Femoral nerve blocks (FNBs) and periarticular injections (PAIs) are often used for analgesia following bone and joint surgery. The purpose of this retrospective analysis was to investigate the association of analgesic technique with outcomes. All patients receiving total knee arthroplasty (TKA) at a regional medical center in 2014 were analyzed. Patients were grouped by whether they received an FNB or PAI of bupivacaine liposome injectable suspension (Exparel) for postoperative analgesia. Outcome variables of pain perception, morphine equivalents administered, length of stay, and total cost of care were compared using 2-tailed t tests. Readmission rate was examined using a 2-sample z test for proportions. One hundred forty-four patients were included in the study. This analysis demonstrated an association between receiving an FNB and less pain perception (P = .0497). Results also demonstrated a possible relationship between less opioid consumption in patients receiving a PAI of liposomal bupivacaine (P = .037). No statistical differences were found for the other variables. Receiving an FNB was preferable regarding patients’ pain perception. Patients received less opioid analgesic when they received a PAI, possibly relating to the particular surgeon performing the primary TKA. Patients were 5 times likelier to require hospital readmission in the PAI group.

Keywords: Analgesia, anesthesia, arthroplasty, opioid, regional.
The choice of FNB or PAI was at the discretion of the surgeon. Femoral nerve blocks were placed in the postanesthesia care unit (PACU) by 1 of 14 anesthesia providers experienced in ultrasound-guided regional anesthesia (anesthesiologist or Certified Registered Nurse Anesthetist). Periarticular injections were placed in the operating room by 1 of 4 attending orthopedic surgeons. Patient data were obtained from the hospital electronic database. Patients were excluded from the study if they were receiving long-term opioid therapy that met or exceeded 3 continual months' duration immediately before their primary joint replacement. Variables examined from the hospital record were patient pain perception, opiate use (morphine equivalents [MEs]), length of stay (LOS) in the hospital, total cost of care in the hospital, and readmission rate.

Patient pain perception was defined using a 0 to 10 numeric pain rating scale value and recorded by a registered nurse chronologically throughout the period beginning with patient admission to the PACU until discharge to home. These pain score values were captured and recorded in the electronic medical record at multiple intervals throughout the hospital stay during nursing assessments (independent of opioid administration) as well as before and after opioid administration. Total pain score data ranged from only a few entries per patient to several dozen entries depending on length of stay. These averages were compared between the FNB and PAI groups using a 2-tailed t test.

Total opioid use for each patient's entire hospital course
was obtained from the nursing record for each patient. All opioid medications were ordered by the surgeon or other attending physician. There were 23 various medication combinations noted (Table 1). For standardizing use, an equianalgesic dose index was used. Criticisms exist in the proposed methods for equivalence calculations and the variability in how providers convert various opioids to a standard of measure. Therefore, we attempted to standardize equivalence by using morphine, 10 mg IV, as the benchmark with an index system that took into account potencies and bioavailability between oral and parenteral routes of administration. The relative potency of all opioid analgesics ordered by the various physicians was calculated as MEs. The total MEs for each patient was calculated. Differences in MEs for each group (FNB and PAI) were analyzed using a 2-tailed t test.

Length of stay in the hospital, calculated as whole 24-hour periods, was obtained from the patient record. Minimum stay was 1 day, and maximum was 7 days. Patient readmissions, which were fewer than 30 days from discharge, were added to the LOS calculation. Total LOS for each group, FNB and PAI, was then compared using a 2-tailed t test.

All hospital-associated costs related to the inpatient hospital course were compiled for each patient. This comprehensive cost database was compiled by the finance office and included the total amount that the institution billed to the third-party payers. This was represented as total cost of care. No cost related to private physician billing was included. Costs were summed for each group, FNB and PAI, and compared using a 2-tailed t test.

Any patient receiving TKA during the study period who was readmitted within 30 days, for any reason, was included in the readmission group and recorded in the readmission rate. This rate, expressed as a percentage, was tabulated for both groups and compared using the 2-sample z test for proportions.

Results
After exclusion criteria were applied, there were 144 patients in the observational group: 71 patients in the FNB group and 73 in the PAI group. Demographically, our sample was reflective of the U.S. population as a whole in regard to marital status and gender (Figures 5 and 6). African American, Hispanic, and other ethnic affiliations represented 4.1% of the PAI group and 2.8% of the FNB group. These results support current evidence of African Americans’ reluctance to choose total joint replacement compared with whites. African Americans represent 22.2% of the population of the state; however, they represent only 1.8% of the county population in which this study was undertaken.

Figure 7 demonstrates how, beginning in 2013, orthopedic surgeons began to use PAI. By 2015, more than 80% of the orthopedic surgeons were opting for PAI over FNB. Figure 7 demonstrates that by using only the 2014 retrospective data, we were able to represent a relatively even distribution in PAI vs FNB cases since this was the midpoint in utilization of each modality of postoperative analgesia. Table 2 summarizes the calculated mean and SD for the study variables for each group.

Our analysis demonstrated that patients who received a regional anesthetic at our facility in the form of an ultrasound-guided FNB in the PACU had lower documented pain scores throughout their hospital course (mean pain perception scores, 4.48 for FNB vs 5.02
for PAI, P = .0497; Figure 8). Additionally, our analysis showed that patients receiving PAIs received fewer opioids during their stays (mean MEs were 168.59 mg for FNB and 126.45 mg for PAI, P = .0370; Figure 9). Both pain perception and ME had small effect sizes (Cohen $d = 0.332912$ and 0.353498, respectively) owing to large,

<table>
<thead>
<tr>
<th>Medication, generic (brand)</th>
<th>Dose and formulation</th>
<th>Medication, generic (brand)</th>
<th>Dose and formulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrocodone/APAP</td>
<td>10/325 mg tablet</td>
<td>Hydromorphone</td>
<td>Low dose: 30 mg/30 mL PCA vial</td>
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<tr>
<td>Hydrocodone/APAP</td>
<td>5/325 mg tablet</td>
<td>Oxycodone/APAP</td>
<td>10/325 mg tablet</td>
</tr>
<tr>
<td>Hydromorphone</td>
<td>1 mg/1 mL injection</td>
<td>Oxycodone</td>
<td>80 mg tablet CR</td>
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<tr>
<td>Hydromorphone</td>
<td>2 mg tablet</td>
<td>Meperidine hydrochloride</td>
<td>50 mg/1 mL</td>
</tr>
<tr>
<td>Morphine</td>
<td>10 mg/1 mL injectable cartridge</td>
<td>Fentanyl</td>
<td>250 μg/5 mL injection</td>
</tr>
<tr>
<td>Morphine</td>
<td>4 mg/1 mL injectable cartridge</td>
<td>Acetaminophen-codeine</td>
<td>5 mL syringe (12 mg codeine)</td>
</tr>
<tr>
<td>Morphine</td>
<td>30 mg PCA syringe</td>
<td>Hydrocodone-acetaminophen</td>
<td>7.5/500 mg, 15 mL (1 c elixir)</td>
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<tr>
<td>Oxycodone CR (Oxycontin)</td>
<td>10 mg tablet CR</td>
<td>Acetaminophen-codeine</td>
<td>300/30 mg tablet</td>
</tr>
<tr>
<td>Oxycodone CR (Oxycontin)</td>
<td>20 mg tablet CR</td>
<td>Hydromorphone</td>
<td>10/650 mg tablet</td>
</tr>
<tr>
<td>Oxycodone/acetaminophen</td>
<td>5/325 mg tablet</td>
<td>Morphine</td>
<td>5 mg tablet ER</td>
</tr>
<tr>
<td>Oxycodone</td>
<td>5 mg tablet</td>
<td>Hydromorphone</td>
<td>2 mg/1 mL vial</td>
</tr>
<tr>
<td>Morphine</td>
<td>5 mg/1 mL vial</td>
<td>Oxycodone CR (Oxycontin)</td>
<td>80 mg tablet CR</td>
</tr>
<tr>
<td>Hydromorphone</td>
<td>2 mg/1 mL vial</td>
<td>Oxycodone/acetaminophen</td>
<td>10/650 mg tablet</td>
</tr>
</tbody>
</table>

Table 1. Documented Opioids Administered to Patients Undergoing Total Knee Arthroplasty in 2014
Abbreviations: APAP, acetyl-para-aminophenol (acetaminophen); CR, controlled release; ER, extended release; PCA, patient-controlled analgesia.

Figure 5. Marital Status
Abbreviations: FNB, femoral nerve block; PAI, periarticular injection.
within-group variability. The remaining variables analyzed, length of stay, cost of care and readmission rate, were not significant. However, the PAI group did have a readmission rate that was 5 times larger than that of the FNB group, although the difference was statistically insignificant ($P = .3678$). This difference could represent a clinically significant finding in this exploratory study. Primary reasons for readmission were wound integrity (PAI, n = 3), pain management (PAI, n = 1), and pneumonia (FNB, n = 1).

**Discussion**

Our study sought to gain understanding in the relationship between 2 analgesic modalities and associated outcome variables. The reported decrease in pain in the group receiving FNB could be due to the increased pain medications ordered by the surgeons, or it could be due to less activity related to decreased quadriceps motor function frequently associated with this form of proximal regional analgesia. This was not examined in the retrospective data. Postoperative pain medications were ordered by the surgeon. Use of patient-controlled analgesia (PCA) and/or oral opioid medications given on a scheduled order set could be a factor or factors in the increase of pain medications in this group and account for the reported decrease in pain.

The readmission rate was statistically the same for both groups in this retrospective analysis. However, the PAI group had 5 times more patients readmitted. The degree of clinical significance pertaining to the observed readmissions in the PAI group strongly supports further study of this topic. The effect this had on costs and length of stay may be significant. In a future study, reasons for readmission should be examined further as well as differences in costs and length of stay. Changing opinions by orthopedic surgeons and modifications in surgical technique during 2014 may have affected the efficacy of analgesic approaches and the resultant outcome variables.

The primary limitation of this research relates to the design as a retrospective data analysis conducted at a relatively small regional medical center. This study examined 2 groups of patients and was therefore limited in ability to describe the observed phenomena on an individual level or measure the degree of meaning that analgesic technique had on each patient's surgical/anesthetic experience. Factors such as multiple surgeons performing TKAs with or without PAs, multiple anesthesia providers performing FNBs (the level of ultrasonography expertise possessed by anesthesiologists and Certified Registered Nurse Anesthetists), and nursing perceptions of as-needed opioid order sets may affect the data analysis to unknown degrees and may have contributed to the statis-

<table>
<thead>
<tr>
<th>Variable</th>
<th>FNB (n = 71)</th>
<th>PAI (n = 73)</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain perception score</td>
<td>4.48 (1.89)</td>
<td>5.02 (1.30)</td>
<td>.0497</td>
</tr>
<tr>
<td>ME, mg</td>
<td>168.59 (130.45)</td>
<td>126.45 (106.79)</td>
<td>.0370</td>
</tr>
<tr>
<td>LOS, d</td>
<td>2.97 (1.08)</td>
<td>2.63 (0.86)</td>
<td>.422</td>
</tr>
<tr>
<td>Cost of care, $</td>
<td>18,572.65 (3,716.11)</td>
<td>19,505.48 (4,4769.16)</td>
<td>.422</td>
</tr>
<tr>
<td>Readmission rate, %</td>
<td>1.4</td>
<td>6.8</td>
<td>.3678</td>
</tr>
</tbody>
</table>

Table 2. Statistical Analysis, Mean (SD)
Abbreviations: FNB, femoral nerve block; LOS, length of stay; PAI, periarticular injection; ME, morphine equivalent.

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**Figure 6. Gender Distribution**
Abbreviations: FNB, femoral nerve block; PAI, periarticular injection; Y, year.

**Figure 7. Number of PAI Versus FNB Cases per Year**
Abbreviations: All, total number of total knee replacements; FNB, femoral nerve block; PAI, periarticular injection.
tical evidence found in this research. This retrospective analysis provides possible associations among variables but fails to demonstrate cause and effect relationships. Examining the role of regional analgesia techniques as they relate to improved pain control and lower incidences of opioid-related adverse effects continues to build credibility. However, the exact causes of lower pain scores and higher opioid consumption were not clarified in the retrospective review of the electronic medical records. Future prospective studies are encouraged to develop deeper understanding of potential causal relationships in analgesic modalities and improved outcomes in patients undergoing TKA.

REFERENCES
