Retrospective Chart Review of Patients Following Unilateral Total Knee Replacement to Assess Achievement of Functional Milestones Based on Type of Anesthetic Used Intra-Operatively

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RETROSPECTIVE CHART REVIEW OF PATIENTS FOLLOWING UNILATERAL TOTAL KNEE REPLACEMENT TO ASSESS ACHIEVEMENT OF FUNCTIONAL MILESTONES BASED ON TYPE OF ANESTHETIC USED INTRA-OPERATIVELY

by

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A capstone project submitted to the Graduate Faculty in Physical Therapy in partial fulfillment of the requirements for the degree of Doctor of Physical Therapy (DPT), The City University of New York

2015
Abstract

Retrospective Chart Review of Patients following Unilateral Total Knee Replacement to Assess Achievement of Functional Milestones Based on Type of Anesthetic used Intra-Operatively

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PURPOSE: Given the large number of Total Knee Replacements (TKR) performed annually in the US and the prediction that those numbers will increase, providing optimal analgesia during TKR is an important strategy for reducing cost and improving patient outcomes. Currently, no standard analgesia protocol for TKR exists and facilities in the US and world-wide use varied methods of analgesia. The purpose of the present study is to determine which analgesic technique; femoral nerve block (FNB), saphenous nerve block (SNB) or periarticular injection (PAI), within the context of a multi-modal pain management regimen, results in optimal TKR patient outcomes and achievement of functional milestones, as well as decreased length of stay (LOS).

METHODS: A retrospective, non-randomized design was employed using a convenience sample of 1,644 patients undergoing primary, unilateral TKR at HSS. 652 patients were included in the FNB group, 873 patients in the SNB group, and 119 patients in the PAI group.
Physical therapists assessing and treating patients post-operatively, documented LOS and achievement of functional milestones, including the ability to transfer, ambulate and perform stairs. The data was analyzed to determine if the various methods of analgesia are associated with improved patient outcomes.

RESULTS: A significant statistical difference in LOS ($p < 0.001$) was found between groups. PAI group had a shorter LOS than patients in both the FNB and SNB groups. Mean LOS of the PAI group was 2.8 days ($\pm 1.0$), mean LOS of the SNB group was 3.1 days ($\pm 1.2$), and mean LOS of the FNB group was 3.7 days ($\pm 1.1$). The three groups also demonstrated a significant statistical difference ($p < 0.001$) in achievement of functional milestones. The PAI group achieved all functional milestones the fastest, followed by the SNB group, and then the FNB group.

CONCLUSIONS: This study suggests that alternate methods of perioperative anesthesia used in TKR, including SNB and PAI, are associated with improved outcomes over FNB. This review supports further research of both SNB and PAI techniques due to their potential in improving patient functional outcomes, reducing LOS and decreasing costs.
Acknowledgements

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INTRODUCTION

Total knee replacement (TKR) is one of the most prevalent orthopedic surgeries in the world, with over 500,000 procedures performed yearly in the US alone (Kosel, Bobik, & Siemiątkowski, 2012). Patients with degenerative joint disease opt for TKR to effectively eliminate pain, restore mobility and improve quality of life (Berend, Lombardi, & Mallory, 2004; Fischer et al., 2008). The knee joint, which consists of the articulation of the distal end of the femur, the proximal end of the tibia and the patella is the largest joint in the body and is vital to many daily activities (AAOS, Total Knee Replacement, n.d.). The ends of both long bones are covered in articular cartilage which serves to protect the bone and allow for smooth gliding within the joint. A synovial membrane containing a lubricating fluid also surrounds the entire joint further minimizing friction during joint movement (AAOS, Total Knee Replacement, n.d.). During a standard TKR, the damaged ends of both bones, are shaved down and resurfaced with metal and plastic implants to restore proper knee alignment and function (AAOS, Total Knee Replacement, n.d.).

Currently in the United States, the average hospital length of stay (LOS) for a patient with TKR is 3.5 days (Cram et al., 2012). The number of TKR surgeries performed per year is expected to rise as life expectancy increases and as the world’s population ages (Ibrahim, Khan, Nizam, & Haddad, 2013; Kosel et al., 2012). Medical advancements have made TKR one of the most successful orthopedic surgeries available. The majority of knee replacements have been found to remain fully functional and intact as long as thirty years after surgery (Berend et al., 2004). Due to the high costs associated with the procedure, hospital stay and the expected rise in the number of surgeries performed annually, a major focus in orthopedics is the further improvement of the TKR procedure and the recovery process.
The recovery of a patient undergoing TKR encompasses two discrete periods of time, each with distinct goals. There is short-term recovery, during which the patient’s primary goal is to regain a certain level of motor function in order to be discharged from the hospital. Short-term goals of the hospital include short hospital stays, avoiding infection, successful treatment of postoperative pain and minimization of morbidities after surgery (Berend et al., 2004). Once a patient is discharged, their long-term goals include relief of pain, improvement of function, and attainment of stability and durability of the new joint (Berend et al., 2004). The aim of this study is to look at the effects of intraoperative anesthesia on LOS and achievement of functional milestones in the short-term recovery period.

The quality of preoperative, intraoperative, and postoperative care that a hospital can offer a patient with TKR will affect a patient’s short-term and long-term recovery processes. Research has shown that the best way to allow patients to reach short-term goals is to focus on the surgical procedure and on non-surgical procedures that are part of the TKR process. Preoperative patient education and pain management, especially the preemptive treatment of pain, has been shown to be beneficial in shortening the recovery process (Berend et al., 2004). Berend et al. (2004) also posit that it is possible to increase the speed of recovery and reduce LOS by reducing perioperative complications. Kosel et al. (2012) assert that effective pain management is directly correlated with early ambulation which allows for more effective postoperative rehabilitation. The connection drawn in these two studies between non-surgical techniques (performed pre-, intra- and postoperatively) and improved therapeutic outcome is hard to ignore. With the support of the findings mentioned above, this study aims to further understand the connection between the method of anesthesia and postoperative outcomes in patients undergoing TKR, specifically through the comparison of functional milestones.
**Post-operative Pain Management Techniques and Peripheral Nerve Blocks**

The traditional techniques for immediate post-operative TKA pain management are intravenous patient controlled analgesia (PCA), opioids or epidural analgesia (Dillon, Brennan, & Mitchell, 2012; Paul et al., 2010). Although PCA provides effective pain management, insufficient dosing may cause inadequate analgesia, whereas excessive dosing can increase the potential for side effects that are common with over-consumption of opioids (Hebl et al., 2008). These side effects include nausea and vomiting, confusion, constipation, urinary retention, sedation, respiratory depression and pruritus, all of which can interfere with the recovery process (Dillon et al., 2012; Hebl et al., 2008; Paul et al., 2010). Epidural analgesia, although effective, may also cause side effects such as hypotension, urine retention, a risk of spinal hematoma and motor block, which can inhibit early mobilization (Dillon et al., 2012). In addition, patients may experience difficulty with ambulation in the non-operative leg (Paul et al., 2010). The adverse effects of the aforementioned methods may interfere with recovery and physical therapy during the acute stage of rehabilitation.

A newer school of thought in post-operative pain management following TKR is the preemptive multimodal approach (Korean Knee Society, 2012; Peters, Shirley, & Erickson, 2006). The Korean Knee Society defines preemptive as “to initiate pain management before surgical stimuli” and multimodal approach as “more than two drugs or modalities with different mechanisms or sites for synergistic effects” (Korean Knee Society, 2012, p.202). A peripheral nerve block (PNB) in the context of a preemptive multimodal approach is one technique being employed for improving post-operative pain management after TKR (Korean Knee Society, 2012; Peters et al., 2006). A nerve block is accomplished by injecting local anesthetic medication near the nerves innervating the operative site, administered either as a single-dose or
continuous blockade (Dillon et al., 2012). The two PNBs that will be discussed in this study are femoral nerve block (FNB) and saphenous nerve block (SNB) performed at the level of the adductor canal.

FNB, the more established of the two nerve blocks, is currently considered the gold standard technique for TKR. It is performed by inserting a thin, two-inch needle near the groin area to locate the femoral nerve. A low level electrical current is then introduced in order to stimulate and identify the specific branch of the femoral nerve innervating the anterior knee. Once the femoral nerve branch is identified, an anesthesiologist injects a long-acting anesthetic to numb the front of the knee. The numbness lasts approximately 16 hours and the pain-relieving capabilities of a FNB last up to 3 days (Hospital for Special Surgery, Femoral Block, n.d.). FNB can be administered as a single shot injection or as a continuous femoral nerve blockade.

Much research has been done to investigate the efficacy of FNB in TKR. Numerous investigators have demonstrated that FNB provides effective pain management and decreases patient opioid consumption, reducing the chance of unwanted side effects (Good, Snedden, Schieber, & Polachek, 2007; Paul et al., 2010). While FNB did prove to have superior analgesic effects, there is less evidence about its ability to improve early mobilization and decrease LOS (Good et al., 2007; Tugay et al., 2006).

Although FNB may have benefits over other forms of anesthesia, it is not without disadvantages. Kandasami, Kinninmonth, Sarungi, Baines, and Scott (2009) discuss some concerns that have been found with FNB. The investigators report five patients who, after receiving FNB for TKA, suffered postoperative falls resulting in significant injuries. The five
patients were between the ages of 65 and 82 with no significant co-morbidities and were
operated on by one of three consultant orthopedic surgeons using the same surgical technique.
The falls occurred on post-operative day 1 or 2 when patients attempted to get out of bed or use
the toilet. The falls may be attributed to quadriceps weakness on the operated leg. The patient
may get a false sense of confidence because their non-operative leg is strong. However, due to
the nature of the femoral nerve, with both sensory and motor components, the patient may still be
experiencing post-operative weakness in the quadriceps. Since the femoral nerve is both a
sensory and motor nerve, there is a possibility of temporarily losing strength in the quadriceps
muscle after receiving a FNB (Charous et al., 2011; Jaeger et al., 2013; Kandasami et al., 2009).
The risk of falls along with prolonged immobilization can interfere with the acute care recovery
process and consequently increase LOS.

Saphenous nerve block (SNB) performed at the adductor canal at mid-thigh level is
another type of PNB used perioperatively to treat immediate postoperative pain from TKR. The
saphenous nerve is a sensory branch of the femoral nerve and courses superficially down the
anteromediaal lower leg. Because the saphenous nerve does not provide motor innervation, this
reduces the possibility of quadriceps muscle weakness post-surgery compared to FNB, resulting
in less muscle impairment while still providing pain relief (Jaegar et al., 2013; Kim et. al, 2014).
SNB is administered by first sedating the patient and then locating the nerve. Once the nerve is
located, a small needle is used to insert local anesthetiic around the nerve. Pain relief is expected
to last between 6-18 hours (Hospital for Special Surgery, Saphenous Nerve Block, n.d.).

A study by Ishiguro et al. (2013) noted that although FNB provided adequate pain relief,
the motor paresis that it causes could lead to falls and other complications. Therefore, they
devised a modified FNB for TKR, targeting the saphenous nerve. After emerging from general
anesthesia, all 25 patients (mean age of 74) who received the SNB were able to raise their operated leg, straighten it, and actively flex and extend the knee. The patients were also able to stand on the operated extremity alone. Therefore, this blockade allowed earlier mobilization, without the use of additional analgesia (Ishiguro et al., 2013).

Mudumbai et al. (2013) provide further evidence to suggest that SNB produces more favorable therapeutic results compared to FNB while providing the same degree of pain control. They compared total ambulation distances on POD1 and 2, opioid consumption, pain scores, and LOS in patients who had undergone TKR and received either a continuous adductor (saphenous) nerve block (n=66) or a continuous FNB (n=102). Ambulation distances were higher in the adductor (saphenous) canal group on POD1 and 2. The secondary outcome measures; opioid consumption, pain scores, and hospital LOS, were similar between both groups. The study notes that early ambulation after TKR is clinically relevant since it has been shown to help decrease deep vein thrombosis (DVT), improve muscle strength and gait, and reduce hospital LOS (Mudumbai et al. 2013). Although further research is necessary, the literature suggests that SNB provides patients with earlier, safer post-operative mobility as well as potentially more effective rehabilitation and decreased LOS.

**Periarticular Injection in TKR**

Periarticular injection (PAI) of multimodal drugs has become an increasingly popular and relatively common analgesic protocol for managing postoperative pain in patients who undergo TKR (Affas, Nygards, Stiller, Wretenberg, & Olofsson, 2011; Essving et al., 2011; McCartney & McLeod, 2011). Several studies support the efficacy of PAI by finding that it is well tolerated and has minimal side effects (Berend et al., 2004; Busch et al., 2006; Chaumeron, Audy, Drolet, Lavigne, & Vendittoli, 2013; Kerr & Kohan, 2008; Meftah et al., 2012). PAI for total hip
arthroplasty (THR) and TKR is a technique popularized by Drs. Kerr and Kohan in Sydney, Australia (Dillon et al., 2012; Kerr & Kohan, 2008). The authors described PAI as the peri- and intraarticular infiltration of a mixture or medication “cocktail” comprised of a long-acting local anesthetic (ropivacaine), a non-steroidal anti-inflammatory drug (ketorolac) and epinephrine, around all structures at the surgical site. The cocktail is administered intra-operatively, around and within the knee joint, at the end of TKR surgery. PAI protocols vary widely from institution to institution. For example, the cocktail may or may not also be injected post-operatively through a catheter placed in the knee joint after the intra-operative injection (Essving et al., 2011; Kehlet & Andersen, 2011; Kerr & Kohan, 2008; Teng et al., 2013). In addition, the drugs that comprise the cocktail and their respective dosages differ, as well as the specific locations and the timing of infiltration (Spreng, Dahl, Hjall, Fagerland, & Raeder, 2010; Teng et al., 2013).

Further research is needed to determine the optimal dosage and composition of the PAI medication cocktail, as well as optimal injection techniques (Kehlet, 2013; Kelley, Adams, Mulliken, & Dalury, 2013; Korean Knee Society, 2012; Raeder, 2011). In a review of knee neuroanatomy and PAI injection technique, Guild, Galindo, Marino, Cushner, and Scuderi (2014) recommend concentrating the PAI in the most highly innervated areas of the knee to maximize analgesic benefits. Additional research is also needed to shed further light on how PAI compares to other methods of postoperative pain control in terms of safety, efficacy and patient outcomes (Raeder, 2011).

**Comparison of PAI and FNB in TKR**

Several studies have found that PAI and FNB both provide effective analgesia after TKR (Affas et al., 2011; Chaumeron et al., 2013; Meftah et al., 2012; Uesugi, Kitano, Kikuchi, Sekiguchi, & Konno, 2014). A systematic review of studies examining PAI for peri-operative
pain control in THR and TKR concluded that “pain levels after TKR were broadly similar” with PAI when compared to FNB (Marques, et al., 2014). However, PAI appears to provide several advantages compared to FNB (Guild et al., 2014; Meftah et al., 2012; Toftdahl et al., 2007). PAI prevents quadriceps muscle block associated with FNB, and it avoids the risk of an uncommon but serious complication of nerve damage that may occur with FNB (Chaumeron et al., 2013; Meftah et al., 2012; Raeder, 2011). PAI can be administered by a surgeon, and is cheaper and easier to perform than FNB. In contrast, FNB requires that staff be trained to administer a catheter using appropriate equipment. (Affas et al., 2011; Chaumeron et al., 2013; Guild et al., 2014; Meftah et al., 2012, YaDeau et al., 2013).

Recent literature provides support for PAI as a good alternative to continuous FNB. Perlas et al. (2013) conducted a retrospective cohort study of 298 patients undergoing TKR in which they examined analgesic and rehabilitation outcomes associated with continuous FNB, PAI, or PAI plus adductor canal (saphenous) nerve block (ACNB). The primary outcome measure was distance walked on POD1. Patients in the PAI group and the PAI plus ACNB group walked significantly farther than patients in the continuous FNB group on POD 1 (median values of 20, 30 and 0 m, respectively; \( p < 0.0001 \)). The authors also found that compared to continuous FNB, patients who received PAI with or without ACNB demonstrated lower pain scores both at rest and with movement during POD0 and with movement on POD1, and lower opioid consumption than with continuous FNB (Perlas et al., 2013). For all three groups, median LOS was 4 days, with a trend toward shorter LOS in the two PAI groups (interquartile range, 3-4 vs. 4-4). Toftdahl et al. (2007) compared 80 patients with TKR who were randomized to receive either continuous FNB or PAI administered via intraoperative infiltration of the knee along with two postoperative bolus injections of the same cocktail. The study found that on the first
postoperative day, the PAI group showed improved mobilization, lower pain scores during activity, and consumed fewer opioids than the continuous FNB group. Chaumeron et al. (2013) studied 60 patients and provided support for PAI, with improved pain scores at 8 postoperative hours, less quadriceps motor block, and therefore, improved ability to perform straight leg raise and earlier ambulation than when compared to continuous FNB. Affas et al. (2011) compared PAI and continuous FNB in 40 patients with TKR. They found analogous levels of pain relief at rest during the first 24 hours, with marginally less pain with movement over the same duration for patients in the PAI group.

At least two studies have compared a group of patients who received PAI with those that received patient-controlled epidural analgesia (PCEA) combined with single-shot FNB. Meftah et al. (2012) studied 90 patients and found that the PAI group and the PCEA/FNB group had similar readiness for discharge (PAI group, 3.2 ± 1.9 days; PCEA/FNB group 3.3 ± 1.2 days) and showed almost equal efficacy of pain management on POD1, 2 and 3. Pain on ambulation during the evening of POD1 was the only measure that was significantly lower in the PCEA/FNB group than in the PAI group. In a similar study of 90 patients, YaDeau et al. (2013) found an identical mean time of 3.2 days until discharge readiness in both the PAI group and the PCEA/FNB group and no difference in actual LOS (PAI group 3.8 days; PCEA/FNB group 3.6 days). Compared to the PCEA/FNB patients, patients receiving PAI had mean pain scores during walking of 0.81 points higher (p = 0.0084) and mean pain scores during physical therapy of 0.55 points higher (p = 0.0951). The mean total opioid usage was also greater in the PAI group (PAI group 228mg; PCEA/FNB 142mg). The authors of this study noted that the pain differences between each group were small.
Need/Purpose/Hypothesis

Given the increasing volume of TKR's performed annually in the US, the drive to improve patient safety and functional outcomes, while decreasing cost, will continue to attract the attention of high procedural volume facilities. No standard protocol has yet been established for TKR, but the use of multi-modal analgesia is widely seen in many facilities, with different methods of anesthesia and analgesia varying by institution. Because pain has been cited as one of the major reasons for longer patient stays, it is also a major focus of surgical improvement and research (Husted et al, 2011). Therefore, further research investigating optimal anesthesia methods seems pivotal to improving TKR outcomes.

The Hospital for Special Surgery (HSS) currently uses a multimodal anesthesia/analgesia protocol consisting of regional epidural or neuroaxial anesthesia, combined with epidural or IV PCA, oral analgesics, in addition to either a PNB (femoral or saphenous) or a locally administered peri-articular/intra-articular medication cocktail. Surgeons performing the procedure choose PNB or PAI depending on individual patient factors and their own personal preferences. To date, there are conflicting results in the comparison of the various anesthetic protocols with some investigators concluding that PNB, particularly FNB, is superior while others conclude that PAI is best. With recent studies supporting its efficacy in TKR, SNB has been gaining momentum as well. Further research is needed to elucidate the superiority of one technique, thus allowing for the development of a standard protocol for anesthesia in TKR. Improvements in pain management have lead to improvements in patient outcomes, and consequently, may significantly reduce LOS and cost.

The purpose of the present study is to determine which anesthetic technique; FNB, SNB or PAI, within the context of a multimodal pain management regimen, results in optimal TKR
patient outcomes and achievement of functional milestones. Due to the increasing popularity of this procedure, the rise in medical costs and the push by insurances and hospitals to shorten inpatient stays, this study will investigate the superiority of each technique by comparing the LOS of patients who have undergone the procedure with different methods of anesthesia. This study is a retrospective review of adult patients who underwent primary unilateral TKR at HSS.

As discussed above, the existing research shows evidence of the efficacy of each of the three anesthetic techniques, however, there is no conclusive evidence demonstrating the superiority of one over another. Of the three techniques, FNB is the most established for use in TKR and although it has been shown to be effective in pain management, concerns about quadriceps motor block and the consequent delay in patient mobilization have driven surgeons and anesthesiologists to pursue alternative methods of pain management. The evidence supporting the use of PAI continues to build, with the most recent research demonstrating its efficacy, highlighting its ease of use, and in a few cases, its superiority over other techniques (Chaumeron et al., 2013; Meftah et al., 2012; Affas et al., 2011). SNB, the least established technique in TKR, has demonstrated its potential in recent research, through its advantage of producing pure sensory nerve block, alleviating any concerns for motor nerve block (Lund, Jenstrup, Jaeger, Sørensen, & Dahl, 2011; Jenstrup et al., 2012). However, SNB is the relative newcomer, having the least amount of evidence supporting its use.

Although a substantial amount of research has been conducted on various perioperative anesthesia methods and TKR, the current literature is far from conclusive regarding superiority of one technique over another. Although more recent research has demonstrated efficacy of SNB and PAI with TKR and support for its use is growing, the body of evidence does not indicate an optimal method of anesthesia for TKR. Therefore, this study hopes to shed further
light on this issue by providing more evidence for one of the three techniques used at HSS. However, since previous research has not found significant improvements in LOS for one technique and limited evidence for significant improvements in functional outcomes, the authors hypothesize that there will be no differences between anesthetic techniques and primary outcomes. The investigators posit that the null hypothesis will be true and all three techniques will produce similar outcomes. However, since more recent studies have demonstrated the efficacy of PAI and SNB, alternative hypotheses are feasible. Results may reveal that one of the newer techniques, either SNB or PAI will be associated with improved LOS and functional outcomes. Despite this recent evidence, the bulk of research continues to favor FNB (Chan, Fransen, Parker, Assam, & Chua, 2014), and an alternative hypothesis includes improved outcomes with use of FNB over the other techniques.

METHODS

The current study seeks to investigate which intraoperative analgesic technique is associated with optimal patient outcomes using a retrospective, non-randomized design, with a convenience sample of patients. The Institutional Review Board of HSS and the Human Research Protection Program of Hunter College granted approval for the study.

Subjects

Subjects included adult patients undergoing primary, unilateral TKR at HSS between January 2012 and December 2014. Exclusion criteria includes patients less than 18 years of age; those presenting with neurological or cognitive disorders such as Multiple Sclerosis, Parkinson’s disease, polio, Alzheimer’s disease, dementia; patients with lower extremity amputations; major medical complications such as acute myocardial infarction, pulmonary embolism; and patients
who were not discharged home, but sent to acute rehabilitation facilities or short-term rehabilitation in skilled nursing facilities.

**Procedures**

All subjects underwent a standard TKR using a medial parapatellar approach, with several surgeons performing the procedure. Anesthesiologists provided spinal anesthesia preoperatively, with general anesthesia provided if an epidural was contraindicated. The protocol for spinal anesthesia included injection of 20-25 mL of local anesthetic into the upper lumbar interspaces, along with a low dose epinephrine IV infusion (initial dose of 2 μg/min, with adjustment as needed) to stabilize circulation. Depending on the surgeon’s and the anesthesiologist’s preferences, subjects received a FNB, SNB or PAI technique intraoperatively. The FNB protocol included administration of 30 ml bupivacaine 0.25%, with adrenaline 1:200 000. The saphenous protocol included injection of 10 ml bupivacaine 0.5% with epinephrine 1:200,000. PAI technique included injection of a medication cocktail into various deep and superficial structures surrounding the knee joint, as well as within the knee capsule. The deep injection consisted of bupivacaine 0.5% with adrenaline, 30 ml; morphine, 8 mg/ml, 1 ml; methylprednisolone, 40 mg/ml, 1 ml; cefazolin, 500 mg in 10 ml in normal saline, 22 ml. The superficial injection consisted of 40 ml 0.25% bupivacaine. Once the surgical procedure was completed, spinal epidural was discontinued and subjects were subsequently connected to patient controlled analgesia (PCA) delivering hydromorphone with bupivacaine (bupivacaine 0.06% /hydromorphone 10 μg/ml) with a 10 min lockout period, until 6 a.m. the next morning. On postoperative day (POD) 1, Dilaudid doses were cut in half at 6 a.m., and then continuous dosages ceased at 12 p.m., and finally were completely discontinued at 5 p.m. Various oral analgesics and anti-emetics were provided postoperatively, as needed.
Staff physical therapists conducted twice a day assessments during each subject's hospital stay, until discharge. Functional milestones were assessed and documented at each visit and included ability to transfer, ambulate and climb stairs, with or without various assisted devices (walker or cane) or therapist support. The milestones included in the assessment were based on work done by Kroll et al. (1994), validating functional progression of patients following total hip arthroplasty (THA). Supplemental information was also collected including attendance of a preoperative education class and preoperative functional status.

All outcome data were recorded on a data collection form, separate from the subject’s medical record. The data form did not contain any protected health information. Demographic information collected included only age and race. After the data collection form was completed and pulled from the subject’s medical record, researchers coded the data into a separate database that did not include any patient identifiers.

**Data Analysis**

Continuous variables are reported as mean ± standard deviation (SD) and categorical variables are presented as frequency and percentages. Between group comparisons of functional milestones and LOS were determined using ANOVA for continuous variables and chi-square for categorical variables, with an alpha level set to $\alpha = 0.05$. Statistical analysis was performed with SPSS Version 17.0 (SPSS Inc, Chicago, IL, USA).

**RESULTS**

**Patients**

Subjects consisted of 1,644 patients who underwent primary, unilateral TKR. There were 652 patients in the FNB group, 873 patients in the SNB group, and 119 patients in the PAI
group. All patient demographic data are found in Table 1. The mean age of the FNB group was 62.3 (± 8.8) years comprised of 50.4% female, the mean age of the SNB group was 62.9 (± 9.7) years with 51.8% female, and the mean age of the PAI group was 65.2 (± 8.4) years with 56.3% female. No significant differences of demographic characteristics existed between the groups.

Table 1

**Demographic characteristics of the 3 groups**

<table>
<thead>
<tr>
<th>Patient Variables</th>
<th>FNB N=652</th>
<th>SNB N=873</th>
<th>PAI N=119</th>
<th>P Value</th>
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<tr>
<td>Age (years), Mean</td>
<td>62.3 ± 8.8</td>
<td>62.9 ± 9.7</td>
<td>65.2 ± 8.4</td>
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<td>Female/male, N</td>
<td>329/323</td>
<td>452/421</td>
<td>67/52</td>
<td>0.48</td>
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<tr>
<td>Female/male, %</td>
<td>50.4%/49.6%</td>
<td>51.8%/48.2%</td>
<td>56.3%/43.7%</td>
<td>0.48</td>
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<tr>
<td>Left/right side unilateral TKR, N</td>
<td>302/350</td>
<td>407/466</td>
<td>62/57</td>
<td>0.49</td>
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<tr>
<td>Left/right side unilateral TKR, %</td>
<td>46.2%/53.8%</td>
<td>46.6%/53.4%</td>
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<td>0.49</td>
</tr>
</tbody>
</table>

Values are mean ± SD or N or percentage.

P was obtained from ANOVA for continuous variables and chi-square for categorical variables, with an alpha level set to 0.05.

**Length of Stay**

There was a highly significant statistical difference in LOS (p <0.001) between groups (Table 2). Patients in the PAI group had a shorter LOS than patients in both the FNB and SNB groups. Patients in the FNB group had the longest LOS. The mean LOS of the PAI group was 2.8 days (± 1.0), the mean LOS of the SNB group was 3.1 days (± 1.2), and the mean LOS of the FNB group was 3.7 days (± 1.1).

**Functional Milestones**

The three groups also demonstrated a highly significant statistical difference (p <0.001) in the amount of time it took to achieve of each of the functional milestones that were assessed in this study. The findings are found in Table 2. Patients in the PAI group achieved all of the
functional milestones the fastest, followed by patients in the SNB group, and then followed finally by patients in the FNB group. The only category that was significantly different in milestones achieved before discharge was cane unassisted with a p value < 0.05.

Table 2

**Comparison of Length of Stay and Functional Milestone Achievement**

<table>
<thead>
<tr>
<th>Outcome Variable</th>
<th>FNB N=652</th>
<th>SNB N=873</th>
<th>PAI N=119</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of Stay (days), Mean(SD)</td>
<td>3.7 ± 1.1</td>
<td>3.1 ± 1.2</td>
<td>2.8 ± 1.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Milestones (days), Mean (SD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transfers Unassisted</td>
<td>3.2 ± 1.1</td>
<td>2.6 ± 1.2</td>
<td>2.2 ± 1.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Walking Unassisted</td>
<td>3.2 ± 1.1</td>
<td>2.7 ± 1.2</td>
<td>2.3 ± 1.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cane Unassisted</td>
<td>3.3 ± 0.9</td>
<td>2.6 ± 1.1</td>
<td>2.1 ± 0.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Crutches Unassisted</td>
<td>3.7 ± 0.8</td>
<td>2.3 ± 1.3</td>
<td>1.7 ± 0.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Stairs Unassisted</td>
<td>3.5 ± 1.1</td>
<td>2.9 ± 1.2</td>
<td>2.5 ± 1.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Patients with milestone achieved before discharge, N (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transfers Unassisted</td>
<td>612 (93.7%)</td>
<td>801 (91.8%)</td>
<td>102 (85.7%)</td>
<td>0.10</td>
</tr>
<tr>
<td>Walking Unassisted</td>
<td>591 (90.5%)</td>
<td>770 (88.2%)</td>
<td>105 (88.2%)</td>
<td>0.34</td>
</tr>
<tr>
<td>Cane Unassisted</td>
<td>235 (36.0%)</td>
<td>381 (43.6%)</td>
<td>43 (36.1%)</td>
<td>0.007</td>
</tr>
<tr>
<td>Crutches Unassisted</td>
<td>20 (3.1%)</td>
<td>14 (1.6%)</td>
<td>3 (2.5%)</td>
<td>0.16</td>
</tr>
<tr>
<td>Stairs Unassisted</td>
<td>642 (98.3%)</td>
<td>873 (100%)</td>
<td>114 (95.8%)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Values are mean ± SD or N and percentage.

*P* was obtained from ANOVA for continuous variables and chi-square for categorical variables, with an alpha level set to 0.05

**DISCUSSION**

Due to the projected rise in the number of TKR done annually in the US alone, hospitals are intent upon lowering costs while improving the quality of patient care (Kosel et al., 2012). With many studies determining intra and post operative pain management to be the key to optimal surgical outcomes, the purpose of this study was to investigate the differences in LOS
and achievement of functional milestones between three groups of patients undergoing TKR under three different methods of anesthesia (Berend et al., 2004). Although the authors theorized the support of the null hypothesis, that there would be no difference in outcomes between the groups, it was ultimately rejected because of the highly significant results in favor of the PAI method. The alternate hypothesis was ruled in when the research found the subjects in the PAI group to have the shortest LOS of 2.8 days, and to achieve functional milestones more rapidly than subjects in both the SNB and FNB groups.

Although the authors were unable to hypothesize the superiority of the PAI method due to the relative newness of the technique and the limited research on it, these are the outcomes that were hoped for. As demonstrated by the results of recent studies, PAI is a more specific, less invasive, and more economical anesthetic alternative that can be offered to patients undergoing TKR (Affas et al., 2011; Meftah et al., 2012). Furthermore, as the results of this study strongly suggest, PAI better serves patients while they are undergoing acute rehabilitation during their post-op hospital stays by eliminating the setback of quadriceps motor block and avoiding the risks and complications that commonly accompany the more traditional method of FNB (Guild et al., 2014; Meftah et al., 2012).

Results revealed a highly significant statistical difference in LOS between PAI, SNB and FNB. Patients in the PAI group had the shortest LOS followed by SNB and then FNB. Research that directly compares the LOS between PAI to SNB is limited. However, there is previous literature that examines the difference in LOS in PAI and SNB compared to FNB. A recent retrospective comparison study of 337 consecutive patients undergoing unilateral TKR for osteoarthritis at Hospital for Special Surgery by Duggal and Cornell (2014) validates our findings that SNB results in shorter LOS than FNB. The study analyzed 116 patients that had
TKR surgery treated with spinal anesthesia with patient-controlled epidural analgesia (PCEA)/femoral nerve block (FNB) and 171 TKR patients treated with spinal anesthesia with SNB and a continuous intra-articular infusion of 0.2% ropivicaine for 48 h post-op. Pre-op discharge planning sent patient home to an intensive home PT program as the preferred approach following surgery. Outcome measures assessed include LOS, post-op nausea and dizziness, falls, occurrence of complications and ROM at 6 weeks, 3 months, and 1 year post-op. Results demonstrated no difference between pain control or return of ROM. LOS, however was significantly reduced from 4.32 days to 3.64 days in the group treated with SNB and a continuous intra-articular infusion as well as decreased nausea and narcotic consumption in the SNB group. The findings suggest that SNB with a continuous intra-articular combined with pre-op discharge planning and an intensive home PT program, reduced average LOS compared to PCEA/FNB. Other studies, however, did not find a significant difference in LOS between SNB and FNB. When comparing 102 patients who received FNB and 66 patients who received SNB, Mudumbai et al. (2013) noted that hospital LOS were similar between both groups.

Our findings suggest that PAI will have the greatest effect on reducing LOS. Although several studies address the topic of PAI and its effects on LOS (Meftah et al., 2012; Perlas et al., 2013; YaDeau et al., 2013), no other study to date has determined a significant decrease in LOS for individuals who received PAI treatment following TKR. YaDeau et al. (2013) conducted a randomized controlled pragmatic trial comparing 45 patients treated with PAI and 45 treated with PCEA + FNB following TKR. Outcome measures included discharge readiness, actual LOS, pain scores and opioid consumption. The study found an identical mean time of 3.2 days until discharge readiness in both the PAI group and the PCEA/FNB group and no difference in actual LOS. A retrospective cohort study by Perlas et al. (2013) examined analgesic and
rehabilitation outcomes of 298 patients undergoing TKR treated with continuous FNB, PAI, or PAI plus adductor canal (saphenous) nerve block (ACNB). For all 3 groups, median LOS was 4 days, with a trend toward shorter LOS in the 2 PAI groups (interquartile range, 3-4 vs. 4-4). Perhaps the shorter LOS for PAI and SNB compared FNB in our study can be attributed to the fact that both SNB and PAI provide effective pain management while preventing loss of quadriceps muscle control that is associated with FNB (Chaumeron et al., 2013; Jaeger et al., 2013; Kim et al., 2014; Meftah et al., 2012; Raeder, 2011). The pain management and quadriceps strength may lead to earlier and more effective rehabilitation, less risk of falls, and thereby decrease LOS.

The results also demonstrate a highly significant statistical difference between PAI, FNB and SNB in milestone achievement, with PAI achieving independence the fastest followed by SNB and then FNB. Previous studies validate the use of PAI and SNB as oppose to FNB due to their greater rehabilitation effects (Jaegar et al., 2013; Kim et al., 2014; Perlas et al. 2013). The rehabilitative efficacy of PAI and SNB over FNB, like LOS, might also be attributed to the decrease in quadriceps motor block compared to FNB (Chaumeron et al., 2013; Jaeger et al., 2013; Kim et al., 2014; Meftah et al., 2012; Raeder, 2011).

**Recommendations for Future Research**

This study provides a better understanding of the benefits of PAI and SNB to patients undergoing TKR. An area for future research can be to compare PAI and SNB in greater depth and to determine if there are any long-term differences between the techniques by conducting a 1 month, 3 month and 1 year follow up. Lastly, with results that establish a strong correlation between the use of both PAI and SNB in TKR and a subsequent reduction in LOS; further research can be done to analyze the cost savings to a hospital when choosing between the two
Limitations

The main limitation of the present study lies in its design. Because we were unable to conduct a randomized controlled clinical trial, no causality between type of intraoperative anesthesia and outcomes such as LOS and functional measures can be inferred. Due to high costs, in addition to staffing issues and ethical concerns involving use of control groups, conducting a randomized clinical trial is extremely challenging in our current healthcare environment. Given this difficulty, other research designs should be utilized to provide important insights that can shape the direction of future research. Especially with emerging techniques, such as PAI and SNB, nonrandomized study designs can provide evidence to support the necessity for more time consuming and costly clinical trials. The current retrospective study is an example of this, demonstrating the association between improved outcomes and shorter LOS with the newer techniques of PAI and SNB over the more traditional FNB technique.

Another limitation of our study is due to our use of a non-randomized, convenience sample of patients. Only patients referred to specific surgeons performing TKR at HSS were included in the study. Due to ethical concerns, only basic demographic information such as age, gender and race were used to compare groups. Therefore, each of our three groups could significantly differ from one another. Variables such as preoperative activity level, pre-operative morbidity, SES, etc, were not compared between groups, and potentially could have great impact on our primary outcomes. Preoperative comorbidities, except for those that comprised the exclusion criteria, were not included in the analysis and are a potential reason for our results. The preoperative health status of participants, including degree of OA in both the operative and nonoperative knee, previous TKR (ie, if this was a first or second TKR), non-systemic and
systemic illnesses (diabetes, atherosclerosis, etc.) all have a huge impact on the degree of function of subjects pre and post surgery. Since were not able to compare preoperative health status between groups we do not know if one group was in better health preoperatively and experienced improved outcomes as a consequence of their superior health status. Participants with higher levels of activity and function preoperatively would likely have higher functional mobility post-operatively. In addition, superior health status preoperatively would likely result in faster healing and recovery times.

An additional source of potential bias in our results, also related to our convenience sample is the skill level of both the surgeon and anesthesiologist. Since surgeon preference dictated use of one particular anesthetic technique, our results could be due to the skill level of the surgeon and anesthesiologist. Anesthesiologists performing each of the various techniques were chosen by surgeons and were not randomly assigned between groups. Consequently, the skill level of both the surgeon and anesthesiologist could have contributed to our results. However, as HSS is ranked a leader in providing orthopedic care (HSS/US News & World Report) in the US and performs a high volume of TKR annually, it is reasonable to believe that the skill level of all surgeons and anesthesiologists is high and should not differ dramatically between groups. In addition, since SNB/ACB is a newer technique, the skill level of anesthesiologists performing this technique could be considered lower than that of those performing the longer standing FNB technique, since those performing FNB likely have many more hours of experience performing the procedure. This was not apparent in our results, since SNB was associated with improved outcomes.

Another source of bias can be attributed to both the assessor and patient. Staff physical therapists treated all patients beginning POD1 till discharge, and none were blinded to the
method of intraoperative anesthesia used. Patients also were not blinded to the specifics of their surgical procedure. Biases from either group could have significantly influenced results. However, it is unlikely that patient knowledge of the various analgesic techniques, within the context of a multimodal analgesia protocol, is refined enough to bias results. Although bias from treating therapists is more feasible, achievement of functional milestones is based on specific HSS rehabilitation protocols. All therapists receive appropriate training on these protocols and evaluation of attainment of milestones should yield low inter rater variability. Nevertheless, since all parties were unblinded to intraoperative anesthesia methods, knowledge of the particular anesthesia technique used could have influenced our results.

Our study investigates the efficacy of various methods of intraoperative anesthesia, by examining LOS and functional milestones, but it does not address safety issues. Since patients that experienced serious postoperative complications were excluded from the study (MI, PE, etc), serious adverse events (SAE) were not compared between groups. Very few patients experienced SAE so a comparison may not have been possible. However, this was not a goal of the study, but both efficacy and safety, especially of the newer techniques, should remain key areas of future research.

CONCLUSION

This retrospective review demonstrates that alternate methods of perioperative anesthesia, including SNB and PAI, are associated with improved outcomes over FNB. Subjects in the PAI group had the shortest LOS and reached functional milestones in the shortest amount of time. The authors hypothesize that these results may be due to the combination of efficacy of the alternative methods and sparing of quadriceps function, ie avoidance of quadriceps motor block.
However, these results must be considered with caution due to the use of non-randomized convenience samples and the potential for significant differences between groups. In addition, the study design does not allow for inference of causality, but only suggests that these alternative methods result in improved outcomes over FNB, particularly PAI. Nonetheless, this review supports further research of both SNB and PAI techniques due to their potential in improving patient functional outcomes, reducing LOS and decreasing costs.
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