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# Nerve block with liposomal bupivacaine yields fewer complications and similar pain relief when compared to an interscalene catheter for arthroscopic shoulder surgery: a randomized controlled trial

Kevin C. Wall, MD, MPH[a], Joseph Elphingstone, MD, MS[a], Kyle D. Paul, MD[a], Alexandra Arguello, MD[b], Akash Pandey, BS[c], Hamza Qureshi, BS[c], Gerald McGwin, PhD[d], Lisa MacBeth, MD[e], Joel Feinstein, MD[e], Amit Momaya, MD[a], Brent Ponce, MD[f], Eugene Brabston, MD[a,*]

[a]*University of Alabama at Birmingham Department of Orthopaedic Surgery, Birmingham, AL, USA*
[b]*Department of Orthopedic Surgery, Mayo Clinic, Rochester, MN, USA*
[c]*University of Alabama at Birmingham, Birmingham, AL, USA*
[d]*University of Alabama at Birmingham Department of Epidemiology, Birmingham, AL, USA*
[e]*University of Alabama at Birmingham Department of Anesthesiology, Birmingham, AL, USA*
[f]*Hughston Clinic Foundation, Columbus, GA, USA*

**Background:** Following orthopedic surgery, patients frequently experience pain and discomfort. Multiple methods of regional anesthesia are available; however, the optimal technique to adequately manage pain while minimizing complications remains under investigation. This study aims to compare the complication rates and pain relief of single-injection, liposomal bupivacaine brachial plexus nerve block to a conventional, indwelling ropivacaine interscalene catheter (ISC) in patients undergoing arthroscopic shoulder surgery. We hypothesize that liposomal bupivacaine will have fewer patient complications with similar pain relief than an indwelling catheter.
**Methods:** Patients undergoing arthroscopic shoulder surgery were prospectively assessed after randomization into either ropivacaine ISC or single-injection liposomal bupivacaine brachial plexus nerve block (LB) arms. All patients were discharged with 5 analgesics (acetaminophen, methocarbamol, gabapentin, acetylsalicylic acid, and oxycodone) for as-needed pain relief. Preoperatively, patient demographics and baseline Visual Analog Scale, Single Assessment Numeric Evaluation, American Shoulder and Elbow Surgeons, and Penn Shoulder Scores were obtained. For the first four days postoperatively, complication rates (nausea, dyspnea, anesthetic site discomfort and/or irritation and/or leakage, and self-reported concerns and complications), pain, medication usage, and sleep data were assessed by phone survey every 12 hours. The primary outcome was overall complication rate. At 12 weeks postoperatively, Visual Analog Scale, Single Assessment Numeric Evaluation, American Shoulder and Elbow Surgeons, and Penn scores were reassessed. Outcome scores were compared with Mann-Whitney U tests, and demographics were compared with chi-squared tests. Significance was set at $P < .05$.

University of Alabama at Birmingham Institutional Review Board approved this study (study no. 300002544).

*Reprint requests: Eugene Brabston, MD, Department of Orthopaedic Surgery, University of Alabama at Birmingham, 1313 13th Street South, Birmingham, AL 35205, USA.
E-mail address: ebrabston@uabmc.edu (E. Brabston).


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**Results:** A total of 63 individuals were allocated into ISC (N = 35) and in the LB arms (N = 28) for analysis. Demographics and preoperative patient-reported outcomes were not different between the arms. Patients in the LB arm experienced fewer (13.1%) overall complications than those in the ISC arm (29.8%) ($P < .001$), with patients in the ISC arm specifically reporting more anesthetic site discomfort (36.4% vs. 7.1%, $P = .007$), leakage (30.3% vs. 7.1%, $P = .023$), and 'other,' free-response complications (ISC: 21.2%; LB: 3.6%; $P = .042$). No differences were noted in pain, sleep, opioid use, or satisfaction between arms during the perioperative period. More nonopioid medications were consumed on average in the ISC (1.8 ± 1.4) than in the LB arm (1.4 ± 1.3) ($P = .001$), with greater reported use of acetylsalicylic acid (40.9% vs. 23.4% $P < .001$) and acetaminophen (69.5% vs. 59.6% $P = .013$). Patient-reported outcome scores did not differ between groups preoperatively or at 12 weeks.
**Discussion:** Patients receiving liposomal bupivacaine experienced fewer complications than traditional ISCs after arthroscopic shoulder surgery. Analgesia, sleep, satisfaction, and functional scores were similar between the 2 groups.
**Level of evidence:** Level I; Randomized Controlled Trial; Treatment Study


**Keywords:** Liposomal bupivacaine; interscalene catheter; nerve block; shoulder; arthroscopy; complications; randomized controlled trial

Following shoulder surgery, patients often experience pain that may be challenging to manage. Multiple protocols and medications are available, but the goal of identifying the regimen that best manages pain while minimizing complications remains under investigation. In addition to oral medications, early postoperative pain control often includes a preoperative nerve block. In shoulder surgery, interscalene nerve blockade of the brachial plexus is a common approach for achieving regional anesthesia, which may be administered as a single-injection nerve block or via a continuous interscalene catheter (ISC) that remains for 48-72 hours postoperatively. Medications frequently selected for these blocks are sodium-channel blockers, such as bupivacaine or ropivacaine.

Liposomal bupivacaine (Exparel; Pacira BioSciences, Inc., Parsippany, NJ, USA) is a long-lasting anesthetic characterized by gradual bupivacaine release from multivesicular liposomes that is typically administered intraoperatively by the surgeon into the tissue directly at the surgical site.[1] Following its 2011 US Food and Drug Administration approval for this use,[3] liposomal bupivacaine's indications were subsequently broadened by the US Food and Drug Administration in 2018 to also allow for interscalene nerve blocks.[4]

Numerous studies have been conducted using liposomal bupivacaine to determine its efficacy and potential superiority over traditional pain management techniques in shoulder surgery. Given the variety of possible medication combinations and routes, the comparative shoulder surgery literature on this topic is predictably fragmented into multiple categories (Fig. 1). When administered directly at the surgical site in shoulder arthroplasty, liposomal bupivacaine has had mixed results in terms of pain scores and opiate consumption.[15,32] When compared to a nonliposomal anesthetic ISC for the same population, liposomal bupivacaine surgical site infiltration again was found to perform comparably.[2,25,31]

Similar results were found in the arthroscopic rotator cuff repair (RCR) literature in which single-injection, nonliposomal interscalene blocks have been compared to liposomal bupivacaine administered both at the surgical site[14,29] and as an interscalene block itself.[7,20,27] Mixed results have been presented, as liposomal bupivacaine both conferred some early and intermittent increased pain relief[14,20,27,29] or performed no different from the nonliposomal block.[7]

Given no marked difference in efficacy, a greater emphasis has subsequently been placed on the increased rate of complications among interscalene indwelling catheter patients.[25,31] Common sequelae of the catheter-based nerve block include the possibility of the block dislodging, discomfort or leakage at the catheter site, return visits to reposition or remove the catheter, and overall patient dissatisfaction.[7]

Although both traditional ISCs and liposomal bupivacaine have been shown to reduce pain and opiate consumption in patients undergoing RCR, no study in the literature has directly compared these 2 methods after arthroscopic shoulder surgery. As complications are commonly noted in the ISC literature, this was selected as the primary outcome of interest. We hypothesize that the single-injection liposomal bupivacaine block will have fewer complications than the ISC. Additionally, no difference is expected in postoperative pain control, opioid consumption, sleep quality and duration, and satisfaction and functional scores between study arms as secondary outcomes.

## Methods

A blinded, randomized controlled trial was employed to compare the control arm (continuous ropivacaine ISC) to the experimental arm (single-injection, brachial plexus nerve block using liposomal bupivacaine) in patients undergoing outpatient arthroscopic RCR at a single, tertiary academic institution. A parallel trial design was used. A power analysis was conducted at 0.8 with an alpha of 0.05, using liposomal bupivacaine and ISC complication rates calculated from prior literature.[13,25,28,30,31] This yielded a

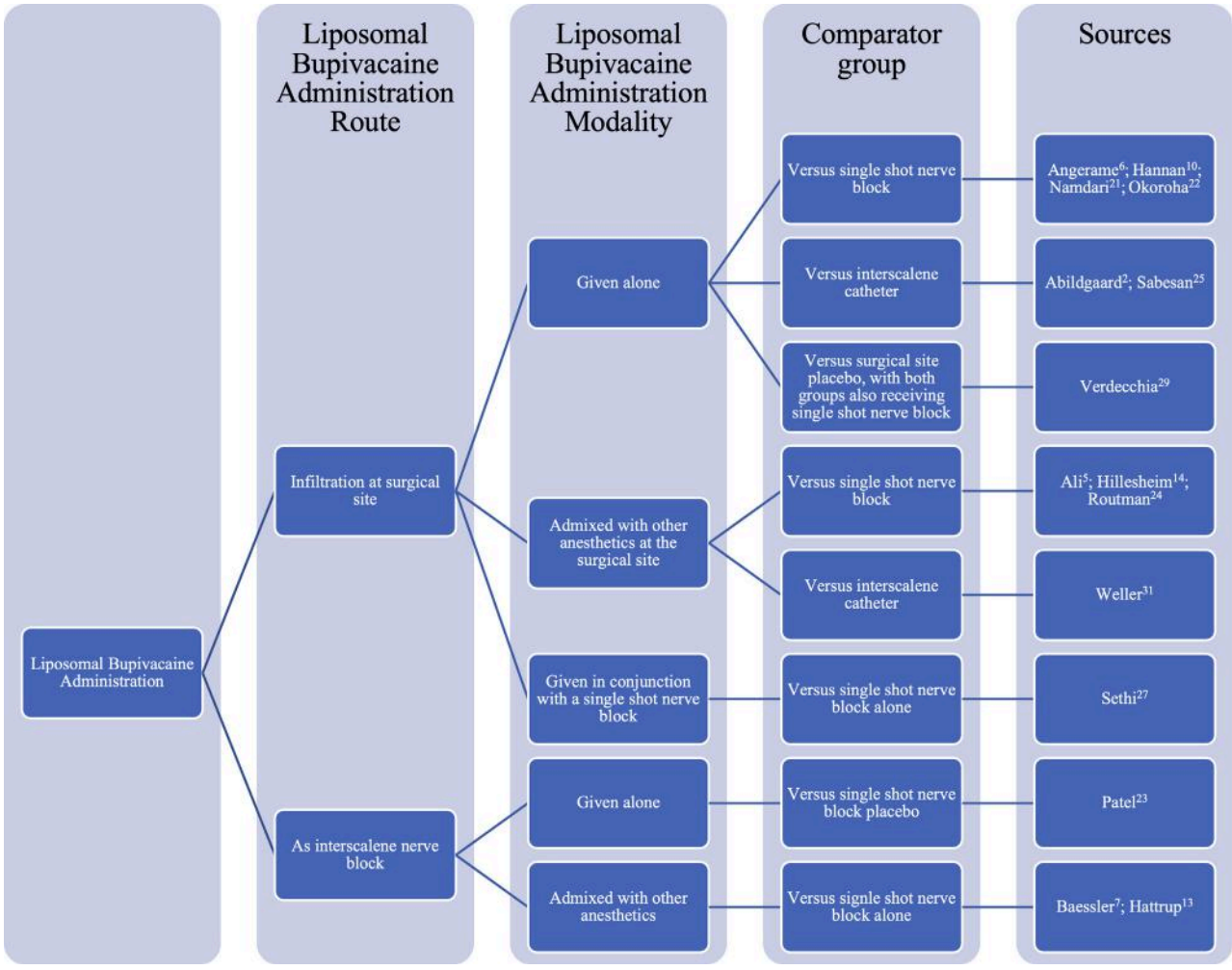


**Figure 1** Summary of current liposomal bupivacaine literature. All comparator group nerve block or catheter modalities utilized a nonliposomal anesthetic or placebo. Only the last name of the first author was listed in the sources column.

minimum of 26 patients per arm. Enrollment occurred between January 1, 2020 and September 1, 2021. Given difficulty with recruitment due to limited elective surgeries as a result of the COVID-19 pandemic, inclusion criteria were broadened in October 2020 to include any arthroscopic shoulder procedure, not solely RCR. No changes were made to study outcomes. Inclusion and exclusion criteria are detailed in Table I. Patients were consented and prospectively surveyed over a 12-week period. The study followed the Consolidated Standards of Reporting Trials[26] guidelines and was approved by our institutional review board and registered at www.clinicaltrials.gov (NCT03738696). This study did not receive any specific funding.

## Randomization

After initial phone consent, patients were enrolled and randomized 1:1 by the study research fellow into either the liposomal bupivacaine single-injection nerve block arm (LB) or ropivacaine ISC arm using the randomization module function within REDCap (Research Electronic Data Capture, Nashville, TN, USA),[11,12] an HIPAA-compliant, online data management system.

Patients and investigators were blinded to study arm allocation before intervention. The anesthesiology investigators became unblinded to randomization several days in advance of surgery to ensure adequate supply of the study drug. Patients were unblinded at the time of intervention when they were administered a single injection or catheter immediately preoperatively. The treating surgeons remained blinded throughout the study as they did not partake in the data collection or analysis, and by the first follow-up appointment, indwelling catheters were removed and primary, perioperative, patient-reported outcomes had been measured. All other nonsurgeon investigators remained blinded prior to data collection and only became unblinded when data were extracted from RedCap following the final patient survey. All study patients were surveyed with the same questions.

## Intervention

All blocks were performed in a preoperative block area. Using standard American Society of Anesthesiologists (ASA) monitoring, patients were sedated with incremental doses of intravenous midazolam and fentanyl. Each patient's skin was prepped

**Table I** Inclusion and exclusion criteria

Inclusion criteria:
- Undergoing outpatient arthroscopic shoulder surgery
- Greater than 19 years of age at the time of surgery

Exclusion criteria:
- Planned operative fixation of the acromioclavicular joint
- Opioid use within six weeks before surgery that is deemed to be chronic or excessive
- Gabapentin use within six weeks before surgery
- History of prior shoulder surgery on the operative side
- Severe pulmonary dysfunction
- Diagnosis of chronic pain, fibromyalgia, or other somatosensory disorder(s)
- History of radicular pain or neuropathy in the operative limb
- Patients who are currently incapacitated to make medical decisions or incarcerated individuals

with chlorhexidine prior to the procedure, and routine sterile technique was followed throughout the procedure. The C5 and C6 nerve roots were identified via a Sonosite X Porte ultrasound (Fujifilm, Tokyo, Japan), and those roots were used as the target for both the bolus of local anesthetics and the terminal location of the catheter tip. All blocks were performed by an anesthesiologist with advanced training in ultrasound guidance and peripheral nerve blocks.

Patients in the ISC arm had a 19 gauge Arrow Continuous Nerve Catheter (Teleflex, Wayne, PA, USA) placed with a bolus of 15-20 mL of 0.5% ropivacaine given through the needle prior to threading the catheter. An elastomeric, basal-only, On-Q infusion pump (Avanos Medical, Alpharetta, GA, USA) with 0.2% ropivacaine was started in the post-anesthesia care unit at 8 mL/hour, and the catheter was removed by the patient after two days. The rate of 8 mL/h is a well-substantiated rate in the literature and clinically in terms of pain relief and side-effects. For patients in the LB arm, 10 mL (133 mg) of liposomal bupivacaine (Pacira BioSciences, Parsippany, NJ, USA) mixed with 7 mL (35 mg) bolus of 0.5% bupivacaine was injected. This was compliant with the package insert recommending that the milligram dose ratio of bupivacaine to liposomal bupivacaine is no higher than 1:2.[4] The decision to administer 15-20 mL of 0.5% ropivacaine as the initial bolus in the ISC arm was founded in the desire to closely approximate the total bolus (17 mL composed of 10 mL of liposomal bupivacaine and 7 mL of 0.5% plain bupivacaine) in the LB arm.

Patients in both arms were discharged on post-operative day (POD) 0 and were prescribed two-week supplies of 4 scheduled, nonopioid analgesics: acetaminophen 1000 mg 3 times per day (TID), methocarbamol 500 mg TID, gabapentin 300 mg TID, and acetylsalicylic acid 325 mg daily. One opioid analgesic (oxycodone 5-10 mg every six hours as needed for pain; 7.5-15 morphine milligram equivalents [MMEs]) was also prescribed. Patients were surveyed on medication use with every perioperative phone survey. Nonopioid medications were dichotomously recorded as either consumed or not, while opioid medications were recorded based on the quantity consumed since the previous survey.

## Patient demographics

Patient demographics, including age, gender, body mass index (BMI), smokable tobacco consumption, operative time, intraoperative complications, ASA class, Charlson Comorbidity Index (CCI), and surgical procedures (RCR, subacromial decompression, biceps tenodesis, etc.), were recorded from the electronic medical record.

## Outcomes

A series of 9 perioperative phone surveys were conducted over POD 0-4 (one on the evening (PM) of POD 0, 8 additional calls every twelve hours). With the exception of the POD 0 PM survey, which asked patients about the hours since they were discharged, all surveys inquired about the interim period from the prior survey and evaluated all complication, pain, sleep, and medication use variables. The primary outcome was the overall complication rate which was a compilation of reported rates of the following: nausea, dyspnea, anesthetic site discomfort (none, mild, moderate, severe), anesthetic site skin irritation (none, mild, moderate, severe), anesthetic site leakage (none, mild, moderate, constant), and any additional, self-reported concerns or complications not otherwise captured.

Additionally collected variables included average and worst pain (0-10 scale, higher values representing increased pain), dose frequency of prescribed opioid analgesics, consumption of prescribed nonopioid analgesics, the longest period of uninterrupted sleep (in hours; only obtained during morning calls) and the subjective quality of sleep (0-10 scale, higher values representing better sleep), and overall satisfaction with pain control (five-point Likert scale, higher values representing increased satisfaction).

Standardized patient-reported outcome measures (PROMs) were obtained preoperatively and 12 weeks postoperatively. The PROMs included Visual Analog Scale (VAS, scored 0-10, with 0 representing no pain and 10 representing the most extreme pain), Single Assessment Numeric Evaluation (SANE), American Shoulder and Elbow Surgeons (ASES) Standardized Shoulder Assessment Form, and Penn Shoulder Score (PSS). Patient data obtained from phone surveys and medical records were stored within REDCap. Once all surveys were collected, data were exported and deidentified to investigators by REDCap's export encryption feature that converts patient identifiers into unrecognizable values.

## Data analysis

Data analysis was performed using IBM SPSS Statistics for Macintosh, version 27 (IBM Corp., Armonk, NY, USA). Prior to study arm comparison, a Shapiro-Wilk test was performed, which indicated non-normally distributed data. Therefore, patient age, BMI, operative time, perioperative pain scores, medication consumption, duration and quality of sleep, satisfaction, and preoperative and postoperative PROMs (VAS, SANE, ASES, and PSS) were compared using Mann-Whitney U tests. Additional patient demographics, including gender, smokable tobacco consumption, intraoperative complications, ASA classification, CCI scores,

surgical procedures, and 6 perioperative complications (nausea, dyspnea, anesthetic site discomfort and/or irritation and/or leakage, and self-reported complications), were compared with chi-squared tests. Graded measures, such as anesthetic site discomfort and irritation, were dichotomized based on severity, into ''none-to-mild'' and ''moderate-to-severe'' categories for analysis. Statistical significance was set to $P < .05$.

Complication rates were counted such that the endorsement of one particular complication across multiple time points for the same patient was recorded as a single event for the said complication. The primary variable, the overall complication rate, was calculated by summing individual complications and dividing it by the total number of potential case events (6 complications multiplied by the number of patients per group).

Shapiro-Wilk testing was again performed to evaluate data distribution across the procedure subtypes, which again confirmed non-normally distributed data. As such, Mann-Whitney U tests were used to also analyze the average perioperative pain, the total perioperative opiate consumption, and the total perioperative nonopioid consumption, stratified by the procedure subtype patients underwent.

## Results

### Demographics

Ninety-one patients were initially assessed for study inclusion. Of these individuals, 27 met exclusion criteria. Thus, 64 individuals were initially included, with 36 (56%) patients randomized into the ISC arm and 28 (44%) into the LB arm (Fig. 2). However, on the morning of surgery, one patient who was randomized to the ISC arm withdrew from the study without undergoing intervention, reducing the final ISC arm size to 35. In the perioperative period (POD 0-4), 33 out of the 35 ISC (94%) and all 28 LB patients responded to phone surveys. At the 12-week time point, 14 patients were lost to follow-up from ISC and 8 were lost from LB. All included patients received their assigned treatment.

The mean patient age was 54.2 ± 13.0 years in the ISC arm and 56.5 ± 12.9 years in the LB arm ($P = .489$). Other patient demographics, including gender, BMI, tobacco smoking history, operative time, ASA, and CCI, did not differ between study arms, and surgical procedures were largely consistent between arms (Table II). However, a greater proportion of LB arm patients underwent subacromial decompression (ISC: 77.1%; LB: 96.4%, $P = .030$). There were no intraoperative complications for either study arm.

### Primary and secondary outcomes

Complications were commonly reported in both study arms, with the overall complication rate lower for patients receiving liposomal bupivacaine than those receiving a catheter (ISC: 29.8%; LB: 13.1%, $P < .001$). Within the surveyed complications, anesthetic site discomfort (ISC: 36.4%; LB: 7.1%, $P = .007$) and leakage (ISC: 30.3%, LB: 7.1%, $P = .023$) were reported in fewer patients in the LB arm than in the ISC group. Nausea, dyspnea, and anesthetic site irritation were reported in a similar frequency of patients between groups. Free-response complaints were expressed in more ISC arm patients (ISC: 21.2%; LB: 3.6%, $P = .042$). These complaints included facial flushing/rash (ISC: 2 [6.1%]; LB: 0), ptosis (ISC: 3 [9.1%]; LB: 0), hand swelling (ISC: 1 [3.0%]; LB: 1 [3.6%]), and hemoptysis (ISC: 1 [3.0%]; LB: 0). No patient experienced more than one free-response complaint during the perioperative period (Table III).

There was no difference in the longest duration of sleep (ISC 4.4 ± 2.4 hours; LB 4.9 ± 2.5 hours, $P = .237$) or overall quality of sleep (ISC: 5.2 ± 2.6; LB 5.7 ± 2.5, $P = .212$) between arms over the perioperative period. Average patient satisfaction was rated excellent and was similar between study arms throughout the perioperative period (ISC: 4.4 ± 0.8; LB: 4.4 ± 0.9, $P = .641$).

Average pain between the ISC and the LB arms was found to be not different over the perioperative study period, although patients in the ISC tended to express higher pain levels (ISC: 3.5 ± 3.0; LB: 3.0 ± 2.7, $P = .108$). The greatest difference in average pain during the first four days postoperatively was reported on the morning following surgery (POD 1 AM; ISC: 3.4 ± 3.1; LB: 2.0 ± 2.8, $P = .062$) (Fig. 3). Similarly, worst pain was marginally greater in the ISC arm over the perioperative period (ISC: 4.5 ± 3.4; LB: 4.2 ± 3.3, $P = .237$). The greatest difference in worst pain was also found within the first 24 hours from surgery (POD 0 PM; ISC: 3.1 ± 3.7; LB:1.5 ± 2.9, $P = .075$). When average pain over the perioperative study period was analyzed by procedure type, there was increased pain among patients undergoing arthroscopic distal clavicle excision in the LB arm (ISC: 2.1 ± 2.3; LB: 3.3 ± 1.4, $P = .044$). No differences between LB and ISC arms existed in terms of pain across the remaining procedure subtypes.

No difference was observed in total opioid consumption over the perioperative period, with ISC patients cumulatively taking 58.5 ± 40.8 MMEs, compared to the 56.4 ± 42.9 MMEs in the LB arm ($P = .693$). There was also no difference in opioid consumption per call at each time point over the perioperative period (ISC: 7.8 ± 10.0 MMEs; LB: 7.0 ± 7.7 MMEs, $P = .832$). The greatest difference in opioid use was between the POD 2 PM and POD 3 AM time points, in which the ISC arm took on average 11.4 MMEs compared to 7.2 MMEs in the LB AM, but this did not reach significance ($P = .140$). Analysis of total opiate consumption over the perioperative study period by procedure type revealed that patients undergoing arthroscopic distal clavicle excision in the LB arm consumed more opiates than their ISC counterparts

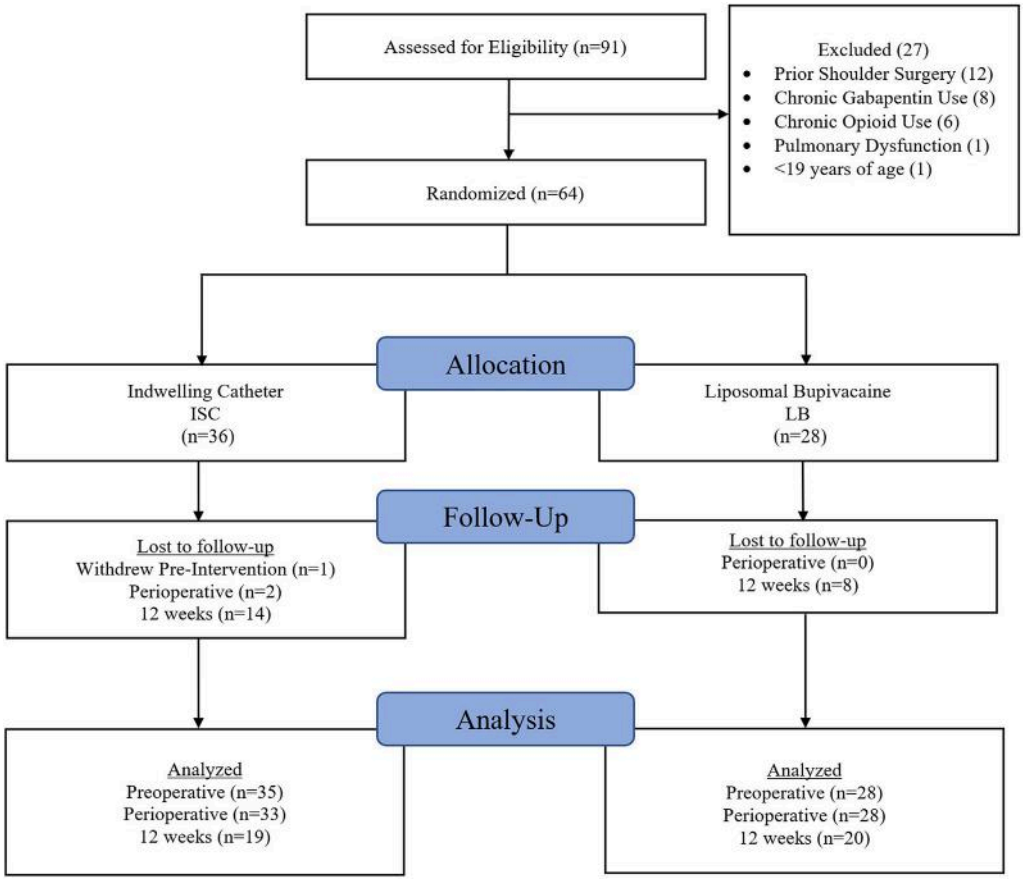


**Figure 2** Study flow diagram.

(ISC: 7.9 ± 7.0; LB: 14.2 ± 4.4, $P = .013$). The perioperative opiate consumption did not differ between study arms across the other procedures.

Similarly, there was no difference in consumption of the 4 nonopioid medications between study arms at any individual time point. However, patients in the ISC arm reported taking more of the scheduled nonopioid medications on average per call (1.8 ± 1.4) than patients in the LB arm (1.4 ± 1.3) ($P = .005$). Across the perioperative period, more ISC group patients consumed acetylsalicylic acid (ISC: 40.9%; LB: 23.4%, $P < .001$) and acetaminophen (ISC: 69.5%; LB: 59.6%, $P = .013$) as instructed. Although the ISC group also reported taking methocarbamol (ISC: 36.4%; LB: 29.9%) and gabapentin (ISC: 34.9%; LB: 31.1%) more frequently than LB, there were no differences between the 2 groups ($P = .118$ and $P = .362$, respectively). Patients in the ISC arm consumed more nonopioid medications over the entire perioperative period than patients in the LB arm when specifically undergoing arthroscopic RCR (ISC: 1.8 ± 1.4; LB: 1.5 ± 1.3, $P = .036$) and subpectoral biceps tenodesis (ISC: 2.0 ± 1.3; LB: 1.4 ± 1.0, $P = .004$). No difference was detected among the remaining procedures.

Preoperative patient-reported pain and functional scores (VAS, SANE, ASES, and PSS) were similar between study arms. All 4 of these measures improved between the preoperative and 12-week postoperative time points (Table IV), but there was no difference at the final time point between study arms.

## Discussion

This blinded, randomized controlled trial demonstrated that patients undergoing a single-injection interscalene nerve block using liposomal bupivacaine for arthroscopic shoulder surgery experience a significantly lower overall complication rate while having similar pain scores and other outcome measurements when compared to patients who received an ISC. Specifically, patients in the LB arm noted less anesthetic site discomfort and leakage and fewer free-response complications not otherwise captured by survey questions. These findings confirm the hypothesis and offer liposomal bupivacaine as a better-tolerated nerve block option than the historically considered standard of care indwelling catheter.

**Table II** Patient demographics

| Demographics | ISC (N = 35) | LB (N = 28) | *P* value |
|---|---|---|---|
| Gender | | | .954 |
| Male | 21 (60%) | 17 (60.7%) | |
| Female | 14 (40%) | 11 (39.3%) | |
| Age | 54.2 ± 13.0 | 56.5 ± 12.9 | .489 |
| Body mass index | 33.0 ± 5.8 | 31.8 ± 6.8 | .462 |
| Tobacco use | 9 (25.7%) | 7 (25.0%) | .985 |
| ASA | | | .314 |
| Class 1 | 2 (5.7%) | 0 | |
| Class 2 | 17 (48.6%) | 11 (39.3%) | |
| Class 3 | 16 (45.7%) | 16 (57.1%) | |
| Class 4 | 0 | 1 (3.6%) | |
| Charlson Comorbidity Index | | | .542 |
| 0 | 10 (28.6%) | 5 (17.9%) | |
| 1 | 8 (22.9%) | 3 (10.7%) | |
| 2 | 8 (22.9%) | 9 (32.1%) | |
| 3 | 4 (11.4%) | 5 (17.9%) | |
| 4 | 4 (11.4%) | 4 (14.3%) | |
| Operative time (minutes) | 84.6 ± 34.0 | 87.6 ± 25.3 | .473 |
| Operative procedure | | | |
| Rotator cuff repair | 28 (80.0%) | 25 (89.3%) | .316 |
| Biceps tenodesis (arthroscopic) | 8 (22.9%) | 7 (25.0%) | .427 |
| Biceps tenodesis (subpectoral) | 6 (17.1%) | 8 (28.6%) | .892 |
| Biceps tenotomy | 1 (2.9%) | 3 (10.7%) | .204 |
| Distal clavicle excision | 2 (5.7%) | 1 (3.6%) | .691 |
| Subacromial decompression | 27 (77.1%) | 27 (96.4%) | **.030** |
| Other | 18 (51.4%) | 10 (35.7%) | .212 |
| Intraoperative complications | 0 | 0 | – |

*ASA*, American Society of Anesthesiologists; *ISC*, interscalene catheter; *LB*, liposomal bupivacaine brachial plexus nerve block.
P values in bold are statistically significant, <0.05

**Table III** Perioperative patient complications

| Complications | ISC (N = 33) | LB (N = 28) | *P* value |
|---|---|---|---|
| Anesthetic site complications | | | |
| Discomfort | 12 (36.4%) | 2 (7.1%) | **.007** |
| Leakage | 10 (30.3%) | 2 (7.1%) | **.023** |
| Irritation | 3 (9.1%) | 1 (3.6%) | .385 |
| Other complications | 7 (21.2%) | 1 (3.6%) | **.042** |
| Facial flushing/rash | 2 (6.1%) | 0 | |
| Ptosis | 3 (9.1%) | 0 | |
| Hand swelling | 1 (3.0%) | 1 (3.6%) | |
| Hemoptysis | 1 (3.0%) | 0 | |
| Nausea | 15 (45.5%) | 8 (28.6%) | .175 |
| Dyspnea | 12 (36.4%) | 8 (28.6%) | .518 |
| Overall complication rate | 59 (29.8%) | 22 (13.1%) | **<.001** |

*ISC*, interscalene catheter; *LB*, liposomal bupivacaine brachial plexus nerve block.

In the present study, there was an overall 13.1% complication rate among LB patients, which is contrasted with the higher rate among ISC patients at 29.8% ($P < .001$). In a 2020 retrospective cohort study by Malige et al studying patients receiving liposomal bupivacaine as an interscalene block prior to shoulder surgery, there was an overall 16.5% rate of complications.[19] The majority of these (12.5% of all patients, 76% of all complications) were dyspnea and chest pain, followed by superficial skin reactions occurring in 1.7% of patients and thus accounting for 10% of all complications. Dyspnea was similarly one of the more common complications among patients in the LB

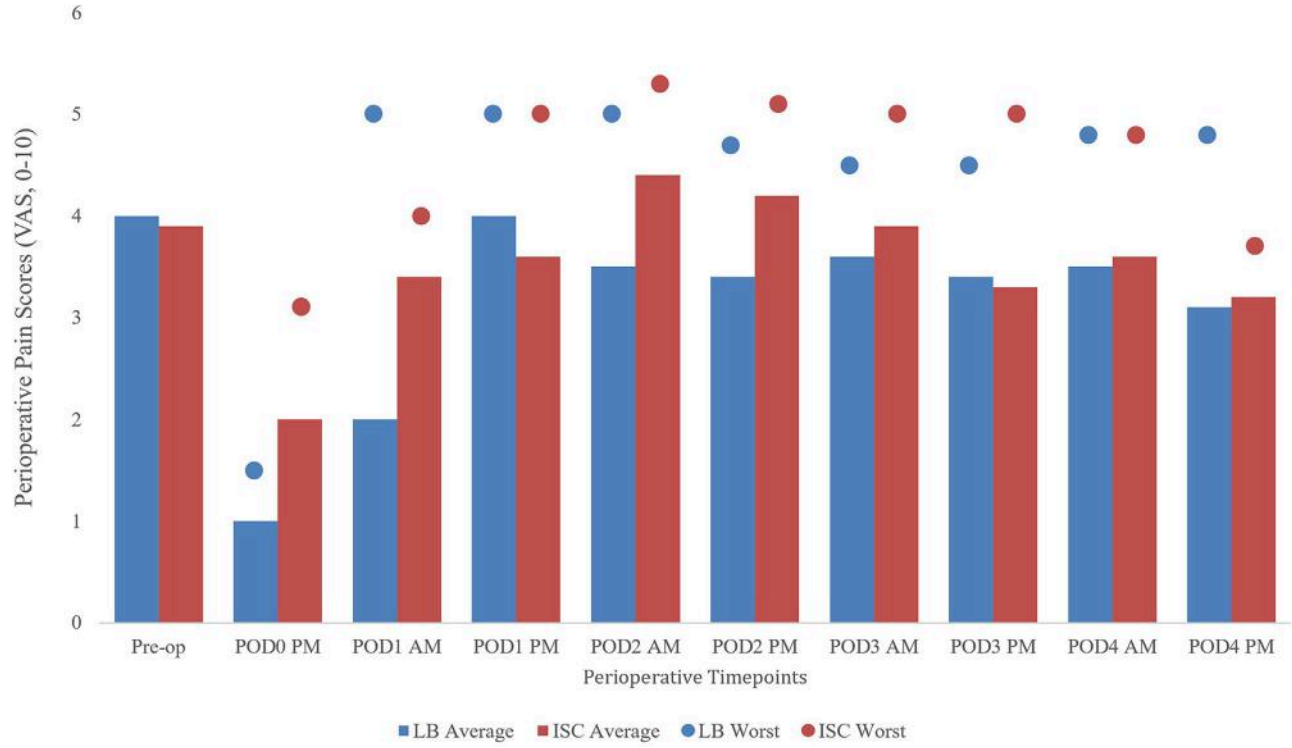


**Figure 3** Perioperative pain. *ISC*, interscalene catheter; *LB*, liposomal bupivacaine.

arm, in addition to nausea, but neither of which was significantly different from the ISC arm rates.

The overall complication rate in the ISC group was 29.8% with select outcomes (anesthetic site discomfort and leakage) occurring at rates over 6-fold that of the LB arm. There was additionally an increased trend within the ISC arm relative to the LB arm for other variables such as nausea and dyspnea, but this did not reach statistical significance. Such a difference might cross the said threshold study with a larger sample size and warrants additional

**Table IV** Functional scores

| Functional scores | Pre-Op | 12-w Post-Op | *P* value |
|---|---|---|---|
| ASES | | | |
| ISC | 44.2 ± 19.3 | 65.3 ± 25.6 | **<.001** |
| LB | 47.6 ± 17.9 | 73.2 ± 18.5 | **<.001** |
| *P* value | .300 | .411 | |
| PSS | | | |
| ISC | 41.2 ± 18.2 | 68.3 ± 23.8 | **<.001** |
| LB | 16.5 ± 41.7 | 74.1 ± 20.9 | **<.001** |
| *P* value | .776 | .461 | |
| VAS | | | |
| ISC | 3.9 ± 2.9 | 2.4 ± 2.8 | **.038** |
| LB | 4.0 ± 3.0 | 2.1 ± 2.2 | **.024** |
| *P* value | .995 | .749 | |
| SANE | | | |
| ISC | 42.6 ± 20.4 | 64.9 ± 24.1 | **.002** |
| LB | 39.1 ± 17.3 | 71.1 ± 19.5 | **<.001** |
| *P* value | .397 | .531 | |

*ASES*, American Shoulder and Elbow Surgeons; *ISC*, interscalene catheter; *LB*, liposomal bupivacaine brachial plexus nerve block; *PSS*, Penn Shoulder Score; *SANE*, Single Assessment Numeric Evaluation; *VAS*, Visual Analog Scale.
P values in bold are statistically significant, <0.05

research. These findings are concordant with multiple sources which note that nausea, dyspnea, catheter malfunction, and dislodgement are among the more common complications associated with indwelling catheters in this area.[9,25,31]

An important issue to consider in selecting a block for patients is the pulmonary status of the patient. Unlike catheter blocks, the duration of diaphragm paralysis with liposomal bupivacaine is unable to be modified. With a catheter block, clamping of the catheter will allow the diaphragm to recover over several hours, whereas a liposomal injection may require pulmonary support until the liposomes break down as there is no reversing agent that can be administered. Despite higher rates of complications, patients with potential pulmonary issues may be better served with a catheter over a liposomal block if longer-lasting relief than a traditional short-lasting block is desired. Patients with severe pulmonary dysfunction were excluded from the present study.

When used as a nerve block, liposomal bupivacaine has been shown to improve, or be equally as efficacious as a catheter for, postoperative pain control and opiate consumption in patients undergoing total shoulder arthroplasty and RCR[7,13,20,23] and a variety of shoulder girdle trauma procedures.[16] As a surgical site infiltrate, it demonstrates similar efficacy for pain control in total shoulder,[6,10,21,22,25] hip,[18] and knee[17] arthroplasty.

This study also demonstrates similar pain control efficacy between these 2 nerve block modalities as measured by both average and worst pain scores and total opiate requirement. This is similar to the existing literature in which liposomal bupivacaine interscalene blocks decrease pain[20] and opiate use[7,20] and fare no better than single-injection nonliposomal bupivacaine blocks in terms of perioperative pain control when compared directly.[7,13] Our results approached but did not reach statistical significance in confirming these findings, with ISC patients experiencing higher average pain levels over POD 0-4 ($P = .108$), specifically at the POD 1 AM time point ($P = .062$), and a higher worst pain level at POD 0 PM ($P = .075$). This is likely attributable to the decision to power this study so as to detect a difference in complication rates between study arms. It is possible that a larger sample size would have also been able to demonstrate a difference between these pain measures, specifically during this potentially critical first 24-hour window postoperatively in which the data suggest but do not confirm that liposomal bupivacaine outperforms the ISC. This is thus an area for potential future research.

As suggested by Ford et al, liposomal bupivacaine nerve blocks prior to arthroscopic shoulder surgery also serve as a viable model to decrease opiate consumption postoperatively.[8] In the present study, overall patient-reported opioid pain medication consumption and sleep did not differ over POD 0-4. However, should the similarity in pain between groups be a true finding and not a result of low power, then it may potentially be explained by the greater nonopioid pain medication consumption within the ISC group, which patients may have used to mitigate their increased pain. These results again suggest that liposomal bupivacaine is at least a similarly efficacious nerve block anesthetic as an ISC and does not increase opioid requirement. Larger studies to better appreciate if this reduction in pain is significant and to further elaborate a patient's use of opioid and nonopioid medication to control said pain would be helpful in the face of the ongoing opioid epidemic in the United States.[27]

Similarly, future work would be prudent in further exploring the increased perioperative pain and opiate consumption specifically among LB patients undergoing arthroscopic distal clavicle excision. This finding may be partly a function of the bony work performed during this procedure in comparison to the soft-tissue nature of the other procedures, but the explanation for why exactly the LB patients experience more pain—and the presumably associated increased opiate consumption—than the ISC patients requires additional investigation. The increased perioperative consumption of nonopioid medication among ISC patients undergoing RCR and subpectoral bicep tenodesis remains poorly explained with the current data. A larger sample size and targeted surveys may help elucidate the nature of these ISC patients' pain and medication consumption decision-making. More granular data collection of this variable would serve to determine if the disparities detected herein constitute a clinically important difference.

In addition to comparing the complication, pain, and medication rates between these 2 nerve block options, numerous other factors have been considered in the literature to help the orthopedic surgeon and anesthesiologist select the optimal pain control option. Liposomal bupivacaine nerve blocks, when compared to ISCs, have been noted to be less complicated, quicker (median 3.5 vs. 9 minutes),[16] and less expensive (average $289 vs. $1559 for an 82% reduction in cost).[31] Furthermore, this cost does not include potential additional encounters in the emergency department or clinic to address patient concerns regarding catheter complications or for catheter removal.

This trial was not without limitations. Despite successfully meeting the target sample size set by power analysis, this study nonetheless had difficulty recruiting patients, a fact largely attributed to the restrictions on elective surgery during the study period due to the COVID-19 pandemic. While this study nonetheless succeeded in detecting a difference between study arms for the primary outcome of overall complication rate, secondary measures such as pain scores only trended toward worse outcomes among patients in the ISC group. However, it is unknown if significance was not met for this analysis due to inadequate power for this variable or if no true difference exists. Further investigation with larger cohorts using various measures of pain, including the postoperative usage of rescue medication in the post-anesthesia care unit, as well as opioids and nonopioid medications after discharge, is warranted.

As a corollary to the difficulty recruiting study patients during this pandemic, the inclusion criteria were broadened during the trial to include patients undergoing any arthroscopic shoulder procedure, not exclusively RCR. This limits the generalizability of the study to a rotator cuff population but does allow for some interpretation of the findings across a larger collection of patients that is still relatively narrow in the context of orthopedic surgery. Given that the primary objective of this study was to assess complication rates, not pain, between nerve block options, it was felt that including other shoulder pathologies and procedures would have a minimal effect on the primary outcome. This rationale also extends to patients who underwent a subpectoral biceps tenodesis as part of their arthroscopic RCR; any confounding effect that may exist by the inclusion of this nonarthroscopic portion of the procedure is likely mitigated by the similar rates ($P = .892$) of subpectoral biceps tenodesis between study arms.

The generalizability of this study is otherwise also affected by the decision to exclude patients who used opioids or gabapentin within six weeks of study enrollment. While this limits the central nervous systemmodulating effects of these drugs as potential confounders during the study, it is not uncommon for the typical patient with a rotator cuff tear, or other shoulder girdle pathology, to be on these medications immediately preoperatively in the general public.

One patient withdrew from the ISC arm prior to any intervention and thus was not analyzed. During the perioperative period, only 2 patients were lost to follow-up, both also belonging to the ISC arm. As a result, of the 63 patients who were randomized and underwent study intervention, 61 of them (97%) were included in the perioperative, POD 0-4, data collection during which the primary outcome was measured. Fifty-four percent of ISC and 71% of LB patients had 12-week data collected, demonstrating a notable lost-to-follow-up rate for this time point. The effect of this is limited, however, to the only assessments performed at this time, the functional scores.

## Conclusion

The study suggests that interscalene nerve blocks using single-injection liposomal bupivacaine result in fewer complications while providing similar perioperative analgesia compared to conventional indwelling ropivacaine catheters in patients undergoing arthroscopic shoulder surgery.

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