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Introduction Of Innovative Medical Practices In Mayo Clinic: Effect Of The Interventions On Patient Outcomes

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INTRODUCTION OF INNOVATIVE MEDICAL PRACTICES IN MAYO CLINIC: EFFECT OF THE INTERVENTIONS ON PATIENT OUTCOMES

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DEDICATION

I dedicate this work to my Dad, who never failed to provide me with his persistent love, encouragement, and support, in any path I took.

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As I end my journey as a student and begin a new journey, I know more than ever that success rarely comes from one person working alone. Many people have played a major role in the successful completion of my doctoral degree.

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ABSTRACT

Purpose: Assessment of health technologies in medical practice is an ongoing process to provide clinicians and policymakers with information on the value of those applications. This dissertation aims to add to the existing body of literature and fill the gaps in prior studies by assessing two health technologies in Mayo Clinic Florida (MCF). The first paper provides an assessment of patient portal adoption and activity during hospitalization among cancer patients, and determines whether a portal application is associated with selected indices of patient safety, utilization and satisfaction. The second paper provides an assessment of a new approach in pain management after total knee arthroplasty (TKA), a periarticular anesthetic injection (PAI), and compares patient outcomes postoperatively among those who had this new pain management approach versus the traditionally used approach of peripheral nerve blocks in a consecutive earlier period. ***Methods:*** The first paper retrospectively reviewed all cancer inpatients admitted in MCF between 2012-2014 (N=4,594), compared portal adopters (i.e., who registered for a portal account) versus non-adopters, and compared inpatient portal activity among active versus inactive users. The second paper retrospectively reviewed consecutive patients who underwent primary unilateral TKA between March 1, 2013, and August 31, 2014 (N=511) and received FNB with SNB versus those who underwent TKA between October 1, 2014 and March 31, 2016 (N=479) and received PAI. In addition to descriptive statistics, postoperative outcomes, including pain scores, time to ambulation, distance walked, in-hospital falls, length of stay, discharge disposition, satisfaction wit pain control, emergency visits within 14 days, readmissions within 30 days, revisions within 90 days, and total cost of hospitalization and 90-day follow-up period, were compared. SAS Version 9.4 was used for all analyses. ***Results:*** We found that 2352 (51.1%) were portal adopters, and of them, 632 (26.8%) were active inpatient users. Adoption was influenced by predisposing and enabling factors, such as age, sex, race, marital status, employment status, income, and type of health insurance. Active inpatient use was similarly influenced by predisposing and enabling factors, such as age, race, and marital status, in addition to factors related to need, such as being sicker, nonlocal and admitted for medical treatment ($P<0.05$). In the second paper, we found that PAI had better analgesic effect at 24 hours after surgery compared to FNB, but no differences at 48 hours. Patients who received PAI had earlier ambulation, longer walking distance, shorter hospital stay, more discharges to home, better patient satisfaction with pain control, and lower hospitalization cost. On average, each patient who had their pain managed using PAI saved $3,539 on their TKA hospitalization cost. ***Conclusion:*** Based on early evidence, cancer patients reached modest levels of portal adoption, with increased adoption associated with predisposing and enabling determinants, and increased inpatient use associated with need. In pain management after TKA, PAI was superior in providing early postoperative pain relief, improved functional recovery, better patient satisfaction with pain, and lower hospitalization cost compared to FNB with single-shot SNB following TKA. Findings may provide insight for clinicians and policymakers who are interested in health technology assessment and directing future research efforts on the value of care.

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LIST OF ABBREVIATIONS

ACS... American Community Survey

ASA.. American Society of Anesthesiologists

APRDRG ....All Patient Refined Diagnostic Related Group

AHRQ ....Agency for Healthcare Research and Quality

BETOS .... Berenson-Eggers Type of Service

BMI .... Body Mass Index

CMS ....Centers for Medicare & Medicaid Services

CCD ....Continuity of Care Document

CCI...Charlson Comorbidity Index

CDC ....Centers for Disease Control and Prevention

DSS ....Decision Support System

EHR... Electronic Health Records

FNB..Femoral Nerve Block

GDP... Gross Domestic Product

HCAHPS.................Hospital Consumer Assessment of Healthcare Providers and Systems

HTA ....Health Technology Assessment

HITECH.......................Health Information Technology for Economic and Clinical Health

HIPAA .... Health Insurance Portability and Accountability Act

IOM...Institute of Medicine

ICD-9-CM International Classification of Diseases, Ninth Revision, Clinical Modification

ICD-10-CM International Classification of Diseases, Tenth Revision, Clinical Modification

ICU .... Intensive Care Unit

LOS .... Length of Stay

MCF .... Mayo Clinic Florida

MU .... Meaningful Use

MSDRG .... Medicare Severity Diagnosis Related Group

OR .... Operating Room

PAI .... Periarticular anesthetic injection

POD.. Post-operative Day

PT .... Physical Therapy

SNB.. Sciatic Nerve Block

TKA .... Total Knee Arthroplasty

UB04 .... Uniform Billing-04

UTAUT .... Unified Theory of Acceptance of Use of Technology

WHO .... World Health Organization

CHAPTER 1

INTRODUCTION

BACKGROUND

Medical practice has made rapid advances over the years through the adoption of innovative clinical and information technologies which help to provide high-quality health care. These technologies can result in more convenient, more-effective care delivery and improved patient outcomes [1-3]. However, they are one of the primary drivers of increased healthcare costs in the United States and society expects these new advances to add benefits to their health outcomes [4, 5]. In fact, 17.4% of United States GDP is currently consumed by the health care sector, and projected to reach about 19.6% by 2024 [6]. The Congressional Budget Office concluded that "roughly half of the increase in health care spending during the past several decades was associated with expanded capabilities of medicine brought about by technological advances" [7].

Although healthcare technology continues to advance remarkably, its assessment continues to lag significantly [8]. This assessment function requires collecting, evaluating, and systematically reviewing all available evidence related to the use of the technology under consideration. The Institute of Medicine reported that the cost of healthcare assessment is less than 0.3% of the total amount spent on healthcare [9].

The Office of Technology Assessment was established in 1972 and was funded by the US Congress to undertake technology assessments to inform federal funding decisions about emerging health and non-health technology [10]. In the 1990s, Health Technology Assessment (HTA) was widely used and the assessments tended to focus on efficacy, safety, cost-effectiveness, as well as patient-reported outcomes [10, 11]. HTA also have the objective of providing a basis for health care that is more evidence-based in order to be use scarce resources more efficiently, and improve health for patients and the general population [12].

As defined by the United States Office for HTA, healthcare technologies include drugs, devices, medical and surgical procedures as well as organizational and supportive systems in which such care are provided [13]. In light of this definition, this dissertation evaluates two healthcare technologies in Mayo Clinic Florida (MCF); an electronic patient portal, and a new pain management approach used after total knee arthroplasty (TKA). The document is presented in the following format: Chapter 1 provides basic background information on the problem, rationale and the research questions related to the two selected health applications; Chapter 2 provides an in depth review of relevant research and the gap in literature; Chapter 3 provides the research methodology; Chapter 4 provides a manuscript related to patient portals; and Chapter 5 provides a manuscript related to pain management after TKA. Results should provide insight for clinicians, policymakers, research community and those interested in improving patient care through technology.

Study I: Patient Portal Adoption and Use by Hospitalized Cancer Patients: A Retrospective Study of its Impact on Adverse Events, Utilization, and Patient Satisfaction

STATEMENT OF THE PROBLEM

A Patient Portal tied to the provider electronic health record systems is a new innovation in health information technology that is gaining popularity [14]. It grants patients' access to their own medical records, which is expected to transform how healthcare is delivered [15, 16]. Since 1996, patients could legally access their clinical records as part of the Health Insurance Portability and Accountability Act. However, fees, illegible handwriting, or time delays were barriers that hindered information access [17]. What sets the portal apart is the speed and flexibility with which patients can access their updated health information securely at any time, to view information like recent doctor visits, discharge summaries, medications, immunizations, allergies, and lab results. More advanced portals enable patients to request prescription refills, schedule appointments, exchange secure messaging with providers, and receive health educational programs.

Most published studies about patient portals describe their use in the primary care or outpatient settings [15, 18, 19]. Numerous research studies have shown that information provided in the portal are effective in stimulating patients with chronic conditions to monitor their care and promote their decision-making ability [20-22]. Yet, few studies were found exploring portal use patterns among patients with Cancer, whom in critical need for additional support for health information and care [23-26]. They receive treatment through complex plans involving multiple care providers and settings such as surgery, radiation, and chemotherapy, which make information availability a crucial part for them to reduce uncertainty and allow them to be responsible for making important decisions.

RATIONALE FOR THE STUDY

Portals are considered a promising innovation to support greater patient engagement. Patients who are engaged in their health have better adherence to safety practices, better compliance and partnership with the healthcare team, and may participate more in clinical trials and research [20, 27-29]. The Institute of Medicine report "Crossing the Quality Chasm" suggested that enhancing the flow of information among patients and medical providers would help reduce medical errors and improve the quality of care [30]. A study by Weingart and colleagues in ambulatory oncology found that active patient participation may reduce the risk of medical errors by providing clinicians with current information about their medical histories, medications and drug allergies [31]. In the inpatient setting, Weingart and colleagues surveyed 2025 patients and found that active patient participation was strongly associated with favorable judgments about hospital quality and reduced the risk of experiencing an adverse event [32]. Prey et al 2014 conducted a systematic review of patient engagement in the inpatient setting and concluded that research on inpatient engagement technologies has been limited [33]. Therefore, patient portals represent a significant shift in the way that health services are delivered and an opportunity to incorporate electronic health technologies into clinical practice.

In 2009, the Health Information Technology for Economic and Clinical Health (HITECH) Act incentivized clinicians to provide patients' with electronic access to clinical records through the "meaningful use" incentive program administered by the Centers for Medicare & Medicaid Services (CMS). Stage 1 meaningful use criteria include providing patients with an electronic copy of their health information, whereas stage 2 criteria were broadened to include enabling patients to view online, download, and transmit information about a hospital admission. Recently, CMS published the final rule for Stage 3, which focuses on the advanced use of the electronic portals to promote health information exchange and improve patients' outcomes [34]. Although providers are subject to a financial penalty if the rules are not met, they are not incentivized if they improve, such as by having a high rate of portal users, or providing advanced functionalities that offer value to providers and patients. Thereby, as a policy implication, policymakers should not only focus on the existence of electronic portals, but on the effective use to achieve better engagement, health and satisfaction.

To this purpose, hospital leaders at MCF were interested to understand the pattern of portal adoption and active use behaviors, specifically to the inpatient setting where research is limited and the pattern in unknown. According to Karahanna et al., adoption and continued use of an IT innovation represent different behavioral intentions [35]. Adoption is the initial usage (new behavior) of an innovation, while usage is the subsequent continued use of an innovation after its adoption. In this study, Adoption is the initial enrollment and signifies receptivity to the portal, while usage represents active engagement, continued use after adoption. Therefore we distinguish between these two behaviors and evaluate them separately.

RESEARCH QUESTIONS:

The study will answer the following research questions:

1. What are the characteristics of patients who are portal adopters, non-adopters, active inpatient users, and inactive inpatient users?
2. What factors influence portal adoption? What factors influence inpatient portal use?
3. Compared to non-adopters, what is the association between: (a) active inpatient use, and (b) inactive inpatient use, with adverse events, utilization (14-days emergency visits, 30-days readmissions), and patient satisfaction (self-management knowledge, overall satisfaction)?

Hypotheses:

1. I hypothesize that majority of portal adopters will be those who are young, Caucasians, male, and married. We also hypothesize that inpatient users will be those who are young, married, and sicker.
2. I hypothesize that predisposing factors (age, race, and marital status) will influence portal adoption, and need factors will influence active inpatient portal use.
3. I hypothesize that inpatient portal use will not be significantly associated with reduced adverse events, emergency visits, and readmission, or improved patient overall satisfaction. However, portal use may have a positive association with self-management knowledge.

Study II: Combined femoral and single-shot sciatic nerve block versus periarticular anesthetic injection for pain management after total knee arthroplasty

STATEMENT OF THE PROBLEM

Pain is one of the main concerns of patients undergoing total knee arthroplasty [36]. Over the last decade, different pain management techniques have become broadly used as an alternative to opioids alone in pain management. The most common pain control methods in TKA are general anesthesia, regional anesthesia using neuraxial blockade (spinal or epidural anesthetic), and peripheral nerve blocks. However, general and regional anesthesia may be inadequate as it causes extended recovery room stays, postoperative nausea or vomiting, and associated added costs [37]. Epidural analgesia is of proven benefit but is associated with side effects such as spinal headache, neurogenic bladder, hypotension, respiratory depression, pulmonary hypertension, cardiac decompensation, and a risk of spinal infection [38, 39]. Continuous infusion of opioids and bupivacaine into the knee has provided good postoperative pain control but may be associated with prolonged wound drainage [40]. Recent studies on continuous femoral nerve blocks found it associated with higher incidence of muscle weakness and opioid consumption, which led to delays in patient ambulation and more falls [41-43]. Recently, the emergence of periarticular injections that provide effective control of postoperative pain with fewer side effects has been one of the most important advances in orthopedic surgery. In fact, adequate pain control using PAI in TKA is viewed as a revolution in the management of postoperative pain, and a paramount to successful outcomes and patients' satisfaction [44]. Previous studies have shown that PAI are easier to administer, provide earlier mobilization, and are less costly [44-49].

At MCF, a peripheral nerve block was the default pain control approach used in total knee arthroplasty, using continuous femoral nerve block with single-shot sciatic nerve block. As the introduction of periarticular injections become a new advancement, the sister site, Mayo Clinic Arizona published results of a major randomized clinical trial conducted between 2010 and 2013, comparing combined femoral and sciatic nerve block with PAI as part of a multimodal pain protocol. Results found that PAI had equivalent pain relief scores, but shorter lengths of stay, and fewer complications than those associated with peripheral nerve blocks [50]. In September 2014, surgeons in Mayo Clinic Florida (MCF) showed interest in pursuing a practice change, following the Arizona model of care for pain management. They piloted the administration of PAI to a couple of patients' undergoing TKA, and preliminary results revealed superior improvements in patients' postoperative pain scores and recovery. Therefore, in October 2014, the orthopedic practice in MCF transitioned to primarily use PAI for pain management after TKA. Since then, the change in practice from the prior to the later pain management approach has not been rigorously evaluated in terms of analgesic efficacy, functional recovery, length of stays, patient satisfaction and total cost. Also, differences between these pain management approaches beyond the inpatient setting are unknown. We documented post-discharge measures including emergency visits (14-days), readmissions (30-days), revisions (90-days), and total cost incurred during the 90-day period. While most published studies did report measures of pain relief and functional recovery, to our knowledge, this is the first study to examine detailed cost per services between PAI and FNB with single-shot SNB for primary TKA.

RATIONALE FOR THE STUDY

There is a rapid increase in the number of TKA procedures performed annually [51]. In 2005, 450,000 primary knee replacements were performed and projected to increase almost eight-fold to 3.48 million in 2030, making joint replacements the most common elective surgical procedures in the coming decades [52]. Because these procedures are elective and expensive; Medicare paid approximately $3.2 billion in 2000 for hip and knee joint replacements, and because the prevalence of arthritis is expected to grow substantially as the population ages, the demand for these procedures are likely to increase [53]. Thus, healthcare services delivery must be planned effectively to meet patients' need and expectations for successful, safe and less painful procedures. Poorly managed postoperative pain can prolongs the recovery and mobilization process, delays discharge, reduces quality of life and increases unnecessary healthcare utilization such as unscheduled readmissions [54]. Proper pain management allows patients' to ambulate faster, decrease their risk of having venous thromboembolism or acquiring hospital-based infections due to longer hospital stays, and consequently reduce cost [55-58].

The IOM report *"Across the Chasm: Six Aims for Changing the Health Care System"* outlined the most important aims to deliver better outcomes, where care should be safe, effective, patient-centered, timely, efficient and equitable [30]. Fortunately, advanced improvements in technology through devices and innovative techniques have broadened the awareness in implementing best practice strategies for surgical and anesthetic management. In fact, the choice of pain anesthetic technique has been shown to play a significant role in promoting favorable surgical outcomes. Yet, few evaluation studies focused on evaluating TKA outcomes associated with using nerve blocks or periarticular injections in light of these specific IOM aims.

The primary aim of this study was to compare patient outcomes postoperatively in two exclusive, yet consecutive periods; a period where peripheral nerve blocks were used versus the use of a periarticular anesthetic injection of ropivacaine, epinephrine, ketorolac, and morphine, for pain management after TKA. Given the high frequency of this procedure, results of this study may provide insight for clinicians to determine efficient pain management approaches after TKA, and promote evidence-based clinical policy for cost-effective pain management in orthopedic care. Results will also be useful for patients to take an active role in their care and make more informed decisions regarding their pain management approach.

RESEARCH QUESTIONS:

This study will answer the following research questions:

1. Are there significant differences in **hospital outcomes** of TKA patients who received FNB versus PAI for pain management in terms of: (1) pain scores at 24 hours and at 48 hours, (2) time to first ambulation, (3) distance walked, (4) in-hospital falls, (5) length of hospital stay, (6) discharge disposition, and (7) total hospitalization cost?
2. Are there significant differences in **post-discharge outcomes** of TKA patients who received FNB versus PAI for pain management in terms of: (1) patient satisfaction, (2) emergency department visits within 14-days, (3) unplanned readmissions within 30-days, (4) revisions within 90-days, and (5) total cost of 90-day post-discharge period?

Hypotheses:

1. I hypothesize that patients' who received PAI compared to nerve blocks will have better hospital outcomes.
2. I also hypothesize that patients' who received PAI will have lower TKA hospitalization cost.

CHAPTER 2

LITERATURE REVIEW

STUDY I: REVIEW OF LITERATURE

SIGNIFICANCE OF CANCER IN THE UNITED STATES

Cancer is a major public health problem in the United States (U.S.) and the second-leading cause of death among Americans [59]. In 2012, an estimated 1,529,078 people were diagnosed with cancer in the U.S., and 582,607 people died of the disease [60]. In 2013, there were an estimated 14,140,254 people living with cancer of any site [61]. In 2016, it was estimated that there 1,685,210 new cases of cancer of any site will emerge, with 595,690 estimated deaths [62]. According to cancer statistics, death rates for cancer are higher among the middle-aged and elderly populations [61]. The percent of cancer of any site deaths is highest among people aged 75-84 (26.9%). Overall cancer age-adjusted incidence rates are higher among men than women (504.5 vs. 409.9 per 100,000) respectively. Among racial and ethnic groups, there are more new cases among African American men (571.8 per 100,000) and white women (422.5 per 100,000) and fewer new cases among Asian/Pacific Islanders of both men and women 317.3 and 296.7 per 100,000) respectively.

Among men, prostate (105.3 per 100,000), lung and bronchus (71.6 per 100,000), colon or rectum (44.8 per 100,000), and urinary bladder (35.4 per 100,000) were the most common cancers. Among women, breast (122.2 per 100,000), lung and bronchus (52.1

per 100,000), colon and rectum (34.1 per 100,000), and uterine corpus (25.7 per 100,000) cancers occurred most frequently [62]. The Agency for Healthcare Research and Quality (AHRQ) estimated that for 2012, the direct medical costs for cancer, including all health care expenditures, were $87.5 billion, which is about 6.7% of total spending [63]. These costs are more likely to increase due to the increased burden of the disease and aging of the U.S. population. To meet these challenges, new approaches to healthcare delivery and comprehensive population health management, education and awareness are required.

INFORMATION: A CRITICAL NEED FOR CRITICAL PATIENTS

Cancer patients usually face multiple active conditions, complex tests, procedures, and treatments. These overwhelming conditions increase their need for information support about their health status, and make them eager to better understand their diagnosis, prognosis, and options for treatment [19, 64, 65]. Kowalski et al. 2014, found that breast cancer patients who are younger, those receiving mastectomy, having health insurance, not living with a partner or having a foreign native language reported higher unmet information needs in hospitals [65]. Beckjord et al. 2008, studied a heterogeneous sample of cancer patients and found that cancer survivors who were younger, had comorbid health conditions or had worse physical or mental health had more information needs [66]. In a population-based study, Nagler and colleagues reported that the rate of information-seeking varied by tumor type, where patients with breast or prostate cancer had higher information-seeking behavior than did patients with colorectal cancer, and the differences were most pronounced in patients with early-stage disease [67]. Many patients are increasingly using the Internet to acquire information, especially through Web-based materials [68]. Online Cancer information seekers tend to be younger, more educated, and higher-income patients [69, 70]. Although the Internet is the most cited source of cancer information, a survey involving patients receiving treatment for lung cancer showed that only 16% actually sought information from the Internet [71]. This study has also found that the Internet-derived information was perceived to be of a similar quality to other non-clinical sources, suggesting that trust in the Internet is not always the primary or only factor impacting patients to act on its information. According to Shea–Budgell and colleagues, cancer patients believe that their health care provider is the most trusted source of cancer information [72]. This finding is also supported by a study focused on prostate cancer patients where they reported their doctor or other health care providers as the trusted information source [73]. Among breast cancer patients, a background survey showed that 86% of participants 'agreed' or 'strongly agreed' that having reliable information approved from the hospital would make them feel more able to make decisions about their treatment and disease [74]. Therefore, healthcare providers have a responsibility to build better communication structure with their patients and meet their information needs. Delivering appropriate information in a strong communication and trust environment is a crucial enabling factor that supports patient-centered care, which is a 'fundamental paradigm shift' in healthcare delivery according to the World Health Organization [75]. The concept of patient-centeredness is specifically defined by the Institute of Medicine (IOM) as "care that is respectful of and responsive to individual patient preferences, needs, and values" [30]. In a patient-centered environment, information exchange between providers and patients goes beyond just providing facts and figures to tailoring information in response to an understanding of a patient's concerns, beliefs, and expectations. Evidence suggests that a patient-centered approach is strongly associated with satisfaction, better engagement and adherence to treatment, and improved health and quality-of-life outcomes [76-78].

In today's healthcare system, information technology is the foundation of the future. Unfortunately, most health care-related information technology investments have been concentrated on the administrative and financial side, rather than on clinical care (Reid, 2005). As a result, little progress has been made toward meeting the information needs of patients and providers. However, current electronic patient portals have brought new opportunities for efficient and high-quality patient centered care by providing patients' access to their own clinical information [15]. Since 1996, the Health Insurance Portability and Accountability Act (HIPPA) guaranteed patients' rights to review their health records [79]. However, before the digital age, patients' medical records were paper-based, and patients' demand for their own records had barriers due to cultural and practical reasons or due to concerns by health care practitioners [80]. Also, illegible handwriting, time delays and photocopying costs were other factors that hindered information access [17]. Nowadays, the transition to electronic health records (EHR) has become a significant factor in medical practice and healthcare systems. It has enhanced the IOM principles of patient safety, timeliness, efficiency, and patient centeredness [30]. Many institutions are implementing electronic portals linked with EHR to fulfill patients need for information and provide them with prompt access to their updated clinical records. This information exchange will eventually transform the delivery of care on all levels of the health care delivery system, the patient, the care team, and the overall health care organization.

Recently, patients do recognize the benefits of portals. In a nationwide survey conducted in 2011, 70% of patients indicated interest in portal access if that was available for them [81]. However, a recent systematic review demonstrated that patients' interest and ability to use patient portals is strongly influenced by personal factors such age, ethnicity, education level, health literacy, and health status [20]. A cohort study at Kaiser Permanente Georgia found that portal registration was more likely among whites, those with Internet access at baseline, and those with more education [82]. A cross sectional observational study by Goel and colleagues at an academic primary care practice found that White patients were significantly more likely to enroll in patient portals than black, Latino, and Asian patients (74% vs. 55%, 64%, 66%, respectively, $p<0.05$) [83]. A study by Weppner and colleagues found that younger age, male sex, higher socioeconomic status and greater illness rates were associated with earlier portal registration [84]. Group Health Cooperative found that portal adopters were more likely to be with commercial insurance and higher than expected clinical need [85]. Among portal registrants at the Cleveland Clinic, whites were more likely than blacks to use the account after registering for it [55]. Yamin and colleagues compared primary care patients who had activated their portal account with those who had not, and found lower utilization among all racial minorities [86]. In contrast, Phelps and colleagues observational study found a greater portal use among those with more medical problems, particularly those with chronic diseases [87]. A retrospective study conducted in New York found greater portal access among those with private insurance [88]. The University of Pittsburgh evaluated the characteristics of portal users and found higher access among those in poorer health, as indicated by greater numbers of diagnoses and medications [89] . In a large oncology cohort, greater healthcare need as expressed by disease burden and case complexity was associated with portal use [24].

Studies indicate that information features enabled by patient portals are intended to make patients more active in managing and monitoring their health. Thus, patients who are armed with information about their condition make more informed choices about their own health care and have greater satisfaction with treatment choices and quality of life [17]. They also have better adherence to safety practices, better compliance and partnership with the healthcare team, and possibly participate more in clinical trials and further research [29]. Other studies found that engaging patients in their care will improve their experience and enable them to take responsibility for their own care after discharge [80, 90].

Several studies showed that access to electronic records in the outpatient setting have increased their ability to self-manage chronic health conditions, medication tracking and provided a safe way to renew their prescriptions [21, 91]. It has also increased the ability to utilize appointment time more effectively, to prepare patients for appointments by accessing results of previous tests and medications, and to interact efficiently with clinicians for clarifying unclear information [16]. Despite potential advantages, systematic reviews demonstrated that the most frequent obstacles reported on using the portals were the complexity faced by those who lack technology experience, frustration faced by complicated medical terminology, and anxiety and confusion when information is viewed without concurrent clinical interpretation, which cause mutual distress for patients and providers [24, 74, 92].

However, most published studies about patient portals describe its use in the primary care or ambulatory settings, with little experience reported on hospitalized patients. In fact, patients need more information and engagement when they are admitted to the hospital to reduce their feeling of isolation, uncertainty, and anxiousness [33, 93]. A controlled trial by O'Leary and colleagues provided the hospitalized intervention group with a mobile portal, and found that the application was able to increase the patients' knowledge of physician names and roles [94]. A qualitative study by Greysen and colleagues evaluated the impact of providing tablet computers with an educational module on patient safety and patient portal access to a pilot sample of 30 hospitalized patients, and found it to be useful for increasing patients' engagement [95]. Among cancer patients, only a few studies have described the pattern of portal use and none was found to evaluate associated outcomes. In a cohort of patients with hematologic malignancies, 89% expressed interest in accessing electronic health records [90]. In another study among breast cancer patients, 98% reported that having access to their personal electronic health record would help them manage their care [74]. In a 10-months study of 186 ambulatory patients with brain tumor, 60% had accessed a personal health record at least one time during the study period, and access was significantly associated with the reduction of their disease-related uncertainty [23]. A retrospective study among heterogeneous cancer patients seen in a national cancer center, online electronic medical record portal use was associated with younger age, white race, and an upper aerodigestive malignancy diagnosis [24]. In this latter study, the majority of patient access occurred during clinic hours, which suggests that access is more common when patients were in the hospital.

Mayo Clinic is a tertiary care non-profit medical practice that is recognized for high-quality patient care. It is regarded as one of the world's greatest hospitals and ranked No. 1 on the 2014–2015 U.S. News & World Report List of *"Best Hospitals"*, maintaining a position near the top for more than 20 years (Harder 2015). The Clinic was first based in Rochester (Minnesota), and currently has major campuses in Jacksonville (Florida), and Phoenix (Arizona), along with the Mayo Clinic Health System, which consists of more than 70 hospitals. The institution has a three-part focus: patient care, research, and education, which are represented by the shields in the Clinic logo. It also has a history of investing in innovation by implementing projects that transform the experience and delivery of healthcare through conducting continuous assessments and improvements in the medical practice.

Innovative applications, particularly electronic patient portals were implemented in Mayo Clinic to contribute to the patient-centeredness approach, aligning with the primary statement of the organization that *"the needs of the patient come first"*. MCF contracted with Cerner solutions to implement the patient portal and integrated it with the system-wide electronic medical record in 2010. When patients schedule an appointment at MCF, they are invited to register for a portal account and are provided with information on why and how to register. With each appointment reminder, patients receive a re-invitation message to the portal. Portal invitations are also offered in all outpatient waiting areas and displayed on electronic screens around the clinic. Once registered, patients are able to access his or her account via a password-protected encrypted Mayo Clinic website or mobile application on Android, Apple, or Amazon devices. The portal includes informational functions, such as viewing lab results, current medications, allergies, and diagnostic reports from clinic visits and hospitalizations, and administrative functions, such as paying bills, processing prescription refills, and coordinating appointments. A Continuity of Care Document (CCD), a complete summary of patient current health status and history, is also available to view, download, or forward to physicians at other hospitals. Although the portal is designed for outpatients, some functions are applicable to inpatient health information needs during the hospital stay. Hospitalized patients have considerable time when they are not occupied with diagnostic testing or other activities, which can be better utilized. For example, the portal gives inpatients real-time access to lab results, admission notes, consultation reports, and surgical notes, to view on their own time and between bedside rounds. This functionality potentially facilitates patient communication and interaction with the healthcare team during their stay, and empowers the patient to be more attentive toward errors in documentation. In addition, the medication function provides patients with information on the type and purpose of their medications, including in-hospital medication intake, which could enable patients to ask questions, review for accuracy, or report medication discrepancies. Before home discharge, a discharge summary and discharge instructions is uploaded to the portal, giving patients time to review closely and ensure their understanding of home self-management instructions. While the development of portal functionality for inpatients is in early stages, the offered content may still help patients become more activated and improve post-discharge care.

STUDY II: REVIEW OF LITERATURE

BURDEN OF JOINT DISEASES AND THE NEED FOR TOTAL KNEE ARTHROPLASTY

Arthritis is the most common cause of chronic knee pain and disability. Although there are many types of arthritis, most knee pain is caused by just three types: osteoarthritis, rheumatoid arthritis, and post-traumatic arthritis [96]. Total knee arthroplasty (TKA), also called total knee replacement, is a common orthopedic operation and an effective treatment for reducing severe arthritis pain and restoring the mobility of patients [96]. Murphy et al. estimated that nearly half of all adults in the United States are at risk of developing symptomatic knee osteoarthritis by 85 years of age [97], and Weinstein et al. estimated that over half of the U.S. adults diagnosed with knee osteoarthritis will undergo a TKA in some point in their lives [98]. The latter study also estimated that the lifetime risk of primary total knee replacement from the age of 25 years was 9.5% for women and 7.0% for men, increasing with age [98]. However, recent trends are indicating an increase in prevalence over time and a shift to younger ages less than 65 years [52, 99]. Further studies found higher TKA procedure rates in women than in men, in whites than in blacks, in those with higher incomes than in those who received Medicaid supplementation, and in those living in the West North Central and Mountain regions than other areas [100]. The rapid increase in TKA surgeries each year can be attributed to the growth in life expectancy, aging population, surgical technical advancements, and the increasing prevalence of population risk factors causing joint problems [29, 52].

PAIN MANAGEMENT AFTER TKA

Total knee arthroplasty have proven to be the most successful surgical intervention aimed at improving mobility and quality of life among patients with arthritis [101-103]. Yet, postoperative pain is one of the main concerns of patients undergoing this procedure, and achieving satisfactory postsurgical pain control is a critical factor for successful recovery [104-106]. Given the importance of the pain experience, the Joint Commission and the Agency for Healthcare Quality and Research (AHRQ) introduced standards for organizations to improve their care for patients with pain.

In the last few years, clinicians' tended to focus more on pain management since severe pain has profound implications on patients' quality of life [107, 108]. Advancements in postoperative pain control headed toward multimodal pain management approaches instead of using opioids alone [109]. Of these approaches, femoral nerve block (FNB) which is a well-established analgesic to reduce pain post-TKA and seen as the gold standard [110, 111]. However, many authors reported a number of disadvantages including quadriceps weakness that delays recovery, increases risks of neurological symptoms, falls, opioids consumption, and complications [43, 112, 113]. For this reason, some clinicians combine sciatic nerve block (SNB) to a FNB, instead of using FNB alone, in order to improve outcomes early after surgery [114-118]. Yet, the advantages of SNB when combined with FNB continue to be debated in the literature [119, 120].

Compared with peripheral nerve block, periarticular anesthetic injections (PAI), a concentrated multi drug injection, have been identified as a preferred alternative approach for pain management after TKA [121]. Earlier clinical studies have been conducted to validate the efficacy and safety of different combinations of the PAI drug mixture, and reported it to be easier to administer and have better patient outcomes [122-124].

Kirkness et al retrospectively compared patient outcomes who recieved PAI with liposome bupivacaine versus those who received FNB, and found that more patients' in the PAI group walked on the day of surgery (22% versus 3%, $p < 0.05$), more likely to be discharged within two days (50% versus 19%, $p < 0.001$), and had shorter length of stay (3.1 days versus 3.6 days, $p < 0.03$) compared to the FNB group [125, 126]. Tfadhhol and colleagues randomized clinical trial presented data suggesting that PAI with ropivacaine, ketorolac, and epinephrine results in faster postoperative ambulation, as indicated by being better able to walk more than 3 meters on the first postoperative day (POD) (74% versus 19%. $p < 0.001$) compared to FNB [127]. Affas and colleagues measured pain during the first 24 hours after TKA, on a numeric rating scale (0–10), and found that pain intensity at rest was marginally lower with infiltration (mean score: 1.6 versus 2.2) than with FNB [128].

Still, other published studies found controversial conclusions. Wang et al meta-analysis found that single-injection FNB have better pain relief in the early postoperative period compared with single and continuous periarticular multimodal drug injections, with no significant difference seen in post-operative complications between the two groups [129]. DeWeese et al conducted a retrospective comparison and found that other injection mixtures such as those with containing fentanyl and bupivacaine resulted in better pain relief than did continuous injection of the knee with bupivacaine [40]. Spanghel et al clinical trial used PAI mixture of ropivacaine, epinephrine, ketorolac, and morphine and found patients who received it had shorter length of stay compared to those who received FNB (2.44 days versus 2.84 days; p=0.02), while no differences in mean pain scores taken in three times points post-surgery were observed between the groups [50].

Recent studies in the literature presented comparisons of direct hospital cost associated with the two pain management approaches. In a single-site retrospective cohort study of 268 patients, the mean adjusted total hospitalization cost per patient was significantly lower among patients who received PAI with liposomal bupivacaine compared to FNB ($8,758 versus $9,213, p=0.033) [126]. Similar conclusions were found in a pre-post study among 125 TKA cases performed using either PAI with liposomal bupivacaine or FNB, and found that the average hospitalization cost was significantly lower with PAI compared to FNB ($26,472 versus $28,546; p< 0.001) [130].

National calculations of aggregate annual costs for TKA hospital stay indicated that it was the second most costly procedure at $11.3 billion after spinal fusion at $12.8 billion [131]. Therefore, it is suggested that effective pain management will influence patients to regain mobility, facilitate recovery, decrease length of hospital stay and consequently lower cost. However, consistent evidence on PAI as better alternative to other pain management approaches is limited and research is needed to support its efficacy [132-136]. Interestingly, healthcare payers and policymakers are currently targeting total joint arthroplasty as an area for quality improvement and healthcare cost-savings initiatives [137, 138]. In addition, because many surgical procedures have migrated to the outpatient setting, stakeholders may be interested in pain control approaches that enable easier and safer TKA that can be provided at lower cost.

TKA IN MAYO CLINIC

In Mayo Clinic, TKA represents the most common elective hospital admission. The Department of Orthopedics has enjoyed a phenomenal reputation for providing this procedure successfully, leading to an extraordinary number of patients seeking care. In fact, the first FDA-approved total joint arthroplasty in the U.S. was performed at Mayo Clinic 45 years ago (first total hip arthroplasty - March 10, 1969 by Dr. Mark Coventry and team at Rochester Methodist Hospital). Since then, Mayo orthopedic care has routinely ranked among the very best in the country. Today, Mayo destination sites in Rochester, Arizona, and Florida perform more than 6000 TKA per year, making it one of the largest practices in the U.S. As such, this service line justifies the work and attention to better delineate objective measurement of quality, cost, and the value of provided care.

CHAPTER 3

METHODOLOGY

STUDY I METHODS

STUDY DESIGN AND SAMPLE:

This was a retrospective review of patients satisfying the following criteria: (1) adults (≥18 years old), (2) had cancer as a primary or secondary diagnosis at time of hospitalization identified through the International Classification of Disease (ICD-9) codes, and (3) admitted to MCF between August 1, 2012 and July 31, 2014 (N=4594). Per the unified theory of acceptance of use of technology (UTAUT), user acceptance and intention to use of information technology is subsequent by usage behavior [139]. Thus, we included the first hospitalization where a portal account had been established prior to admission to examine consequent inpatient use. If the patient had not established a portal account prior to any admission, then the first hospitalization in the study period was selected. Patients who had a portal account prior to admission were defined as "adopters", and those without a portal account were "non-adopters". Among adopters, inpatients who logged in their portal during the hospital stay were "active inpatient users" and those who never logged in were referred to as "inactive inpatient users". The study cohorts and sample size are presented in Figure 3.1.

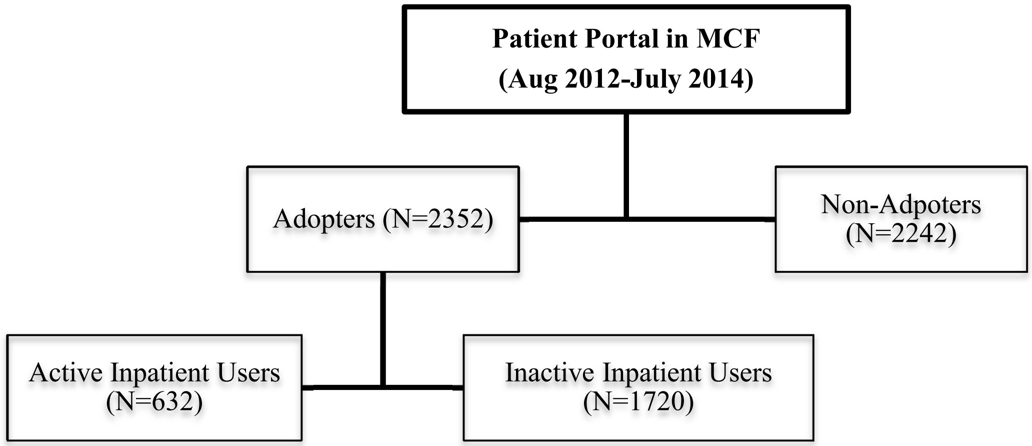

Figure 3.1 Study I Cohorts and Sample Size

CONCEPTUAL MODEL:

A study theoretical model was developed based on Andersen's model of Healthcare Utilization (Figure 3.2). Andersen's model was initially developed to understand health services use and later revised to include consumer satisfaction and dimensions of health status [140, 141]. Shortly after the model was developed, health services use was portrayed as a health behavior influenced by multiple factors [142]. According to the World Health Organization (WHO), health behavior was defined as "any activity undertaken by an individual, regardless of actual or perceived health status, for the purpose of promoting, protecting or maintaining health, whether or not such behavior is objectively effective towards that end" [143]. Because the portal is a tool to maintain and promote health, we considered portal adoption and inpatient use as health behaviors that could be studied using Andersen's model. We assumed that all study participants had a common environmental context, as all patients in MCF received their care in the same structure. Patient characteristics were classified into predisposing, enabling, and need factors as described in the model below.

STUDY MEASURES:

A. Predisposing Factors:

This included demographic variables such as gender (male as the reference group), age (categorized as: 18-44, 45-54, 55-64, 65-74 "reference", 75-84, and 85 or above), and race (categorized as Caucasian "reference", African American, and Other group that includes Asian, Native Hawaiian or other Pacific Islander, American Indian, and those with more than one race.

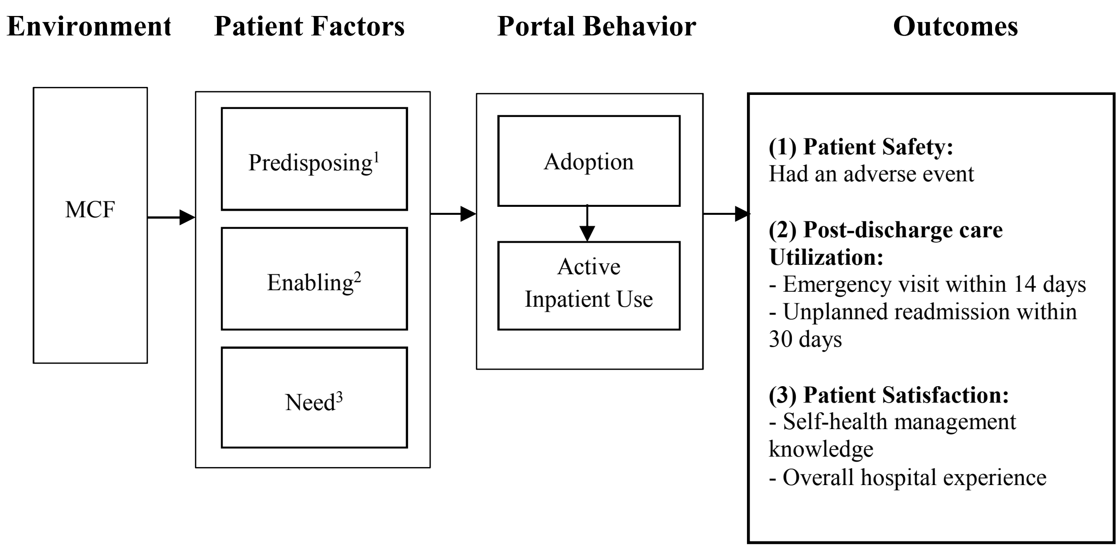

Figure 3.2 Study I Theoretical Model
1 Predisposing factors: age, sex, and race.
2 Enabling factors: marital status, employment status, health insurance type, and income.
3 Need factors: geographic area of residence, comorbidities, and frequency of hospitalizations. Additional need factors related to the admission: MSDRG type and APRDRG disease severity weight.

B. Enabling Factors:

This included social and financial factors, including marital status (broken into divorced, married "reference", single and widowed), employment status (broken into disabled, employed "reference", not-employed, retired, and unknown, where patients did not report their employment in their registration forms). Initial analysis showed a large segment of the study sample with unknown employment, and that is why it was included and analyzed as a category. Geographical area of residence was broken into international, national, regional (North East Florida and South Georgia), and local (Jacksonville area), where "local" was used as the referent level.

Financial factors included health insurance type (broken into governmental (i.e., Medicare & Medicaid) "reference", and non-governmental insurance (i.e., commercial insurance and self-payers). Self-payers were less than 3% of the sample, thus was included as a separate category. We reported whether patients had a median household income less than Florida's state median income ($48,277) based on their residential ZIP code, a surrogate for socio-economic status. The median household income was extracted from the most recently available (2006-2010) American Community Survey (ACS), matched to our sample at the ZIP code level [144]. We were unable to match 1% of the sample with ACS, either due to being an international patient or no data was available in ACS for the patient ZIP code, thus, patients were assigned the average median income for the study sample.

C. Need Factors:

This category included the frequency of hospitalizations in the study period as a continuous variable and number of comorbidities categorized in three groups: no comorbidities "reference", one to two, and three or more. Comorbidities were counted by the presence of any Deyo-Charlson diseases "yes/no" 12 months prior to the encounter. Deyo-Charlson is a validated measure to categorize comorbidities of patients based on the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) diagnosis codes found in administrative data [145]. The original Index was developed with 19 categories, but has been modified to 17 categories, which are myocardial infarction, congestive heart failure, peripheral vascular disease, dementia, ulcer, cerebrovascular disease, chronic pulmonary disease, mild liver disease, metastatic solid tumor, tumor without metastasis, diabetes, diabetes with organ damage, hemiplegia, moderate or severe renal disease, moderate or severe liver disease, aids, and rheumatologic disease. We excluded the count of metastatic solid tumor and tumor without metastasis categories as all patients included in the study do have tumor, and our interest was to count other existing diseases.

Additional need determinants related to the hospital admission were documented including admission service (medical "reference" versus surgical) based on the Medicare Severity-Diagnosis Related Group (MSDRG) codes. We also documented disease severity weight as measured by "All Patient Refined Diagnostic Related Groups" (APRDRG) classification system, which classifies patients according to their reason of admission, severity of illness and risk of mortality [146].

D. Outcomes:

1. Emergency visits within 14-days after discharge obtained from hospital internal records. (categorical: yes/no)

2. All cause unplanned readmission within 30-days after discharge obtained from hospital internal records. (categorical: yes/no)
3. Patient Satisfaction, obtained from the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) survey[147]. HCAHPS is a national standard validated survey to measure patients' perspectives on hospital care developed by the Centers for Medicare & Medicaid Services (CMS) and the Agency for Healthcare Research and Quality (AHRQ)[148]. HCAHPS in Mayo Clinic was distributed by mail to a random sample of patients between 48 hours and 6 weeks after discharge. The survey is 32 questions in length. However, initial analysis showed low received responses and therefore we could not include all survey questions, and selected the relevant items with highest response. We also could not calculate the response rate as MCF contracted with an external company "Cerner" for data collection, and the agreement included only returned surveys, which was hence a study limitation.

We measured patient self-health management knowledge with two questions:

1. *HCAHPS 24: When I left the hospital, I had a good understanding of the things I was responsible for in managing my health,*
2. *HCAHPS 25: When I left the hospital, I clearly understood the purpose for taking each of my medication,*

and measured overall hospital satisfaction with one question:

3. *HCAHPS 21: Using any number from 0 to 10, where 0 is the worst hospital possible and 10 is the best hospital possible, what number would you use to rate this hospital during your stay.*

Responses were transformed and averaged, resulting in a 0 to 100 linear-scaled score as follows: ("Strongly Disagree" = 0; "Disagree" = 33.3; "Agree" = 66.7; and "Strongly Agree" = 100) for HCAHPS questions 24 and 25, and (Overall Rating "0" = 0; Overall Rating "1" = 10; Overall Rating "2" = 20; …; Overall Rating "10" = 100) for HCAHPS question 21.

DATA ACQUISITION:

Data was extracted from the EHR and the Decision Support System (DSS). These two databases were matched to obtain information on patient characteristics and outcomes for the selected hospitalization. HCAHPS patient experience data were obtained from the quality management department.

DATA ANALYSIS:

We described the characteristics of oncology patients according to their portal adoption and inpatient activity behaviors and examined differences between groups using Pearson $\chi 2$ and Wilcoxon nonparametric tests. Univariate and multivariable logistic regression models were used to test the association between patient characteristics, and adoption behaviors separately adjusting for patient characteristics. Multivariate logistic and linear regression models were used to examine the association between outcomes and portal behaviors. Statistical analyses were performed using SAS Version 9.4 (SAS Institute Inc., Cary, NC, USA), and significance was defined as $P<0.05$. Detailed analysis plan is shown in Table 2.

BUDGET:

None

ETHICAL CONSIDERATIONS:

The study proposal was approved by the Institutional Review Board (IRB) in Mayo Clinic (# 14-006039). All extracted data were stored on a password-protected server known only to the researcher.

CONFLICT OF INTEREST:

None

STUDY II: METHODS

STUDY DESIGN AND SAMPLE:

This was a retrospective chart review of patients who were at least 18 years of age and received a primary unilateral total knee arthroplasty at Mayo Clinic Florida. International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) and International Classification of Diseases, 10th Revision, Clinical Modification (ICD-10-CM) procedure codes for total knee arthroplasty were used to extract eligible patients, as the practice transitioned to use the later coding system in December 2014. A total of 1158 TKA patients were screened to obtain 990 eligible patients for the study. Figure 3.3 illustrates the process of screening patients for eligibility. We compared patients cohorts who received FNB combined with single-shot SNB for pain control after TKA between March 1, 2013 and August 31 2014 versus patients who received PAI between October 1, 2014 and March 31, 2016.

Table 3.1 Detailed analysis plan for Study I

Objectives	Comparison groups	Variables	Type of analysis
Question #1 **Patient Characteristics**	Adopters vs. non-adopters	Predisposing, enabling, and need factors	1. Descriptive analyses including frequencies, means and standard deviations, and percentages as appropriate. 2. Examine differences between groups using Pearson $\chi 2$ and Wilcoxon nonparametric test.
	Among adopters: Active vs. inactive inpatient users		
Question #2 **Predictors for adoption**	Dependent: Portal Adopter: Yes/no	Adjusting for patient predisposing, enabling, and need factors	Logistic regression model for each dependent variable
Question #2 **Predictors for active inpatient use**	Dependent: Active inpatient user: Yes/no		
Question #3 **Association of inpatient portal behaviors and outcomes**	Dependent: (5 separate models) 1. Adverse event (yes/no) 2. Emergency visit (yes/no) 3. Readmission (yes/no) 4. Self-management knowledge score 5. Overall satisfaction score	Portal behavior: nonadopter (reference), active inpatient user, inactive inpatient user adjusting for age and disease severity (APRDRG weight)	Logistic regression for adverse events, emergency visits, and readmissions. Linear regression for self-health management knowledge and overall hospital experience scores.

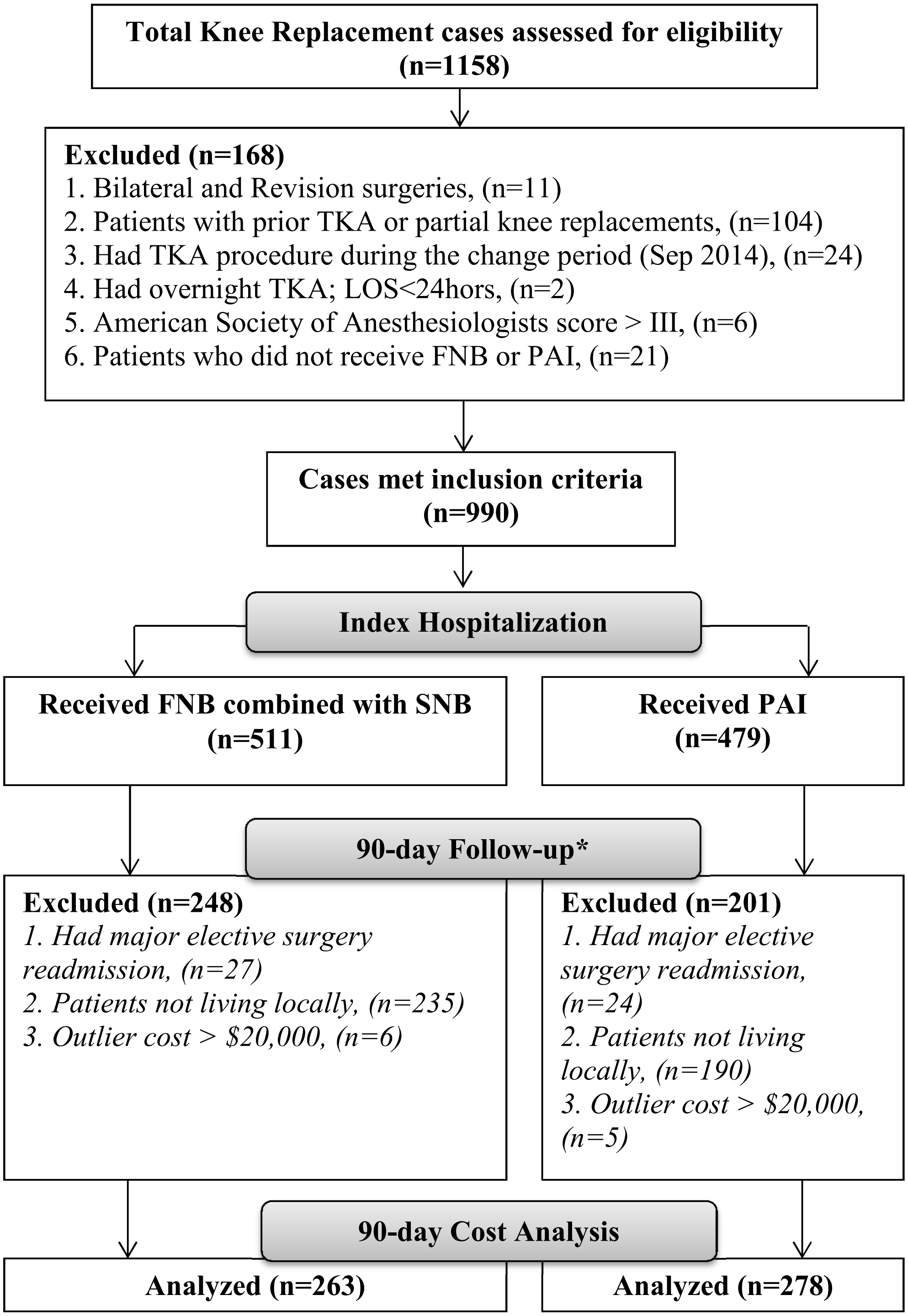

Figure 3.3 Study II Flow diagram of patients' exclusions and eligibility
*Exclusion criteria in the 90-day follow up period are not mutually exclusive.

DESCRIPTION OF THE PAIN MANAGEMENT APPROACHES

Identical surgical procedure, implants, and same surgery team with similar patient distribution for each surgeon, performed TKA in the two periods, minimizing the chance for variability and provider factors. For patients who received FNB combined with single-shot SNB, the same anesthesiologist performed the anesthesia for all cases, using a pre-procedure sedation with 0.5 mg midazolam and fentanyl. After that, patients had an indwelling continuous femoral catheter supplemented with a single-shot SNB in cases that did not have significant valgus deformity or radiculopathy. Ultrasound imaging aids the anesthesiologist in placing the needle in exactly the right location, under surgical aseptic conditions. For patients who received PAI, the anesthetic mixture was administered based on weight, as previously used by Spanghel and colleagues in Mayo Clinic Arizona and presented in Table 3.2 [50]. PAI was administered by the same surgeon, minimizing the potential for confounding effects on injection technique. The injection was administered by 18 gauge needle as multiple boluses into the periarticular tissue surrounding the knee joint prior to site closure, with no additional infusion or injections after site closure. 30cc was placed in the posterior capsule and the rest was throughout the anterior knee periarticular tissues and subcutaneous tissues. Detailed description of the procedure is explained elsewhere [50]. The efficacy and safety of several different combinations of the mixture have been established in earlier studies [123, 124, 149].The postoperative pain control was the same for both groups and included the use of analgesia such as morphine, acetaminophen, celecoxib, tramadol, and narcotics, administered via oral or intravenous means as necessary.

Table 3.2 Periarticular injection concentrations:

Weight (kg)	50-74.9	77-99.9	100-125
Ropivacaine	200 mg	300 mg	400 mg
Epinephrine	100 mg	200 mg	300 mg
Ketorolac	30 mg	30 mg	30 mg
Morphine sulphate	5 mg	5 mg	5 mg
Normal saline added to bring volume to 120 mL.			

CONCEPTUAL MODEL:

The conceptual model was developed based on Donabedian model of structure, process and outcomes (Figure 3.4).

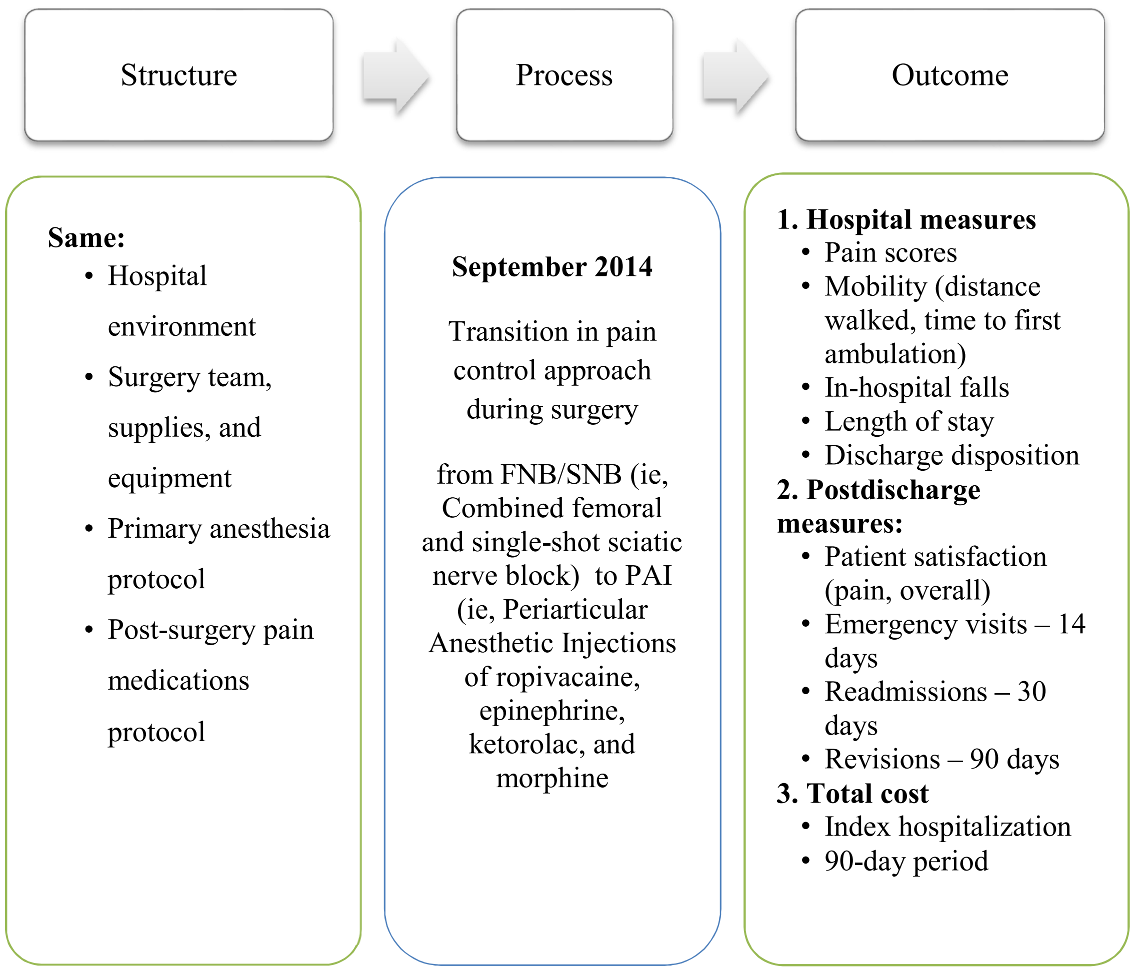

Figure 3.4 Study II Theoretical Model

Our assessed outcomes are also aligned with IOM aims of healthcare quality [30]. Please refer to Figure 3.5 that demonstrates how our outcomes are related to those aims, putting the issue of patient safety and quality on the radar screen of clinicians and policymakers.

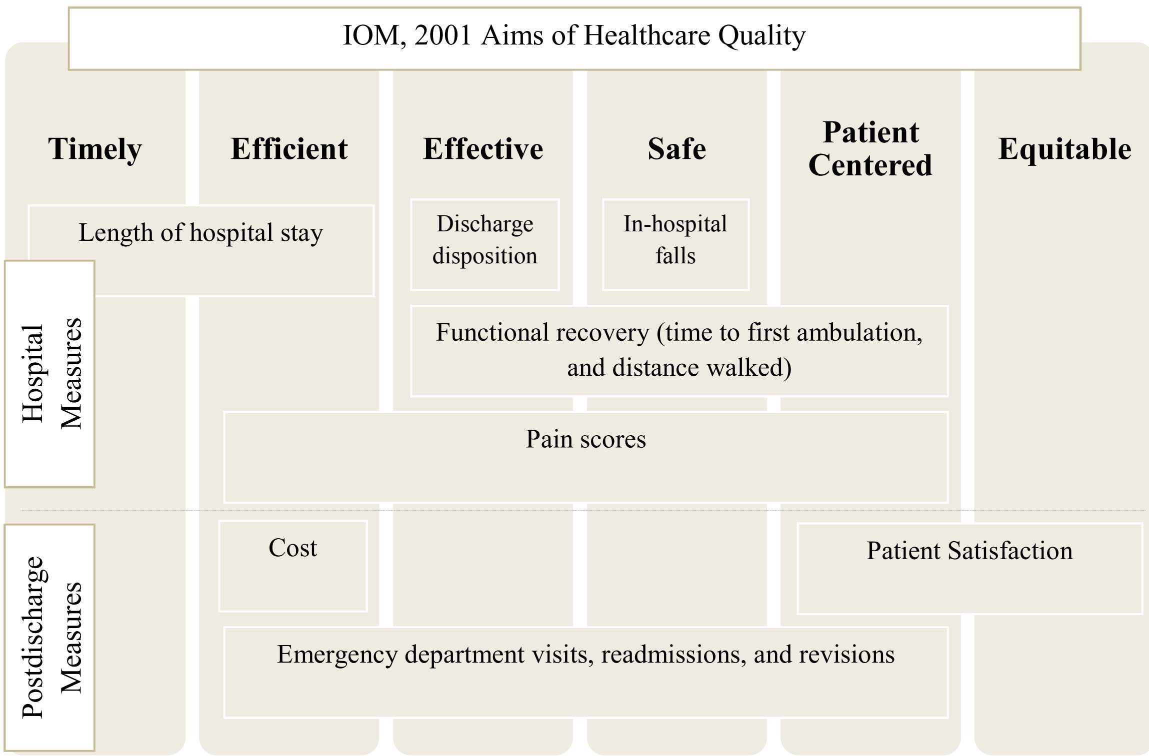

Figure 3.5 Study II outcomes and IOM aims of healthcare quality

STUDY MEASURES:

A. Patients' Characteristics:

Age was reported continuously and broken-down to categories of (<54), (55-64), (65-74), and (75 and above) to give a detailed description of the sample, where (55-64) group was used as the referent level as it was the majority of our sample. Body Mass Index (BMI) was categorized into normal (18.5-24.9), overweight (25.0-29.9), and obese (30.0 and above), based on the BMI classification by CDC. Sex was broken into male and female, where the male group was used as the referent level. Race was broken into Caucasian "reference", African American, and Other group that included Asian, Native Hawaiian or other Pacific Islander, American Indian, and those with more than one race. Marital status variable was broken into either married "reference" or divorced, single or widowed. Employment status was broken into employed "reference", retired, or not-employed and disabled. Health insurance type was categorized in governmental "reference" and non-governmental insurance groups. Tobacco smoking status was categorized in ever smoker (i.e., current of former smoker) versus never smokers, where the later was the referent group.

Physical status was measured using the American Society of Anesthesiologists (ASA) classification system, a validated measure for preoperative measurement to identify patients with an increased risk of death or surgical complications, and rank them in groups based on disease severity [102]. The classification adopts a five-category classification system ranging from I to IV, but the study will only use; class I: normal healthy patient, class II: patient with mild systemic disease (with no functional limitation), and class III: patient with severe systemic disease (with some functional limitation). Comorbid conditions present during the 12 months prior the index hospitalization was collected based on diseases included in the Deyo-Charlson index, a validated measure of comorbidity [145], and categorized in three groups: no comorbidities "reference", one to two, and three or more. We counted additional diseases that are not included in Charlson index, and known to be of the most common comorbidities associated with patient outcomes in orthopedic care. These include congestive heart failure, cerebrovascular disease, peripheral vascular disease, chronic pulmonary disease, and anxiety or depression [51, 57, 102, 150]. The top comorbidities among patients were reported separately in the descriptive analysis.

B. Outcomes:

All study outcomes were measured postoperatively.

1. Analgesic effect (continuous): measured by pain scores using a numerical rating scale ranging from 0 (No pain) to 10 (Worst possible pain) and reported for the 0-24 hours and 24-48 hours interval after surgery.
2. Functional recovery (continuous): measured by time from end of surgery to first walk, and by distance walked each day as documented in physical therapy (PT) notes. We then reported cumulative distance walked in the first three PT sessions, which was the minimum sessions received by all patients.
3. Length of hospital stay (continuous): from end of surgery to discharge.
4. In-hospital falls (categorical variable: yes/no).
5. Discharge disposition (categorical): whether a patient was discharged to home/ home care, or to other facility including skilled nursing facility (SNF), hospice, or rehabilitation center.

6. Patients' satisfaction (continuous): measured by the validated Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) survey, distributed to a random sample of discharged patients ranging between two days and six weeks after discharge [147, 148]. Two questions were selected to assess satisfaction with pain: (1) "How often was your pain well controlled?", and (2) "How often did the hospital staff do everything they could to help you with your pain?". One question assessed the overall satisfaction with hospital experience: "Using any number from 0 to 10, where 0 is the worst hospital possible and 10 is the best hospital possible, what number would you use to rate this hospital during your stay".
7. Cost (continuous), using standardized, inflation adjusted costs for services and procedures billed during the index hospitalization and 90-day follow up period.
8. Emergency visits within 14 days after discharge (categorical: yes/no).
9. Unplanned readmission for any cause, 30 days after discharge (categorical: yes/no).
10. Surgery revision within 90 days after discharge (categorical: yes/no), which includes prosthesis loosening, wear, and/or osteolysis, instability, infection, bone or prosthesis fracture.

DATA ACQUISITION:

Patients' cohorts were identified from the Decision Support System (DSS), and then subsequent demographic and clinical data were matched with data in the EHR. In-hospital falls were obtained from the quality management department. Patient satisfaction data were obtained from the office of patient experience. Responses to satisfaction items were transformed and averaged (never=0, sometimes= 33.3, usually=66.6, and always= 100), resulting in a 0 to 100 linear-scaled score. Cost data were obtained from the institution cost data warehouse [151], which applied Medicare reimbursement to professional services, multiplied service line hospital charges by Medicare cost report cost-to-charge ratios, and adjusted for inflation with the gross domestic product implicit price deflator to create 2016 standardized costs. Cost was reported separately for the index hospitalization and 90-day follow-up period excluding hospitalization, using Berenson-Eggers Type of Service (BETOS) and Uniform Billing-04 (UB04) codes to classify the line item data. A further grouping of cost categories was carried out to create cost components by type of service: analgesic approach (i.e., nerve block and the periarticular supplies and medications); room and board (i.e., observation and intensive care unit stay); operating and recovery room occupation; orthopedic procedure; physical therapy; pain medications; laboratory and pathology; supplies; and other costs including blood transfusion, other medications/intravenous fluids, and miscellaneous. Follow-up cost data did not include medications obtained from outpatient pharmacies. Other outcomes such as emergency visits, readmissions, and revisions were collected and obtained from the EHR.

DATA ANALYSIS:

Analyses utilized SAS version 9.4 (SAS Institute, Cary, NC). Insignificant differences were found in the majority of patient characteristics between the groups. As providers were the same surgery team during the study period, there was no risk of learning affect among providers in the two cohorts. The distribution of cases per provider was tested to ensure consistency, and both surgeons had the same volume of cases. Secular trend of specific outcomes (pain scores at 24 and 48 hours, time to first ambulation, distance walked in the first 3 PT sessions, postoperative LOS) were tested per cohort using interrupted time analysis, and the consistency of outcomes was ensured to be the same within each cohort ($P>0.05$). Thus, our analysis was focused on comparing between the outcomes of patients who had FNB with SNB (group 1) versus PAI (group 2). Our sample had a non-normal distribution; thus, we performed univariate chi-squared test for categorical variables, an independent Wilcoxon signed-rank test for mean comparison among continuous variables, with Fisher's exact test for cell counts <40. Cost variables were presented as mean and median cost per patient including SDs and interquartile ranges. We used repeated generalized linear regression models to determine if receiving PAI was a predictor for (1) pain scores at 24 hours, (2) pain scores at 48 hours, (3) distance walked, (4) postoperative LOS, and (5) total cost of index hospitalization. Independent variables in the regression analysis included age, sex, race, marital status, BMI, ASA class, and comorbidities. In modelling the index hospitalization total cost, we used log-transformed costs. For the 90-day follow up period, we excluded selected patient groups (i.e., patients with costs exceeding $20,000 that was not related to TKA, non-local patients as they were less likely to follow up in the Mayo Clinic, and patients who were electively readmitted for major surgeries).

BUDGET: None

ETHICAL CONSIDERATIONS:

This study was approved by the Mayo Clinic Institutional Review Board. All extracted data were accessed using techniques that are in compliance with the Health Insurance Portability and Accountability Act of 1996 (HIPAA), and stored on a password-protected server known only to the researcher.

CONFLICT OF INTEREST: None

Table 3.3 Detailed analysis plan for Study II

Objectives	Comparison groups	Variables	Type of analysis
Question #0 Patient Characteristics	FNB/SNB vs. PAI	Patient demographic and clinical characteristics	1. Descriptive analyses including frequencies, means and standard deviations, and percentages as appropriate. 2. Examine differences between groups using Pearson $\chi 2$ and Wilcoxon nonparametric test.
Question #1 Differences between groups in hospital outcomes	FNB/SNB vs. PAI	(1) pain scores at 24hr and at 48hr, (2) time to first ambulation, (3) distance walked in first 3 PT sessions, (4) in-hospital falls, (5) length of hospital stay, (6) discharge disposition, and (7) total hospitalization cost	1. Examine differences between groups using Pearson $\chi 2$ and Wilcoxon nonparametric test. 2. Graphic comparison for cost per service using bar graph.
Question #2 Differences between groups in postdischarge outcomes	FNB/SNB vs. PAI	(1) patient satisfaction, (2) emergency department visits /14days, (3) unplanned readmissions/ 30days, (4) revisions/ 90 days, and (5) total cost of follow-up during the 90 day period	Examine differences between groups using Pearson $\chi 2$ and Wilcoxon nonparametric test.
Secondary analysis	Dependent variables (analyzed separately): pain scores at 24 hours, at 48 hours, time to first ambulation, distance walked, post-operative LOS, and total cost of the hospitalization	Independent variable: PAI (yes/no*) *no (i.e., FNB/SNB)	Several linear regression models, adjusting for age, gender, race, marital status, BMI, ASA and comorbidities.

CHAPTER 4

Manuscript I Patient Portal Adoption and Use by Hospitalized Cancer Patients: A Retrospective Study of its Impact on Adverse Events, Utilization, and Patient Satisfaction

ABSTRACT

Background: Portal use has been studied among outpatients, but its utility and impact on inpatients is unclear. This study describes portal adoption and use among hospitalized cancer patients and investigates associations with selected safety, utilization, and satisfaction measures.

Methods: A retrospective review of 4,594 adult hospitalized cancer patients was conducted between 2012 and 2014 at Mayo Clinic in Jacksonville, Florida, comparing portal adopters, who registered for a portal account prior to hospitalization, with nonadopters. Adopters were classified by their portal activity during hospitalization as active or inactive inpatient users. Univariate and several logistic and linear regression models were used for analysis.

Results: Of total patients, 2,352 (51.2%) were portal adopters, and of them, 632 (26.8%) were active inpatient users. Portal adoption was associated with patients who were young, female, married, with higher income, and had more frequent hospitalizations ($P<.05$). Active inpatient use was associated with patients who were young, married, nonlocals, with higher disease severity, and were hospitalized for medical treatment ($P<.05$).

In univariate analyses, self-management knowledge scores were higher among adopters vs nonadopters (84.3 and 80.0, respectively; *P*=.01) and among active vs inactive inpatient users (87.0 and 83.3, respectively; *P*=.04). In regression models adjusted for age and disease severity, the association between portal behaviors and majority of measures were not significant (*P*>.05).

Conclusions: Over half of our cancer inpatients adopted a portal prior to hospitalization, with increased adoption associated with predisposing and enabling determinants (eg: age, sex, marital status, income), and increased inpatient use associated with need (eg: nonlocal residence and disease severity). Additional research and greater effort to expand the portal functionality is needed to impact inpatient outcomes.

Keywords: adverse events; cancer; hospitalization; portal; satisfaction; utilization.

INTRODUCTION

Two decades ago, the National Academy of Medicine (formerly the Institute of Medicine recommended implementation of electronic health records to improve quality of care in the United States [30]. Since then, health information technologies have been rapidly adopted, with a focus on providers rather than patients. In 1996, the Health Insurance Portability and Accountability Act legally allowed patients to access their own clinical records. However, record retrieval fees, illegible handwriting, and time delays hindered accessibility [17]. An additional challenge is the fragmented health system with many independently owned and operated health care service locations [19, 152, 153]. An integrated information system that aggregates and offers updated health information to patients through a single access point was needed. In 2009, the Health Information Technology for Economic and Clinical Health Act incentivized clinicians to provide patients with electronic access to clinical records through meaningful use rules, administered by the Centers for Medicare & Medicaid Services [34]. This incentive program remains the principal driver of patient portal development by funding nearly $30 billion in provider incentives to encourage appropriate use [24, 154]. Investigations where information access was offered via patient portals in the outpatient settings showed encouraging positive effects in patient satisfaction and self-management behaviors [14, 15, 18, 19, 21, 27, 80, 85, 155-157]. However, providing patients access to information is important not only in home and outpatient settings, but also when patients are hospitalized [93].

When patients are able to see their own health information during the hospital stay, they become more informed, empowered to ask questions, and gain ownership of their health care [158, 159]. Despite daily bedside rounds, important patient informational needs may not be met due to the cost of reviewing tailored information with each patient individually [160]. Thus, the portal technology may provide opportunity for inpatients to meet informational needs, facilitate awareness, and improve understanding of their care during hospitalization and after discharge [17, 161]. Meeting informational needs could reduce uncertainties surrounding the care process, reduce information asymmetry between patients and providers, promote shared decision-making, and increase patient self-management and adherence to care [33, 162].

Unfortunately, assessments of patient portal use among hospitalized cancer patients are limited [23-25, 64, 74, 90]. For many patients, the hospital is a challenging and intimidating setting, compounded by unmet information needs and limited patient engagement [162, 163]. The rapid dynamic and pace of clinical care, changing medical teams, reliance on verbal communication, and absence of an established relationship with the care providers further challenge patients' effective participation in their own care [164, 165]. Additional affective and emotional challenges are faced by inpatients with cancer due to the nature of their disease, frequently uncertain outcomes of treatments, and the need to understand their multiple active conditions to make treatment decisions [65, 66]. In a study of breast cancer patients, those who desired an active role in treatment decision making also desired detailed information of their diagnosis, treatment procedures, and alternatives [166]. Similar information needs were vital to gynecologic and colorectal cancer patients who felt that information about the likelihood of cure, spread of disease, and treatment options were priorities for decision making [167]. Providing clinical information through patient portals may have the potential to transform the patient-physician relationship and help patients to become active in their disease management [91]. Recent documentation on hospital-based patient portals is encouraging [26, 94, 168, 169]. Creber et al published a protocol for developing a personalized inpatient portal at an urban academic medical center to improve cardiology inpatients engagement [17]. Greysen et al conducted pilot interviews showing patients' enthusiasm for a tablet application that provides health information during their inpatient stay [95]. Vawdrey et al assessed the patient-perceived efficacy of tablets to improve cardiothoracic surgery patients' engagement in care, showing a favorable response regarding usability of the application [93]. Several other studies assessed the feasibility of web-based applications to increase patient engagement in both pediatric and adult care [170-172]. Yet, the evaluation of patient portals among cancer inpatients is still limited, a knowledge gap addressed by this study. We hypothesized that patient adoption of a portal and active use during a hospital stay may be associated with greater patient safety, postdischarge care utilization and satisfaction, similar to outpatient settings. According to Karahanna et al, adoption and continued use represent different behaviors [35]. Adoption is the initial enrollment and signifies receptivity to the portal, while usage represents active engagement, continued use after adoption. Therefore we distinguish between these 2 behaviors and evaluate them separately. Our specific aims were to 1) identify the key patient factors predicting adoption and active inpatient use behaviors, and 2) examine the association between portal use behaviors and adverse events, postdischarge utilization (emergency visits and readmissions), and selected patient satisfaction measures (self-health management knowledge and satisfaction with the overall hospital experience).

MATERIALS AND METHODS

Study Setting and Description of the Portal

The site of the study was Mayo Clinic, Jacksonville, Florida (MCF), a large nonprofit, specialized tertiary care practice and medical research center with more than 1.3 million domestic and international patients seen each year. Physicians are salaried, not linked to care volume, thus reducing monetary incentives in patient treatment. MCF contracted with Cerner Solutions (Cerner Corp) to implement the patient portal and integrate it with the system-wide electronic health record in 2010. When patients schedule an appointment at MCF, they are invited to register for a portal account and are provided with information on why and how to register. With each appointment reminder, patients receive a reminder message to register for the portal. Portal invitations are also offered in all outpatient waiting areas and displayed on electronic screens around the clinic.

Once registered, patients' are able to access informational functions, such as viewing lab results, current medications, allergies, and diagnostic reports from clinic visits and hospitalizations, and administrative functions, such as paying bills, processing prescription refills, and coordinating appointments. A Continuity of Care Document, a complete summary of patient current health status and history, is also available to view, download, or forward to physicians at other hospitals. Additional information on MCF patient portal is documented elsewhere [173]. Although the portal is designed for outpatients, some functions are applicable to inpatient health information needs during the hospital stay. Hospitalized patients potentially have time to access the portal when they are not occupied with diagnostic testing or other activities [174]. For example, the portal gives inpatients real-time access to laboratory results, admission notes, consultation reports, and surgical notes, to view on their own time and between bedside rounds. This functionality potentially facilitates patient communication and interaction with the health care team during their stay, and empowers the patient to be more attentive toward errors in documentation [158]. In addition, the medication function provides patients with information on the type and purpose of their medications, including in-hospital medication intake, which could enable patients to ask questions, review for accuracy, or report medication discrepancies [32, 175]. Before home discharge, a discharge summary and discharge instructions is uploaded to the portal, giving patients time to review closely and ensure their understanding of home self-management instructions. While the development of portal functionality for inpatients is in early stages, the offered content may still help patients become more activated and improve postdischarge care.

Study Design and Participants

This was a retrospective review of patients satisfying the following criteria: 1) adults 18 years of age or older, 2) cancer as a primary or secondary diagnosis at time of hospitalization identified through the *International Classification of Diseases, Ninth Revision* (ICD-9) codes, and 3) admitted to MCF between August 1, 2012, and July 31, 2014 (N=4,594). Per the unified theory of acceptance of use of technology, user acceptance and intention to use a technology is followed by actual use [139]. Therefore, we included the first hospitalization where a portal account had been established prior to admission to examine consequent inpatient use. If the patient had not established a portal account prior to any admission, then the first hospitalization in the study period was selected. Patients who had a portal account prior to admission were defined as *adopters*, and those without a portal account were *nonadopters*. Among adopters, inpatients who logged in their portal during the hospital stay were *active inpatient users* and those who never logged in were referred to as *inactive inpatient users*. The study was approved by the Mayo Clinic Institutional Review Board.

Study Model

Our study was informed by Andersen's Model of Healthcare Utilization [140]. The model was initially developed in 1968 to understand health services use and later revised to include consumer satisfaction and dimensions of health status [142]. Shortly after the model was developed, health services use was portrayed as a health behavior influenced by multiple factors [141]. According to the World Health Organization, health behavior is defined as "any activity undertaken by an individual, regardless of actual or perceived health status, for the purpose of promoting, protecting or maintaining health, whether or not such behavior is objectively effective towards that end" [143]. Because the portal is a tool to maintain and promote health, we considered portal adoption and use as health behaviors that could be studied using Andersen's model. As shown in Figure 4.1, we examined the influence of patients' characteristics in three major components: predisposing, enabling, and need factors, on portal adoption and use behaviors.

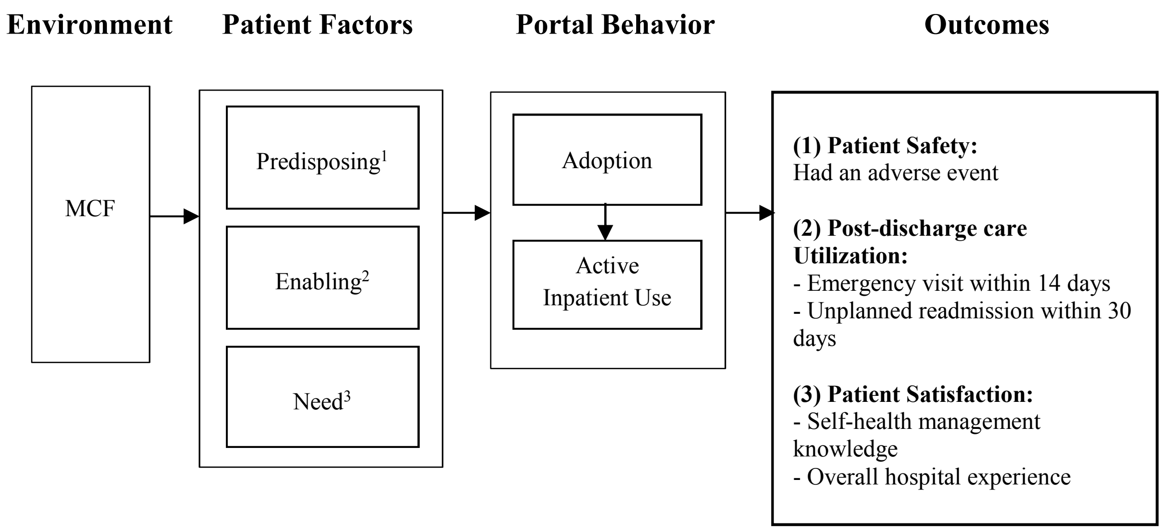

Figure 4.1 Study Theoretical Model Derived from Andersen's Model of Healthcare Utilization
1 Predisposing factors: age, sex, and race.
2 Enabling factors: marital status, employment status, health insurance type, and income.
3 Need factors: geographic area of residence, comorbidities, and frequency of hospitalizations. Additional need factors related to the admission: MSDRG type and APRDRG disease severity weight. APRDRG indicates All Patients Refined Diagnostic Related Group; MSDRG, Medicare Severity-Diagnosis Related Group.

Measures

Environment and Patient Characteristics

In this study, we assumed that all study participants had a common environmental context, as all patients in MCF received their care in the same structure. Predisposing determinants included age, sex, and race. Enabling determinants included marital status, employment status, health insurance type, and median income in the residential ZIP code less than Florida's state median income, a surrogate for socioeconomic status. Need factors included geographic area of residence, comorbidities, and frequency of hospitalizations in the study period. Additional need determinants related to the hospital admission included patient's disease severity weight as measured by the 3M All Patients Refined Diagnosis Related Groups (APDRG) classification system, and whether the hospitalization was for medical or surgical treatment, based on the Medicare Severity-Diagnosis Related Group (MSDRG) codes [146].

Demographic data were extracted from the patient electronic health records. The ZIP code median income was obtained from the 2006-2010 American Community Survey and matched to the patient sample at the ZIP code level [144]. A count of comorbidities included in Charlson Comorbidity Index during the 12 months prior to hospitalization was documented [145].

Patient Safety, Utilization, and Satisfaction

We examined selected patients' measures to investigate associations with portal use. For patient safety, we studied the occurrence or otherwise of provider-reported, in-hospital, adverse events, such as falls, accidental self-injuries, or other events related to the surgery, vascular, equipment or devices, medication, or skin events, obtained from quality management services. For postdischarge utilization, we examined the occurrence of emergency department visits within 14 days and unplanned readmissions within 30 days, both obtained from the hospital records. We measured patient satisfaction by obtaining data from the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) survey. The survey is a validated instrument used since 2006 to assess patients' perspectives of hospital care, and distributed to a random sample of discharged patients between 2 days and 6 weeks after discharge [147]. While the survey included many important questions, we selected the relevant items with highest response. We measured *patient self-health management knowledge* with 2 questions: "When I left the hospital, I had a good understanding of the things I was responsible for in managing my health", and "When I left the hospital, I clearly understood the purpose for taking each of my medications", and measured *overall hospital satisfaction* with 1 question: "Using any number from 0 to 10, where 0 is the worst hospital possible and 10 is the best hospital possible, what number would you use to rate this hospital during your stay" [148]. Responses were transformed and averaged, resulting in a 0 to 100 linear-scaled score.

Data Analysis

We described the characteristics of cancer patients according to their portal adoption and inpatient activity behaviors and examined differences between groups using Pearson χ^2 and Wilcoxon nonparametric tests. Multivariate regression models were conducted to predict factors associated with portal adoption and active inpatient use, as well as to examine the association between selected outcomes and portal behaviors. All analyses were conducted in SAS Version 9.4 (SAS Institute Inc, Cary, North Carolina, USA), and significance was defined as $P<.05$.

RESULTS

Participants, Adopters, and Active Inpatient Users

Of the 4,594 study-eligible hospitalized patients with cancer, 2,352 (51.2%) had a portal account prior to admission (ie, adopters), of whom 632 (26.8%) used the portal account during their hospital stay (ie, active inpatient users). Patient characteristics at admission were reported in Table 4.1. Significant differences in patient characteristics were present among portal adoption and inpatient use behaviors (Table 4.2). Adoption was influenced by a majority of predisposing and enabling factors, such as age, sex, race, marital status, employment status, income, and type of health insurance. While active inpatient use was similarly influenced by predisposing and enabling factors, such as age, race, and marital status, we found greater influence associated with need, such as having greater disease severity, being nonlocal, and admitted for medical rather than surgical treatment.

Bivariate Associations of Portal Behaviors With Adverse Events, Care Utilization, and Patient Satisfaction

Bivariate associations of portal adoption with our selected measures (Table 4.3) showed that adopters had more emergency visits and readmissions than nonadopters, while reporting higher self-health management knowledge. Similarly, active inpatient users had more readmissions than inactive inpatient users, and marginally higher self-management scores. Logistic and linear regression analyses showed that after adjusting for age and disease severity, the association between portal behaviors and majority of our assessed measures were not significant (Table 4.4). Adverse events and overall hospital experience did not differ among groups in either univariate or multivariate regression analyses ($P>.05$).

DISCUSSION

To date there remains a gap in the literature evaluating the use of inpatient portals among cancer patients. This study provides important information to clinicians, administrators, and researchers, on the key patient determinants associated with portal adoption and use. Prior studies reported significant interest in patient portals among oncology populations [64, 74, 176]. Yet, to our knowledge, this is the first study to examine portal use in a large inpatient oncology cohort. In this sample, we found that portal adoption and use during hospitalization has reached modest levels and somewhat higher usage than published reports on inpatient portal use. Over half of our inpatient oncology population voluntarily adopted the portal before hospital admission and 27% actively used the portal during the stay. Dumitrascu et al found that of 44.2% patients who had a portal account at the time of admission, only 20.8% accessed the portal during their stay [173]. Davis et al found that of 34.4% registered portal patients, 23.4% used it while hospitalized [26]. Robinson et al reported that 16% of surgical inpatients with a portal account used it while being in the hospital [177].

There were noteworthy differences in patient characteristics between adopters and nonadopters in a majority of predisposing and enabling factors. Portal adoption increased among patients who were female, married, and with higher income, and decreased among patients who were African American, unemployed, and had governmental health insurance. Interestingly, the likelihood of portal adoption was similar for patients aged 65 to 75 years as the middle-aged adults 45 to 55 years, contradicting popular beliefs that older patients were less likely to engage in health technologies [178]. Portal adoption, however, considerably decreased among patients aged over 75 years. Similar to our findings, portal use among outpatient oncology patients was reported to be greater among younger, white patients, and those with upper aerodigestive malignancy diagnosis, greater disease severity, and case complexity [24]. Among nononcology populations, a similar digital divide was reported by age groups, race/ethnicity, income, and education [20, 83, 86, 88, 179, 180]. Our findings showed higher portal adoption among those with more frequent hospitalizations, which was the only notable need determinant. Other studies have reported higher interest in the portal among those with more medical problems, greater severity of illness, or higher than average clinical need [14, 55, 85, 87].

Similarly, inpatient portal use increased with younger age and being married, but more influenced with need determinants. Active access was associated with residing outside the city of Jacksonville (nonlocals); suggesting that commuting patients found health information important to view during the stay. Additionally, access was greater among those with higher disease severity and those admitted for medical rather than surgical treatment. Medical admissions for cancer patients are usually associated with investigating the origin and cause of disease, or evaluating chemo or radiation treatments, compared to surgical admissions that involve typical procedural routines and surgical recovery that may fully occupy the patient's time in the hospital [181]. Because a cancer diagnosis is a stressful life event, patients' information-seeking behavior was thought to become more active, possibly as a coping strategy to overcome uncertainties [23, 74, 182].

Patient Safety

Several studies have assumed that information technology systems have the potential to improve patient safety by identifying errors in medications and preventing adverse drug reactions. Yet, limited evidence exists regarding the effectiveness of a portal as a tool in reducing adverse events. One recent study by Kelly et al found that 8% of parents with hospitalized children recognized errors in their child's medication list after using an inpatient portal application [172]. Further optimistic views about the ability of portals to reduce errors were derived from patient participation in care, where patients could notify clinicians of their medication allergies, unexpected toxicity symptoms, and lapses in care to prevent adverse events [31, 175, 183, 184]. Among surgical inpatients who were portal users, postoperative infection was their most frequent ICD-9 code, suggesting that experiencing a safety-event may activate patients to follow up their personal health information to avoid further complications [177]. In contrast to this evidence, our study did not find an association between portal adoption or use and adverse events. Likewise, a randomized controlled trial by Weingart et al did not find sufficient evidence to support an association between adverse drug events and portal use [32]. Earlier research reported that patient history evaluation in cancer care is more focused, providing the patient an opportunity to recall medical and medication information to prevent errors. [185, 186] In addition, most adverse events at hospitals are underreported and the events in our data were limited to those reported by providers. A new initiative within the portal that is gaining popularity and has the potential to prevent errors is the OpenNotes national movement, which invites patients to read their clinicians' notes online and report back errors or safety concerns that, in turn, may avert mistakes from happening [187, 188]. Hence, it opens up a new possibility to engage patients as safety partners through their reported documentation errors.

Utilization

Studies that examined the effect of portal use on subsequent utilization of health services showed mixed results [14, 20, 189]. A study using propensity score matching found no difference between portal users and nonusers on clinical service utilization [190]. Among members of Kaiser Permanente, a retrospective study in the Northwest found that patient access to an online portal was associated with decreased rates of primary care office visits and phone calls [191], whereas the opposite was found by Palen et al where portal users had higher rates of office visits, phone encounters, after-hour clinic visits, emergency department visits, and hospitalizations [192]. The assumption was that if patients could view personal health information, they will be more aware, able to manage their health, and need less emergency service or hospitalizations. This expectation was not validated in our study, suggesting that a portal technology may be a complementary technology and does not substitute for health services needs of oncology patients. Mayer et al reported 77.2% of cancer patients' visits to the emergency department were due to pain, respiratory problems, and gastrointestinal issues, with 63.2% of those visits resulting in hospital admission [193]. Barbera et al reported that 83.8% of cancer patients who died had visited the emergency department during their final 6 months of life with issues related to abdominal pain, dyspnea, pneumonia, fatigue, and pleural effusion [194]. Shapiro et al found that those who had surgery during their index admission were 3 times more likely to be readmitted [195]. Weaver et al examined cancer inpatients and found 48% of readmissions were within 1 to 2 days of discharge

[196]. Donze et al developed a predictive model and found that discharge from an oncology service was a significant predictor of unplanned readmission [197]. Similarly, a recent systematic review reported that comorbidities, older age, advanced disease, and index hospitalization length of hospital stay were significant predictors for readmission in oncology [198]. Thus, emergency department visits and readmissions may be influenced more by the nature of illness, treatment-related complications, and other such factors than avoidable reasons by portal use.

Patient Satisfaction

Our findings suggest limited evidence of the relationship between patient satisfaction and portal use. Self-management knowledge scores appear to be considerably higher among both adopters and inpatient users in bivariate associations; however, in regression analyses, associations with satisfaction were somewhat attenuated and no longer statistically significant. Our interpretation of results needs to be cautiously taken as they were limited by the random selection of sample surveyed and the selection of self-management questions. In addition, we have no assessment of self-health management knowledge at baseline. Therefore, the association between portal use and self-health management knowledge may have already been existed.

Prior research has shown inconsistent conclusions regarding associations between portal use and patient satisfaction; with wide variability in the offered portal features, the outcomes evaluated, and the populations studied [14, 18, 19, 163]. In addition, the potential of patient portals for patients with chronic conditions was available, but relatively nascent for cancer [199]. Among chronically ill patients, the portal showed promise for improving diabetic patients' satisfaction with care, ability to self-manage, and adhering to treatments [200]. This has been accompanied by evidence of improved blood pressure control among people with newly diagnosed hypertension [201]. Patient portal access was also superior in general adherence and satisfaction with doctor-patient communication among patients with congestive heart failure [80, 202]. Yet, not all findings in the literature showed that patients with chronic conditions were amenable to improved outcomes with portal use [74, 203-205].

There are many potential recommendations to improve portal functions for inpatients. Hospitals often provide patients and families with standard information on disease and treatment options while being hospitalized, but that is not always enough [206]. An effective tool for awareness and self-management may include problem-solving support, regular education provision, treatment options with cost estimations that aid patient decision making, and consistent patients training on how to take responsibility for their own health [207].

It should be noted that emotional factors, such as anxiety or low self-efficacy, may dramatically influence self-management or symptom-coping behaviors [208, 209]. Of interest, some researchers suggest technology-based applications to provide recreational social supports to help patients cope with their illness. O'Leary et al reported favorable patient perceptions toward games offered in the hospital-based portal [94]. The same was reported by Jameson et al*,* who indicated that electronic gaming can be a positive distraction away from pain [210]. Innovative social support approaches offering recreational avenues via the portal may attract more users, which in turn, may improve self-management, symptom-coping, and quality of life [211]. Thus, greater attention is needed to improve the portal content and functionality for inpatients to improve patient outcomes.

This study has a number of limitations. There is limited generalizability given that our oncology cohort was from a single center. Technology limitations restricted our analysis; we could not examine frequency of inpatient log-ins, or distinguish if a portal activity was carried out by the patient or a delegated family member. Further, it would be interesting to understand if there was a dose-response type curve associated with portal use but information on the extent of use was not available. Post-discharge utilization measures were limited to care utilization at MCF, with no data on utilization elsewhere. Conclusions regarding patient safety and satisfaction measures were limited by the range of variable values; adverse events were uncommon, and patient satisfaction was almost uniformly high among all patients. Finally, low response to the HCAHPS resulted in a small sub-sample size to analyze satisfaction, a major limitation, but no other measures were readily available. Despite these limitations, the study uncovered determinants of adoption and use behaviors among a large sample of hospitalized cancer patients. Additionally, it adds new information to the growing body of literature on inpatient engagement using acute care portals. Future research directions should investigate the extent of inpatient portal use, incorporate inpatient-centered education materials, and improve the portal with functions that add the most value for cancer inpatients.

CONCLUSIONS

We found that cancer patients had reached modest levels of portal adoption. While portal adoption increased with predisposing and enabling determinants (eg: age, sex, marital status, income), active inpatient use increased with need (eg: commute residence and high disease severity). While these findings should be cautiously interpreted, the study adds to the growing evidence that patient portals should be further addressed for inpatient care. Particularly, the study provides insights for the informatics research community and those interested in improving inpatient care and self-management support through technology.

Table 4.1 Sample Baseline Characteristics by Portal Behavior[a]

Characteristics	Adopters (n=2,352)	Nonadopters (n=2,242)	*P* value	Active Inpatient Users (n=632)	Inactive Inpatient Users (n=1,720)	*P* value
Age group (years)						
Mean (SD)	62.3 (14.0)	65.4 (14.8)	<.01[b]	60.2 (14.3)	63.0 (13.8)	<.01[b]
≤44	259 (11.0)	191 (8.5)	<.01[c]	82 (13.0)	177 (10.3)	<.01[c]
45-54	339 (14.4)	281 (12.5)		106 (16.8)	233 (13.5)	
55-64	632 (26.9)	480 (21.4)		185 (29.3)	447 (26.0)	
65-74	702 (29.8)	652 (29.1)		166 (26.3)	536 (31.2)	
75-84	339 (14.4)	454 (20.2)		80 (12.7)	259 (15.1)	
≥85	81 (3.4)	184 (8.2)		13 (2.1)	68 (4.0)	
Sex						.22[c]
Female	1,148 (48.8)	1,055 (47.0)	.25[c]	295 (46.7)	852 (49.5)	
Male	1,204 (51.2)	1,188 (53.0)		337 (53.3)	869 (50.5)	
Race/ethnicity			<.01[c]			<.01[c]
African American	121 (5.2)	273 (12.4)		18 (2.9)	103 (6.1)	
White	2,120 (91.3)	1847 (84.0)		575 (91.9)	1,545 (91.2)	
Other	80 (3.4)	78 (3.5)		33 (5.3)	47 (2.8)	
Marital status			<.01[c]			<.01[c]
Married	1,786 (75.9)	1,454 (64.9)		506 (80.1)	1,280 (74.4)	
Single/divorced/widowed	566 (24.1)	788 (35.1)		126 (19.9)	440 (25.6)	
Employment status			<.01[c]			.79[c]
Employed	739 (37.7)	547 (28.9)		206 (38.1)	533 (37.5)	
Retired	836 (42.6)	935 (49.4)		208 (38.5)	628 (44.2)	
Not employed/ disabled	386 (19.7)	411 (21.7)		126 (23.3)	260 (18.3)	

Income			<.01[c]			.54[c]
< FL median	645 (28.3)	803 (37.2)		167 (26.5)	478 (27.8)	
=> FL median	1,707 (71.7)	1,439 (64.1)		465 (73.5)	1,242 (72.2)	
Health insurance type			<.01[c]			<.01[c]
Commercial/self	1,145 (48.7)	815 (36.4)		339 (53.6)	806 (46.9)	
Medicare/Medicaid /other government	1,207 (51.3)	1,427 (63.6)		293 (46.4)	914 (53.1)	
Area of residence			.89[c]			<.01[c]
Nonlocal	521 (22.2)	493 (22.0)		166 (26.3)	335 (20.6)	
Local	1,831 (77.8)	1,749 (78.0)		466 (73.7)	1,365 (79.4)	
Comorbidity [d]			.58[c]			.32[c]
None	1,115 (47.4)	1,052 (46.9)		289 (45.7)	826 (48.0)	
One or more	1,237 (52.6)	1,190 (53.1)		343 (54.3)	894 (52.0)	
Comorbidity type[e]						
CHF	145 (6.2)	171 (7.6)	.05[c]	51 (8.1)	94 (5.5)	.02[c]
Peripheral vasc.	322 (13.7)	338 (15.1)	.18[c]	83 (13.1)	239 (13.9)	.63[c]
Cerebrovascular	165 (7.0)	224 (10.0)	<.01[c]	42 (6.6)	123 (7.2)	.67[c]
Chronic pulmonary	262 (11.1)	256 (11.4)	.77[c]	61 (9.7)	201 (11.7)	.16[c]
Mild liver disease	432 (18.4)	291 (13.0)	<.01[c]	129 (20.4)	303 (17.6)	.12[c]
Diabetes mellitus	392 (16.7)	351 (15.7)	.35[c]	115 (18.2)	277 (16.1)	.23[c]
Mod./sev. renal	196 (8.3)	179 (8.0)	.66[c]	53 (8.4)	143 (8.3)	.96[c]
Mod./sev. liver	121 (5.1)	86 (3.8)	.03[c]	49 (7.8)	72 (4.2)	<.01[c]
Frequency of hospitalizations mean (SD)	1.8 (1.5)	1.4 (1.1)	<.01[b]	2.0 (1.7)	1.7 (1.4)	<.01[b]

Admission type based on MSDRG			<.01[b]			<.01[b]
Surgical	1,504 (63.9)	1,315 (58.7)		348 (55.1)	1,156 (67.2)	
Medical	848 (36.1)	927 (41.3)		284 (44.9)	564 (32.8)	
APRDRG weight			.24[b]			<.01[b]
Mean, (median, SD)	2.5 (1.5, 2.9)	2.3 (1.5, 2.3)		3.1 (1.9, 3.6)	2.3 (1.4, 2.6)	

Abbreviations: APRDRG, All Patients Refined Diagnosis Related Group; MSDRG, Medicare Severity-Diagnosis Related Group.
[a]Data are reported as No. (%) for count variables and mean (SD) for continuous variables.
[b]Wilcoxon nonparmetric.
[c]Pearson χ^2 test.
[d]Comorbidity groups are not mutually exclusive as a patient may have more than 1 comorbidity diagnosis.
[e]Comorbidity type was reported for diseases with > 5% of patients.

Table 4.2 Logistic Regression Analysis Showing the Predictors of Portal Behaviors

Factors	Characteristics	Odds Ratio (95% CI)[a]	
		Adoption[b]	Active Inpatient Use[c]
Predisposing	Age		
	44-	**1.42 (1.03, 1.95)**	**1.89 (1.16, 3.06)**
	45-54	1.10 (0.82, 1.47)	**1.73 (1.10, 2.72)**
	55-64	1.22 (0.95, 1.57)	**1.48 (1.00, 2.19)**
	65-74 (reference)	1.00	1.00
	75-84	**0.71 (0.57, 0.87)**	1.08 (0.75, 1.56)
	85+	**0.36 (0.24, 0.54)**	0.77 (0.34, 1.75)
	Sex		
	Male (reference)	1.00	1.00
	Female	**1.26 (1.10, 1.45)**	0.97 (0.78, 1.21)
	Race		
	White (reference)	1.00	1.00
	African American	**0.34 (0.27, 0.45)**	**0.51 (0.29, 0.89)**
	Others	0.84 (0.58, 1.23)	1.39 (0.82, 2.37)
Enabling	Marital status		
	Divorced/single/widowed (reference)	1.00	1.00
	Married	**1.60 (1.37, 1.87)**	**1.49 (1.14, 1.94)**
	Employment		
	Employed (reference)	1.00	1.00
	Retired	1.04 (0.83, 1.30)	1.04 (0.75, 1.46)
	Not employed/disabled	**0.70 (0.57, 0.86)**	1.04 (0.77, 1.40)

	Health insurance type		
	Commercial (reference)	1.00	1.00
	Medicaid/Medicare	**0.76 (0.61, 0.95)**	1.07 (0.77, 1.50)
	Income		
	< FL median (reference)	1.00	1.00
	=> FL median	**1.39 (1.20, 1.60)**	1.10 (0.87, 1.39)
Need	Area of residence		
	Local (reference)	1.00	1.00
	Nonlocal	1.13 (0.96, 1.33)	**1.34 (1.04, 1.71)**
	Comorbidities		
	None (reference)	1.00	1.00
	1+	1.05 (0.91, 1.21)	0.97 (0.77, 1.22)
	Frequency of hospitalizations	**1.43 (1.33, 1.55)**	1.08 (0.99, 1.19)
	MSDRG type [d]		
	Surgical (reference)	-	1.00
	Medical		**2.17 (1.68, 2.78)**
	APRDRG weight [d]	-	**1.13 (1.09, 1.17)**

[a]Bold values are statistically significant at $P<.05$. Odds ratios greater than 1 imply increased chance for behavior; less than 1 imply decreased chance for behavior.
[b]Predictors for adoption: age, sex, race, marital status, employment status, income, health insurance type, and frequency of hospitalizations.
[c]Predictors for active inpatient use: age, race, marital status, geographic area of residence, APRDRG weight, and MSDRG type.
[d]Variables related to the hospital admission were not examined among adopters as the adoption behavior was established prior to admission.

Table 4.3 Adverse Events, Postdischarge Care Utilization and Patient Satisfaction Among the portal Behavior Groups

Measures	**Outcomes**	**Adopters (n=2,352)**	**Nonadopters (n=2,242)**	***P* value**	**Active Inpatient Users (n=632)**	**Inactive Inpatient Users (n=1,720)**	***P* value**
Patient safety	Had an adverse event, No. (%)	40 (1.7)	47 (2.1)	.36[a]	13 (2.1)	27 (1.6)	.42[a]
Postdischarge care utilization	Emergency visit within 14-days of discharge, No. (%)	272 (11.6)	214 (9.5)	.03[a]	75 (11.9)	197 (11.5)	.78[a]
	30-day unplanned readmission, No. (%)	299 (12.7)	222 (9.9)	<.01[a]	96 (15.2)	203 (11.8)	.03[a]
Patient satisfaction[c]	Understand responsibilities for self-health management, mean score (SD)	87.6 (19.6)	85.5 (20.1)	.02[b]	89.1 (18.4)	87.1 (20.0)	.22[b]
	Understand the purpose for taking each medication, mean score (SD)	90.0 (18.8)	87.8 (20.9)	.05[b]	91.8 (16.0)	89.4 (19.7)	.21[b]
	Aggregate self-health management knowledge score	84.3 (21.3)	80.0 (23.1)	<.01[b]	87.0 (19.2)	83.3 (21.9)	.05[b]
	Overall rating of the hospital stay, mean score (SD)	95.6 (9.1)	95.3 (10.3)	.75[b]	95.6 (10.5)	95.7 (8.6)	.56[b]

[a]Pearson χ^2 test. [b]Wilcoxon nonparametric. [c]Satisfaction survey was distributed to a random sample of discharges; thus, the sample size was as follows: adopters; n=788, nonadopters; n=646, active inpatient users; n=205, and inactive inpatient users; n=577.

Table 4.4 Association Between Patient Outcomes and Portal Behaviors: Results From Regression Models

	Independent Variables			
	Active Inpatient Users vs Nonadopters		**Inactive inpatient Users vs Nonadopters**	
Dependent Variables[a]	**OR (95% CI)**	***P* value**	**OR (95% CI)**	***P* value**
[adverse events=yes]	0.76 (0.40, 1.45)	.41	0.71 (0.44-1.16)	.17
[emergency visits=yes]	1.28 (0.97, 1.70)	.08	1.23 (1.00-1.51)	.08
[readmissions=yes]	1.60 (1.23, 2.08)	<.01	1.21 (0.99-1.48)	.06
Dependent Variables[a]	**Beta Coefficient**	***P* value**	**Beta Coefficient**	***P* value**
Self-health management knowledge	2.18	.07	1.15	.17
Overall hospital experience	0.16	.83	0.28	.60

[a]Five regression models were conducted adjusting for age and disease severity. A logistic regression was used for adverse events, emergency visits, and readmissions. A linear regression was used for self-health management knowledge and overall hospital experience scores.

CHAPTER 5

Manuscript II Femoral and Sciatic Nerve Block Versus Periarticular Anesthetic Injection After Total Knee Arthroplasty

ABSTRACT

Background: Pain is a main concern of patients undergoing total knee arthroplasty (TKA). **Questions/Purposes:** This study compares whether receiving a periarticular anesthetic injection (PAI) of ropivacaine, epinephrine, ketorolac, and morphine versus femoral nerve block (FNB) combined with single-shot sciatic nerve block (SNB) offers better patient outcomes. **Patients and Methods:** We retrospectively reviewed consecutive patients who underwent primary unilateral TKA between March 1, 2013, and August 31, 2014 (N=511) and received FNB with SNB versus those who underwent TKA between October 1, 2014 and March 31, 2016 (N=479) and received PAI. Postoperative outcomes, including pain scores, time to first ambulation, cumulative distance walked, in-hospital falls, length of stay, discharge disposition, satisfaction with pain control, emergency visits within 14 days, readmissions within 30 days, revisions within 90 days, and total cost of hospitalization and 90-day follow-up period, were compared. **Results:** The PAI group had lower pain scores during the first 24 hours after TKA, but there was no difference at 48 hours. Patients who received PAI had earlier ambulation, longer walking distance, shorter hospital stay, increased discharges home, and better satisfaction with pain control.

Total cost of hospitalization was less expensive for PAI; on average, each patient who had their pain managed using PAI saved $3,539. Insignificant differences were found in other variables. **Conclusions:** PAI is superior in providing early postoperative pain relief, improved functional recovery, better patient satisfaction with pain, and lower hospitalization cost compared to FNB with single-shot SNB following TKA.

Level of Evidence: III

Keywords: Femoral nerve block, Periarticular injections, Pain control, Cost, Total knee arthroplasty

INTRODUCTION

Total knee arthroplasty (TKA), also known as total knee replacement, was the third most common operating room procedure (718,000 procedures) in the United States in 2011, with an aggregate hospitalization cost of $11.3 billion per year [131]. TKA is projected to increase to 3.48 million procedures per year by 2030 due to population aging and obesity, contributing to further growth in health care spending [52, 53]. The wide diffusion and high cost of this procedure has led clinicians to focus on pain management, since severe pain has profound implications on patients' recovery [107, 108]. Accordingly, medical and economic consequences are expected, including dissatisfaction, prolonged length of stay (LOS), and increased cost [212]. Thus, effective pain control is crucial to improve clinical care and avert unfavorable outcomes. Given the importance of pain management, the Joint Commission and the Agency for Healthcare Quality and Research introduced standards for organizations to improve their care for patients with pain [213, 214].

In the last few years, advancements in postoperative pain control moved toward multimodal pain management methods, instead of using opioids alone [109]. Of these approaches, femoral nerve block (FNB), which is a well-established analgesic to reduce pain post-TKA, has been the gold standard [110, 111]. However, many authors reported a number of disadvantages, including quadriceps weakness that delays recovery, increased risk of neurologic symptoms, falls, opioid abuse, and adverse events [43, 112, 113]. For this reason, some clinicians combine sciatic nerve block (SNB) with FNB, instead of using FNB alone, in order to improve outcomes early after surgery [114-118]. Yet, the advantages of SNB when combined with FNB continue to be debated in the literature [119, 120].

Compared with peripheral nerve block, periarticular anesthetic injection (PAI), a concentrated multidrug combination, has been identified as a preferred alternative approach for pain management after TKA [121]. Earlier clinical studies were conducted to validate the efficacy and safety of different combinations of PAI medication mixture, and have reported it to be easier to administer with fewer adverse events [122-124]. However, evidence on PAI as a better alternative to other pain management approaches is limited, and research is needed to support its efficacy [132-136].

For several years, our institution had used continuous FNB combined with a single-shot SNB and 0.5% ropivacaine for postoperative pain control after TKA. In September 2014, the orthopedic practice showed interest in pursuing a change in the pain management approach after TKA, and transitioned to use of PAIs. Thus, comparing the analgesic effect and other related patient outcomes among patients who used FNB with SNB versus PAI was a topic of interest. Outcomes were evaluated postoperatively, including pain scores at 24 and 48 hours after surgery, time to first ambulation, cumulative distance walked, patient falls, LOS, discharge disposition, patient satisfaction with pain control, and postdischarge measures, including emergency visits within 14 days, readmissions within 30 days, and revisions within 90 days. We also compared detailed cost per type of service and total cost for both the hospitalization episode and the 90-day follow-up period, separately, for these 2 pain management approaches.

To our knowledge, there are few reports comparing efficacy, safety, and cost of FNB combined with SNB versus PAI in TKA. Our motivation was to examine if the latter approach was cost-effective. We found limited research available to inform policy on drivers of health care costs in TKA; therefore, results of this study may add value to policy-makers and clinicians who are interested in pain management in orthopedic care. Because many surgical procedures have migrated to the outpatient setting, many orthopedic surgeons are interested in pain control approaches that enable easier and safer outpatient TKA that can be provided at lower cost. It is equally important to disseminate results of this comparison to patients, which may empower them to take an active role in their care and make more informed decisions.

MATERIALS AND METHODS

We conducted a retrospective review of patients at least 18 years of age who received a primary unilateral TKA. A total of 1,158 TKA patients were screened to obtain 990 eligible patients for the study (Figure 5.1). Study outcomes were compared between patients who received FNB combined with single-shot SNB between March 1, 2013, and August 31, 2014, versus patients who received PAI between October 1, 2014, and March 31, 2016). Surgeries in September 2014 were excluded to allow the new practice to stabilize.

The surgical procedure, implants used, and surgery team were consistent in the 2 periods, minimizing differences in patient and provider factors. Table 1 shows most patient characteristics are similar. All patients received a primary general or spinal anesthesia by an anesthesiologist using the same preprocedure sedation protocol. Combined FNB with SNB or PAI were additional anesthesia given for postoperative pain control. For all patients in the FNB group with no notable valgus deformity or radiculopathy, the same anesthesiologist administered an indwelling continuous femoral catheter supplemented with a single-shot SNB. For patients in the PAI group, the anesthetic mixture was administered based on weight, as previously used by Spangehl and colleagues [50]. PAI was administered by the performing surgeon, minimizing the potential for confounding effects on injection technique. The injection was administered by 18-gauge needle as multiple boluses into the periarticular tissue surrounding the knee joint prior to site closure, with no additional infusion or injections after site closure. A 30 cc bolus was injected into the posterior capsule and the remaining boluses were injected throughout the anterior knee periarticular and subcutaneous tissues. Postoperative pain control was the same for both groups and included use of analgesia, such as morphine, acetaminophen, celecoxib, tramadol, and narcotics, administered via oral or intravenous means as necessary.

Patient Characteristics

Patient demographic and clinical data were obtained from the electronic health record (EHR). Comorbidities were counted by the presence of any of the 19 common chronic medical conditions included in the Charlson Comorbidity Index, in addition to hypertension, stroke, anxiety, and depression in the 12 months prior to hospitalization.

Obesity was determined by the body mass index (BMI) documented at time of admission, rather than on the International Classification of Diseases code for obesity, which is rarely coded. We then classified BMI using weight categories defined by the Centers for Disease Control and Prevention. American Society of Anesthesiologists physical status classification was used to classify patient disease severity on admission.

Study Measures

Pain was assessed postoperatively using a numeric rating scale ranging from 0 (no pain) to 10 (worst possible pain) and reported at 24 and 48 hours after surgery. Patient functional recovery was measured by time from end of surgery to first walk, and by distance walked each day as documented in physical therapy (PT) notes. An attempt was made for each patient to receive a PT session on the same day of surgery, with a standardized protocol to assist in knee ambulation, standing, and walking. Because some patients rejected PT after surgery due to pain or other reasons, the frequency of received PT sessions varied between cohorts. Thus, our calculation of distance walked was exclusive to the first 3 PT sessions, which was the minimum number of sessions received by all patients.

All patients had TKA on the day of admission, thus, we documented hospital LOS, in hours, throughout the hospitalization and from the end of surgery to discharge. Patient falls and surgical site infections were obtained from the Quality Management Services database for adverse events. Additionally, discharge disposition, emergency visits within 14 days after discharge, readmissions within 30 days, and revisions within 90 days were extracted from the EHR.

Patient satisfaction was measured by the normal hospital procedure, using the validated Hospital Consumer Assessment of Healthcare Providers and Systems

(HCAHPS) survey; distributed to a random sample of discharged patients ranging between 2 days and 6 weeks after discharge [148]. Thus, only a subset of our patients were assessed; 185 (36.2%) from the FNB group and 199 (41.5%) from the PAI group. We selected 2 questions to assess satisfaction with pain: "How often was your pain well controlled?" and "How often did the hospital staff do everything they could to help you with your pain?" Responses were transformed and averaged (never=0, sometimes= 33.3, usually=66.6, and always=100), resulting in a 0 to 100 linear-scaled score. One question assessed the overall satisfaction with hospital experience: "Using any number from 0 to 10, where 0 is the worst hospital possible and 10 is the best hospital possible, what number would you use to rate this hospital during your stay?" Scores were multiplied by 10 to create a consistent linear scale.

Cost data were obtained from our institution's cost data warehouse [151], which applied Medicare reimbursement to professional services, multiplied service line hospital charges by Medicare cost report cost-to-charge ratios, and adjusted for inflation with the gross domestic product implicit price deflator to create 2016 standardized costs. We reported costs separately for the index hospitalization and 90-day follow-up period excluding hospitalization, using Berenson-Eggers Type of Service and Uniform Billing-04 codes to classify the line item data. We further summed cost by type of service, grouped in different categories: analgesic approach (i.e., nerve block and the periarticular supplies and medications); room and board (i.e., observation and intensive care unit stay); operating and recovery room occupation; orthopedic procedure; physical therapy; pain medications; laboratory and pathology; supplies; and other costs including blood transfusion, other medications/intravenous fluids, and miscellaneous. Follow-up cost data did not include medications obtained from outpatient pharmacies.

Data Analysis

Statistical analyses were performed using SAS Version 9.4 (SAS Institute Inc.); significance was defined as $P<.05$ in a 2-tailed test. We performed univariate χ^2 tests for categorical variables with Fisher's exact test for cell counts <40, and Wilcoxon signed rank tests for mean comparisons among continuous variables to account for skewed distributions. Cost variables were presented as mean and median cost per patient, including SDs and interquartile ranges. We used repeated generalized linear regression models to determine if receiving PAI was a predictor for (1) pain scores at 24 hours, (2) pain scores at 48 hours, (3) distance walked, (4) postoperative LOS, and (5) total cost of index hospitalization. Independent variables in the regression analysis included age, sex, race, marital status, BMI, ASA class, and comorbidities.

In modelling the index hospitalization total cost, we used log-transformed costs. For the 90-day follow-up period, we excluded patients with costs exceeding $20,000 not related to TKA and patients who were electively readmitted for major surgeries, and focused on local patients (n=263 and n=278 for FNB and PAI patients, respectively), who were more likely to have follow-up services performed at our institution. This study was approved by the institutional review board, and no external source of funding was obtained.

RESULTS

Of the total population, more than 99% of patients had their TKA as an elective procedure. The majority were white (91.3%), married (74.0%), women (61.5%), living locally in Jacksonville, Florida (57.1%), with a mean age of 68.0 years (SD 9.4 years). With regards to comorbidities, 55.3% did not have any comorbid conditions reported in the last 12 months, and among those who did have comorbidity, 25.7% were hypertensive, 10.2% were diabetic, and 6.5% suffered from cancer. Patient demographic and clinical characteristics were similar in both FNB and PAI groups, except for ASA class that was included as a covariate in regression analyses. Baseline characteristics are reported in Table 5.1.

Postoperative Outcomes

Analgesic Efficacy: Patient pain scores at 24 hours after surgery were significantly lower in the PAI group (2.2 [1.5]) versus the FNB group (2.8 [1.7]; $P< .01$). No significant differences were reported between the groups in the next postoperative day (24-48 hours). Statistical tests were not performed for 48 and thereafter, due to the limited number of patients remaining to be hospitalized (Table 5.2).

Functional Recovery: Patients in the PAI group experienced earlier ambulation, where 33 (6.8%) walked on the day of surgery compared to 4 (0.8%) in the FNB group ($P<.01$). Distance walked was also higher among the PAI group (86.5 meters [82.2]) than the FNB group (48.0 meters [67.0]; $P<.01$) in the first 3 PT sessions. We also noted fewer patient falls among the PAI group, but differences were not statistically significant ($P>.05$) (Table 5.2).

Other Outcomes: We found patients in the PAI group had a significant decrease in postoperative LOS by about 14.4 hours, from 71.2 hours with FNB to 56.8 hours with PAI ($P<.01$). In addition, 382 (79.3%) patients who received PAI were able to be discharged home rather than to other care or rehabilitation facilities, compared with 248

(48.2%) who received FNB. We found 4 PAI cases with surgical site infections, while none were seen among the FNB patients (*P*=.05), but no significant differences were detected in emergency visits, readmissions, and revisions (Table 5.2).

Patient Satisfaction

Patient satisfaction with pain control was significantly higher among patients in the PAI group compared to FNB (*P*<.01), but no differences were observed in the overall hospital experience (Table 5.3).

Cost

The total standardized cost of hospitalization was 22.8% more expensive for pain management using FNB combined with single-shot SNB compared to PAI ($15,542 [$2,464] vs $12,002 [$3,079]; *P*<.01). Differences in cost per type of service between the 2 pain management approaches were significant in almost all categories (Table 5.4 and Figure 5.2). However, the total cost throughout the 90-day period after discharge was similar for the 2 pain management approaches (Table 5.5).

PAI as a Predictor for Study Outcomes

As a secondary analysis, we applied several linear regression models to test if PAI (independent variable) was a predictor for selected study outcomes, including pain scores at 24 and 48 hours, time to first ambulation, distance walked, postoperative LOS, and total cost of hospitalization after adjusting for patient demographic and clinical factors. Our results indicated that receiving PAI was a significant predictor for lower pain at the first 24 hours postoperatively (β=-0.55, *P*<.01), earlier ambulation (β=-8.88, *P*<.01), further distance walked (β=27.42, *P*<.01), shorter postoperative LOS (β=-13.72, *P*<.01), and lower hospitalization cost (β=-0.26, *P*<.01; $4,040 savings). Regression model results are presented in Table 5.6.

DISCUSSION

Both FNBs with single-shot SNB and PAIs have been widely used to alleviate postoperative pain after TKA. Our retrospective study was conducted to determine whether using PAI had advantages on patient outcomes compared to FNB with SNB in the immediate postoperative time period. Based on study results, patients who received PAI reported lower pain scores at 24 hours after TKA and were more satisfied with pain control. PAI patients were able to ambulate earlier, walk further, and be discharged sooner, and to home rather than a rehabilitation center. In addition, findings from adjusted regression models provided further evidence of the positive association between using PAI and these patient outcomes.

A likely key to patient recovery is controlling postoperative pain [215]. The psychological factor of feeling better after a major surgery like TKA, known to be a painful procedure, could increase patient motivation to engage in rehabilitation and recovery efforts [216, 217]. As the PT protocol in our institution began on the day of surgery, patients in the PAI group who experienced less pain were more able to initiate therapy immediately after TKA. In return, earlier mobility and improved functional recovery were observed among this cohort. Consistent with our results, other researchers have reported positive association of PAI with reduced pain and effective motor function compared to other pain management approaches [45, 218-220]. Toftdahl et al [127] compared early functional benefits of PAI compared to FNB and reported more patients in the PAI group could walk greater than 3 meters on the day of surgery. In contrast, Tanikawa et al [133] found that FNB with SNB was more effective than PAI in reducing pain within 3 hours after TKA, but less effective than PAI at 24 hours. The authors speculate that PAI may have had a longer acting time because, while SNB was performed prior to surgery, PAI was administered during surgery and may not have taken immediate effect. Jian et al's [221] meta-analysis results indicated equivalence of analgesic effect between SNB and PAI groups at 24 hours. Chaubey et al [222] determined that FNB provided better pain relief but reduced range of motion, while Carli et al [223] concluded that FNB provided improved recovery initially and at 6 weeks. Beebe et al [41] reported that FNB did not prevent early ambulation, and several studies agreed that FNB and PAI had comparable pain intensity and effect on mobilization [50, 224-226].

Contrary to common concerns, occurrence of inpatient falls did not differ significantly between the 2 groups, although 6 patients (1.2%) in the FNB group fell after TKA compared with 2 in the PAI group (0.4%). Similarly in another study, 3 of 79 patients (4%) with FNB combined with SNB fell after TKA compared with 1 fall in 81 patients (1%) in the PAI group, but differences were not statistically significant [50]. We previously reported a higher number of surgical site infections in the PAI group; these patients were more likely to be readmitted (2 of 4), have revisions (3 of 4), and were more expensive cases (above the average mean), both during the hospitalization and follow-up. Iwakiri et al [227] studied 106 TKA patients who received PAI with or without morphine and did not detect any infection cases. Further reports found no differences in the rate of adverse events between FNB and PAI groups, and none of the adverse events were directly related to analgesic approach [121, 129, 133, 219, 228].

In terms of hospital LOS, we found a significant decrease in duration of stay among patients in the PAI group. In an earlier report by Dalury [229], the mean hospital LOS among patients who received PAI was 1.2 days, with most patients being discharged home within 24 hours, and all by 48 hours. Similarly, Broome and Burnikel [230] found a decrease in LOS from 60 hours to 53 hours when PAI was used compared to FNB. Yet, contradicting results in the literature do exist, indicating no differences between FNB with or without SNB or PAI in reducing hospital LOS [133, 136, 223, 225, 231].

As might be anticipated from the low pain scores reported in the PAI group, patients also reported higher satisfaction with pain control compared to patients who received FNB. However, while PAI patients had improved pain experience, no significant differences were noted in overall satisfaction. Our patient satisfaction metrics were collected after discharge, and so, are subject to recall bias; yet, it was interesting to find a remarkably high satisfaction with pain control in the postdischarge period in both groups. Apfelbaum et al [232] reported more patients experience pain after discharge than before, and Lostak et al [233] demonstrated that the rate of satisfaction is high shortly after surgery, but declines gradually thereafter. According to the literature, patient dissatisfaction with pain after TKA is very common, ranging from 7.5% to 28.3%, while our PAI group only had a 7.3% dissatisfaction rate [234, 235]. With many research efforts conducted to seek early pain control and improved patient satisfaction, using PAI continues to be an effective option [123].

Our study found evidence of significant savings when pain was managed using PAI (P<.01). The standardized cost of analgesic approach materials (i.e., medications and supplies) was 2.6 times higher for FNB compared to PAI; ($1,900 [$664] vs $713 [$150], respectively). In addition, the cost of pain medications was 1.4 times higher for FNB patients, suggesting that using PAI may be possible to decrease the consumption of opioids among patients. However, decisions about cost-effectiveness need to be based on the entire cost of the episode rather than type of services; thus, our study concludes that each patient who had their pain managed using PAI of ropivacaine, epinephrine, ketorolac, and morphine saved approximately $3,539 on their total TKA hospitalization (P<.01). This lower total cost is not strictly due to earlier discharges, as our calculation of cost per type of service showed lower costs across majority of services. We observed no significant differences the total cost of the 90-day follow-up period after discharge, suggesting that savings from post-surgical pain management approach during the hospitalization episode are not offset with higher follow-up costs.

Among other studies that used nonstandardized costing methods, the cost of PAI with liposomal bupivacaine was $285, compared to the cost of FNB, which was $640 [230]. Dalury et al [229] estimated the cost of PAI with ropivacaine, epinephrine, ketorolac, and clonidine as $46, and Corman et al [236] estimated cost of PAI with bupivacaine, morphine, methylprednisolone, and cefuroxime as low as $16. The latter study also estimated the cost of PAI with bupivacaine liposome as $319 and of continuous peripheral nerve block with ropivacaine as $757.

It is important to point out that the mixed conclusions regarding PAI efficacy and cost may be driven by differences in PAI mixture and methodology [212, 237]. Currently, little scientific data exist to define guidelines for the most effective medication combination or pain management protocol [122, 228, 229, 238, 239]. Therefore, use of different PAI medication combinations (ie, medication type and volume) adds to the variability in cost across studies. The injection administration technique may also vary among surgeons, and few studies provide clear descriptions of their administration technique. Broome [49] demonstrated that using a small needle, such as 22-gauge instead of 18-gauge, and infiltrating small amounts in a large number of locations provides better efficacy. Dalury [229] recommended the use of control syringes, which allow for aspiration before injection and are more comfortable for a surgeon's hand. More studies may be needed to identify the best PAI approach before final conclusions are made on cost-effective pain management approaches.

Our study is limited by a retrospective, single-institution design using consecutive patients at 2 exclusive, yet consecutive, time periods. The pain control protocol transition from FNB with SNB to PAI was the only change introduced in the study time periods, patient cohorts were clinically similar, and the same surgeons performed the operations. Furthermore, our EHR did not contain detailed information on the progress of rehabilitation; thus, our mobility measures were limited to the in-hospital phase, yet these data are important to report as short-term mobility indicators. Additionally, patient self-reported pain scores often have great disparity due to variability in tolerance of pain. Still, electronically-documented pain scores in the EHR, a major study asset, ensured accuracy, synchronous collection and easy data retrieval for this large patient cohort. Conclusions regarding patient satisfaction with pain control are limited due to the smaller sample size, a consequence of the randomized nature of HCAHPS collection, but no other satisfaction measures were readily available. While regression analyses were applied to demonstrate associations adjusted for potential covariates, causation cannot be proven. Finally, our cost analysis relied upon administrative claims data from our institution and we were unaware about post-care consumed elsewhere. Our calculation of cost in the follow-up period was limited to local patients, who were more likely to have follow-up services performed at our institution. Despite these limitations, the study uncovered differences between 2 well established pain management approaches used for TKA in nearly 1,000 patients. Our unique ability to combine patient clinical data from medical records with administration billing data, categorizing all line item services according to type into related categories, and then applying cost standardization instead of nominal charges, provides valuable information for policy makers and clinicians who are interested in measuring value in health care. To our knowledge, this is the first study to examine detailed cost per services between PAI and FNB with single-shot SNB for primary TKA.

CONCLUSIONS

The replacement of FNB with PAI led to improvements in hospital value metrics, including early pain relief, recovery, LOS, patient satisfaction with pain, and total hospitalization cost. Our findings provide valuable insight for clinicians and policymakers to determine the most efficient and cost-effective pain management approach after TKA, and can promote evidence-based clinical policy for cost-effective pain management in orthopedic care. It is suggested to improve and expand the use of PAI, but with caution in relation to possible infections or increased postdischarge cost.

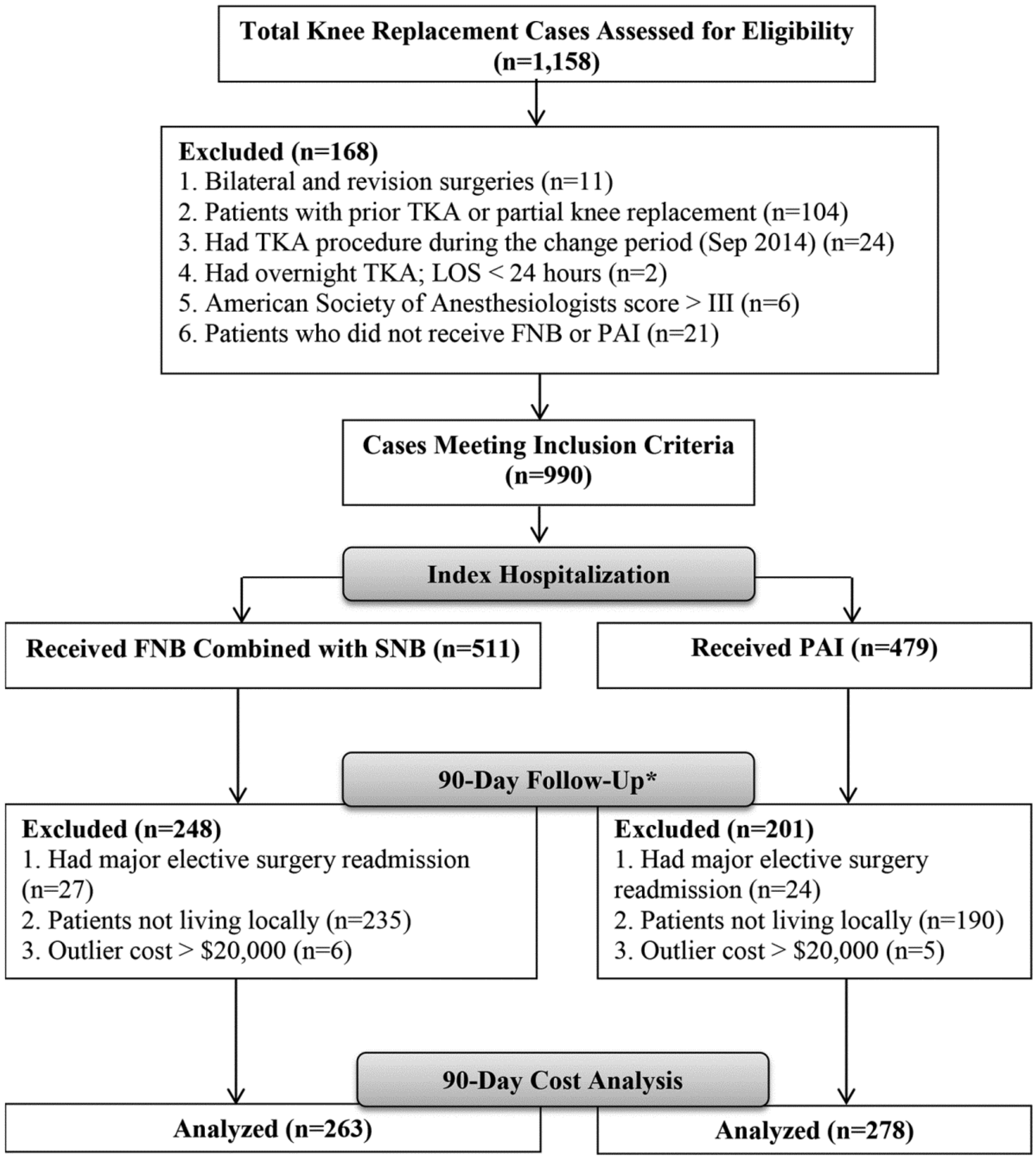

Figure 5.1 Flow Diagram of Patient Exclusions and Eligibility.
FNB indicates femoral nerve block; LOS, length of stay; NB, nerve block; PAI, periarticular anesthetic injection; SNB, sciatic nerve block; and TKA, total knee arthroplasty.
*Exclusion criteria in the 90-day follow-up period are not mutually exclusive.

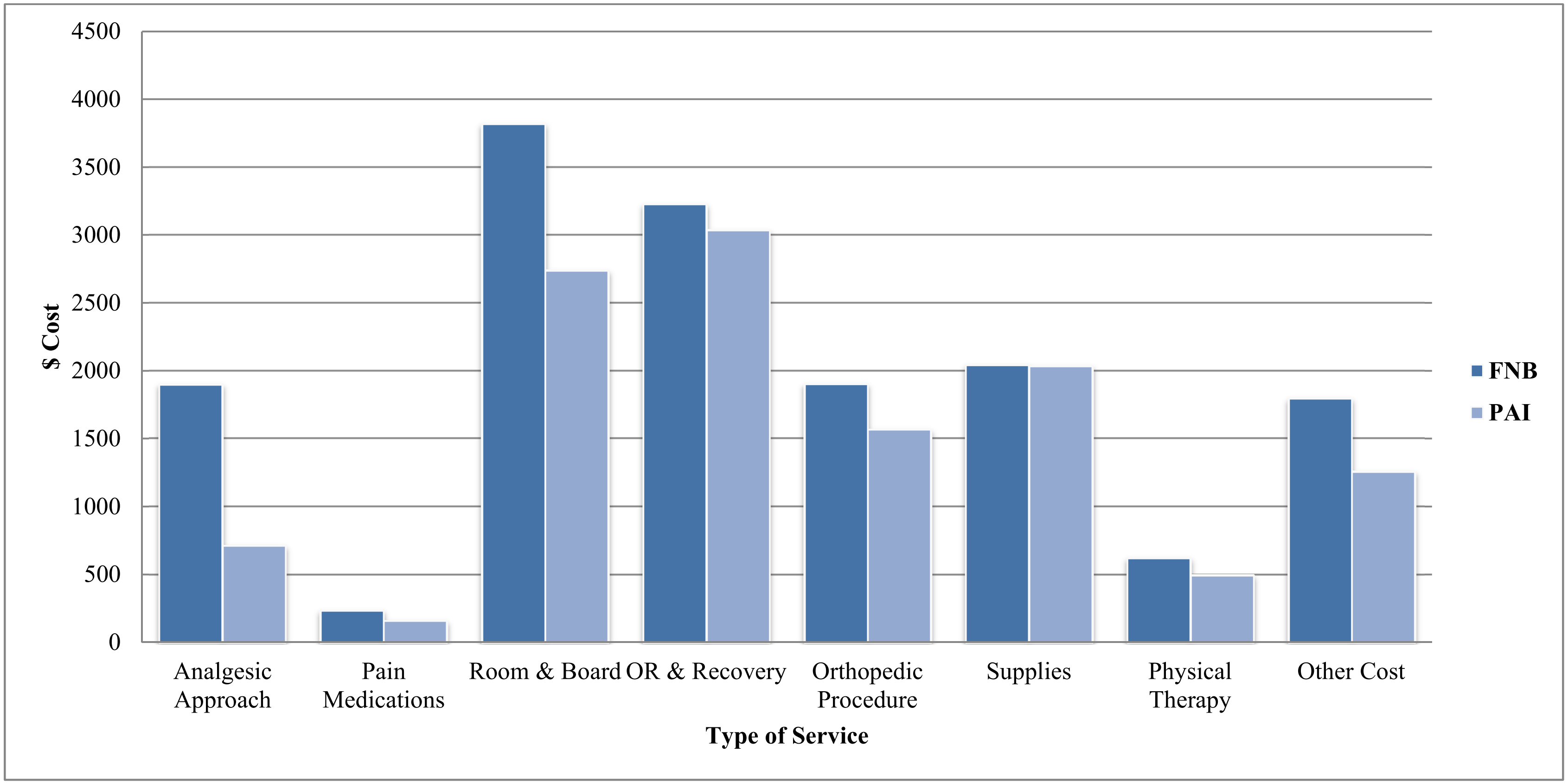

Figure 5.2 Comparison of Hospitalization Cost Per Service Between FNB and PAI.
FNB indicates femoral nerve block; OR, operating room; and PAI, periarticular anesthetic injection.

Table 5.1 Sample Baseline Characteristics By Pain Management Approach

Characteristics	Total Sample, No. (%) N=990	FNB, No. (%) n=511	PAI, No. (%) n=479	*P* Value
Age, y				
Mean (SD)	68.0 (9.4)	68.2 (9.3)	67.7 (9.6)	0.52[a]
≤ 54	67 (6.8)	35 (6.8)	32 (6.7)	0.77[b]
55-64	285 (28.8)	140 (27.4)	145 (30.3)	
65-74	402 (40.6)	214 (41.9)	188 (39.2)	
≥ 75	236 (23.8)	122 (23.9)	114 (23.8)	
BMI				
Normal (18.5-24.9)	141 (14.2)	79 (15.4)	62 (12.9)	0.46[b]
Overweight (25.0-29.9)	315 (31.8)	166 (32.4)	149 (31.1)	
Obese (≥ 30.0)	534 (54.0)	266 (52.2)	268 (56.0)	
Sex				
Female	609 (61.5)	328 (64.2)	281 (58.7)	0.07[b]
Male	381 (38.5)	183 (35.8)	198 (41.3)	
Race				
African American	58 (6.0)	25 (5.0)	33 (7.0)	0.37[b]
White	885 (89.3)	456 (89.2)	429 (89.5)	
Other	47 (4.7)	30 (5.8)	17 (3.5)	
Marital status				
Married	733 (74.0)	377 (73.8)	356 (74.3)	0.85[b]
Single/divorced/widow	257 (26.0)	134 (26.2)	123 (25.7)	

Employment status				
Employed	240 (30.7)	112 (28.6)	128 (32.8)	0.25[b]
Retired	422 (54.0)	223 (56.9)	199 (51.0)	
Not employed/disabled	120 (15.3)	57 (14.5)	63 (16.2)	
Area of residence				
Local (Jax area)	565 (57.1)	276 (54.0)	289 (60.3)	0.13[b]
Regional (120-mile)	276 (27.9)	151 (29.5)	125 (26.1)	
Distant (national/international)	149 (15.1)	84 (16.4)	65 (13.6)	
Payer type				
Nongovernment insurance	353 (35.7)	171 (33.5)	182 (38.0)	0.14[b]
Government insurance	637 (64.3)	340 (66.5)	297 (62.0)	
Tobacco use				
Ever (current or former)	469 (47.4)	229 (44.8)	240 (50.1)	0.10[b]
Never	521 (52.6)	282 (55.2)	239 (49.9)	
ASA score[c]				
Normal healthy person	10 (1.0)	7 (1.4)	3 (0.6)	0.02[b]
Mild systematic disease	464 (46.9)	219 (42.9)	245 (51.1)	
Severe systematic dis.	516 (52.1)	285 (55.8)	231 (48.2)	
CCI				
Weighted, mean (SD)	0.6 (1.2)	0.7 (1.2)	0.6 (1.1)	0.22[a]
Age-weighted, mean (SD)	3.0 (1.6)	3.1 (1.6)	2.9 (1.6)	0.19[a]

Comorbidity[d]				
0	547 (55.3)	270 (52.8)	277 (57.8)	0.16[b]
1-2	359 (36.3)	190 (37.2)	169 (35.3)	
≥ 3	84 (8.5)	51 (10.0)	33 (6.9)	
Top comorbid conditions[e]				
Hypertension	254 (25.7)	152 (29.7)	102 (21.3)	<0.01[b]
Diabetes	101 (10.2)	56 (11.0)	45 (9.4)	0.46[b]
Peripheral vascular	65 (6.6)	42 (8.2)	23 (4.8)	0.04[b]
Cancer	64 (6.5)	33 (6.5)	31 (6.5)	>0.99[b]
Chronic pulmonary	60 (6.1)	35 (6.8)	25 (5.2)	0.30[b]
Anxiety/depression	43 (4.3)	17 (3.3)	26 (5.4)	0.12[b]
Elective admission				
Elective	987 (99.7)	509 (99.6)	478 (99.8)	0.60[b]
Surgery time, m				
Mean (SD)	96.1 (21.5)	96.0 (22.8)	96.2 (20.3)	0.84[b]
Anesthesia time, m				
Mean (SD)	150.2 (25.7)	149.9 (26.9)	150.5 (24.3)	0.62[b]

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; CCI, Charlson Comorbidity Index; FNB, femoral nerve block; PAI, periarticular anesthetic injection.
[a]Wilcoxon signed rank test
[b]Univariate χ^2 test
[c]ASA score
[d]Comorbidity includes the number of conditions in CCI in addition to: depression/anxiety, hypertension, and stroke
[e]Comorbid conditions are not mutually exclusive as a patient may have more than 1 comorbidity diagnosis

Table 5.2 Comparison of Outcomes Between FNB and PAI Groups

Outcomes	**FNB (n=511)**	**PAI (n=479)**	***P* Value**
Pain scores, mean (SD)			
At 24 hours	2.8 (1.7)	2.2 (1.5)	<0.01[a]
At 48 hours	3.1 (1.6)	3.1 (1.7)	0.68[b]
Functional recovery			
PT sessions received by patients, mean (SD)	3.5 (1.4)	4.4 (1.6)	<0.01[a]
Median (IQR)	4.0 (3.0, 4.0)	4.0 (3.0, 5.0)	
Range	(3.0-9.0)	(3.0-15.0)	
Walked during first 24 h postoperatively, No. (%)	4 (0.8)	33 (6.8)	<0.01[b]
Walked during 24-48 h postoperatively, No. (%)	494 (96.7)	477 (99.6)	0.01[c]
Distance walked in first 3 PT sessions, mean (SD), m	48.0 (67.0)	86.5 (82.2)	<0.01[a]
Time to first ambulation, mean (SD), h	31.3 (13.3)	22.3 (9.0)	<0.01[a]
In-hospital falls, No. (%)	6 (1.2)	2 (0.4)	0.29[b]
Surgical site infections	0 (0.0)	4 (0.8)	0.05[b]
Length of stay			
Time from admission to surgery, mean (SD), h	3.6 (1.2)	3.8 (4.7)	0.40[a]
Time from admission to discharge			
mean (SD), h	76.3 (15.9)	62.2 (20.7)	<0.01[a]
mean (SD), d	2.9 (0.7)	2.3 (0.9)	<0.01[a]
Time from end of surgery to discharge			
mean (SD), h	71.2 (15.9)	56.8 (20.0)	<0.01[a]
mean (SD), d	2.9 (0.7)	2.3 (0.8)	<0.01[a]

Discharge disposition[d]			
Home/home health, No. (%)	248 (48.2)	382 (79.3)	<0.01[c]
Other facility, No. (%)	266 (51.8)	100 (20.7)	<0.01[c]
Postdischarge			
Emergency visit within 14 days, No. (%)	19 (3.7)	19 (3.9)	0.87[b]
Readmission within 30 days, No. (%)	9 (1.8)	10 (2.1)	0.82[b]
Revision within 90 days, No. (%)	1 (0.2)	3 (0.6)	0.36[b]

Abbreviations: FNB, femoral nerve block; PAI, periarticular anesthetic injection; POD, postoperative day; PT, physical therapy.
[a]Wilcoxon signed rank test
[b]Fisher exact test
[c]Univariate χ^2 test
[d]Inpatient mortality was 0 in both groups

Table 5.3 Comparison of Patient Satisfaction Between FNB and PAI Groups

Questions[a]	**FNB (n=158)**[b]	**PAI (n=199)**[b]	***P* Value**
How often was your pain well controlled?	88.4 (18.4)	92.7 (16.8)	0.01[c]
How often did the hospital staff do everything they could to help you with your pain?	95.3 (12.8)	98.5 (8.5)	<0.01[c]
Your overall rating of the hospital stay	96.6 (8.1)	97.4 (6.5)	0.54[c]

Abbreviations: FNB, femoral nerve block; PAI, periarticular anesthetic injection.
[a]Satisfaction survey was distributed to a random sample of discharges (FNB=158 patients, PAI=199 patients).
[b]Values expressed as mean (SD).
[c]Wilcoxon signed rank test.

Table 5.4 Comparison of Hospitalization Cost Between FNB and PAI Groups

Services[a]	Groups	Mean (SD)	Median	IQR	*P*
Analgesic approach	FNB	2,273.9 (673.5)	2,546.3	1,717.2, 2,674.2	<0.01[b]
	PAI	1,087.6 (177.9)	1,063.7	968.0, 1,188.5	
Pain medications	FNB	238.0 (148.3)	235.0	107.0, 316.9	<0.01[b]
	PAI	160.3 (103.3)	138.7	79.3, 208.9	
Room and board	FNB	3,820.3 (1,192.9)	3,972.6	3,069.7, 4,153.2	<0.01[b]
	PAI	2,739.5 (1,277.2)	2,437.7	1,805.7, 3,340.6	
OR and recovery	FNB	3,226.8 (556.5)	3,189.5	2,865.4, 3,488.8	<0.01[b]
	PAI	3,037.9 (497.4)	2,996.3	2,705.3, 3,285.8	
Orthopedic procedure	FNB	1,901.0 (790.2)	1,400.3	1,400.3, 1,624.4	0.02[b]
	PAI	1,564.0 (345.1)	1,400.3	1,400.3, 1,624.4	
Supplies	FNB	2,040.5 (718.9)	2,070.6	1,599.6, 2,316.7	0.09[b]
	PAI	2,035.6 (875.1)	2,041.9	1,577.5, 2,256.4	
Physical therapy	FNB	622.9 (172.7)	601.1	518.9, 686.7	<0.01[b]
	PAI	496.9 (177.7)	468.2	386.4, 573.5	
Other costs	FNB	1,792.4 (582.5)	1,634.2	1,497.4, 1,863.0	<0.01[b]
	PAI	1,255.7 (1,519.0)	1,025.1	884.6, 1,249.3	
Total cost in 2016 $US	FNB	15,541.9 (2,463.7)	15,090.3	14,202.0, 16,415.9	<0.01[b]
	PAI	12,002.8 (3,079.5)	11,375.9	10,455.0, 12,559.7	

Abbreviations: FNB, femoral nerve block; IQR, interquartile range; OR, operating room; PAI, periarticular anesthetic injection; TKA, total knee arthroplasty.
[a] Categories of services: (1) analgesic approach, including nerve block and periarticular supplies and medications; (2) pain medications; (3) room and board, including observation and intensive care unit room and board; (4) OR and recovery; (5) orthopedic procedure; (6) supplies, including prostheses and nonprosthesis; (7) physical therapy; (8) laboratory and pathology; and (9) other costs, including blood transfusion, other medications/intravenous fluids, and miscellaneous. [b]Wilcoxon signed rank test.

Table 5.5 Comparison of 90-day Postdischarge[a] Care Costs Between FNB and PAI

Services[b]	**Group**	**Mean (SD)**	**Median**	**Range**[d]	***P***
Evaluation & manag.	FNB	204.2 (342.2)	73.4	(0.0-2,725.7)	0.52[c]
	PAI	220.7 (348.0)	90.2	(0.0-2,522.7)	
Room and board	FNB	137.7 (795.4)	0.0	(0.0-7,854.9)	0.64[c]
	PAI	173.7 (862.6)	0.0	(0.0-6,828.5)	
OR and recovery	FNB	73.1 (423.7)	0.0	(0.0-5,901.4)	0.48[c]
	PAI	57.9 (329.1)	0.0	(0.0-3,025.6)	
Orthopedic procedure	FNB	15.3 (133.2)	0.0	(0.0-1,961.2)	0.01[c]
	PAI	26.4 (177.9)	0.0	(0.0-2,584.5)	
Pain medications	FNB	45.5 (211.1)	0.0	(0.0-2,284.1)	0.21[c]
	PAI	39.7 (247.2)	0.0	(0.0-3,550.3)	
Other pharma.	FNB	85.7 (726.7)	0.0	(0.0-10,992.6)	0.44[c]
	PAI	62.5 (442.6)	0.0	(0.0-5,775.9)	
Lab and Pathology	FNB	23.2 (93.3)	0.0	(0.0-695.2)	0.42[c]
	PAI	29.3 (102.4)	0.0	(0.0-719.9)	
Supplies	FNB	14.0 (59.2)	0.0	(0.0-404.2)	0.47[c]
	PAI	25.4 (141.3)	0.0	(0.0-1,457.5)	
Physical therapy	FNB	13.9 (77.1)	0.0	(0.0-795.5)	0.96[c]
	PAI	12.1 (62.0)	0.0	(0.0-518.9)	
Other costs	FNB	459.7 (897.5)	122.8	(0.0-7,921.8)	0.21[c]
	PAI	584.1 (1,337.4)	148.4	(0.0-15,214.1)	

Total cost inflated to 2016 US dollars	FNB	1,078.1 (2,314.5)	258.5	(0.0-16,302.2)	0.39[c]
	PAI	1,236.1 (2,513.1)	317.9	(0.0-16,868.5)	

Abbreviations: FNB, femoral nerve block; PAI, periarticular anesthetic injection; OR, operating room.

[a]90-day postdischarge cost was calculated for 263 FNB patients and 278 PAI patients. Refer to the list of exclusion criteria in Figure 1.

[b]Categories of services: (1) evaluation and management; (2) room and board, including observation and intensive care unit room and board; (3) OR and recovery; (4) orthopedic procedure; (5) pain medications; (6) other pharmaceuticals, including intravenous; (7) laboratory and pathology; (8) supplies, including prostheses and nonprosthesis; (9) physical therapy; and (10) other costs, including blood transfusion and miscellaneous.

[c]Wilcoxon signed rank test.

[d]Interquartile range was 0.00-0.00 for most categories; thus, range was reported to provide better information about spread of cost. IQR for total cost was [FNB (51.1, 1,072) and PAI (39.4, 1,245.4)].

Table 5.6 Linear Regression Analysis of Predictors of Selected Outcomes in TKA

Dependent Variables	Pain Scores (at 24 hours)		Pain Scores (at 48 hours)		Time to First Ambulation[a]		Distance Walked[b]		Postoperative LOS[c]		Total Cost Index (Transformed Log)	
	β	*P* Value	β	*P* Value	β	*P* Value	β	*P* Value	β	*P* Value	β	*P* Value
Intercept	2.08	**<0.01**	2.24	**<0.01**	29.05	**<0.01**	93.85	**<0.01**	67.37	**<0.01**	9.60	**<0.01**
Approach												
FNB (reference)												
PAI	-0.55	**<0.01**	0.08	0.38	-8.86	**<0.01**	34.48	**<0.01**	-13.73	**<0.01**	-0.26	**<0.01**
Age												
≤ 54	0.93	**<0.01**	1.01	**<0.01**	-0.80	0.61	11.61	0.21	-3.42	0.15	0.05	**0.03**
55-64	0.26	**0.03**	0.39	**<0.01**	-0.48	0.59	12.64	**0.02**	-2.55	0.06	0.02	0.20
65-74 (reference)												
≥ 75	-0.37	**<0.01**	-0.36	**<0.01**	1.44	0.14	-11.49	**0.05**	3.81	**0.01**	-0.02	0.18
Sex												
Male (reference)												
Female	0.44	**<0.01**	0.47	**<0.01**	1.70	**0.02**	-41.82	**<0.01**	5.43	**<0.01**	0.02	0.12
Race												
White (reference)												
African American	-0.02	0.93	0.04	0.85	-1.52	0.34	-0.38	0.96	-0.29	0.90	0.04	0.10
Other	-0.10	0.74	-0.54	0.08	-1.28	0.56	51.64	**<0.01**	-2.65	0.45	-0.05	0.15

Marital Status												
Not married (reference)												
Married	0.03	0.79	0.09	0.44	-1.11	0.20	0.22	0.96	-3.62	**<0.01**	-	-
Obesity (BMI ≥ 30 kg/m^2)												
No (reference)												
Yes	0.18	0.08	0.13	0.21	0.75	0.33	-20.77	**<0.01**	0.95	0.41	0.02	0.08
Comorbidity												
0 (reference)												
1-2	0.20	**0.05**	0.24	**0.02**	0.53	0.50	-3.02	0.53	1.80	0.12	-0.03	0.65
≥ 3	0.45	**0.01**	0.44	**0.01**	-0.34	0.80	-11.82	0.16	3.41	0.10	0.05	**0.02**
ASA												
Normal or mild (reference)												
Severe	0.26	**0.01**	0.38	**<0.01**	2.75	**<0.01**	-15.63	**<0.01**	2.78	**0.02**	0.04	**<.01**

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; FNB, femoral nerve block; LOS, length of stay; PAI, periarticular anesthetic injection; TKA, total knee arthroplasty.
[a]Hours from end of surgery to first walk.
[b]Meters walked in first 3 physical therapy sessions after surgery.
[c]Hours from end of surgery to discharge.

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