3 months	Morphine Equivalents until Discharge, Number of Paracetamol and Oxycodone Capsules Consumed for Weeks 1 and 2: M = KM = S, from 0 to 2 weeks
				KM: Ketamine + morphine	50 mg ketamine + 10 mg/10 mL morphine, 20 minutes before surgery	15	57.7 ± 2.4		
				S: Saline	.9% 10 mL saline, 20 minutes before surgery	15	54.1 ± 2.6		
Saritas et al., 2015[80]	1	Rotator cuff repair	Intra-articular injection	Magnesium	1,000 mg magnesium sulfate (100 mg/mL) intra-articularly in 10 mL saline, at end of surgery	30	39.8 ± 9.2	VAS: Magnesium < Control, from 1 to 12 hours. Magnesium = Control, from 18 to 24 hours	Total PCA Morphine: *Magnesium < Control, total consumption
				Control	10 mL IV saline, at end of surgery	30	41.6 ± 10.4		
Lee et al., 2015[62]	1	Rotator cuff repair	Local analgesic injection	GJ: Glenohumeral joint injection	20 mL bupivacaine + 10 mL lidocaine, postoperatively	40	57.2	VAS: GJ = SS = GJ + SS, from 20 min to 24 hours	Boluses of Rescue Analgesic: GJ = SS = GJ + SS, from 1 to 24 hours
				SS: Subacromial space injection	20 mL bupivacaine + 10 mL lidocaine, postoperatively	42	58.1		
				GJ+SS: Glenohumeral joint + subacromial space injection	10 mL bupivacaine + 5 mL lidocaine in each of the two injection sites, postoperatively	39	58.6		
Lu et al., 2017[64]	1	Shoulder arthroscopy	Infusion	SD: Sufentanil + dexmedetomidine	.04 µg/kg/h Sufenanil + .06 µg/kg/h Dexmedetomidine, postoperatively	75	65.5 ± 5.3	VAS: SD < S from 6 to 48 hours	Amount of Rescue Analgesia, and Analgesic Liquid Pump Volume: SD < S, from 24 to 48 hours. SD = S, from 1 to 3 hours
				S: Sufentanil only	.04 µg/kg/h Sufenanil, postoperatively	76	65 ± 5.8		
Spence et al., 2011[83]	1	Shoulder arthroscopy	Oral medication	Gabapentin	300 mg Gabapentin 1 hour before surgery, then twice a day for 2 days after surgery. Interscalene nerve block also used.	26 military patients	31.8 ± 10.48	NRS: Gabapentin = Control, on days 1 and 2	Morphine Equivalents: Gabapentin = Control, on days 1 and 2
				Control	Placebo 1 hour before surgery, then twice a day for 2 days after surgery. Interscalene nerve block also used.	31 military patients	31.51 ± 8.9		

(continued)

Table 2. Continued

Author, Publication Year	Level of Evidence	Surgical Procedure	Intervention	Treatment Groups	Dosage	Patients (*n*)	Age (years)	Post-Op Pain Differences	Post-Op Opioid Consumption Differences
Ahn et al., 2016[27]	1	Bankart repair (25%) and rotator cuff repair (75%)	Oral medication	Pregabalin	1 150-mg Pregabalin capsule, 1 hour before anesthesia induction	30	55 ± 9	NRS: Pregabalin < Control, from 6 to 48 hours. Pregabalin = Control, in PACU	Fentanyl Consumption: Pregabalin < Control, 0-6 hours and 0-48 hours. *Pregabalin < Control, 24-48 hours. Pregabalin = Control, total consumption and 6-24 hours
				Control	Placebo capsule, 1 hour before anesthesia induction	30	51 ± 12		
Mardani-Kivi et al., 2016[67]	1	Bankart repair	Oral medication	Gabapentin	1 600-mg Gabapentin capsule, 2 hours before surgery	38	30.2 ± 5.0	VAS: Gabapentin = Placebo	Pethidine Consumption: Gabapentin < Placebo, from 6 to 24 hours
				Placebo	Identical placebo capsule, 2 hours before surgery	38	28.3 ± 4.4		
Cho et al., 2011[39]	1	Rotator cuff repair	Multimodal protocol	Multimodal pain control	Preoperative written and oral education + pre-op prophylactic oral medication + intra-op 50 mL cocktail of local analgesics	40	57.6 ± 8.2	VAS: Multimodal = IV PCA, days 1 and 2. Multimodal < IV PCA, immediately after surgery. *Multimodal < IV PCA, days 3-5	Analgesic Consumption: Multimodal < IV PCA, days 0-5
				Intravenous patient-controlled analgesia (IV PCA)	Individualized doses of fentanyl, ketorolac, and ondansteron HCl	30	55.1 ± 7.5		
Kraeutler et al., 2015[61]	1	All had rotator cuff repair and/or subacromial decompression, with distal clavicle excision (41%) and biceps tenodesis (37%) as most common concomitant procedures	Nonpharmacological intervention	CC: Postoperative compressive cryotherapy	Used cryotherapy device every other hour for days 0-2 postsurgery, then 2-3 times per day for an hour on days 3-7 postsurgery	25	55.4	VAS: CC = IW, from 4 to 6 hours and on days 1-7	Morphine Equivalents: CC = IW, from days 1-7
				IW: Postoperative standard ice wrap	Used standard ice wrap every other hour for days 0-2 postsurgery, then 2-3 times per day for an hour on days 3-7 postsurgery	21	55.8		
Mahure et al., 2017[66]	2	Rotator Cuff Repair	Non-pharmacological intervention	Active transcutaneous electrical nerve stimulation (TENS)	Continuous frequency of 150 pps with pulse duration of 150 microseconds, active for 30 seconds then ramp down for 15 seconds. Use TENS unit 4 sessions/day, 45 minutes/session, through first postoperative week	21	60.5 ± 11.1	VAS: TENS < Placebo, from 12 to 48 hours, and from days 3 to 7	Percocet pills used: TENS < Placebo, on days 2 and 7
				Placebo TENS		16	56.4 ± 12.2		
Syed et al., 2018[84]	1	Rotator cuff repair	Nonpharmacological intervention	No pre-op opioid education	No video or handout	66	58.0 ± 9.4	VAS: *Pre-op Education < No Pre-op Education from 2 to 6 weeks. Pre-op Education = No Pre-op Education, at 3 months	Percocet pills used: Pre-op education < No Pre-op Education, from 6 weeks to 3 months. Pre-op Education = No Pre-op Education, at 2 weeks
				Pre-op opioid education	2-minute narrated video with handout detailing the risks of narcotic overuse and abuse	68	59.2 ± 9.2		

Findings with a *P* value <.01 are marked with an asterisk (*) and findings with a *P* value <.001 are in bold.
VAS, visual analog scale; NRS, numeric pain rating scale, DVPRS, defense and veterans pain rating scale, PACU, post-anesthesia care unit.

showed significant differences in postoperative pain, while 19 studies also found significant differences in opioid consumption.

ACL Reconstruction

Five studies assessed the adductor canal block for ACL reconstruction.[24,25,33,65,92] Three studies compared the adductor canal block to the femoral nerve block,[24,65,33] with all three studies finding no difference in pain relief, and only Lynch et al.[65] finding a difference in opioid consumption, with the adductor canal block allowing for less opioid consumption from 0 to 4 hours postoperatively. Meanwhile, Abdallah et al.[25] used an adductor canal block with 20 mL of 1:1 ropivacaine and Lidocaine at three different locations: proximal, middle, and distal. They found that using the proximal block significantly decreases pain from 0 to 6 hours postoperatively, while dramatically decreasing opioid consumption from 0 to 24 hours as well. Lastly, Thapa et al.[92] showed that an intermittent adductor canal block with .5% ropivacaine provides similar pain relief, but dramatically decreased opioid consumption, relative to a continuous adductor canal block with the same dosage.

Meniscectomy

Three studies evaluated injections for meniscectomy.[60,79,93] Sanel et al.[79] found that adding 20 mg of tenoxicam to an intra-articular injection with .5% bupivacaine dramatically decreases both pain at 12 hours postoperatively and opioid consumption at 24 hours postoperatively, as opposed to adding 2 mg of morphine with the bupivacaine. However, pain was similar between the groups at 1, 2, 4, 6, and 24 hours postoperatively, so the dramatic difference in pain at 12 hours is not clear. Koltka et al.[60] also evaluated intra-articular injections, but instead compared 500 mg magnesium, 100 mg of .5% levobupivacaine, 8 mg lornoxicam, and a saline placebo. All three intervention groups helped with pain relief and opioid consumption, with the only clear difference between intervention groups being that Lornoxicam decreased opioid consumption relative to magnesium from 0 to 24 hours postoperatively. Lastly, Lee et al.[93] compared a control group with 2.5-, 5-, and 10-μg dosages of hydromorphone added to bupivacaine intrathecal injections, finding that all the intervention groups provided better outcomes than the control group, but no significant differences between the hydromorphone dosage groups.

Hip Arthroscopy

Eight RCTs assessed pain and opioid consumption after hip arthroscopy (Table 4): 3 studies evaluated various types of nerve blocks, while 1 compared nerve block to intra-articular injection, 2 assessed localized injections, and 2 evaluated oral medication. Four RCTs isolated patients that underwent femoroacetabular impingement surgery. Four studies showed significant differences in postoperative pain, and 2 studies found significant differences in opioid consumption.

Femoroacetabular Impingement

Two studies evaluated nerve blocks for femoroacetabular impingement surgery.[34,88] Behrends et al.[34] found that a preoperative fascia iliaca block with 40 mL of .2% bupivacaine provides similar pain relief and opioid consumption as a saline placebo. Xing et al.[88] found more encouraging pain management results, showing that a preoperative femoral nerve block with 20 mL of .5% bupivacaine significantly decreases pain at several time points throughout the first postoperative week, and that opioid consumption also decreases from 1 to 2 days postoperatively, relative to a saline placebo. Unfortunately, the femoral nerve block also increased the rate of postoperative falls.

Oral Medications

Several studies show encouraging results for oral medications across shoulder, knee, and hip arthroscopy. For shoulder arthroscopy, Ahn et al.[27] provided either a 150 mg Pregabalin capsule or a placebo 1 hour before anesthesia induction (25% Bankart repair, 75% rotator cuff repair), and found that Pregabalin dramatically decreased pain from 6 to 48 hours postoperatively and opioid consumption from 0 to 48 hours postoperatively. Mardani-Kivi et al.[67] instead provided either 600 mg Gabapentin or a placebo to Bankart repair patients 2 hours before surgery, finding similar pain relief but significantly decreased opioid consumption from 6 to 24 hours postoperatively in the Gabapentin group. However, Spence et al.[83] did not see a difference due to Gabapentin when provided to military patients preoperatively and postoperatively from shoulder arthroscopy, clouding the overall efficacy of Gabapentin. Across ACL reconstruction, meniscectomy, and knee arthroscopy, in general, providing either 120 mg Etoricoxib and 400 mg Celecoxib preoperatively leads to significant improvements in both pain and opioid consumption.[63,68] Furthermore, Zhou et al.[91] provided 400 mg Celecoxib at various time points (1 day preoperatively, 1 hour preoperatively, and 4 hours postoperatively) to partial meniscectomy patients, finding that both the 1 day and 1 hour preoperative groups have better pain relief and slightly less opioid consumption relative to the 4 hours postoperative group. Lastly, in hip arthroscopy, 200 mg Celecoxib given 1 hour before surgery may provide some pain relief and slightly decrease opioid consumption after femoroacetabular impingement surgery or labral repair; however, the effects are not strong and differ across studies.[51,90]

Table 3. Treatment Provided, Patient Population, Postoperative Pain, and Postoperative Opioid Consumption Summarized from all Included RCTs Regarding Knee Arthroscopy

Author, Publication Year	Level of Evidence	Surgical Procedure	Intervention	Treatment Groups	Dosage	Patients (n)	Age (years)	Post-Op Pain Differences	Post-Op Opioid Consumption Differences
Abdallah et al., 2016[24]	1	Unilateral ACL Reconstruction	Nerve block	A: Adductor canal block (ACB)	20 mL .5% ropivacaine (with epinephrine)	52	31.6	VAS: ACB = FNB, from 30 min to 24 hours	Oral Morphine Equivalents: ACB = FNB, at 24 hours
				B: Femoral nerve block (FNB)	20 mL .5% ropivacaine (with epinephrine)	48	33.3		
Abdallah et al., 2019	1	ACL reconstruction	Nerve block	Proximal adductor canal block	20 mL of 1:1 ropivacaine .5% and Lidocaine 2% with epi 1:200,000	34	30	VAS: *Proximal Adductor Canal Block < Mid < Distal, from PACU-6 hr. All groups are equal from 12 to 24 hours	**Total Morphine and Morphine Equivalents Consumed: Proximal Adductor Canal Block < Mid + Distal, until discharge and from 1 to 24 hours**
				Mid adductor canal block	20 mL of 1:1 ropivacaine .5% and Lidocaine 2% with epi	38	31		
				Distal Canal Block	20 mL of 1:1 ropivacaine .5% and Lidocaine 2% with epi	36	29		
Thapa et al., 2016[92]	1	ACL reconstruction	Nerve block	Continuous Adductor Canal Block (ACB)	.5% ropivacaine @ 2.5 mL/hr	25	25.2 ± 6.4	VAS: Intermittent ACB < Continuous ACP, from 4 to 12 hours. Intermittent ACB = Continuous ACB, at 2 and 24 hours	**Cumulative Oral Morphine Equivalents: Intermittent ACB < Continuous ACB, total consumption**
				Intermittent ACB	.5% ropivacaine, every 6 hours	25	27.7 ± 7.2		
Lynch et al., 2019[65]	1	ACL Reconstruction, with concomitant partial meniscectomy (35%) or meniscal repair (10%)	Nerve block	Adductor canal block (ACB)	20 mL .5% ropivacaine	30	21.2 ± 4.2	VAS: ACB=FNB, from 0 hours to 3 days	Morphine Equivalents: ACB < FNB, from 0 to 4 hours. ACB = FNB, 4 hours to 3 days
				Femoral nerve block (FNB)	30 mL .5% ropivacaine	30	21.5 ± 5.4		
Bailey et al., 2019[33]	1	ACLR with patellar tendon autograft, concomitant meniscal repair in 78%	Nerve block	Femoral nerve blockade (FNB)	30 mL of 0.2% ropivacaine with 100 mcg clonidine	38	24.4 ± 8.8	NRS: FNB = ACB, until discharge	Morphine Equivalents: FNB = ACB, until discharge
				Adductor canal nerve blockade (ACB)	15 mL of 0.2% ropivacaine with 100 mcg clonidine	40	21.0 ± 7.3		
Espelund et al., 2014[42]	1	Minor arthroscopic knee surgery	Nerve block	Ropivacaine	30 mL of 7.5 mg/mL ropivacaine	36	46 ± 14	VAS: Ropivacaine=control, from 0 to 24 hours	Total opioid consumption: Ropivacaine < control, from 0 to 2 hours. Ropivacaine = control, from 2 to 24 hours.
				Control	30 mL of isotonic saline	35	43 ± 14		
Espelund et al., 2014[43]	1	50% ACL reconstruction, 50% other major arthroscopic knee surgery	Nerve block	Ropivacaine	30 mL of 7.5 mg/mL ropivacaine, 30 mL isotonic saline 45 minutes later	25	38 ± 12	VAS: Ropivacaine < control, from 15-45 min. Ropivacaine = control, from 60-90 min	Sufentanil consumption: Ropivacaine = control, from 0 to 90 min
				Control	30 mL of isotonic saline, 30 mL of 7.5 mg/mL ropivacaine 45 minutes later	25	34 ± 14		
Hanson et al., 2013[46]	1	Medial meniscectomy	Nerve block	ACB: Ultrasound-guided adductor canal block	15 mL of .5% ropivacaine with 1:400,000 epinephrine	24	54 ± 11	NRS: ACB < sham, in PACU, at discharge, and from 12 to 24 hr. ACB = sham, at 6 hours	Oral Morphine Equivalents: ACB < Sham, over 24 hours
				Sham: Ultrasound-guided sham injection	2 mL normal saline	24	51 ± 11		
Hsu et al., 2013[48]	1	87% soft-tissue (meniscectomy, meniscal repair), 26% single osseous, 24% multiple osseous procedures	Nerve block	INF: Block of infrapatellar branch of saphenous nerve	10 mL of .25% bupivacaine	33	51.7 ± 12.1	NRS: INF < Placebo, immediately postoperatively, at 1 hour, and on arrival at home. INF = Placebo, from 2 to 4 hours postoperatively, and 0-24 hours after arriving home	IV Ketorolac, Hydrocodone, and Fentanyl, oral Hydrocodone, and Total Oral Morphine Equivalents: INF = Placebo, 0-48 hours
				Placebo	Saline solution	32	49.6 ± 14.1		

(continued)

Table 3. Continued

Author, Publication Year	Level of Evidence	Surgical Procedure	Intervention	Treatment Groups	Dosage	Patients (*n*)	Age (years)	Post-Op Pain Differences	Post-Op Opioid Consumption Differences
Westergaard et al., 2014[86]	1	61% synovectomy, 53% meniscectomy, 37% chondrosectomy, with other concomitant procedures	Nerve block	Ropivacaine	20 mL of .75% ropivacaine prepared − 7.5 mL around the saphenous nerve and 7.5 mL around the posterior branch of obturator nerve	29	31	NRS: ropivacaine = Saline, from 0 to 24 hours	Morphine consumed: ropivacaine = Saline, from 0 to 24 hours
				Saline	20 mL of isotonic saline prepared − 7.5 mL around the saphenous nerve and 7.5 mL around the posterior branch of obturator nerve	30	42		
Marinković et al., 2016[69]	1	Knee arthroscopy	Peripheral nerve block	GA: General anesthesia	—	30 children	13.5 ± 3.2	**Wong Baker Faces Scale: PNB + GA < GA, from 2 to 12 hours**	**Morphine Equivalents: PNB + GA < GA, until discharge**
				PNB+GA: Peripheral nerve block + general anesthesia/ sedation	1 mL/kg of .25% or.33% levobupivacaine administered with ultrasound guidance. 43% femoral, obturator, ischiatic block; 33% femoral, obturator block; 23% femoral, ischiatic block	30 children	15.2 ± 1.6		
Keller et al., 2019[56]	1	ACL reconstruction	Nerve block vs nerve block + local injection	Femoral Nerve Block (FNB)	20 mL .5% Bupivacaine without epi	21	35.1	VAS: *FNB + PCI < FNB, at until discharge and at 1 hour. FNB + PCI = FNB, at 20 min and days 1-4	Number of Vicodin Pills Used: FNB + PCI < FNB, on day 4
				FNB + Posterior capsule injection (PCI)	FNB + 20 mL .5% Bupivacaine without epi in posterior capsule, injected before drilling femoral tunnel	21	32.5		
Moyano et al., 2016[73]	1	35% ACL repair, 28% multiple procedures, 24% meniscectomy, 13% other	IV injection	DM: Dexamethasone	2 mL of a 5 mg/mL dexamethasone phosphate solution, during anesthetic induction	37	39.9	VAS: DM > S, at 4 hours. DM = S, in PACU, and at 8 and 12 hours	Number of Codeine Tablets Taken: DM = S, from 0 to 48 hours
				S: Saline	2 mL of .9% normal saline, during anesthetic induction	41	44.3		
Amin et al., 2011[29]	2	ACL reconstruction	Intraarticular patient-controlled analgesia (PCA)	RMX: Morphine + ropivacaine + xefocam mixture	PCA of .25% ropivacaine, .2 mg/mL morphine, 1 mg/mL xefocam (Lornoxicam)	15	32 ± 3	VAS: RMX = RM = C, at 4 hr. RMX < RM + C, at 8-16 hours. RMX < RM < C, at 24 hours	Rescue IV Morphine: RMX < RM, at 24 hours. *RM < C, at 24 hours
				RM: Ropivacaine + morphine mixture	PCA of .25% ropivacaine, .2 mg/mL morphine	15	27 ± 3		
				Control: No drug	—	15	35 ± 3		
Sanel et al., 2016[79]	1	Isolated partial meniscectomy	Intra-articular injection	TEN: tenoxicam with bupivacaine	22 mL of .5% bupivacaine 100 mg + tenoxicam 20 mg, after the surgery and before tourniquet deflation	120	36	**VAS and NRS: TEN < MOR, at 12 hours.** TEN = MOR, at 1, 2, 4, 6, and 24 hours	**Total Analgesic: TEN < MOR, at 24 hours**
				MOR: morphine with bupivacaine	22 mL of .5% bupivacaine 100 mg + morphine 2 mg, after the surgery and before tourniquet deflation	120	40		

(continued)

Table 3. Continued

Author, Publication Year	Level of Evidence	Surgical Procedure	Intervention	Treatment Groups	Dosage	Patients (*n*)	Age (years)	Post-Op Pain Differences	Post-Op Opioid Consumption Differences
Arti and Mehdinasab, 2011[30]	1	ACL reconstruction	Intra-articular injection	Morphine	At end of procedure: 9.5 mL bupivacaine + 5 mg morphine	30	31.5 ± 5.9	VAS: Morphine < all other groups, 0-12 hours after surgery. All other groups < Placebo, 0-12 hours after surgery	Morphine Equivalents: Morphine + Methadone < Pethidine + Tramadol < Placebo, 0-12 hours after surgery
				Methadone	At end of procedure: 9.5 mL bupivacaine + 5 mg methadone	30	28.9 ± 7.6		
				Pethidine	At end of procedure: 9.5 mL bupivacaine + 37.5 mg pethidine	30	26.8 ± 7.8		
				Tramadol	At end of procedure: 9.5 mL bupivacaine + 100 mg tramadol	30	27.5 ± 7.4		
				Placebo	At end of procedure: 9.5 mL bupivacaine + .5 mL normal saline	30	28.6 ± 5.3		
Mitra et al., 2011[72]	1	70% ACL repair, 20% diagnostic arthroscopy, 10% other	Intra-articular injection	Tramadol	30 mL .25% bupivacaine + 1 mL (50 mg) tramadol, at end of surgery	20	31.65 ± 12.86	**VAS: Fentanyl < Tramadol + Saline, from 0 to 8 hr.** *Tramadol < Saline, from 0 to 8 hours	Total Analgesic: Fentanyl + Tramadol < Saline, from 0 to 8 hours
				Fentanyl	30 mL .25% bupivacaine + 1 ML (50 μg) fentanyl, at end of surgery	20	26.55 ± 8.02		
				Saline	30 mL .5% bupivacaine + 1 mL normal saline, at end of surgery	20	28.05 ± 10.76		
Kager et al., 2011[50]	2	75% meniscus resection and cartilage smoothing, 19% cartilage smoothing only, and 6% cruciate ligament repair	Intra-articular injection	5 mg labetalol	20 mL intra-articularly with 5 mg labetalol, at end of surgery	21	48.0 ± 3.5	VAS and VRS: 5 mg = 2.5 mg = Placebo, from 30 min to 24 hours	Morphine Consumption: Placebo + 5 mg < 2.5 mg, from 30 min to 24 hours. Placebo < 5 mg, from 30 min to 1 hour, and from 4 to 24 hours. Placebo = 5 mg, from 2 to 3 hours
				2.5 mg labetalol	20 mL intra-articularly with 2.5 mg labetalol, at end of surgery	18	41.4 ± 3.9		
				Placebo	20 mL intra-articularly with normal saline, at end of surgery	24	49.0 ± 2.5		
Koltka et al., 2011[60]	1	Meniscectomy	Intra-articular injection	Magnesium	500 mg magnesium sulfate intra-articularly in 20 mL saline, before tourniquet deflation	30	48.4 ± 11	NRS: All groups are equal at 1 hour *Lornoxicam < Placebo, at 2 hours. Levobupivacaine < Placebo, at 2 hours. Magnesium = Placebo, at 2 hours. **Magnesium + Levobupivacaine + Lornoxicam < Placebo, at 4 hours.** All groups are equal from 12 to 48 hours	Tramadol Consumption and Number of Pills Consumed: *Lornoxicam < Placebo, from 0 to 4 hr. **Magnesium + Levobupivacaine < Placebo, from 0 to 4 hr.** *Lornoxicam < Placebo, from 0 to 48 hr. Magnesium = Levobupivacaine = Placebo, from 0 to 48 hours. Lornoxicam < Magnesium, from 0 to 24 hours
				Levobupivacaine	100 mg levobupivacaine (.5%) of 20 mL local anesthetic, before tourniquet deflation	30	50.6 ± 12		
				Lornoxicam	8 mg lornoxicam intra-articularly in 20 mL saline, before tourniquet deflation	30	42.5 ± 9.7		
				Placebo	20 mL saline intra-articularly, before tourniquet deflation	30	46 ± 15.6		

(continued)

Table 3. Continued

Author, Publication Year	Level of Evidence	Surgical Procedure	Intervention	Treatment Groups	Dosage	Patients (n)	Age (years)	Post-Op Pain Differences	Post-Op Opioid Consumption Differences
Lee et al., 2012[93]	2	Partial meniscectomy	Intrathecal injection	10 HM: 10 µg hydromorphone	Spinal anesthesia with: 10 µg hydromorphone + 1.2 mL (6 mg) of .5% hyperbaric bupivacaine, in .05 mL isotonic saline, prior to surgery	15	36.3 ± 12.3	VAS: All groups are equal, at 30 min and 2 hours 2.5 HM, 5 HM, and 10 HM < Control, from 4-6 hours. 5 HM and 10 HM < Control, at 12 hours. 2.5 HM = Control, at 12 hours. All groups are equal, at 24 hours	Number of required analgesic injections: 5 HM and 10 HM < Control and 2.5 HM, 0-24 hours
				5 HM: 5 µg hydromorphone	Spinal anesthesia with: 5 µg hydromorphone + 1.2 mL (6 mg) of .5% hyperbaric bupivacaine, in .05 mL isotonic saline, prior to surgery	15	36.5 ± 15.1		
				2.5 HM: 2.5 µg hydromorphone	Spinal anesthesia with: 2.5 µg hydromorphone + 1.2 mL (6 mg) of .5% hyperbaric bupivacaine, in .05 mL isotonic saline, prior to surgery	15	38.9 ± 12.4		
				Control	Spinal anesthesia with: 6 mg hyperbaric bupivacaine in .05 mL isotonic saline, prior to surgery	15	39.9 ± 13.7		
Sayin et al., 2015[76]	1	Meniscopathic knee surgery	Local anesthesia	C: Control	No description	20	30.2 ± 6.8	VAS: *L+T and L + F < C and L, from 1 to 24 hours. Also *L + T < L + F, from 2 to 4 hours	Number of times needing post-op Analgesia: L + T and L + F < C and L, total doses
				L: Levobupivacaine	20 mL of Levobupivacaine 2.5 mg/mL, 7 mL before surgery and 13 mL at the end of surgery	20	32.6 ± 7.0		
				L+T: Levobupivacaine + Tramadol	20 mL of Levobupivacaine 2.5 mg/mL + 50 mg Tramadol, 7 mL before surgery and 13 mL at the end of surgery	20	36.2 ± 8.8		
				L+F: Levobupivacaine + Fentanyl	20 mL of Levobupivacaine 2.5 mg/mL + 50 mcg Fentanyl, 7 mL before surgery and 13 mL at the end of surgery	20	34.7 ± 10.2		
Premkumar et al., 2016[98]	2	ACL reconstruction with quadriceps autograft	Surgical site injection	Local liposomal bupivacaine (LLB)	40 mL suspension of 20 mL liposomal bupivacaine + 20 mL Saline, 30 mL injected into graft harvest site and 10 mL into superficial skin	14		NRS: LLB = LB, from PACU until day 6	PACI IV Hydromorphone, PACE Fentanyl, and PACE Oxycodone Equivalents Consumed: LLB = LB, from PACU until day 6
				Local bupivacaine (LB)	40 mL suspension of 20 mL bupivacaine + 20 mL Saline, 30 mL injected into graft harvest site and 10 mL into superficial skin	15			
Zhou et al., 2017[91]	1	Partial Meniscectomy	Oral medication	Celecoxib 4 hours post-op	400 mg Celecoxib	60	35.9 ± 6.6	VAS: Very Early + Early < Post op Celecoxib, from 4 to 36 hours	Rescue analgesic consumed: Very Early + Early *almost* < Post-op Celecoxib ($P = .06$), from 24 to 48 hours
				Celecoxib 1 hour Pre-op (early)	400 mg Celecoxib	62	36.0 ± 6.1		
				Celecoxib 1 Day Pre-op (very early)	400 mg Celecoxib	60	34.7 ± 7.1		

(continued)

Table 3. Continued

Author, Publication Year	Level of Evidence	Surgical Procedure	Intervention	Treatment Groups	Dosage	Patients (*n*)	Age (years)	Post-Op Pain Differences	Post-Op Opioid Consumption Differences
Lierz et al., 2012[63]	1	Therapeutic knee arthroscopy	Oral medication	Etoricoxib	One tablet of 120 mg etoricoxib, 1 hour before anesthesia induction	33	54 ± 10	VAS: Etoricoxib < Placebo, at 0 hour and from 4 to 24 hours. Etoricoxib = Placebo, at 2 hours	Total morphine consumption: Etoricoxib < Placebo, from 2 to 24 hours
				Placebo	One look-alike placebo tablet, 1 hour before anesthesia induction	33	56 ± 14		
Mardani-Kivi et al., 2013[68]	1	52% isolated ACL reconstruction (ACLR), 48% isolated partial meniscectomy	Oral medication	Celecoxib	400 mg celecoxib, 2 hours prior to operation	57	ACL: 25.8 ± 7.7. Meniscectomy: 32.7 ± 8	VAS: Celecoxib < Placebo, from 6 to 24 hours, for both ACLR and meniscectomy	Opioid (Pethidine) Consumption: Celecoxib < Placebo, from 6-24 hours, for meniscectomy only. *Celecoxib < Placebo, at 6 hours, for ACLR. Celecoxib < Placebo, at 24 hours
				Placebo	Identical placebo, 2 hours prior to operation	60	ACL: 26.7 ± 4.9. Meniscectomy: 32.2 ± 9.8		
Tompkins et al., 2011[85]	2	ACL reconstruction	Oral medication	Postoperative Zolpidem (sleep-aid) with ibuprofen	7 zolpidem tartrate tablets (10 mg), taken once a day for 7 days after surgery. Also 800 mg ibuprofen, taken every 8 hours as needed.	6	36.9	VAS: All groups are equal, days 0-7	Number of Vicodin tablets: Zolpidem groups < Placebo groups, days 0-7. Ibuprofen did not affect opioid consumption.
				Postoperative Zolpidem without ibuprofen	7 zolpidem tartrate tablets (10 mg), taken once a day for 7 days after surgery.	7			
				Postoperative Placebo with ibuprofen	7 gelatin pills, taken once a day for 7 days after surgery. Also 800 mg ibuprofen, taken every 8 hours, as needed.	7	35.6		
				Postoperative Placebo without ibuprofen	7 gelatin pills, taken once a day for 7 days after surgery.	9			
Reda et al., 2016[78]	1	ACL reconstruction with anatomical single-bundle technique	Nonpharmacological intervention	A: Tourniquet	Inflated to 350 mm mercury (64 ± 8.7 min)	29	25.5 ± 4.0	VAS: *No Tourniquet < Tourniquet, from 4 to 10 hours. Tourniquet = No Tourniquet, from 16 to 22 hours	Morphine Equivalent Consumption: *No Tourniquet < Tourniquet, until discharge
				B: No tourniquet	Tourniquet not inflated; received intra-articular injection of 60 cc (250 cc saline + 10 mg morphine + 1 mg Adrenaline)	29	25.0 ± 4.6		
Hartwell et al., 2020[94]	1	Knee arthroscopy with partial meniscal debridement	Nonpharmacological	Electronic prescription: automatically provided opioids with multimodal pain medications from pharmacist	20 tablets of 5-mg oxycodone, automatically provided after surgery	48	45.0 ± 12.3	VAS: Electronic prescription = paper prescription, at 2, 24, and 48 hours, as well as at 7 and 21 days	Number of Pills Taken: Electronic prescription = paper subscription, total number of pills taken
				Paper prescription: optional opioids, only if absolutely necessary for pain control	20 tablets of 5-mg oxycodone, available if needed after surgery	47	43.6 ± 12.8		

Findings with a *P* value <.01 are marked with an asterisk (*) and findings with a *P* value <.001 are in bold. NRS, numeric pain rating scale; PACU, postanesthesia care unit; VAS, visual analog scale.

Table 4. Treatment Provided, Patient Population, Postoperative Pain, and Postoperative Opioid Consumption Summarized from All Included RCTs Regarding Hip Arthroscopy

Author, Publication Year	Level of Evidence	Surgical Procedure	Intervention	Treatment Groups	Dosage	Patients (*n*)	Age (years)	Post-Op Pain Differences	Post-Op Opioid Consumption Differences
Behrends et al., 2018[34]	1	Femoroacetabular impingement	Nerve block	Fascia iliaca block (FI)	40 mL .2% ropivacaine	38	35 ± 11	NRS: FI=Saline, from 0 to 24 hours	Morphine and Morphine Equivalent Consumption: FI = Saline, from 1 to 24 hours
				Saline	Saline	37	32 ± 9		
Xing et al., 2015[88]	1	Femoroacetabular impingement	Nerve block	Femoral nerve block (FNB)	20 mL .5% bupivacaine	27	32 ± 11	**VAS: FNB < Saline, at 6 hours.** *FNB < Saline, from 30 min to 1 hour and from 2 to 4 hours. FNB < Saline, at 48 hours and day 7. FNB = Saline, at 90 minutes and 24 hours	Total morphine consumed: *FNB < Saline, from 24 to 48 hours. FNB = Saline, from 1-24 hours and from days 2-7
				Saline	Saline	23	31 ± 8		
Purcell et al., 2019[77]	1	96% labral repair, 93% pincer resection, 87% cam osteoplasty, 83% capsular repair	Nerve block	PB: Plain bupivacaine	40 mL of .25% plain bupivacaine (100 mg)	37 military veterans	30.2	DVPRS: PB = LB + PB, from the PACU until 2 weeks	Oxycodone Consumed: PB = LB + PB, from days 1-14
				LB + PB: Liposomal bupivacaine + plain bupivacaine	20 mL of .5% plain bupivacaine (100 mg) + 20 mL of liposomal bupivacaine (266 mg)	33 military veterans	32.8		
Glomset et al., 2020[45]	1	Labral repair with both acetabuloplasty and femoroplasty (76%), labral repair with acetabuloplasty or femoroplasty (14%), other (10%)	Nerve block vs. intra-articular injection	Ultrasound-guided fascia iliaca block (FIB)	Up to 60 mL .35% ropivacaine at 3 mg/kg, with 100-mg clonidine (per 60 mL) and epinephrine 1:400,000	41	40.6 ± 12.4	VAS: FIB = IA, in PACU, and at 2 weeks, 6 weeks, and 3 months	Morphine Equivalents: FIB = IA, in PACU
				Intra-articular (IA) injection, at completion of surgery	20 mL .5% ropivacaine, at the end of surgery	43	36.8 ± 12.1		
Cogan et al., 2020[40]	1	Hip arthroscopy, labral repair, and acetabuloplasty	Intra-articular injection	M + C: Morphine + clonidine	11 mL of 10 mg morphine, and 100 mcg clonidine, in .9% NaCl solution, at the conclusion of arthroscopy	33	40	VAS: M + C = control, in PACU, and at 7, 18, 24, and 48 hours, as well as at 7 days	Morphine Equivalents: M + C = control, in PACU, and at 7, 18, 24, and 48 hours, as well as at 7 days
				Control: Normal saline	11 mL of .9% NaCl solution, at conclusion of arthroscopy		36		

(continued)

Table 4. Continued

Author, Publication Year	Level of Evidence	Surgical Procedure	Intervention	Treatment Groups	Dosage	Patients (*n*)	Age (years)	Post-Op Pain Differences	Post-Op Opioid Consumption Differences
Shlaifer et al., 2017[82]	1	Femoroacetabular impingement	Surgical Site Injection	Periacetabular Injection	20 mL .5% bupivacaine with epi (1:200,000), before surgery	21	39.6 ± 16.1	VAS: Periacetabular < Intra-articular, 30 min. *Periacetabular < Intra-articular, at 18 hours Periacetabular = Intra-articular, from 1 to 12 hours, and from days 1 to 14	Morphine Equivalents: Periacetabular = Intra-articular, until discharge and days 1-7
				Intra-articular Hip Injection	20 mL .5% bupivacaine with epi (1:200,000), before surgery	21	36 ± 15.6		
Kahlenberg et al., 2017[51]	1	61% labral repair, 24% labral repair with acetabular osteoplasty, 11% other	Oral medication	Celecoxib	1 hour pre-op: 2 pills, 200 mg celecoxib each	50	34.2	VAS: Celecoxib < control at 1 hour, and Celecoxib almost < control at 2 hours (*P* = .06). Celecoxib = control, until discharge	Morphine Equivalents: Celecoxib = control, in PACU
				Placebo	1 hour pre-op: 2 lactose-based placebo pills	48	35.8		
Zhang et al., 2014[90]	1	Femoroacetabular impingement with labral tears	Oral medication	Celecoxib	200 mg celecoxib 1 hour before surgery	27	41.0 ± 4.9	VAS: Celecoxib = Placebo, in recovery room. Celecoxib < Placebo, from 12 to 24 hours	Number of Narcotic Pills Used: Celecoxib < Placebo, in recovery room
				Placebo	200 mg placebo 1 hour before surgery	26	43.5 ± 5.1		

Findings with a *P* value <.01 are marked with an asterisk (*), and findings with a *P* value <.001 are in bold.
DVPRS, defense and veterans pain rating scale; VAS, visual analog scale; NRS, numeric pain rating scale, PACU, postanesthesia care unit.

Postoperative Interventions for Pain Management

Ten studies evaluated interventions for postoperative pain management protocols, six in shoulder arthroscopy,[61,66,71,75,83] four in knee arthroscopy,[29,85,91,94] and none in hip arthroscopy. Notable in shoulder arthroscopy, Yun et al.[89] found that subacromial patient-controlled analgesia (PCA) provided postoperatively for 48 hours to rotator cuff repair patients provided better pain relief at 1 hour postoperatively compared to IV PCA, while opioid consumption was similar. Merivirta et al.[71] and Oh et al.[75] found that a 72-hour postoperative fentanyl batch provided similar outcomes to a bupivacaine infusion and that Nefopam IV PCA provided similar outcomes to a Ketorolac IV PCA, respectively. For knee arthroscopy, Tompkins et al.[85] found that providing the sleep aid Zolpidem (10 mg) to ACL reconstruction patients for *days 0*-7 postoperatively decreased opioid consumption, while not affecting pain relief. Amin et al.[29] compared three groups of intra-articular PCA for ACL reconstruction patients: an RM group (.25% ropivacaine + .2 mg/mL morphine), an RMX group (ropivacaine + morphine + 1 mg/mL xefocam [i.e. Lornoxicam]), and a control group. They found that the RMX group had the best pain relief from 8 to 24 hours postoperatively and dramatically less opioid consumption than the RM group at 24 hours.

Nonpharmacological Interventions

Six studies evaluated nonpharmacological interventions for pain management, four for shoulder arthroscopy,[39,61,66,84] two for knee arthroscopy,[78,94] and none for hip arthroscopy. Both Cho et al.[39] (orally and written) and Syed et al.[84] (2-minute video) provided preoperative opioid education to rotator cuff repair patients, and both studies found opioid education to decrease postoperative pain and opioid consumption throughout short-term (<1 week) and mid-term (up to 3 months) recovery. Mahure et al.[66] also evaluated rotator cuff repair patients, finding that using a transcutaneous electrical nerve stimulation (TENS) unit throughout the first postoperative week can decrease pain and opioid consumption throughout that week. However, Kraeutler et al.[61] found no difference in outcomes between shoulder arthroscopy patients who used compressive cryotherapy versus a standard ice wrap postoperatively. Reda et al.[78] showed that for ACL reconstruction patients, the use of a tourniquet negatively affects outcomes, with tourniquet use showing increased pain from 4 to 10 hours postoperatively and increased opioid consumption until discharge. Also, Hartwell et al.[94] evaluated whether the mode of prescription affects postoperative outcomes by providing one group of patients with optional paper prescriptions for 20 tablets of 5 mg oxycodone and the other group with the same prescriptions automatically provided (not optional) from the pharmacist. However, there were no differences in pain or opioid consumption at any time point up to 21 days postoperatively.

Discussion

On the basis of current evidence, we recommend interscalene nerve blocks with a dexamethasone-dexmedetomidine combination for rotator cuff repair, a proximal continuous adductor canal block for ACL reconstruction, and local infiltration analgesia (e.g., periacetabular injection with 20 mL of .5% bupivacaine) for hip arthroscopy. Several oral medications appear to be optimal as well, such as 150 mg Pregabalin for shoulder arthroscopy, 400 mg Celecoxib for knee arthroscopy, and 200 mg Celecoxib for hip arthroscopy. There is promising evidence for the use of various nonpharmacological modalities, specifically preoperative opioid education for rotator cuff repair patients; however more clinical trials evaluating nonpharmacological interventions should be performed.

Shoulder Arthroscopy

A number of different nerve block locations and formulations were examined following shoulder arthroscopy. While bupivacaine alone was shown to reduce postoperative opioid consumption, the addition of dexamethasone to the interscalene block resulted in even lower postoperative pain for rotator cuff repair patients.[32] However, Kang et al.[54] compared IV dexamethasone to IV dexamethasone-dexmedetomidine and showed that a combination of dexamethasone and dexmedetomidine (IV dexamethasone .11 mg/kg + IV dexmedetomidine 1.0 μg/kg) decreased postoperative pain and opioid consumption in a cohort of 73% rotator cuff repair patients. These findings were further supported by Bengisun et al.,[35] who reported similarly superior outcomes with the addition of dexmedetomidine to an interscalene levobupivacaine and epinephrine block; however, this study involved a cohort of subacromial decompression patients. While other studies conflicted on the effects of block location, the overall trend was that interscalene brachial plexus blocks performed equal to or greater than supraclavicular and suprascapular blocks for both pain and opioid control.[26,31,74] Cabaton et al.[37] had results opposing the superiority of the interscalene brachial plexus block for rotator cuff repair patients, as they reported less opioid consumption after injection at a supraclavicular site; however, these authors used a levobupivacaine and clonidine block rather than a ropivacaine formulation.

Nerve blocks appear to be the optimal pain management modality for shoulder arthroscopy, as the bupivacaine interscalene brachial plexus block was superior to bupivacaine intra-articular injections for both pain control and opioid consumption in a cohort of mostly rotator cuff repair (67%) and Bankart repair (20%)

patients.[28] However, intra-articular injections for shoulder arthroscopy may be optimized by using morphine (20 mg morphine/10 mL) or magnesium (1 g magnesium sulfate in 10 mL saline).[57,80] Before a clear clinical recommendation can be provided, further high-quality studies comparing morphine, magnesium, bupivacaine, and any other viable intra-articular injections formulations should be conducted. Lastly, preemptively providing the oral medication Pregabalin can help patients after shoulder arthroscopy. Mardani-Kivi et al.[67] found that 600 mg Gabapentin significantly decreased postoperative opioid consumption in Bankart repair patients; however, Spence et al.[83] had conflicting results in a military patient population undergoing unspecified shoulder arthroscopy. Meanwhile, Ahn et al.[27] showed that 150 mg Pregabalin decreased both postoperative pain and opioid consumption compared to placebo in a cohort of 75% rotator cuff repair patients, ultimately providing pain relief, while Gabapentin did not significantly decrease pain in either aforementioned study.

Knee Arthroscopy

Postoperative pain following knee arthroscopy was reported as equivalent, and opioid consumption appears similar, when comparing ropivacaine as an adductor canal block (ACB) to a femoral nerve block (FNB) in ACL reconstruction patients.[24,33,65] This is supported by a network meta-analysis performed by Davey et al.[95] who found that nerve blocks are efficacious for ACL reconstruction, but that no specific nerve block proved superior. However, proximal ACBs were found to significantly reduce pain within the first 6 hours after ACL reconstruction compared to middle and distal ACBs.[25] In addition, continuous nerve blocks were shown to reduce pain between hours 4 and 12 after ACL reconstruction compared to intermittent ACBs.[92] Proximal and continuous ACBs were also superior to comparison groups for the minimization of postoperative opioid consumption, suggesting that the proximal and continuous ACB may be the most effective modality for pain management for ACL reconstruction.[25,92] Regarding intra-articular injections, Davey et al.[95] also found that intra-articular injections with bupivacaine decrease pain for up to 12 hours postoperatively, while also decreasing postoperative opioid consumption. Unfortunately, the optimal pain management for meniscectomy is less clear, as several injections provided better outcomes than placebo, but no studies have compared these interventions to determine superiority.[60,79,93] Providing either 120 mg Etoricoxib and 400 mg Celecoxib preoperatively leads to significant improvements in both pain and opioid consumption for various knee arthroscopy procedures.[63,68,91] An RCT comparing preoperative Etoricoxib and Celecoxib would help clarify whether one oral medication is superior to the other for knee arthroscopy.

Hip Arthroscopy

Following hip arthroscopy, Xing et al.[88] found a decrease in postoperative pain relief and opioid consumption with the use of a bupivacaine femoral nerve block compared to saline controls. However, the nerve block was also associated with a significant increase in the risk of falls within the first 24 hours following the procedure, which ultimately led to the discontinuation of bupivacaine femoral nerve blocks for outpatient hip arthroscopy procedures at the respective institution.[88] The fascia iliaca block also may be an inferior form of pain management, as the fascia iliaca block provides equal pain relief compared to saline placebo.[34,45,77] No RCTs included in this study evaluated the lumbar plexus nerve block; however, it is possible that the lumbar plexus nerve block may provide the best clinical outcomes of the common hip arthroscopy nerve blocks.[96,97] For example, YaDeau et al.[97] described in a brief report of an RCT that the addition of a lumbar plexus nerve block with a combined spinal epidural leads to significantly decreased postoperative pain compared to only receiving the spinal epidural. Also, in a retrospective cohort study, Wolff et al.[96] found that a lumbar plexus nerve block with general anesthesia leads to much less postoperative pain than a fascia iliaca nerve block with general anesthesia. However, until several high-quality RCTs compare the lumbar plexus nerve block to other viable nerve blocks, the lumbar plexus nerve block should not be considered the gold standard of nerve blocks for hip arthroscopy.

Interestingly, the network meta-analyses performed by Kunze et al.[15] suggest that local infiltration anesthesia is more effective than nerve block for limiting both postoperative pain and opioid consumption for hip arthroscopy. Specifically regarding local infiltration anesthesia within our included studies, Shlaifer et al.[82] reported a decrease in postoperative pain if 20 mL of .5% bupivacaine was used as periacetabular injection as opposed to an intra-articular injection. Interestingly, the use of morphine and clonidine as an intra-articular injection provided equivalent pain relief and opioid consumption compared to placebo.[40] Lastly in regard to oral medication, while the use of oral celecoxib resulted in decreased postoperative pain compared to controls, only Zhang et al.[90] reported a decrease in postoperative opioid consumption.[51,90]

Nonpharmacological Interventions

Several nonpharmacological interventions appear to provide clinical benefit for arthroscopic surgery patients. Preoperative patient opioid education of any form appears to provide clear benefits regarding both postoperative pain and opioid consumption for rotator cuff repair patients.[39,84] Syed et al.[84] also found that preoperative education patients were more than 2 times more likely to stop their narcotic use by 3 months postoperatively. Considering how easily preoperative opioid education was provided by Syed et al.,[84] providing patients with an educational 2-minute video and a handout, preoperative opioid education can be a realistic and beneficial intervention for managing postoperative pain and opioid consumption. The use of a TENS unit throughout the first postoperative week may also help rotator cuff repair patients; however, the feasibility depends on the finances of each institution and adherence of the patient.[66] For ACL reconstruction, abandoning the tourniquet appears advantageous.[78] Surgeons that feel comfortable abandoning tourniquet use may be able to decrease postoperative pain and opioid consumption for ACL reconstruction patients.[78] Unfortunately, several nonpharmacological interventions do not appear to provide additional pain relief or minimize opioid consumption, such as cryotherapy for shoulder arthroscopy patients or optional paper prescriptions for knee arthroscopy patients.[61,94]

Postoperative Interventions for Pain Management

Similarly, several postoperative interventions may prove beneficial for certain arthroscopic surgery populations. For example, rotator cuff patients have decreased postoperative pain when given subacromial PCA instead of IV PCA for 48 hours postoperatively.[89] Similarly, postoperative pain and opioid consumption can be decreased for ACL reconstruction patients by including ropivacaine, morphine, and xefocam (Lornoxicam) for intra-articular PCA.[29] ACL reconstruction patients may also benefit from the use of a sleep aid such as Zolpidem 10 mg.[85] While taking Zolpidem postoperatively days 0-7 did not decrease pain, opioid consumption significantly decreased.[85]

Clinical Recommendations

Development of an optimal analgesic strategy based on the articles examined is difficult due to the paucity of direct comparisons between various treatment modalities. However, each anatomic location demonstrated similar trends in regard to maximizing pain relief and minimizing opioid consumption. First, a distinct nerve block may be superior at each surgical location. Interscalene brachial plexus blocks with ropivacaine appear superior for rotator cuff repair,[17,32,37,87,44] while proximal continuous adductor canal blocks were superior for ACL reconstruction.[24,25,33,65,92,95] Second, certain oral medications taken preoperatively may limit both postoperative pain and opioid consumption, with 150 mg Pregabalin being optimal for shoulder arthroscopy,[27,67,83] 400 mg Celecoxib for knee arthroscopy,[63,68] and 200 mg Celecoxib for hip arthroscopy.[51,90] Lastly, several nonpharmacological interventions have the potential to improve pain management with minimal risk to the patient. For example, preoperative patient opioid education, minimization of tourniquet use, and postoperative TENS unit usage can decrease pain and opioid consumption, while replacing electronic prescriptions with paper prescriptions may minimize the amount of unused opioid tablets available to the public.[39,66,84,94]

Limitations

This review is not without limitations. The included studies were separated on the basis of anatomic location. However, many studies included a number of different surgical procedures at the anatomic site. In addition, studies used different drug formulations for pain control and different morphine equivalents for opioid consumption. As a result, directly comparing outcomes between studies was not feasible. Also, the heterogeneity of data prevented pooling of results, which weakens the strength of the study conclusions. Plus, complications and patient-reported outcomes were not evaluated in this systematic review. Finally, minimal clinically important differences (MCIDs) were not evaluated in this study, only statistical significance.

Conclusions

Many multimodal pain management protocols offer improved pain control and decreased opioid consumption after arthroscopic surgery. On the basis of the current evidence, we recommend an interscalene nerve block with a dexamethasone-dexmedetomidine combination for rotator cuff repair, a proximal continuous adductor canal block for ACL reconstruction, and local infiltration analgesia (e.g., periacetabular injection with 20 mL of .5% bupivacaine) for hip arthroscopy. When evaluating oral medication: the evidence supports 150 mg Pregabalin for shoulder arthroscopy, 400 mg Celecoxib for knee arthroscopy, and 200 mg Celecoxib for hip arthroscopy, all taken preoperatively. There is promising evidence for the use of various nonpharmacological modalities, specifically preoperative opioid education for rotator cuff repair patients; however, more clinical trials evaluating nonpharmacological interventions should be performed.

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