Postoperative pain control is a primary concern for surgeons and patients undergoing total joint arthroplasty. Poorly managed postoperative pain can compromise patient satisfaction, rehabilitation, and outcomes. The use of parenteral narcotics has been the mainstay of treatment for acute postoperative pain. However, the use of opioid pain medication is associated with increased cardiac, respiratory, gastrointestinal, and neurologic adverse events. Further, wound complications may be more common with the use of opioid analgesics as a result of respiratory depression and lower blood oxygen tension. These effects are potentiated by a higher volume of pharmacologic distribution and decreased renal clearance in the elderly population, a group that accounts for a substantial portion of patients undergoing total joint arthroplasty.

For these reasons, providers tend to prescribe suboptimal doses of pain medication. Some reports on total joint arthroplasty have focused on alternative forms of pain control.

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A commonly used perioperative pain control modality during total shoulder arthroplasty is interscalene brachial plexus block (interscalene block).\textsuperscript{11-13} Interscalene block is associated with less postoperative pain and narcotic use, less nausea, shorter hospital stay, and fewer unplanned hospital admissions.\textsuperscript{14} However, these blocks are not without complications, and they are costly.\textsuperscript{14-16} In addition, the block can wear off during the nighttime hours after surgery and ultimately may lead to worse overall patient satisfaction.\textsuperscript{17-19}

A recent innovation in multimodal pain therapy is intraoperative injection of extended-release liposomal bupivacaine. Orthopedic studies have found liposomal bupivacaine to last longer, decrease time to rescue opioid medications, and reduce total postoperative opioid use.\textsuperscript{20-23} Decreasing inflammation and blocking pain receptors at the surgical site may help to prevent central sensitization and neuropathic pain.\textsuperscript{24} In 2011, the US Food and Drug Administration approved Exparel (Pacira Pharmaceuticals, Inc, Parsippany, New Jersey), an extended-release liposomal bupivacaine, for intraoperative periarticular injection. One recent study assessed pain control with injectable bupivacaine compared with interscalene block and found no major difference in pain scores throughout the immediate postoperative period.\textsuperscript{25} However, this study included a heterogeneous mix of primary anatomic total shoulder and reverse total shoulder arthroplasty procedures performed by several surgeons. The goal of the current study was to assess postoperative pain control in a homogeneous cohort of patients undergoing primary anatomic total shoulder arthroplasty by a single surgeon with use of injectable extended-release liposomal bupivacaine vs interscalene block.

**Materials and Methods**

This retrospective study was approved by the institutional review board at the study institution and included 79 consecutive patients who underwent total shoulder arthroplasty during a 16-month period. All procedures were performed by a single fellowship-trained shoulder and elbow surgeon (N.H.). The study included patients (1) who were older than 18 years; (2) who underwent unilateral primary total shoulder arthroplasty for either osteoarthritis of the glenohumeral joint or avascular necrosis of the humeral head; and (3) who received, in addition to general anesthesia, either periarticular injection of extended-release liposomal bupivacaine at the time of surgery or a single preoperative interscalene brachial plexus block (interscalene block) of the operative extremity. Excluded from the study were patients (1) who had prolonged hospital stay that was clearly documented as a result of complications with medical comorbidities unrelated to total shoulder arthroplasty and (2) who received neither or both of the types of anesthesia being studied (liposomal bupivacaine periarticular injection or interscalene block). Patients chose which type of anesthesia they would like to receive after discussion of the risks and benefits with the surgeon. Patients were separated into 2 cohorts based on whether they received liposomal bupivacaine or interscalene block.

The primary outcome measure was the Numeric Pain Rating Scale (NPRS) score during hospitalization after total shoulder arthroplasty. The NRPS scores were obtained from the electronic medical record and were recorded every 4 to 6 hours. To mitigate the effect of missing NRPS data as a result of inconsistent documentation, pain scores were averaged across 12-hour segments. Repeated measures analysis of variance with least square means was used to assess longitudinal changes in the NPRS score.

Secondary outcome variables included postoperative opioid use, length of hospital stay, independent variables, and complications. All opioid analgesics were administered on an as-needed basis, and no patient-controlled analgesia or scheduled opioids were ordered. Postoperative opioid use was tabulated by converting all doses of opioids given in the postoperative period into morphine equivalents with the opioid dose calculator developed by the Washington State Agency Medical Directors’ Group used in conjunction with the Interagency Guideline on Opioid Dosing for Chronic Non-cancer Pain.\textsuperscript{26} Differences in length of stay, total morphine equivalents, and age were assessed with Wilcoxon tests. Sex differences were assessed with a chi-square test.

For this study, 69 patients met the criteria to be included in the analysis. One patient was excluded because the hospital stay was prolonged by complications of diabetes management. Nine additional patients were excluded from the study because they had received both interscalene block and Exparel or neither of these. The interscalene block cohort included 44 patients, and the liposomal bupivacaine cohort included 25 patients.

**Technique of Liposomal Bupivacaine Periarticular Injection**

The periarticular injection included 20 mL Exparel and 20 mL 0.25% bupivacaine without epinephrine, for a total injection volume of 40 mL. The mixture was injected into the skin, subcutaneous tissue, pectoralis muscle, deltoid muscle, and pericapsular area during total shoulder arthroplasty. Injection was performed with a 22-gauge needle, and small aliquots were injected through the soft tissues with multiple entry points. Periarticular injection was performed immediately before implantation of the glenoid component (Figures 1A-B), and the remaining injection was administered before closure of the exposure (Figures 1C-F).

**Results**

No statistically significant difference was found for age between the 2 groups (interscalene block: mean, 68.8 years; range, 58-70 years) (liposomal bupivacaine: mean, 66 years; range, 58-71 years)
The nerve block group comprised 59% men and 41% women. The liposomal bupivacaine group comprised 61% men and 39% women. No statistically significant difference was found between the 2 groups for patient sex ($P=.89$). The median American Society of Anesthesiologists score for both groups was 3 (interquartile range, 2-3). The difference between the American Society of Anesthesiologists scores was not significant ($P=.50$). Before undergoing total shoulder arthroplasty, 3 of the 44 patients in the interscalene block cohort and 4 of the 25 patients in the liposomal bupivacaine cohort were using opioid pain medication. The difference in preoperative opioid use was not statistically significant between the 2 groups ($P=.41$). The 1 complication that occurred involved iatrogenic pneumothorax as a result of placement of preoperative interscalene brachial plexus block. No wound complications occurred. Postoperatively, the nerve block cohort had a mean total of 123 morphine equivalents (range, 79-192 morphine equivalents). The liposomal bupivacaine cohort had a mean total of 134 morphine equivalents (range, 92-195 morphine equivalents). The difference between the 2 groups was not statistically different ($P=.71$). Analysis of the median total morphine equivalents used was not statistically significant between patients who used narcotics preoperatively (median, 130 morphine equivalents) and those who did not (median, 133.8 morphine equivalents) ($P=.95$). Median postoperative length of stay also was not statistically different between the 2 groups. For the interscalene block group, median postoperative length of stay was 48 hours (range, 31-51 hours), and for the liposomal bupivacaine group, median postoperative length of stay was 49 hours (range, 46-52 hours) ($P=.33$).

Pain scores for the cohort of patients who were treated with liposomal bupivacaine trended better than those for the interscalene block cohort for the first 12 hours after surgery. However, no statistically significant differences in pain scores were found for NPRS scores, based on a minimal clinically important difference of 2.17, as defined by Michener et al.\(^\text{27}\) (Figure 2). Between 0 and 12 hours postoperatively, mean pain score for the interscalene block group was 4.41 (n=44) vs 3.01 (n=25) for the liposomal bupivacaine group ($P=.25$). Between 13 and 24 hours postoperatively, mean pain score for the interscalene block group was 4.89 (n=44) vs 5.20 (n=25) for the liposomal bupivacaine group ($P=1.00$). Between 25 and 36 hours postoperatively, mean pain score for the interscalene block group was 4.76 (n=39) vs 4.66 (n=18) for the liposomal bupivacaine group ($P=1.00$). Between 37 and 48 hours postoperatively, mean pain score for the interscalene block group was 4.19 (n=37) vs 4.90 (n=16) for the liposomal bupivacaine group ($P=.98$). Finally, between 49 and 60 hours postoperatively, mean pain score for the interscalene block group was 4.49 (n=17) vs 4.51 (n=8) for the liposomal bupivacaine group ($P=.73$). Although pain scores for all patients changed over time (main effect, time, $P=.001$), no difference was noted between the 2 cohorts (main effect, liposomal bupivacaine, $P=.73$).

**Discussion**

This study compared periarticular injection of liposomal bupivacaine vs interscalene block in terms of in-hospital postoperative pain scores, postoperative opioid use, length of stay, and complications. Although no statistically significant difference was found for those parameters between the 2 cohorts, this study furthers the literature on an increasingly popular procedure, total shoulder arthroplasty.\(^\text{28}\) Okoroa et al.\(^\text{25}\) first published a randomized prospective trial of patients who underwent either anatomic total shoulder arthroplasty or a posterior approach for total shoulder arthroplasty.\(^\text{29}\)
arthroplasty (33 procedures) or reverse total shoulder arthroplasty (24 procedures) and received either liposomal bupivacaine periarticular injection or interscalene block. Their study included 57 patients. The liposomal bupivacaine group had more pain 0 to 8 hours postoperatively; however, thereafter, pain scores were not statistically different. Interestingly, in the current study, patients who received liposomal bupivacaine and those who received interscalene block did not have statistically significantly different pain scores at any interval. Further, unlike the study of Okoroha et al., the current study did not capture the rebound pain often described by patients and surgeons that occurs while the interscalene block wears off. The study by Okoroha et al. has been criticized for including a combination of anatomic and reverse total shoulder arthroplasty procedures performed by multiple surgeons. The current study excluded patients who had undergone reverse total shoulder arthroplasty because the superior margin capsule and rotator cuff are often excised during the procedure to improve range of motion and mitigate the risk of postoperative scarring. Without this capsule, periarticular injection of any analgesic likely would not work as well. However, in the current study, despite the homogeneous study population of patients undergoing primary anatomic total shoulder arthroplasty performed by a single surgeon, the results were similar to those of Okoroha et al. who found no significant difference in postoperative pain scores between the liposomal bupivacaine and interscalene block cohorts.

Hannan et al. recently published a retrospective review comparing interscalene block with liposomal bupivacaine for anatomic shoulder arthroplasty, reverse total shoulder arthroplasty, and hemiarthroplasty. With relatively small numbers in each cohort (interscalene block, n=21; liposomal bupivacaine, n=37), the authors found that the liposomal bupivacaine cohort had less pain 18 to 24 hours after surgery ($P=.001$), less opioid use on postoperative days 2 ($P=.001$) and 3 ($P=.002$), and shorter length of stay compared with the interscalene block group (46 hours vs 57 hours, $P=.012$). Similar to comparisons with the study of Okoroha et al., the current findings differed from those of Hannan et al. in that the current study included a homogeneous group of patients who underwent only anatomic shoulder arthroplasty procedures. Unlike Hannan et al., the current study found no difference between cohorts with regard to pain scores, opioid use, or length of stay.

Some of the earliest orthopedic reports of the use of liposomal bupivacaine have been in the spine, foot and ankle, and adult reconstruction literature. Interscalene brachial plexus block is arguably the gold standard for adjunctive analgesia for total shoulder arthroplasty. Surdam et al. found no statistically significant difference between the 2 groups for pain, nausea and vomiting, and narcotic use. Although the liposomal bupivacaine group had decreased length of stay, pain relief was similar in the liposomal bupivacaine and femoral nerve block groups, as measured by in-hospital postoperative pain scores. With no differences found between cohorts for pain scores, total opioid use, or length of stay, the current study showed that periarticular injection with liposomal bupivacaine is as efficacious as interscalene block for postoperative pain control after total shoulder arthroplasty.

Interscalene brachial plexus block is for 80 consecutive patients undergoing total knee arthroplasty. Gohl et al. reported a pain control regimen that included interscalene block in patients undergoing open shoulder procedures. Their study found that patients who received interscalene block in addition to general anesthesia had lower postoperative pain scores compared with those
who did not receive an adjunctive block.\textsuperscript{13} Multiple studies showed that scalene anesthesia is safe and has low complication rates.\textsuperscript{12,16,37,38} Weber and Jain\textsuperscript{11} published a retrospective review of 218 patients undergoing shoulder procedures with scalene block anesthesia. Of these patients, 33\% required immediate intravenous opioid medication in the postanesthesia care unit, and 13\% of blocks failed. Further, 8 complications occurred, including persistent nerve paresthesia, seizure, and cardiopulmonary demise.\textsuperscript{11} Lelters et al\textsuperscript{14} also looked at complications associated with scalene anesthesia at a community medical center where 3172 interscalene brachial plexus blocks were performed during a 15-year period. These authors reported 27 peripheral neuropologic injuries, and 14 were still present at the most recent follow-up. In addition, 3 central nervous system complications, 6 respiratory complications, and 5 cardiovascular complications occurred.\textsuperscript{14} Neurologic complications of scalene anesthesia often are permanent and disabling.\textsuperscript{14} In the current study, the only complication occurred in the interscalene block group. A patient had iatrogenic pneumothorax that necessitated tube thoracostomy and a postoperative stay in the intensive care unit. In this study, liposomal bupivacaine was as efficacious as scalene anesthesia for adjunctive pain control for total shoulder arthroplasty and avoided potentially severe complications.

Padegimas et al\textsuperscript{28} predicted a 9-fold increase in the rate of shoulder arthroplasty for all patients by 2030. More specifically, they predicted a 755.4\% increase in shoulder arthroplasty in patients older than 55 years and suggested that only 4\% of shoulder arthroplasty procedures will be performed on patients younger than 55 years of age.\textsuperscript{28} This has significance in light of the current findings. Perioperative analgesia for total shoulder arthroplasty will be of utmost importance, given the importance of patient satisfaction.\textsuperscript{39} Operative costs are continuously being scrutinized, particularly for the Medicare population. At the study institution, the average interscalene block costs $1104.50. The cost of the intraoperative liposomal bupivacaine injection is $316.44. The finding that there was no statistically significant difference between the interscalene block and liposomal bupivacaine cohorts in terms of postoperative pain scores, opioid consumption, or length of stay suggests that cost should be a strong consideration in the selection of perioperative pain control.

Limitations

There are several limitations to this study. Because of the inherent weakness of a retrospective review, pain scores could not be captured at 6-hour intervals. This information may have shown a more dramatic crest in the pain curves seen with interscalene block.\textsuperscript{25} All procedures were performed by a single surgeon at a single institution, and the cohorts had unequal numbers of patients. However, a potential strength of the study is that periarticular injections performed by a single, fellowship-trained shoulder and elbow surgeon are likely to be standardized across a consecutive series of patients. In addition, findings on the superiority of liposomal bupivacaine vs plain bupivacaine are conflicting. Although most well-controlled studies show that liposomal bupivacaine is superior to plain bupivacaine, some reports have shown equivalent results.\textsuperscript{21,40} Further study may help to clarify this disparity.

CONCLUSION

Periarticular injection with liposomal bupivacaine is a useful adjunctive analgesic in lieu of scalene anesthesia for total shoulder arthroplasty. Liposomal bupivacaine has the potential to be as efficacious as interscalene brachial plexus block in controlling pain and limiting opioid consumption while avoiding the risk of potentially severe complications and high cost.

REFERENCES

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