JSES International 4 (2020) 357–361

Contents lists available at ScienceDirect

JSES International

journal homepage: www.jsesinternational.org

Efficacy of local infiltration anesthesia versus interscalene nerve blockade for total shoulder arthroplasty

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ARTICLE INFO

Keywords:
Bupivacaine
interscalene
analgesia
opioid
pain
shoulder arthroplasty

Level of evidence: Level III; Retrospective Cohort Comparison; Treatment Study

Background: Optimal modalities for pain control in shoulder arthroplasty are not yet established. Although regional nerve blockade has been a well-accepted modality, complications and rebound pain have led some surgeons to seek other pain control modalities. Local injection of anesthetics has recently gained popularity in joint arthroplasty. The purpose of this study was to evaluate the effectiveness and complication rate of a low-cost local anesthetic injection mixture for use in total shoulder arthroplasty (TSA) compared with interscalene brachial plexus blockade.

Methods: A total of 314 patients underwent TSA and were administered general anesthesia with either a local injection mixture (local infiltration anesthesia [LIA], n = 161) or peripheral nerve block (PNB, n = 144). Patient charts were retrospectively reviewed for postoperative pain scores, 24-hour opioid consumption, and 90-day postoperative complications.

Results: Immediate postoperative pain scores were not significantly different between groups ($P = .94$). The LIA group demonstrated a trend toward lower pain scores at 24 hours postoperatively ($P = .10$). Opioid consumption during the first 24 hours following surgery was significantly reduced in the LIA group compared with the PNB group ($P < .0001$). There was a trend toward fewer postoperative nerve and cardiopulmonary complications in the LIA group than the PNB group ($P = .22$ and $P = .40$, respectively)

Conclusion: Periarticular local injection mixtures provide comparable pain control to regional nerve blocks while reducing opioid use and postoperative complications following TSA. Local injection of a multimodal anesthetic solution is a viable option for pain management in TSA.

Postoperative pain management is an important variable that requires careful consideration for patients undergoing total shoulder arthroplasty (TSA). Anesthetic technique can influence factors such as pain relief, length of hospital stay, participation in physical therapy, and patient satisfaction.[7,14,20,30] With the growing opioid epidemic, a greater emphasis is being placed on alternative pain management strategies aimed at reducing the prescription and consumption of opioids.

Peripheral nerve blockade, such as interscalene brachial plexus blockade, is a common anesthetic technique for TSA that has proved effective for controlling pain up to 8 hours after surgery.[21,22] However, after the effects of a peripheral nerve block (PNB) wear off, there can be a sharp increase in pain scores and narcotic utilization from 8-24 hours.[21,22] Previous studies have investigated the safety of interscalene brachial plexus blockade for patients undergoing shoulder surgery.[4,6,26] Clinical examination and electromyography showed that 14% of patients had nerve-related complications 10 days after surgery whereas 2.1%-3.9% of patients experienced complications lasting up to 3 months postoperatively.[4,6,26] These complications consisted of carpal tunnel syndrome, complex regional pain syndrome, sensory neuropathy, and brachial plexus damage.

Periarticular injections including long-lasting liposomal bupivacaine as well as bupivacaine and ropivacaine anesthetic cocktails are also widely used in total joint arthroplasty. Liposomal bupivacaine has been shown to provide safe and long-lasting analgesia for up to 72 hours after surgery.[7,9,12,14,20,30] In addition, studies have shown that patients administered liposomal bupivacaine displayed comparable pain scores and opioid use to patients who received

This study was approved by the Institutional Review Board at Penn State Health Hershey Medical Center (study no. 00011215).

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https://doi.org/10.1016/j.jseint.2019.12.007

peripheral nerve blockade during the first 24 hours following TSA.[21,22,29]

Although the use of bupivacaine and ropivacaine cocktails is less common in TSA, they are commonly used and effective for total hip and knee arthroplasty. Several studies have directly compared liposomal bupivacaine, bupivacaine and ropivacaine cocktails, and peripheral nerve blockade in total hip and knee arthroplasty.[3,7,8,10,13,14,18,30] They concluded that all 3 modalities provided similar pain relief whereas periarticular injection reduced the risk of nerve complications associated with peripheral nerve blockade. Bupivacaine and ropivacaine cocktails provide the additional benefit of being significantly lower in cost compared with both liposomal bupivacaine and regional nerve blockade.[3,8,13,22,28,29]

Because bupivacaine and ropivacaine injection cocktails have proved a viable method of postoperative pain control in total hip and knee arthroplasty, further investigations regarding their use in shoulder arthroplasty are warranted. The anesthesia technique of the senior author was modified in 2015 to use local infiltrate anesthesia in an attempt to manage postoperative pain and reduce nerve injury complications. The purpose of this study was to compare postoperative pain scores and opioid consumption following TSA for patients receiving either regional anesthesia via PNB or local infiltration anesthesia (LIA) with a mixture of ropivacaine, morphine, epinephrine, and ketorolac. We hypothesized that patients receiving LIA would demonstrate similar pain scores and opioid use following surgery to patients receiving PNB whereas the frequency of nerve-related complications would be reduced.

Methods

Patient selection

A shoulder arthroplasty registry database containing all patients who underwent shoulder surgery performed at a single institution by a single fellowship-trained shoulder surgeon was queried. From this registry, 305 patients who underwent TSA and reverse TSA from 2012-2018 were included in this study. Of the patients, 144 were administered general anesthesia with regional anesthesia (PNB) from June 21, 2012, to December 13, 2015. The interscalene nerve block was performed by anesthesiologists who are facile and skilled in this procedure. Nerve blocks were performed under ultrasound guidance with nerve stimulation as indicated by the anesthesiologist. PNB was considered successful if the nerve was visualized under ultrasound and the anesthetic was appropriately administered. From December 14, 2015 to June 25, 2018, 161 patients who underwent shoulder arthroplasty were administered general anesthesia in addition to a local injection consisting of a mixture of 0.25% ropivacaine, morphine, epinephrine, and ketorolac (LIA). This solution was a weight-based mixture that was prepared preoperatively in the hospital pharmacy and administered by the operative surgeon intraoperatively. For a 75- to 99.9-kg patient, this mixture includes a 120-mL total dose containing 60 mL of ropivacaine 0.5%; 0.2 mL of epinephrine, 1 mg/mL; 1 mL of ketorolac, 30 mg/mL; 0.5 mL of morphine, 10 mg/mL; and 58.3 mL of normal saline solution 0.9%. The solution was injected both in and around the joint; this included the glenohumeral joint, deltoid, and subacromial space, as well as the subcutaneous tissue surrounding the incision. Only patients who underwent anatomic, reverse, or revision reverse TSA were included. All procedures were performed by the same surgeon, in the same manner, with standard implants. There was no change in this established surgeon's technique during the study period from 2012 to 2018. Patients who underwent hemiarthroplasty, those with incomplete medical records, and those with known psychiatric illnesses were excluded.

Data collection

After eligible patients were identified from the registry, patient charts were retrospectively reviewed to obtain the data for analysis. Demographic data including sex, age, body mass index, surgical procedure, and complications were recorded. Primary outcome measures were numeric rating scale pain scores and 24-hour postoperative opioid consumption. Pain scores were recorded immediately prior to surgery, immediately following surgery in the postanesthesia recovery unit, and 24 hours postoperatively. Total opioid consumption was also recorded for the first 24 hours following surgery and converted to standard morphine equivalent units (MEUs). Intraoperative narcotic use was not included in the calculation. Secondary outcome measures included length of surgery, operating room time, perioperative anesthesia time, blood loss, hospital length of stay, and intraoperative and 90-day postoperative complication rates. Postoperative complications were further categorized as nerve related, cardiopulmonary, and musculoskeletal (fracture or tendon rupture).

Statistical analysis

Statistics were compared between groups using a 2-sample *t* test for normally distributed variables. The Wilcoxon rank sum test was used for non–normally distributed variables. A general linear model with correlated errors was used to account for repeated pain score assessments over time for each subject. The Fisher exact test was used for categorical variables. Summary statistics were reported as the mean and standard deviation for data analyzed using the 2-sample *t* test and general linear models. The median and 25th and 75th percentiles were reported for the Wilcoxon rank sum test. The frequency (ie, n) and percentage were reported for data analyzed using the Fisher exact test. A *P* value of .05 was designated as the threshold for statistical significance.

Results

The mean patient age was 66.8 ± 10.3 years in the LIA group and 68.3 ± 8.2 years in the PNB group ($P = .16$). The LIA group consisted of 77 male patients (47.8%) and 84 female patients (52.2%), whereas the PNB group contained 92 male patients (63.9%) and 52 female patients (36.1%); the difference was statistically significant ($P = .006$). The mean patient body mass index was 31.6 ± 6.8 kg/m^2 and 32.7 ± 6.5 kg/m^2 in the LIA and PNB groups, respectively ($P = .15$). In the LIA group, 107 patients (66.5%) underwent anatomic TSA, 48 (29.8%) underwent reverse TSA, and 6 (3.7%) underwent revision reverse TSA. This was significantly different from the PNB group, in which 114 patients (79.2%) underwent anatomic TSA, 28 (19.4%) underwent reverse TSA, and 2 (1.4%) underwent revision reverse TSA ($P = .03$; Table I).

Preoperatively, the LIA and PNB groups displayed average pain scores of 3.7 ± 3.2 points and 3.7 ± 3.3 points, respectively ($P = .91$). Immediately following surgery, patients receiving LIA displayed an average pain score of 4.7 ± 3.5 points compared with 4.8 ± 3.4 points in those receiving PNB ($P = .90$). The average 24-hour postoperative pain scores were 4.0 ± 2.6 points in the LIA group and 4.4 ± 2.7 points in the PNB group, which trended toward significance ($P = .10$; Fig. 1). Patients receiving LIA demonstrated median opioid use of 31.5 MEUs (25th percentile, 19.0 MEUs; 75th percentile, 51.5 MEUs) compared with 47.5 MEUs (25th percentile, 26.8 MEUs; 75th percentile, 72.0 MEUs) in those receiving PNB. The difference was statistically significant ($P < .0001$; Fig. 2).

Table I
Comparison of population demographic data in LIA and PNB groups

Variable	LIA	PNB	*P* value
Age, yr	66.8 ± 10.3	68.3 ± 8.2	.16
Sex, n (%)			
Male	77 (47.8)	92 (63.9)	.006
Female	84 (52.2)	52 (36.1)	
BMI, kg/m^2	31.6 ± 6.8	32.7 ± 6.5	.15
Total shoulder arthroplasty, n (%)			
Anatomic	107 (66.5)	114 (79.2)	.03
Reverse	48 (29.8)	28 (19.4)	
Revision reverse	6 (3.7)	2 (1.4)	
Hospital length of stay, d	1.0 (1.0-1.0)	2.0 (2.0-2.0)	<.0001

LIA, local infiltration anesthesia (local injection mixture); *PNB*, peripheral nerve block; *BMI*, body mass index.
Data are presented as number of patients, mean ± standard deviation, or median (25th percentile–75th percentile).

The mean surgery length was 123.0 ± 36.3 minutes in the LIA group and 117.8 ± 20.5 minutes in the PNB group, which was not significantly different ($P = .68$). The mean operating room time was 185.4 ± 37.3 minutes in the LIA group and 185.8 ± 26.5 minutes in the PNB group ($P = .20$). However, an additional 25.0 ± 10.1 minutes of perioperative anesthesia time was required for nerve catheter placement in the PNB group, whereas patients receiving LIA required no additional time. Blood loss was similar between groups ($P = .69$). The median hospital length of stay was 1 day (25th percentile, 1 day; 75th percentile, 1 day) in the LIA group and 2 days (25th percentile, 2 days; 75th percentile, 2 days) in the PNB group, which was statistically significant ($P < .0001$).

No 90-day postoperative nerve complications occurred in the LIA group, whereas 2 patients who received PNB (1.4%) had nerve complications ($P = .22$). Both patients experienced wrist drop as well as persistent pain in the thumb and index finger for 6 months after surgery in one patient and numbness in the index and middle fingers lasting for 13 months in the other patient. Ninety-day postoperative cardiopulmonary complications occurred in 5 patients in the LIA group (3.1%) compared with 8 patients in the PNB group (5.6%) ($P = .40$). These included deep venous thrombosis, hematoma, stroke, myocardial infarction, and severe hypoxia with saturation of less than 80% requiring intensive care unit admission. There were 2 intraoperative musculoskeletal complications in the LIA group (1.2%), both of which were fractures and unrelated to the anesthesia. One was a fracture of the anterior glenoid during baseplate insertion, and the other was an intraoperative fracture of the greater tuberosity. No intraoperative musculoskeletal complications occurred in the PNB group. This difference was not significant ($P = .50$). In the LIA group, 2 patients (1.2%) experienced musculoskeletal complications in the 90-day postoperative time frame. One was a fracture of the greater tuberosity, and the other was a subscapularis tendon rupture. In the PNB group, 1 patient (0.7%) experienced musculoskeletal complications in the 90-day postoperative time frame: a stress fracture of the acromion ($P > .99$; Table II).

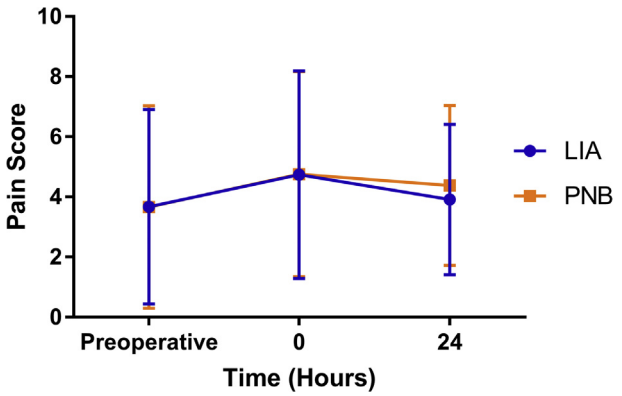

Figure 1 Graph depicting numeric rating scale pain scores preoperatively as well as 0 and 24 hours postoperatively. Data are presented as mean values, with *error bars* indicating standard deviations. No significant difference was noted between groups at any time point ($P > .05$). *LIA*, local infiltration anesthesia (local injection mixture); *PNB*, peripheral nerve block.

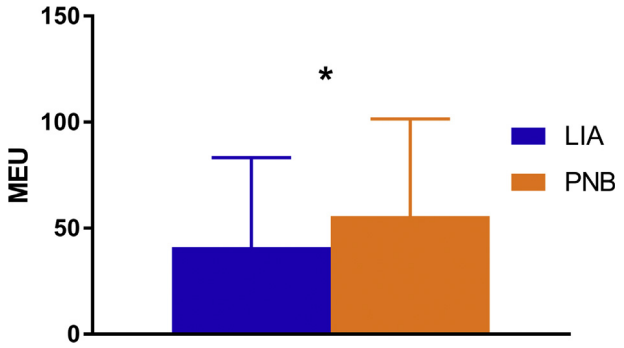

Figure 2 Bar graph depicting total narcotic use in morphine equivalent units (*MEU*) during first 24 hours following surgery. *Error bars* indicate 25th and 75th percentiles. *Significant difference ($P < .0001$). *LIA*, local infiltration anesthesia (local injection mixture); *PNB*, peripheral nerve block.

Discussion

Patients undergoing shoulder arthroplasty with general anesthesia and a periarticular local injection cocktail containing ropivacaine used less morphine in the first 24-hour postoperative period than patients undergoing shoulder arthroplasty under general anesthesia with preoperative regional PNB ($P < .0001$). Both groups had similar postoperative pain scores. Length of stay averaged 1 day for the local anesthesia group compared with 2 days for the regional block group ($P < .0001$). Patients with the local injection of analgesic also had a trend toward fewer postoperative nerve and cardiopulmonary complications compared with those who underwent PNB ($P = .22$ and $P = .40$, respectively).

Shoulder arthroplasty, as in the case of many surgical procedures, has evolved regarding pain control options. Whereas opioids have been the mainstay of treatment in the past after general anesthesia, regional blocks and local anesthetic have become the new norm. Multimodal pain management techniques have evolved to help decrease postoperative opioid requirements and use in an effort to provide better and more consistent pain control. This, in turn, has helped improve patient safety while also battling the current opioid epidemic. Periarticular local injections such as bupivacaine liposome injectable suspensions or cocktails containing bupivacaine or ropivacaine have been shown to be successful for postoperative analgesia in hip and knee arthroplasty.[3,7,8,10,19,30] Although several studies have investigated the use of liposomal

Table II
Comparison of intraoperative and postoperative complication rates between LIA and PNB groups

Type	Complications, n (%)		*P* value
	LIA	PNB	
Intraoperatively	2 (1.24)	0 (0)	.50
90 d postoperatively			
Musculoskeletal	2 (1.24)	1 (0.69)	>.99
Nerve	0 (0)	2 (1.39)	.22
Cardiopulmonary	5 (3.11)	8 (5.56)	.40

bupivacaine in the setting of TSA, the efficacy of local injection cocktails remains less well characterized.[1,20,22,24,27]

This study focused on 2 cohorts of patients. The first group underwent general anesthesia and was treated with a preoperative interscalene brachial plexus blockade (PNB) performed by an anesthesiologist. The second group also underwent general anesthesia for the procedure but received a periarticular injection of a local anesthetic solution administered by the operative surgeon intraoperatively (LIA). Opioid use, reported in MEUs, during the first 24 hours postoperatively was significantly less in the LIA group compared with the PNB group. During this period, both groups showed similar pain scores.

Nerve injuries after regional anesthetic are well documented, with some authors abandoning the use of regional anesthesia in shoulder arthroplasty because of the high complication rate.[4,6,11] In the PNB group, 2 patients (1.4%) had postoperative nerve complications including wrist drop as well as pain in the thumb and index finger in one patient and numbness in the second and third digits in the other. This persisted for 6 months and 13 months, respectively, after surgery. No patient in the LIA group experienced a nerve-related complication. Although the PNB group demonstrated a higher rate of nerve-related complications, this difference did not reach statistical significance ($P = .20$). Similar findings for long-lasting complications with an interscalene nerve block have been shown in other studies.[2,5,16,28] There was also a trend, although not statistically significant, in this study toward decreased cardiopulmonary-related complications in the LIA group compared with the PNB group ($P = .40$). There was no significant difference in intraoperative complications between the groups ($P = .50$).

One unexpected finding of this study was that length of stay was decreased in the local injection group. We believe part of this effect was related to the fact that it was our routine to wait for the block to wear off to allow for sensation and motor function to return to baseline. We preferred to allow this to happen in the hospital to ensure adequate pain control prior to discharge. This was intended to address any rebound pain as a result of the regional anesthesia. Namdari et al[21] showed that patients who received interscalene brachial plexus blockade experienced rebound pain at 24 hours. This effect was not encountered in the group undergoing local intraoperative soft-tissue infiltration of bupivacaine liposome injectable suspension in their study.[21] Although other studies did not demonstrate a change in length of stay, similar increases in narcotic requirements after the regional block effect had worn off have been observed in prospective studies.[1,22] In our practice with local anesthetic injection (ie, LIA), patients do not experience rebound pain, and we no longer anticipate a 2-day length of stay, counseling patients to anticipate a discharge home on post-operative day 1. The causation of this effect is not fully understood and may not be related directly to the anesthetic administered. Similar findings of a decreased length of stay with use of local anesthetic infiltration during hip and knee arthroplasty have been reported in a systematic review and meta-analysis.[18]

Primarily because of cost concerns, we chose not to use a liposomal bupivacaine injectable suspension. At our institution, we have a history of using the local injection “cocktail” solution for knee arthroplasty in place of liposomal bupivacaine. Studies have evaluated the use of liposomal bupivacaine and have noted good pain control, with the limitation of a sometimes prohibitive cost.[3,8,10,15,17] Prior studies have also shown similar effectiveness with local anesthetic and analgesic mixtures compared with liposomal bupivacaine.[13,23] Although a cost analysis was not formally completed in this study, the price of the injection was a factor in determining treatment protocols. The cost of bupivacaine liposome injectable suspension has been reported to be as much as $315.[3,22] The cost of the weight-based injection mixed in a hospital pharmacy similar to that used is our study is approximately $25.[3,8,13] In contrast to regional anesthesia, local injections can be performed in minimal time, usually less than a minute, and the cost is negligible when considering the cost of operative time. In this study, length of surgery and operating room time were comparable between groups ($P = .68$ and $P = .20$, respectively), which suggests that the time required to administer local injections is minimal. The cost of regional anesthetic supplies, ultrasound use, and professional fees has been cited to range from $1500-1800.[22,28,29] The cost-effectiveness of periarticular injection solutions has also been supported in the hip and knee literature.[3,7,8,10] A secondary cost benefit of local injections that should also not be overlooked is improved operating room efficiency. On average, an additional 25.0 minutes was required to administer the regional block in the PNB group, whereas no additional time was required in the LIA group. With this decrease in perioperative time in the LIA group, such cases have the potential to start more promptly, most notable with on-time first-start cases of the day. Reduced perioperative time also allows for faster turnover times between cases.

There are a number of limitations of this study. This is a cohort comparison of 2 groups owing to a change in standard practice for pain control following total joint replacement at our institution. Thus, no randomization was performed; rather, the groups were formed by the time frame in which the procedure was performed. The LIA group had a higher proportion of reverse shoulder arthroplasty to anatomic arthroplasty, as well as an increased number of revision arthroplasties, compared with the PNB group. In addition, the local analgesic injection is a mixture formulated at our institution. This mixture is easily reproducible, and previous studies have shown similar pain control effectiveness with a variety of medication mixtures.[8,13,14] Bupivacaine liposome injectable suspension was not used in this study, although this medication is often used for local injections in the literature; thus, its effectiveness cannot be directly compared with our data. In addition, non-narcotic multimodal pain medications and preoperative pain medications were not included in the analysis. Another limitation is the lack of concise data on pain during the immediate post-operative to 24-hour postoperative period. Because of lack of consistent documentation of pain scores and timing, this information is not available in this study. This could allow for some unknown variance in pain scores with the 2 methods prior to the 24-hour assessment.

No patients in our study received both regional nerve block and periarticular local injection. In the setting of regional anesthesia, adjunctive treatment with periarticular local anesthetic injection has been shown to provide no additional benefit regarding improved pain control or decreased postoperative narcotic use.[20,25]

Conclusion

Periarticular injection of a local anesthetic solution that was mixed at our institution provides reliable and consistent pain control with a trend toward less immediate postoperative opioid use after TSA compared with regional blocks. In addition, fewer complications were observed and length of stay was shorter with local anesthetic compared with regional blocks. Periarticular local injection of a multimodal anesthetic solution is a viable option for pain management in TSA patients and has become our institution's preferred method.

Disclaimer

Allen R. Kunselman has stock options of less than $5000 in Merck and is a biostatistician for a clinical trial funded by Guerbet, USA.

April D. Armstrong is a consultant for Zimmer Biomet.

The other authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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