AN ABSTRACT OF THE DISSERTATION OF

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Title: The Association Between Patient Activation and Cost, Utilization, and Outcomes Among Patients Undergoing Elective, Primary Total Knee Arthroplasty.

Abstract approved:

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Background. Total knee arthroplasty, or replacement, is a common, generally successful, and expensive procedure. Tools to predict outcomes following orthopedic procedures are abundant, yet no commonly used assessment accounts for an individual's propensity to engage in adaptive health behavior. The 13-item Patient Activation Measure (PAM) questionnaire is a tool that quantifies a patient's ability and confidence in managing their healthcare needs. A patient who is highly activated has the knowledge and skill to navigate the healthcare system and engage in healthy behaviors. A patient who scores within PAM Level 4 has an ability to maintain healthy behaviors (highest level); Level 3 patients are taking action toward managing their health; Level 2 patients are building confidence; and Level 1 patients are not yet taking a role. The PAM assessment may help fill a pocket-of-need in the surgeon's pre-operative evaluation of surgical readiness and post-acute risk. This study reports results of retrospective analysis of a double-blinded, prospective cohort study designed to assess the role of patient activation in a population of orthopedic surgical patients. The hypothesis is lower pre-operative patient activation scores are associated with higher costs incurred, higher post-operative service utilization, and lower patient-reported outcome measures in the first three months following total knee arthroplasty (TKA), commonly referred to as total knee replacement.

Methods. The study population includes 754 patients who elected to undergo primary, unilateral total knee arthroplasty, with no contralateral procedure during the study period, performed by surgeons at a single orthopedic clinic in Oregon, at two participating hospital sites between September 2014 and December 2015. Patients consented to be included in the research study under an alternative consenting process via an iPad application. Retrospectively, two different data sources were available: (1) patient survey data and (2) administrative billing data. Survey data were collected prospectively from patients pre-operatively and at three months (± one month) post-operatively. Pre-operatively, patients completed the Patient Activation Measure (PAM), an extremity-specific patient reported outcome instrument (Oxford Knee Score; OKS), a health-related quality of life tool (Veteran's RAND VR-12 Health Survey; physical health component score and mental health component score, PCS and MCS, respectively), and pain assessment (Visual Analogue Pain Scale; VAS). A single de-identified data set with a unique study identification number for each patient, containing all billing data for the date of surgery through 90-days post-operatively, was received from the orthopedic clinic, one ambulatory surgery center, one regional hospital system (four hospitals), and a single community-hospital. Utilization counts, and payments deflated to 100% of Medicare, were summed for each patient for inpatient, outpatient, emergency department, and orthopedic clinic settings, and for a subset of patients participating in post-acute therapy services at the orthopedic clinic.

Patient activation level (lowest - Level 1 & 2, Level 3, to highest - Level 4) and score (0-100, low to high), separately, were utilized as the explanatory variable of interest, with a theoretically-driven, identical set of covariates across all multivariate models. First, logit models were constructed to identify the probability of accessing services after hospital discharge (post-acute) across each care setting, including assessment of any hospital-based access. Models were constructed utilizing robust standard error and average marginal effects (AME), calculated utilizing bootstrapped standard errors to produce 95% confidence intervals, are reported.

Next, ordinary-least-squares (OLS) was employed to estimate parameters in a series of regression models assessing: (1) total payments for the TKA episode of care (inpatient through 90-days post-operatively); (2) post-acute hospital payments (inpatient, outpatient, emergency department); (3) total post-acute payments, hospital plus the orthopedic clinic, excluding routine post-operative appointments; and (4) payments for therapy services. Duan's smearing algorithm was applied to obtain a more accurate prediction of post-acute payments. Quantile-regression was used to further examine the effect of patient activation at different levels of payment for the total TKA episode of care (75th and 90th percentiles) and total post-acute payments (25th, 50th, 75th and 90th percentiles), utilizing bootstrapped standard errors. Due to limitations in the distribution of post-acute visits in the study population, only physical therapy services were examined in negative binomial regression models, where AME for PAM Levels is interpreted utilizing the finite-difference method.

Finally, OLS was additionally utilized to test the hypothesis that lower patient activation is associated with lower scores on patient-reported outcome measures in the first three months after surgery. Overall 90-day post-operative score and change in score from pre- to post-operative assessment were examined. Approach to model building and reporting is consistent with payment models described above. Across all study aims and models, model specification and sensitivity tests were performed. Data were analyzed in Stata, version 14 (College Station, TX). This study was approved by the Oregon State University Institutional Review Board, Corvallis, OR, and PeaceHealth System Institutional Review Board, Eugene, OR.

Results. The mean PAM score for the study population was 64.4 (sd = 12.8), with a median score of 60.6. Only 3% of patients fell within PAM Level 1 pre-operatively; 16% in Level 2; and the majority of patients had a pre-operative score within PAM Level 3 (55%) and Level 4 (26%). Overall, 23% of patients utilized at least one post-acute care service (n=174); 34 patients (4.5%) were readmitted; 110 accessed outpatient hospital or surgery center services (14.6%); and 65 patients (8.6%) had at least one ED visit.

In multivariate models, neither patient activation functional form was not associated with increased probability of accessing post-acute hospital services when assessed separately. However, patients within PAM Level 3 have 8.1% higher probability of accessing *any* hospital-based post-acute care location compared to Level 4 patients (95% CI = 1%, 16%). Similarly, after adjusting for model covariates, patients in Level 3 have, on average, 2% higher total expenditures for the TKA episode of care than patients at the highest level of activation (95% CI = <1%, 4%). Patients in Level 3 also had 90% higher total post-acute payments (hospital plus clinic) compared to patients in the highest level of activation (95% CI = 11%, 227%). Patients at the highest level of activation (Level 4) have predicted total post-acute payments averaging $290 (sd = $402), compared to Level 3 patients who average a predicted $860 (sd = $407). Patients at the lowest two levels of activation have predicted total post-acute payments of $615 (sd = $248).

Within the 75th percentile, patients who scored within PAM Level 3 have, on average, 167% higher post-acute payments compared to patients at the highest level of activation (95%

CI = 0.3%, 610%). The effect is larger among the most expensive patients, those in the 90th percentile; Level 3 patients have 186% higher total post-acute payments (95% CI = 3%, 700%). Generally, patients in PAM Level 1 & 2 have positive coefficients in assessed models (i.e., higher than Level 4), but results were not statistically significant. There was no association between patient activation level or score and the initial length of hospital stay, after adjusting for all other potential confounders.

Results of negative binomial regression demonstrated PAM Level 3 is significantly associated with the count of physical therapy visits (p=0.020). Compared to patients at the highest level of activation (Level 4), Level 3 patients have, on average, 1.79 more physical therapy visits (95% CI = 0.28, 3.28). Although not statistically significant, there is a gradient across the PAM Levels, with the most visits occurring among PAM Level 1 & 2 patients (1.87, 95% CI = -0.63, 4.38).

There were 368 patients (48.8%) of patients who completed evaluable pre- and post-operative VR-12 questionnaires. Fewer patients (n=350, 46.4%) had paired pre- and post-VAS responses and the least number of patients completed both Oxford Knee Score (OKS) assessments (n=320, 42.4%). On average, patients in PAM Level 3 pre-operatively show 2.63 fewer points of improvement over time compared to Level 4 patients (95% CI = -5.08, -0.19). Patients in the two lowest levels of PAM have less improvement; 3.74 fewer than PAM Level 4 patients on average (95% CI = -7.19, -0.30). In contrast, for PAM Level as the predictor of interest, patients at lower activation levels demonstrate a greater improvement in MCS between pre- and post-operative assessments compared to Level 4 patients, but Level 4 patients had significantly higher MCS at baseline.

There was no association between patient activation level, or score, and change in OKS over time. Among model covariates, pre-operative BMI and the performing surgeon resulted were significant predictors of OKS change. The amount of improvement, measured in the magnitude of score change, increases as BMI increases in the study population. For every 5-point increase in BMI, patients improve by two OKS points, on average (1.9 points, 95% CI = 1.3, 2.6). Results are consistent when assessing reductions in pain. For example, a patient with a pre-operative BMI equal to 25 would be expected to demonstrate a 2.4 point reduction in knee pain; BMI of 30 reports a 2.7 point reduction; and BMI equal to 35 reports 3.2 point reduction in pain between assessments.

Both PAM Level and PAM score models yielded significant associations with VAS score. At the mean, the predicted change in pain assessment among Level 1 & 2 patients is -2.34 (sd

= 0.86), or approximately a two-point reduction in pain post-operatively compared to pre-operative assessments. In contrast, Level 4 patients report, at the predicted mean, a 3.41 (sd = 0.77) reduction in self-reported pain. For every 10-point increase in PAM score the difference in VAS score between pre- and post-operative assessments grows increasingly more negative; 0.40 additional point *reduction* over time (95% CI = -0.59, -0.12). Across all patient-reported outcome measure, the performing surgeon was significantly associated with the magnitude of change between pre- and post-operative assessments.

Discussion. This study is the first known investigation into the association between patient activation and post-acute payment and utilization following TKA. By combining electronic health records with administrative billing data, the current study successfully captured the majority of factors known to influence total knee arthroplasty outcomes. Under value-based care initiatives, providers can expect downward payment adjustments for complications resulting in post-acute utilization, and as a result of patients reporting lower gains on health-related quality of life metrics. Utilizing models predicting more than 1.3 million primary TKAs in 2020, PAM Level 3 patients will incur $784 million in additional total post-acute costs than patients who score within PAM Level 4 before surgery. This study is also consistent with prior research reporting higher patient activation leads to improved patient-reported physical health status and reductions in post-operative pain scores. While targeting medically complex patients for post-surgical optimization is an evidence-based strategy for managing post-acute costs, the current study demonstrates patient activation provides an additional piece of information useful for triaging patients into risk-based care coordination pathways.

There remains only one other published study to assess patient activation and total joint arthroplasty functional outcomes, and this study is more representative of joint arthroplasty patients nationally. Although the distribution of patients within each PAM Level appears consistent with established research, the current pre-operative joint replacement education program may have systematically increased activation prior to baseline measurement. In addition, there is no way ascertain whether post-acute utilization was planned, or due to post-discharge complications from TKA. Data are limited to patients who were readmitted to the inpatient setting, or accessed another hospital-based service. Future work should seek to better understand and capture the relationship between patient activation and the population who were likely the most expensive post-operatively – those who were admitted to skilled nursing or rehabilitation centers following initial discharged to home.

Conclusion. The orthopedic literature remains generally focused on medical and surgical predictors of “success” or “failure” following joint replacement surgery. Yet, after adjusting for many of the known risk factors for post-surgical complications, a patient’s level of activation – a measurement and patient characteristic unaddressed by the majority of orthopedic surgeons – explains differences in post-operative payments, utilization, and patient-reported health status. Two incentives are driving provider and delivery system change around total knee replacement; federal mandates to participate in bundled care payment programs for lower extremity reconstruction and the opportunity to shift select patients to outpatient ambulatory surgery centers. Both situations are propelling surgeons to adopt a population health framework for managing the TKA episode of care. Not all patients require the same level of support to achieve quality outcomes. The results of this study provide sound rationale for continuing to explore how patient activation influences patient experiences and outcomes for major elective surgical procedures, including TKA and more broadly total joint replacement.

The Association Between Patient Activation and Cost, Utilization, and Outcomes Among Patients Undergoing Elective, Primary Total Knee Arthroplasty

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Erin Callahan Owen

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I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

Erin Callahan Owen, Author

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Use of Patient-Reported Outcome Measures**.** Permission was granted to use the three questionnaires reported in the current study. Use of the Patient Activation Measure (PAM) was approved and licensed for use in the current study by Insignia Health, LLC; © Insignia Health, LLC 2013. The VR-12 12-Item Health Survey was developed at RAND as part of the Medical Outcomes Study. Dr. Lewis E. Kazis, ScD, Associate Professor and Director, Center for the Assessment of Pharmaceutical Practices, Boston University School of Public Health provided written permission for the use of VR-12 in the current investigation and in the ongoing assessment of patient outcomes at the orthopedic clinic. A copyright license agreement for the Oxford Knee Score Health Outcomes Questionnaire was obtained by the orthopedic clinic for standard of care assessments of knee-specific outcomes. © Copyright, Isis Innovation Limited 1998. All Rights Reserved. The authors, being Professor Ray Fitzpatrick and Dr. Jill Dawson, have asserted their moral rights.

CONTRIBUTION OF AUTHORS

Drs. Viktor Bovbjerg, Jeff Luck, Jangho Yoon, and Jason Tavakolian assisted with the study design and methodological approaches, and provided feedback for revisions to approach and final document execution. Dr. Stephanie Bernell provided assistance with crafting the economic framework, interpretation of data, and suggestions that led to the final work product. Drs. Jason Tavakolian, Brick Lantz, and Brian Jewett provided orthopedic expertise and will further assist in the development of manuscripts stemming from this work.

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LIST OF ABBREVIATIONS

APM	Advanced Alternative Payment Models
ASC	Ambulatory Surgery Center
BPCI	Bundled Payment for Care Improvement
CJR	Comprehensive Care for Joint Replacement Model
CMS	Centers for Medicare & Medicaid Services
CPT	Current Procedural Terminology
DRG	Diagnosis-Related Groups
FFS	Fee-For-Service
IPPS	Inpatient Prospective Payment System
MCID	Minimally Important Clinical Difference
MACRA	Medicare Access and CHIP Reauthorization Act
MIPS	Merit-based Incentive Payment System
OKS	Oxford Knee Score
PAM	Patient Activation Measure
PROM	Patient-reported Outcome Measure
SF-12	Short-Form Health Survey
SGR	Sustainable Growth Rate
SOI	Severity of Illness
TJA	Total Joint Arthroplasty
TKA	Total Knee Arthroplasty (or replacement)
VR-12	Veteran’s RAND 12-Item Health Survey
VR-12 MCS	Veteran’s RAND 12-Item Health Survey Mental Health Component Score
VR-12 PCS	Veteran’s RAND 12-Item Health Survey Physical Component Score
VAS	Visual Analogue Pain Scale
VTE	Venous Thromboembolism

DEDICATIONS

It is the encouragement of my children, Avery and Keane, and the time, championing, and grit supplied by my husband, Ben, which helped me achieve this long-sought personal goal. My parents, Mike and Jill, have supported all of my aspirations, selflessly, my entire life. Their countless hours of support, short-notice and no-notice childcare rescues, made this work possible. Finally, I would not have been able to complete my course requirements on campus without my in-laws, Tom and his late wife, Jane, who gave me the opportunity to commute from Eugene to Corvallis by taking care of my kids while I was away.

CHAPTER ONE

Introduction

1.1 Rationale and justification

Medicare payments for orthopedic care increased by one billion dollars between 2000 and 2010, a 63.7% increase. Despite significant increases in utilization, costs for orthopedic procedures have not outpaced other specialties [1]. However, orthopedics continue to be a significant Medicare expenditure, with costs shifting from the inpatient to outpatient setting across the 87% of hospitals who offer orthopedic-specific services [2]. The quality-adjusted life years gained from common orthopedic procedures is generally favorable – suggesting procedures such as anterior cruciate ligament reconstruction, rotator cuff repair and joint arthroplasty, or replacement, are cost-effective [3-7]. Achieving an optimal outcome after surgery can require a multi-faceted approach, even among potentially high-value procedures. Risk factors for poor post-surgical outcomes range from surgical and implant-related factors, to patient demographics, presence of comorbid conditions and provider or system-level predictors [8-10]. More recently, reports of associations between patient mental health, psychosocial factors [11-13], and post-operative outcomes have emerged [12, 14].

In spite of known potential risk, interventions to address anxiety or catastrophizing attitudes are not generally within the scope of work for orthopedic specialists. As a result, orthopedists may not find pre-operative scores from mental health assessment tools actionable, particularly when the explained variance in clinical and functional outcomes attributed to psychosocial factors differ in the presence of other patient characteristics [13]. Tools to predict outcomes following orthopedic procedures are abundant and include limb or procedure-specific measures and health-related quality of life, yet no commonly used assessment accounts for an individual's propensity to engage in adaptive health behavior [15].

The Patient Activation Measure (PAM) has emerged as a tool that aims to quantify a patient's ability and confidence in managing their healthcare needs [15]. A patient who is highly activated has the knowledge and skill to navigate the healthcare system and engage in healthy behaviors [15-17]. Research suggests high patient activation level is predictive of better health outcomes [16, 18] and higher patient reported experience of care [19]. Fewer reports of the evidence of an association between patient activation and cost exist [16], but one recent study suggests patients with low activation incur significantly higher costs even after adjusting for actuarial risk scores [20].

Orthopedic procedures often require physical therapy, coordination of providers and between facilities and strict medication adherence. A limited body of literature exists to describe the role of patient activation outcomes for common orthopedic procedures; a single centers' reports on the role of a patient's level of activation in post-operative spine surgery [21-25]; a second study assesses patient activation and disability in upper extremities [26]; and one recent article describes the association between pre-operative patient activation and post-operative patient reported outcomes in total knee and total hip arthroplasty [27]. Although reports of an association between PAM score and post-operative outcomes demonstrated an association in a total knee replacement population, the approach had several limitations to overcome before translation to clinical practice can be justified [27]. Finally, there have been no previous reports examining the impact of pre-operative PAM scores on post-operative cost or health services utilization in any orthopedic population.

1.2 Purpose and specific aims

The long-term goal of the current study is to examine the role of patient activation across defined episodes of orthopedic care, design individually tailored interventions for low-activation patients if an association is demonstrated, and explore payment models for efforts designed to increase activation. This study reports results of the retrospective analyses of a double-blinded, prospective cohort study designed to assess the role of patient activation in a population of orthopedic surgical patients. The hypothesis is lower pre-operative patient activation scores are associated with higher costs incurred, higher post-operative service utilization and lower patient-reported outcome measures in the first three months following total knee arthroplasty (TKA), commonly referred to as total knee replacement.

The hypothesis is based on the following observations: First, TKA is an increasingly common orthopedic procedure; the demand for TKA is expected to grow more than 200% by 2030 [28]. In addition, hip and knee replacement procedures are the most common inpatient procedure for Medicare beneficiaries [29]. Tools currently utilized in orthopedic settings fail to capture all the variability in patient reported outcomes, suggesting factors contributing to favorable outcomes following TKA have not been fully described [30, 31]. Second, previous studies have reported associations between patient activation and ability to manage complex chronic diseases [32-35]. Primary TKA consistently requires inpatient hospitalization, adherence to deep venous thrombosis prophylaxis regimens, and aggressive post-operative physical therapy to achieve optimal outcomes. Yet, although complex and multifaceted, the period of patient engagement is acute and episodic. Finally, no evidence exists as to whether patient activation level is predictive of cost or utilization outcomes in joint replacement populations. As a result, a novel study designed to achieve the following specific aims was pursued.

1.2.1 Specific Aim #1

The first aim of this study is to describe the effect of patient activation level on payments during the episode of care within the first 90 days post-operatively. Facility (hospital) and professional (clinic) data were collected retrospectively for patients who underwent TKA. Charges were standardized to 100% of Medicare reimbursement by current procedural terminology code (CPT) and Diagnosis Related Groups (DRG). Quantile regression was used to capture the effect of patient activation level on episodic payments, at different percentiles of expenditure, controlling for patient demographic characteristics, payer type, and Charleston Comorbidity Index. Additional analyses were used to examine the subset of patients who incurred payments for physical therapy at the orthopedic clinic.

1.2.2 Specific Aim #2

The second aim of the study is to describe differences in post-surgical service utilization by patient activation level. Two modeling approaches will be used to detect difference in utilization of hospital-based services and clinic visits, separately, as well as total service utilization, relative to key outcomes of interest for TKA patients (e.g. post-discharge re-admission or emergency-department visit after TKA). First, logit models will be used to assess the probability of accessing additional hospital, emergency department, and/or orthopedic clinic services following discharge. Negative binomial regression was employed to detect difference in the count of physical-therapy services provided during the three-month post-operative episode, controlling for a vector of covariates consistent with Specific Aim #1.

1.2.3 Specific Aim #3

The final aim of the study describes the association between patient activation level and patient reported outcomes for post-operative pain, functional status, and health-related quality of life. In the limited studies examining the association between PAM and orthopedic procedures, functional status and health-related quality of life measures were examined as the primary endpoint [9, 22, 23, 25, 26]. Examination of functional outcomes in the current study will add to the body of literature regarding the association between PAM and orthopedic outcomes, potentially informing the consistency of the association direction or magnitude. Further, prior orthopedic studies failed to employ the validated methodological approach to scoring the PAM, reporting PAM score as a continuous measure, not in PAM developmental levels as intended [17]. Standard, well-validated survey instruments were administered to patients pre-operatively and at three months (± one month) post operatively.

CHAPTER TWO

Literature Review

2.1 Patient activation: An emerging measure of engagement

Surgeons spend limited time with patients, yet often assign patients a list of “to-do” items to try to alleviate physical health burdens, or offer lifestyle directives aimed at improving health-related quality of life [17]. Most physicians have no way to gauge how well a patient will adhere to medical advice or attempt to modify lifestyle risk factors. Across medical conditions and specialties, reported measures of patient intentions to comply [36], self-efficacy [37], coping strategies [38] and pain-related catastrophizing attitudes [39] have been tested to better explain outcomes following surgical interventions. However, the healthcare system remains complex and fragmented. Patients are expected to manage day-to-day health conditions, make decisions about care seeking, navigate the healthcare system, be active and ask questions during an encounter with a healthcare provider and understand health information. Understanding the variability in patient surgical outcomes necessitates an understanding of comorbid risk factors, psychosocial factors and the level of patient engagement across the continuum of care.

Patient activation has been broadly defined as an individual’s knowledge, skill and confidence in self-management. Successful self-management is multifaceted, requiring knowledge about health conditions, medications, and treatment alternatives; beliefs about one’s own role in achieving better health; confidence in interactions with medical providers; and ability to problem solve and maintain self-management behaviors under stressful conditions (Figure 1) [15, 40]. The Patient Activation Measure (PAM) has been demonstrated to achieve validity and reliability in measuring an individual’s propensity to engage in positive health behaviors [15-17]. The measure is comprehensive, addressing health fatalism, consumeristic behaviors, personal beliefs and ability to act on health needs and recommendations [15].

The 13-item PAM short form has been predictive of health seeking behaviors, including emergency department utilization and cancer screening [41]. In 2014, Mitchell et al. reported significantly higher rate ratio of 30-day post discharge hospital utilization among patients in the bottom two PAM levels, PAM Level 1 and PAM Level 2 [42]. The tool has also been associated with diabetes self-management behaviors [43], as well as engagement in physical activity and obesity rates [41]. In two recent articles, low activation levels predict higher healthcare costs and future healthcare costs, even after adjusting for patient disease burden and demographics [20, 44].

Despite the growing body of literature reporting PAM results, few studies explore the applicability of the tool to episodic care settings, such as a surgical procedure. Instead, PAM measurement and interventions designed to increase activation focus on chronic diseases such as hypertension [45, 46], diabetes [18, 32, 43, 46-51], schizophrenia [52, 53], and HIV [54]. Emergency department use is potentially attributable to an episodic event. The first study to assess PAM level at the point-of-care in the emergency department reports low activation levels are associated with hospital admission, although limited demographic or morbidity covariates were included in the regression models reported [55].

2.1.1 Development of the Patient Activation Measure

There exists a myriad of tools attempting to identify and measure key psychosocial traits and their relationship to health behaviors and outcomes. Two tools of relative importance to the development of PAM are the Pain and Self-Efficacy Questionnaire (PSEQ) [56] and the Coping Strategies Questionnaire (CSQ), with particular emphasis on the Catastrophizing scale [57]. Both tools target behavioral characteristics, and to some degree, resilience in the face of acute or chronic pain conditions [56, 57]. The PSEQ score has been a strong predictor of disability and functional changes after interventions targeting better pain management [58]. Similarly, the CSQ captures the degree to which an individual may exaggerate the threat of pain, and has been reported as a measurement of pain coping ability that consistently predicts poor outcomes [57, 59]. These tools provide important information about the role of pain, specifically, on health behaviors, but do not lend insight into the knowledge, skill, ability or motivation for effective self-management of health conditions, or the level of willingness to do so [15]. As an increasing demand for consumer engagement in healthcare decision-making gained traction, Hibbard et al. (2004) sought to gain consensus on the key components of "activation," utilizing characteristics from existing principles of self-efficacy, catastrophizing attitudes, health behavior change models, and chronic disease management strategies [15].

In 2004, Hibbard, Stockard, Mahoney & Tusler published the results of a multifaceted approach to defining, measuring, and reporting patient activation. At the time, review of current literature indicated six domains should be considered when defining activation: "(1) self-manage symptoms/problems; (2) engage in activities that maintain functioning and reduce health declines; (3) be involved in treatment and diagnostic choices; (4) collaborate with providers; (5) select providers and provider organizations based on performance or quality; and (6) navigate the healthcare system (Hibbard et al. 2004, pg. 1008). These domains were further broken down to include the beliefs, knowledge and skills required to achieve each. An expert panel used the composition of domains and sub-domains to define a conceptual definition of activation: “Those who are activated believe patients have important roles to play in self-care, collaborating with providers, and maintaining their health. They know how to manage their condition and maintain functioning and prevent health declines; and they have the skills and behavioral repertoire to manage their conditions, collaborate with their health providers, maintain their health functioning, and access appropriate and high quality care (Hibbard et al. 2004, pg. 1009).”

From a pool of 80 possible questions comprised from existing tools and new questions, 75 items underwent pilot testing. Psychometric analyses were conducted on responses, resulting in retention of a 22 item preliminary activation measure, utilizing interval levels. From these 22 items, Hibbard et al. (2004) suggest activation is developmental; beliefs and knowledge about one’s condition occur before skill and confidence. Results were validated in a large national sample of diverse groups, including adults aged 45 years and older, who were representative of national census data. Last, PAM scores were compared to health status, health behaviors, and healthcare utilization (i.e., doctor’s office visits, emergency room visits and inpatient hospitalization). Higher activated respondents had better health status, lower utilization, were more likely to exercise regularly and eat a healthy diet, and less likely to smoke when compared to lower activated respondents [15].

In 2005, Hibbard, Mahoney, Stockard, and Tusler reported results of efforts to condense the 22-item PAM into a shorter tool, while maintaining tool precision. Statistical and conceptual approaches were used to examine each of the 22-items and the resulting psychometric properties of the tool upon deletion of single response items. The PAM was condenses to a 13-item questionnaire through item-reduction analysis, scored on a scale of zero to 100. Raw scores are transformed using a curvilinear transformation to produce the PAM score. The 13-item PAM has lower reliability among the very old (85 years or older); respondents without chronic health conditions; those who self-report poor health status; and respondents who have lower education and income. Overall, the 13-item PAM accounts for 92% of the variation in activation level estimation when regressed onto the 22-item score [17].

The most activated patients are able to maintain healthy lifestyles, confidently handle problems as they arise, and do not let disease or illness burden interfere with their life [15]. Refinement of the measure confirmed activation is linear, even hierarchical in nature (Figure 1): Level 1 – Beliefs about the importance of the patient's role; Level 2 – Confidence and knowledge to take action; Level 3 – Taking action; and Level 4 – Staying the course under stress. The authors further conclude interventions aimed at increasing activation are dependent upon where an individual is on the activation continuum [15]. A difference of four points on the PAM scale is meaningful change or difference between study groups [33].

2.1.2 Interventions to increase patient activation

Interventions to increase patient activation present an opportunity to better understand how use of the PAM questionnaires may lead to changes in health outcomes. Although the literature focuses predominantly to date on the use of PAM for explaining variability in health status or utilization, far less has been reported suggesting how clinicians may be able to leverage PAM scores to target at-risk populations. Recently, Greene et al. (2016), shared results of study aiming to better understand which types of clinician behaviors are effective for increasing patient activation. Physicians with the following strategies had patients with a mean increase in PAM score of 7.5 from baseline: patient ownership of health; physician-patient partnership emphasized; frequent follow-up visits; personalized care approaches [60]. In contrast, patients who paired with providers demonstrating much lower changes in activation over time (3.1 points), relied on identification of negative consequences associated with desired behavior change. Given each one point increase in PAM score is correlated with a 2% decrease in hospitalization [42], the difference between approaches may be appreciable.

Strategies focused on peer-led, health coach or online interventions have assessed effect on patient activation level, to varying degrees, in both physical [40, 47, 61-65] and mental health settings [66-68]. Developers of the well know Stanford Chronic Disease Self-Management Program (CDSMP) [69], assessed PAM scores before and after an online-based intervention aiming to reduce hemoglobin A1C and increase exercise. After 18 months, PAM scores were higher among participants randomized to the intervention group, compared to the control group [65]. Similarly, Solomon, Wagner, and Goes (2014) report a web-based intervention to support chronic disease self-management produced significant effects toward increasing PAM scores. The degree of improvement varied based on pre-intervention PAM score, with those in the lowest PAM level (Level 1) demonstrating most improvement in activation level [70].

One peer-led mental health intervention demonstrated significant improvements on patient activation, and further suggested participants in the intervention group who had early improvements in activation had improved attendance over the course of the study period [66]. An alternative approach to peer-led models, in which peers generally have the same disease, condition, or experience as participants, are community health workers (CHW) who share similar socioeconomic circumstances, values or needs as the patients they serve [62]. The CHW model tested used three specific strategies to improve hospital outcomes for high-risk patients: (1) setting a measurable goals; (2) supporting patient achievement of goals through frequent in-person or telephone based contact; and (3) better continuity and coordination with primary care. Compared to standard of care hospital stay and discharge procedures, significantly more patients assigned a CHW completed follow-up visits with primary care (60% versus 48%); however, groups did not differ on initial hospital readmission rates. Patients paired with a CHW demonstrated significant improvement in mental health component score as measured by the 12-item Short Form Health Survey (SF-12) and significant improvement in PAM score [62].

Hibbard, Greene, and Tusler (2009) partnered with a disease management group to determine whether individual care plans could be tailored based on PAM level among patients with diabetes. Patients received either activation level tailored telephone coaching or standard telephone coaching, resulting in significant gains in PAM scores among the intervention group. Clinical indicators such as blood pressure demonstrated significant improvement in the intervention group. Finally, inpatient and emergency department utilization also declined among those with PAM developmental level tailored coaching plans [33]. Another coaching-style intervention among Spanish speaking participants targeted empowerment through advance preparation of questions prior to a medical appointment. The intervention demonstrated significant improvements in PAM scores before and after the physician visit. However, PAM score improvement was also noted in the control group, leading authors to suggest simply administering the PAM may increase awareness and, thereby, raise activation [61].

2.2 Patient activation in surgical procedures and orthopedics

In general orthopedic care, one recent study demonstrated a correlation between upper extremity disability at one-to-two months following treatment and patient activation [71]. The population studied presented with a variety of diagnoses for hand and upper extremity issues, limiting the clinical applicability of results even to upper extremity complaints. There was also no information regarding the type or extent of treatment; however, the lack of discussion regarding surgical procedures leads the reader to believe all treatments were non-surgical. In addition, Gruber et al. (2014) analyzed the PAM measure as a continuous scale instead of the categorical high-low activation categories that would more easily translate to point-of-care interventions. The authors concluded increasing patient activation may decrease pain intensity and the magnitude of disability in an upper extremity population. Last, outcomes for the upper extremity population were limited to patient reported functional status and pain, without examining the potential impact of post-treatment service utilization or cost variables [71].

Pre-surgical or pre-procedure administration of PAM has been explored in three settings: preparation for colonoscopy [72]; advance of spine surgery [22, 23, 25]; and most recently in a combined population of total knee arthroplasty patients [27]. Lower patient activation was significantly associated with poor adherence to bowel preparation protocols [72]. A single center reports high patient activation predicts improved functional recovery after spine surgery, significant reductions in self-reported disability, and pain [25]. Additionally PAM scores were positively correlated with participation and engagement in post-operative physical therapy [23]. However, the sample size of spine patients was small (N = 65), greatly limiting the robustness of the analytical approach.

Andrawis et al. (2015) provide the first known information regarding patient activation in total joint arthroplasty patients. The study reports results of 174 and 135 patients undergoing primary total hip and total knee arthroplasty, respectively. The study is limited to first time total joint candidates with advanced arthritis. A limited set of demographic characteristics including age, gender, education were collected via pre-operative patient self-reported questionnaires. The study employed use of the Charleston Comorbidity Index to quantify presence of comorbid health conditions. A battery of patient-reported functional outcomes, including assessment of pain and activity (Knee or Hip Injury and Osteoarthritis Outcome Score, KOOS or HOOS, respectively, and the UCLA activity score), physical health, and mental health (SF12v2). In addition, post-operative patient satisfaction was assessed by the Hip and Knee Satisfaction

Scale (HKSS). Patient outcomes were assessed at six weeks, six months, and/or 12-month follow-up appointment with their surgeon. Linear regression models with repeated measures were applied to assess the association between preoperative PAM scores and patient outcomes over time.

Results of the Andrawis et al. (2015) article point favorably toward a positive relationship between preoperative PAM score and post-operative pain; unit increases in PAM (0-100 scale) were associated with small, but significant improvements in pain scores. For every one unit increase in PAM score, HOOS or KOOS pain score increased by 0.26, suggesting high versus low activated patients present with clinically meaningful differences (threshold 8-10 points [73]). No association was detected for HOOS or KOOS subscales measuring activities of daily living, sports and recreation, or quality of life scores. In comparison, higher PAM scores were associated with higher post-operative SF12v2 mental health scores, and not associated with SF12v2 physical health score. Since PAM relies heavily on patient beliefs, confidence, and to some degree, resilience, assessed as ability to handle health or healthcare logistical challenges [15], correlations with mental health scores may be anticipated.

In examining the Andrawis study in detail, there are several notable limitations. First, the small sample size required combining total hip and total knee patients into a single cohort despite differences in the surgical procedure, associated recovery protocols, and the length of time anticipated for post-operative disability. Second, the patient population is not readily generalizable; likely attributable to geographic location (Berkeley, CA), half (50%) of the patient population enrolled had a college degree (19.6%) or post-graduate degree (30.4%). In comparison, the US Census Bureau reports 15% of the population over 25 years old holds at post-graduate professional or academic doctorate in the same time period [74]. Next, the mean baseline pre-operative PAM score was more than 20-points higher than Hibbard's report of PAM's characteristics during validation [17]. In addition, PAM score is most clinically relevant when patients can be categorized into the four PAM levels; however, this study utilized PAM as a continuous outcome due to small sample size. Finally, while understanding how PAM may predict long-term outcomes is important, the potential role of patient activation within the 90-day global reimbursement period is particularly relevant. A six-week follow-up period is generally too short of a time to detect changes in patient reported functional and pain outcomes. In contrast, a six- and 12-month follow-up are outside of the current 90-day global period of reimbursement.

2.3 Total knee arthroplasty

2.3.1 Prevalence, cost, and benefits of total knee arthroplasty

Total knee arthroplasty (TKA) is primarily performed in patients with severe, degenerative osteoarthritis (OA) or rheumatologic joint disease. The demand for TKA has risen across the world, with an annual growth rate ranging from 5.3% to 17% internationally [75]. Prevalence estimates recently published report 4.7 million people (64% female) TKA procedures were performed in 2010 [76]. In the United States, TKA is one of the most common and expensive surgical procedures, driven by an aging population and increased per capita procedures [77]. At the same time, the benefit to the patient measured in terms of improved physical functioning [78], reduced pain and improved health-related quality of life, has consistently resulted in favorable cost-effectiveness measures, from the societal and payer perspectives [79]. Further, evidence exists on longer term benefits of TKA, including reduced probability of heart failure and mortality, as well as reduced all-cause costs for healthcare services after surgery [78].

Between 2005 and 2011, the hospital reimbursement for TKA increased by 0.05% among Medicare beneficiaries, with average facility payment of $12,000-$21,000 in 2011 [80, 81], and median hospital charges between $46,000 and $71,000 for total joint replacements without and with comorbid conditions, respectively [81]. Patients with multiple chronic comorbidities require additional resources and often have increased length of stay, which results in higher marginal costs [82]. Disparities in resource utilization also exist between payer types. Research suggests Medicaid patients have significantly higher total costs, are more likely to be discharged to an inpatient facility, and have longer length of stay (LOS) compared to non-Medicaid patients, even after controlling for demographic characteristics, hospital characteristics and comorbidities [83]. Even with noted disparities, strategies such as early ambulation have been recently implemented to control hospital costs by reducing length of stay by an average of 0.44 days [84]. In 2015, the Centers for Medicare & Medicaid Services (CMS) began penalizing hospitals for 30-day readmission following TKA [85], which provides an incentive for hospitals and surgeons to implement interventions to optimize patient health across the continuum of total joint care.

Compared to non-operative management of OA, TKA is associated with an incremental cost-effectiveness ratio (ICER) of $18,300 [5] – $19,800 [86] per quality adjusted life year

(QALY) gained. For low risk surgical candidates, the ICER is estimated at $9,700 per QALY gained, while higher risk cases are $28,000 per QALY gained [5]. Losina et al. (2016) further report an increase in quality adjusted life expectancy (QALE) from 6.82 to 7.95 QALYs for patients with OA who elect to undergo TKA. These findings are fairly consistent with a 2013 article describing an age-weighted QALY gain of 2.4 QALYs for TKA. From a society perspective, net societal benefit for TKA are primarily attributable to employment earnings through reduction of time off work and declining disability payments [87].

2.3.2 Complications arising from total knee arthroplasty

In general, TKA is a successful, evidence-based medical intervention, with risk of mortality attributable to post-operative arthroplasty complications estimated at 0.6% in 2011 [88]. Despite a low mortality rate, the procedure is not without complications. Venous thromboembolism events (VTE), myocardial infarction, stroke, bleeding and infection may require hospitalization within 90 days after surgery [88, 89].

Higher volume joint replacement centers enjoy improved outcomes and less complications compared to low-volume centers [5]. Although some complications following TKA are out of the patient’s control, a series of pre- and post-operative care protocols improve outcomes and may decrease risk for complications. First, prior to surgery, patients colonized with or carriers of methicillin-resistant Staphylococcus aureus (MRSA), are asked to adhere to a decolonizing protocol consisting of home-based chlorohexidine gluconate scrubs [90]. Second, early mobilization in the hospital is associated with decreased length of stay [91] and reduced pain thresholds [92]. Third, guidelines for preventing a venous thromboembolism (VTE) event following arthroplasty state patients receive a minimum 10 day prophylaxis [93], which can be taken as patient-administered subcutaneous injections or oral anticoagulants. Last, to mitigate muscle atrophy and restore function, patients are asked to engage in early, intensive physical therapy, including outpatient visits for therapy services and home-based exercises. Together, these requirements for achieving shorter-term clinical indicators of success, including prevention of VTE and infection, as well as achieving optimal range of motion (> 120 flexion, 0 degrees extension), are dependent upon patient adherence to prescribed post-operative treatment plans.

Readmission after TKA often occur in the first week following hospital discharge [94]. Surgical causes account for an estimated 54% of readmissions (46% medical) [95]. The unplanned hospital re-admission rate ranges from 4% in the first month to 8% up to 90 days post-operatively, mostly attributable to infection or deep venous thrombosis [96, 97] or surgical site infection [89]. A retrospective cohort analysis using data from the Surgical Care Improvement Project (SCIP) and the Veteran's Affairs Surgical Quality Improvement Program (VASQIP) report readmission rates for TKA are 6.6% among 16,808 total and partial procedures performed over a five-year period [98]. Merkow et al. (2015) identified surgical site infections (SSI) as the most common reason for readmission across all types of surgical procedures, in which arthroplasty, generally, accounted for 18.8% of all 30-day re-admits [89]. Obesity [99, 100], female gender, high ASA class, and increased operative time have been cited as increased risk factors for readmission [94]. Recently, a trend toward decreasing length of stay has led researchers to question whether faster discharge will lead to potentially preventable readmissions; however, Bini, Inacio, and Cafri (2015) published data suggesting a two-day hospital stay is not inferior to a three-day stay with respect to odds of 30-day hospital readmission [101].

Surgical site infections can result in hospitalization up to one year after surgery, or longer. Overall, 1.3% of total hip or knee replacement procedures, combined, require readmission due to surgical site infections specifically [102]. Known risk factors for surgical site infections include compromised immune system, diabetes and smoking [103]. Patients may experience superficial wound infections, deep wound infections and/or periprosthetic joint infections. One small single-center study reports the economic burden of periprosthetic joint infections results in more than four times the mean annual cost compared to patients without joint infections ($116,383 versus $28,249, respectively). Increased costs are incurred as a result of increased length of stay, readmission and increased frequency of clinic visits [104].

Historically, the incidence of deep venous thromboembolisms (i.e., blood clots) and pulmonary embolism (PE) have been difficult to capture. In the absence of prophylaxis, DVT occurs in approximately 45-70% of patients undergoing TKA [105, 106]. Prophylactic aspirin and compression devices dramatically reduce this figure and are commonly used in combination as standard practice. Clinically significant PE is quite rare, occurring between 0-4% of patients [105, 107-112]. However, asymptomatic PE at rates are estimated between 3-15% [105, 109, 113-115]. Smoking is a known risk factor for DVT/PE; however, smoking reliably predicts comorbidity [116] which has confounded studies attempting to quantify risk associated with smoking alone. Similarly, obesity may increase risk for PE [106]. Some research report a higher overall complication rate [117] for obese patients, while conflicting reports cite no significant difference in morbidity or mortality [118].

2.3.3 Tools for comparing pre- and post-operative TKA patient reported outcomes

Increasing emphasis has been placed on collecting patient reported outcome measures (PROMs) following knee arthroplasty procedures. The purpose of collecting PROMs is to capture the patient's own evaluation of pain, ability to perform acts of daily living, ability to participate in employment or recreation activities, and degree to which patient's expectations have been fulfilled [31]. In 2015, CMS published the final rule for the Comprehensive Care for Joint Replacement (CJR) Model. CJR will test a new bundled payment approach to encourage collaboration across facility and provider types. In addition, CJR defines the collection of PROMs pre- and post-operatively [29, 119], including health-related quality of life and functional outcomes. The requirement to collect and report PROMs by Medicare is seen as an incremental step toward value-based reimbursement approaches.

There are a number of commonly used PROM tools utilized in total joint populations. A recent systematic review of PROMs used to evaluate TKA outcomes identified 47 different survey instruments published, in which six tools met psychometric criteria for development, validity, reliability and responsiveness: Oxford Knee Score (OKS); New (2011) Knee Society Score (KSS); Knee Osteoarthritis Outcome Score (KOOS); and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) [31]. The current study utilizes PROMs collected per standard of care at the research site. The intervals of collection are consistent with published literature in joint arthroplasty populations, and overlap with Medicare-required assessment windows: pre-operative; three months post-operatively; one-year post-operatively, and annually thereafter as recommended by the surgeon.

The Oxford Knee Score (OKS; Isis Innovation Limited, 1998) was first described in 1996 and 1998, and emphasized a shorter questionnaire for use in TKA populations specifically. The resulting 12-question tool is as reliable as clinical scores in assessing post-surgical outcomes, and able to capture clinically important changes [120]. The Oxford suite of tools, including hip and shoulder replacement assessments in addition to TKA, are unique in they were designed from a series of exploratory interviews with patients to establish the list of 12-items assessed. The OKS scoring system is based on a 0-48 scale, in which a score of 48 is the best outcome (i.e., least pain and highest functioning) [121]. Independently conducted studies have reported the OKS to be among most reliable and valid tool for assessing TKA specifically [122, 123]. An effect size of 1.0 is equivalent to a change of one standard deviation of the sample. The published effect size for preoperative versus post-operative change at six months is 2.19 [120, 124]. Research suggests the minimally important clinical difference (MCID) comparing pre- and post-operative scores is between three and five points [121]. Recently, Clement, MacDonald and Simpson (2013) established the MCID specific to TKA as 5.0 (95% Confidence Interval 4.4 – 5.5) for the OKS [125].

The Veterans RAND 12-Item Health Survey (VR-12) is a health-related quality of life (HRQoL) instrument, developed to extend the work of the RAND Medical Outcomes Study (MOS) into a VA setting [126]. The VR-12 is the short form of the VR-36, both of which are modified versions of the SF-36/SF-12 (Optum, Inc., San Francisco, CA). The SF tools produces psychometrically-based physical and mental health summary measures, which are reflected in the VR adaptation. The VR modifications are cited [126, 127] as superior to the original SF scales, but more appropriate for use in Veterans and co-morbid populations [124, 126, 128]. Scoring for the physical component summary (PCS) and the mental component summary (MCS) are based on weights derived from the 1996 Ambulatory Care Survey using the VR-36. A constant standardizes scores to a United States population norm with a mean of 50 and standard deviation of 10 [126]. Effect sizes are 0.2, 0.5, and 0.8 defining small, medium, and large degrees of change, respectively [120, 124].

A change of one-to-two units or greater in PCS or MCS score is clinically and socially relevant when analyzing a population [126, 127]. For example, a one-point increase in PCS is associated with 6% lower total health expenditures, and a one point increase in MCS is associated with 15% lower rate of inpatient visits [129]. For individual-level assessments, larger changes (e.g., 6.5 unit increase in PCS) are required for assessments of clinically relevant change [130]. For TKA populations specifically, it has been suggested 4.5 and 4.8 should be used to identify MCID in PCS and MCS, respectively [125]. It should be noted; however, the MCID for TKA was identified using the SF-12, not the VR-12, although the tools have minor differences. Finally, in 2011, methodology allowing for the generation of a single utility index from the VR-12, consistent with the SF-6D was reported. This new approach allows for the generation of a VR-6D from a VR-12 score for use in cost-effectiveness analyses [131].

A Visual Analogue Pain Scale (VAS) is a 10-point, sliding bar scale, which allows a patient to indicate current pain level from 0-10, where 10 is worst pain possible. The line on which patients select pain level is 10 cm long, with scores captured in millimeters, resulting in a possible score of 0-100 millimeters [132]. VAS for assessment of pain in TKA has been broadly used and reported [133-136]. There has been some debate regarding the MCID using the VAS [137, 138]. Lee et al. (2003) identify a mean reduction of 30 mm as clinically important and reflective of a patient's own perception of pain control. In contrast, Kersten, White and Tennant (2014) utilized a Rasch Analysis to assess the use of VAS as an interval scale, a common technique in published literature. The authors concluded VAS captures pain at one point in time and is not linear; therefore, the use of pre- and post- change scores are likely over- or under-estimated without using nonparametric statistics. The authors further cautioned against using VAS anticipated MCID to conduct power calculations based on interval scaled parametric assumptions [137]. However, in orthopedic literature use of the VAS is common place and analytic methods are generally limited to mean change over time.

2.4 Policy implications

The purpose of the current study is to examine whether pre-operative patient activation score or level, as measured by the Patient Activation Measure (PAM) is predictive of cost, utilization and patient-reported outcome measures in the 90-days following TKA. The current study is unique for two reasons. First, despite the level of effort and adherence required by patients electing total knee arthroplasty, the degree to which patient activation level effects post-operative utilization and cost in orthopedics has not been previously explored. Second, the proposed empirical approach introduces modern methods for assessing study outcomes of interest in a larger sample size, which are less frequently published in orthopedic literature. Evidence provided by this study has the potential to influence how surgeons care for TKA patients before, during and after surgery. If demonstrated to be predictive of post-operative resource utilization, expectations for successful management of TKA patients may shift from technical factors (e.g., surgical approach, VTE prophylaxis) to patient-centered characteristics [139]. The shift toward pre-operative optimization of patient activation may have broad implications for how TKA procedures are reimbursed.

2.4.1 Payment policies and programs for total knee arthroplasty

The payment landscape for total joint arthroplasty procedures has changed dramatically over the past decade. Initially in 2005, Medicare introduced separate diagnosis-related groups (DRGs) for primary versus revision TKA recognizing resource needs differed between TKA procedure types. TKA payment was revised again under the Medicare Inpatient Prospective Payment System (IPPS) in 2007 to allow for higher reimbursement to the global payment based on presence of comorbidities and surgical complexity (Severity of Illness; SOI) [140]. Although hospitals benefited from better matching of reimbursement to actual resource use [140], significant variations in hospital charges and payments persist [81]. In addition, separate payments to hospitals and professionals (i.e., surgeons) under a fee-for-service (FFS) approach provide little incentive to better organize care transitions and address delivery system gaps [141]. Unlike the FFS model, bundling all TKA care from preadmission services to post-discharge care under a single, episodic payment theoretically establishes an incentive for all care team members to find efficiencies through better coordination, integration [141] and, potentially, consolidation of services. Under the bundled payment approach, doctors, hospitals, and other care providers share a single payment for the continuum of total joint care, including absorbing risk of readmissions for complications [142].

Total joint arthroplasty procedures are optimal for piloting *value-based care* approaches; the outcomes achieved per dollar spent. Under a value-based care approach, maximum health benefit is emphasized and measured through comprehensive outcome assessment and reporting [143]. Medicare took meaningful steps toward a value-based approach in 2011 under the Bundled Payment for Care Improvement (BPCI) initiative, impacting Medicare beneficiaries enrolled in Part A and Part B in which Medicare is the primary payer and the beneficiary has not elected a managed care plan. BPCI aimed to achieve higher quality, more coordinated care at lower costs to Medicare under a voluntary participation model. Hospitals, physician group practices, health systems or non-provider business entities could elect to bear financial risk [119]. For total joints (BPCI model 2), retrospective claims for a given hospital are reviewed by Medicare and delivery system participants, a target payment is set, claims for BPCI participants are assessed from 72 hours prior to admission through 30, 60, or 90-days after surgery against the target price. Participating providers can share in achieved savings [144, 145]. Early adopters of bundled payment pilots have demonstrated cost reductions mostly attributed to decreased length of stay and shifts in hospital discharge disposition from inpatient skilled nursing facilities to home [142, 145, 146].

In 2016, Medicare launched a five-year performance period for a new bundled payment initiative, the Comprehensive Care for Joint Replacement Model (CJR) for acute care hospitals furnishing lower extremity joint replacement services. The bundle includes the lower extremity procedure (DRG 469 or 470), all related care under Medicare Parts A and B within 90 days after discharge, inclusive of hospital, physician and post-acute services, post-acute outpatient service utilization, therapy services, laboratory tests, and pharmaceuticals (Part B drugs). Participation is required in multiple geographic regions, among hospitals not opting into prior bundled payment pilots (e.g., BPCI). Under CJR, hospitals bear the financial risk and the responsibility for better managing inpatient resources and post-acute discharge planning toward avoiding costly readmission and utilization of skilled nursing facilities. At the end of each performance year, Medicare claims for all beneficiaries receiving care are assessed against a target price; hospitals with savings are paid the savings and hospitals who overspend must repay Medicare commensurate to the excess beginning in 2017. Under CJR, hospital-level performance measures will include patient-reported outcomes for assessment of pain, mobility and quality of life. Established tools including the Patient Reported Outcomes Measurement Information System (PROMIS) or VR-12, and the Knee Osteoarthritis Outcome Score (KOOS) will be used to develop a composite metric, which will ultimately inform risk adjustments for hospital performance evaluation. Medicare estimates a savings of $153 million over the five year performance period [119].

As practices struggle to meet the requirements defined under CJR, there are still details emerging regarding how procedure- or population-specific programs will intersect with Medicare's new value-based payment strategies being implemented between 2016 and 2018. The Medicare Access and CHIP Reauthorization Act of 2015 (MACRA) ends the Medicare sustainable growth rate (SGR) physician fee schedule methodology, which has been used to control Medicare spending on physician services, and replaces it with the Quality Payment Program, which includes the Merit-based Incentive Payment System (MIPS). MIPS accomplishes consolidation of three disparate, but related quality improvement programs under Medicare (Meaningful Use, Physician Quality Reporting System, and the Value-Based Modifier Program). Four performance categories will be tied to the new payment model: quality, advancing care information, clinical practice improvement activities, and cost or resource use. Physicians already participating in qualifying alternative payment models (APMs), such as accountable care organizations, may be exempt from MIPS [147].

Under MIPS, healthcare providers will be graded on a composite score of the four performance categories. Physicians or group practices who score high will receive positive increases to payments, while those who score low will be adjusted down. In addition, there are incentives (up to 5% bonus) for participating in APMs [148]. On July 25, 2016, the Centers for Medicare and Medicaid Services announced a proposed rule which would may qualify the CJR model as an APM under MACRA.

2.4.2 The potential intersection between patient activation and TKA payment policy

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Although CJR will identify a core set of benchmarks for performance, the metrics proposed will not necessary reflect patient or system-level factors providers should address to achieve meaningful cost reduction [149]. Moreover, effective pre-operative management and risk assessment well in advance of hospital admission will give care teams participating in bundled payment programs an opportunity to impact medical and psychosocial risk factors before hospital admission. Under a prospective payment system retrospectively adjusted to reflect achievement of value-based benchmarks, patients at risk for poor medical outcomes or who self-report limited improvement in pain, function or satisfaction need to be identified and supported throughout the continuum of care. The responsibility for identifying patients at high risk for poor surgical or functional outcomes will be on the performing surgeon and affiliated practice staff. This study investigates whether the patient activation tool can help address practices' needs for better triaging of patients at risk for potentially preventable post-surgical utilization and expenditures.

Private practices have started to explore care delivery opportunities to control more components of the total joint arthroplasty services in bundled care models. The most significant delivery system change over the last decade is the reduction in hospital length of stay among all patients, and the shift of service location from the hospital to ambulatory surgery centers (ASCs). Hospitals frequently own their own day surgery centers, but ASCs are smaller, physician-owned and typically complete with hospital-based day surgery centers [150]. More data are needed to assess the safety of ambulatory, or outpatient, total joint arthroplasty; however, early reports suggest the health of the patient before surgery is the most significant predictor of post-acute service utilization and medical complications [151, 152]. As a result, healthier, commercially insured patients are being shifted in increasing numbers nationwide to ASCs who are legally able to admit patients for up to 23 or 24 hours, dependent upon state-specific regulations [153].

The private practice's interest in ASC-based outpatient total joint replacement balances a reaction to downward price adjustments by Medicare, which may require physicians to act as price-takers, with advancements in minimally invasive surgical techniques. Longer-acting local anesthetics and improved blood loss management are key advancements that permit shorter hospital stays [154]. Surgeons who own ASCs now have an opportunity to capture the professional fee component for total joint arthroplasty and the facility fee in addition. ASC-based total joint programs provide an ancillary source of revenue by which surgeons may be able to achieve their target practice revenue and individual income without increasing surgeon time outputs. By shifting service location, the physician time, a barrier to physician-induced demand, can remain constant while net revenues increase [155].

The movement toward bundled payment for total joint arthroplasty in same-day surgery centers, where the payment for the entire treatment episode is capped, forces the physician to assume more risk for type and quantity of services generated. For surgeons who own their own ASCs, individual target income will be driven more by net revenue and profit, and the relative importance of gross revenues will decline. Profit within the surgical episode of care bundle will be maximized when follow-up visits, subsequent hospitalizations, and ancillary services are minimized [156], and variability among surgeons declines to allow for aggressive group purchasing negotiations (e.g., surgical implants). The bundled payment structure in a physician-owned ASC environment mitigates physician-induced demand, as the ordering of unnecessary goods and services will decrease net revenue, and thereby decrease individual provider income [157].

To maximize profit, the practice will seek to increase the number of procedures performed in an ASC setting over time. It is likely a combination of physician behavior, informed by successful experiences with outpatient total joint replacements, as well as the increased price-sensitivity among healthier, commercially insured adults, who have less cost-sharing for an ASC-based procedure than an inpatient stay, will increase demand for same-day TJA. Figure 2.2 depicts the likely short-run opportunity for profit in a monopolistically competitive surgical practice with a physician-owned ASC utilized for TKA procedures, where the practice performs the number of TKA procedures in the ASC (*Q*) at the point where marginal revenue (*MR*) is equal to marginal cost (*MC*). The price in the monopolistically competitive practice (P_m) is set higher than the average cost (*AC*), generating a profit.

Over time, however, the result of an increase in demand will drive up marginal revenue and price, but not without also increasing marginal cost. Costs to practices pursing arthroplasties in ASCs would likely increase commensurate with technology, staffing, and material requirements. Potential to generate initial profit, coupled with the long-run prospects of increased reimbursement has orthopedic surgeons developing comprehensive, vertically integrated service models that place more components of the entire surgical episode of care in the control of the group practice, from pre-surgical optimization to post-operative physical therapy and rehabilitation. To increase the quantity of ambulatory total joint replacement procedures and effectively manage post-operative risk, new strategies for pre-operatively triaging patients and identifying those with certain characteristics will be of great interest to orthopedic surgeons and their group practices:

1) patients at lower risk post-acute utilization,
2) more likely to report and/or experience improvements in health-related quality of life and physical functioning, and
3) patients who are more apt to expressing high satisfaction with their surgical outcome.

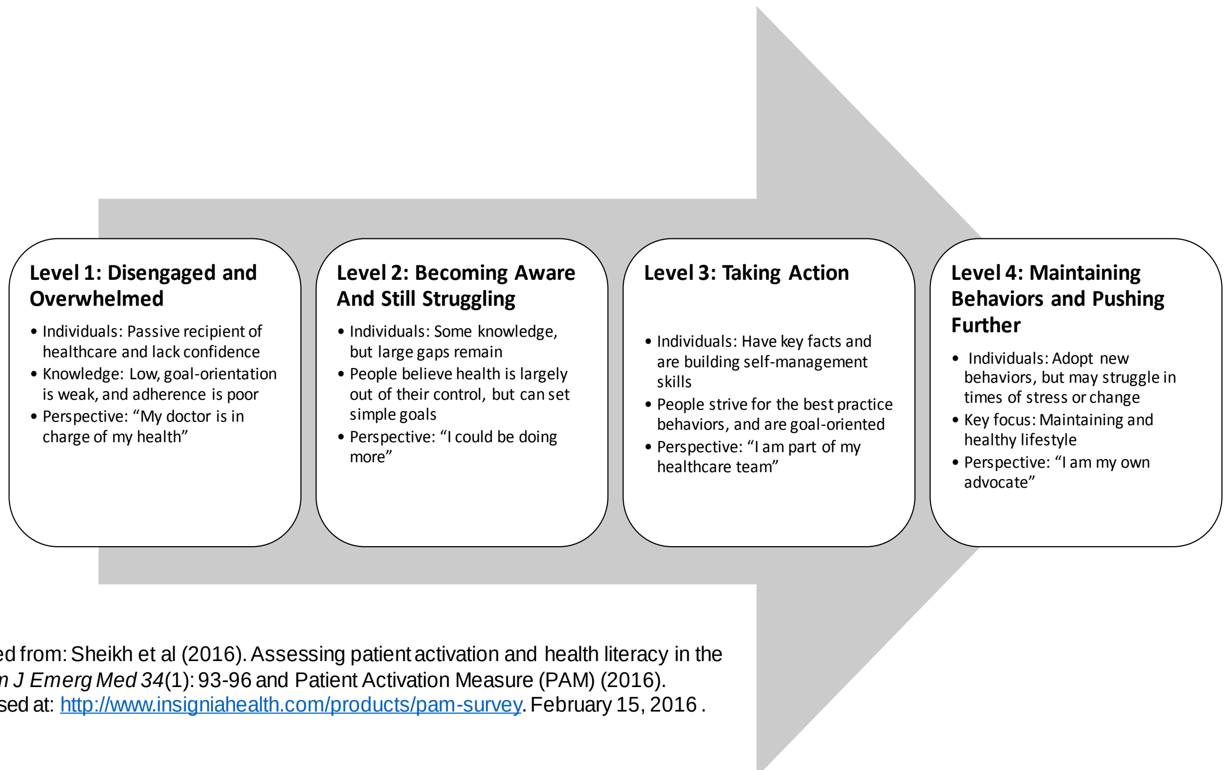
While no published orthopedic-specific tool has the potential to aid in the identification of patients who are likely to be "successful" in an outpatient total joint procedure, the Patient Activation Measure may help fill a pocket-of-need in the surgeon's pre-operative assessment of patient surgical readiness and appropriateness for the ASC environment. In addition, for patients who not healthy enough for outpatient total joint surgery, Medicare bundled payment models remain focused on reducing post-acute utilization and will financially award surgeons who achieve target reductions in expenditure, suggesting improved pre-operative patient screening and planning is required regardless of place of service.

In the only known orthopedic total joint arthroplasty study to have reported on the impact of PAM scores on patient reported outcomes, patients with higher baseline PAM scores self-reported better pain relief and functioning, as well as better post-operative mental health utilizing the KOOS and VR-12 MCS, respectively. In addition, higher PAM scores were correlated with greater satisfaction at six and 12 months after surgery [27]. These limited results suggest surgeons may want to evaluate patient activation level as part of the surgical readiness assessment.

Patient level of activation is changeable [15, 158], and when patient activation level increases health outcomes are improved [16, 41, 44]. Green et al. (2013) report conversely, when patient activation level declines, predicted costs increase. In a large, primary care health system, PAM scores were more accurate in predicting high cost patients than purchased software designed to identify those at risk for high cost utilization based on demographics, comorbidities and severity of comorbidities [20]. These findings were recently reinforced with a 2016 report demonstrating PAM scores were predictive of future emergency department visits, and hospitalizations among patients identified with actuarial-based "high risk" scores [159]. Interventions aimed at raising patient activation prior to TKA and supporting increased activation throughout the post-operative period may help hospitals and care providers meet target benchmarking goals. For example, health coaching models targeting specific behavior change have reported increases in PAM scores over time [160].

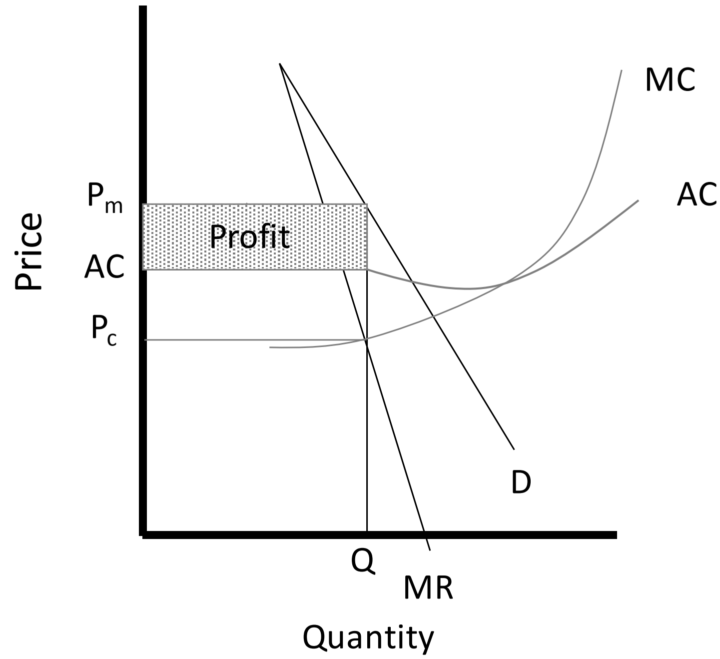
The current study will establish whether pre-operative PAM score is associated with: post-operative payments and utilization in the 90-days after surgery, and further substantiate whether an association exists between PAM and PROMs. From a policy perspective, if a single 13-question assessment is predictive of both components of the CJR proposed value equation, the tool may help identify patients who require increased resource to obtain maximum health benefits of TKA. Achievement of maximum health benefits will also maximize payment under CJR. Further, in a payment system that acknowledges payment adjustments for resource use by differentiating between surgical complexity and the presence of comorbid risk factors, it may not be unreasonable to consider payment adjustment based on patient level of activation; low activated patients may require additional resource independent of surgical or comorbid risk factors.

Figure 2.1: Increasing levels of activation (Level 1 – Level 4) resulting from administration and scoring of the Patient Activation Measure (PAM).



Adapted from: Sheikh et al (2016). Assessing patient activation and health literacy in the ED. *Am J Emerg Med 34*(1): 93-96 and Patient Activation Measure (PAM) (2016). Accessed at: http://www.insigniahealth.com/products/pam-survey. February 15, 2016 .

Figure 2.2: Potential short-run economic profit for ASC-based TKA procedures in a monopolistically competitive practice.



Adapted from: Bernell, S., *Health Economics: Core Concepts and Essential Tools*, Figure 7.8. Gateway to Healthcare Management. 2016, Chicago, IL: American College of Healthcare Executives, pp. 153.

CHAPTER THREE

Methods

3.1 Study design

The current study is an observational study of a retrospective cohort. Survey data for the cohort were obtained in a prospective, double-blind, approach in which neither patient or provider had access to patient activation measure (PAM) scores at any time during the study period. Survey data were combined with hospital, clinic and therapy services administrative billing data, de-identified, and analyzed as a retrospective cohort of 1036 patients.

3.2 Study population

Patients electing primary, unilateral total knee arthroplasty performed by surgeons affiliated with a single orthopedic clinic in Oregon, who had surgery performed at a local hospital system, with four total hospital locations, or a separate community hospital between September 2014 and December 31, 2015.

Inclusion Criteria.

- Patient were at least 18 years of age or older on the date of pre-operative appointment (at the time of study consent).
- Elective, primary unilateral total knee arthroplasty.

Exclusion Criteria.

- Patients with staged TKA procedures within the 90-day global period.

Period of Evaluation.

- Date of pre-operative clinic visit with performing surgeon (pre-operative health-related quality of life, function, PAM score, patient demographics).
- Three-month post-operative clinic appointment (± one month)

3.3 Data sources and research sites

The study utilized two different data sources: (1) patient survey data and (2) administrative billing data.

3.3.1 Patient survey data

Survey data were collected from patients pre-operatively and at three months (± one month) post-operatively. Pre-operatively, patients completed the Patient Activation Measure (PAM), an extremity-specific patient reported outcome instrument, and a health-related quality of life tool (described in *Data Elements* below). PAM data collection was double-blind, neither patients nor clinicians had access to responses or PAM score. Data were aggregated and de-identified by a database analyst at the orthopedic clinic. A randomly generated unique patient identifier was be assigned to each patient who elected to participate in the study (N=1036).

3.3.2 Administrative billing data

Administrative billing data were acquired from four sites:

1. **Orthopedic Practice**: Professional charges incurred by patients at pre-operative, routine and non-routine follow-up appointments for the affected limb. Clinic-based and outpatient physical therapy services are included.
2. **Community Hospital:** Inpatient, outpatient and emergency department facility charges incurred by patients from the date of admit through three-months post-TKA. Hospital-based outpatient physical therapy services are excluded.
3. **Hospital System (Oregon)**: Inpatient, outpatient and emergency department facility charges incurred by patients from the date of admit through three-months post-TKA or DRF surgery. Hospital-based outpatient physical therapy services are excluded.
4. **Orthopedic Ambulatory Surgery Center**: All charges incurred as a result of TKA from the date of admit until three months post-operatively, for the affected limb.

3.3.3 Electronic health records

Patient body mass index and smoking status were pulled from electronic medical records at the Slocum Center for Orthopedics & Sports Medicine. High BMI, classified as morbid obesity (BMI ≥ 30), has been associated with complications [161].

3.3.4 Additional research sites and participating institutions

- Orthopedic Research & Education Foundation; Storage of aggregate, de-identified data, data analysis, manuscript and report preparation.
- Orthopedic clinic; data collection per routine operating procedures, compilation of de-identified data set for study team, coordination with hospital sites and surgery center to follow patient de-identification procedures.
- Oregon State University; Faculty oversight, manuscript and report preparation.
- Community hospital (one hospital): Provision of de-identified billing data for the study populations.
- Hospital system (four regional hospitals included): Provision of de-identified billing data for the study populations.

3.4 Data elements

Table 3.1 describes the data elements consistent with hospital or practice billing data. Items identified with an asterisks (*) were obtained from the orthopedic medical record only. The orthopedic clinic provided the two separate hospital data analysts with a unique client ID number that was imputed on each service-level claim line in the hospital encounter data. A detailed description of the fields was provided to assure accurate matching of patient records is described.

Additional data elements were collected from patients at the orthopedic clinic during a pre-operative and post-operative/treatment visit to the clinic, by clinical support staff as part of routine care. Table 3.2 describes the survey instruments included in the study. Responses were be collected to individual questions and scored, consistent with survey licensing and scoring guidelines. An indicator of research-specific versus standard of care data collection is included.

3.5 Data collection, acquisition and cleaning

All survey data were collected electronically, on iPads provided to patients by clinical staff, as part of the routine patient data collection process. Clinical staff identified patients by encounter and procedure type. Data were housed in a secure, password protected database, consistent with clinic procedures for collecting and housing patient reported outcome data. Information regarding patient activation score or level were not accessible to clinical staff or patients. A single, retrospective data pull was performed upon the completion of 18-months of data collection (patients with date of surgery between September 2014 and December 2015, follow-up through March 2016). The database analyst employed by the orthopedic clinic de-identified patient demographic and survey data.

3.5.1 Creation of an unique patient identifier

The database analyst at the orthopedic clinic created a single, study-specific unique patient identifier based on the presence of a qualifying CPT code (27447) in the practice management billing system. Patient demographics, survey data, clinic and surgery center billing data were be exported in seven separate files, each containing the new research-specific patient identifier.

3.5.2 Acquisition and cleaning of billing data

An orthopedic clinic database analyst provided a list of patient names, date of birth, date of surgery, performing provider, and unique study patient ID to hospital information technology staff. Hospital staff pulled all billing/encounter data for three months following the date of surgery, per the data specification request outlined, for patients included on the clinic list. De-identified file(s) containing the unique study patient identifier were encrypted and transmitted securely to the orthopedic clinic database analyst. The database analyst confirmed complete de-identification of data before providing the hospital billing data to the investigator.

The clinic database analyst also provided three separate billing data files: physician professional fees on the study procedure date of service (initial TKA); physician professional and technical component (e.g., x-rays) fees within the global period; and post-operative procedures performed at the orthopedic clinic-owned Ambulatory Surgery Center (ASC).

Each data source required cleaning, recoding, and finally coding for standardization prior to importing into a single analytic data file. First, each data set was assess for duplicate billing lines and invalid code sets. In the event an invalid code was used or missing, effort was made to compile more complete data. Next, temporality of the study events was assessed by importing the known study data of surgery into each billing file. Any billing lines for events prior to the study date of surgery, or those occurring greater than 90 days post-operatively, were identified and excluded from cost and utilization analyses.

3.6 Analytic approach

Epidemiological and econometric methods were used to evaluate study aims. All analyses were conducted using Stata 14 (StataCorp LP, College Station, TX).

3.6.1 Explanatory variable of interest

Across all three study aims, the PAM score is the explanatory variable of interest. The PAM instrument results in a score that can range from 0 – 100 [15], with most falling in the range of 30 – 69. Curvilinear transformed PAM scores have been defined according to four levels of activation: level 1 (≤ 47.0); level 2 (47.1 – 55.1); level 3 (55.2 – 72.4); level 4 (≥ 72.5) [17, 44]. Studies have suggested Level 1 versus Level 4 is predictive of health behaviors, utilization and expenditures [16, 20]. Regression models were assessed within each study aim defining PAM as continuous score, and separately as a categorical Level. Strong preference was given to use of PAM as a categorical variable per tool guidelines and potential for translation to clinical practice. Levels were collapsed into the two lowest Levels (1 & 2 combined), Level 3, and Level 4 due to small sample size in PAM Level 1.

Because PAM Level is generated using a curvilinear transformation, the distance between each PAM category is not equal. As a result, although PAM Levels are ordinal developmentally, the levels are more similar to educational levels (e.g., elementary school, middle school, high school, etc.), and are treated as categorical in data analyses.

3.6.2 Model covariates

A vector of additional regressors, defined from a theoretical framework, are included in each of the modeling approaches described for each specific aim. Covariates were re-categorized using a combination of percentile distributions and theoretical and literature derived rationale:

- **Age** was collected as age in months at the time of surgery. Data were transformed to years, which is used as a continuous variable in modeling approaches. Consistent with Medicare eligibility, mean PAM score is compared for patients who were less than 65 versus 65 years or older at the time of surgery.
- **Gender** is recorded as male or female based on patient self-report. Female was used as the reference group.
- **Race** was collected as White, Black or African American, American Indian or Alaskan Native, Asian, Native Hawaiian or Pacific Islander, multiracial, or preferred not to answer. Race was collapsed to White, Other, and Declined for analyses. White is the reference group.
- **Ethnicity** was also collected with the option to decline a response; Hispanic, Non-Hispanic or Declined. Non-Hispanic is the reference group.
- **Insurance type** was collected with specificity regarding the type of panel or coverage (e.g., commercial PPO versus HMO, traditional Medicare or Medicare Advantage). Insurance status at the time of surgery was recoded to commercial, Medicare, Medicaid, and other, where other includes Veteran's Administration beneficiaries and worker's compensation. When applicable, commercial population is used as the reference category.
- **Body Mass Index (BMI)** were collected at pre-operative clinic appointments, or an appointment prior to surgery when no pre-operative BMI was available. BMI was also collapsed into BMI was also categorized into three standardized categories to describe the population: less than 25.0 (underweight or normal); 25.0 – 29.9 (overweight); and 30.0 and above (obese).

- **Smoking status** was collected as current every day smoker, current some day smoker, former smoker, heavy tobacco smoker, light tobacco smoker, smoker with current status unknown and never smoker. Smoking status was recoded as never, former and current, with current as the reference group.
- **Charlson Comorbidity Index** ranges from zero (no major comorbidities) to seven; however, the highest Charlson Index in the study population was four. Comorbidity burden are reported as 0, 1, and ≥ 2. Charlson scores of 0 are the reference population.
- There were 12 surgeons who performed at least one TKA in the study population, which were collapsed into the top three **performing surgeons** individually, and the remaining nine surgeons were combined into "all others." Surgeon #1 is used as the reference group when applicable.
- **VR-12** baseline pre-operative scores (physical health component and mental health component) are used as continuous variables.
- **Distance from home**, collected in geographic miles from the hospital where the patient had surgery performed, was collapsed into < 45 miles and greater than 45 miles away. The distance may play a role in addressing endogeneity as a result of omitted variable bias for patients who experienced post-acute utilization and did not return for care at their surgical hospital.
- **Discharge location** included home, home with home health, skilled nursing, or transferred to other inpatient rehabilitation facility. Discharge location was categorized into home vs. other

The Charlson Comorbidity Index was calculated using hospital billing data, limiting the data to only the diagnoses included on the initial index hospitalization event (the comorbidities present at the time of admission). Hospital data were judged to be more accurate for capturing and coding comorbidities compared to clinic-based data; to code for a higher severity of illness (SOI) on inpatient claims, diagnostic codes supporting the SOI should be present. Two different user-written coding packages were downloaded through Stata; one to generate a Charlson Comorbidity Score from ICD-9 coding (September 2014 – September 2015) and the second to generate scores for admissions occurring after the switch to ICD-10 (October 2015 – December 2015). Four different inpatient files were created, scores computer from all diagnostic codes available on the encounter, then final scores were merged back into the analytic file, matching by unique patient study ID number.

Modeling approaches need to control for the performing provider, as provider behavior and surgical techniques/skill could may be a source of endogenity in the study design unless provider-specific effects are partialed out. Finally, for cost and utilization models, physical and mental health component scores (PCS and MCS) from VR-12 assessments will be included as covariates. Studies have suggested physical health status (e.g., functional limitations) and mental health status (e.g., depression) are associated with patient activation score [162, 163] and total joint replacement outcomes [13, 39, 135].

3.6.3 Care Settings

The hospital billing data provides a greater level of granularity on the care setting than the five settings used in analyses (inpatient, outpatient, emergency department, clinic and outpatient physical therapy). The following definitions were applied to categorize utilization and expenditures by care setting:

- **Inpatient:** Inpatient admission status code or observation admission status code. DRG 461, 462, 469, or 470 and dates of service were used to identify and exclude staged TKA procedures. Admission to inpatient rehabilitation (DRG 945 or 946) were excluded from inpatient charges.
- **Outpatient:** Outpatient admission status code; same day admission and discharge with no DRG (missing) or DRG other than 461, 462, 469, or 470; series bills excluding rehabilitation (DRG 945 or 946) and outpatient physical therapy (Revenue Codes 420-429 on encounter); outpatient surgery status code or surgical procedure with same day admission and discharge (hospital data); or procedures originating from the Slocum ASC (ASC data).
- **Emergency department:** Emergency department status code; Revenue codes 0450-0459. No resulting admission to the inpatient care setting.
- **Clinic:** Any bill originating from Slocum Orthopedics in which the place of service was "Clinic" and CPT codes were consistent with physician procedures.
- **Therapy:** Any bill originating from Slocum Orthopedics in which the place of service was "Therapy" and CPT codes were consistent with therapy procedures.

Since Medicare implemented policies penalizing hospitals for re-admissions in 2012, the number of patients admitted for observation has been increasing, while admissions to the inpatient setting have declined [164]. As a result, patients re-admitted for observation were categorized as “inpatient” as assigned inpatient costs (described in section 3.6.5 below).

Patient discharge location for the initial admission (TKA procedure) is reported. The two hospitals’ discharge status codes were standardized to create four discharge categories: home (including discharged to home with home health services); hospital-based or community-based inpatient rehabilitation; and skilled nursing facility. In the study population, no patients were discharged to another hospital, hospice, or died during the study period. Last, patients who were discharged to home, and subsequently entered hospital-based inpatient rehabilitation, are identified. However, a number of community based rehabilitation centers may have been accessed by the study population. As a result, data on post-discharge admits to rehabilitation centers is incomplete. Analyses for each specific aim address how utilization and cost are assessed for post-discharge admit to rehabilitation centers.

3.6.4 Descriptive statistics: Study population and patient activation

Descriptive frequencies describe the TKA population who provided consent acknowledgement and had a valid pre-operative PAM score available:

- Gender (percent; dichotomous)
- Age at the time of surgery (mean; continuous)
- Race/ethnicity (percent; dichotomous)
- Payer classification (percent Medicare, Commercial, Medicaid, other; categorical)
- Explanatory variable of interest: PAM score and/or level (mean score, percent in each level; continuous and categorical)
- Performing provider ID (percent; categorical)
- BMI (mean BMI and < 25, 25-29.9, ≥ 30;continuous and categorical)
- Smoking status (percent current, former, never; categorical)
- Charlson Comorbidity Index Score (percent 0, 1, ≥ 2; ordinal)
- Hospital length of stay (mean LOS and percent less than three days, three days or greater; continuous and dichotomous, respectively)
- Discharge location (percent home, not home; dichotomous)
- Hospital distance from home (percent within 45 miles, greater than 45 miles; dichotomous)

The frequency and distribution of each demographic characteristic were reviewed. Continuous variables were assessed for normality (age, BMI, VR-12 scores, and PAM score) using a combination of frequency distribution on a histogram, as well as skewness and kurtosis statistics. First, characteristics between the study population, unilateral, non-staged TKA patients with evaluable PAM scores are compared to those without evaluable PAM scores. Differences in demographic characteristics are compared using measures of central tendency dependent upon variable type (continuous, categorical).

An independent samples t-test was used to compare age, BMI, length of stay, and VR-12 physical health component scores and mental health component scores. For categorical variables, resulting cell counts less than five utilized Fisher's exact test when comparing proportions, otherwise a chi-square test was preferred. Statistical tests applied to each variable are noted in the table footnotes. Next, the study population is compared to the population of excluded staged TKA patients with available PAM scores to characterize differences in PAM score and level, as well as demographic characteristics. Chi-square was used to compare the proportion of patients in each PAM developmental level; *t*-test for difference in PAM score between the populations.

Mean PAM score for the study population was compared by demographic characteristic and health-related measures ascertained pre-operatively. Continuous variables were categorized (age, BMI, length of stay). Analysis of variance (ANOVA) was utilized to compare PAM scores within each characteristic.

Demographic characteristics were next compared by the proportion of the study population in each developmental PAM Level (1-4). PAM Level was treated as categorical level. The resulting frequencies within each characteristic and PAM Level were assessed and a Fisher's exact test was judged to be the appropriate test of statistical significance for categorical population characteristics (except in the case of payer and performing provider where the number of rows and columns, combined with small cell size exceeded the computational enumerations in Stata; chi square is performed alternatively and noted). For continuous variables, two-way analysis of variance (ANOVA) was performed (Age, BMI, VR-12 scores).

3.6.5 Specific Aim #1 and Specific Aim #2: Care payments and utilization

Hypotheses

Specific Aim #1: Lower pre-operative patient activation scores are associated with higher **payments** incurred in the first three months following total knee arthroplasty (TKA).

Specific Aim 2: Lower pre-operative patient activation scores are associated with higher post-operative service **utilization** in the first three months following total knee arthroplasty (TKA).

Outcome Measures

There were five separate billing data files utilized to ascertain utilization: orthopedic clinic and therapy services encounters (follow-up visits for initial TKA plus professional fees for any post-acute procedures in any place of service); orthopedic professional fees assessed for facility-based procedures (initial TKA); ambulatory surgery center procedures; community hospital encounters; and hospital system encounters (initial place of surgery for some patients, plus any follow-up visits occurring at hospitals within the regional network – four hospital system).

Payment data. All charges were deflated to the Medicare average payment rates. Adjustment to the Medicare fee schedule allows for internal reliability across hospital sites with different charge masters and has a greater likelihood of external generalizability to any jurisdiction. For cost data, calendar year 2014 was selected commensurate with study start; cost estimates for services provided in 2015 will be conservative. The following sources were accessed and utilized to assign average cost data:

1) **Inpatient;** Medicare Fee-for-Service Provider Utilization and Payment Data Inpatient Public Use File (Version 2014) and the FY 2017 Final Rule and Correction Notice Tables, Table 5 (DRG geometric mean length of stay, Version 2017).

2) **Outpatient**; Medicare Final Outpatient Prospective Payment System Payment by HCPCS code (Version 2014, Addendum B) and the Medicare Fee-for-Service Provider Utilization and Payment Data Physician and Other Supplier Public Use File (Version 2014).

3) **Emergency department;** Medicare Final Outpatient Prospective Payment System Payment (OPPS) by HCPCS code (Version 2014, Addendum B) and the Medicare Fee-for-Service Provider Utilization and Payment Data Physician and Other Supplier Public Use File (Version 2014).

4) **Orthopedic clinic and outpatient physical therapy**; Medicare Fee-for-Service Provider Utilization and Payment Data Physician and Other Supplier Public Use File (Version 2014).

5) **Ambulatory Surgery Center (ASC)**: Addendum AA – Final ASC Covered Surgical Procedures (2014), Including Surgical Procedures for Which Payment is Packaged) to Reflect Revised Payment Rates Based on Changes to the Medicare Physician Fee Schedule Created by the Bipartisan Budget Act of 2013 (Version January 2014).

Total payment for care. Total payment for care includes all estimated payments from the day of admission for the TKA through 90 day post-operatively: professional fees for the surgical procedure (CPT 27447, $730.55); DRG payment for the initial admission based on presence or absence of complex chronic conditions (DRG 469 or 470); and post-acute payments in the orthopedic clinic and hospital (inpatient, outpatient, and emergency department) as described below for each place of service. Post-acute physical therapy services and unplanned re-admits to rehabilitation centers are excluded; these data are not available for all patients, resulting in unbalanced assessment of exposure.

Total payments for hospital-based post-acute care. The total cost of post-acute hospital/facility care is the sum of inpatient, outpatient, and emergency department care as defined below.

Inpatient payments. The single DRG average rate was used to assess payment for inpatient admissions, including emergency department visits resulting in inpatient admission. Because geographic practice patterns vary with regard to admission versus observation, all admits for observation were treated as an inpatient event and assigned the respective DRG. For models with inpatient payments as the outcome, only payments after the index knee event will be included. The DRG for the initial TKA is included in the total cost of care, but excluded from post-acute inpatient payments. One patient had a same day TKA in the hospital setting (admit date equals discharge date). For this patient, the DRG payment was divided by the geometric mean length of stay for the inpatient payment, resulting in an estimated per diem amount.

Outpatient and emergency department payments. The APC payments were merged separately into each hospital file and matched by HCPCS code. Addendum D1 to the Outpatient Prospective Payment System provides status indicators for the OPPS payment system for each CPT code. The CPT codes for APC status indicator "B, codes not recognized by APC" were reviewed. Three groups of codes were identified: new patient physician visits, established physician visits, and electrocardiogram (EKG) reports and interpretation.

In 2014, CMS replaced hospital clinic physician visit codes for new (99201-99205) and established patients (99211-99215) with a single G-code, mapping to APC 0634 at a rate of $102.19. The hospital data contained CPT codes for hospital physician visits and not the G-code; therefore, APC pay was imputed. Similarly, EKGs should be assigned under HCPCS code G0404 which is paid at $12.60, which was also imputed. For items with a status indicator of "A, Services furnished to a hospital outpatient that are paid under a fee schedule or payment system other than OPPS," the physician facility average payment multiplied by the quantity of services received was imputed.

In the hospital data, services identified in the "ambulatory" setting, which represent ambulatory outpatient surgery, did not contain CPT codes, but contained revenue codes consistent with an outpatient surgical procedure (e.g., 360, operating room services). Because the post-operative period for major procedures represents the current study's data capture, subsequent procedures for complications relating to the index TKA are not a covered item [165]. To account for the costs attributable to re-operations in the global period, the DRG facility payment was applied to the hospital encounter, then divided by the geometric mean length of stay. The resulting fee represents the per diem equivalent DRG payment for a single day of service. This methodology was applied to two musculoskeletal codes 551 and 554 when the facility setting was coded as ambulatory/day surgery. All other ambulatory service codes mapped to an APC payment (i.e., not included under the original TKA global fee).

The final outpatient payment amounts are the sum of hospital-based visit fees billed by the hospital and the ASC facility payment for outpatient surgical procedures, and the imputed facility payment for hospital-based ambulatory surgeries resulting from complications to the index TKA. The physician professional component of outpatient procedures is included as a clinic payment (described below). There were two emergency department visits without useable CPT codes; therefore, utilization is reported, but payment for the two ED visits is $0.

Orthopedic clinic and physical therapy payments. Average Medicare payments were merged into the post-operative orthopedic physician office file and matched by HCPCS code. Data were assigned a type of charge (clinic or physical therapy) and a place of service (practice, hospital, or surgery center name). Data were validated to confirm visits not reimbursed by Medicare (e.g. post-operative visits in the global period and physical therapy G codes) were not assigned a payment amount. Post-operative office visits were assigned a payment type with payment code “O” indicating office visit fee. The surgeon’s professional fee, performed at the hospital or ASC, were assigned an average payment amount with the code identifier “F” for facility-based fee in a separate file containing procedures performed. Total visit payments were calculated by multiplying the service line item quantity by the average service item payment. Follow-up post-operative appointments in the global period were not assigned payment (clinic or radiology CPTs). The total clinic payments are the sum of the services billed by the clinic; clinic-based office visits plus professional facility fees for inpatient or outpatient procedures.

Utilization data. Unique visits were identified based on study participant unique identification number, visit start date and visit stop date, and unique account number, which groups all billing lines under a single billing event (i.e., visit). Billing lines were counted for each line in a visit, then the first line in each visit was identified uniquely. Unique events were summed by study identification number, yielding a total count of visits for each person, calculated separately for all post-acute hospital or facility access, inpatient, outpatient, emergency department, clinic, and therapy services. Definitions for assigning place of service are consistent with definitions provided in Section 3.6.3 above. Utilization was counted for clinic visits regardless of whether payments were incurred during the global period (i.e., routine post-operative visits were counted, but visit payment may be $0).

Length of stay. TKA length of stay (LOS) was collected as an ordinal variable (days) from hospital billing data by calculating the duration between the date of admission and discharge. The expected length of stay for an inpatient TKA is two days; therefore, LOS was dichotomized to less than three days and three or greater days. Length of stay impacts hospital margin on a fixed DRG payment; more inpatient days reduces profit. Further, predictors of long length of stay are important to identifying patients who are suitable for ASC-based joint replacement in the future (i.e., same day discharge).

Descriptive Statistics

Descriptive statistics were used to first examine:

- Proportion of patients with any **post-acute hospital access** (inpatient, outpatient, or emergency department)
- Median and mean total payments for the **TJA episode of care** (initial admission facility and professional fee plus all post-acute hospital-based services and clinic services received, excludes physical therapy)
- Median and mean total visits and payments for **post-acute hospital care** (inpatient, outpatient, or emergency department
- Median and mean total visits and payments for post-acute **inpatient care**
- Median and mean total visits and payments for post-acute **outpatient care**
- Median and mean total visits and payments for post-acute **emergency department** care
- Proportion of patients with post-acute **clinic access** and additional visits beyond routine post-operative care
- Median and mean total visits and payments for post-acute **clinic care**
- Proportion of patients with post-acute **physical therapy** access
- Median and mean total visits and payments for post-acute **physical therapy** care
- Proportion of patients with **inpatient stays longer than practice goal** (≤ 3 days)
- Median and mean **total inpatient days** (length of stay) for initial TKA admission

For descriptive statistics examining differences in the proportion of patients who accessed each place of service was stratified by demographic and surgical characteristic. Chi-square and Fisher’s exact test were utilized to identify differences in service access. Chi-square was applied when all resulting cell sizes were greater than 10, otherwise, Fisher’s exact test was preferred.

Next, payment and visit data were summarized, stratified by place of service. First, the distribution of payment data were reviewed by place of service, separately, and combined payment outcomes (i.e., total care and total hospital-based post-acute care). Data that were right skewed were log-transformed and descriptive statistics are reported for both the actual payment amount and the log-transformed payment. Payment data were summarized for each patient characteristic, reporting both median and mean payments. For total actual payments and visits in each place of service, data were not normally distributed; therefore, non-parametric approaches to testing for differences between population distributions were applied. For dichotomous characteristics, Mann Whitney U was performed and groups with more than two categories were compared using the Kruskal-Wallis test. Natural logarithm-transformed payment data were assessed for normality of distribution. Normally distributed transformed payment data were compared using a test-test and two-way analysis of variance (ANOVA) to detect differences in mean payments and visit counts. Transformed data remaining skewed was also analyzed using non-parametric statistical tests (defined above). Differences in utilization or payments by PAM Level are presented in tables; however, results of simple linear regression for log-transformed total payments are discussed separately for each service location(s) (for services greater than $0).

Health related quality of life was measured by pre-operative VR-12 physical health component scores and mental health component scores (PCS and MCS, respectively). The results of simple linear regression for log-transformed total payments are reported for each service location as defined above (semi-elasticity model). Outcomes were log-transformed if data were skewed. The direction of the coefficient, coefficient value, and standard error (se) are reported to assess the linear relationship. When examining length of stay (count) as the outcome, a simple Poisson regression model was employed to describe the basic relationship between continuous variables; PAM score, pre-operative VR-12 PCS and MCS, respectively.

Effect Estimation

Prior to initiating regression modeling, correlations between the explanatory variables and with the dependent variables of interest were investigated. Covariates in each of the models presented are identical and driven by previously published literature (discussed in literature review). Compared to descriptive statistics, model covariates were collapsed for Race, Ethnicity, and Charlson Comorbidity Index to preserve degrees of freedom and minimize small sample sizes within demographic and surgical characteristics. Race was categorized as White (reference) vs. Non-White; Ethnicity was categorized to Non-Hispanic (reference) and “Other than non-Hispanic,” which includes 131 patients who refused to provide an ethnicity and 12 patients who self-identified as Hispanic; and Charlson Comorbidity Index equal to 0 (reference) versus Index scores of one or greater. For the predictor of interest, PAM Level, the highest Level of activation (Level 4) is the reference category.

Access by Place of Service. Logit models will be used to identify the probability of services being accessed for each care setting, examining patient activation as the predictor of interest. Access models are based on visit count > 0 for each place of service identified. For each model type identified below, the outcome of interest is assessed in two separate models, one utilizing PAM Level as the predictor of interest, and the second the continuous PAM score:

- **Models 1-2**: Hospital-based post-acute access (inpatient, outpatient, emergency department combined visit count > 0)
- **Models 2-3:** Inpatient post-acute visit count > 0
- **Models 5-6**: Outpatient post-acute visit count > 0
- **Models 7-8:** Emergency department visit count > 0

The models are consistently specified as:

$$\Pr(Access_i > 0) = \beta_0 + \beta_1 PAM\ Level_i + X_i\beta + \varepsilon_i \qquad \text{(Equation 4.1)}$$

$$\Pr(Access_i > 0) = \beta_0 + \beta_1 PAM\ score_i + X_i\beta + \varepsilon_i \qquad \text{(Equation 4.2)}$$

where *PAM* represents PAM levels (PAM Levels 1 and 2 combined, 3, and 4; Equation 4.1) or PAM score (Equation 4.2), *X* is a vector of controls, the subscript *i* refers to individual-level observations and ε_i is the error term. All models are estimated using robust standard errors. Coefficients and standard errors are reported for each covariate.

To facilitate translation of potential impact, average marginal effect (AME) for PAM Level on the probability of post-acute access are presented. In linear probability models, marginal effects are defined as the average change in the predicted probability of the sample, comparing predictions for each observation as the covariate changes from a value of 0 to 1, holding all other exogenous variables equal. AME are reported using bootstrapped standard errors, generated from 1000 repetitions, to produce a 95% confidence interval.

Length of Stay (LOS). Models 9 and 10 were constructed to assess the probability a patient incurred an initial length of stay following the TKA procedure that exceeded standard of care expectations (two days). The binary dependent variable is defined as length of stay < 3 days (reference) versus ≥ 3 days.

Models 9 and 10 are consistently specified as:

$$\Pr(LOS_i \geq 3) = \beta_0 + \beta_1 PAM\ Level_i + X_i\beta + \varepsilon_i \qquad \text{(Model 9, Equation 4.3)}$$

$$\Pr(LOS_i \geq 3) = \beta_0 + \beta_1 PAM\ score_i + X_i\beta + \varepsilon_i \qquad \text{(Model 10, Equation 4.4)}$$

where LOS is length of stay, *PAM* represents PAM levels (PAM Levels 1 and 2 combined, 3, and 4; Equation 4.3) or PAM score (Equation 4.4), *X* is a vector of controls, the subscript *i* refers to individual-level observations and ε_i is the error term. All models are estimated using robust standard errors. Coefficients and standard errors are reported for each covariate. AME are reported using bootstrapped standard errors, generated from 1000 repetitions, to produce a 95% confidence interval.

Payment for Care. Ordinary least squares (OLS) was used to estimate parameters in a series of multiple regression models. The following models were examined, utilizing an identical set of covariates, and natural-logarithm transformed payments to help mitigate skewness and heteroskedasticity, for both PAM Levels and PAM score, separately:

- **Models 11-12**: Total payments for the TKA episode of care
- **Models 13-14:** Total post-acute hospital payments (inpatient, outpatient, emergency department).
- **Models 15-16:** Total post-acute payments (inpatient, outpatient, emergency department and non-routine/new problem orthopedic clinic payments)

Each set of models is specified as:

$$\ln(payment_i) = \beta_0 + \beta_1 PAM\ Level_i + X_i\beta \qquad \text{(Models 11, 13, 15, Equation 4.5)}$$

$$\ln(payment_i) = \beta_0 + \beta_1 PAM\ Score_i + X_i\beta \qquad \text{(Models 12, 14, 16, Equation 4.6)}$$

Unlike the places of service identified above, physical therapy payments were normally distributed; therefore, no log-transformation was pursued when modeling predictors of post-acute physical therapy appointments (**Models 17-18**). The set of regressors included in the model for physical therapy payments are consistent with Equation 4.5 and 4.6 above. For all models, a joint F-tests were performed to report the joint statistical significance of the entire subset of categorical covariate regressors.

Payment data are utilized in log-level (semi-elasticity) models to generate coefficients representing the effect of a one unit change in covariates (*x*) on a percentage change in payments (*y*). For dummy variables, such as PAM Level coefficients, the exact percentage change in *y*, which is the average marginal effect, is interpreted as:

$$\%\widehat{\Delta y} = \left[\exp\left(\widehat{\beta \iota}\right) - 1\right] * 100 \qquad \text{(Equation 4.7)}$$

Payment data in the study population is highly skewed across all service locations, and combinations of service locations (e.g., all post-acute care). Where OLS is sensitive to the presence of outliers, quantile regression (QR) may yield more efficient estimates by allowing assessment of PAM Level or score at defined quantiles. The QR approach captures the effect of PAM level/score at different levels of payment, allowing intercepts and slopes to vary within each quantile. QR, a form of least-absolute-deviations regression, is more robust to outliers than standard ordinary-least-squares (OLS) regression. As a result, QR may perform better than OLS for detecting differences in the population of patients with low (e.g. 25th percentile) versus high payments (e.g. 90th percentile). Two QR regression modeling approaches were pursued utilizing PAM Levels as the explanatory variable of interest:

- **Model 19:** Total payments for the TKA episode of care (initial TKA facility and professional payments, plus post-acute payments at the hospital or orthopedic clinic), modeled at the 75th and 90th percentiles to detect predictors of the most expensive patients overall. Total payment was highly skewed even after log-transformation, which may mean OLS estimates are being influenced by outliers at the highest payment levels. This approach seeks to better understand the characteristics of the potentially influential observations.
- **Model 20:** Total payments for all post-acute hospital (inpatient, outpatient and emergency department) plus clinic care, modeled at the 25th, 50th, 75th and 90th percentiles to examine predictors or potentially avoidable additional post-acute service utilization beyond typical orthopedic clinic post-operative care.

QR models were specified as:

$$Q_q(y_i|x_i) = \beta_0 + \beta_1 PAM\ Level_i + F_{\epsilon i}^{-1}(q) \quad \text{(Equation 4.8)}$$

where the *q*th conditional quantile function of *y* given *x* is $Q_q(y_i|x_i)$ and $F_{\epsilon i}^{-1}$ is the distribution function of ε. Standard errors are determined using a bootstrapping approach with 300 repetitions. The marginal effects can be estimated at any quantile for the logged dependent variable, and depends on the value of *x*. Average marginal effects (AME) are reported for significant coefficients, at respective quantiles by multiplying the AME calculated the median quantile by the resulting coefficient for significant predictors of interest.

Model specification tests and sensitivity analyses

A series of regression diagnostics were used to assure the most efficient and parsimonious model fit. The variance inflation factor (VIF) was calculated to detect potential collinearity in the OLS model, collectively (mean VIF) and among individual covariates prior to constructing QR models. White's test will be utilized to identify violations in the homoskedasticity assumption, and assure correction with the application of robust or bootstrapped standard errors. Because variable-specific heterokedasticity may be an increased concern when using transforming the dependent variable, each independent variable was also regressed on the squared error.

Next, OLS regression results were compared to OLS regression with the Duan smearing estimator applied to produce estimates that better approximate actual spending compared to the resulting naïve expected values from the model [166]. Last, the following sensitivity analyses will examine changes in PAM Level or score, with the following modeling modifications to select models demonstrating significant coefficients for PAM Level or score:

- Limiting the population to patients discharged to home (n=661) who surgeons have pre-determined to be at less of a risk for post-acute utilization compared to patients with planned discharge to post-acute care facilities (e.g. rehabilitation centers or skilled nursing facilities)
- Limiting the population to patients who live within 45 miles of the surgical hospital (n=608) who may be more likely to return for post-acute care to one of the hospitals that contributed to study data

- Exclusion of influential observations (OLS models only). Application of the dfits statistic will identify influential observations, and a series of models that exclude outliers will be constructed and compared.
- Restricted cubic spline regression. To improve model performance, select models were reassessed using restricted cubic spline regression with knots (junction between intervals) defined according to published PAM levels (0-55.1, 55.2-72.4, 72.5-100). The output produces a linear coefficient on PAM score; PAM spline 1 which fits a new cubic line and tests for non-linearity ($p<0.05$ indicated non-linear relationship); and PAM spline 2, which focuses on assessing the association between PAM Level 3 (55.2) and the highest PAM value in Level 4 (100).

Restricted cubic spline regression allows for use of the continuous form of PAM score, but allows associations between PAM and the payment outcomes to vary within and between categories. The cubic spline approach tests a dose-response relationship and assumption of linearity. Joint F-tests or chi-square tests, dependent upon modeling approach, may be performed to assess the overall significance of spline coefficients [167].

Power and sample size considerations for logit and OLS models

No known previously published reports on the effect of pre-operative PAM score or level on post-operative costs or utilization generally following surgery, or specifically, in an orthopedic population are available to support sample size calculation.

Post-Acute Visits. Prior to initiating regression modeling, correlations between the explanatory variables and with the dependent variables of interest were investigated. Post-acute utilization beyond routine orthopedic clinic post-operative care occurred in less than one-quarter of all study patients. The study aimed to report predictors of post-acute visit counts by the following service locations:

- All post-acute hospital (inpatient, outpatient, emergency department) visits
- Count of post-acute inpatient visits (readmissions)
- Count of post-acute outpatient visits
- Count of post-acute emergency department visits
- Count of post-acute orthopedic visits
- Count of post-acute orthopedic visits for new problems (excludes routine post-operative visits)
- Count of post-acute physical therapy visits

A two-step (hurdle model) approach was pursued. Logit models were first used to identify the probability of post-discharge hospital based utilization and longer than standard of care hospital stays (≥ 3 days), then count data models were compared, limiting the study population to patients with visit count > 0 for each place of service. A preliminary graphical check on model fit was conducted to assess the observed versus actual predicted probabilities in Poisson regression models. For all places of hospital-based service, the Poisson approach under-predicted visit counts equal to 1. As a result, negative binomial regression was assessed for potential improvements in model fit.

Negative binomial regression models were attempted. However, hurdle model approaches for all places of service except for physical therapy was unable to produce consistent parameter estimates, particularly when specified with robust standard errors. Further exploration revealed two limitations with visit counts: (1) count data were highly skewed, with 90% or more patients experiencing only one post-acute visit to any service location and (2) the range of post-acute visits was small. Maximum counts by place of service ranged from three in inpatient and emergency department services, and five in outpatient services. As a result, the descriptive statistics, combined with logit models (Models 1 – 8) provide the most accurate information regarding the relationship between pre-operative PAM and post-acute utilization.

Physical therapy visit counts were normally distributed with large enough sample size to model. Poisson predicted counts compared to actual count under-predicted PT visit counts greater than three. Models 21 and 22 report the results of negative binomial regression models for PAM Levels and PAM score, respectively. The covariates are specified consistent with Models 1-20.

The physical therapy count models were specified as:

$$PT\ visits_i = \beta_0 + \beta_1 PAM\ Level_i + X_i\beta + \varepsilon_i \qquad \text{(Equation 4.9)}$$

$$PT\ visits_i = \beta_0 + \beta_1 PAM\ Score_i + X_i\beta + \varepsilon_i \qquad \text{(Equation 4.10)}$$

For binary variables, the finite-difference method (with “i.” operators) was used to interpret coefficients:

$$me_{xj} = (exp^{Bj} - 1)\ E(y|X^*) \qquad \text{(Equation 4.11)}$$

where me is the marginal effect, reported as a count change. The average marginal effect (AME) is reported with 95% confidence intervals. Last, for some categorical variables, a joint F-test is performed to report the joint statistical significance of the entire subset of regressors.

Model specification tests and sensitivity analysis for count data models

A series of regression diagnostics were employed to assure the most efficient and parsimonious model fit. Data were assessed for dispersion characteristics, such as examining the mean-variance plot, and for serial correlation. To assess the fit of Poisson versus negative binomial regression, the likelihood ratio test was used. Model fits were compared by examining deviance, Akaike information criterion (AIC) and Bayesian information criterion (BIC). For sensitivity analyses, results for Models 21 and 22 were compared to an approach utilizing restricted cubic splines for PAM score, with knots defined according to PAM Levels (1 and 2 combined, 3, and 4) as described for OLS and logit models above. In addition, because patients not discharged to home have less opportunity for incurring PT visits, a model excluding PT patients not discharged to home is also compared.

Power and sample size considerations for count data models

No known previously published reports on the effect of pre-operative PAM score or level on post-operative costs or utilization generally following surgery, or specifically, in an orthopedic population are available to support sample size calculation.

3.6.6 Specific Aim #3: Post-operative pain, functional status and health-related quality of life.

Hypothesis

Lower pre-operative patient activation scores are associated with lower patient-reported outcome measures in the first three months following total knee arthroplasty (TKA).

Outcome Measures

Patients are administered iPad questionnaires as part of routine pre- and post-surgical practice at the orthopedic clinic. There are three standardized, validated sets of questionnaires administered:

- **VR-12 (Health related quality of life)**. Results in two scores; physical health component score (PCS) and mental health component score (MCS). Higher scores indicate higher quality of life.
- **Oxford Knee Score (OKS, functional assessment of the knee).** Results in a single numeric score, ranging from 0-60 points. Higher scores indicate higher functional status.
- **Visual Analogue Pain Scale (VAS).** Pain scale in which patients can reflect current level of pain on a slider bar (0 to 10 scale), where a score of zero is no pain and a score of 10 indicates extreme pain.

Outcome measures to be assessed for each of the above questionnaires include:

1) Post-operative score
2) Change from pre-operative score to post-operative score

Patient-reported outcome measures (PROMs) were administered pre-operatively and post-operatively. Questions appear in sequential order as defined above, resulting in decreasing sample sizes for each tool. Patients may be interrupted by the surgeon while completing questionnaires and fail to resume questionnaire completion before leaving clinic.

De-identified, raw survey response files were received from the orthopedic clinic data analyst. Each question set was scored according to directions and specifications provided in the licensing agreement for each tool. For the VR-12 PCS and MCS, code was translated from SAS to Stata and code was validated utilizing the data validation file provided by Dr. Lewis Kazis (Center for Assessment of Pharmaceutical Practices, CAPP Health Services Department, Boston University; Boston, MA). After validating VR-12 scores, orthopedic clinic data were loaded to produce resulting scores for each assessment period.

For all instruments, pre-operative questionnaires were evaluable up to three months prior to surgery and within a range of 60-120 days post operatively (target 90 days ± 1 month). In the event of duplicated question sets within the evaluable window, the date closest to the day of surgery was selected. In the event of a duplicated administration of any questionnaire on the same day, the lower (more conservative) score was utilized.

Descriptive Statistics

Descriptive statistics were used to first examine:

- Proportion of patients who had evaluable paired pre- and post-surgical scores, separately for each PROM, compared to the population of patients who did not have evaluable scores.
- Comparison of mean post-operative PROM score among patients with paired pre- and post-operative evaluable scores, and mean difference (change) in score from pre- to post-operative assessment.
- Simple, unadjusted linear relationship between PAM score (0-100 scale) and:
    - 90-day post-operative score
    - Change in pre- to post-operative score

For descriptive statistics, the proportion of patients within each demographic or surgical characteristic who had evaluable, paired PROM scores (VR-12, VAS, and OKS, separately), was compared to the proportion of patients who did not have evaluable PROM scores. Chi-square and Fisher's exact test were utilized to identify differences in service access. Chi-square was applied when all resulting cell sizes were greater than 10, otherwise, Fisher's exact test was preferred. A t-test was used to compare mean differences in PAM scores between patients with paired outcome data and those without.

Each outcome score was assessed separately for normality utilizing skewness and kurtosis statistics, as well as review of the distribution of scores on a histogram. For normally distributed outcome scores, a t-test or two-way analysis of variance (ANOVA) was used to compare means within each demographic or surgical characteristic. T-test was preferred for characteristics with two response levels, ANOVA for characteristics with three or more categories. For outcome scores with a skewed distribution, Mann Whitney U (two response categories) and Kurskall-Wallis (three or more response categories) were employed.

Simple linear regression models were used to assess the linear relationship between PAM score pre-operatively and post-operative PROM score, then pre- to post-operative change in score, separately. For PROM scores with skewed data, the linear relationship for the raw score and log-transformed score (ln(PROM score + 1), semi-elasticity model) were assessed. If the PROM had large negative values, the constant was adjusted to a value of 100. The coefficients and standard errors (se) are reported for each PROM score.

Effect Estimation

Prior to initiating regression modeling, correlations between the explanatory variables and with the dependent variables of interest were investigated. The only known reports of pre-operative PAM administration in total joint arthroplasty patients demonstrated a correlation between PAM score and post-operative patient-reported outcome measures [27], although the measures selected were different from the current study. Nevertheless, assessment of PAM score is important for consistency with existing literature. Similar to modeling for payment and utilization aims, PAM Level and PAM score will be examined for each outcome of interest.

Heterogeneity bias inherent to panel data models would be addressed by using the within-transformation on data collected across time intervals (pre-operatively and three months post-operatively). A fixed effects model would first estimate the within-group average model. Next, the within-group average model will be subtracted from the estimated equation to create time-demeaned data. Finally, an OLS model on the time-demeaned data would remove all unobserved heterogeneity attributed to time-invariant data from the composite error term. This approach would be optimal for eliminating bias from all time-invariant sources. However, a panel data approach is not as useful to employ if the majority of covariates demonstrate no variation between time points. Because the current study is limited to the immediate post-operative period only, with the majority of covariates collected pre-operatively, or at the time of hospital admission, all covariates are fixed. A multiple response approach will be better utilized at one-year, where key potential confounders such as smoking status and BMI would have the opportunity to change over time.

To examine the association between patient activation and post-operative patient reported outcomes, an OLS modeling approach, consistent with the methodology described for payment data presents the best opportunity for exploring the relationship. The following models were examined, utilizing an identical set of covariates, for both PAM Levels and PAM score, separately:

- **Models 23-24**: VR-12 physical component score (PCS) at 90-days post-operatively
- **Models 25-26:** Change in PCS (post-operative minus pre-operative)
- **Models 27-28:** VR-12 mental health component score (MCS) at 90-days post-operatively (natural-logarithm transformed scale)
- **Models 29-30:** Change in MCS (post-operative minus pre-operative, natural logarithm transformed scale)
- **Models 31-32:** Oxford Knee Score (OKS) at 90-days post-operatively
- **Models 33-34:** Change in OKS (post-operative minus pre-operative)
- **Models 35-36:** Visual Analogue Pain Scale (VAS) at 90-days post-operatively (natural logarithm transformed scale)
- **Models 37-38:** Change in VAS (post-operative minus pre-operative)

To reduce skewness and heteroscedasticity, select models (identified above) were assessed utilizing natural logarithm transformed dependent variables. Models are specified identically to Equation 4.5 or 4.6, with the exception of patient reported outcome measures not requiring log-transformation to better adhere to OLS assumptions. For dummy variables, such as PAM Level coefficients, the exact percentage change in y, which is the average marginal effect, is interpreted according the approach described in equation 4.7. For some categorical variables, a joint F-test is performed to report the joint statistical significance of select subsets of regressors.

Model specification and sensitivity tests

A series of regression diagnostics were used to assure the most efficient and parsimonious model fit. The variance inflation factor (VIF) was calculated to detect potential collinearity in the OLS model, collectively (mean VIF) and among individual covariates prior to constructing QR models. White's test was utilized to identify violations in the homoskedasticity assumption, and assure correction with the application of robust or bootstrapped standard errors. Because variable-specific heterokedasticity may be an increased concern when using transforming the dependent variable, each independent variable was also regressed on the squared error.

Last, the following sensitivity analyses will examine changes in PAM Level or score, with the following modeling modifications to select models demonstrating significant coefficients for PAM Level or score:

- Exclusion of influential observations. Application of the dfits statistic will identify influential observations, and a series of models that exclude outliers will be constructed and compared.
- Restricted cubic spline regression. To improve model performance, select models were reassessed using restricted cubic spline regression with knots (junction between intervals) defined according to published PAM levels (0-55.1, 55.2-72.4, 72.5-100).

Limiting the population to only those discharged to home or within the geographic region was not sought for PROM models as part of the sensitivity analyses. Current available information suggests surgeons will be accountable to PROM outcomes under CJR, or other iterations of Medicare payment and care delivery reforms, regardless of discharge disposition or patient geography [119].

Power and Sample Size Considerations

Detectable changes in the Oxford Knee Score are likely to be the most influential among orthopedic surgeons. The current study utilizes the effect size of 2.19 and a standard deviation of 7.0 based on the work of Dawson et al. (1998). Assuming bidirectional change is possible at 80% power, to assess change in the OKS score, 166 pairs of pre- and post-operative responses are required:

$$166 = \frac{2(1.96 + 0.8416)^2 \, (7.0)^2}{(2.19)^2} \qquad \text{(Equation 4.12)}$$

3.6.7 Protection of Human Subjects

IRB of Record

The IRB of record for the current study is the PeaceHealth System IRB located in Springfield, Oregon. An Authorization Agreement between the Oregon State University IRB and the PeaceHealth IRB exists in which Oregon State is deferring to PeaceHealth for initial and continuing reviews. Per Oregon State University guidelines and federal regulations, the Oregon State IRB files will be updated with each annual continuing review.

Confidentiality

Data elements collected are presented in Table 3.1 & Table 3.2. The orthopedic clinic staff, who routinely access PHI as part of routine business operations provided de-identified files, containing a unique research-specific identifier. Data analysis files did not include patient names, specific dates of birth or specific geographic indicators for subjects (e.g. zip codes). All data was acquired and stored electronically. No coded or de-identified data and/or samples were provided to anyone outside of the research team during the conduct of this study.

Confidentiality risks were minimized through data security practices. First, data files limited the identifying information. For example, only patient age in years; a new, fictitious unique person identifier (transformed by orthopedic clinic staff) that cannot reasonably be traced back to the real patient ID number or medical record number(s), was utilized. Any provider information was limited to an ID number only. Second, data security and storage protocols further minimized risks of confidentiality and privacy breach. All investigators involved in the study had documented completion of Human Subjects Training. Data was stored on a password-protected computer, behind a limited access, key-entry door. Because the primary research team member was housed within a HIPAA compliant, highly secure data protection environment, research data were protected by the same physical, technical, and policy protections as patient medical records.

A potential breach in confidentiality was the only known source of harm to study participants. It is anticipated the harm resulting from a breach would be low, as there is no program identifier, or real human identifier contained in the data that could reasonably be traced by manual or electronic means to the study subjects. When generating reports or manuscripts, all data is reported in aggregate, with no personal identifying information. In addition, no cell counts of less than “5” observations are reported in result tables.

Upon study completion, licensing of the PAM tool requires transmission of de-identified, limited data sets to Insignia Healthcare. Data will be transferred through a secure, encrypted FTP upload. Transferred files will contain only summary level information (e.g. no specific claim-line details or full sets of patient reported outcome questionnaires). Only the rolled up total count of visits, total expenditure and final patient reported outcome score will be provided to Insignia to fulfill product licensing requirements.

Risks

The primary risk to human subjects was privacy and breach of confidentiality. All data are retrospective and no patient names will be included. Patient ID numbers were transformed prior to data transfer. There was no direct intervention as part of this study. Because billing data includes all diagnostic codes, vulnerable populations such as individuals living with HIV/AIDS and/or co-morbidly mental health conditions was included and may provide important information about the effect of PAM score/level on specific high-risk subpopulations, as part of the coding for comorbidity measures (i.e., Charleston Comorbidity Index). Pregnant women, children and prisoners were excluded; pregnant women are not candidates for total knee arthroplasty. Prisoners may complete study questionnaires as part of routine care at Slocum; however, the retrospective data extraction excluded prisoners based on payer type classification. There was no reasonable way to ascertain whether total patients were institutionalized at any point during the study period. Efforts to minimize risks are discussed in the confidentiality section above.

Benefits

There was no direct benefit of participation to study subjects. From a methodological perspective, data were analyzed as a retrospective cohort study. No interventions were conducted as part of this study. At the time of PAM survey administration, there was little evidence to suggest pre-operative PAM scores/levels were associated with orthopedic outcomes to an extent that would justify intervention. The current research will inform care delivery models in the future, because patient activation explains variance in patient reported outcome measures, cost and utilization.

Assessment of Risk: Benefit Ratio

The potential benefits to orthopedic patients in the future outweighed the minimal risk of confidentiality breach. Currently, there exists no standard mechanism in orthopedics available to clinicians to gauge an individual's propensity to engage in healthy behaviors or future adherence to treatment regimens. Understanding patient activation level will improve a clinician's ability to provide patient-centered care by tailoring interventions to patients at risk of poor outcomes.

Alternative Consenting Process

An alternative consenting process, limited to an explanation of research in which patients have the right to opt in or out of study participation at the time of questionnaire administration, was completed with IRB review and approval. No direct intervention occurred, and the procedures described pose not more than minimal risk to subject privacy; however, the research could not be practically conducted without access to the use of protected health information.

Data was analyzed as a retrospective cohort. Patients and investigators were blinded to the responses and scores of the single research-specific questionnaire being collected pre-operatively (Patient Activation Measure). The remaining questionnaires were collected per standard clinical operating procedures for routine monitoring of patient outcome data. Due to the high volume of patients electing total knee arthroplasty, in addition to the number of surgeons who perform total knee arthroplasty procedures at the orthopedic clinic, it was not feasible to have a full informed consent discussion and process.

A HIPAA authorization waiver was granted, allowing for patients to agree or disagree to participation upon reading an Explanation of Research (below). Consenting was managed through an iPad application. Patients received a prompt in advance of completing the study questionnaire and routine standard of care questionnaires that allows the patient to indicate permission to use aggregated, anonymous data for research purposes, or decline.

Explanation of Research Provided to Patients

The following script was presented to patients as an alternative to the informed consent process:

Purpose. We are doing a study to learn information about how to improve the surgical experience and outcomes for patients. Before knee replacement surgery, patients have different levels of understanding about the surgery and different healthcare needs. We are investigating whether these differences have any effect on how your knee feels and functions after surgery, how much your care costs and what healthcare services you need after surgery.

*Activities***.** We have a tool called the *Patient Activation Measure* that you will fill out today at your pre-operative appointment. Other questions will be asked that are a routine part of your care at [omitted for privacy and confidentiality] which you will also fill out around three months after surgery and one year after surgery. These questions ask you about your quality of life, what activities you can or cannot do, and your knee pain. There are no other activities or procedures for you to complete.

Time. The questionnaires will take you between 15 and 20 minutes to complete today, three-months after surgery and one year after surgery.

Risks. Your knee replacement surgery has risks that your surgeon will discuss with you. The only risk to you for participating in our research is a potential breach of confidentiality. The risk of a breach is very low. However, [omitted for privacy and confidentiality] takes your information security very seriously. The study team will not have any access to your name, date of birth, or personally identifiable information.

*Benefits***.** There are no direct benefits to you for participating in this study. We don't know whether knowing patient activation has any relationship to knee replacement surgery outcomes, but that is why we are doing this study.

Alternatives. If you decide not to participate, your information will not be used for research, but you will still be asked to complete the questionnaires. Your surgeon uses the information to take care of you and keep track of your progress.

Contact Information. If you have questions about this study, you should contact [omitted for privacy and confidentiality].

Voluntariness. After reading this information, you will be asked to decide whether it is ok to anonymously use your answers to the questionnaires as part of our research study. Your participation is voluntary. If you decide not to participate, the care you receive at [omitted for privacy and confidentiality] will not be impacted in anyway. There is no penalty or loss of benefits for choosing not to participate now, or deciding to withdraw your consent to participate later.

Funding. This study was funded by the Slocum Research & Education Foundation and the PacificSource Charitable Foundation [omitted for privacy and confidentiality] are Board members of the Slocum Foundation and Erin Owen, the Director of the Slocum Foundation is also part of the study team.

Table 3.1: Data request specifications for hospitals and practice billing data, or practice electronic medical records.

Patient Information		
No.	Element	Description and Intended Use
1*	Client ID number	Unique person identifier.
2*	Patient age	Calculated age at the time of pre-operative assessment; data analysis, stratification, independent covariate for predictive models.
3*	Gender	Data analysis, stratification, independent covariate for predictive models.
4*	Race/Ethnicity	Data analysis, stratification, independent covariate for predictive models.
5*	Preferred Language	Data analysis, stratification, independent covariate for predictive models.
6*	Payer classification (Medicare, Commercial, Medicaid, Other)	Data analysis, stratification, independent covariate for predictive models.
7*	Body Mass Index	Data analysis, stratification, independent covariate for predictive models.
8*	Smoking status	Data analysis, independent covariate
Service-level Information		
9*	Performing Provider ID	Data analysis, stratification, independent covariate for predictive models. Must control for provider ID when developing predictive models.
10	Start date of service	Data validation, quantification of length of stay.
11	End date of service	Data validation, quantification of length of stay.
12	Claim number	Or equivalent bill identifier, quantification of service utilization.
13	Line number	Accurate quantification of service utilization (e.g. visits/encounters versus units).
14	CPT code	Data validation; Identification of study endpoints.
15	Revenue code	Data validation; Identification of study endpoints.
16	DRG code	Data validation; Identification of study endpoints.
17	ICD-9/10 procedure code	Data validation; Identification of study endpoints.
18	ICD-9/10 procedure code description	Data validation; Identification of study endpoints.
19	Units (service quantity)	To accurately quantify utilization
20	Primary ICD-9/10 diagnosis code	Identification of study endpoints, creation of Charlson Comorbidity Index.
21	ICD-9/10 diagnosis code 2 – n (Each code as separate cell)	Identification of study endpoints, creation of Charlson Comorbidity Index.
22	ICD-9/10 diagnosis code 2 – n (Each code as separate cell) Descriptions	Identification of study endpoints, creation of Charlson Comorbidity Index.
23	Discharge Disposition/Discharge Status	Analysis by intermediate outcomes; exclusion criteria. Discharge to home health will be excluded.
24	Place of Service Code	Identification of study outcomes based on place of service. Excludes RiverBend place of service codes 51-56 which designate psychiatric/behavioral health encounters.
25	CPT modifier (if applicable)	To aid in data management and accurate quantification of cost data.
26	Other CPT modifiers (each as a separate variable)	To aid in data management and accurate quantification of cost data.

Table 3.2. Pre-operative and post-operative survey instruments used as explanatory variables and/or outcomes of interest.

Instrument Name	**Type**	**Collection Frequency, Number of Response Items**	**Collected per Standard of Care or Research-Specific**
Patient Activation Measure	Patient Reported Survey – Explanatory variable of interest	Pre-Operative, 13 items	Research
Oxford Knee Score	Patient Reported Survey – Pain and Functional Status	Pre-Operative & Post-Operative at 3 months, 12 items	Standard of Care
VR-12	Patient Reported Survey – Health-related quality of life	Pre-Operative & Post- Operative at 3 months, 12 items	Standard of Care
Visual Analogue Pain Scale	Patient reported assessment of pain, visual scale 1-10	Pre-Operative & Post- Operative at 3 months, 1 item	Standard of Care

CHAPTER FOUR

Results

4.1 Study population and baseline PAM characteristics

In total, 1044 patients were eligible to participate in the study between September 2014 and December 2015. There were 1020 patients who gave permission to use PAM data for research; however, 52 patients initiated PAM questionnaires post-operatively and no pre-operative scores were available. Among the 968 pre-operative PAM scores attempted, 954 were completed. Simultaneous bilateral patients (n=98) were excluded, resulting in a study population of 918 unilateral total knee arthroplasty procedures. Baseline pre-operative PAM survey data were available in 853 (93%) unilateral total knee arthroplasty procedures. The 853 procedures with PAM data available were performed among 806 unique patients. There were 52 patients who had staged TKAs during the study period (one knee replaced, and the contralateral knee replaced within the global billing period). The final dataset contains 754 evaluable unilateral total knee procedures performed on 754 unique patients.

Continuous covariates were assessed for normality (age, BMI, VR-12 scores). All continuous variables were approximately normally distributed in the non-staged, unilateral TKA population ("study population"): age, skewness = -0.32 and kurtosis = 3.44; BMI, skewness = 0.56 and kurtosis = 3.2; baseline physical health component score (PCS), skewness = 0.52 and kurtosis = 2.97; and baseline mental health component score (MCS), skewness = -0.79 and kurtosis = 3.11). Table 4.1 reports available demographic characteristics for non-staged, unilateral total knee arthroplasty patients with available baseline PAM survey data (n=754) compared to patients who were not administered, or who did not have an evaluable pre-operative PAM score (n=56). The majority of the study population is over 65 years old (62%), female (61%), White (91%), Non-Hispanic (81%) and insured by Medicare (62%). Current smoking is uncommon (< 8%) and the majority of patients report never smoking (60%). More than 75% of patients did not have a significant comorbidity captured by the Charlson Comorbidity Index at the time of admission. Most of the TKAs were performed by the three highest volume surgeons (73%) with a mean length of stay of 2.4 days (sd = 0.7). Nine lower volume surgeons comprise the "all others" category. Finally, 81% of patients reside within 45 miles of the hospital where they had surgery and more than 87% of patients were discharged to home (which includes discharges to home with home health and home with outpatient physical therapy). There was one patient who identified preference for Spanish over English. As a result, language preference was excluded from reporting (data not shown).

The population with a valid pre-operative PAM score is fairly comparable to the non-staged, unilateral TKA population without a PAM score in demographic characteristics and health status, as measured by the VR-12 physical health component score (PCS), mental health component score (MCS), or Charlson Comorbidity Index. The population without a PAM score is significantly older than the study population (p=0.002) and consistent with age differences, more likely to have Medicare insurance (p=0.014).

Table 4.2 reports available demographic characteristics for unilateral arthroplasty patients with baseline PAM data available (n=754) compared to excluded staged, unilateral TKA patients (n=52). There were no significant differences in demographic characteristics, health related quality of life (VR MCS or PCS) or presence of complex comorbidities at admission (p>0.05). Patients with staged procedures were more likely to be treated by Surgeon 2 compared to the study population (p=0.045). Of note, the 52 patients with a staged TKA in the global period had significantly different PAM level scores at baseline. Significantly more patients scored in the highest PAM Level – *Maintaining health behaviors* (42%) compared to the study population (26%) (p=0.031); however, there is no difference in mean PAM score (p=0.987).

The mean PAM score for the study population is 64.4 (standard deviation, sd = 12.8), with a median score of 60.6 (N=754). PAM score is reasonably normally distributed (1.01 skewness; 3.6 kurtosis). PAM scores ranged from 42.2 to 100. Table 4.3 compares mean PAM pre-operative PAM score by patient demographic characteristics and pre-operative health-related measures. Notably, less than one out of every 10 patients is normal weight or underweight; 90.4% of patient are overweight or obese. Two out of three patients were discharged from the hospital in less than three days (68%).

Mean pre-operative PAM scores (Table 4.3) vary significantly by gender. Females have significantly higher PAM scores compared to males; 65.5 (sd = 13.0) compared to 62.8 (sd = 12.4), respectively (p=0.005). There is also a significant difference in PAM score by payer type. Patients with commercial insurance have the highest PAM score (mean = 65.6, sd =13.0). The study population varies significantly by type of insurance (p=0.028). Patient who were discharged from home after surgery have significantly higher mean pre-operative PAM scores (mean = 64.9, sd = 12.8) compared to patients who were discharged to skilled nursing or inpatient rehabilitation facility (mean = 61.2, sd = 12.5) (p=0.009).

The majority of patients had a pre-operative PAM Level 3 – *Taking action* (55%) and 26% of patients achieved the highest PAM Level 4 – *Maintaining health behaviors*. Very few patients were *Not yet taking a role* (PAM Level 1, 3%) or *Building confidence and knowledge*

(PAM Level 2, 16%). Table 4.4 reports the proportion of patients in each PAM Level for categorical characteristics or the mean age, BMI, and VR-12 scores achieved at each Level. There is a significant difference in mean patient by PAM Level (*p*=0.035); however, there is no direction or gradient to report. Level 1 patients have a mean age most similar to Level 4 patients (mean = 65.9 and 65.8, sd = 10.9 and 9.0, respectively). There was no significant difference in the proportion of the population represented in each PAM Level by gender, race, ethnicity, payer type, smoking status, performing surgeon or home distance from the hospital (*p*>0.05).

The populations are also comparable in the presence of significant comorbidities as reported by the Charlson Index (*p*=0.322). In contrast, self-reported physical health status and mental and emotional health status, reported by the VR-12 tool does vary significantly by PAM Level (PCS *p*=0.038 and MCS, *p*<0.0001). In addition, there is a clear gradient as a patient moves from Level 1 to Level 4, VR-12 MCS increases from Level 1 mean MCS 51.2 (sd = 12.7) to Level 4 mean 59.3 (sd = 9.1). The gradient is not as notable for PCS, although Level 1 and Level 2 patients do have, on average a two-to-four point lower PCS than Level 3 or 4 patients. Finally, the proportion of patients in each PAM Level varies by discharge location (*p*=0.002). Notably, nearly 12% of patients not discharged to home ("other" location) scored in PAM Level 4 compared to 28% of patients discharged to home. Consistent with these findings, 5% of patients not discharged to home scored within PAM Level 1 compared to less than 3% of patients who when home after surgery.

4.2 Specific Aim #1 & Specific Aim #2: Payments and utilization

4.2.1 Descriptive statistics

Access to post-acute services. Table 4.5 reports the proportion of patients within each demographic and surgical characteristic who accessed at least one post-acute hospital or facility-based service in the 90 days after discharge, stratified by place of service location. Overall, 23% of patients utilized at least one post-acute care service (n=174). Patients in PAM Level 3 represented the highest proportion of any access location (27%), which was driven primarily by higher outpatient (*p*=0.154) and ED access (*p*=0.759), although the results are not statistically significant. Inpatient access approaches statistical significance (p=0.054), with patients in PAM Level 1 representing the highest proportion of re-admits at nearly 9%. There were no significant differences in pre-operative PAM score and the proportion of patients who accessed each service location compared to those who did not, for access to any post-acute hospital care setting, or separately (data not shown).

Medicaid beneficiaries represent the highest proportion of post-acute access at 36% of the population, which is significantly higher than other payer types (*p*=0.005), although the number of Medicaid patients in the study population is small (n=36). This trend is consistent in the outpatient setting (*p*=0.045) and emergency room (*p*=0.013). Obese patients visited any post-acute setting at a significantly higher proportion, double that of patients who are normal weight or underweight (25% compared to 11%, respectively, *p*=0.027). It is interesting to note, patients who had surgery performed by the nine lowest volume TKA surgeons accessed all post-acute services at 28% compared to closer to 20% among the three highest volume surgeons, although the difference is not statistically significant.

Patients who stayed at the hospital longer than anticipated (3 days or longer) accessed post-acute services in significantly higher proportions across all post-acute services. Overall, 32% of patients who initially stayed at the hospital three days or longer, compared to 19% of patients who were discharged on post-operative day two (*p*<0.0001). With the exception of re-admission to the inpatient setting, patients who live more than 45 miles from their surgical hospital have significantly less post-acute utilization captured in the data compared to patients who live closer. More than one out of every four patients who live closer to the hospital (27%) accessed at least one post-acute hospital or facility service, compared to less than 8% of patients who live further away (*p*<0.0001). Finally, patients discharged to home have significantly lower proportions of post-acute access overall (22%) compared to patients initially discharged to a skilled nursing facility or inpatient rehabilitation center (32% “Other”, *p*=0.035). Readmission to the inpatient setting and ED access were both significantly higher among patients not initially discharged to home.

Health-related quality of life was measured by the VR-12 physical and mental health component scores obtained at their pre-operative visit. There was a significant difference in mean physical health component scores for patients with post-acute inpatient access compared to those who were not readmitted (*p*=0.038). The 34 patients readmitted (4.5%) had, on average, 3.3 lower VR-12 PCS compared to patients not readmitted (mean = 26.7, sd = 1.4). There was no significant difference in pre-operative mean VR-12 PCS score between patients who accessed any hospital services (combined), outpatient, or emergency department services. Mental health component scores (MCS) were not different between patients who did and did not access post-acute services (data not shown).

Total payments. Total payment for the TKA episode of care, from surgical procedure through 90-days post-operatively averaged $13,634 (sd = $2,794) with a median of $12,949. Payment ranged from $12,949, which accounts for DRG 470 for the initial inpatient hospitalization without major medical comorbidities and the surgeon professional fee, to $52,478 after adding post-acute hospital and clinic-based utilization and payment. Total payment data were highly skewed (skewness = 7.4, kurtosis = 78.9). Table 4.6 reports median and mean total healthcare payments by patient characteristic, for actual Medicare-equivalent dollars, and separately for the log-transformed payment. There were no significant differences in mean payment by PAM Level. Similarly, there was no linear association between PAM score and log-transformed total payments (p=0.370), although the coefficient was negative (data not shown). Medicare beneficiaries have significantly higher mean total payment ($13,784, sd = $3,073, p=0.012) compared to other payer types which range from $13,217 ("other", sd = $1,443) to $13,435 (Medicaid, sd = $1,065).

Patients who stay less than three days for their initial hospitalization, live within 45 miles of the surgical hospital, and are initially discharged to home, separately, incur lower mean total healthcare payments compared to patients with longer length of stay, further home distance, and do not discharge to home. On average, total payment for the episode of care increases by more than $1,000 for patients who stay in the hospital more than two days (p<0.0001). A similar mean difference is noted among patients who discharge to rehabilitation or skilled nursing facilities (mean = $14,622, sd = $5,221) compared to patients who discharge home (mean = $13,495, sd = $2,225).

In simple linear regression, there was no relationship between pre-operative VR-12 PCS (p=0.117) or MCS (p=0.914) and log-transformed total payments. The coefficient on each score was negative, but small (PCS = -0.0006, MCS = -0.00005, data not shown).

Post-acute hospital utilization and payments. Among the 174 patients (23%) who accessed post-acute hospital or facility services, half had only one visit in the 90 days after surgery (median = 1.0). Visit counts for any hospital place of service ranged from one to eight (mean = 1.5, sd = 1.1). Payment data were not normally distributed (skewness = 4.05, kurtosis = 24.5). Payment for post-acute services ranged from $10.84 to $39,528 (mean = $2,574, sd = $5,055).

Table 4.7 reports the mean and median visit counts and payments for total post-acute care accessed in the 90 days following surgery, stratified by patient characteristic. Most patient incurred additional payment of $633 (median) or less. PAM Levels 1 and 2 were combined to assess differences in mean utilization and payment for post-acute hospital services; however, there was no significant difference in visit count or total payments by PAM Level (p = 0.986 and p=0.485, respectively). Results remain consistent when comparing means across PAM Levels for log-transformed payments (p=0.528), and assessing the linear relationship between PAM score as a continuous variable and log-transformed payments (coef = -0.012, se = 0.008, *p*=0.158).

Overall, only Hispanic ethnicity resulted in a mean difference in log-transformed payments; Hispanics had fewer post-acute payments (4.67, sd = 1.91) incurred compared to Non-Hispanics (6.61, sd = 1.64); however, the sample size for non-Hispanics is too small and should be interpreted cautiously. Finally, there was no significant linear relationship between pre-operative VR-12 PCS (*p*=0.794) or MCS (*p*=0.929) and log-transformed total post-acute hospital payments. The coefficient on PCS was -0.004 (se = 0.015). The direction of the coefficient on MCS was also negative (-0.001, se = 0.012).

Inpatient utilization and cost (readmission). There were 34 patients (4.5%) readmitted in the 90 days following initial TKA surgery. These data exclude two patients who were readmitted to hospital inpatient rehabilitation facilities after being discharged to home. Overall, most patients (90%) were readmitted only one time (range 1 to 3 readmissions). Inpatient count data were right-skewed (skewness = 3.58, kurtosis = 15.3).

Table 4.8 reports the median and mean count and payment for readmissions. Neither the count of readmissions nor the mean payment for patients readmitted varied significantly by PAM Level (*p*=0.349 and *p*=0.509, respectively). Results are consistent when evaluating the association between continuous PAM score and log-transformed inpatient payments; no significant relationship is present (*p*=0.906). Patients who were less than 65 years old had a significantly higher mean readmit count (mean = 1.17, sd = 0.58) compared to older patients (mean = 1.10, sd = 0.29). Inpatient visit count and payments were not significantly different between any other demographic or service-related characteristic. However, pre-operative VR-12 PCS was not significantly associated with log-transformed inpatient payments (*p*=0.908) among those incurring readmission payments. Consistent with PCS, pre-operative MCS was also not associated with post-acute inpatient payments (p=0.881), and the coefficient was positive (coef = 0.002, se = 0.010).

Outpatient utilization and payments. There were 110 patients (14.6%) who accessed post-acute outpatient hospital services and/or ambulatory surgery center services within 90 days after TKA surgery. Outpatient visit counts ranged from one to five among unique patients who accessed any outpatient service (mean = 1.3, sd = 0.7), and 90% of patient had only one visit. Visit counts were not normally distributed (skewness = 2.8, kurtosis = 12.0). The mean payment for outpatient visits, among those who incurred any outpatient payment, was $809 (sd = 1135). Payment ranged from $11 to $5,726. Overall, 75% of patients incurred less than $966 of payments for post-acute outpatient services. Payment data were also right skewed (skewness = 2.2, kurtosis = 7.5).

Table 4.9 reports the median and mean count of post-operative visits to outpatient services for patients incurring at least outpatient visit. Neither mean outpatient visits nor actual payments were significantly different by PAM level (*p*=0.690 and *p*=0.945, respectively). In a simple linear regression model, there was also no significant association between continuous PAM score and log-transformed outpatient payments (*p*=0.344). There were no significant differences in the mean count of outpatient visits within any patient or surgery characteristic. Patients who declined to self-identify an ethnicity had significantly higher mean payments (mean = $1,101, sd = $1,328) for outpatient services compared to patients who self-identified as Non-Hispanic (mean = $796, sd = $1,106) or Hispanic (mean = $85, sd = $86) (*p*=0.041). These results are consistent when log-transforming costs and comparing data with an approximate normal distribution (*p*=0.007). The p-value for smoking status approaches statistical significance, in which a gradient is present from never smokers through current smokers, showing a decrease in outpatient payments (actual, *p*=0.067 and log-transformed, *p*=0.117). There was no significant linear relationship between VR-12 PCS or MCS pre-operatively and log-transformed post-operative payments in the outpatient setting (*p*=0.100 and *p*=0.886, respectively). PCS approaches statistical significance at p=0.100, and the coefficient is positive (coef = 0.026, se = 0.016).

Emergency department utilization and payments. There were 65 patients (8.6%) who had at least one post-operative ED visit, although valid payment data could only be obtained 63 patients. Two patients had one ED visit in which the CPT codes billed were not accurate. As a result, utilization is captured for all 65 patients, but payment data are limited to 63 patients with evaluable billing codes for ED visits. Visit count ranged from one to three ED visits among patients with any ED access (mean = 1.3, sd = 0.4). Ninety percent of patients who accessed the ED did so only one time during the study period. ED utilization was not normally distributed (skewness = 2.3, kurtosis = 6.5) as were ED payments (skewness = 2.0, kurtosis = 7.2). The median ED payment was $532, with payment ranging from $13 to $2883. Overall, 75% of patients incurred ED payments of $834 or less.

Table 4.10 describes differences in population and surgery characteristics for post-acute emergency department visits. Mean ED visit count and actual payments were not statistically significant between PAM Levels (p=0.690 and p=0.927, respectively). Results are consistent when evaluating the linear relationship between PAM score and log-transformed ED payments, among those incurring any ED payment; no significant linear relationship is present (*p*=0.322).

Further, the coefficient on PAM score for ED payments is positive (coef = 0.008, se = 0.008). Patients with higher comorbidity burden at hospital admission, as measured by the Charlson Comorbidity Index had significantly higher log-transformed total ED payments (mean = 6.55, sd = 0.65), compared to patients without any high-risk comorbidities (mean = 6.29, sd = 0.76). In contrast, those with the highest comorbidity burden (Charlson ≥ 2) had less mean visits; however, the sample size is too small to draw conclusions (n=2).

Among patients with any ED visit payments, neither VR-12 pre-operative PCS (*p*=0.725) or MCS (*p*=0.452) demonstrated a linear relationship with log-transformed ED payments. The coefficient on each score was negative (PCS coef = -0.005, se = 0.014 and MCS coef = -0.008, se = 0.011) (data not shown).

Orthopedic clinic visits. Nearly all patients had at least one post-operative clinic visit per standard of care (99.1%, n=747). In comparison, 12.2% of patients (n=92) had a new billable encounter during the 90-day post-operative period. Table 4.11 compares the population and surgical characteristics among patient with any post-operative clinic visits compared to those without, and additionally, the patients who had clinic visits resulting in additional payments. Overall, populations were similar with the exception of the surgical provider. There was a significant difference in the proportion of patients with extra clinic visits by surgeon (*p*=0.019). Among the three highest volume surgeons (Surgeon 1-3), 11% or fewer patients incurred additional post-acute clinic visits, compared to more than 18% of patient who elected to have surgery with a lower volume TKA surgeon ("all others").

On average, the majority of patients had between one and two post-operative visits within 90-days post-operatively (mean = 1.6, sd = 0.9). Total visit count ranged from zero to nine visits. Overall, 75% of patients had two or less visits. Among the 92 patients with visits beyond standard post-operative care, the mean visit count was 2.9 (sd = 1.5). Total payments for post-acute clinic care ranged from $0 (all covered within global period) to $1,050 (new problem and billable visit). Mean post-operative clinic payments were $26 (sd = $109). Overall, 90% of all patients had payments under $45. Total clinic payments were not normally distributed (skewness = 6.3, kurtosis = 47.5).

Although there was no significant difference in mean PAM score among those with any clinic visits (*p*=0.305), or patients with extra clinic visits beyond routine post-operative care (*p*=0.546), results for PAM Level do suggest differences in total post-acute clinic payments (Table 4.12). Patients in PAM Level 3 (Taking action), have significantly higher actual mean post-acute clinic payments (*p*=0.012) and log-transformed clinic payments (*p*=0.009). On average, patients in PAM Level 3 (mean = $287, sd = $294) have payments that are 185%

more than Level 1 patients (mean = $101, sd = $62) and 117% more than Level 4 patients (mean = $132, sd = $140) on post-acute orthopedic clinic care.

It is also important to note, the count of clinic visits varies significantly by performing surgeon, with the higher volume surgeons consistently demonstrating 1.5 or less mean visits compared to all other lower volume surgeons combined whose patients averaged 2.3 mean visits (sd = 1.0) (p<0.0001). These results do not translate to total post-acute payments; however, suggesting the extra visits were unlikely to result in extra billable events. Last, pre-operative health related quality of life (VR-12) PCS and MCS did not have a significant linear relationship with post-operative log-transformed clinic payments (p=0.836 and p=0.347, respectively) (data not shown). The coefficients for each measure are negative (PCS coef = -0.001, se = 0.001 and MCS coef = -0.005, se = 0.347). These results are consistent when examining the population extra clinic visits in that no significant linear relationship exists (PCS p=0.707 and MCS p=0.791); however, the coefficients on PCS and MCS are positive (PCS coef = 0.005, se = 0.014 and MCS coef = 0.003, se = 0.010).

Physical therapy (PT) services. There were 199 patients (26%) who elected to have physical therapy services at the orthopedic clinic. Table 4.13 compares the characteristics of the 199 patients who had PT at the clinic compared to those who had PT elsewhere. The populations were comparable across all demographics and pre-operative characteristics collected. As expected, patients who have prolonged length of stay (discharge after post-operative day two) and those not initially discharged to home sought PT at the orthopedic clinic less (p<0.0001 and p=0.022, respectively).

The mean PT visit count was 13.0 (sd = 5.3) with PT visit counts ranging from two to 30 visits within 90 days post-operatively. Overall, 90% of patients had 19 or fewer PT visits. The count of PT visits was approximately normally distributed (skewness = 0.4, kurtosis = 3.4). Payment for all PT visits averaged $811 (sd = $324), and ranged from $138 to $1,831. Despite the broad range, PT payment data was also approximately normally distributed (skewness = 0.4, kurtosis = 3.4). Ninety percent of patients incurred PT payments less than $1,200.

Table 4.14 compares PT utilization and payment among the 26% of patients electing PT at the orthopedic clinic. There was no significant difference in the PT visit count or payment by PAM Level (p=0.874 and p=0.846, respectively). Similarly, among those incurring payment for PT, there was no linear relationship between PAM score and actual PT payments (p=0.895, coef = -0.256, se = 1.94) (data not shown).

Patient self-identifying as male had on average, two more visits to PT (mean = 14.4, sd = 5.7) compared to females (mean = 12.1, sd = 4.8) (p=0.003). Mean payments were also significantly higher among males; $893 (sd = $351) compared to $764 (sd = 299) (*p*=0.006). Payer type approaches statistical significance for visit count (*p*=0.116) and payment (*p*=0.093), with commercially insured patients completely more PT visits on average than Medicare, Medicaid, or other payer types. In general, patient who are healthier at hospital admission, as captured by the Charlson Comorbidity Index, have nearly three more PT visits on average (mean = 13.4, sd = 5.3) compared to less healthy patient with Charlson score equal to “1” (mean = 10.8, sd = 4.4) (*p*=0.026). In contrast, patients who have the highest disease burden (Charlson ≥ 2) required the highest count of post-operative PT visits (mean = 14.5, sd = 5.4). Patients with shorter length of stays (less than three days, *p*=0.002), who are discharged to home (*p*=0.010), and live closer to the orthopedic clinic (within 45 miles, *p*=0.015) have significantly higher counts of PT visits, with consistent payment results.

There was no significant linear relationship between pre-operative VR-12 physical health component score (PCS) and post-operative PT payments (p=0.149), although the association approaches statistical significance. The coefficient is negative (-3.76, sd = 2.59). Mental health component scores, in comparison, have a significant linear relationship with post-operative PT payments (*p*=0.013). On average, for each 1-point increase in VR-12 MCS pre-operatively, post-operative PT payments increase by $5.21 (se = 2.09).

Length of stay for initial TKA hospital admission. The orthopedic clinic’s standard of care is for the patient to discharge on post-operative day two. In total, nearly 68% of patients achieved the goal, while 1/3 patients (32%) had a prolonged length of stay. Table 4.15 compares the proportion of patients who had a long length of stay (≥ 3 days) compared to patients discharged on or before post-operative day two. There is a notable gradient in the proportion of patients who had a long length of stay by PAM Level. The differences approach statistical significance at *p*=0.081. A larger proportion of patients in the lowest two PAM Levels (37.6%) had longer admissions compared to patients at higher levels of activation (PAM 3 = 32.9% and PAM 4 = 26.4%). There was no significant difference in mean PAM score among those who went home as anticipated (mean = 64.9, sd = 0.6) and patients with long length of stay (mean = 63.5, sd = 0.8) (*p*=0.184) (data not shown).

There were a number of demographic and surgical characteristics with significant differences in proportion of prolonged admission including: age, gender, insurance type, BMI, Charlson Comorbidity Index, performing surgeon, and planned discharge location. Nearly 40% of females had prolonged length of stay compared to 20% of males (*p*<0.0001). Half of Medicaid beneficiaries were admitted for three or more days compared to 38% of Medicare beneficiaries and less than 20% of commercially insured patients (*p*<0.0001). More than one-out-of three (36%) of obese patients experienced longer length of stay compared to 31% or fewer of overweight, normal or underweight patients (*p*=0.005). Healthier patients with admission Charlson Index Scores equal to "0" experienced prolonged hospitalization less than half as often (24%) compared to patients with Charlson scores equal to "2" or greater (53%, *p*<0.0001). Approximately one-out-of-three patients has prolonged hospitalization among nearly all the performing provider categories with the exception of Surgeon 3 (19%, *p*=0.008).

Mean VR-12 pre-operative mental health and physical health component scores are significantly different between populations who are discharged on post-operative day two compared to patients who stay three or more days. The mean PCS among patients who discharge on post-operative day two or earlier is 30.8 (sd = 9.1) compared to 28.0 (sd = 8.9) among patients who have prolonged length of stay (*p*=0.0001). Patients who leave the hospital in less than three days also have significantly higher mean MCS (mean =56.1, sd = 10.1 compared to mean = 54.0, sd = 11.6, *p*=0.010).

Overall, length of stay ranged from zero to 12 days, with 95% of patients admitted for three or fewer days. The mean length of stay was 2.4 days (sd = 0.7). Count of inpatient days was right-skewed (skewness = 4.0, kurtosis = 46.0). Table 4.16 reports the median and mean count of inpatient days for the initial TKA admission by patient and surgical characteristic. Results are consistent with those reported in Table 4.15 in the differences detected in mean count of inpatient days. Younger patients (< 65 years), males, commercially insured patients, those who elected to have surgery with Surgeon #3, and who were discharged to home had fewer mean inpatient days. In contrast, the difference in mean inpatient days by PAM Level resulted in higher p-value (*p*=0.250) compared to the proportion of patients who stayed three or more days compared to earlier discharges (Table 4.15, *p*=0.081). There was no relationship detected between PAM score and count of inpatient days in a simple Poisson regression model (*p*=0.341). In contrast, pre-operative VR-12 PCS (*p*=0.036) and MCS (*p*=0.017) were both significantly associated with initial inpatient length of stay count. The coefficient on both scores was negative, suggesting higher pre-operative VR scores result in decreased length of stay (PCS coef = -0.003, se = 0.002 and MCS = -0.002, se = 0.001).

4.2.2 Logit models examining the probability of accessing post-acute hospital services

Table 4.17 reports the predictors of accessing post-acute hospital based services in the 90-day post-operative period, stratified by any access, and separately, inpatient, outpatient and emergency services (Models 1-8). Access occurs when a patient incurs at least one visit in any of the hospital service locations. Across all service locations, there was no significant association ($p>0.05$) between the continuous PAM score and accessing post-acute services after adjusting for model covariates. In contrast, by utilizing PAM Level categories, PAM Level is significantly associated with the probability of incurring at least one post-acute visit at the hospital (any access). Compared to patients at the highest level of activation (Level 4), patients with pre-operative activation within the Level 3 category have significantly increased probability of any post-acute access (Model 1, coef = 0.503, se = 0.234, p=0.032). Table 4.18 reports the average marginal effect (AME) for the association; patient within PAM Level 3 have 8.1% higher probability of accessing at least one hospital-based post-acute care location compared to Level 4 patients (95% CI = 1%, 16%).

For models exploring the probability of any post-acute access (Models 1-2), the patient's geographic home proximity to the hospital (≥ 45 miles, p<0.0001) and the initial length of hospital stay (≥ 3 days, p=0.009) were significant predictors in PAM Level and score models. On average, patients who live more than 45 miles away have 18.5% less probability of any hospital access compared to patients who reside closer to the surgical hospital (AME, 95% CI = -24.5%, -12.4%). Patients who spent at least three days as inpatients following TKA have 10.0% higher probability of any post-acute access compared to patients discharged on post-operative day two (AME, 95% CI = 1.8%, 18.1%). For PAM score (Model 2), patients with an insurance type "other," which includes Veteran's benefits and worker's compensation, had decreased probability of post-acute access (p=0.050); however, the sample size (n=3) is sufficiently small to limit generalizability of these findings. Of note, although the coefficient on VR-12 baseline PCS score is not statistically significant (p=0.386), together PAM Level 3 and VR-12 PCS are jointly significant (p=0.034).

The direction of the coefficients for PAM Levels are consistent across the specific places of hospital service (Table 4.17, Models 3-8); a negative coefficient (reduced probability of access) for patients in the lowest two levels of access and increased probability for patients in Level 3, both compared to patients with the highest level of activation (Level 4). The probability of inpatient readmission (Model 3) among Level 3 patients, compared to Level 4, approached statistical significance (p=0.053), resulting in an AME of 3.5% (95% CI = -2.0%, 9.2%). Within the inpatient setting, every 10-point increase in pre-operative VR-12 PCS score results in a significant 5% decrease in the probability of readmission in the first 90 days after surgery (p=0.019, one point decrease AME = -0.5%, 95% CI = -1.4%, 0%). Results for inclusion of PAM score (Model 4) are consistent with PAM Level for pre-operative physical-health related quality of life (VR-12 PCS). Inpatient readmission was the only set of models in which patient's home proximity to the surgical hospital was not significantly associated with post-acute access (PAM Level *p*=0.107 and PAM score *p*=0.118).

Although there is no association between PAM Level or score and emergency department access, payer type did result in significant findings (Models 7-8). Medicaid beneficiaries have a higher probability of accessing emergency services compared to commercially insured patients (PAM Level *p*=0.046 and PAM score *p*=0.042). On average, Medicaid beneficiaries have 11% higher probability of incurring at least one emergency department visits (AME, 95% CI = -0.5%, 28%). Results are consistent for Model 8, with PAM score as the predictor of interest (AME = 11.6%, 95% CI = -0.5%, 28.2%).

Table 4.19 reports predictors of extended length of hospital stay (≥ 3 days) following the initial TKA procedure, which are similar when evaluating PAM Level (Model 9) or PAM score (Model 10) as the predictor of interest. As a result, the results are shared for the preferred predictor, PAM Level (Model 9).There is no association between patient activation level or score and the initial length of hospital stay, after adjusting for all other potential confounders. Overall, the most significant predictors of extended length of stay were whether the patient was ultimately discharged to home (*p*<0.0001, AME = 58%, 95% CI = 49%, 67%) and had Medicaid coverage (*p* = 0.002, AME = 24% higher than commercially insured patients, 95% CI = 8% - 41%). Compared to patients with commercial coverage, Medicare patients have a 12% higher probability of delayed discharge (*p*=0.004, AME 95% CI = 4%, 20%). On average, males have a 9% decreased probability of staying beyond post-operative day two compared to females (*p*=0.006, AME 95% CI = -15%, -0.3%). The performing surgeon also influences the probability of extending the initial hospital stay; patients who were treated by Surgeon 3 have 12% lower probability, on average, of exceeding two inpatient days compared to patients who elected to have the procedure performed by Surgeon 1 (*p*=0.014, AME 95% CI = -20%, -0.04%).

Health status pre-operatively and at the time of admission plays a role in length of hospital stay. There is decreased probability of having a longer length of stay for every one point increase in VR-12 PCS score (*p*=0.006); however, the average marginal effect (-0.006%, 95% CI = -0.010, -0.002) is small. Every 10-point increase in pre-operative VR-12 PCS score decreases the probability of incurring additional inpatient days (≥ 3 days) by 0.6%. Recall Table 4.2, in which one standard deviation around VR-12 PCS is 9.1 points; therefore, the overall effect of VR-12 PCS score pre-operative appears small. Similarly, the effect of BMI on inpatient length of stay is statistically significant, but with questionable clinical relevance (AME = 0.004%, 95% CI = 0.002%, 0.005%).

The association between PAM Level and the probability of incurring an extended length of stay are fairly consistent when limiting Model 9 to patients who were initially discharged to home (Table 4.20, Sensitivity Analyses). The direction of the coefficients (increased probability) remains consistent, and the magnitude of the coefficient for patients in the lowest two PAM Levels (1 & 2) is reduced. Further assessment of the behavior of the continuous PAM score within each PAM Level (restricted cubic splines) reveals the probability of having an extended length of stay is slightly elevated among patients below the first knot (under PAM score equivalent Level 3). The first spline is negative, but not significant, indicating the relationship is reasonably linear in nature. The second spline reports as PAM score increases among patients at the highest level of PAM, the probability of having an extended length of stay decreases. None of the spline coefficients are significantly associated with having an extended length of stay, however.

4.2.3 Models examining payment for the episode of care and post-acute care

The association between PAM Level and PAM score, separately, are reported for total payments for the TKA episode of care (Models 11-12), total hospital-based post-acute payments (Models 13-14), total post-acute payments overall (hospital plus clinic, Models 15-16), and among a subset of patients electing to have post-operative outpatient physical therapy services at the orthopedic clinic (Table 4.21). Overall, patient activation level was associated with total payments for the TKA episode of care (Model 11), total post-acute hospital plus clinic payments (Model 15), and physical therapy payments (Model 17).

Compared to Level 4 patients (*Maintaining health behaviors*), patients in Level 1 & 2 and Level 3 demonstrate positive coefficients (increased payments for care) for the entire TKA episode of care (Model 11). However, only patients in Level 3 result in statistically significant findings. After adjusting for model covariates, patients in Level 3 have, on average, 2% higher total expenditures for the TKA episode of care than patients at the highest level of activation (p=0.045, 95% CI = <1%, 4%). The resulting model demonstrated homoskedastic errors (White's test, p=0.264) and no concerning multicollinearity (VIF = 1.35). Actual mean total payment for the TKA episode of care was $13,634 (sd = $2,794), although the model resulted in an under-prediction (mean $13,477, sd = $451). Application of Duan's smearing approach to obtain a more accurate prediction for predicted total cost of care between PAM level yielded PAM Level 4 estimated mean payment of $13,352 (sd = $364); $13,800 (sd = $445) among

PAM Level 3 patients; and $13,516 (sd = $492) among patients in the two lowest levels of activation (PAM 1-2).

Patient’s pre-operative BMI was also significantly associated with total payments for the TKA episode of care (Models 11, *p* = 0.026 & Model 12, *p*=0.022). On average, for each 10-point increase in BMI, total payment for the TKA episode of care decreased by 2% (95% CI = -3%, -0.23%). Last, patients with an initial length of stay of three or more days had significantly higher total payments for the entire episode of care through 90-days post-operatively compared to patients who left the hospital on or before post-operative day two (Model 11 & Model 12, *p*=<0.0001). Initial extended length of stay results in 5% higher total payments for care, on average, after adjusting for all other covariates (Model 11, 95% CI = 2%, 8%).

Models 15-16 examine the differences in total post-acute payments, which includes hospital and clinic services accessed after initial discharge. Patients in Level 3 (Taking action) have 90% higher total post-acute payments compared to patients in the highest level of activation (Model 15, *p*=0.020, 95% CI = 11%, 227%). Model specification tests demonstrate the model is homoskedastic (White’s test, *p*=0.462) and multicollinearity is not significantly biasing estimates (VIF = 1.51). Actual mean total post-acute payments were $2,060 (sd = $4585); however, Model 15 under-predicts total post-acute payments by approximately $1,500 (mean = $525, sd = $366). Duan’s smearing algorithm was applied to obtain a more accurate prediction of post-acute payments at each PAM Level of activation. Patients at the highest level of activation (Level 4) have predicted total post-acute payments averaging $290 (sd = $402), compared to Level 3 patients who average a predicted $860 (sd = $407). Patients at the lowest two levels of activation have predicted total post-acute payments of $615 (sd = $248). Next, total post-acute physical therapy (PT) payments, among the subset of patients who elected physical therapy at the orthopedic clinic, were examined utilizing non-transformed dollars, as payments were normally distributed for PT (Models 17-18). Compared to patients in the highest level of activation pre-operatively (Level 4), patients in PAM Level 3 incurred on average, $118 more for physical therapy payments between discharge and 90-days post operatively (Model 17, *p*=0.023, 95% CI = $17, $220). There is no association between PAM score and PT payments, although the coefficient on PAM score is negative and approaches statistical significance (*p*=0.064).

In addition to the patient activation level at baseline, physical health-related quality of life, as measured by the VR-12 PCS pre-operatively, was significantly associated with PT payments (*p*=0.010). For every one point increase in VR-12 PCS score before surgery, PT payments decreased by $7.87 (95% CI = -$13.84, -$1.91). There were approximately 45 points separating the minimum and maximum VR-12 PCS in the study population at baseline, which translates to an estimated $354 difference in PT payments in the first 90 days. Finally, the patient's distance from the surgical hospital, which is approximately the distance from the orthopedic clinic also, strongly predicted post-acute PT payments (Model 17, p<0.0001). On average, patients who live more than 45 miles from the surgical hospital have $294 less PT payments compared to patients who reside in more proximal areas (95% CI = -$570, -$18). The models for PAM Levels and score are homoskedastic according to White's test (Model 17, p=0.496 and Model 18, p=0.579) with no multicollinearity detected (Model 17, VIF = 1.43 and Model 18, VIF = 1.40).

Tables 4.22 and 4.23 present quantile regression (QR) models predicting the TKA total episode of care and total post-acute (hospital plus clinic) payments, separately, in Models 19 and 20. First, Model 19 examines the relationship between PAM Level and the most expensive patients overall, by focusing on the top 75^{th} and 90^{th} payment percentiles. Neither percentile demonstrated a significant association between patient activation level and high payments for the total TKA episode of care. Having an initial length of stay of three or more days was a significant predictor in the 90^{th} percentile. Among the most expensive patients in the cohort, on average, patients with extended length of stay had 28% higher total payments (95% CI = 8%, 52%). Employing median regression on the total payment model, the multiplier utilized to report average marginal effect was calculated as $12,950; therefore, patients in the 90^{th} percentile with an extended length of stay incur, on average, $3,173 additional payments for the total TKA episode of care compared to patients discharged on or before post-operative day two.

Simultaneous QR was also pursued to explain potential differences in effect of pre-operative PAM Level at four quantiles of expenditure (25^{th}, 50^{th}, 75^{th}, 90^{th}), among the patients who incurred additional post-acute payments (hospital and/or clinic). Model 20 (Table 4.23) reports patient activation level is significantly associated with post-acute payments at the 75^{th} and 90^{th} expenditures; however, no association was detected among patients who incurred less post-acute payments (25^{th} and 50^{th} percentiles). Patients who scored greater than zero on the Charlson Comorbidity Index (i.e., patients with comorbidities) had significantly less expenditures within the 25^{th} percentile compared to healthier patients (Charlson = 0). On average, healthier patient within the 25^{th} percentile, had 63% lower post-acute payments (95% CI = -84%, -8%, p=0.032). Again employing median regression to obtain the multiplier utilized for calculating AME at any quantile yielded in $480.65; therefore, these savings among healthier patients with total post-acute payments in the lower 25^{th} percentile translate to an AME of -$473.

Within the 75th percentile, patients who scored within PAM Level 3 have, on average, 167% higher post-acute payments compared to patients at the highest level of activation (95% CI = 0.3%, 610%, *p*=0.026). The effect is larger among the most expensive patients, those in the 90th percentile; Level 3 patients have 186% higher total post-acute payments (95% CI = 3%, 700%, *p*=0.048). Jointly, there is no statistically significant difference in the coefficient on PAM 3 between any of the four quantiles (Wald test, *p*=0.447). Even when comparing the coefficient of PAM 3 at the 25th percentile (coef = 0.091) to that of the 90th percentile (coef = 1.05), there effects of PAM 3 are not statistically different from one another (*p*=0.270). For patients in the 75th percentile of post-acute payments, Level 3 patient incur an average of $190 higher payments compared to patients who are Level 4 pre-operatively.

Tables 4.24 and 4.25 report the sensitivity analyses for select logit, OLS, and QR payment models. First, table 4.24 reports alternations to model specifications for the total TKA episode of care. For total payments in OLS Model 11, when excluding patients originally not discharged to home the coefficient on PAM Levels do not change appreciably in magnitude; however, the coefficient on PAM 3 is no longer statistically significant (*p*= 0.099). In addition, the direction of the coefficient for the two lowest PAM Levels (1 & 2) changes. A second sensitivity analysis model for total payment limits the population to patients who reside within 45 miles of the surgical hospital, who may be more likely to utilize hospitals participating in the study for post-acute care. This restriction results in coefficients of similar magnitude and direction to Model 11, without statistical significance for PAM Level 3 (*p*=0.101). Next, there were 37 outliers identified. Removing influential observations resulted in a significant finding for PAM 3 (p=0.026); however, the magnitude of the association was smaller (AME < 1%). Finally, assessment of continuous restricted cubic splines defined at PAM Level intervals reveals a positive coefficient on payment with PAM Levels 1 & 2 and PAM Level 4, but a negative coefficient on PAM Level 3. Although the results are not statically significant, the data suggest the relationship between PAM Levels and total payments may not be linear. As PAM Levels increase within Level 1 & 2, or Level 4, payments also increase. In contrast, increasing PAM levels within PAM Level 3 may lead to decreasing payments within the TKA total episode of care.

Table 4.24 also reports sensitivity analyses on the most expensive patients (75th and 90th percentiles) presented in QR Model 19. None of the sensitivity analyses pursued resulted in statistically significant associations for PAM Level. Of note, for the reported Model 19, the coefficient on PAM Level 3 within the 75th percentile is appreciably smaller than the OLS model (coef = 0.003), while in the 90th percentile, the magnitude of PAM 3's relationship is greater than the OLS approach (coef = 0.036). For patients in the 75th percentile, limited the sample to only patients discharged to home changed the direction of the coefficient on PAM Level 1 & 2 from positive to negative. Finally, there is no evidence the relationship between PAM score and total cost for the TKA episode of care is non-linear. The coefficients on the PAM score spline 1 and spline 2 are not significant. Jointly, the coefficients for PAM in the spline models are not significant (F-test, p=0.658).

Table 4.25 extends the sensitivity analyses to the models reported examining total post-acute payments in the hospital setting and, separately, all post-acute payments including hospital and clinic care. First, the logit models reported examined the probability of accessing post-acute hospital services. The coefficient on PAM Level 3 was positive, which remained consistent when excluding patients not discharged to home and those who reside outside of the likely hospital catchment area (45 miles). The standard errors for coefficients on PAM 3 increased with the reduction in population in both sensitivity models, resulting in loss of statistical significance identified in the original logit model for PAM Level (Model 1). In addition, inclusion of PAM score (Model 2) as the predictor of interest in the logit model for post-acute access did not result in a statistically significant finding (p=0.173); however, assessing PAM score within restricted cubic splines did produce significant findings.

The first value for the restricted cubic spline output indicates there exists a significant linear relationship between PAM score and the probability of accessing post-acute hospital services before the first knot (before PAM Level 3 equivalent scores. For the lower PAM Level subset of patients, the probability of access increases as PAM score increases. The coefficient value and significance on PAM score spline 2 indicates the relationship between PAM score and the probability of post-acute hospital access is non-linear (p=0.039). Finally, the final spine coefficient (PAM spline 2) indicates for patients in PAM Level 3 or above (greater than PAM score 55.2), the magnitude of the probability for post-acute access greatly increases, and approaches statistical significance (p=0.056). Jointly, the coefficients for PAM score, in the restricted cubic spline functional form, are not significantly associated with the probability of post-acute access (χ^2, p=0.084).

Models 13 and 14 reported results of OLS regression on total post-acute hospital payments. Original model results produced no significant association between patient activation level (Model 13) or score (Model 14) and post-acute hospital payments. Sensitivity analyses did not produce significant findings; however, it did alter the coefficients on PAM Levels. The insignificant association between PAM Level 3 and post-acute payments remained positive, while the magnitude decreased when excluding study patients based on discharge location, geography of their residence, or identification as an outlier. For patients with PAM Level 1 or 2, the direction of the coefficient changed when limiting the population to only patients who reside within 45 miles of the surgical hospital, and separately, when excluding outliers. The results for the cubic spline models are consistent with logit models reporting the probability of access; for the PAM Level 1 & 2 spline, and Level 4, the coefficient is positive, and for Level 3 the coefficient is negative.

Models 15 and 16 reported the association between patient activation level (Model 15) and score (Model 16) and total post-acute hospital and clinic charges, where the coefficient on PAM Level 3 was positive and statistically significant. Reductions in the sample population by employing the restrictions on discharge location, geographic location, or by eliminating influential observations reduced the magnitude of the coefficient and increased standard errors. The increased standard errors resulted in the coefficient on PAM 3 losing statistical significance. The same effect was observed across the 75th and 90th percentiles of the QR sensitivity analysis models.

The same sensitivity analyses were applied to QR Model 19. Only coefficients in the 25th percentile yielded statistically significant findings and changed the direction of one of the PAM Level coefficients relative to the base model. Among patients discharged to home who incurred the lower 25th percentile of total post-acute plus clinic payments, patients within PAM Level 3 had significantly higher payments compared to Level 4 patients (AME 153%, 95% CI = 29%, 523%, p= 0.044). The magnitude of change on PAM 3 was dramatically different from the base model (Model 20), and the direction of the coefficient changed for Level 1 & 2 patients. Within PAM Level 3, there were 59 patients discharged to home (14%), relative to Level 4 patients in which only 5.6% were discharged to home (data not shown). Further investigation reveals the mean post-acute payments among patients discharged to home in Level 3 were $2075 (sd = $4,101) compared to Level 4 patients with $1238 (sd = $2,559). The 25th percentile of payment was $159 and $83 in Level 3 and Level 4 patients, respectively.

For the top two percentiles assessed for total post-acute expenditures, none of the sensitivity analyses changed the direction of the coefficients. The magnitude of the association; however, was dramatically different across models. Further, reduction in sample size increased standard errors substantially when restricted the sample to patients discharged to home, including only patients who reside within 45 miles of the surgical hospital, and when excluding influential observations.

The restricted cubic spline models for OLS and QR payments models were not significantly associated with post-acute hospital (Model 14) or post-acute hospital plus clinic payments (Models 16, 20). However, there direction and magnitude of the coefficients for PAM score were consistent across each model; a positive coefficient for patients below the first knot (scores lower than PAM Level 3), negative coefficient for the fitted spline model overall, and a larger positive coefficient for the final spline which focuses on patients with PAM scores above the PAM Level 3 knot. Together, this evidence is creates a high suspicion of non-linearity between PAM score and post-acute payments.

4.2.4 Negative binomial regression models examining utilization

For utilization (visit count) models, only physical therapy utilization models yielded evaluable models. Table 4.26 reports predictors of physical therapy visit counts in the 90 days following surgery, among the subset of patients who elected physical therapy at the orthopedic clinic (n=199). Results of negative binomial regression demonstrated PAM Level 3 is significantly associated with the count of physical therapy visits (p=0.020). Compared to patients at the highest level of activation (Level 4), Level 3 patients have, on average, 1.79 more physical therapy visits (AME 95% CI = 0.28, 3.28). Although not statistically significant, there is a gradient across the PAM Levels, with the lowest level of activation (Levels 1 & 2) potentially requiring or seeking the most physical therapy visits. Unlike PAM Level, there is no association between PAM score and physical therapy visits.

A number of co-variates demonstrated significant associations with physical therapy utilization. Excluding the geographic location of the patient's home, which is a logistical barrier to attending physical therapy with similar frequency to a patient who resides in close proximity, being a Medicaid beneficiary has the largest marginal effect on PT visit count. On average, Medicaid beneficiaries average nearly two fewer PT visits compared to commercially insured patients (AME = -1.95, 95% CI = -3.76, -0.14). In addition, males average 1.56 more PT visits compared to females (AME 95% CI = 0.12, 3.00). Finally, for every 10 point increase in VR-12 physical health component score (PCS) pre-operatively, physical therapy visit count decreases by approximately one visit (AME for 10-point increase = -1.2, 95% CI = -2.2, -0.3). Results for Model 22, assessing PAM score as the predictor of interest, yield similar findings for insurance type, VR-12 PCS score, and geographic location. The coefficient on male gender approaches statistical significance at p=0.063.

The negative binomial regression model was compared to a standard Poisson model utilizing model fit statistics. Overall, the model fits were not significantly different in the count predictions, although the negative binomial regression model was still preferred (likelihood ratio test, p<0.0001). For the reported negative binomial regression model the BIC statistic is 1301, AIC is 1226. In comparison, Poisson fit is 28 points higher for BIC and 32 points higher for AIC.

Table 4.27 reports the sensitivity analyses pursued for the PT utilization models reported (Models 21 & 22). Focusing on PAM Level coefficients, limiting the 87% patients discharged to home only (n=174), changed the direction of the coefficient on PAM Level 1 & 2 patients and reduced the magnitude of the association for PAM Level 3 patients. Upon further inspection patients discharged to home had higher mean PT visit counts than patients discharged elsewhere among PAM Level 1 & 2 patients and PAM Level 3 patients. In contrast, among the reference population, Level 4 patients, visit counts for the two patients not discharged to home were higher (not discharged home mean = 15 compared to discharged to home mean = 12.6). Patients discharged to home had more similar mean visit counts across activation levels, with Level 4 patients having one less mean visit count compared to patients in lower activation categories. In short, the PT seeking and utilization habits are significantly different based on discharge location, as previously reported in Table 4.13.

Output for the restricted cubic spline output in Table 4.27 is consistent with the trends for magnitude and direction reported on each spline coefficient for OLS and QR payment models. There is a smaller coefficient on the linear association between patients below the first knot (less than PAM score 55.2, Level 3); a negative association on the fitted spline curve across the population, which is opposite the linear or spline 2 coefficients, suggesting potential non-linearity; and a larger, positive coefficient on PAM score spline 2 among patients at the higher ends of the PAM score scale (Level 3 or above).

4.3 Specific Aim #3: Patient-reported outcome measures (PROMs)

4.3.1 Descriptive statistics

There were 368 patients (48.8%) of patients who completed evaluable pre- and post-operative VR-12 questionnaires. Fewer patients (n=350, 46.4%) had paired pre- and post-VAS responses and the least number of patients completed both Oxford Knee Score (OKS) assessments (n=320, 42.4%). Table 4.28 reports differences in the characteristics of patients with evaluable paired pre- and post-surgical PROM, for each tool separately, compared to patients who did not have evaluable paired PROM measures. The populations vary by a number of characteristics, suggesting the population responding to both questionnaires is not representative of the study population. First, the proportion of patients with evaluable paired responses was significantly different within PAM levels. The higher the patient activation level, the higher the proportion of patients with paired responses. Patients with the highest level of activation (Level 4) comprised greater than 50% of the population across all PROM tools, while 41% or fewer Level 1 patients had complete responses. The differences were highly significant (p=0.004 or smaller) across each survey type. In addition, patients who complete pre- and post-VR-12 surveys had significantly higher pre-operative PAM scores (mean = 65.7, sd = 13.0) compared to patients without paired surveys (mean = 63.2, sd = 12.5), across all surveys administered (p=0.008). These results are consistent across all three PROMs (OKS p=0.003 and VAS p=0.001). The mean difference in PAM scores between groups is approximately three points for the OKS (66.0 with paired vs 63.3 not paired) and VAS (66.1 with paired vs. 63.0 not paired) (data not shown).

Table 4.28 reports respondents are significantly different consistently across all three PROMs by ethnicity, insurance type, performing surgeon, and discharge location. Uniquely, the OKS paired responses represent significantly lower age among respondents (48.4% are less than 65 years old, p=0.010). Higher proportions of non-Hispanics (44% - 50%) had paired responses ($p < 0.05$ across all PROMs), and commercially insured patients contributed disproportionately to the population with paired PROM responses ($p < 0.01$ across all PROMs). Patients who were discharged to home had a higher proportion of paired responses (44% to 48%) compared to patients discharged to skilled nursing facilities or inpatient rehabilitation centers ("other," $p < 0.04$ across all PROMs).

Finally, examining differences in response populations by performing surgeon suggests certain clinics do better at data capture than others. Patients who had surgeries performed by surgeon 1 (59% to 68%) or surgeon 2 (48% to 67%) had much higher proportions of pre- and post-PROM survey completion compared to patients treated by surgeon 3 (45% to 52%) or all other surgeons (7%) (p<0.0001 across all PROMs).

Health-related Quality of Life (VR-12). Post-operative physical health component scores ranged from 17.8 to 63.2 (mean = 40.5, sd = 9.6), with 90% of patients scoring 54 or lower. Post-operative VR-12 PCS was normally distributed (skewness = -0.2, kurtosis = 2.6) among the 48% of patients who had paired responses. On average, patients reported a 10.1 point increase in PCS after surgery compared to scores obtained at their pre-operative appointments (sd = 10.3). Change in PCS ranged from -11.7 points to 39.7 points, with 90% of patients reporting increases less than 24 points. Data on PCS change were normally distributed (skewness = 0.3, kurtosis = 2.7).

Post-operative mental health component scores ranged from 26.2 to 70.4, with a mean score of 56.4 (sd = 9.6). Some patients reported a decline in mental health related quality of life (low range = -27.1) while other patients reported increases in MCS (high range 38.4). On average, MCS did not change between pre- and post-operative appointments (mean = 0.7, sd = 10.3). Data on post-operative MCS (skewness = -1.3, kurtosis = 4.4) and change in MCS from pre- to post-operative appointments (skewness = 0.1, kurtosis = 4.4) were not normally distributed.

Table 4.29 reports differences in mean 90-post operative score and mean score change from pre- to post-operative appointment for the PCS and MCS, separately. There was a significant difference in 90-day post-operative score achieved by PAM Level (*p*=0.040). Patients entering surgery with the highest level of activation (Level 4) had significantly higher mean PCS (mean = 41.7, sd = 9.8) compared to patients in a lower level of activation; nearly four points higher than Level 1 or 2 patients (mean = 37.8, sd = 10.1). Although mean change over time was not significantly different, a gradient is noted from Level 1 and 2 patients (mean = 8.9 points, sd = 10.3), to Level 3 (mean = 9.6 points, sd = 10.0), and resulting in the largest mean improvement (mean = 11.6 points, sd = 10.8 points) (*p*=0.153). In contrast, results from MCS do not present clear trends. Although patients with increasing levels of activation have increasing pre-operative MCS, post-operative scores do not demonstrate consistency in direction or magnitude of change over time. While patients in Level 1 – Level 3 report slight improvement in MCS over time (Level 1 & 2 mean change = 1.6, sd = 8.9 and Level 3 mean change = 2.4, sd = 10.2), patients at the highest level of activation, Level 4, report a decline in MCS (mean change = -2.7, sd = 10.3) (*p*<0.0001).

The majority of PCS and MCS post-operative scores and change in scores over time are not significantly different within each characteristic. There are some notable exceptions when comparing scores by age, gender, insurance type, smoking status, BMI category, and preforming surgeon. Younger patients have lower post-operative MCS scores (mean score = 54.5, sd = 10.8) compared to older patients (mean score = 57.6, sd = 8.6); however, younger patients also had lower pre-operative scores, and neither age cohort reported significant change in mean MCS score over time (p=0.570). Females experience a significant, although clinically small, decline in MCS between pre- and post-operative assessments (mean change = -1.0, sd =9.9), while males report a small increase in MCS (mean change = 1.7, sd = 10.4) (*p*=0.023).

Patients who are commercially insured report the highest post-operative PCS (mean score = 41.5, sd = 8.7), while Medicaid and Other insurance types have mean post-operative scores three to eight points lower, on average (*p*=0.006). However, there is no significant difference in PCS (*p*=0.624) or MCS (*p*=0.495) score improvement or decline between pre- and post-operative assessments among the different insurance types. While never smokers have significantly higher post-operative PCS (mean score = 41.7, sd = 9.0) and MCS scores (mean score = 56.9, sd = 9.2), particularly compared to current smokers (PCS mean score = 38.1, sd = 10.4 and MCS mean score = 51.1, sd = 11.6), improvement in PCS and MCS over time is consistent between groups (PCS *p*=0.225 and MCS *p*=0.970).

There was no significant differences in post-operative PCS (*p*=0.106) or MCS (*p*=0.508) score by BMI category; both scores varied by approximately two-to-three points between categories. Of note, there was a significant difference in mean improvement in PCS over time between BMI categories (*p*=0.016). Patients in the obese category (BMI 30.0 or above) reported the highest mean increase in physical functioning related quality of life (mean change = 11.3, sd = 9.6). The improvement is nearly three and four-points greater than overweight (mean change = 8.5, sd = 11.2) and normal or underweight patients (mean change = 7.4, sd = 9.5), respectively.

The resulting 90-day post-operative PCS score varies between performing surgeons. Surgeon 1 operates on patients who have the highest post-operative physical health-related quality of life (mean score = 42.3, sd = 9.0), which is between two and six points higher, on average, then the other three surgeon groups (*p*=0.010). Consistent with high post-operative scores, Surgeon 1 also has the largest mean change in scores from pre- to post-operative assessments (mean change = 11.3, sd = 10.4); however, the improvement is not statistically significant (*p*=0.125). Finally, patients not discharged to home improve significantly more in mental health related quality of life over time (mean change = 4.0 points, sd = 10.5) compared to patients discharged to home who report essentially unchanged MCS over time (mean change = 0.3 points, sd = 10.2).

Oxford Knee Score (OKS) – Functional assessment of the knee. Among the 42% of patients (n=320) who had a paired pre- and post-operative OKS, post-operative scores ranged from 16 to 48 points (mean = 54.9, sd = 7.4). While on average, the majority of patients reported improvement from pre- to post-operative assessments (mean = 11.4, sd = 8.7), change in score over time ranged from -10 points to 32 points. Post-operative OKS scores were slightly left skewed (skewness = -0.8, kurtosis = 3.2); however, change in OKS score over time was approximately normal (skewness = -0.2, kurtosis = 2.8).

Table 4.30 reports the mean pre-operative, post-operative and change between assessments among patients with paired OKS assessments. Between PAM Levels, differences in post-operative OKS score approaches statistical significance (*p*=0.060), with patients in the two lowest levels reporting score approximately three points lower, on average (mean score = 33.7, sd = 8.4), than patients in Level 3 (mean score = 36.6, sd = 6.8) or 4 (mean score = 36.3, sd = 7.8). Yet, patients across each level of activation demonstrate somewhat consistent improvement between pre- and post-surgical assessments (*p*=0.753).

Consistent with PAM Level, age category, insurance type, and smoking status, have significantly different 90-day post-operative scores between categories within each characteristic, but the mean change in scores from pre- to post-operative assessment did not demonstrate significantly different improvement. Patients 65 years or older report, on average, nearly a three point higher post-operative OKS (mean score = 37.2, sd = 6.8) compared to younger TKA patients (mean score = 34.6, sd = 7.9) (*p*=0.002). In addition, patients with commercial insurance and Medicare beneficiaries have significantly higher post-operative scores compared to Medicaid beneficiaries or other types of payers (*p*<0.0001). Last, never smokers have the highest mean 90-day post-operative OKS (mean score = 36.9, sd = 6.9), with a decreasing mean score among former smokers (mean score = 35.6, sd = 7.8) and current smokers (mean score = 31.8, sd = 8.5) (*p*=0.005).

There were three characteristics in which the change in pre- to post-operative OKS was significantly different between categories: performing provider, BMI, and length of stay. Performing provider was the only category in which the actual post-operative OKS score (*p*=0.0002) and change in score from pre- to post-operative assessment (*p*=0.002) were both significantly different. Consistent with VR-12 PCS score, patients who had procedures performed by Surgeon 1 report the highest post-operative OKS score (mean score = 37.8, sd = 6.7). Unlike VR-12 PCS score, the result extends to mean change between survey administrations, in which Surgeon 1 also produces the highest mean improvement in physical functioning of the knee, specifically (mean change = 12.8 points, sd = 8.4). Contrasted with the lower volume Surgeon 3, in which pre-operative OKS is nearly identical to Surgeon 1; however, patients improve, on average, five points less after surgery (mean change = 7.3, sd = 8.2).

BMI categories for the OKS are also consistent with overall physical health-related quality of life (VR-12 PCS); obese patients reported greater pre- to post-operative improvement in knee-specific functioning (mean change = 12.9, sd = 8.4) compared to overweight (mean change = 9.1, sd = 8.8) and normal or underweight patients (mean change = 9.2, sd = 8.8) (*p*=0.0008). Despite a six point gap in pre-operative OKS scores, obese patients close the gap post-operatively and average only a two-point lower post-operative OKS, although these data are not statistically significant (*p*=0.063).

Finally, patients who have a longer length of stay (≥ 3 days) report higher overall mean improvement in OKS over time (mean change = 13.1, sd = 8.6). There was no significant change in 90-day post-operative score overall (mean difference between typical and long length of stay = 1.3 points) (p=0.159).

Visual Analogue Pain Scale (VAS). Among the 46% of patients (n=350) with paired pre-operative and post-operative VAS scores, post-operative pain ratings ranged from zero to 9, with a mean of 3.8 (sd = 1.2). Overall, 90% of patients reported 90-day post-operative pain equal to four or less on the zero to 10 pain scale. Post-operative VAS score was not normally distributed (skewness = 1.2, kurtosis = 4.2). In contrast, change in VAS score from pre- to post-operative assessment was approximately normally distributed (skewness = 0.2, kurtosis = 3.2). More than 75% of patients reported at least a one-point improvement in self-reported pain between assessments. On average, pain decreased by 3.1 points (sd = 2.7), but change in pain ranged from a nine-point decrease to a six point increase between collection intervals.

Table 4.31 provides the mean pre-operative, 90-day post-operative, and difference in self- reported pain on the VAS, within each demographic or surgical characteristic. There was no significant difference in post-operative score (p=0.538) or change from pre- to post-operative VAS between PAM Levels (p=0.246). Although not statistically significant, it is important to note a gradient in pain reduction between the lowest two PAM Levels (mean change = -2.3 points, sd = 3.0) through Level 3 (mean change = -3.2, sd = 2.5), with the largest pain reduction reported among Level 4 patients (mean change = -3.4, sd = 2.7).

Similar to OKS functional assessments, patients ages 65 years or older have significantly lower post-operative pain scores (mean score = 1.6, sd = 1.9) compared to younger patients (mean score = 2.5, sd = 2.2) (p=0.0001); however, there was no significant difference in the amount of pain reduction over time by age group (p=0.789). There was also a significant difference by self-identified race that was not detected in other PROM measures. Patients who declined race identification had the lowest post-operative pain scores (mean score = 1.3, sd -= 1.5), while patients of a race other than White had the highest 90-day post-operative scores (mean score = 3.4, sd = 2.2) (p=0.024). Also consistent with OKS and VR-12 PCS, patients with commercial insurance or Medicare beneficiaries report, on average, at least one point lower on the VAS compared to Medicaid beneficiaries or those with other types of insurance (p=0.006). However, the amount of pain reduction from pre- to post-assessment is consistent across insurance types (p=0.995).

Current smokers report the highest post-operative pain scores (mean score = 3.4, sd = 2.6), which is nearly double that of never smokers (mean score = 1.8, sd = 1.8) (p=0.021). Consistent with the PROM reported above, post-operative pain score also varies by performing Surgeon; patients of Surgeon 1 have the lowest mean pain score (mean score = 1.7, sd = 1.9).

However, unlike OKS functional knee outcomes, there was no significant difference in the change in VAS from pre- to post-operative assessments by performing surgeon (*p*=0.808).

BMI category again presents significantly different mean reduction in pain between assessment periods (*p*=0.045). Obese patients report the highest mean reduction in pain (-3.4 points, sd = 2.8); followed by overweight patients and normal or underweight patients who report pain reductions of 2.8 points (sd = 2.7) and 2.4 points (sd = 3.1), respectively. The only other characteristic with notable significant differences in pain reduction over time is discharge status; patients not discharged to home have, on average, 1.4 additional reduction in VAS pain score compared to patients who were discharged to home (*p*=0.004).

Linear relationship between PAM score and PROMs. Each PROM measure is a linear score in which a low score is less functioning, or pain, and a higher score indicates the patient has higher health related quality of life, knee function, or pain. Table 4.32 reports the unadjusted linear relationship between PAM score and each patient reported outcome measure. OKS and VR-12 PCS scores were approximately normally distributed for both post-operative assessments. However, VR-12 MCS post-operative assessment and change from pre- to post-operative assessment were skewed, as was the 90 day post-operative VAS. As a result, Table 4.32 reports the linear relationship between the raw score or the normally distributed log-transformed score, where applicable (semi-elasticity model).

A significant linear relationship exists between PAM score and at least one outcome measure (post-operative score or change in pre- to post-operative score) across all PROMs assessed. First, when assessing 90 day post-operative outcome score, on average, every 10-point increase in PAM score:

- **increases** post-operative **OKS** by 0.7 points (*p*=0.026).
- **increases** post-operative **VR-12 PCS** by 1.1 points (*p*=0.003).
- **increases** post-operative **VR-12 MCS** by 0.98 points (*p*=0.011)

There was no significant linear relationship between PAM score and post-operative self-reported pain on the VAS (*p*=0.129). There was also no significant linear relationship between the change in score from pre- to post-operative assessment on the OKS (*p*=0.520) or VR-12 PCS (*p*=0.185). However, as PAM score increases, the change from pre- to post-operative VR-12 MCS and self-reported pain both decrease. When assessing score change over time, on average, every 10-point increase in PAM score:

- **decreases** change from pre- to post-operative **MCS** score by 1.2 points (*p*=0.004).
- **decreases** the change from pre- to post-operative **VAS** self-reported pain by 0.24 points (*p*=0.026).

4.3.2 OLS models examining predictors of 90-day post-operative score and change in score from pre- to post-operative assessment

VR-12 PCS and MCS (Health-related quality of life). Table 4.33 reports the predictors of physical health related quality of life score, as measured by VR-12 PCS, and mental health related quality of life score, the VR-12 MCS. Overall score at 90-days post-operatively and change in score from pre- to post-operative assessments are reported in separate OLS models for PAM Level and score, respectively. Both PAM Level and PAM score were significantly associated with patient-reported post-operative PCS. Model 23 reports, on average, patients at the lowest two levels of activation score 3.42 fewer points on the VR-12 PCS post-operatively compared to patients at the highest level of activation (95% CI = -6.54, -0.30, p=0.032). Although not statistically significant, there is a gradient across the three PAM Level categories, with PAM Level 3 patients performing better than Level 1 & 2 patients, but still achieving a lower score compared to Level 4 patients. Commensurate with PAM Level findings, in Model 24, there is a significant association between the continuous PAM score and post-operative physical health related quality of life. On average, for every 10 point increase in PAM score, post-operative VR-12 PCS increases by one point (p=0.010), after adjusting for all other model covariates.

Insurance type, smoking status, and performing surgeon are also associated with post-operative VR-12 PCS. Other insurance type is primarily worker's compensation and Veteran's benefits; however, there were only 19 patients with "Other" payer type. Compared to never smokers, former smokers have, on average, 2.25 lower post-operative PCS scores (Model 23, 95% CI = -4.36, -0.13, p=0.037). Finally, patients who elected to have surgery with Surgeon 3 score an average of 3.71 less points on the VR-12 PCS post-operatively compared to patient who had surgery performed by Surgeon 1 (Model 23, 95% CI = -6.47, -0.96, p=0.008). Findings are similar for Model 24, assessing PAM score as the predictor of interest. Errors for Model 23 and 24 were verified to be homoskedastic (White's test Model 23 p=0.365; Model 24 p=0.563), and no concerning multicollinearity was detected (mean VIF Model 23 = 1.35; Model 24 = 1.33). The highest degree of inflation detected was for age (VIF = 2.42) and Medicare insurance type (VIF = 2.26). The two variables are correlated at 0.637; however, all other covariates had VIF values under 2.0 and pairwise correlations less than 0.300.

Models 25 and 26 report predictors of change in pre- to post-operative VR-12 PCS. There is a significant association between patient activation level (Model 25) and the improvement gained in health-related quality of life between assessment periods. Patients in the highest level of activation (Level 4, reference) achieve the most improvement in score over time, followed by Level 3 patients, and Level 1 & 2 patients report the least amount of change. On average, patients in PAM Level 3 pre-operatively show -2.63 fewer points of improvement over time compared to Level 4 patients (95% CI = -5.08, -0.19, *p*=0.035). Patients in the two lowest levels of PAM have less improvement; -3.74 fewer than PAM Level 4 patients on average (95% CI = -7.19, -0.30, *p*=0.033). In contrast, there is no association between PAM score (Model 26) and change in VR-12 PCS over time, although the coefficient did approach statistical significance (*p*=0.070).

There is a significant positive association between BMI and the magnitude of PCS score change from pre- to post-operative assessment. The magnitude of the association is consistent across PAM functional forms; for each 5-point increase in BMI, change in VR-12 PCS improves by 1.4 points, on average (95% CI = 0.64, 2.19, *p*<0.0001). Patients who elected surgery with Surgeon 3 compared to Surgeon 1, achieve on average, 4.06 fewer points of improvement on the VR-12 PCS (Model 25, 95% CI = -7.11, -1.01, *p*=0.009). The difference in score change over time is approximately two points less than Surgeon 2 and all other surgeons combined.

Models 27 through 30 compare the mental health related quality of life score (VR-12 MCS) post-operatively and over time (pre- to post-operatively). Patient activation is significantly associated with overall post-operative VR-12 MCS as well as the change in MCS between pre- and post-operative assessments, in both functional forms of PAM. Model 27 reports patients at the lowest two levels of activation have, on average, nearly 5-point lower post-operative MCS compared to PAM Level 4 patients (ceof = -4.98, 95% CI = -8.50, -1.47, *p*=0.006). Level 3 patients report slightly higher MCS compared to Level 4, although the association is not statistically significant (*p*=0.571). Patients who self-reported race as Non-White had a higher a significantly higher post-operative MCS compared to White patients (*p*=0.032). Overall, Model 27 remained heteroskedastic after employing robust standard errors (White's test; *p*=0.016). When regressing PAM Level 1 & 2 and Non-White covariates, separately, on the squared error of Model 27, no local heteroscedasticity was detected in either statistically significant variable reported. No concerning multicollinearity was detected (VIF = 1.35).

Model 28 outputs a positive, significant linear relationship between PAM score and post-operative MCS at 90-days (*p*=0.007). For every 10-point increase in PAM score, MCS increases by nearly one-point post-operatively (coef = 0.09, 95% CI= 0.01, 0.17, *p*=0.025). No other model covariates were associated with post-operative MCS. Consistent with Model 27, general heteroscedasticity was detected after employing robust standard errors (White's test; *p*=0.030). No local heteroscedasticity was present in the PAM score predictor of interest.

Models 29 and 30 were reasonably well specified, resulting in homoskedastic errors (White's test; Model 29 *p*=0.382 and Model 30 *p*=0.140). In addition, there was no concerning multicollinearity detected in either model (VIF; Model 29 = 1.35 and Model 30 = 1.33). Improvement in MCS over time was significantly associated with both PAM Level and score models. For PAM Level as the predictor of interest, patients at lower activation levels demonstrate a greater improvement in MCS between pre- and post-operative assessments compared to Level 4 patients. Both groups have approximately 5-point gain in MCS compared to patients at the highest level of activation. However, patients at Level 4 activation pre-operatively had a mean pre-operative score of 59.3, compared to Level 3 patients at 55.0 and Level 1 & 2 patients at 51.4; therefore, lower level patient had greater opportunity for improvement in MCS (see Table 4.4). Model 30 presents with a similar trend for PAM score; as pre-operative PAM score increases, the magnitude of change between assessments decreased. For every 10-point increase in PAM score, the magnitude of change in MCS declined by 1.2 points (95% CI = -20.0, -3.2, *p*=0.007).

In both PAM function form models, males reported less change in MCS compared to females. On average, males had 3.1 points less change in MCS compared to females (Model 29, 95% CI = -5.1, -0.57, *p*=0.014). Results for the association of self-identified gender on MCS change was similar for Model 30. In contrast, the performing surgeon was significantly associated with MCS change in Model 30 (PAM score), but did not result in significant findings for Model 29 (PAM Level, Surgeon 3 coefficient, *p*=0.061). The magnitude of the coefficients were similar between models; however, with approximately 3-point less change among males (Model 30 95% CI = -6.1, -0.10, *p*=0.046). Finally, patients with initial extended length of stays following the TKA procedure have significantly less change in MCS over time compared to patients discharged on or before post-operative day two in Model 29 and Model 30 (coef = -2.6).

Oxford Knee Score and Visual Analogue Pain Scale (Functional status and pain).

Table 4.34 reports predictors of functional status of the knee, via the Oxford Knee Score (OKS) and patient self-reported pain utilizing a Visual Analogue Pain Scale (VAS). Both measure are reported for 90-days after TKA surgery, and separately, the change in OKS an pain rating between pre-operative and post-operative assessments.

Similar to the VR-12 MCS at 90-days post-operatively, the model for examining predictors of OKS score remained heteroskedastic after utilizing robust standard errors for Model 31 (White's test, *p*=0.037) and Model 32 (White's test, *p*=0.029). To address the potential impact of the remaining unrestricted heteroscedasticity on the interpretation of the covariates of interest, each covariate was regressed on the respective model's squared error. Variables identified as significant in Model 31 and 32 were patient age, insurance type identified as "other," and performing Surgeon 3. Local heteroscedasticity was present for patients with "other" insurance types ($p<0.0001$), and neared significance for patient age ($p=0.063$). Because the variance of the error term is not constant at different levels of age, or within patients with "other" payer types, interpreting coefficients for the population mean (i.e., coefficient for patient age) may be misleading. The coefficient for PAM score in Model 32 did result in local heteroskedasticty ($p=0.046$). There is a significant positive relationship between PAM score and 90-day OKS, after adjusting for all other model covariates (coef = 0.07, 95% CI = 0.003, 0.13, $p=0.039$).

In constrast, change in OKS between pre- and post-operative assessments was modeled successfully with homoskedastic errors after specification of robust standard errors (White's test; Model 33 $p=0.557$ and Model 34 $p=0.381$) and no concerning multicollinearity was detected (VIF; Model 33 p=1.35 and Model 34 p=1.33). There was no association between patient activation level, or score, and change in OKS over time. Albeit not statistically significant, there is a potential gradient between PAM Levels with Level 4 patients (reference) demonstrating the greatest increase in score over time, followed by PAM Level 3, and then Level 1 & 2 patients.

Among model covariates, pre-operative BMI and the performing surgeon resulted were significant predictors of OKS change. The amount of improvement, measured in the magnitude of score change, increases as BMI increases in the study population. For every 5-point increase in BMI, patients improve by two OKS points, on average (Model 33 OKS Change = 1.9, 95% CI = 1.3, 2.6, $p<0.0001$). Results are consistent with Model 34, utilizing PAM score as the predictor of interest. In addition, compared to patients who elected to have surgery performed by Surgeon 1, patients who were treated by Surgeon 3 have significantly lower pre- to post-operative improvement in OKS (Model 33 and Model 34 $p<0.0001$). On average, Surgeon 3's patients report 5.5 points less improvement in OKS between assessment periods (Model 33 95% CI = -8.1, -2.8).

Models 35 and 36 identify predictors of post-operative self-reported pain on the VAS at 90-days. Application of robust standard errors did not address model heteroscedasticity in 90-day post-operative models (White's test; Model 35 $p=0.041$ and Model 36 $p=0.031$). There was no local heteroskedasticity present among covariates significantly associated to patient pain scores at 90-days post-operatively. Increasing age resulted in lower pain scores; for each 10-year increase in age, post-operative VAS scores were 15% lower (Model 35, 95% CI = -27%, -4%, $p=0.007$). The performing surgeon was positively associated with post-operative pain.

Patients who had their TKA performed by Surgeon 3 had, on average, 28% higher pain scores post-operatively compared to patients who were treated by Surgeon 1 (Model 35 95% CI = 3%, 58%, *p*=0.025). Extended length of stay following the TKA procedure had a similar effect (20%; 95% CI = 3%, 42%, *p*=0.035). Results are consistent for Model 36 examining PAM score as the predictor of interest.

Last, Models 37 and 38 report change in pain level from pre- to post-operative assessment (Table 4.34). Unlike 90-day outcome models, VAS change over time was better specified, resulting in no general heteroskedasticity (White's test; Model 37 *p*=0.428 and Model 38 *p*=0.454). The variable set was consistent with prior models presenting no concerning multicollinearity. Both PAM Level and PAM score models yielded significant associations between patient activation and post-operative VAS score. Compared to PAM Level 4 patients, patients identified as PAM Level 1 or 2 pre-operatively report 1.58-point higher change in pain score, on average (95% CI = 0.61, 2.55, *p*=0.001). However, when measuring pain reduction, the lower the negative value, the better the improvement in pain; therefore, examining mean predicted values for self-reported pain reduction more readily identifies the impact of patient activation on pain self-assessment. At the mean, the predicted change in pain assessment among Level 1 & 2 patients is -2.34 (sd = 0.86), or approximately a two-point reduction in pain post-operatively compared to pre-operative assessments. In contrast, Level 4 patients report, at the predicted mean, a 3.41 (sd = 0.77) reduction in self-reported pain. In Model 38, the direction of the association is consistent; as PAM score increases the reduction in pain score continues to increase. For every 10-point increase in PAM score the difference in VAS score between pre- and post-operative assessments grows increasingly more negative; 0.40 additional point *reduction* over time (95% CI = -0.59, -0.12, *p*=0.001).

Consistent with knee functional status and physical-health VR-12 component score, in which increasing BMI was associated with improved outcomes over time, as BMI increases, the post-operative pain score declines. On average, for every 5-point increase in BMI, the pre- to post-operative change in pain declines by nearly one-half point (0.45, 95% CI = -0.66, 0.22, *p*<0.0001). For example, a patient with a pre-operative BMI equal to 25 would be expected to demonstrate a 2.4 point reduction in knee pain; BMI of 30 reports a 2.7 point reduction; and BMI equal to 35 reports 3.2 point reduction in pain between assessments.

Last, compared to patients discharged to home, patients who went to a skilled nursing facility or inpatient rehabilitation center following surgery self-report a greater reduction in self-reported pain. On average, patients who originally were discharged to a care facility reported a 1.84 point greater pain reduction (Model 37 95% CI = -2.79, -0.89, *p*<0.0001). Of note, unlike the previously reported patient reported outcomes scores at 90-days and change in scores over time, the performing surgeon was not significantly associated with change in patient self-reported pain assessment. Results for discharge location in Model 38 were consistent with findings for Model 37.

Table 4.35 reports changes in the coefficient on PAM Level and PAM score for select sensitivity analyses. First, there were five outliers identified by employing the difference in fits statistic to Models 23-24 (VR-12 PCS 90-day post-operative score). Excluding influential observations did not change the direction or significance of the coefficient on PAM Level 3. The magnitude of the coefficient slightly increased from -3.42 to -3.48. These findings are consistent with the assessment of post-operative MCS, as well as the change in VR-12 PCS score over time and change in VAS pain score between assessments.

Restricted cubic spline regression reveals important information regarding the linearity of the association between PAM score and the model outcomes for patient-reported health related quality of life (VR-12), functional status (OKS) and pain (VAS). All three coefficients in the spline models for 90-day VR-12 PCS were significant. The first linear coefficient reveals a larger coefficient than the reported model (Model 24) and can be interpreted as the association between PAM score and VR-12 PCS below the first knot (PAM Level 1 & 2). For patients who score at the lowest levels of PAM, every one-point increase in PAM score results in a two point-gain in post-operative VR-12 PCS (95% CI = 0.44, 3.56, p=0.012). The coefficient on PAM spline 2 is significant at p=0.014, which means across the entire population, the relationship is significantly non-linear. Finally, for patients at the highest two levels of activation, the relationship is also significantly non-linear and the magnitude of the association between PAM score and VR-12 post-operative PCS is greater for patients at higher levels of activation (p=0.012). Jointly, PAM spline coefficients are significantly associated with 90-day VR-12 PCS (F-test, p=0.004). For all other patient reported outcome measures, the assumption of linearity holds (p>0.05), as evaluable by the coefficient and robust standard errors on PAM spline 1 and spline 2.

Table 4.1: Characteristics[a] of patients with non-staged, unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015, stratified by patients with accompanying Patient Activation Measure baselines score "study population" compared to those without, "excluded" (N=810),[b] Table 1 of 2.

Characteristic	**Study population:** Unilateral TKA with baseline PAM score (n=754)		**Excluded:** Unilateral TKA without baseline PAM score (n=56)		*p* value
	(%)[f]	*n*	(%)[f]	*n*	
Age, years (mean, sd)	67.3 (9.2)	754	71.0 (7.6)	56	0.002**
Gender					
Male	38.9	754	48.2	56	0.167
Female	61.1		51.8		
Race					
White	90.9	754	92.7	55	0.804
Other	4.1		1.8		
Declined	5.0		5.5		
Ethnicity					
Non-Hispanic	81.0	754	83.6	55	0.270
Hispanic	1.6		3.6		
Declined	17.4		12.7		
Insurance Type					
Commercial	27.3	754	12.5	56	0.014*
Medicare	62.3		83.9		
Medicaid	4.8		1.8		
Other[c]	5.6		1.8		
Smoking Status					
Never Smoker	59.7	744	70.4	54	0.050
Former Smoker	32.8		29.6		
Current Smoker	7.5		0.0		
Body Mass Index (mean, sd)	33.0 (6.7)	754	32.5	53	0.699
Charlson Comorbidity Index[e]					
0	75.2	754	67.9	56	0.258
1	20.3		23.2		
≥ 2	4.5		8.9		
Health-Related Quality of Life[a]					
VR-12 PCS	29.9 (9.1)	754	30.8 (7.2)	20	0.677
VR-12 MCS	55.4 (10.6)		52.8 (15.1)		0.276
Performing Provider					
Surgeon 1	29.4	754	23.2	56	0.300
Surgeon 2	28.7		32.1		
Surgeon 3	15.1		23.2		
All others[d]	26.8		21.4		

Table 4.1: Characteristics[a] of patients with non-staged, unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015, stratified by patients with accompanying Patient Activation Measure baselines score "study population" compared to those without, "excluded" (N=810),[b] Table 2 of 2.

Characteristic	**Study population:** Unilateral TKA with baseline PAM score (n=754)		**Excluded:** Unilateral TKA without baseline PAM score (n=56)		*p* value
	(%)[f]	*n*	(%)[f]	*n*	
Home Distance from Hospital					
≤ 45 miles	80.6	754	83.9	56	0.546
> 45 miles	19.4		16.1		
Length of Stay (mean, sd)[e]	2.4 (0.7)	754	2.4 (0.7)	56	0.886
Discharge Location[e]					
Home	87.7	754	78.6	56	0.051
Other	12.3		21.4		

[a] Abstracted from electronic health record unless otherwise noted.
[b] Percent may not total 100 due to rounding.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
[f] Percent unless indicated in characteristic column.
*$p < 0.05$ ** $p < 0.01$ *** $p < 0.001$; $\chi 2$ or Fisher's exact test (categorical data), *t*-test (continuous data).

Table 4.2: Comparison of characteristics[a] between non-staged, unilateral total knee arthroplasty patients and excluded staged patients (two TKA procedures occurring during the index knee global period), with PAM score collected at pre-operative visit, performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015, (N=806),[b] Table 1 of 2.

Characteristic	**Study population:** Unilateral TKA with baseline PAM score (n=754)		**Excluded:** Staged, unilateral TKA with baseline PAM score (n=52)		*p* value
	(%)[f]	*n*	(%)[f]	*n*	
PAM score (mean, sd)	64.4 (12.8)	754	68.6 (16.5)	52	0.987
PAM Level					
1 – Not yet taking a role	3.1	754	5.8	52	0.031*
2 – Building confidence	15.6		13.5		
3 – Taking action	55.2		38.5		
4 – Maintaining behaviors	26.1		42.3		
Age, years (mean, sd)	67.3 (9.2)	754	65.4 (8.6)	52	0.069
Gender					
Male	38.9	754	57.7	52	0.622
Female	61.1		42.3		
Race					
White	90.9	754	88.5	52	0.592
Other	4.1		3.9		
Declined	5.0		7.7		
Ethnicity					
Non-Hispanic	81.0	754	76.9	52	0.319
Hispanic	1.6		3.9		
Declined	17.4		19.2		
Insurance Type					
Commercial	27.3	754	42.3	52	0.078
Medicare	62.3		48.1		
Medicaid	4.8		1.9		
Other[c]	5.6		7.7		
Smoking Status					
Never Smoker	59.7	744	62.8	51	0.922
Former smoker	32.8		31.4		
Current Smoker	7.5		5.9		
Body Mass Index (mean, sd)	33.0 (6.7)	754	33.5 (6.9)	52	0.706
Charlson Comorbidity Index[e]					
0	75.2	754	71.2	52	0.795
1	20.3		23.1		
≥ 2	4.5		5.8		
Health-Related Quality of Life[a]					
VR-12 PCS	29.9 (9.1)	754	30.7 (7.9)	52	0.519
VR-12 MCS	55.4 (10.5)	754	56.7 (11.6)	52	0.407

Table 4.2: Comparison of characteristics[a] between non-staged, unilateral total knee arthroplasty patients and excluded staged patients (two TKA procedures occurring during the index knee global period), with PAM score collected at pre-operative visit, performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015, (N=806),[b] Table 2 of 2.

Characteristic	**Study population:** Unilateral TKA with baseline PAM score (n=754)		**Excluded:** Staged, unilateral TKA with baseline PAM score (n=52)		*p* value
	(%)[f]	*n*	(%)[f]	*n*	
Performing Provider					
Surgeon 1	29.4	754	26.9	52	0.045*
Surgeon 2	28.7		38.5		
Surgeon 3	15.1		23.1		
All others[d]	26.8		11.5		
Length of Stay[e]	2.4 (0.7)	754	2.3 (0.6)	52	0.605
Home Distance from Hospital					
≤ 45 miles	80.6	754	80.8	52	0.981
> 45 miles	19.4		19.2		
Discharge Location[e]					
Home	87.7	754	92.3	52	0.320
Other	12.3		7.7		

[a] Abstracted from electronic health record unless otherwise noted.
[b] Percent may not total 100 due to rounding.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
[f] Percent unless indicated in characteristic column.
*$p < 0.05$ ** $p < 0.01$ *** $p < 0.001$; $\chi 2$ or Fisher's exact test (categorical data), *t*-test (continuous data).

Table 4.3: Mean PAM score by demographic characteristic[a] for non-staged, unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754),[b] Table 1 of 2.

Characteristic	n (%)	Mean pre-operative PAM score (standard deviation)	*p* value
Age			
Less than 65 years	285 (37.8)	64.2 (11.9)	0.638
65 years or older	469 (62.2)	64.6 (13.4)	
Gender			
Male	293 (38.9)	62.8 (12.4)	0.005**
Female	461 (61.1)	65.5 (13.0)	
Race			
White	685 (90.8)	64.4 (12.8)	0.688
Other	31 (4.2)	63.9 (12.7)	
Declined	38 (5.0)	66.2 (14.3)	
Ethnicity			
Non-Hispanic	611 (81.0)	64.5 (12.9)	0.889
Hispanic	12 (1.6)	62.7 (13.0)	
Declined	131 (17.4)	64.4 (12.4)	
Insurance Type			
Commercial	260 (34.5)	65.6 (11.6)	0.028*
Medicare	470 (62.3)	64.5 (13.6)	
Medicaid	36 (4.8)	62.6 (11.6)	
Other[c]	42 (5.6)	59.3 (9.4)	
Smoking Status			
Never Smoker	444 (59.7)	65.0 (13.4)	0.229
Former smoker	244 (32.8)	63.3 (11.8)	
Current Smoker	56 (7.5)	64.5 (12.0)	
Body Mass Index			
Less than 25.0	72 (9.5)	67.0 (14.9)	0.063
Overweight (25.0 – 29.9)	191 (25.3)	65.4 (12.9)	
Obese (30.0 and above)	491 (65.1)	63.7 (12.4)	
Charlson Comorbidity Index[e]			
0	567 (75.2)	64.7 (13.1)	0.220
1	153 (20.3)	64.5 (12.2)	
≥ 2	34 (4.5)	60.7 (10.4)	
Performing Surgeon			
Surgeon 1	222 (29.4)	65.1 (12.5)	0.530
Surgeon 2	216 (28.6)	64.6 (13.7)	
Surgeon 3	114 (15.1)	64.9 (13.4)	
All others[d]	202 (26.8)	63.3 (11.8)	
Length of Stay[e]			
Less than 3 days	512 (67.9)	64.9 (13.0)	0.184
≥ 3 days	242 (32.1)	63.5 (12.3)	

Table 4.3: Mean PAM score by demographic characteristic[a] for non-staged, unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754),[b] Table 2 of 2.

Characteristic	n (%)	Mean pre-operative PAM score (standard deviation)	*p* value
Home Distance from Hospital			
≤ 45 miles	608 (80.6)	64.4 (12.7)	0.799
> 45 miles	146 (19.4)	64.7 (13.4)	
Discharge Location[e]			
Home	661 (64.8)	64.9 (12.8)	0.009**
Other	93 (61.2)	61.2 (12.5)	

[a] Abstracted from electronic health record unless otherwise noted.
[b] Percent may not total 100 due to rounding.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
*$p < 0.05$ ** $p < 0.01$ *** $p < 0.001$; analysis of variance (ANOVA), *F*-test

Table 4.4: Demographic characteristics[a] for non-staged, unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015, stratified by Patient Activation Measure (PAM) Level (N=754),[b] Table 1 of 2.

Characteristic	N	PAM Levels (% within characteristic)[e]								*p*-value
		1 - Not yet taking a role	*n*	2 – Building knowledge & confidence	*n*	3 – Taking action	*n*	4 – Maintaining behaviors	*n*	
Age, years (mean, sd)	754	65.9 (10.9)	23	67.8 (9.3)	118	68.0 (9.1)	416	65.8 (9.0)	197	0.035*
Gender										
Male	293	2.4	23	14.8	118	54.7	416	22.2	197	0.222
Female	461	4.1		17.1		56.0		22.8		
Race										
White	685	3.2	23	15.6	118	54.7	416	26.4	197	0.713
Other	31	--		12.9		71.0		16.1		
Declined	38	2.6		18.4		50.0		29.0		
Ethnicity										
Non-Hispanic	611	3.6	23	15.4	118	54.2	416	26.8	197	0.424
Hispanic	12	--		16.7		75.0		8.3		
Declined	131	0.8		16.8		58.0		24.4		
Insurance Type										
Commercial	206	1.9	23	11.2	118	55.3	416	31.6	197	0.092
Medicare	470	3.0		17.0		54.7		25.3		
Medicaid	36	5.6		13.9		58.3		22.2		
Other[c]	42	7.1		23.8		57.1		11.9		
Smoking Status										
Never Smoker	444	3.4	23	15.1	117	53.4	411	28.2	193	0.650
Former smoker	244	2.9		16.4		59.0		21.7		
Current Smoker	56	1.8		17.9		53.6		26.8		
Body Mass Index (mean, sd)	754	32.9 (6.0)	23	34.6 (6.2)	118	32.7 (6.8)	416	32.7 (6.7)	197	0.040*
Charlson Comorbidity Index[e]										
0	567	3.4	23	15.2	118	55.2	416	26.3	197	0.322
1	153	2.6		15.0		53.6		28.8		
≥ 2	34	--		26.5		61.8		11.8		
Health-Related Quality of Life[a]										
VR-12 PCS	754	26.3 (10.0)	23	28.4 (8.0)	118	30.4 (9.0)	416	30.3 (9.7)	189	0.038*
VR-12 MCS	754	51.2 (12.7)	23	51.4 (10.8)	118	55.0 (10.5)	416	59.3 (9.1)	189	<0.0001***

Table 4.4: Demographic characteristics[a] for non-staged, unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015, stratified by Patient Activation Measure (PAM) Level (N=754),[b] Table 2 of 2.

Characteristic	N	PAM Levels (% within characteristic)[e]								*p*-value
		1 - Not yet taking a role	*n*	2 – Building knowledge & confidence	*n*	3 – Taking action	*n*	4 – Maintaining behaviors	*n*	
Performing Surgeon										
Surgeon 1	222	3.2	23	11.3	118	58.1	416	27.5	197	0.333
Surgeon 2	216	4.2		18.1		50.5		27.3		
Surgeon 3	114	1.8		18.4		50.9		29.0		
All others[d]	202	2.5		16.3		59.4		21.8		
Length of stay[e]										
Less than 3 days	512	2.7	23	14.5	118	54.5	416	28.3	197	0.154
≥ 3 days	242	3.7		18.2		56.6		21.5		
Home Distance from Hospital										
≤ 45 miles	608	2.8	23	15.3	118	56.3	416	25.7	197	0.550
> 45 miles	146	4.1		17.1		50.7		28.1		
Discharge Location[e]										
Home	661	2.7	23	15.1	118	54.0	416	28.1		0.002**
Other	96	5.4		19.4		63.4		11.8		

[a] Abstracted from electronic health record unless otherwise noted.
[b] Percent may not total 100 due to rounding.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
*$p < 0.05$ ** $p < 0.01$ *** $p < 0.001$; ANOVA (age, BMI, VR-12 PCS and MCS), χ^2 (payer, performing surgeon), Fisher's exact (all else).

Table 4.5: Percent of non-staged, unilateral total knee arthroplasty (TKA) patients who accessed at least one post-acute service within 90 days, with initial TKA procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015, stratified by place of service (N=754),[b] Table 1 of 2.

Characteristic[a]	N	Accessed at least one post-acute service (% within characteristic)							
		Any hospital (n=174)	*p* value	Inpatient (n=34)	*p* value	Outpatient (n=110)	*p* value	ED (n=65)	*p* value
PAM Level									
1 - Not yet taking a role	23	17.4	0.082	8.7	0.054	8.7	0.154	8.7	0.759
2 – Building confidence	118	19.5		1.7		11.9		7.6	
3 - Taking action	416	26.7		6.1		17.3		9.6	
4 – Maintaining behaviors	197	18.3		2.5		11.2		7.1	
Age									
Less than 65 years	285	23.2	0.967	4.2	0.758	16.1	0.347	9.5	0.515
65 years or older	469	23.0		4.7		13.6		8.1	
Gender									
Male	293	24.5	0.241	5.2	0.247	14.1	0.633	10.0	0.096
Female	461	20.8		3.4		15.4		6.5	
Race									
White	685	23.2	0.431	4.8	0.503	14.9	0.535	8.5	0.647
Other	31	29.0		3.2		16.1		12.9	
Declined	38	15.8		--		7.9		7.9	
Ethnicity									
Non-Hispanic	611	23.1	0.074	4.8	0.896	14.1	0.150	8.8	0.342
Hispanic	12	50.0		--		33.3		16.7	
Declined	131	20.6		3.8		15.3		6.9	
Insurance Type									
Commercial	206	19.4	0.005**	2.9	0.476	14.1	0.045*	5.3	0.013*
Medicare	470	25.1		5.5		15.3		9.8	
Medicaid	36	36.1		2.8		22.2		19.4	
Other[c]	42	7.2		2.4		2.4		2.4	
Smoking Status									
Never Smoker	444	22.3	0.568	4.5	1.000	13.3	0.259	8.6	0.978
Former smoker	244	22.5		4.5		14.3		8.6	
Current Smoker	56	22.9		3.6		21.4		8.9	

Table 4.5: Percent of non-staged, unilateral total knee arthroplasty (TKA) patients who accessed at least one post-acute service within 90 days, with initial TKA procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015, stratified by place of service (N=754),[b] Table 2 of 2.

Characteristic[a]	N	Accessed at least one post-acute service (% within characteristic)[e]							
		Any hospital (n=174)	*p* value	Inpatient[f] (n=34)	*p* value	Outpatient[g] (n=110)	*p* value	ED[h] (n=65)	*p* value
Body Mass Index									
Less than 25.0	72	11.1	0.027*	1.4	0.410	6.9	0.139	5.6	0.712
Overweight (25.0 – 29.9)	191	23.0		4.2		15.8		8.9	
Obese (30.0 and above)	491	24.9		5.1		15.5		9.0	
Charlson Comorbidity Index[e]									
0	567	22.6	0.107	4.4	0.341	13.6	0.051	9.4	0.543
1	153	21.6		3.9		15.0		6.5	
≥ 2	34	38.2		8.8		29.4		5.9	
Performing Surgeon									
Surgeon 1	222	20.3	0.240	3.6	0.839	14.4	0.069	6.3	0.321
Surgeon 2	216	22.2		5.1		10.7		9.7	
Surgeon 3	114	21.1		5.3		13.2		7.0	
All others[d]	202	28.2		4.5		19.8		10.9	
Length of Stay[e]									
Less than 3 days	512	18.8	<0.0001***	2.5	<0.0001***	12.5	0.020*	6.1	<0.0001***
≥ 3 days	242	32.2		8.7		19.0		14.1	
Home Distance from Hospital									
≤ 45 miles	608	26.8	<0.0001***	5.1	0.125	16.8	<0.0001***	10.5	<0.0001***
> 45 miles	146	7.5		2.1		5.5		0.7	
Discharge Location[e]									
Home	661	21.8	0.035*	3.8	0.027*	13.9	0.161	7.6	0.010*
Other	93	32.3		9.7		19.4		16.1	

[a] Abstracted from electronic health record unless otherwise noted.
[b] Percent may not total 100 due to rounding.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
[f] Any inpatient hospital post-acute readmission, excluding two patients with post-acute admission to rehabilitation facilities after home discharges.
[g] Outpatient includes hospital-based outpatient services or surgery and procedures at the orthopedic ambulatory surgery center (ASC).
[h] Emergency department (ED).
*$p < 0.05$ ** $p < 0.01$ *** $p < 0.001$; χ^2 (age and gender, all service locations and smoking status for any hospital); Fisher's exact (all else).

Table 4.6: Median and mean total payments[a] and log-transformed total payments, by place of service among non-staged, unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754), Table 1 of 2.

Characteristic[b]	n	Total payments (US dollars)		*p* value[f]	Ln Total Payments (US dollars)		*p* value[f]
		median	mean (sd)		median	mean (sd)	
PAM Level							
1 - Not yet taking a role	23	12,949	14,206 (4,335)	0.478	9.47	9.53 (0.22)	0.448
2 – Building confidence	118	12,949	13,380 (1,914)		9.47	9.50 (0.10)	
3 - Taking action	416	12,949	13,810 (3,290)		9.47	9.52 (0.16)	
4 – Maintaining behaviors	197	12,949	13,348 (1,599)		9.47	9.49 (0.09)	
Age							
Less than 65 years	285	12,949	13,568 (2,651)	0.994	9.47	9.50 (0.14)	0.994
65 years or older	469	12,949	13,674 (2,879)		9.47	9.51 (0.14)	
Gender							
Male	293	12,949	13,664 (3,446)	0.420	9.47	9.51 (0.13)	0.420
Female	461	12,949	13,615 (2,289)		9.47	9.50 (0.15)	
Race							
White	6858	12,949	13,647 (2,874)	0.695	9.47	9.51 (0.14)	0.695
Other	31	12,949	13,967 (2608)		9.47	9.53 (0.15)	
Declined	38	12,949	13,128 (554)		9.47	9.48 (0.04)	
Ethnicity							
Non-Hispanic	611	12,949	13,636 (2712)	0.466	9.47	9.51 (0.13)	0.466
Hispanic	12	12,952	13,115 (369)		9.47	9.48 (0.03)	
Declined	131	12,949	13,669 (3266)		9.47	9.51 (0.16)	
Insurance Type							
Commercial	206	12,949	13,410 (2,511)	0.012*	9.47	9.49 (0.12)	0.012*
Medicare	470	12,949	13,784 (3,073)		9.47	9.51 (0.15)	
Medicaid	36	12,949	13,435 (1,065)		9.47	9.50 (0.07)	
Other[c]	42	12,949	13,217 (1,443)		9.47	9.49 (0.08)	
Smoking Status							
Never Smoker	444	12,949	13,597 (2,494)	0.719	9.47	9.51 (0.13)	0.719
Former smoker	244	12,949	13,552 (2,281)		9.47	9.50 (0.13)	
Current Smoker	56	12,949	13,589 (2,473)		9.47	9.51 (0.13)	

Table 4.6: Median and mean total payments[a] and log-transformed total health payments by place of service among non-staged, unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754), Table 2 of 2.

Characteristic[b]	n	Total payments (US dollars)		*p* value[f]	Ln Total Payments (US dollars)		*p* value[f]
		median	mean (sd)		median	mean (sd)	
Body Mass Index							
Less than 25.0	72	12,949	13,201 (1,103)	0.239	9.47	9.49 (0.07)	0.239
Overweight (25.0 – 29.9)	191	12,949	13,798 (3,097)		9.47	9.52 (0.15)	
Obese (30.0 and above)	491	12,949	13,634 (2,839)		9.47	9.51 (0.14)	
Charlson Comorbidity Index[e]							
0	567	12,949	13,581 (2,686)	0.371	9.47	9.51 (0.13)	0.371
1	153	12,949	13,775 (3,807)		9.47	9.51 (0.16)	
≥ 2	34	12,949	13,877 (2,276)		9.47	9.52 (0.14)	
Performing Surgeon							
Surgeon 1	222	12,949	13,570 (2,326)	0.412	9.47	9.51 (0.13)	0.418
Surgeon 2	216	12,949	13,502 (1,813)		9.47	9.50 (0.11)	
Surgeon 3	114	12,949	13,492 (1,960)		9.47	9.50 (0.11)	
All others[d]	202	12,949	13,926 (4,184)		9.47	9.52 (0.19)	
Length of Stay[e]							
Less than 3 days	512	12,949	13,301 (1,819)	<0.0001***	9.47	9.49 (0.10)	<0.0001***
≥ 3 days	242	12,949	14,341 (4,080)		9.47	9.55 (0.20)	
Home Distance from Hospital							
≤ 45 miles	608	12,949	13,713 (3,013)	0.0001**	9.47	9.51 (0.15)	0.0001**
> 45 miles	146	12,949	13,306 (1,550)		9.47	9.49 (0.09)	
Discharge Location[e]							
Home	661	12,949	13,495 (2,225)	0.012	9.47	9.50 (0.12)	0.012*
Other	93	12,949	14,622 (5,221)		9.47	9.56 (0.23)	

[a] Includes initial admission DRG and professional fee, plus all post-acute hospital, ASC, and clinic payments (excludes routine post-operative clinic payments).
[b] Abstracted from electronic health record unless otherwise noted.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
[f] Mann-Whitney U (age, gender, length of stay, distance from hospital, discharge location) and Krustall-Wallis (all else)
p* < 0.05 ** *p* < 0.01 * *p* <0.001

Table 4.7: Median and mean count and payment for **total post-acute hospital or facility-based visits** (inpatient, outpatient and emergency department),[a] by place of service among non-staged, unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754), Table 1 of 2.

Characteristic[b]	*n*	Count of Post-Acute Visits > 0		*p* value	Total Post-Acute Payments (US dollars)		*p* value	Ln Total Post-Acute Payments (US dollars)		*p* value
		median	mean (sd)		median	mean (sd)		median	mean (sd)	
PAM Level										
1 - Not yet taking a role & 2 – Building confidence	27	1.0	1.63 (1.50)	0.986	638	2,590 (5,015)	0.485	6.46	6.50 (1.65)	0.528
3 - Taking action	111	1.0	1.50 (1.03)		638	2,876 (5,586)		6.46	6.66 (1.74)	
4 – Maintaining behaviors	36	1.0	1.44 (0.97)		497	1,633 (2,890)		6.30	6.30 (1.47)	
Age										
Less than 65 years	66	1.0	1.65 (1.13)	0.136	638	2,501 (4,799)	0.831	6.46	6.53 (1.78)	0.834
65 years or older	108	1.0	1.42 (1.08)		568	2,620 (5,227)		6.34	6.58 (1.61)	
Gender										
Male	61	1.0	1.61 (1.24)	0.579	567	3,037 (6,918)	0.873	6.57	6.54 (1.74)	0.893
Female	113	1.0	1.45 (1.02)		638	2,325 (3,695)		6.46	6.57 (1.63)	
Race										
White	159	1.0	1.59 (1.11)	0.529	629	2,637 (5,214)	0.798	6.45	6.56 (1.68)	0.988
Other	9	1.0	1.44 (0.73)		743	2,590 (3,633)		6.61	6.63 (2.13)	
Declined	--	--	--	--	--	--		--	--	
Ethnicity										
Non-Hispanic	141	1.0	1.48 (1.11)	0.625	638	2,595 (4,928)	0.071	6.45	6.61 (1.64)	0.016*
Hispanic	6	1.0	1.33 (0.82)		159	320 (454)		6.61	4.67 (1.91)	
Declined	27	1.0	1.67 (1.11)		532	2,971 (6,157)		6.50	6.75 (1.55)	
Insurance Type										
Commercial	40	1.0	1.40 (0.84)	0.349	619	2,175 (5,067)	0.602	6.43	6.48 (1.72)	0.669
Medicare	118	1.0	1.51 (1.15)		572	2,825 (5,317)		6.35	6.60 (1.71)	
Medicaid	13	2.0	1.92 (1.38)		637	1,270 (1,452)		6.46	6.59 (1.11)	
Other[c]	--	--	--	--	--	--		--	--	
Smoking Status										
Never Smoker	99	1.0	1.49 (1.09)	0.489	638	2,414 (4467)	0.492	6.46	6.61 (1.60)	0.515
Former smoker	55	1.0	1.44 (1.07)		448	2,372 (3869)		6.11	6.50 (1.67)	
Current Smoker	16	1.0	1.81 (1.33)		376	2,091 (4303)		5.93	6.10 (1.98)	

Table 4.7: Median and mean count and payment for **total post-acute hospital or facility-based visits** (inpatient, outpatient and emergency department, n=174),[a] by place of service among non-staged, unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754), Table 2 of 2.

Characteristic [b]	*n*	Count of Post-Acute Visits > 0		*p* value	Total Post-Acute Payments (US dollars)		*p* value	Ln Total Post-Acute Payments (US dollars)		*p* value
		median	mean (sd)		median	mean (sd)		median	mean (sd)	
Body Mass Index										
Less than 25.0	8	1.0	1.25 (0.71)	0.748	712	1,118 (1,489)	0.981	6.56	6.48 (1.04)	0.991
Overweight (25.0 – 29.9)	44	1.0	1.55 (1.21)		638	2,679 (5,454)		6.56	6.55 (1.77)	
Obese (30.0 and above)	122	1.0	1.51 (1.09)		572	2,632 (5,068)		6.35	6.57 (1.68)	
Charlson Comorbidity Index[e]										
0	128	1.0	1.51 (1.09)	0.985	638	2,489 (4,432)	0.673	6.46	6.64 (1.58)	0.580
1	33	1.0	1.54 (1.30)		454	3,231 (7,519)		6.12	6.31 (2.07)	
≥ 2	13	1.0	1.38 (0.65)		638	1,754 (2,789)		6.46	6.46 (1.48)	
Performing Surgeon										
Surgeon 1	45	1.0	1.53 (0.81)	0.690	637	2,420 (4,290)	0.988	6.46	6.52 (1.63)	0.991
Surgeon 2	48	1.0	1.48 (1.27)		625	2,246 (3,084)		6.48	6.58 (1.71)	
Surgeon 3	24	1.0	1.38 (0.82)		532	2,136 (3,351)		6.26	6.46 (1.72)	
All others[d]	57	1.0	1.56 (1.25)		629	3,158 (7,166)		6.45	6.59 (1.69)	
Length of Stay[e]										
Less than 3 days	96	1.0	1.38 (0.76)	0.184	583	1,724 (3,709)	0.180	6.37	6.35 (1.53)	0.063
≥ 3 days	78	1.0	1.67 (1.40)		722	3,622 (6,199)		6.58	6.82 (1.81)	
Home Distance from Hospital										
≤ 45 miles	163	1.0	1.52 (1.12)	0.459	567	2,064 (5,168)	0.365	6.34	6.54 (1.69)	0.442
> 45 miles	11	1.0	1.27 (0.65)		796	2,138 (3,025)		6.94	6.94 (1.30)	
Discharge Location[e]										
Home	144	1.0	1.48 (1.12)	0.235	620	2,772 (4,080)	0.497	5.43	6.51 (1.65)	0.380
Other	30	1.0	1.63 (1.03)		681	4,028 (8,229)		6.52	6.81 (1.79)	

[a] Outpatient includes visits and payments to orthopedic ambulatory surgery center.
[b] Abstracted from electronic health record unless otherwise noted.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
[f]Total payments = Mann-Whitney U (age, gender, length of stay, distance from hospital, discharge location) and Krustall-Wallis (all else); ln transformed total payments = t-test (age, gender, length of stay, distance from hospital, discharge location) and analysis of variance (ANOVA, all else)
$^{*}p < 0.05$ $^{**}p < 0.01$ $^{***}p < 0.001$;

Table 4.8: Median and mean count and payment for total post-acute **inpatient visits** (n=34),[a] among non-staged, unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754), Table 1 of 2.

Characteristic[b]	*n*	Count of Post-Acute Inpatient Visits > 0		*p* value	Total Post-Acute Inpatient Payments (US dollars)		*p* value	Ln Total Post-Acute Inpatient Payments (US dollars)		*p* value
		median	mean (sd)		median	mean (sd)		median	mean (sd)	
PAM Level										
1 - Not yet taking a role & 2 – Building confidence	--	--	--	0.349	--	--	0.406	--	--	0.509
3 - Taking action	25	1.0	1.10 (0.40)		6,183	9,045 (8,296)		8.73	8.88 (0.62)	
4 – Maintaining behaviors	5	1.0	1.00 (0.00)		9,296	7,910 (3,247)		9.14	8.90 (0.46)	
Age										
Less than 65 years	12	1.0	1.17 (0.58)	<0.0001***	5,794	8,936 (7,726)	0.438	8.66	8.85 (0.68)	0.622
65 years or older	22	1.0	1.10 (0.29)		6,476	9,401 (7,366)		8.77	8.97 (0.56)	
Gender										
Male	10	1.0	1.30 (0.67)	0.134	6,550	12,688 (12,231)	0.748	8.74	9.09 (0.86)	0.311
Female	24	1.0	1.04 (0.20)		6,265	7,799 (3,997)		8.79	8.86 (0.46)	
Race										
White	33	1.0	1.12 (0.42)	0.756	6,265	9,189 (7,665)	0.333	8.74	8.91 (0.61)	0.545
Other	--	--	--		--	--		--	--	
Declined	--	--	--		--	--		--	--	
Ethnicity										
Non-Hispanic	29	1.0	1.07 (0.26)	0.610	6,265	8,961 (7,060)	0.923	8.74	8.91 (0.58)	0.744
Hispanic	--	--	--		--	--		--	--	
Declined	--	--	--		--	--		--	--	
Insurance Type										
Commercial	6	1.0	1.33 (0.82)	0.978	5,698	9,427 (10,365)	0.570	8.65	8.80 (0.84)	0.820
Medicare	26	1.0	1.08 (0.27)		6,477	9,356 (7,284)		8.77	8.96 (0.56)	
Medicaid	--	--	--		--	--		--	--	
Other[c]	--	--	--		--	--		--	--	
Smoking Status										
Never Smoker	20	1.0	1.15 (0.49)	0.556	5,936	8,016 (6,309)	0.532	8.69	8.81 (0.55)	0.687
Former smoker	11	1.0	1.00 (0.00)		6,688	8,509 (3,949)		8.81	8.95 (0.48)	
Current Smoker	--	--	--		--	--		--	--	

Table 4.8: Median and mean count and payment for total post-acute **inpatient visits** (n=34),[a] among non-staged, unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754), Table 2 of 2.

Characteristic[b]	*n*	Count of Post-Acute Inpatient Visits > 0		*p* value	Total Post-Acute Inpatient Payments (US dollars)		*p* value	Ln Total Post-Acute Inpatient Payments (US dollars)		*p* value
		median	mean (sd)		median	mean (sd)		median	mean (sd)	
Body Mass Index										
Less than 25.0	--	--	--	0.963	--	--	0.594	--	--	0.710
Overweight (25.0 – 29.9)	8	1.0	1.3 (0.71)		6,591	9,771 (8,794)		8.79	8.93 (0.72)	
Obese (30.0 and above)	25	1.0	1.1 (0.28)		6,265	9,254 (7,408)		8.74	8.94 (0.58)	
Charlson Comorbidity Index[e]										
0	25	1.0	1.12 (0.44)	0.920	6,265	8,648 (5,930)	0.377	8.74	8.91 (0.55)	0.283
1	6	1.0	1.17 (0.41)		8,837	13,727 (13,083)		9.02		
≥ 2	--	--	--		--	--		--	--	
Performing Surgeon										
Surgeon 1	8	1.0	1.25 (0.46)	0.810	6,903	9,134 (5,683)	0.463	8.83	8.95 (0.62)	0.304
Surgeon 2	11	1.0	1.00 (0.00)		6,265	6,823 (2,730)		8.74	8.76 (0.40)	
Surgeon 3	6	1.0	1.00 (0.00)		5,121	6,899 (3,472)		8.53	8.74 (0.47)	
All others[d]	9	1.0	1.25 (0.67)		6,916	13,837 (12,348)		8.84	9.22 (0.80)	
Length of Stay[e]										
Less than 3 days	13	1.0	1.15 (0.55)	0.914	5,698	7,725 (7,046)	0.107	8.65	8.75 (0.58)	0.186
≥ 3 days	21	1.0	1.10 (0.30)		6,916	10,173 (7,870)		8.84	9.03 (0.60)	
Home Distance from Hospital										
≤ 45 miles	31	1.0	1.13 (0.43)	0.555	6,265	9,589 (7,750)	0.137	8.74	8.97 (0.58)	0.156
> 45 miles	--	--	--		--	--		--	--	
Discharge Location[e]										
Home	25	1.0	1.12 (0.44)	0.812	6,688	8,419 (5,598)	0.785	8.81	8.89 (0.52)	0.633
Other	9	1.0	1.11 (0.33)		11,550	11,511 (11,550)		8.70	9.01 (0.82)	

[a] Includes admissions for observation status.
[b] Abstracted from electronic health record unless otherwise noted.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
[f]Total payments = Mann-Whitney U (age, gender, length of stay, distance from hospital, discharge location) and Krustall-Wallis (all else); ln-transformed total payments = t-test (age, gender, length of stay, distance from hospital, discharge location) and analysis of variance (ANOVA, all else)
p* < 0.05 ** *p* < 0.01 * *p* <0.001.

Table 4.9: Median and mean count and payment for total post-acute **outpatient visits** (n=110),[a] among non-staged, unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754), Table 1 of 2.

Characteristic [b]	*n*	Count of Post-Acute Outpatient Visits > 0		*p* value	Total Post-Acute Outpatient Payments (US dollars)		*p* value	Ln Total Post-Acute Outpatient Payments (US dollars)		*p* value
		median	mean (sd)		median	mean (sd)		median	mean (sd)	
PAM Level										
1 – Not yet taking a role & 2 – Building confidence	16	1.0	1.56 (1.09)	0.672	294	840 (1,042)	0.612	5.59	5.87 (1.51)	0.637
3 – Taking action	72	1.0	1.25 (0.62)		310	919 (1,260)		5.72	5.88 (1.52)	
4 – Maintaining behaviors	22	1.0	1.27 (0.63)		165	429 (596)		5.11	5.56 (1.02)	
Age										
Less than 65 years	46	1.0	1.26 (0.65)	0.587	166	823 (1,088)	0.851	5.12	5.75 (1.57)	0.683
65 years or older	64	1.0	1.33 (0.76)		271	799 (1,176)		5.60	5.86 (1.33)	
Gender										
Male	45	1.0	1.31 (0.67)	0.653	426	976 (1,323)	0.100	6.06	6.03 (1.46)	0.191
Female	65	1.0	1.29 (0.74)		159	694 (979)		5.08	5.67 (1.39)	
Race										
White	102	1.0	1.27 (0.66)	0.240	212	740 (1,030)	0.269	5.36	5.78 (1.36)	0.354
Other	5	1.0	1.20 (0.45)		318	1,954 (2,457)		5.77	5.96 (2.66)	
Declined	--	--	--		--	--		--	--	
Ethnicity										
Non-Hispanic	86	1.0	1.31 (0.71)	0.720	268	796 (1,106)	0.041*	5.59	5.83 (1.38)	0.007**
Hispanic	--	--	--		--	--		--	--	--
Declined	20	1.0	1.30 (0.80)		382	1,101 (1,328)		5.94	6.15 (1.30)	
Insurance Type										
Commercial	29	1.0	1.24 (0.69)	0.773	318	816 (1,097)	0.895	5.77	5.80 (1.52)	0.932
Medicare	72	1.0	1.31 (0.72)		213	816 (1,186)		5.36	5.79 (1.44)	
Medicaid	8	1.0	1.50 (0.76)		327	749 (986)		5.79	6.05 (1.07)	
Other[c]	--	--	--		--	--		--	--	--
Smoking Status										
Never Smoker	59	1.0	1.36 (0.74)	0.577	426	906 (1,175)	0.067	5.06	6.01 (1.41)	0.117
Former smoker	35	1.0	1.20 (0.72)		159	622 (1,047)		5.08	5.51 (1.31)	
Current Smoker	12	1.0	1.33 (0.65)		159	615 (1,193)		5.08	5.28 (1.62)	

Table 4.9: Median and mean count and payment for total post-acute **outpatient visits** (n=110),[a] among non-staged, unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754), Table 2 of 2.

Characteristic [b]	*n*	Count of Post-Acute Outpatient Visits > 0		*p* value	Total Post-Acute Outpatient Payments (US dollars)		*p* value	Ln Total Post-Acute Outpatient Payments (US dollars)		*p* value
		median	mean (sd)		median	mean (sd)		median	mean (sd)	
Body Mass Index										
Less than 25.0	5	1.0	1.00 (0.00)	0.707	337	541 (463)	0.866	5.82	5.96 (0.93)	0.941
Overweight (25.0 – 29.9)	29	1.0	1.31 (0.67)		318	940 (1,383)		5.77	5.87 (1.57)	
Obese (30.0 and above)	79	1.0	1.32 (0.75)		173	777 (1,066)		5.16	5.79 (1.41)	
Charlson Comorbidity Index[e]										
0	77	1.0	2.27 (0.66)	0.871	318	856 (1,214)	0.735	5.77	5.90 (1.37)	0.403
1	23	1.0	1.39 (0.89)		171	711 (992)		5.15	5.46 (1.71)	
≥ 2	10	1.0	1.30 (0.67)		523	676 (831)		6.24	5.97 (1.17)	
Performing Surgeon										
Surgeon 1	32	1.0	1.41 (0.61)	0.375	365	871 (1,157)	0.091	5.89	6.00 (1.35)	0.126
Surgeon 2	23	1.0	1.44 (0.99)		159	761 (1,250)		5.08	5.50 (1.58)	
Surgeon 3	15	1.0	1.20 (0.77)		159	277 (288)		5.08	5.21 (1.03)	
All others[d]	40	1.0	1.18 (0.55)		638	988 (1,217)		6.46	6.07 (1.45)	
Length of Stay[e]										
Less than 3 days	64	1.0	1.25 (0.62)	0.401	374	735 (969)	0.369	5.92	5.85 (1.36)	0.754
≥ 3 days	46	1.0	1.37 (0.83)		159	913 (1,337)		5.08	5.77 (1.52)	
Home Distance from Hospital										
≤ 45 miles	102	1.0	1.30 (0.73)	0.804	213	815 (1,166)	0.406	5.36	5.78 (1.45)	0.381
> 45 miles	8	1.0	1.25 (0.46)		638	739 (677)		6.46	6.24 (0.94)	
Discharge Location[e]										
Home	92	1.0	1.32 (0.75)	0.926	311	874 (1,208)	0.243	5.74	5.88 (1.45)	0.293
Other	18	1.0	1.22 (0.43)		159	478 (557)		5.08	5.49 (1.29)	

[a] Outpatient includes visits and payments to orthopedic ambulatory surgery center.
[b] Abstracted from electronic health record unless otherwise noted.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
[f]Total payments = Mann-Whitney U (age, gender, length of stay, distance from hospital, discharge location) and Krustall-Wallis (all else); ln transformed total payments = t-test (age, gender, length of stay, distance from hospital, discharge location) and analysis of variance (ANOVA, all else)
$*p < 0.05$ $**p < 0.01$ $***p < 0.001$.

Table 4.10: Median and mean count and payment for total post-acute **emergency department (ED) visits** (n=65),[a] among non-staged, unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754), Table 1 of 2.

Characteristic [b]	Count of Post-Acute ED Visits > 0			*p* value	Total Post-Acute ED Payments > 0 (US dollars)			*p* value	Ln Total Post-Acute ED Payments > 0 (US dollars)		*p* value
	n	median	mean (sd)		*n*	median	mean (sd)		median	mean (sd)	
PAM Level											
1 – Not yet taking a role & 2 – Building confidence	11	1.0	1.18 (0.60)	0.690	11	650	738 (743)	0.927	6.48	6.32 (0.73)	0.945
3 – Taking action	40	1.0	1.23 (0.62)		39	519	693 (547)		6.25	6.34 (0.92)	
4 – Maintaining behaviors	14	1.0	1.36 (0.63)		13	567	753 (636)		6.34	6.30 (0.89)	
Age											
Less than 65 years	27	1.0	1.37 (0.74)	0.188	26	538	767 (679)	0.817	6.29	6.32 (0.85)	0.705
65 years or older	38	1.0	1.16 (0.49)		37	524	675 (531)		6.26	6.23 (0.90)	
Gender											
Male	19	1.0	1.37 (0.76)	0.382	19	493	762 (513)	0.385	6.30	6.46 (0.60)	0.264
Female	46	1.0	1.20 (0.54)		44	545	692 (629)		6.20	6.19 (0.96)	
Race											
White	58	1.0	1.22 (0.59)	0.826	56	528	724 (621)	0.910	6.27	6.26 (0.91)	0.949
Other	--	--	--		--	--		--	--	--	--
Declined	--	--	--		--	--		--	--	--	--
Ethnicity											
Non-Hispanic	54	1.0	1.20 (0.56)	0.592	53	519	709 (625)	0.664	6.25	6.23 (0.92)	0.705
Hispanic	--	--	--		--	--		--	--	--	--
Declined	9	1.0	1.33 (0.71)		8	645	724 (402)		6.47	6.47 (0.49)	
Insurance Type											
Commercial	11	1.0	1.09 (0.30)	0.591	11	545	614 (498)	0.614	6.30	6.17 (0.77)	0.809
Medicare	46	1.0	1.22 (0.59)		44	527	715 (597)		6.27	6.28 (0.87)	
Medicaid	7	1.0	1.71 (0.95)		7	376	797 (781)		5.93	6.22 (1.13)	
Other[c]	--	--	--		--	--		--	--	--	--
Smoking Status											
Never Smoker	38	1.0	1.16 (0.55)	0.164	37	567	680 (506)	0.578	6.34	6.25 (0.90)	0.638
Former smoker	21	1.0	1.24 (0.54)		21	492	717 (683)		6.20	6.24 (0.85)	
Current Smoker	5	2.0	2.00 (1.00)		4	791	1076 (932)		6.51	6.68 (0.91)	

Table 4.10: Median and mean count and payment for total post-acute **emergency department (ED)** visits (n=65),[a] among non-staged, unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754), Table 2 of 2.

Characteristic [b]	Count of Post-Acute ED Visits > 0			*p* value	Total Post-Acute ED Payments > 0 (US dollars)			*p* value	Ln Total Post-Acute ED Payments > 0 (US dollars)		*p* value
	n	median	mean (sd)		*n*	median	mean (sd)		median	mean (sd)	
Body Mass Index											
Less than 25.0	--	--	--	0.795	--	--	--	0.745	--	--	0.998
Overweight (25.0 – 29.9)	17	1.0	1.18 (0.53)		17	679	734 (508)		6.52	6.28 (1.09)	
Obese (30.0 and above)	44	1.0	1.30 (0.67)		43	492	715 (644)		6.20	6.27 (0.81)	
Charlson Comorbidity Index[e]											
0	53	1.0	1.26 (0.62)	0.886	52	534	701 (560)	0.323	6.28	6.29 (0.76)	0.006**
1	10	1.0	1.20 (0.63)		9	629	881 (794)		6.45	6.55 (0.65)	
≥ 2	--	--	--		--	--		--	--	--	--
Performing Surgeon											
Surgeon 1	14	1.0	1.00 (0.00)	0.680	14	625	570 (261)	0.941	6.44	6.09 (1.07)	0.843
Surgeon 2	21	1.0	1.29 (0.64)		20	534	763 (733)		6.28	6.30 (0.85)	
Surgeon 3	8	1.0	1.13 (0.35)		7	796	815 (622)		6.68	6.39 (0.94)	
All others[d]	22	1.0	1.41 (0.80)		22	506	727 (617)		6.23	6.32 (0.76)	
Length of Stay[e]											
Less than 3 days	31	1.0	1.19 (0.48)	0.958	30	479	601 (440)	0.253	6.17	6.10 (0.95)	0.141
≥ 3 days	34	1.0	1.29 (0.72)		33	711	815 (695)		6.57	6.42 (0.76)	
Home Distance from Hospital											
≤ 45 miles	64	1.0	1.25 (0.62)	0.671	62	527	712 (598)	0.474	6.27	6.26 (0.87)	--
> 45 miles	--	--	--		--	--		--	--	--	--
Discharge Location[e]											
Home	50	1.0	1.28 (0.64)	0.315	49	524	741 (638)	0.856	6.55	6.33 (0.76)	0.310
Other	15	1.0	1.13 (0.52)		14	628	617 (404)		6.74	6.06 (1.18)	

[a] ED visits not resulting in hospital admission. Two ED visits had unusable CPT codes; therefore, the visits are excluded from payment, but included in utilization.
[b] Abstracted from electronic health record unless otherwise noted.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
[f]Total payments = Mann-Whitney U (age, gender, length of stay, distance from hospital, discharge location) and Krustall-Wallis (all else); ln transformed total payments = t-test (age, gender, length of stay, distance from hospital, discharge location) and analysis of variance (ANOVA, all else)
p* < 0.05 ** *p* < 0.01 * *p* <0.001.

Table 4.11: Percent of non-staged, unilateral total knee arthroplasty (TKA) patients who incurred **additional payments for orthopedic clinic care beyond routine post-operative visits** compared to those who did not incur additional payments, initial TKA procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754),[b] Table 1 of 2.

Characteristic[a]	Any clinic visits[f] (n=747)		*p* value	Clinic visits resulting in additional payment[f] (n=92)		*p* value
	n	%		*n*	%	
PAM Level						
1 – Not yet taking a role & 2 – Building confidence	140	99.3	0.673	18	12.8	0.942
3 – Taking action	411	98.8		51	12.3	
4 – Maintaining behaviors	196	99.1		23	11.7	
Age						
Less than 65 years	284	99.7	0.197	41	14.4	0.153
65 years or older	463	98.7		51	10.9	
Gender						
Male	461	99.7	0.180	41	11.1	0.231
Female	293	98.7		51	14.0	
Race						
White	678	98.9	1.00	83	12.1	0.732
Other	31	100.0		3	9.7	
Declined	38	100.0		6	15.8	
Ethnicity						
Non-Hispanic	607	99.4	0.204	75	12.3	1.000
Hispanic	12	100.0		1	8.3	
Declined	128	97.7		16	12.2	
Insurance Type						
Commercial	206	100.0	0.175	26	12.6	0.156
Medicare	464	98.7		59	12.6	
Medicaid	35	97.2		6	16.7	
Other[c]	42	100.0		1	2.4	
Smoking Status						
Never Smoker	437	98.4	0.128	48	10.8	0.334
Former smoker	244	100.0		33	12.5	
Current Smoker	56	100.0		9	16.1	
Body Mass Index						
Less than 25.0	72	100.0	0.470	7	9.7	0.409
Overweight (25.0 – 29.9)	188	98.4		19	10.0	
Obese (30.0 and above)	487	99.2		66	13.4	
Charlson Comorbidity Index[e]						
0	561	98.9	1.00	64	11.3	0.318
1	152	99.4		22	14.4	
≥ 2	34	100.0		6	17.7	
Performing Surgeon						
Surgeon 1	220	99.1	0.714	22	9.9	0.019*
Surgeon 2	215	99.5		20	9.3	
Surgeon 3	112	98.3		13	11.4	
All others[d]	200	99.0		37	18.3	

Table 4.11: Percent of non-staged, unilateral total knee arthroplasty (TKA) patients who incurred **additional payments for orthopedic clinic care beyond routine post-operative visits** compared to those who did not incur additional payments, initial TKA procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754),[b] Table 2 of 2.

Characteristic[a]	Any clinic visits[f] (n=747)		*p* value	Clinic visits resulting in additional payment[f] (n=92)		*p* value
	n	%		*n*	%	*n*
Length of Stay[e]						
Less than 3 days	604	99.3	0.136	73	12.0	0.778
≥ 3 days	143	97.9		19	13.0	
Home Distance from Hospital						
≤ 45 miles	656	99.2	0.210	81	12.3	1.000
> 45 miles	91	97.9		11	11.8	
Discharge Location[e]						
Home	510	99.6	0.038	60	11.7	0.553
Other	237	97.9		32	13.2	

[a] Abstracted from electronic health record unless otherwise noted.
[b] Percent may not total 100 due to rounding.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
[f] Count includes routine post-operative visits plus any additional visits (e.g., for complications or new problems); Payments are only for visits incurring payment (routine post-operative appointments and associated imaging are excluded).
*$p < 0.05$ ** $p < 0.01$ *** $p < 0.001$; χ^2 any clinic visits and additional visits resulting in payments (age, gender, performing surgeon); Fisher's exact any clinic visits (Race, Ethnicity) and additional visits resulting in payments (all else).

Table 4.12: Median and mean count and payment for total post-acute **orthopedic clinic visits** (n=747),[a] among non-staged, unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754), Table 1 of 2.

Characteristic [b]	Count of Post-Acute Clinic Visits > 0			*p* value	Total Post-Acute Clinic Payments > 0 (US dollars)			*p* value	Ln Total Post-Acute Clinic Payments > 0 (US dollars)		*p* value
	n	median	mean (sd)		*n*	median	mean (sd)		median	mean (sd)	
PAM Level											
1 – Not yet taking a role & 2 – Building confidence	140	1.0	1.61 (0.88)	0.630	18	87	101 (62)	0.012*	4.47	4.40 (0.77)	0.009**
3 – Taking action	411	1.0	1.67 (1.01)		51	175	287 (294)		5.17	5.11 (1.15)	
4 – Maintaining behaviors	196	1.0	1.56 (0.82)		23	80	132 (140)		4.39	4.43 (1.00)	
Age											
Less than 65 years	284	1.0	1.74 (1.09)	0.058	41	150	243 (272)	0.363	5.01	4.91 (1.14)	0.369
65 years or older	463	1.0	1.60 (0.83)		51	148	187 (220)		5.01	4.71 (1.06)	
Gender											
Male	292	1.0	1.71 (1.08)	0.167	41	157	201 (200)	0.345	5.06	4.90 (0.95)	0.433
Female	455	1.0	1.57 (0.84)		51	109	221 (278)		4.71	4.72 (1.21)	
Race											
White	678	1.0	1.64 (0.97)	0.281	83	157	216 (243)	0.634	5.06	4.82 (1.11)	0.779
Other	31	2.0	1.71 (0.69)		3	83	85 (10)		4.44	4.45 (0.12)	
Declined	38	1.0	1.42 (0.60)		6	70	221 (332)		4.26	4.62 (1.31)	
Ethnicity											
Non-Hispanic	607	1.0	1.60 (0.88)	0.330	75	150	194 (218)	0.799	5.01	4.78 (1.03)	0.802
Hispanic	12	1.0	1.42 (0.51)		--	--	--		--	--	
Declined	128	2.0	1.77 (1.20)		16	153	304 (342)		4.89	4.93 (1.42)	
Insurance Type											
Commercial	206	1.0	1.67 (1.07)	0.624	26	163	253 (264)	0.579	5.09	5.03 (1.08)	0.609
Medicare	464	1.0	1.59 (0.87)		59	134	200 (246)		4.91	4.72 (1.10)	
Medicaid	35	1.0	1.86 (1.14)		6	117	162 (177)		4.70	4.57 (1.21)	
Other[c]	42	1.0	1.67 (0.85)		--	--	--		--	--	
Smoking Status											
Never Smoker	437	1.0	1.56 (0.88)	0.020*	48	108	175 (210)	0.347	4.69	4.65 (1.03)	0.383
Former smoker	244	1.0	1.67 (1.01)		33	175	253 (278)		5.17	4.90 (1.24)	
Current Smoker	56	2.0	1.93 (1.02)		9	159	265 (311)		5.08	5.13 (0.96)	

Table 4.12: Median and mean count and payment for total post-acute **orthopedic clinic visits** (n=747),[a] among non-staged, unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754), Table 2 of 2.

Characteristic [b]	Count of Post-Acute Clinic Visits > 0			*p* value	Total Post-Acute Clinic Payments > 0 (US dollars)			*p* value	Ln Total Post-Acute ED Payments > 0 (US dollars)		*p* value
	n	median	mean (sd)		*n*	median	mean (sd)		median	mean (sd)	
Body Mass Index											
Less than 25.0	72	1.0	1.64 (0.81)	0.633	7	71	176 (210)	0.304	4.28	4.46 (1.36)	0.419
Overweight (25.0 – 29.9)	188	1.0	1.64 (1.13)		19	175	236 (232)		5.17	5.05 (1.02)	
Obese (30.0 and above)	487	1.0	1.62 (0.88)		66	143	209 (254)		4.97	4.76 (1.09)	
Charlson Comorbidity Index[e]											
0	561	1.0	1.60 (0.94)	0.207	64	158	231 (259)	0.339	5.07	4.92 (1.07)	0.292
1	152	1.5	1.70 (0.87)		22	75	179 (233)		4.33	4.49 (1.22)	
≥ 2	34	1.0	1.82 (1.20)		6	139	126 (66)		4.90	4.68 (0.70)	
Performing Surgeon											
Surgeon 1	220	1.0	1.50 (0.92)	0.0001**	22	167	225 (234)	0.495	5.12	4.98 (0.99)	0.523
Surgeon 2	215	1.0	1.20 (0.51)		20	74	186 (257)		4.32	4.49 (1.24)	
Surgeon 3	112	1.0	1.42 (0.69)		13	138	218 (255)		4.93	4.86 (1.11)	
All others[d]	200	2.0	2.34 (1.04)		37	150	217 (251)		5.01	4.84 (1.09)	
Length of Stay[e]											
Less than 3 days	510	1.0	1.63 (0.96)	0.947	60	167	214 (229)	0.227	5.12	4.89 (1.03)	0.284
≥ 3 days	237	1.0	1.62 (0.91)		32	87	208 (276)		4.47	4.62 (1.22)	
Home Distance from Hospital											
≤ 45 miles	604	1.0	1.64 (0.96)	0.332	73	134	201 (243)	0.271	4.91	4.73 (1.10)	0.254
> 45 miles	143	1.0	1.56 (0.86)		19	175	256 (256)		5.17	5.06 (1.09)	
Discharge Location[e]											
Home	656	1.0	1.64 (0.93)	0.102	81	148	205 (233)	0.995	5.00	4.79 (1.08)	0.756
Other	91	1.0	1.56 (1.04)		11	157	266 (330)		5.06	4.90 (1.25)	

[a] Count includes routine post-operative visits plus any additional visits (e.g., for complications or new problems); Payments are only for visits incurring payment (routine post-operative appointments and associated imaging are excluded).
[b] Abstracted from electronic health record unless otherwise noted.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
[f] Total payments = Mann-Whitney U (age, gender, length of stay, distance from hospital, discharge location) and Krustall-Wallis (all else); ln transformed total payments = t-test (age, gender, length of stay, distance from hospital, discharge location) and analysis of variance (ANOVA, all else)
*$p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

Table 4.13: Percent of non-staged, unilateral total knee arthroplasty (TKA) patients who had **physical therapy (PT) visits** within each patient characteristic compared to patients who did not have PT at the orthopedic clinic, initial TKA procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754),[b] Table 1 of 2.

Characteristic[a]	Any PT visits[f] (n=199)		*p* value
	n	%	
PAM Level			
1 – Not yet taking a role & 2 – Building confidence	31	22.0	0.259
3 – Taking action	109	26.2	
4 – Maintaining behaviors	59	30.0	
Age			
Less than 65 years	73	25.6	0.705
65 years or older	126	26.9	
Gender			
Male	73	26.4	0.463
Female	126	27.3	
Race			
White	179	26.1	0.820
Other	9	29.0	
Declined	11	29.0	
Ethnicity			
Non-Hispanic	152	24.9	0.136
Hispanic	--	--	
Declined	43	32.8	
Insurance Type			
Commercial	49	23.8	0.462
Medicare	126	26.8	
Medicaid	13	36.1	
Other[c]	11	26.2	
Smoking Status			
Never Smoker	118	26.6	0.736
Former smoker	62	25.4	
Current Smoker	17	30.4	
Body Mass Index			
Less than 25.0	21	29.2	0.709
Overweight (25.0 – 29.9)	53	27.8	
Obese (30.0 and above)	125	25.5	
Charlson Comorbidity Index[e]			
0	157	27.7	0.376
1	34	22.2	
≥ 2	8	23.5	
Performing Surgeon			
Surgeon 1	62	27.9	0.676
Surgeon 2	51	26.6	
Surgeon 3	29	25.4	
All others[d]	57	28.2	

Table 4.13: Percent of non-staged, unilateral total knee arthroplasty (TKA) patients who had **physical therapy (PT) visits** within each patient characteristic compared to patients who did not have PT at the orthopedic clinic, initial TKA procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754),[b] Table 2 of 2.

Characteristic[a]	Any PT visits[f] (n=199)		*p* value
	n	%	
Length of Stay[e]			
Less than 3 days	193	31.7	<0.0001***
≥ 3 days	6	4.1	
Home Distance from Hospital			
≤ 45 miles	174	26.3	0.900
> 45 miles	25	26.9	
Discharge Location[e]			
Home	122	23.8	0.022*
Other	77	31.8	

[a] Abstracted from electronic health record unless otherwise noted.
[b] Percent may not total 100 due to rounding.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
[f] Physical therapy visits performed and billed by the orthopedic clinic.
*$p < 0.05$ ** $p < 0.01$ *** $p < 0.001$; χ^2 (age, gender); Fisher's exact (all else).

Table 4.14: Median and mean count and payment for total post-acute **physical therapy (PT) visits** (n=199),[a] among non-staged, unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754), Table 1 of 2.

Characteristic [b]	Count of Post-Acute PT Visits > 0			*p* value	Total Post-Acute PT Payments > 0 (US dollars)		*p* value
	n	median	mean (sd)		median	mean (sd)	
PAM Level							
1 – Not yet taking a role & 2 – Building confidence	31	12.0	13.0 (5.0)	0.874	794	802 (312)	0.846
3 – Taking action	109	13.0	13.1 (5.4)		826	823 (331)	
4 – Maintaining behaviors	59	13.0	12.7 (5.3)		797	794 (323)	
Age							
Less than 65 years	73	12.0	12.4 (5.2)	0.232	784	778 (319)	0.275
65 years or older	126	13.0	13.3 (5.3)		830	830 (327)	
Gender							
Male	73	14.0	14.4 (5.7)	0.003**	880	893 (351)	0.006**
Female	126	12.0	12.1 (4.8)		757	764 (299)	
Race							
White	179	13.0	12.9 (5.3)	0.800	797	806 (324)	0.712
Other	9	13.0	13.0 (5.2)		839	814 (318)	
Declined	11	13.0	14.0 (5.4)		861	889 (345)	
Ethnicity							
Non-Hispanic	152	13.0	12.9 (5.2)	0.271	811	807 (325)	0.353
Hispanic	--	--	--		--	--	
Declined	43	13.0	13.6 (5.3)		839	845 (318)	
Insurance Type							
Commercial	49	14.0	13.9 (5.1)	0.116	871	877 (318)	0.093
Medicare	126	13.0	12.7 (5.4)		796	793 (334)	
Medicaid	13	11.0	10.6 (2.8)		682	657 (173)	
Other[c]	11	15.0	14.7 (5.0)		906	912 (316)	
Smoking Status							
Never Smoker	18	13.0	13.3(5.6)	0.664	819	833 (348)	0.624
Former smoker	62	13.0	12.7 (4.9)		820	792 (300)	
Current Smoker	17	13.0	12.5 (3.6)		818	773 (213)	

Table 4.14: Median and mean count and payment for total post-acute **physical therapy (PT) visits** (n=199),[a] among non-staged, unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754), Table 2 of 2.

Characteristic [b]	Count of Post-Acute PT Visits > 0			*p* value	Total Post-Acute PT Payments > 0 (US dollars)		*p* value
	n	median	mean (sd)		median	mean (sd)	
Body Mass Index							
Less than 25.0	21	13.0	13.0 (4.7)	0.999	804	826 (301)	0.966
Overweight (25.0 – 29.9)	53	13.0	13.0 (5.2)		839	815 (321)	
Obese (30.0 and above)	125	13.0	13.0 (5.4)		792	807 (332)	
Charlson Comorbidity Index[e]							
0	157	13.0	13.4 (5.3)	0.026*	834	834 (331)	0.032*
1	34	11.0	10.8 (4.4)		698	683 (259)	
≥ 2	8	15.0	14.5 (5.4)		915	910 (334)	
Performing Surgeon							
Surgeon 1	62	13.0	12.9 (5.1)	0.787	812	803 (306)	0.801
Surgeon 2	51	13.0	13.2 (5.3)		819	829 (333)	
Surgeon 3	29	13.0	13.7 (5.9)		823	849 (363)	
All others[d]	57	13.0	12.5 (5.1)		798	784 (320)	
Length of Stay[e]							
Less than 3 days	122	13.5	13.9 (5.2)	0.002**	862	868 (322)	0.001**
≥ 3 days	77	12.0	11.5 (5.1)		719	720 (308)	
Home Distance from Hospital							
≤ 45 miles	193	13.0	13.1 (5.2)	0.015*	819	820 (321)	0.020*
> 45 miles	6	6.5	7.8 (5.0)		408	510 (309)	
Discharge Location[e]							
Home	174	13.0	13.3 (5.1)	0.010*	829	832 (317)	0.016*
Other	25	10.0	10.4 (5.4)		662	665 (340)	

[a] Physical therapy visits performed and billed by the orthopedic clinic. Utilization and payment sample size is the same (n=199).
[b] Abstracted from electronic health record unless otherwise noted.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
[f] Dichotomous variables = t-test; analysis of variance (ANOVA) = all else.
*p < 0.05 ** p < 0.01 *** p <0.001.

Table 4.15: Percent of non-staged, unilateral total knee arthroplasty (TKA) patients who had **a long length of stay (≥ 3 days)** within each patient characteristic compared to patients who were discharged on or before post-operative day two, initial TKA procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754),[b] Table 1 of 2.

Characteristic[a]	Long length of stay (≥ 3 days)[f] (n=242)		*p* value
	n	%	
PAM Level			
1 – Not yet taking a role & 2 – Building confidence	53	37.6	0.081
3 – Taking action	137	32.9	
4 – Maintaining behaviors	52	26.4	
Age			
Less than 65 years	77	27.0	0.020*
65 years or older	165	35.2	
Gender			
Male	59	20.4	<0.0001***
Female	183	39.7	
Race			
White	220	32.1	0.845
Other	11	35.5	
Declined	11	29.0	
Ethnicity			
Non-Hispanic	199	32.6	0.265
Hispanic	6	50.0	
Declined	37	28.2	
Insurance Type			
Commercial	40	19.4	<0.0001***
Medicare	178	37.9	
Medicaid	18	50.0	
Other[c]	6	14.3	
Smoking Status			
Never Smoker	146	32.9	0.217
Former smoker	79	32.4	
Current Smoker	12	21.4	
Body Mass Index			
Less than 25.0	22	30.6	0.005**
Overweight (25.0 – 29.9)	44	23.0	
Obese (30.0 and above)	176	35.9	
Charlson Comorbidity Index[e]			
0	160	23.8	<0.0001***
1	64	41.8	
≥ 2	18	52.9	
Performing Surgeon			
Surgeon 1	69	31.1	0.008**
Surgeon 2	78	36.1	
Surgeon 3	22	19.3	
All others[d]	73	36.1	

Table 4.15: Percent of non-staged, unilateral total knee arthroplasty (TKA) patients who had **a long length of stay (≥ 3 days)** within each patient characteristic compared to patients who were discharged on or before post-operative day two, initial TKA procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754), Table 2 of 2.

Characteristic[a]	Long length of stay (≥ 3 days)[b] (n=242)		*p* value
	n	%	
Home Distance from Hospital			
≤ 45 miles	204	33.6	0.080
> 45 miles	38	26.0	
Discharge Location[e]			
Home	160	24.2	<0.0001***
Other	82	88.2	

[a] Abstracted from electronic health record unless otherwise noted.
[b] Orthopedic practice goal is to discharge on post-operative day two.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
*$p < 0.05$ ** $p < 0.01$ *** $p < 0.001$; Fisher's exact (ethnicity, payer) χ^2 (all else)

Table 4.16: Comparison of median and mean **inpatient day count (length of stay)** among patients undergoing non-staged, unilateral total knee arthroplasty, performed by surgeons at two participating community-based hospitals between September 2014 and December 2015, (N=754), Table 1 of 2.

Characteristic[a]	Count of inpatient days[b]			*p* value
	n	median	mean (sd)	
PAM Level				
1 – Not yet taking a role & 2 – Building confidence	141	2.0	2.4 (0.7)	0.250
3 – Taking action	416	2.0	2.4 (0.8)	
4 – Maintaining behaviors	197	2.0	2.3 (0.6)	
Age				
Less than 65 years	285	2.0	2.3 (0.6)	0.015*
65 years or older	469	2.0	2.4 (0.8)	
Gender				
Male	293	2.0	2.2 (0.5)	<0.0001***
Female	461	2.0	2.5 (0.8)	
Race				
White	685	2.0	2.4 (0.6)	0.807
Other	31	2.0	2.6 (1.8)	
Declined	38	2.0	2.3 (0.5)	
Ethnicity				
Non-Hispanic	611	2.0	2.4 (0.6)	0.528
Hispanic	12	2.5	2.4 (0.6)	
Declined	131	2.0	2.4 (1.1)	
Insurance Type				
Commercial	206	2.0	2.2 (0.5)	0.0001**
Medicare	470	2.5	2.4 (0.8)	
Medicaid	36	2.5	2.5 (0.6)	
Other[c]	42	2.0	2.1 (0.6)	
Smoking Status				
Never Smoker	444	2.0	2.4 (0.8)	0.375
Former smoker	244	2.0	2.3 (0.6)	
Current Smoker	56	2.0	2.2 (0.5)	
Body Mass Index				
Less than 25.0	72	2.0	2.4 (0.6)	0.040*
Overweight (25.0 – 29.9)	191	2.0	2.3 (0.9)	
Obese (30.0 and above)	491	2.0	2.4 (0.6)	
Charlson Comorbidity Index[e]				
0	567	2.0	2.3 (0.7)	0.002**
1	153	2.0	2.5 (0.6)	
≥ 2	34	3.0	2.7 (0.8)	
Performing Surgeon				
Surgeon 1	222	2.0	2.4 (0.6)	0.048*
Surgeon 2	216	2.0	2.4 (0.6)	
Surgeon 3	114	2.0	2.2 (0.5)	
All others[d]	202	2.0	2.4 (1.0)	

Table 4.16: Comparison of median and mean **inpatient day count (length of stay)** among patients undergoing non-staged, unilateral total knee arthroplasty, performed by surgeons at two participating community-based hospitals between September 2014 and December 2015, (N=754), Table 2 of 2.

Characteristic[a]	Count of inpatient days[b]			*p* value
	n	median	mean (sd)	
Home Distance from Hospital				
≤ 45 miles	608	2.0	2.4 (0.8)	0.162
> 45 miles	146	2.0	2.3 (0.5)	
Discharge Location[e]				
Home	661	2.0	2.3 (0.7)	<0.0001***
Other	93	3.0	3.1 (0.6)	

[a] Abstracted from electronic health record unless otherwise noted.
[b] Orthopedic practice goal is to discharge on post-operative day two.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
*$p < 0.05$ ** $p < 0.01$ *** $p < 0.001$; Mann-Whitney U (age, gender, distance from hospital, discharge location) and Krustall-Wallis (all else).

Table 4.17: Predictors of accessing post-acute services in the 90-day post-operative period, by place of service, among patients undergoing non-staged, unilateral total knee arthroplasty, performed by surgeons at two participating community based hospitals between September 2014 and December 2015 (N=754), Table 1 of 2.

Characteristic[a]	Logit model of Post-Acute Access > 0 Visits[b] coefficient (robust se)							
	Any Hospital Access (n=174)		Inpatient[f] (n=34)		Outpatient[g] (n=110)		Emergency Department[h] (n=65)	
	Model 1 PAM Level	Model 2 PAM Score	Model 3 PAM Level	Model 4 PAM Score	Model 5 PAM Level	Model 6 PAM Score	Model 7 PAM Level	Model 8 PAM Score
PAM Score	--	-0.011 (0.008)	--	-0.014 (0.014)	--	-0.011 (0.009)	--	-0.005 (0.012)
PAM Level								
1 – Not yet taking a role & 2 – Building confidence	0.024 (0.304)	--	-0.094 (0.729)	--	-0.015 (0.377)	--	-0.115 (0.461)	--
3 – Taking action	**0.503 (0.234)***	--	0.936 (0.484)	--	0.514 (0.28)	--	0.182 (0.339)	--
4 – Maintaining behaviors	--	--	--	--	--	--	--	--
Age	-0.012 (0.015)	-0.010 (0.014)	-0.026 (0.030)	-0.022 (0.029)	-0.027 (0.016)	-0.026 (0.016)	0.009 (0.024)	0.008 (0.024)
Male	0.006 (0.201)	-0.030 (0.201)	-0.147 (0.452)	-0.213 (0.452)	0.304 (0.238)	0.257 (0.237)	-0.202 (0.306)	-0.233 (0.311)
Non-White	-0.098 (0.359)	-0.083 (0.355)	-1.230 (1.147)	-1.233 (1.102)	-0.461 (0.479)	-0.437 (0.476)	0.396 (0.460)	0.381 (0.459)
Other than Non-Hispanic[i]	-0.077 (0.253)	-0.039 (0.251)	-0.225 (0.546)	-0.107 (0.550)	0.240 (0.307)	0.271 (0.304)	-0.44 (0.371)	-0.395 (0.369)
Insurance Type								
Commercial	--	--	--	--	--	--	--	--
Medicare	0.337 (0.272)	0.299 (0.27)	0.76 (0.616)	0.669 (0.670)	0.268 (0.318)	0.227 (0.317)	0.347 (0.421)	0.336 (0.422)
Medicaid	0.369 (0.430)	0.392 (0.424)	-0.729 (1.200)	-0.636 (1.191)	0.058 (0.491)	0.085 (0.488)	**1.116 (0.558)**	**1.129 (0.554)****
Other[c]	-1.256 (0.643)	**-1.268 (0.641)***	-0.23 (1.150)	-0.315 (1.123)	**-2.088 (1.043)***	**-2.117 (1.046)***	-0.944 (1.063)	-0.961 (1.070)
Smoking Status								
Never Smoker	--	--	--	--	--	--	--	--
Former smoker	-0.088 (0.206)	-0.068 (0.206)	-0.125 (0.411)	-0.095 (0.411)	-0.045 (0.243)	-0.023 (0.243)	-0.026 (0.311)	-0.015 (0.310)
Current Smoker	0.203 (0.358)	0.206 (0.352)	-0.114 (0.866)	-0.078 (0.805)	0.27 (0.405)	0.272 (0.406)	-0.136 (0.524)	-0.122 (0.516)
BMI	-0.006 (0.014)	-0.008 (0.014)	-0.027 (0.025)	-0.029 (0.025)	0.002 (0.017)	0.0004 (0.017)	-0.025 (0.020)	-0.025 (0.020)
Charlson Comorbidity Index ≥ 1	-0.081 (0.216)	-0.080 (0.215)	-0.280 (0.434)	-0.265 (0.429)	0.170 (0.248)	0.164 (0.248)	-0.663 (0.376)	-0.672 (0.374)
VR-12 PCS	-0.019 (0.010)	-0.016 (0.01)	**-0.049 (0.021)***	**-0.042 (0.020)***	-0.016 (0.012)	-0.013 (0.012)	-0.016 (0.015)	-0.015 (0.015)
VR-12 MCS	0.005 (0.009)	0.008 (0.009)	0.012 (0.018)	0.015 (0.018)	0.004 (0.011)	0.007 (0.011)	-0.009 (0.012)	-0.006 (0.012)
Performing Surgeon								
Surgeon 1	--	--	--	--	--	--	--	--
Surgeon 2	0.128 (0.251)	0.104 (0.250)	0.435 (0.523)	0.365 (0.502)	-0.374 (0.311)	-0.391 (0.309)	0.522 (0.378)	0.507 (0.381)
Surgeon 3	0.223 (0.303)	0.212 (0.305)	0.909 (0.615)	0.825 (0.596)	-0.040 (0.351)	-0.044 (0.351)	0.378 (0.492)	0.376 (0.493)
All others[d]	0.389 (0.245)	0.401 (0.243)	0.163 (0.547)	0.205 (0.538)	0.318 (0.277)	0.329 (0.277)	0.594 (0.379)	0.606 (0.377)

Table 4.17: Predictors of accessing post-acute services in the 90-day post-operative period, by place of service, among patients undergoing non-staged, unilateral total knee arthroplasty, performed by surgeons at two participating community based hospitals between September 2014 and December 2015 (N=754), Table 2 of 2.

Characteristic[a]	Logit model of Post-Acute Access > 0 Visits[b] coefficient (robust se)							
	Any Hospital Access (n=174)		Inpatient[f] (n=34)		Outpatient[g] (n=110)		Emergency Department[h] (n=65)	
	Model 1 PAM Level	Model 2 PAM Score	Model 3 PAM Level	Model 4 PAM Score	Model 5 PAM Level	Model 6 PAM Score	Model 7 PAM Level	Model 8 PAM Score
Home is > 45 miles	**-1.474 (0.331)*** **	**-1.475 (0.334)*** **	-1.043 (0.647)	-1.022 (0.653)	**-1.206 (0.394)** **	**-1.207 (0.394)** **	**-2.742 (0.979)** **	**-2.751 (0.985)** **
Not discharged home	0.049 (0.286)	0.064 (0.284)	0.163 (0.527)	0.218 (0.530)	0.081 (0.324)	0.090 (0.326)	0.305 (0.414)	0.302 (0.413)
Long length of stay (≥ 3 days)	**0.581 (0.223)** **	**0.578 (0.221)** **	**1.172 (0.481)* **	**1.150 (0.473)* **	0.403 (0.264)	0.406 (0.260)	0.654 (0.334)	0.654 (0.337)

[a] Abstracted from electronic health record unless otherwise noted.
[b] Logit model based on visit count > 0.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
[f] Any inpatient readmission or admission for observation; excluding two patients with post-acute admission to rehabilitation facilities after home discharges.
[g] Outpatient includes hospital-based outpatient services or surgery and procedures at the orthopedic ambulatory surgery center (ASC).
[h] Visits not resulting in hospital admission.
[i] Includes patients self-identified as Hispanic (n= 12) and those who declined (n=131).
p* < 0.05 ** *p* < 0.01 * *p* <0.001

Table 4.18: Average marginal effect of PAM Level on post-acute services access [a] in the 90-day post-operative period, by place of service, among patients undergoing non-staged, unilateral total knee arthroplasty, performed by surgeons at two participating community based hospitals between September 2014 and December 2015 (N=754).

	Average Marginal Effect of PAM Level on Post-Acute Access[b] AME (95% CI)			
	Any Hospital Access (n=174)	Inpatient[c] (n=34)	Outpatient[d] (n=110)	Emergency Department[e] (n=65)
	Model 1 Level	Model 3 Level	Model 5 Level	Model 7 Level
PAM Level				
1 – Not yet taking a role & 2 – Building confidence	0.004 (-0.097, 0.105)	-0.004 (-0.101, 0.093)	-0.002 (-0.094, 0.090)	-0.008 (-0.078, 0.062)
3 – Taking action	**0.081 (0.006, 0.156)***	0.035 (-0.016, 0.087)	0.059 (-0.006, 0.123)	0.013 (-0.043, 0.069)
4 – Maintaining behaviors	--	--	--	--

Note: AME = Average Marginal Effect; CI = Confidence Interval using robust, boot-strapped standard errors (1000 repetitions).
[a] Logit model based on visit count > 0.
[b] Abstracted from TKA admission hospital billing data.
[c] Any inpatient readmission or admission for observation; excluding two patients with post-acute admission to rehabilitation facilities after home discharges.
[d] Outpatient includes hospital-based outpatient services or surgery and procedures at the orthopedic ambulatory surgery center (ASC).
[e] Visits not resulting in hospital admission.
*$p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Table 4.19: Predictors of extended (≥ 3 days) hospital length of stay[a] and corresponding average marginal effects, among patients undergoing non-staged, unilateral total knee arthroplasty, performed by surgeons at two participating community based hospitals between September 2014 and December 2015 (N=754).

	Logit model of Hospital Length of Stay ≥ 3 Days coef (robust se)[b]			
Characteristic[b]	Model 9 PAM Level coef (robust se)[b]	Model 9 AME (95% CI)	Model 10 PAM Score coef (robust se)[b]	Model 10 AME (95% CI)
PAM Score	--	--	0.002 (0.007)	<0.00 (-0.002, 0.002)
PAM Level				
1 – Not yet taking a role & 2 – Building confidence	0.138 (0.294)	0.02 (-0.07, 0.11)	--	--
3 – Taking action	0.069 (0.235)	0.01 (-0.06, 0.08)	--	--
4 – Maintaining behaviors	--	--	--	--
Age	-0.007 (0.016)	< 0.01 (-0.01, 0.003)	-0.006 (0.016)	< -0.00 (-0.001, 0.003)
Male	**-0.576 (0.209)****	**-0.09 (-0.15, -0.03)****	**-0.562 (0.210)****	**-0.09 (-0.15, -0.02)****
Non-White	0.339 (0.329)	0.05 (-0.06, 0.16)	0.346 (0.328)	0.06 (-0.06, 0.17)
Other than Non-Hispanic[e]	-0.224 (0.245)	-0.03 (-0.10, 0.04)	-0.227 (0.245)	-0.03 (-0.11, 0.04)
Insurance Type				
Commercial	--	--	--	--
Medicare	**0.819 (0.284)****	**0.12 (0.04, 0.20)****	**0.818 (0.283)****	**0.12 (0.04, 0.20)****
Medicaid	**1.366 (0.452)****	**0.24 (0.08, 0.41)****	**1.373 (0.454)****	**0.24 (0.08, 0.41)*****
Other[c]	-0.374 (0.565)	-0.05 (-0.20, 0.10)	-0.352 (0.561)	-0.05 (-0.20, 0.10)
Smoking Status				
Never Smoker	--	--	--	--
Former smoker	0.016 (0.207)	<0.01 (-0.06, 0.06)	0.020 (0.207)	<0.01 (-0.06, 0.07)
Current Smoker	-0.830 (0.440)	-0.11 (-22, -0.01)	-0.837 (0.443)	-0.11 (-0.21, 0.01)
BMI	**0.045 (0.015)****	**0.004 (0.002, 0.005)****	**0.045 (0.015)****	0.004 (0.002, 0.005)
Charlson Comorbidity Index ≥ 1[c]	0.319 (0.218)	0.05 (-0.02, 0.12)	0.323 (0.218)	0.05 (-0.02, 0.12)
VR-12 PCS	**-0.032 (0.012)****	**-0.006 (-0.010, -0.002)****	**-0.033 (0.012)****	**-0.006 (-0.010, -0.002)**
VR-12 MCS	-0.002 (0.009)	< -0.00 (-0.003, 0.003)	-0.003 (0.009)	-0.001 (0.003, 0.002)
Performing Surgeon				
Surgeon 1	--	--	--	--
Surgeon 2	0.219 (0.248)	0.03 (-0.04, 0.11)	0.224 (0.248)	0.03 (-0.04, 0.11)
Surgeon 3	**-0.887 (0.359)***	**-0.12 (-0.20, -0.04)***	**-0.882 (0.359)***	**-0.12 (-0.21, -0.03)**
All others[d]	0.174 (0.256)	0.03 (-0.05, 0.11)	0.182 (0.255)	0.03 (-0.05, 0.11)
Home is > 45 miles	-0.176 (0.244)	-0.03 (-0.10, 0.04)	-0.175 (0.243)	-0.03 (-0.10, 0.04)
Not discharged home[c]	**3.139 (0.351)*****	**0.58 (0.49, 0.67)*****	**3.149 (0.351)*****	**0.58 (0.49, 0.67)*****

Note: AME = Average Marginal Effect utilizing the finite-difference method; CI = Confidence Interval using robust, boot-strapped standard errors (1000 repetitions).
[a] Logit model based on hospital length of stay abstracted from hospital billing data; robust standard errors.
[b] Abstracted from electronic health records unless otherwise noted.
[c] Abstracted/calculated from hospital billing data.
[d] Includes nine lower volume surgeons.
[e] Includes patients self-identified as Hispanic (n= 12) and those who declined (n=131).
*p < 0.05, ** p < 0.01, *** p <0.001

Table 4.20: Sensitivity analyses for predictors of extended length of stay (≥ 3 days), comparing changes in modeling approaches on PAM coefficients (Models 9-10).

Models	**Extended (≥ 3 days) Length of Stay**[a] coefficient (robust se)
	Models 9-10
Coefficients Reported in Identified Models	
1 – Not yet taking a role & 2 – Building confidence	0.138 (0.294)
3 – Taking action	0.069 (0.235)
4 – Maintaining behaviors	--
PAM score	0.002 (0.007)
Limited to Patients Discharged to Home Only (n=661)	
1 – Not yet taking a role & 2 – Building confidence	0.071 (0.306)
3 – Taking action	0.062 (0.237)
4 – Maintaining behaviors	**--**
Restricted Cubic Spline Regression	
PAM score spline linear	0.016 (0.148)
PAM score spline 1	-0.003 (0.144)
PAM score spline 2	-0.128 (0.790)

[a] Logit model based on hospital length of stay abstracted from hospital billing data; robust standard errors.
p* < 0.05, ** *p* < 0.01, * *p* <0.001

Table 4.21: Predictors of payments for care through the 90-day post-operative period among patients undergoing non-staged, unilateral total knee arthroplasty, performed by surgeons at two participating community based hospitals between September 2014 and December 2015 (N=754), stratified by payment and place of service type, Table 1 of 2.

Characteristic[a]	OLS if Payment > $0 coefficient (robust se)[b]							
	Ln Total Payments for the TKA Episode of Care[g] ($US) (n=754)		Ln Total Post-Acute Hospital Payments[h] ($US) (n=174)		Ln Total Post-Acute Hospital plus Clinic Payments[i] ($US) (n=227)		Total Post-Acute Physical Therapy Payments[j] ($US) (n=199)	
	Model 11 PAM Level	Model 12 PAM Score	Model 13 PAM Level	Model 14 PAM Score	Model 15 PAM Level	Model 16 PAM Score	Model 17 PAM Level	Model 18 PAM Score
PAM Score	--	<0.000 (0.000)	--	-0.004 (0.011)	--	-0.007 (0.010)	--	-3.57 (1.91)
PAM Level								
1 – Not yet taking a role &								
2 – Building confidence	0.001 (0.013)	--	0.090 (0.447)	--	0.039 (0.399)	--	100.26 (75.67)	--
3 – Taking action	**0.020 (0.010)***	--	0.358 (0.291)	--	**0.644 (0.275)***	--	**118.21 (51.47)***	--
4 – Maintaining behaviors	--	--	--	--	--	--	--	--
Age	-0.001 (0.001)	<0.000 (0.001)	-0.014 (0.024)	-0.008 (0.024)	-0.022 (0.022)	-0.011 (0.023)	3.25 (4.33)	3.81 (4.37)
Male	0.013 (0.012)	0.012 (0.012)	0.005 (0.306)	0.004 (0.309)	-0.267 (0.268)	-0.293 (0.274)	92.87 (49.48)	81.71 (49.56)
Non-White	0 (0.018)	0.001 (0.018)	0.169 (0.506)	0.162 (0.506)	-0.148 (0.472)	-0.163 (0.478)	77.65 (73.18)	87.62 (74.05)
Other than Non-Hispanic[f]	-0.008 (0.017)	-0.007 (0.017)	-0.408 (0.380)	-0.360 (0.384)	-0.229 (0.355)	-0.116 (0.365)	-26.62 (63.35)	-27.44 (64.32)
Insurance Type								
Commercial	--	--	--	--	--	--	--	--
Medicare	0.017 (0.014)	0.015 (0.014)	0.481 (0.445)	0.387 (0.446)	0.305 (0.390)	0.091 (0.397)	-62.54 (77.63)	-70.14 (76.74)
Medicaid	-0.013 (0.018)	-0.013 (0.018)	0.587 (0.597)	0.594 (0.601)	0.248 (0.577)	0.253 (0.586)	-123.46 (63.73)	-126.12 (63.02)
Other[c]	-0.015 (0.018)	-0.015 (0.018)	1.118 (0.602)	1.069 (0.581)	**1.317 (0.490)****	**1.238 (0.462)****	-2.02 (108.47)	-12.28 (108.63)
Smoking Status								
Never Smoker	--	--	--	--	--	--	--	--
Former smoker	-0.009 (0.012)	-0.008 (0.012)	-0.283 (0.280)	-0.248 (0.280)	-0.214 (0.259)	-0.147 (0.264)	-27.43 (47.13)	-23.80 (47.68)
Current Smoker	<0.000 (0.021)	<0.000 (0.021)	-0.807 (0.622)	-0.782 (0.608)	-0.528 (0.567)	-0.413 (0.546)	-17.60 (65.98)	-6.47 (64.04)
BMI	**-0.002 (0.001)***	**-0.002 (0.001)***	-0.030 (0.024)	-0.031 (0.024)	-0.039 (0.023)	-0.039 (0.023)	-0.52 (3.65)	-0.71 (3.66)
Charlson Comorbidity Index ≥ 1	0.002 (0.014)	0.002 (0.014)	-0.389 (0.345)	-0.387 (0.346)	-0.484 (0.310)	-0.526 (0.312)	-62.33 (54.61)	-70.83 (55.32)
VR-12 PCS	-0.001 (0.001)	-0.001 (0.001)	-0.011 (0.017)	-0.010 (0.017)	-0.013 (0.015)	-0.01 (0.015)	**-7.87 (3.02)***	-7.39 (2.98)
VR-12 MCS	<0.000 (0.001)	<0.000 (0.001)	-0.006 (0.014)	-0.005 (0.014)	0.004 (0.012)	0.008 (0.012)	4.04 (2.32)	4.13 (2.26)
Performing Surgeon								
Surgeon 1	--	--	--	--	--	--	--	--
Surgeon 2	0.001 (0.012)	<0.000 (0.012)	-0.070 (0.361)	-0.085 (0.360)	-0.165 (0.333)	-0.18 (0.337)	37.90 (61.78)	41.28 (61.60)
Surgeon 3	0.006 (0.015)	0.004 (0.014)	0.075 (0.457)	0.099 (0.452)	-0.317 (0.407)	-0.23 (0.406)	26.72 (72.68)	26.83 (72.53)
All others[d]	0.012 (0.017)	0.012 (0.017)	-0.041 (0.351)	-0.026 (0.351)	-0.106 (0.319)	-0.061 (0.322)	-59.76 (59.16)	-44.96 (58.46)

Table 4.21: Predictors of payments for care through the 90-day post-operative period among patients undergoing non-staged, unilateral total knee arthroplasty, performed by surgeons at two participating community based hospitals between September 2014 and December 2015 (N=754), stratified payment and place of service type, Table 2 of 2.

Characteristic[a]	OLS if Payment > $0[b] coefficient (robust se)							
	Ln Total Payments for the TKA Episode of Care[g] ($US) (n=754)		Ln Total Post-Acute Hospital Payments[h] ($US) (n=174)		Ln Total Post-Acute Clinic plus Hospital Payments[i] ($US) (n=227)		Total Post-Acute Physical Therapy Payments[j] ($US) (n=199)	
	Model 11 PAM Level	Model 12 PAM Score	Model 13 PAM Level	Model 14 PAM Score	Model 15 PAM Level	Model 16 PAM Score	Model 17 PAM Level	Model 18 PAM Score
Home is > 45 miles	-0.018 (0.009)	**-0.019 (0.009)***	0.292 (0.462)	0.366 (0.466)	-0.364 (0.364)	-0.314 (0.380)	**-294.07 (140.02)***	**-290.14 (136.68)***
Not discharged home	0.020 (0.027)	0.021 (0.027)	-0.053 (0.464)	-0.046 (0.474)	0.181 (0.434)	0.199 (0.454)	-80.15 (87.12)	-79.46 (86.43)
Long length of stay (≥ 3 days)	**0.051 (0.014)*****	**0.051 (0.014)*****	0.529 (0.312)	0.537 (0.314)	0.383 (0.298)	0.384 (0.303)	-89.42 (47.39)	-87.92 (47.04)

Note: OLS = Ordinary least squares, utilized with robust standard errors.
[a] Abstracted from electronic health record unless otherwise noted.
[b] Includes only patients who incurred each type of payment, in each location.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
[f] Includes patients self-identified as Hispanic (n= 12) and those who declined (n=131).
[g] Includes DRG for initial inpatient hospitalization and professional fees for procedure, all post-acute charges for each place of service (inpatient, outpatient, emergency department, clinic) through 90-days post-operatively.
[h] Includes post-acute inpatient, outpatient, and emergency department payments through 90-days post-operatively.
[i] Includes professional fees for billable post-operative events for new problems or procedures (i.e., routine post-operative visits and imaging excluded), plus post-acute hospital payments (inpatient, outpatient, and emergency department); 92 patients incurred additional post-operative clinic payments.
[j] Includes the subset of patients who elected outpatient physical therapy at the orthopedic clinic.
*p < 0.05 ** p < 0.01 *** p <0.001

Table 4.22: PAM Level as a predictor of total payment for the TKA episode of care through the 90-day post-operative period among patients undergoing non-staged, unilateral total knee arthroplasty, performed by surgeons at two participating community based hospitals between September 2014 and December 2015 (N=754), stratified by 75th and 90th percentiles, Table 1 of 2.

Characteristic[a]	Model 19: Simultaneous QR Ln Total Payments for the TKA episode of care (N=754)[b] coefficient (bootstrapped se)	
	75th Percentile ln($US)	90th Percentile ln($US)
PAM Level		
1 – Not yet taking a role & 2 – Building confidence	0.001 (0.002)	-0.006 (0.018)
3 – Taking action	0.003 (0.002)	0.036 (0.022)
4 – Maintaining behaviors	--	--
Age	<0.000 (0.000)	-0.001 (0.001)
Male	<0.000 (0.002)	-0.003 (0.016)
Non-White	0.004 (0.006)	0.018 (0.046)
Other than Non-Hispanic[f]	-0.004 (0.002)	-0.014 (0.029)
Insurance Type		
Commercial	--	--
Medicare	0.003 (0.002)	0.032 (0.020)
Medicaid	0.024 (0.023)	-0.024 (0.037)
Other[c]	-0.002 (0.003)	-0.012 (0.029)
Smoking Status		
Never Smoker	--	--
Former smoker	<0.000 (0.002)	-0.003 (0.019)
Current Smoker	-0.004 (0.004)	0.001 (0.055)
BMI	<0.000 (0.000)	-0.002 (0.001)
Charlson Comorbidity Index ≥ 1	0.001 (0.002)	0.002 (0.021)
VR-12 PCS	<0.000 (0.000)	-0.001 (0.001)
VR-12 MCS	<0.000 (0.000)	<0.000 (0.001)
Performing Surgeon		
Surgeon 1	--	--
Surgeon 2	<0.000 (0.002)	-0.011 (0.018)
Surgeon 3	0.001 (0.003)	0.014 (0.035)
All others[d]	0.004 (0.004)	0.014 (0.033)

Table 4.22: PAM Level as a predictor of total payment for the TKA episode of care through the 90-day post-operative period among patients undergoing non-staged, unilateral total knee arthroplasty, performed by surgeons at two participating community based hospitals between September 2014 and December 2015 (N=754), stratified by 75th and 90th percentiles, Table 2 of 2.

Characteristic[a]	Model 19: Simultaneous QR Ln Total Payments for the TKA episode of care (N=754)[b] coefficient (bootstrapped se)	
	75th Percentile ln($US)	90th Percentile ln($US)
Home is > 45 miles	-0.004 (0.002)	-0.023 (0.016)
Not discharged home	0.012 (0.012)	0.152 (0.111)
Long length of stay (≥ 3 days)	0.009 (0.006)	**0.245 (0.083)****

Note: QR = Quantile regression, utilized with bootstrapped standard errors (300 repetitions)
[a] Abstracted from electronic health record unless otherwise noted.
[b] Includes DRG for initial inpatient hospitalization and professional fees for procedure, all post-acute charges for each place of service (inpatient, outpatient, emergency department, clinic) through 90-days post-operatively.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
[f] Includes patients self-identified as Hispanic (n= 12) and those who declined (n=131).
*$p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Table 4.23: PAM Level as a predictor of total post-acute payments (hospital plus clinic) through the 90-day post-operative period among patients undergoing non-staged, unilateral total knee arthroplasty, performed by surgeons at two participating community based hospitals between September 2014 and December 2015 (N=754), stratified by 25th, 50th, 75, and 90th percentiles, Table 1 of 2.

Characteristic[a]	Model 20: Simultaneous QR Ln Total Payments for Post-Acute Care (Hospital + Clinic) if Payment > $0 (n=227)[b] coefficient (bootstrapped se) (n=227)			
	25th Percentile ln($US)	50th Percentile ln($US)	75th Percentile ln($US)	90th Percentile ln($US)
PAM Level				
1 – Not yet taking a role & 2 – Building confidence	-0.168 (0.635)	-0.148 (0.521)	-0.279 (0.711)	0.928 (0.799)
3 – Taking action	0.091 (0.471)	0.396 (0.355)	**0.983 (0.434)***	**1.052 (0.513)***
4 – Maintaining behaviors	--	--	--	--
Age	-0.014 (0.032)	-0.045 (0.030)	-0.044 (0.041)	-0.016 (0.040)
Male	-0.512 (0.362)	-0.447 (0.396)	-0.308 (0.474)	0.079 (0.497)
Non-White	0.2 (0.799)	0.496 (0.707)	-0.340 (0.762)	-0.084 (0.777)
Other than Non-Hispanic[f]	-0.46 (0.492)	-0.481 (0.546)	0.154 (0.682)	-0.849 (0.685)
Insurance Type				
Commercial	--	--	--	--
Medicare	0.24 (0.563)	0.559 (0.526)	0.462 (0.704)	0.555 (0.731)
Medicaid	1.113 (0.932)	0.677 (0.808)	0.054 (0.922)	-0.658 (0.953)
Other[c]	1.861 (0.977)	1.554 (0.824)	0.057 (0.996)	0.033 (1.295)
Smoking Status				
Never Smoker	--	--	--	--
Former smoker	-0.116 (0.334)	-0.111 (0.350)	-0.417 (0.495)	0.011 (0.463)
Current Smoker	-0.656 (0.658)	-0.931 (0.718)	-0.873 (1.025)	0.017 (1.117)
BMI	-0.019 (0.033)	-0.039 (0.030)	-0.065 (0.040)	-0.044 (0.042)
Charlson Comorbidity Index ≥ 1	**-0.985 (0.374)****	-0.280 (0.428)	-0.067 (0.545)	-0.557 (0.539)
VR-12 PCS	-0.002 (0.02)	0.001 (0.018)	-0.038 (0.028)	-0.034 (0.031)
VR-12 MCS	0.007 (0.018)	0.013 (0.019)	0.017 (0.024)	0.003 (0.022)
Performing Surgeon				
Surgeon 1	--	--	--	--
Surgeon 2	-0.247 (0.445)	0.098 (0.445)	0.166 (0.579)	-0.276 (0.623)
Surgeon 3	-0.146 (0.581)	-0.405 (0.559)	-0.386 (0.877)	0.299 (0.728)
All others[d]	0.068 (0.484)	0.280 (0.451)	0.016 (0.531)	-0.061 (0.512)

Table 4.23: PAM Level as a predictor of total post-acute payments (hospital plus clinic) through the 90-day post-operative period among patients undergoing non-staged, unilateral total knee arthroplasty, performed by surgeons at two participating community based hospitals between September 2014 and December 2015 (N=754), stratified by 25th, 50th, 75, and 90th percentiles, Table 2 of 2.

Characteristic[a]	Model 20: Simultaneous QR Ln Total Payments for Post-Acute Care (Hospital + Clinic) if Payment > $0[b] coefficient (bootstrapped se) (n=227)			
	25th Percentile ln($US)	50th Percentile ln($US)	75th Percentile ln($US)	90th Percentile ln($US)
Home is > 45 miles	-0.088 (0.612)	-0.121 (0.577)	-0.485 (0.677)	-0.608 (0.689)
Not discharged home	0.345 (0.569)	0.551 (0.613)	-0.148 (0.739)	-0.266 (0.654)
Long length of stay (≥ 3 days)	0.110 (0.393)	-0.227 (0.454)	0.806 (0.586)	0.915 (0.495)

Note: QR = Quantile regression, utilized with bootstrapped standard errors (300 repetitions)
[a] Abstracted from electronic health record unless otherwise noted.
[b] Includes professional fees for billable post-operative events for new problems or procedures (i.e., routine post-operative visits and imaging excluded), plus post-acute hospital payments (inpatient, outpatient, and emergency department); 92 patients incurred additional post-operative clinic payments.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
[f] Includes patients self-identified as Hispanic (n= 12) and those who declined (n=131).
*$p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Table 4.24: Sensitivity analyses for select modeling output, comparing changes in modeling approaches on PAM coefficients (Models 11-12 & 19).

Models	**TKA Episode of Care[b]** coefficient (robust se)		
	Model 11 -12 OLS Payments[a]	Model 19 QR 75th Percentile	Model 19 QR 90th Percentile
Coefficients Reported in Identified Models			
1 – Not yet taking a role & 2 – Building confidence	0.001 (0.013)	0.001 (0.002)	-0.006 (0.018)
3 – Taking action	**0.020 (0.010)***	0.003 (0.002)	0.036 (0.022)
4 – Maintaining behaviors	--	--	
PAM score	<0.000 (0.000)	NA	NA
Limited to Patients Discharged to Home Only (n=661)			
1 – Not yet taking a role & 2 – Building confidence	-0.003 (0.012)	-0.001 (0.001)	-0.015 (0.020)
3 – Taking action	0.015 (0.010)	0.002 (0.002)	0.020 (0.019)
4 – Maintaining behaviors	**--**	**--**	--
Limited to patients who reside within 45 miles of the hospital (n=608)			
1 – Not yet taking a role & 2 – Building confidence	0.002 (0.016)	-0.001 (0.003)	0.006 (0.032)
3 – Taking action	0.015 (0.011)	0.004 (0.004)	0.027 (0.027)
4 – Maintaining behaviors	--	--	--
Excluding Influential Observations[e] (n=717)			
1 – Not yet taking a role & 2 – Building confidence	-0.002 (0.004)	NA	NA
3 – Taking action	**0.009 (0.004)***	NA	NA
4 – Maintaining behaviors	--	NA	NA
Restricted Cubic Splines			
PAM score linear	0.008 (0.011)	0.002 (0.001)	0.015 (0.017)
PAM score spline 1	-0.008 (0.010)	-0.002 (0.001)	-0.015 (0.016)
PAM score spline 2	0.037 (0.052)	0.009 (0.008)	0.080 (0.084)

Note: OLS = Ordinary least squares, utilized with robust standard errors. QR = Quantile regression, utilized with boot-strapped standard errors (300 repetitions).
[a] Includes only patients who incurred each type of payment, in each location.
[b] Includes DRG for initial inpatient hospitalization and professional fees for procedure, all post-acute charges for each place of service (inpatient, outpatient, emergency department, clinic) through 90-days post-operatively (N=754).
[c] Includes post-acute inpatient, outpatient, and emergency department payments through 90-days post-operatively.
[d] Influential observations identified utilizing difference in fits statistics (dfits) of Welsch and Kuh (1977).
*$p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Table 4.25: Sensitivity analyses for select modeling output, comparing changes in approaches on PAM coefficients (Models 1-2, 13-16, 20).

Models	**Post-Acute Hospital Only**[b] coefficient (robust se)		**Post-Acute Hospital Plus Clinic Payments**[a, c] coefficient (robust se)				
	Model 1 - 2 Logit Access	Model 13 -14 OLS Payments[a]	Model 15 -16 OLS Payments[a]	Model 20 QR 25th Percentile	Model 20 QR 50th Percentile	Model 20 QR 75th Percentile	Model 20 QR 90th Percentile
Coefficients Reported in Identified Models							
1 – Not yet taking a role & 2 – Building confidence	0.024 (0.304)	0.090 (0.447)	0.039 (0.399)	-0.168 (0.635)	-0.148 (0.521)	-0.279 (0.711)	0.928 (0.799)
3 – Taking action	**0.503 (0.234)***	0.358 (0.291)	**0.644 (0.275)***	0.091 (0.471)	0.396 (0.355)	**0.983 (0.434)***	**1.052 (0.513)***
4 – Maintaining behaviors	--	--	--	--	--	--	--
PAM score	-0.011 (0.008)	-0.004 (0.011)	-0.011 (0.009)	Not reported	Not reported	Not reported	Not reported
Limited to Patients Discharged to Home Only							
1 – Not yet taking a role & 2 – Building confidence	-0.023 (0.324)	0.145 (0.487)	0.129 (0.434)	1.103 (0.674)	-0.195 (0.678)	-0.255 (0.832)	0.921 (0.851)
3 – Taking action	0.457 (0.246)	0.145 (0.316)	0.520 (0.294)	**0.929 (0.458)***	0.203 (0.446)	0.464 (0.506)	0.779 (0.541)
4 – Maintaining behaviors	--	--	--	--	--	--	
Limited to patients who reside within 45 miles of the hospital							
1 – Not yet taking a role & 2 – Building confidence	0.011 (0.318)	-0.020 (0.466)	-0.193 (0.439)	-0.069 (0.670)	-0.576 (0.572)	-0.855 (0.725)	0.438 (0.813)
3 – Taking action	0.401 (0.245)	0.258 (0.304)	0.436 (0.306)	0.297 (0.505)	0.112 (0.392)	0.460 (0.538)	0.837 (0.565)
4 – Maintaining behaviors	--	--	--	--	--	--	--
Excluding Influential Observations[d]							
1 – Not yet taking a role & 2 – Building confidence	NA	-0.138 (0.383)	-0.179 (0.322)	NA	NA	NA	NA
3 – Taking action	NA	0.232 (0.259)	0.360 (0.247)	NA	NA	NA	NA
4 – Maintaining behaviors	NA	--	--	NA	NA	NA	NA
Restricted Cubic Splines							
PAM score linear	**0.383 (0.172)***	0.132 (0.318)	0.393 (0.281)	0.424 (0.328)	0.408 (0.338)	0.785 (0.516)	0.237 (0.530)
PAM score spline 1	**-0.378 (0.167)***	-0.140 (0.302)	-0.397 (0.269)	-0.449 (0.324)	-0.394 (0.324)	-0.760 (0.483)	-0.277 (0.504)
PAM score spline 2	1.926 (0.906)	0.844 (1.56)	2.217 (1.417)	2.704 (1.800)	2.032 (1.722)	3.949 (2.459)	1.800 (2.636)

Note: OLS = Ordinary least squares, utilized with robust standard errors. QR = Quantile regression, utilized with boot-strapped standard errors (300 repetitions).
[a] Includes only patients who incurred each type of payment, in each location.
[b] Includes post-acute inpatient, outpatient, and emergency department payments through 90-days post-operatively (n=174).
[c] Includes professional fees for billable post-operative events for new problems or procedures (i.e., routine post-operative visits and imaging excluded), plus post-acute hospital payments (inpatient, outpatient, and emergency department); 92 patients incurred additional post-operative clinic payments (n=227).
[d] Influential observations identified utilizing difference in fits statistics (dfits) of Welsch and Kuh (1977).
$^*p < 0.05$ $^{**}p < 0.01$ $^{***}p < 0.001$

Table 4.26: Predictors of physical therapy visit count in the 90-day post-operative period among patients undergoing non-staged, unilateral total knee arthroplasty, performed by surgeons at two participating community based hospitals between September 2014 and December 2015 (N=754), who elected to receive physical therapy services at the orthopedic clinic (n=199).

Characteristic[b]	Negative binomial regression of PT Visit Count (n=199)			
	Model 21 PAM Level		Model 22 PAM Score	
	coefficient (robust se)	AME (95% CI)	coefficient (robust se)	AME (95% CI)
PAM Score	--	--	-0.004 (0.002)	-0.06 (-0.12, 0.00)
PAM Level				
1 – Not yet taking a role & 2 – Building confidence	0.137 (0.089)	1.87 (-0.63, 4.38)	--	--
3 – Taking action	**0.138 (0.060)***	**1.79 (0.28, 3.28)***	--	--
4 – Maintaining behaviors	--	--	--	--
Age	0.004 (0.005)	0.05 (-0.09, 0.18)	0.004 (0.005)	0.05 (-0.09, 0.18)
Male	**0.119 (0.055)***	**1.56 (0.12, 3.00)***	0.108 (0.056)	1.42 (-0.04, 2.89)
Non-White	0.055 (0.089)	0.73 (-1.63, 3.10)	0.067 (0.090)	0.90 (-1.51, 3.31)
Other than Non-Hispanic[e]	-0.021 (0.077)	-0.27 (-2.20, 1.68)	-0.022 (0.078)	-0.27 (-2.20, 1.68)
Insurance Type				
Commercial	--	--	--	--
Medicare	-0.066 (0.090)	-0.86 (-3.18, 1.47)	-0.071 (0.090)	-0.92 (-3.26, 1.41)
Medicaid	**-0.162 (0.081)***	**-1.95 (-3.76, -0.14)***	**-0.165 (0.080)***	**-1.99 (-3.78, -0.20)***
Other[c]	0.010 (0.118)	-0.13 (-2.90, 3.17)	0.002 (0.118)	-0.03 (-2.99, 3.04)
Smoking Status				
Never Smoker	--	--	--	--
Former smoker	-0.041 (0.058)	-0.52 (-1.97, 0.93)	-0.038 (0.059)	-0.48 (-1.96, 0.99)
Current Smoker	-0.010 (0.079)	-0.13 (-2.13, 1.86)	0.001 (0.078)	0.01 (-1.97, 1.99)
BMI	0.001 (0.005)	0.01 (-0.11, 0.13)	0.001 (0.005)	0.01 (-0.11, 0.13)
Charlson Comorbidity Index ≥ 1[c]	-0.094 (0.068)	-1.18 (-2.83, 0.46)	-0.104 (0.069)	-1.31 (-2.96, 0.34)
VR-12 PCS	**-0.009 (0.004)***	**-0.12 (-0.22, -0.03)***	**-0.009 (0.004)***	**-0.11 (-0.21, -0.02)***
VR-12 MCS	0.005 (0.003)	0.07 (-0.01, 0.14)	0.005 (0.003)	0.06 (-0.01, 0.14)
Performing Surgeon				
Surgeon 1	--	--	--	--
Surgeon 2	0.024 (0.072)	0.31 (-1.55, 2.17)	0.026 (0.073)	0.33 (-1.54, 2.21)
Surgeon 3	0.014 (0.083)	0.19 (-2.0, 2.3)	0.013 (0.083)	0.17 (-1.97, 2.30)
All others[d]	-0.092 (0.073)	-1.17 (-2.95, 0.62)	-0.076 (0.073)	-0.97 (-2.77, 0.82)
Home is > 45 miles	-0.480 (0.256)	**-5.00 (-9.11, -0.89)***	-0.479 (0.253)	**-4.99 (-9.04, -0.94)***
Not discharged home[c]	-0.124 (0.117)	-1.53 (-4.20, 1.14)	-0.124 (0.116)	-1.53 (-4.19, 1.13)
Length of Hospital Stay ≥ 3 days	-0.106 (0.058)	-1.36 (-2.78, 0.06)	-0.106 (0.058)	-1.36 (-2.78, 0.06)

Note: AME = Average Marginal Effect with 95% confidence interval (CI); average change in actual visit count.
[a] Negative binomial regression model, utilized with robust standard errors.
[b] Abstracted from electronic health records unless otherwise noted.
[c] Abstracted/calculated from hospital billing data.
[d] Includes nine lower volume surgeons.
[e] Includes patients self-identified as Hispanic (n= 12) and those who declined (n=131).
*$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4.27: Sensitivity analyses for physical therapy visit count predicted utilizing negative binomial regression, comparing changes in modeling approaches on PAM coefficients (Models 21 & 22).

Models	**Physical Therapy Utilization (Count)** coefficient (robust se) Model 21 & 22 Negative Binomial Regression[a]
Coefficients Reported in Identified Models (n=199)	
1 – Not yet taking a role & 2 – Building confidence	0.137 (0.089)
3 – Taking action	**0.138 (0.060)***
4 – Maintaining behaviors	--
PAM score	-0.004 (0.002)
Limited to Patients Discharged to Home Only (n=174)	
1 – Not yet taking a role & 2 – Building confidence	**-0.005 (0.002)***
3 – Taking action	0.009 (0.005)
4 – Maintaining behaviors	--
Restricted Cubic Splines (n=199)	
PAM score linear	0.052 (0.074)
PAM score spline 1	-0.051 (0.070)
PAM score spline 2	0.225 (0.360)

[a] Includes only patients who accessed physical therapy services at the orthopedic clinic.
*p < 0.05 ** p < 0.01 *** p <0.001

Table 4.28: Comparison of the proportion of patients within each demographic and surgical characteristic[a] who had pre-surgical and post-surgical **evaluable patient reported outcome measures** for the Oxford Knee Score (OKS), Veteran's Rand (VR-12), and Visual Analogue Pain Scale (VA), among patient who underwent non-staged, unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754), Table 1 of 2.

Characteristic[a]	Proportion of patients with pre-surgical and post-surgical paired evaluable patient reported outcome measure compared to study population								
	OKS (n=320)			VR-12 (n=368)			VAS (n=355)		
	n	%	*p* value	n	%	*p* value	n	%	*p* value
PAM Level									
1 – Not yet taking a role									
2 – Building confidence	46	32.6	0.001**	58	41.1	0.004**	54	38.3	0.002**
3 – Taking action	171	41.1		195	46.9		185	44.5	
4 - Maintaining behaviors	103	52.3		115	58.4		111	56.4	
Age									
Less than 65 years	138	48.4	0.010*	148	51.9	0.181	143	50.2	0.107
65 years or older	182	38.8		220	46.9		207	44.1	
Gender									
Male	119	42.4	0.419	137	46.8	0.370	132	45.1	0.548
Female	201	43.6		231	50.1		218	47.3	
Race									
White	296	43.2	0.167	338	49.3	0.058	322	47.0	0.134
Other	8	25.8		9	29.0		9	29.0	
Declined	16	42.1		21	55.3		19	50.0	
Ethnicity									
Non-Hispanic	271	44.4	0.012*	310	50.7	0.019*	294	48.1	0.043*
Hispanic	--	--		--	--		--	--	
Declined	48	36.6		56	42.8		54	41.2	
Insurance Type									
Commercial	112	54.4	<0.0001***	121	58.7	0.010*	118	57.3	0.004*
Medicare	174	37.0		211	44.9		198	42.1	
Medicaid	17	47.2		17	47.2		16	44.4	
Other[c]	17	40.5		19	45.2		18	42.9	
Smoking Status									
Never Smoker	182	41.0	0.508	210	27.3	0.157	199	44.8	0.119
Former Smoker	111	45.5		130	53.3		126	54.6	
Current Smoker	23	41.1		23	41.1		22	39.3	

Table 4.28: Comparison of the proportion of patients within each demographic and surgical characteristic[a] who had **evaluable patient reported outcome measures** for the Oxford Knee Score (OKS), Veteran's Rand (VR-12), and Visual Analogue Pain Scale (VA), among patient who underwent non-staged, unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754), Table 2 of 2.

Characteristic[a]	Proportion of patients with evaluable patient reported outcome measure compared to study population[f]								
	OKS			VR-12			VAS		
	n	%	*p* value	n	%	*p* value	n	%	*p* value
Body Mass Index									
Less than 25.0	46	45.6	0.115	40	55.7	0.108	37	51.4	0.103
Overweight (25.0 – 29.9)	171	47.1		102	53.4		99	51.8	
Obese (30.0 and above)	103	39.7		226	46.0		214	43.6	
Charlson Comorbidity Index[e]									
0	244	43.0	0.765	282	49.7	0.667	266	46.9	0.889
1	61	39.9		70	45.8		69	45.1	
≥ 2	15	44.1		16	47.1		15	44.1	
Performing Surgeon									
Surgeon 1	130	58.6	<0.0001***	151	68.0	<0.0001***	142	64.0	<0.0001***
Surgeon 2	125	47.9		144	66.7		137	63.4	
Surgeon 3	51	44.7		59	51.8		57	50.0	
All others[d]	14	6.9		14	6.9		14	6.9	
Length of Stay[e]									
Less than 3 days	226	44.1	0.169	258	50.4	0.206	244	27.7	0.322
≥ 3 days	94	38.8		110	45.5		106	43.8	
Home Distance from Hospital									
≤ 45 miles	264	43.4	0.266	299	49.2	0.677	286	47.0	0.486
> 45 miles	56	38.4		69	47.3		64	43.8	
Discharge Location[e]									
Home	291	44.0	0.019*	332	50.2	0.037	317	48.0	0.024*
Other	29	42.4		36	38.7		33	35.5	

[a] Abstracted from electronic health record unless otherwise noted.
[b] Pre-operative assessments within three months of surgery.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
[f] Sample size varies for each patient reported outcome score as a result of variability in standard of care data collection between physician practices, and order of questionnaire presentation within an iPad application.
*$p < 0.05$ ** $p < 0.01$ *** $p < 0.001$; Fisher's exact (race and ethnicity); χ^2 (all else).

Table 4.29: Paired pre-operative compared to 90 day (± 1 month) post-operative mean **VR-12 Physical Health Component Score (PCS) and Mental Health Component Score (MCS)** by demographic and surgical characteristic[a] for non-staged, unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754), Table 1 of 2.

Characteristic	n	**Physical Health Component Score** Mean (standard deviation) (n=368)					**Mental Health Component Score** Mean (standard deviation) (n=368)				
		Pre-Operative[b]	90-day post-operative	*p* value	Mean difference	*p* value	Pre-Operative[b]	90-day post-operative	*p* value	Mean difference	*p* value
PAM Level											
1 – Not yet taking a role											
2 – Building confidence	58	28.9 (9.1)	37.8 (10.1)	0.040*	8.9 (10.3)	0.153	50.2 (12.5)	51.8 (11.0)	0.001***	1.6 (8.9)	0.0001***
3 – Taking action	195	31.0 (9.4)	40.7 (9.2)		9.6 (10.0)		55.0 (10.6)	57.5 (8.7)		2.4 (10.2)	
4 – Maintaining behaviors	115	30.0 (9.8)	41.7 (9.8)		11.6 (10.8)		59.5 (9.5)	56.8 (9.7)		-2.7 (10.3)	
Age											
Less than 65 years	148	28.9 (9.1)	39.8 (9.8)	0.209	10.8 (10.5)	0.308	54.1 (11.6)	54.5 (10.8)	0.010*	0.4 (11.4)	0.570
65 years or older	220	31.4 (9.6)	41.1 (9.4)		9.7 (10.2)		56.7 (10.5)	57.6 (8.6)		0.9 (9.4)	
Gender											
Male	137	30.6 (9.7)	40.1 (9.9)	0.546	9.5 (10.0)	0.390	56.8 (11.0)	55.8 (10.7)	0.923	1.7 (10.4)	0.023*
Female	231	30.3 (9.4)	40.8 (9.4)		10.5 (10.5)		55.0 (11.0)	56.7 (9.0)		-1.0 (9.9)	
Race											
White	338	30.5 (9.3)	40.5 (9.5)	0.245	10.0 (10.2)	0.423	55.3 (11.2)	56.2 (9.8)	0.610	0.9 (10.4)	0.588
Other	9	27.5 (9.6)	36.3 (9.9)		8.8 (10.8)		59.6 (9.8)	58.7 (8.5)		-0.8 (6.4)	
Declined	21	29.7 (11.5)	42.6 (10.5)		12.9 (11.6)		59.3 (8.2)	58.0 (7.6)		-1.3 (8.8)	
Ethnicity											
Non-Hispanic	310	30.3 (9.4)	40.5 (9.3)	0.922	10.2 (10.3)	0.876	55.6 (10.9)	56.5 (9.5)	0.901	0.9 (10.4)	0.355
Hispanic	--	--	--		--		--	--		--	
Declined	56	30.8 (10.0)	40.3 (11.0)		9.5 (10.8)		56.1 (11.8)	55.5 (10.4)		-0.7 (9.6)	
Insurance Type											
Commercial	121	30.4 (9.7)	41.5 (8.7)	0.006**	11.0 (11.0)	0.624	56.0 (9.3)	56.0 (8.8)	0.064	0.05 (10.3)	0.495
Medicare	211	31.1 (9.4)	40.8 (9.5)		9.6 (9.9)		56.4 (10.8)	57.4 (8.9)		1.0 (9.7)	
Medicaid	17	29.1 (7.1)	38.1 (12.1)		9.0 (12.6)		48.2 (16.5)	52.8 (13.8)		4.5 (15.4)	
Other[c]	19	23.3 (7.0)	33.7 (10.4)		10.4 (9.7)		52.7 (14.5)	50.4 (14.4)		-2.3 (11.1)	
Smoking Status											
Never Smoker	210	30.8 (9.7)	41.7 (9.0)	0.015*	10.9 (10.6)	0.225	56.2 (10.5)	56.9 (9.2)	0.025*	0.8 (10.8)	0.970
Former smoker	130	29.9 (9.4)	38.9 (10.1)		9.0 (9.6)		55.6 (11.3)	56.2 (9.8)		0.6 (9.7)	
Current Smoker	23	23.1 (7.8)	38.1 (10.4)		9.0 (11.1)		50.0 (13.5)	51.1 (11.6)		1.2 (8.9)	

Table 4.29: Paired pre-operative compared to 90 day (± 1 month) post-operative mean **VR-12 Physical Health Component Score (PCS) and Mental Health Component Score (MCS)** by demographic and surgical characteristic[a] for non-staged, unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754), Table 2 of 2.

Characteristic[a]	n	**Physical Health Component Score** Mean (standard deviation) (n=368)					**Mental Health Component Score** Mean (standard deviation) (n=368)				
		Pre-Operative[b]	90-day post-operative	*p* value	Mean difference	*p* value	Pre-Operative[b]	90-day post-operative	*p* value	Mean difference	*p* value
Body Mass Index											
Less than 25.0	40	35.7 (10.7)	43.1 (10.8)	0.106	7.4 (9.5)	0.016*	53.3 (12.4)	55.4 (0.1)	0.636	2.0 (9.6)	0.508
Overweight (25.0 – 29.9)	102	32.5 (9.6)	41.1 (10.6)		8.5 (11.2)		55.9 (11.3)	57.0 (8.8)		1.1 (9.9)	
Obese (30.0 and above)	226	28.5 (8.6)	39.8 (8.9)		11.3 (9.6)		56.0 (10.6)	56.2 (9.9)		0.2 (10.6)	
Charlson Comorbidity Index[e]											
0	282	31.0 (9.4)	40.8 (9.5)	0.624	9.8 (10.1)	0.305	56.2 (10.6)	56.6 (9.5)	0.274	0.5 (10.3)	0.687
1	70	29.2 (9.3)	39.9 (10.1)		10.7 (11.0)		53.2 (12.3)	54.8 (10.6)		1.6 (10.3)	
≥ 2	16	25.3 (9.0)	38.9 (7.9)		13.6 (10.8)		57.9 (10.5)	58.0 (8.0)		0.6 (10.7)	
Performing Surgeon											
Surgeon 1	151	31.0 (9.7)	42.3 (9.0)	0.010*	11.3 (10.4)	0.125	55.9 (10.1)	57.4 (8.2)	0.419	1.4 (8.8)	0.280
Surgeon 2	144	30.1 (9.7)	39.9 (10.0)		9.9 (10.4)		55.0 (11.5)	55.6 (10.7)		0.6 (11.4)	
Surgeon 3	59	30.9 (8.5)	38.5 (9.1)		7.8 (9.7)		57.2 (11.1)	55.8 (10.4)		-1.4 (10.3)	
All others[d]	14	25.6 (8.4)	36.0 (9.7)		10.4 (10.7)		53.5 (14.4)	56.2 (8.4)		2.7 (12.5)	
Length of Stay[e]											
Less than 3 days	258	31.2 (9.6)	41.1 (9.2)	0.098	9.8 (10.1)	0.383	55.8 (10.8)	56.5 (9.6)	0.608	0.7 (10.5)	0.909
≥ 3 days	110	28.4 (8.8)	39.3 (10.4)		10.8 (10.8)		55.4 (11.6)	56.0 (9.6)		0.6 (9.6)	
Home Distance from Hospital											
≤ 45 miles	299	30.8 (9.6)	40.7 (9.7)	0.393	9.7 (10.1)	0.534	55.7 (11.1)	56.1 (9.7)	0.239	0.5 (10.1)	0.449
> 45 miles	69	28.8 (8.9)	39.6 (8.9)		10.8 (11.1)		56.0 (10.8)	57.6 (9.4)		1.5 (11.2)	
Discharge Location[e]											
Home	332	30.6 (9.5)	40.6 (9.5)	0.619	10.0 (10.2)	0.338	56.2 (10.7)	56.6 (9.6)	0.225	0.3 (10.2)	0.044*
Other	36	28.1 (8.4)	39.8 (10.5)		11.7 (11.3)		50.5 (12.9)	54.5 (9.5)		4.0 (10.5)	

[a] Abstracted from electronic health record unless otherwise noted.
[b] Pre-operative assessments within three months of surgery.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
*$p < 0.05$ ** $p < 0.01$ *** $p < 0.001$; PCS t-test (age, gender, length of stay, discharge location), analysis of variance (ANOVA) (all else) and MCS Mann Whitney U (age, gender, length of stay, discharge location) and Kruskall-Wallis (all else).

Table 4.30: Paired pre-operative compared to 90 day (± 1 month) post-operative mean **Oxford Knee Score** (OKS) by demographic and surgical characteristic[a] for non-staged, unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754), Table 1 of 2.

Characteristic[a]	Oxford Knee Score Mean (standard deviation) (n=320)					
	n	Pre-Operative	90-day post-operative	*p*-value	Mean difference	*p*-value
PAM Level						
1 – Not yet taking a role						
2 – Building confidence	46	22.9 (7.8)	33.7 (8.4)	0.060	10.8 (8.6)	0.753
3 – Taking action	171	25.2 (8.2)	36.6 (6.8)		11.3 (8.9)	
4 - Maintaining behaviors	103	24.4 (8.1)	36.3 (7.8)		11.9 (8.5)	
Age						
Less than 65 years	138	23.2 (7.7)	34.6 (7.9)	0.002**	11.4 (8.7)	0.936
65 years or older	182	25.7 (8.3)	37.2 (6.8)		11.5 (8.8)	
Gender						
Male	119	25.6 (8.3)	36.4 (7.8)	0.581	10.8 (9.6)	0.329
Female	201	24.0 (7.9)	35.9 (7.2)		11.8 (8.2)	
Race						
White	296	24.8 (8.0)	36.2 (7.3)	0.127	11.4 (8.8)	0.903
Other	8	19.3 (7.1)	31.0 (7.8)		11.8 (9.1)	
Declined	16	24.8 (9.6)	37.1 (9.1)		12.4 (8.0)	
Ethnicity						
Non-Hispanic	271	24.7 (8.1)	36.1 (7.4)	0.587	11.3 (9.0)	0.587
Hispanic	--	--	--		--	
Declined	48	24.0 (8.2)	36.2 (7.5)		12.1 (7.4)	
Insurance Type						
Commercial	112	25.3 (7.5)	36.7 (6.6)	<0.0001***	11.4 (8.2)	0.568
Medicare	174	25.2 (8.5)	36.8 (7.0)		11.6 (9.1)	
Medicaid	17	19.4 (6.0)	32.1 (9.2)		12.8 (10.2)	
Other[c]	17	19.7 (5.7)	28.5 (9.6)		8.8 (7.3)	
Smoking Status						
Never Smoker	182	25.7 (8.2)	36.9 (6.9)	0.005*	11.2 (8.6)	0.707
Former Smoker	111	23.6 (7.7)	35.6 (7.8)		12.0 (8.6)	
Current Smoker	23	20.9 (8.0)	31.8 (8.5)		10.9 (10.7)	
Body Mass Index						
Less than 25.0	35	28.4 (10.2)	37.6 (8.6)	0.063	9.2 (8.8)	0.0008***
Overweight (25.0 – 29.9)	90	28.1 (7.8)	37.2 (7.3)		9.1 (8.8)	
Obese (30.0 and above)	175	22.4 (7.0)	35.3 (7.1)		12.9 (8.4)	
Charlson Comorbidity Index[e]						
0	244	25.2 (8.2)	36.2 (7.4)	0.848	11.0 (8.8)	0.253
1	61	22.7 (7.4)	35.7 (8.0)		12.9 (8.2)	
≥ 2	15	24.0 (7.9)	36.7 (6.4)		12.7 (10.5)	
Performing Surgeon						
Surgeon 1	130	25.0 (8.0)	37.8 (6.7)	0.0002***	12.8 (8.4)	0.002**
Surgeon 2	125	24.3 (8.3)	36.9 (7.5)		11.7 (8.7)	
Surgeon 3	51	25.6 (8.2)	32.9 (7.4)		7.3 (8.2)	
All others[d]	14	21.1 (7.1)	33.1 (8.1)		12.0 (9.8)	

Table 4.30: Paired pre-operative compared to 90 day (± 1 month) post-operative mean **Oxford Knee Score** (OKS) by demographic characteristic[a] and PAM level for unilateral total knee arthroplasty procedures performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754), Table 2 of 2.

Characteristic[a]	Oxford Knee Score Mean (standard deviation) (n=320)					
	n	Pre-Operative[b]	90-day post-operative	*p* value	Mean difference	*p* value
Length of Stay[e]						
Less than 3 days	226	25.7 (8.3)	36.5 (7.2)	0.159	10.8 (8.7)	0.030*
≥ 3 days	94	22.1 (6.9)	35.2 (7.9)		13.1 (8.6)	
Home Distance from Hospital						
≤ 45 miles	264	25.0 (8.1)	36.2 (7.2)	0.848	11.2 (8.6)	0.871
> 45 miles	56	23.2 (8.0)	35.8 (8.3)		12.6 (9.3)	
Discharge Location[e]						
Home	291	25.1 (8.1)	36.2 (7.4)	0.604	11.1 (8.7)	0.989
Other	29	20.4 (6.5)	36.4 (7.1)		15.0 (8.8)	

[a] Abstracted from electronic health record unless otherwise noted.
[b] Pre-operative assessments within three months of surgery.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
*$p < 0.05$ ** $p < 0.01$ *** $p < 0.001$; *p* value reflects test of differences in mean change from pre- to post-operative score, t-test (age, gender, length of stay, discharge location), analysis of variance (ANOVA) (all else)

Table 4.31: Paired pre-operative compared to 90 day (± 1 month) post-operative mean **Visual Analogue Pain Scale** (VAS, 0-10 pain rating) by demographic characteristic[a] among patients undergoing non-staged, unilateral total knee arthroplasty performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754), Table 1 of 2.

Characteristic[a]	Visual Analogue Pain Scale (VAS) Mean (standard deviation) (n=350)					
	n	Pre-Operative[b]	90-day post-operative	*p* value	Mean difference	*p* value
PAM Level						
1 – Not yet taking a role & 2 – Building confidence	54	4.6 (2.4)	2.3 (2.2)	0.538	-2.3 (3.0)	0.246
3 – Taking action	185	5.0 (2.4)	1.9 (1.8)		-3.2 (2.5)	
4 – Maintaining behaviors	111	5.4 (2.5)	2.0 (2.1)		-3.4 (2.7)	
Age						
Less than 65 years	143	5.6 (2.2)	2.5 (2.2)	0.0001***	-3.1 (2.5)	0.789
65 years or older	207	4.8 (2.4)	1.6 (1.7)		-3.2 (2.8)	
Gender						
Male	132	5.0 (2.4)	2.1 (2.0)	0.250	-3.3 (2.7)	0.092
Female	218	5.2 (2.4)	1.9 (1.9)		-2.8 (2.6)	
Race						
White	332	5.0 (2.3)	2.0 (1.9)	0.024*	-3.1 (2.6)	0.335
Other	6	6.3 (2.1)	3.4 (2.2)		-2.9 (3.6)	
Declined	19	5.3 (2.9)	1.3 (1.5)		-4.0 (2.6)	
Ethnicity						
Non-Hispanic	294	5.1 (2.4)	2.0 (1.9)	0.964	-3.1 (2.6)	0.762
Hispanic	--	--	--		--	
Declined	54	5.1 (2.4)	2.0 (2.1)		-3.1 (2.9)	
Insurance Type						
Commercial	118	5.3 (2.2)	2.1 (2.0)	0.006**	-3.1 (2.3)	0.995
Medicare	198	4.8 (2.3)	1.7 (1.7)		-3.1 (2.9)	
Medicaid	16	6.1 (2.6)	3.3 (2.9)		-2.9 (3.6)	
Other[c]	18	6.2 (1.9)	3.1 (2.3)		-3.1 (1.9)	
Smoking Status						
Never Smoker	199	5.0 (2.3)	1.8 (1.8)	0.021*	-3.2 (2.6)	0.963
Former Smoker	126	5.1 (2.4)	2.0 (2.0)		-3.2 (2.8)	
Current Smoker	22	6.1 (2.3)	3.4 (2.6)		-2.8 (3.0)	
Body Mass Index						
Less than 25.0	37	4.2 (2.8)	1.8 (2.0)	0.175	-2.4 (3.1)	0.045*
Overweight (25.0 – 29.9)	99	4.6 (2.3)	1.7 (1.8)		-2.8 (2.7)	
Obese (30.0 and above)	214	5.5 (2.2)	2.1 (2.0)		-3.4 (2.5)	
Charlson Comorbidity Index[e]						
0	265	5.0 (2.4)	2.0 (1.8)	0.762	-3.0 (2.7)	0.618
1	69	5.4 (2.2)	2.0 (2.3)		-3.4 (2.7)	
≥ 2	15	5.0 (2.2)	1.9 (2.1)		-3.2 (2.8)	
Performing Surgeon						
Surgeon 1	142	4.8 (2.4)	1.7 (1.9)	0.016*	-3.1 (2.8)	0.808
Surgeon 2	137	5.2 (2.5)	1.9 (1.7)		-3.3 (2.6)	
Surgeon 3	57	5.4 (2.1)	2.6 (2.3)		-2.8 (2.8)	
All others[d]	14	5.5 (2.3)	2.6 (1.9)		-2.9 (1.4)	

Table 4.31: Paired pre-operative compared to 90 day (± 1 month) post-operative mean **Visual Analogue Pain Scale** (VAS, 0-10 pain rating) by demographic characteristic[a] among patients undergoing non-staged, unilateral total knee arthroplasty performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754), Table 2 of 2.

Characteristic	Visual Analogue Pain Scale (VAS) Mean (standard deviation) (n=350)					
	n	Pre-Operative[b]	90-day post-operative	*p* value	Mean difference	*p* value
Length of Stay[e]						
Less than 3 days	244	5.0 (2.4)	1.9 (1.9)	0.279	-3.1 (2.8)	0.411
≥ 3 days	106	5.4 (2.2)	2.1 (2.0)		-3.3 (2.4)	
Home Distance from Hospital						
≤ 45 miles	286	5.0 (2.4)	1.9 (1.9)	0.438	-3.1 (2.7)	0.235
> 45 miles	64	5.6 (2.0)	2.2 (2.2)		-3.4 (2.7)	
Discharge Location[e]						
Home	317	5.0 (2.4)	2.0 (2.0)	0.657	-3.0 (2.7)	0.004**
Other	33	6.1 (2.1)	1.8 (1.7)		-4.4 (2.1)	

[a] Abstracted from electronic health record unless otherwise noted.
[b] Pre-operative assessments within three months of surgery.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
p* < 0.05 ** *p* < 0.01 * *p* <0.001; Mann Whitney U (age, gender, length of stay, distance from home, discharge location) and Kruskall-Wallis (all else).

Table 4.32: Unadjusted linear relationship between 90 day (± 1 month) post-operative patient reported outcome scores, mean change in score outcome score (pre-operative to post-operative) for patients who underwent non-staged, unilateral total knee arthroplasty performed by surgeons at two participating community-based hospitals, between September 2014 and December 2015 (N=754).[a]

Patient Reported Outcome	*n*	PAM score (0-100) coefficient (se[d])	*p*-value
Oxford Knee Score[b]			
90-Day Post-Operative	329	0.071 (0.032)	0.026*
Change in score pre-to post-op	320	0.025 (0.038)	0.520
VR-12 Physical Health Component			
90-Day Post-Operative	368	0.113 (0.038)	0.003**
Change in score pre-to post-op	368	0.055 (0.041)	0.185
VR-12 Mental Health Component			
90-Day Post-Operative	368	0.098 (0.038)	0.011*
Change in score pre- to post-op	368	-0.117 (0.041)	0.004**
Visual Analogue Pain Scale			
ln (90-Day Post-Operative)[c]	355	-0.004 (0.003)	0.129
Change in score pre-to post-op[b]	350	-0.024 (0.011)	0.026*

[a] Sample size varies for each patient reported outcome score as a result of variability in standard of care data collection between physician practices, and order of questionnaire presentation in an iPad application.
[b] OKS sample resulted in nine patients with post-operative scores, but no pre-operative scores. VAS sample resulted in five patients with post-operative scores, but no pre-operative scores.
[c] Dependent variable was skewed; log-transformed data is normally distributed.
[d] Standard error (se)
*$p < 0.05$ ** $p < 0.01$ *** $p < 0.001$; simple linear regression.

Table 4.33: Predictors of post-operative 90-day physical and mental health related quality of life (VR-12 PCS and MCS) and change in scores from pre-operative to post-operative period, among patients undergoing non-staged, unilateral total knee arthroplasty, performed by surgeons at two participating community based hospitals between September 2014 and December 2015 (N=754), Table 1 of 2.

Characteristic[a]	OLS Models of VR-12 Physical Health Component and Mental Health Component Scores coefficient (robust se)							
	VR-12 **PCS** 90-Day (n=368)		Change in VR-12 **PCS** (Pre- to Post-Operative) (n=368)		VR-12 **MCS** 90-Day (n=368)		Change in VR-12 **MCS** (Pre- to Post-Operative) (n=368)	
	Model 23 PAM Level	Model 24 PAM Score	Model 25 PAM Level	Model 26 PAM Score	Model 27 PAM Level	Model 28 PAM Score	Model 29 PAM Level	Model 30 PAM Score
PAM Score	--	**0.10 (0.04)***	--	0.09 (0.05)	--	**0.09 (0.04)***	--	**-0.12 (0.04)****
PAM Level								
1 – Not yet taking a role & 2 – Building confidence	**-3.42 (1.59)***	--	**-3.74 (1.75)***	--	**-4.98 (1.79)****	--	**4.55 (1.57)****	--
3 – Taking action	-1.06 (1.12)	--	**-2.63 (1.24)***	--	0.64 (1.14)	--	**5.05 (1.23)*****	--
4 – Maintaining behaviors	--	--	--	--	--	--	--	--
Age	0.09 (0.08)	0.09 (0.08)	0.11 (0.09)	0.10 (0.09)	0.15 (0.09)	0.15 (0.09)	0.06 (0.09)	0.07 (0.08)
Male	0.14 (1.05)	0.25 (1.05)	-0.48 (1.11)	-0.53 (1.12)	-0.32 (1.07)	-0.10 (1.09)	**-3.05 (1.14)****	**-2.85 (1.16)***
Non-White	0.99 (2.02)	0.76 (1.98)	2.18 (2.23)	2.04 (2.25)	**4.14 (1.93)***	3.48 (1.84)	-1.67 (1.76)	-1.72 (1.72)
Other than Non-Hispanic[f]	-1.17 (1.59)	-1.23 (1.56)	-1.12 (1.62)	-1.12 (1.61)	-2.40 (1.65)	-2.42 (1.65)	-0.46 (1.46)	-0.47 (1.45)
Insurance Type								
Commercial	--	--	--	--	--	--	--	--
Medicare	-1.64 (1.45)	-1.74 (1.45)	-2.3 (1.59)	-2.35 (1.60)	0.01 (1.56)	-0.05 (1.58)	0.03 (1.58)	0.09 (1.59)
Medicaid	-0.63 (3.23)	-0.32 (3.23)	-1.2 (3.14)	-1.08 (3.15)	0.58 (3.52)	1.17 (3.55)	5.47 (4.11)	5.51 (4.26)
Other[c]	**-6.16 (2.41)***	**-6.06 (2.44)***	1.29 (2.46)	1.31 (2.42)	-4.63 (3.25)	-4.92 (3.47)	-2.22 (2.82)	-2.39 (2.86)
Smoking Status								
Never Smoker	--	--	--	--	--	--	--	--
Former smoker	**-2.25 (1.08)***	**-2.27 (1.08)***	-1.95 (1.11)	-2.00 (1.11)	-0.13 (1.02)	-0.27 (1.04)	-0.27 (1.07)	-0.25 (1.08)
Current Smoker	-2.42 (2.35)	-2.50 (2.36)	-0.77 (2.64)	-0.88 (2.66)	-4.27 (2.75)	-4.65 (2.71)	-0.88 (2.37)	-0.86 (2.44)
BMI	-0.09 (0.08)	-0.08 (0.08)	**0.28 (0.08)*****	**0.28 (0.08)*****	0.09 (0.08)	0.09 (0.08)	0.04 (0.08)	0.04 (0.08)
Charlson Comorbidity Index ≥ 1	-0.56 (1.23)	-0.32 (1.21)	1.54 (1.27)	1.62 (1.29)	-1.29 (1.18)	-0.82 (1.21)	-0.15 (1.28)	-0.1 (1.3)
Performing Surgeon								
Surgeon 1	--	--	--	--	--	--	--	--
Surgeon 2	-1.64 (1.09)	-1.81 (1.09)	-1.82 (1.20)	-1.86 (1.21)	-1.26 (1.05)	-1.72 (1.08)	-0.49 (1.22)	-0.62 (1.22)
Surgeon 3	**-3.71 (1.4)****	**-3.77 (1.38)****	**-4.06 (1.55)****	**-3.97 (1.55)***	-0.84 (1.38)	-0.94 (1.39)	-2.84 (1.51)	**-3.05 (1.52)***
All others[d]	-4.51 (2.72)	-4.64 (2.72)	-2.22 (3.16)	-2.12 (3.15)	-0.19 (2.57)	-0.20 (2.62)	2.99 (3.10)	2.81 (3.43)

Table 4.33: Predictors of post-operative 90-day physical and mental health related quality of life (VR-12 PCS and MCS) and change in scores from pre-operative to post-operative period, among patients undergoing non-staged, unilateral total knee arthroplasty, performed by surgeons at two participating community based hospitals between September 2014 and December 2015 (N=754), Table 2 of 2.

Characteristic[a]	OLS Models of VR-12 Physical Health Component and Mental Health Component Scores coefficient (robust se)							
	VR-12 **PCS** 90-Day (n=368)[g]		Change in VR-12 **PCS** (Pre- to Post-Operative) (n=368 [g]		VR-12 **MCS** 90-Day[b] (n=368)[g]		Change in VR-12 **MCS**[b] (Pre- to Post-Operative) (n=368)[g]	
	Model 23 PAM Level	Model 24 PAM Score	Model 25 PAM Level	Model 26 PAM Score	Model 27 PAM Level	Model 28 PAM Score	Model 29 PAM Level	Model 30 PAM Score
Home is > 45 miles	-1.06 (1.19)	-0.96 (1.19)	0.93 (1.42)	0.98 (1.44)	1.57 (1.20)	1.72 (1.21)	1.72 (1.44)	1.71 (1.49)
Not discharged home	0.88 (2.03)	0.87 (1.99)	2.06 (2.11)	1.84 (2.09)	-1.67 (1.84)	-1.79 (1.83)	3.70 (1.93)	4.05 (1.94)
Long length of stay (≥ 3 days)	-1.66 (1.30)	-1.69 (1.29)	0.01 (1.35)	-0.01 (1.34)	-0.27 (1.28)	-0.36 (1.26)	**-2.63 (1.21)***	**-2.64 (1.23)***

[a] Abstracted from electronic health record unless otherwise noted.
[b] Dependent variable was skewed; log-transformed data did not improve upon skewness.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
[f] Includes patients self-identified as Hispanic (n= 12) and those who declined (n=131).
[g] Sample size varies for each patient reported outcome score as a result of variability in standard of care data collection between physician practices, and order of questionnaire presentation in an iPad application.
p* < 0.05 ** *p* < 0.01 * *p* <0.001

Table 4.34: Predictors of post-operative 90-day knee-specific functioning on the Oxford Knee Score (OKS) and self-reported pain on a Visual Analogue Pain Scale (VAS), and change in scores from pre-operative to post-operative period, among patients undergoing non-staged, unilateral total knee arthroplasty, performed by surgeons at two participating community based hospitals between September 2014 and December 2015 (N=754), Table 1 of 2.

Characteristic[a]	OLS Models of Oxford Knee Score (OKS) and Self-Reported Pain on a Visual Analogue Pain Scale (VAS) coefficient (robust se)							
	OKS 90-Day[h] (n=329)[g]		**Change in OKS**[h] (Pre- to Post-Operative) (n=320)[g]		**Ln VAS** 90-Day[b, h] (n=355)[g]		**Change in VAS**[h] (Pre- to Post-Operative) (n=350)[g]	
	Model 31 PAM Level	Model 32 PAM Score	Model 33 PAM Level	Model 34 PAM Score	Model 35 PAM Level	Model 36 PAM Score	Model 37 PAM Level	Model 38 PAM Score
PAM Score	--	**0.07 (0.03)***	--	0.06 (0.04)		-0.005 (0.003)	--	**-0.04 (0.01)****
PAM Level								
1 – Not yet taking a role & 2 – Building confidence	-2.21 (1.33)	--	-2.19 (1.48)	--	0.125 (0.116)	--	**1.58 (0.49)****	--
3 – Taking action	-0.18 (0.86)	--	-1.33 (1.03)	--	0.025 (0.081)	--	0.42 (0.31)	--
4 – Maintaining behaviors	--	--	--	--	--	--	--	--
Age	**0.18 (0.07)***	**0.19 (0.07)****	0.13 (0.08)	0.13 (0.08)	**-0.015 (0.006)****	**-0.016 (0.006)****	-0.02 (0.02)	-0.02 (0.02)
Male	1.25 (0.83)	1.39 (0.83)	-0.27 (1.07)	-0.26 (1.07)	0.035 (0.076)	0.027 (0.076)	0.40 (0.31)	0.37 (0.31)
Non-White	-0.51 (1.81)	-0.64 (1.77)	0.30 (1.85)	0.18 (1.84)	-0.062 (0.140)	-0.054 (0.139)	-0.74 (0.59)	-0.61 (0.59)
Other than Non-Hispanic[f]	-0.19 (1.23)	-0.24 (1.20)	1.17 (1.34)	1.18 (1.34)	0.047 (0.101)	0.052 (0.100)	0.12 (0.43)	0.13 (0.42)
Insurance Type								
Commercial	--	--	--	--	--	--	--	--
Medicare	-2.15 (1.13)	-2.25 (1.12)	-1.10 (1.37)	-1.13 (1.38)	0.020 (0.105)	0.027 (0.104)	0.18 (0.39)	0.21 (0.39)
Medicaid	-0.97 (2.25)	-0.67 (2.25)	2.03 (2.69)	2.16 (2.69)	0.013 (0.199)	-0.004 (0.199)	0.26 (0.85)	0.13 (0.88)
Other[c]	**-6.91 (2.36)****	**-6.83 (2.41)****	-1.73 (2.03)	-1.65 (2.02)	0.169 (0.181)	0.161 (0.180)	-0.54 (0.51)	-0.50 (0.51)
Smoking Status								
Never Smoker	--	--	--	--	--	--	--	--
Former smoker	-0.61 (0.83)	-0.64 (0.83)	1.24 (0.96)	1.20 (0.96)	-0.018 (0.074)	-0.020 (0.074)	-0.17 (0.30)	-0.15 (0.30)
Current Smoker	-3.34 (1.92)	-3.42 (1.93)	0.72 (2.43)	0.66 (2.44)	0.226 (0.159)	0.224 (0.159)	-0.22 (0.55)	-0.15 (0.56)
BMI	-0.04 (0.06)	-0.04 (0.06)	**0.39 (0.07)*****	**0.39 (0.07)*****	-0.006 (0.005)	-0.007 (0.005)	**-0.09 (0.02)*****	**-0.09 (0.02)*****
Charlson Comorbidity Index ≥ 1	0.40 (0.09)	0.56 (0.88)	1.11 (1.06)	1.21 (1.06)	-0.059 (0.085)	-0.072 (0.084)	-0.08 (0.34)	-0.19 (0.34)
Performing Surgeon								
Surgeon 1	--	--	--	--	--	--	--	--
Surgeon 2	-0.85 (0.83)	-1.04 (0.84)	-1.48 (1.03)	-1.55 (1.04)	0.061 (0.079)	0.069 (0.079)	-0.09 (0.33)	-0.02 (0.33)
Surgeon 3	**-3.96 (1.18)****	**-4.05 (1.16)****	**-5.46 (1.33)*****	**-5.45 (1.33)*****	**0.247 (0.110)***	**0.251 (0.109)***	0.50 (0.43)	0.49 (0.43)
All others[d]	-2.79 (2.08)	-2.95 (2.11)	-1.93 (2.47)	-1.94 (2.47)	0.243 (0.190)	0.254 (0.190)	0.67 (0.40)	0.66 (0.40)

Table 4.34: Predictors of post-operative 90-day knee-specific functioning on the Oxford Knee Score (OKS) and self-reported pain on a Visual Analogue Pain Scale (VAS), and change in scores from pre-operative to post-operative period, among patients undergoing non-staged, unilateral total knee arthroplasty, performed by surgeons at two participating community based hospitals between September 2014 and December 2015 (N=754), Table 2 of 2.

Characteristic[a]	OLS Models of Oxford Knee Score (OKS) and Self-Reported Pain on a Visual Analogue Pain Scale (VAS) coefficient (robust se)							
	OKS 90-Day[h] (n=329)[g]		**Change in OKS**[h] (Pre- to Post-Operative) (n=320)[g]		**Ln VAS** 90-Day[b, h] (n=355)[g]		**Change in VAS**[h] (Pre- to Post-Operative) (n=350)[g]	
	Model 31 PAM Level	Model 32 PAM Score	Model 33 PAM Level	Model 34 PAM Score	Model 35 PAM Level	Model 36 PAM Score	Model 37 PAM Level	Model 38 PAM Score
Home is > 45 miles	0.03 (1.03)	0.16 (1.03)	2.12 (1.33)	2.17 (1.34)	0.043 (0.094)	0.038 (0.094)	-0.42 (0.38)	-0.47 (0.39)
Not discharged home	-0.42 (1.47)	-0.27 (1.47)	3.69 (2.09)	3.60 (2.06)	-0.085 (0.115)	-0.088 (0.113)	**-1.84 (0.48)*** **	**-1.76 (0.47)*** **
Long length of stay (≥ 3 days)	-0.94 (0.96)	-1.01 (0.96)	0.10 (1.22)	0.09 (1.22)	**0.183 (0.086)***	**0.182 (0.085)***	0.46 (0.33)	0.47 (0.33)

[a] Abstracted from electronic health record unless otherwise noted.
[b] Dependent variable was skewed; log-transformed data is normally distributed.
[c] Includes worker's compensation and veteran's affairs (VA).
[d] Includes nine lower volume surgeons.
[e] Abstracted from TKA admission hospital billing data.
[f] Includes patients self-identified as Hispanic (n= 12) and those who declined (n=131).
[g] Sample size varies for each patient reported outcome score as a result of variability in standard of care data collection between physician practices, and order of questionnaire presentation in an iPad application.
[h] OKS, High score is higher functioning; VAS, low score is lower pain.
*p < 0.05 ** p < 0.01 *** p <0.001

Table 4.35: Sensitivity analyses for select modeling output, comparing changes in modeling approaches on PAM coefficients for patient-reported outcome measures.

Models[a]	VR-12 **PCS** 90-Day Models 23-24	VR-12 **PCS** Change in Score Model 25-26	VR-12 **MCS** 90 Day Model 27-28	VR-12 **MCS** Change in Score Model 29-30	**OKS** 90-Day Model 31-32	**OKS** Change in Score Model 33-34	**Ln VAS** 90-Day Model 35-36	**VAS** Change in Score Model 37-38
	Sensitivity Analyses coefficient (robust se)							
Coefficients Reported in Identified Models								
1 – Not yet taking a role & 2 – Building confidence	**-3.42 (1.29)***	**-3.74 (1.75)***	**-4.98 (1.79)****	**4.55 (1.57)****	-2.21 (1.33)	-2.19 (1.48)	0.125 (0.116)	**1.58 (0.49)****
3 – Taking action	-1.06 (1.12)	**-2.63 (1.24)***	0.64 (1.14)	**5.05 (1.23)*****	-0.18 (0.86)	-1.33 (1.03)	0.025 (0.081)	0.42 (0.31)
4 – Maintaining behaviors	--	--	--	--	--	--	--	--
PAM score	**0.10 (0.04)***	0.06 (0.04)	0.09 (0.05)	**-0.12 (0.04)****	**0.07 (0.03)***	0.06 (0.04)	-0.005 (0.003)	**-0.04 (0.01)****
Excluding Influential Observations[b]								
1 – Not yet taking a role & 2 – Building confidence	**-3.48 (1.59)***	**-3.76 (1.75)***	**-5.24 (1.79)****	**4.23 (1.57)****	-2.41 (1.34)	-2.40 (1.34)	0.140 (0.118)	**1.63 (0.49)****
3 – Taking action	-1.10 (1.14)	**-2.61 (1.25)***	0.43 (1.14)	**4.87 (1.23)*****	-0.31 (0.87)	-0.34 (0.87)	0.043 (0.081)	0.47 (0.32)
4 – Maintaining behaviors	--	--	--	--	--	--	--	--
Restricted Cubic Spline Regression								
PAM score linear	**2.00 (0.79)***	-0.05 (0.92)	**1.79 (0.86)***	1.27 (0.78)	1.38 (0.84)	0.01 (0.92)	-0.053 (0.067)	-0.33 (0.23)
PAM score spline 1	**-1.88 (0.76)***	0.21 (0.89)	-1.60 (0.82)	-1.40 (0.77)	-1.26 (0.79)	0.003 (0.88)	0.047 (0.064)	0.24 (0.22)
PAM score spline 2	**10.27 (4.06)***	-2.03 (4.80)	7.81 (4.32)	7.91 (4.22)	6.57 (4.09)	-0.99 (4.61)	-0.239 (0.038)	-0.86 (1.21)

[a] VR-12 PCS, VR-12 MCS and OKS, High score is higher functioning; VAS, low score is lower pain.
[b] Influential observations identified utilizing difference in fits statistics (dfits) of Welsch and Kuh (1977).
*p < 0.05 ** p < 0.01 *** p <0.001

CHAPTER FIVE

Discussion

The current study is the first known investigation into the association between patient activation and post-acute healthcare access for a defined episode of surgical care, total knee arthroplasty (TKA). TKA remains a significant cost-driver for Medicare. Payments for arthroplasty procedures increased 63.7% between 2000 and 2010 [1], which was insensitive to the economic downturns during this period [168]. At the same time, the proportion of patients less than 65 years old who will seek elective joint replacement is expected to comprise 50% of procedures by 2030 [169]. The implications of increasing incidence, and the shift toward younger, employed adults electing TKA, are putting pressure on all players in the delivery system to better optimize patients for surgery, reduce length of stay, and minimize potentially preventable post-acute service utilization.

The policy landscape for total joint care continues to point toward broad-reaching reimbursement reform, with patient-reported outcomes informing future risk adjustment for hospital performance evaluation [119]. Findings in the current study suggest understanding pre-operative patient activation will play a role in identifying patients at risk for impacting provider and facility reimbursement. In the future, providers can expect downward payment adjustments for potentially preventable post-acute utilization and complications, and as a result of patients reporting lower gains on health-related quality of life metrics, such as the Veteran's RAND 12-Item Health Survey or Patient Reported Outcomes Measurement Information System (PROMIS) [119]. An increasing body of literature suggests patient activation can be impacted through targeted interventions, particularly when clinicians having positive beliefs regarding the role of patient self-management achieving better health outcomes [60, 170] .

5.1 Study population and PAM

The epidemiology of joint replacement among Medicare beneficiaries suggests primary TKA occurs in primarily females (66%), who are white (92%), and more than half occur in the cohort of patients between 65 and 74 years of age. In comparison, the current study is also primarily comprised of females, although 5% fewer (61%), with comparable race proportions (91% White). Compared to one large (N=300,000) study examining risk factors for TKA complications after surgery, in which 62% of the sample included patients from New York, and the balance patients from California, the current population has similar proportion of patients with in each payer type; 62% Medicare, 26% commercial, 5% Medicaid, and 6% other versus 60% Medicaid, 31% commercial, 4% Medicaid, and 5% other reported in the larger, geographically disperse cohort [171].

Nationally, approximately 64% of patients score a “0” on the Charlson Comorbidity Index [172]. More TKA patients scored a Charlson Comorbidity Index score equal to zero (75%) overall, and limiting the Charlson scores to study patients who are Medicare eligible (> 64 years, n=469), results in comparable pre-operative disease burden (76%). These findings are somewhat at odds with published baseline VR-12 PCS and MCS scores; the study population has lower mean pre-operative physical health-related quality of life (29.9, sd = 9.1) compared to a Veteran’s population of total joint arthroplasty patients, while MCS scores were four-points higher (MCS mean study population = 55.4, sd = 10.6 vs. Veteran population mean = 51.0, sd = 11.8) [173].

The mean PAM score in the study population of 754 patients undergoing non-staged, unilateral TKA was 64.4 (sd =12.8). Mean PAM scores are consistent with scores reported during the PAM validation process; 61.9 overall and in the 65-74 year old age cohort, specifically [17]. Previous studies report it is typical to have four out of five adults in the two highest levels of activation [44]. Consistent with established knowledge, the current study found patient activation levels were skewed toward the two highest Levels; 80% of the patients reported pre-operative activation in PAM Level 3 or 4.

In 2015, Andrawis et al. reported the first investigation into the possible roll of pre-operative patient activation on post-operative outcomes in total joint arthroplasty, including assessment of pain, limb-specific functional status, and satisfaction. However, the mean PAM score in the Andrawis study was 80 (sd = 16) among a population of total hips and knees combined. The current study population may be more representative of a typical total knee replacement patient population in other jurisdictions. It is likely the Andrawis study PAM scores were skewed upward by a patient population with 50% college or graduate degrees. Higher education level has been previously associated with higher levels of activation [174]. In the current study, no information was available on the patient population’s level of formal education. Future evaluation of patient activation should seek to include education level as a covariate to better inform pre-operative risk assessment and minimize endogeneity due to the omission of potentially relevant variables.

This study highlights the association between patient activation and post-operative outcomes in a very specific population, single-side TKAs not known to be staged during the study period (i.e., patients with known contralateral, second TKA during the 90-day global period following the index knee were excluded). There are two important points of interest regarding the population. First, patient history of joint replacement surgery was not known. It is possible patients included in the study population had previous knee or hip replacement surgery, which may alter patient activation for the reported study knee. Second, Table 4.2 reported a statistically significant difference in patient activation level among the patients with known staged TKA procedures. Reviewing the distribution of patients in each PAM Level between groups re-affirms the prior concern of measurement error in PAM assessment. Among the 52 patients with known staged procedures, 42% scored within the highest level of PAM (Level 4 – *Maintaining behaviors*), compared to 26% in the study population (p=0.031). However, the staged population of Level 3 and 4 patients combined still comprises 80% of the population overall, albeit with more patients in Level 4 than Level 3 (38.5%).

Although the distribution of patients within each PAM Level appears consistent with established research, the current pre-operative joint replacement care program may have systematically increased activation prior to baseline measurement. The pre-operative protocol for joint replacement includes pre-anesthesia testing (e.g., medical clearance for surgery) and attendance at a hospital-based joint replacement education course, in which the patient, joined by a family or friend “coach,” is provided with information regarding the hospital inpatient stay, and an introduction to physical therapy exercises. The pre-anesthesia testing appointment and joint replacement course attendance occurs, for the majority of patients, two-to-four weeks prior to surgery. The pre-operative visit with the performing surgeon generally occurs five-to-10 days before surgery, almost always after the pre-anesthesia appointment and hospital-based education. For the current study, the PAM tool was administered at the pre-operative appointment with the performing surgeon.

There are a number of studies published on efforts to increase patient activation through education [58, 175-178]. Diabetes management has been a research focus for targeted interventions. In one study, community health representatives, similar in background to community health workers (CHWs), led a one-hour group class to educate a Native American population of diabetics on healthy lifestyle choices. The class was followed by a series of home-based educational interventions. At the six-month follow-up session, PAM scores increased by at least one level in more than half of the participants [175]. Similarly, among a cohort of patients with a variety of chronic diseases, a 12-week web-based intervention resulted in a positive, significant effect on increasing activation levels [70]. Even use of social networking sites among individuals with a chronic condition has demonstrated a positive correlation between frequency and duration of use and increased PAM score [178]. Interventions effective at raising activation have also been reported in large employer-based health improvement program, with a more diverse mix of patient health risk profiles and statuses. Harvey et al. (2012) reported positive gains in health behaviors at every level of activation, further suggesting there is no ceiling effect for improvement, even among the most activated patients [179].

What is less clear from the available literature is whether a one-time pre-operative education course has the potential to raise patient activation score; particularly as to whether an older, surgical population can experience change in activation level after a brief intervention. In one older adult population with diabetes, Chubak et al. (2012) reported 52% of adults ages 65 years and older changed patient activation level between annual assessment periods; 54% of those who changed increased activation level, 46% decreased. Neither patient characteristics nor undergoing surgical procedures were associated with changes in activation [32], suggesting patient activation level is dynamic over time. Greene et al. substantiated this speculation in 2015 by reporting 42% of patients changed levels of patient activation over a two-year period and impact on clinical indicators and health behaviors [44] .

For orthopedic surgeons, and the majority of surgical specialties, the nature of the relationship is episodic. The surgical care team manages the patient for a relatively short period of time; therefore, interventions should be short and feasible. Maranda et al. (2014) detailed significant gains in activation after a one-time intervention to encourage more question-asking during medical visits among a population of Latino patients in New York, where the most significant gains in PAM score were among those who scored in the lower levels of activation prior to intervention. The study reported by Maranda et al. reinforces concerns PAM measurement in the current study may have been inflated prior to baseline measurement [61]; however, not all patients attend the pre-operative hospital course. Patient activation may also be associated with hospital course attendance. In the future, understanding which patients attended, and who did not may help with model specification and better explain the association between patient activation and post-operative outcomes. In the event patients moved out of PAM Level 1 or 2 into Level 3, for example, after the hospital education course, the current study establishes patients within each activation level have unique risk profiles for post-acute service utilization, health related quality of life metrics, and joint-specific outcomes.

5.2 Patient activation and post-acute service payments and utilization following TKA

5.2.1 Post-acute utilization and payments

The current study hypothesized lower patient activation scores pre-operatively were are associated with higher payments for post-operative care in the 90-day global period following total knee arthroplasty. Accordingly, post-acute service utilization was anticipated to follow the same trend in magnitude and direction; lower pre-operative PAM was hypothesized to lead to higher post-acute service utilization. The study utilized data from five different hospital service locations serving more than 300,000 residents, one multi-subspecialty orthopedic practice, the ambulatory surgery center, and physical therapy services owned by the orthopedic clinic to assess study aims. By combining electronic health record data with administrative billing data, the current study successfully captured the majority of factors known to influence total knee arthroplasty outcomes including performing surgical provider, gender, smoking status, obesity, pre-operative physical and mental-health related quality of life, and Charlson Comorbidity Index score at the time of hospital admission, as the measurement of co-morbid disease burden.

For patient activation to play a role in triaging patient risk prior to a major procedure, such as total joint arthroplasty, the evidence needs to extend beyond patient-reported health outcomes or health behaviors, toward demonstrating a clear impact on healthcare expenditures and potentially preventable utilization. Hibbard, the lead developer of PAM, and key PAM researchers recently published a study reporting the odds of incurring ambulatory care sensitive (ACS) emergency department visits and admissions for varying levels of PAM. The study of more than 98,000 individuals with available PAM scores demonstrated patients at the three lower levels of PAM have increased odds of ACS utilization compared to patients at the highest PAM Level, Level 4 [180].

After controlling for patient demographics, surgical characteristics, and pre-operative measures of health, the current study reports patients in PAM Level 3 pre-operatively have 8.1% higher probability of accessing at least one hospital-based service in the 90-days after TKA. The direction of the association for PAM Level 1 & 2 patients was also positive, although smaller in magnitude and not statistically significant. Further, the coefficients on PAM Level 3 for inpatient readmission and outpatient services access also approached statistical significance (p=0.053 and p=0.067, respectively). A large number of covariates were included in the models to reduce endogeneity; however, the sample size is small. As a result, the confidence intervals around the point estimates are large, which would likely be improved upon by increasing the number of study participants.

There is no way to establish whether post-acute hospital services utilization were planned, nor did utilization or payment models attempt to establish if services accessed were due to post-discharge complications from TKA. Under current advanced alternative payment models for diagnosis-related groups including lower extremity joint replacement, all post-acute utilization in the 90-days following TKA would be counted in the benchmark against the surgeon's target price, except for transplantation, trauma services, acute surgical procedures, and cancer care [181]. As a result, the current study's lack of differentiation regarding the reason for post-acute visits may over-report post-acute utilization the surgeon or hospital would be penalized for under BPCI or CJR financing models.

In the current study, 23.1% of unilateral, non-staged TKA patients accessed at least one post-acute hospital-based service following discharged, regardless of discharge location or initial length of stay. Mitchell et al. (2013) examined the association between patient activation and 30-day post-discharge hospital utilization following a patient education and self-management focused intervention as part of the discharge planning process. Overall, 24% of patients had at least one post-discharge service utilization following the index admission, suggesting the TKA population in the current study may not be different from all-cause post-discharge utilization [42]. In contrast, however, the all-cause post-discharge study reported significant findings across all levels of patients activation, with highest odds for re-utilization among Level 1 patients (odds ratio, OR = 1.75), Level 2 OR = 1.50, and Level 3 OR = 1.30. Results of the Mitchell study may not be fully comparable, as the authors report utilizing a shortened form of the PAM, utilizing eight items (PAM-8) of the 13-question tool [42].

Recent reports utilizing CMS data suggest 30-day readmission following TKA is approximately 2.9%, which is lower than the 4.5% of patients readmitted in the study cohort [94]. Tayne et al. (2014) report ASA Class (ASA – American Society of Anesthesiologists) and increased operative time are significantly associated with higher rates of readmission, neither of which were available to include as covariates for the current study. Consistent with prior reports, an initial extended length of stay following TKA was significantly associated with post-acute readmission [182], as well as the probability of having any post-acute hospital-based utilization in the 90-days after surgery (AME = 10%, 95% CI = 2%, 18%).

The descriptive statistics for post-acute hospital-based utilization provide valuable information regarding the post-discharge behavior of TKA patients. Although the probability of incurring access (at least one visit to any hospital place of service), most patients (72%) had only one visit to any hospital-based service. These results are nearly identical to Mitchell et al. (2013) in which 73% of the study participants had a single post-acute hospital event in the 30-days following all-cause discharge. In descriptive results, there was no significant difference in the mean count of hospital-based visits in any post-acute setting when stratified by PAM Level. Regrettably, in the current study's low count of visits overall prohibited more advanced modeling approaches.

Recently, Kinney et al. (2015) performed a systematic review of the association between patient activation and hospital and emergency department utilization among patients with chronic illnesses. Out of the five studies reported, with varying methodology, four studies demonstrated some association between PAM and inpatient admission. Although not statistically significant, the coefficient on PAM at the two lowest levels (Level 1 & 2) assessed in the logit model for emergency department access was negative. These results contradict the review of patient activation's association with emergency department utilization reported by Kinney et al.; three studies reviewed all found increased likelihood of utilizing ED services among the lowest levels of patient activation [41, 42, 183, 184].

The patient population in the TKA-specific study is likely healthier, as a cohort, than the populations evaluated in prior PAM-based research, which have often been focused on patients with specific chronic disease conditions. Even among TKA patients scoring greater than "0" on the Charlson Comorbidity Index, the coefficients on post-acute access for any hospital access, inpatient admission, and emergency department visits were negative. Only for outpatient visits, which includes hospital-based outpatient procedures and hospital or ASC-based day surgeries, was the coefficient positive among the presumably unhealthier patients in the study population. Perhaps more comparable in patient population, Greene et al. (2015) recently established a gradient effect between PAM Levels, among patients with all types of conditions and health statuses, and the avoidance of emergency department utilization. Higher baseline PAM Levels demonstrated higher avoidance of ED visits [44]. Further investigation by Greene et al. in 2016 identified patients at the lowest Level of PAM (1) had significantly higher odds (OR = 1.33-1.51) of ED utilization for ACS conditions after controlling for age, gender, tertile of median income for the zip code of residence, and baseline chronic health conditions. The current study was not able to control for income level, but insurance type was utilized. Medicaid beneficiaries had 11% higher probability of accessing post-discharge emergency department services after adjusting for all other model covariates, including patient activation level, and Medicaid payer status was the only significant predictor of ED service utilization after TKA.

It is important to note, although also not statistically significant, the coefficient on PAM score, in the continuous functional form, was inversely related to post-acute hospital access across all places of hospital service. When reviewed in combination with inclusion of PAM score in restricted cubic spline functional form (Table 4.25, Sensitivity Analyses), the influence of patient activation on post-acute hospital utilization is explained further. While use of PAM Level is more easily translatable to clinical practice and directing interventions, results suggest the nature of the association between PAM and post-acute access changes across PAM scores (i.e., the relationship is not linear).

The body of literature regarding the association between PAM and cost of care is very limited [16, 20, 44]. The current study presents, perhaps, the most focused assessment of patient activation as a predictor of future healthcare costs, and the only known study to model expenditures for a defined, surgical episode of care. Most recently, Greene et al. (2015) reported the predicted average per capita costs in a large metropolitan healthcare system, in the two years after establishing baseline PAM scores. In the Greene et al. study, patients who maintained Level 4 activation over time had predicted costs just above $6,000, and patients who were consistently measured at the lowest level of activation (Level 1 or 2) had projected costs 31% higher [44]. This study falls on the heels of a 2013 report examining all billed costs within the same multispecialty hospital system, which patients with specific diagnoses, such as hypertension and asthma, as well as more than 33,000 patients across the system, had significantly increased predicted costs in Level 1 compared to Level 4 [20]. The 2015 report expanded upon the initial report to more clearly establish a dose-response, or gradient effect, between PAM Level and predicted future costs across increasing levels of activation, and also capture the effect of changes in activation over time [20, 44].

Among TKA patients, patients in the lowest two levels of activation did not have significantly higher predicted payments for the TKA episode of care, post-acute hospital care, or post-acute hospital and clinic care combined; however, the coefficient was positive when comparing to patients in the highest level of activation pre-operatively. Level 3 patients, in contrast, had significantly higher payments for care; 2% higher total payments, including surgery fees, and 90% higher total post-acute (hospital plus clinic) payments. The association between patient activation Level 3 and total payments remained statistically significant after excluding influential observations, although the magnitude was reduced by approximately half. Although total payments for the TKA episode of care are projected to increase over time commensurate with increasing procedure volume, under current and evolving reforms to payment policies, post-acute payments are the primary focus for targeted intervention. Re-transformed to actual predicted dollars, patients in Level 4 averaged $290 in total post-acute payments compared to Level 3 patients with $860, and patients in the two-lowest PAM Levels (1 & 2) at $615 of billable events. Utilizing projection models published by Kurtz et al. (2014), predicting more than 1.3 million primary TKAs in 2020, PAM Level 3 patients will incur $784 million in additional total post-acute costs than patients who score within Level 4 before surgery.

Results of the quantile regression models predicting total post-acute payments provider further insight the relationship between patient activation and cost at different levels of expenditure. Among the most expensive patients, patients who incurred the most visits and associated payments (90^{th} percentile), patients in Level 1 & 2 and Level 3 have large, positive coefficients relative to patients in Level 4 activation. The AME of patient activation on total post-acute payments was 186% in the 90^{th} percentile and 167% in the 75^{th} percentile, comparing Level 4 to Level 3 patients. The association between patient activation and post-acute payments was inconsistent across percentiles among the lowest two levels of PAM score. Compared to Level 4 patients, Level 1 & 2 patients had less predicted post-acute expenditure in every percentile except for the highest (90^{th} percentile), although the coefficient was not statistically significant. Further, the direction and magnitude of the association for Level 1 & 2 patients in the 25^{th} percentile changed when limiting the study population to only those discharged home, although the sample size is small (n=31 Level 1 & 2 patients with additional total post-acute payments). These data suggest OLS, which assumes a single rate of change, is not entirely sufficient to describe the association between patient activation and total post-acute healthcare costs.

5.2.2 Length of stay

For hospitals reductions in length of stay, and reducing the proportion of patients who have prolonged length of stay following the initial TKA present another opportunity for improving margins on global DRG reimbursement. For surgeons seeking to perform single-day discharge TKAs in ambulatory surgery centers, understanding the characteristics of patients who will be successful in an outpatient setting is essential. Patients in the current study stayed in the hospital, on average, 2.4 days, which is under Medicare's specified standard of care, three days. Nationally, length of stay has been steadily falling from an average of 7.9 days in the early 1990s to 3.5 days by 2010. However, with reductions in length of stay, 90-day all cause readmission rates increased across the same time period [77]. El Bitar et al. (2015) recently reported 75% of patients had inpatient stays of three or fewer days based on a nationwide inpatient sample [185]. In contrast, the TKA population in the current study include 66% of patients who discharged on or before post-operative day two, and overall 96% of patients were discharged within three days.

A review of recent literature yields almost no information regarding the potential association between patient activation and hospital length of stay following surgical procedures. Bergmo et al (2015) describe a new care delivery model aimed at improving the continuum of care for frail elderly patients after discharge, in which one of the secondary outcomes is to reduce hospital length of stay, but study results are not yet available [186]. In a study of acute post-surgical cardiac patients, a patient engagement intervention reported a 16% reduction in mean length of stay and corresponding reductions in hospital charges (5.2%) [187]. This report differs from evaluation of a spinal cord injury self-efficacy program in which improvements in patient activation over time did not yield any statistically significant differences in length of stay [188].

In the TKA population, there were a number of factors that significantly predicted patients with a length of stay greater than two days including male gender, Medicaid payer type, Medicare payer type, increasing BMI, lower pre-operative physical health status (VR-12 PCS); however, neither pre-operative patient activation level nor score significantly increased the probability of a longer initial hospitalization. It is important to note the coefficients on PAM Level in the logit models explored are different than the previously discussed post-acute utilization models; patients at the lowest levels of activation (Level 1 & 2) have an increased probability of extended length of stay, and there is a potential gradient effect as activation level increases. This trend is sustained in the sensitivity analyses performed when examining only patients discharged to home and the restricted cubic spline regression model. In cubic spline functional form, patients at the lowest end of the activation scale had suggested increased probability, while patients at the higher end in PAM score spline 2 demonstrate decreased probability as PAM score increases.

Results for BMI and VR-12 PCS are consistent with recent reports by Prohaska et al. (2017) which report higher pre-operative BMI and lower PCS significantly increase length of stay. Prohaska and colleagues demonstrated a dose-response relationship with each characteristics [189]. The current study identified a small, but statistically significant probability of having a length of stay ≥ 3 days for each covariate. The AME was too low to be clinically relevant (< 1%); however, models examining count of inpatient days were not pursued. Further assessment may be warranted to better explain how pre-operative optimization of either characteristic could translate to reducing length of stay and associated hospital costs [189].

Because the volume of outpatient TKA procedures continues to increase, and payers are beginning to trial locally driven bundled TJA care approaches, the association between patient activation and length of stay warrants further investigation. Further, ambulatory TJA can be a profitable procedure to perform in physician-owned ASCs, which according to one recent report, will increase the probability of TJAs occurring in an outpatient setting [150]. Evidence as to whether post-discharge complications negatively offset theoretical procedure cost savings are only just beginning to emerge. Lovecchio et al. (2016) recently performed a propensity score matched analysis on a population of 1476 patients with length of stay ≤ 3 days, consistent with the current TKA study, compared to 492 same-day outpatient procedures. The approach demonstrated no difference in readmission rates, but significantly higher rates of post-discharge complications overall (6.3% outpatient compared to 1.1% inpatient) [190]. Patient activation level may provide an additional tool for physicians to identify patients who can safely undergo outpatient total joints, particularly given the association between PAM Level and post-acute service utilization.

5.2.3 Physical therapy utilization and payments

Among the 199 patients who elected outpatient physical therapy (PT) services at the orthopedic clinic, PAM Level was significant associated with the number of post-operative PT visits and the total payments for PT. Although small, the AME between levels suggests patients at the lowest levels of activation sought, or required, more PT services than patients in Level 3, who in turn attended more PT sessions than patients at the highest level of activation (Level 4).

Skolasky and colleagues have published a number of studies over the past six years regarding the association between patient activation and physical therapy adherence and functional outcomes following spine surgery [21-23, 25, 191, 192]. The group’s most recent work details the effects of a motivational interviewing behavior change intervention on engagement in physical therapy. While patient activation predicted engagement, the impact of the behavioral intervention was mediated by patient activation [191]. The intervention follows previous reports of a positive correlation between patient activation levels and physical therapy attendance and activation in a similar cohort of lumbar spine patients [23]. The current TKA study is not directly comparable, in that billing data were used to count attended visits; therefore, the number of visits in which the patients did not show up for scheduled appointments was not assessed. These data would be available through the clinic's appointment management system and present a unique opportunity to add to Skolasky's work.

Skolasky's earlier work further establishes PAM correlations with measures of optimism, hope, self-efficiacy, and internal locus of control. The report concluded by articulating an opportunity for the potential for PAM to identify surgical patients at risk for poor follow-through on prescribed rehabilitation programs [22]. While there is no way to determine the level of engagement the current cohort had in their prescribed PT program (i.e., completing home-based exercises between appointments), the study does have a limited amount of patient-reported outcome measures (VR-12, Oxford Knee Score, and post-operative pain). Future work will determine whether PT session counts are associated with higher or lower post-operative outcomes, and change in patient reported outcomes over time, and further establish if patient activation level may modify effects.

The role of patient activation may be important to surgical practices seeking to participate in value-based care initiatives, where physical therapy utilization during the global period may be included in the service bundle. Surgical practices who wish to optimize outcomes while bearing the risk of resource utilization will need to identify the best possible balance between the two. In the current study, patients at activation Level 3 had, on average, $118 in additional PT payments in the first 90 days after surgery compared to Level 4 patients, which was statistically significant. Additional research will aim to determine whether the extra services provide to Level 3 patients were required to achieve outcomes comparable to Level 4 patients.

5.2.4 Does PAM predict utilization and payment following TKA?

After adjusting for the majority of patient demographic and surgical characteristics known to impact TKA outcomes, patient activation is predictive of utilization and payments across a number of models examined. Although most of the standard errors are large, suggesting opportunity to improve upon model specification in future work, there are a number of trends that persist across logit and OLS models presented. First, when reported, the coefficient on PAM score is negative across models, with the exception of Model 12 (Table 4.21). Although not statistically significant, the consistency of the inverse relationship between PAM score and the probability of accessing each hospital-based services, separately, or jointly, and the payment amount for the services suggests overall, as PAM score increases, utilization and cost may decrease. It is clear; however, from the sensitivity analyses utilizing a restricted cubic spline approach, and the results of the quantile regression models (Tables 4.22 and 4.23), activation is not linear, and has a different magnitude of effect at each quantile of payment.

Patient activation level can be more readily translated into clinical practice than score, particularly given the PAM tool has already defined Levels based on a curvilinear transformation. Combining PAM Level 1 & 2 into a single category due to sample size is a limitation of the current approach, nevertheless, results yielded useful information about the role of patient activation in joint replacement care. There are a number of trends in the coefficient direction across payment and utilization models. PAM Levels 1 & 2 and PAM Level 3 have positive coefficients in Model 1, the probability of accessing any hospital-based service (Table 4.17), as well as the payments received for services for the total TKA episode of care (Model 11), total post-acute hospital payments (Model 13), total post-acute payments (hospital plus clinic, Model 15), and physical therapy payments (Model 17) (Table 4.21). Of these, total payments, total post-acute payments, and physical therapy payments yielded statistically significantly higher payments for PAM Level 3 compared to patients at the highest level of activation (Level 4). In addition, in quantile regression models for total post-acute payments (Table 4.23), the largest coefficients on PAM Level 3 were among the patients who incurred the highest payments. At the 90th percentile, although not statistically significant PAM Level 1 & 2 patients also had large positive coefficients.

While PAM Level was not significantly associated with total hospital-based post-acute payments, when adding in total clinic fees, a significant association was detected. Although additional research is needed to infer further, patients who had extra billable appointments with their surgeon, for new problems not covered under standard global post-operative care, may be driving up total post-acute payments. These results are particularly useful to surgeons who bear financial risk under bundled payment models. When combined with physical therapy utilization data, demonstrating patients at lower levels of activation had nearly two more PT visits in the study period (Table 4.26), results suggest surgeons who seek to vertically integrate and own more services within the post-operative care continuum should know their patient activation levels. However, any interventions to address lower activated patients will have to proactively balance resource utilization with clinical outcomes.

5.3 Patient activation and patient-reported outcomes following TKA

The patients who had evaluable, paired pre- and post-patient reported outcome measures (PROMs) were significantly different from the patients who did not complete both assessments on a number of important characteristics. Of concern, patients who had paired assessments had significantly different proportions of patients represented in each PAM Level. For example, more PAM Level 4 patients participated in pre- and post- VR-12 assessments compared to Level 1 patients (58% compared to 41%). The distribution of patients within each PAM Level in the entire TKA population was more consistent with the distribution PAM levels in existing literature [44]. The population with paired responses is skewed toward higher PAM Levels, with more than 84% of patients VR-12 paired respondents comprising Level 3 and 4 combined compared to 80% overall.

The contribution of individual Surgeon's to the sub-group of paired survey patients may systematically bias results. Surgeon 1's practice successfully administered pre- and post-operative assessments to more than half of study patients across all PROMs. In contrast, almost no patients (7%) who had surgery performed by a lower volume surgeon ("all others") had evaluable pre- and post-data to analyze. A 2012 systematic review of the relationship between volume and patient outcomes suggests lower volume surgeons have worse patient reported outcomes measures, although volume thresholds are inconsistent across the literature [193]. Wilson et al. (2016) recently used advanced methods to identify volume thresholds associated with complication rates and 90-day mortality. The study established ≥ 146 TKAs per year as the highest volume; 60-145 as the second highest; and three lower-threshold categories. Employing this stratification, Surgeon 1 and Surgeon 2 are in the highest volume categories focusing on only the study population, Surgeon 3 is in the second highest quintile; and all other surgeons are in lower volume categories [194]. However, it is likely Surgeon 3 would be elevated to the highest quintile of volume when considering staged and bilateral procedures. No data exists regarding the impact of these particular thresholds of surgical volume on patient self-assessment of health and functional status; however, there is reason to apply appropriate levels of skepticism to PROM results with higher proportions of missing data among lower-volume providers.

The current study demonstrates the impact of pre-operative PAM scores on changes in pre- to post-operative patient reported outcomes within the 90-day global billing period. In contrast, many PROMs in orthopedic total joint arthroplasty research are compared at six-months post-operatively. Validation and responsiveness for the Oxford Knee Score, for which sample size assumptions were based, are based on a minimum six-month follow-up [120]. Despite the shorter follow-up period, patient activation is predictive of changes in VR-12 PCS, VR-12 MCS, and pain score (VAS) within the 90-day post-operative period. This finding contributes to existing knowledge regarding optimization of post-operative outcomes for primary TKAs.

5.3.1 Health-related quality of life (VR-12)

A standardized health-related quality of life metric, such as the VR-12, has been identified for inclusion in the American Joint Replacement Registry (AJRR) [195]. Available information to date suggest, comparison of pre- to post-operative health related quality of life metrics will likely be part of value-based care reimbursement models [196, 197]. To date, CMS has requested patient reported outcome measures be *collected* on TKAs as a process measure under MIPS; the actual direction and magnitude of score change is not currently tied to payment.

In 2009, the U.S. population standards for the VR-12 were updated. Application of the updated standards to the Medicare Health Outcomes Survey yielded an average PCS score of 39.8 (sd = 12.2) and average MCS score equal to 50.1 (sd = 11.4) [198]. Among a pre-operative TKA population, one recent report identifies mean PCS and MCS at 32.6 and 48.6, respectively. In comparison, the current cohort had lower mean pre-operative PCS across all three categories of patient activation level reported. There is a gradient in pre-operative PCS and MCS, with lowest scores identified in the PAM Level 1 & 2 patients, and highest scores in the Level 4 patients. The same report from Rissman et al. (2016) also provides a 3-month post-operative comparison. Post-operatively, patients improved an average of 8.3 points on the PCS and 5.2 points on the MCS (mean PCS = 40.9 and mean MCS = 53.8). In the current study population, the mean VR-12 pre-operatively was 29.9 (sd = 9.1) and mean MCS was 55.4 (sd = 10.6), both of which vary significantly by PAM Level (PCS p=0.024 and MCS p=<0.0001). In comparison to the Rissman cohort, patients scores, on average, changed 10.1 points (sd = 10.3), achieving higher mean change over time. This trend was not sustained for MCS; patients had almost no mean change in MCS score pre- to post-operatively (mean = 0.69, sd = 10.3). Interestingly, patients in the two lower categories of activation reported (PAM Level 1 & 2 and PAM 3), reported increases in MCS, whereas patients at the highest level of activation reported decline of 2.7 points, on average. A literature search for article with “patient activation” or “PAM” and VR-12 yielded no results for additional comparison. As a result, the current study is the first known report of the association between patient activation and physical health related quality of life, as measured by the VR-12.

Although models reporting achievement of 90-day post-operative VR-12 scores yield interesting results, the potential policy and payment intersection is likely in the relationship between patient activation and change in VR-12 PCS and MCS over time. After adjusting for model covariates, patient activation level significantly predicts a dose-response change in PCS. Compared to patients at the highest level of activation, patients in Level 3 self-report -2.63 less change in pre- to post-operative assessment, and patients in Levels 1 and 2 are an additional one point below Level 3 patients (-3.74). Results were also robust to sensitivity analyses performed, and the model met OLS assumptions. Finally, across all levels of activation, the study population achieved a PCS change score greater than the previously published threshold for achieving minimally important clinical difference (MCID), 4.5 points (based on SF-12, from which the VR-12 was derived) [125].

There are a number of covariates that could better inform the models predicting 90-day post-operative PCS and change in PCS over time. Desmerules et al. (2013) reported variability in post-operative health-related quality of life, as measured by the SF-36, was better explained by inclusion of pre-operative pain scores, marital status, employment status, and the presence or absence of contralateral knee pain [199]. The current study does have pre-operative pain scores which could be included in models in future research, and marital and employment status could be obtained, but may not be reliably updated in the clinical record (i.e. status at the pre-operative appointment specifically may not be accurate). Except for these potentially important omissions, the models examining PCS controlled many of the published demographic and surgical characteristics associated with post-operative PCS and change in PCS over time.

Performing surgeon and increasing BMI were also associated with change in VR-12 PCS between pre- and post-operative assessments. A recent study examining pre-operative pain and function as indicators for TKA reports across more than 100 surgeons at 24 sites, the pre-operative PCS varied by less than the MCID [200]. Data in the current study were consistent with this finding between Surgeon 1, Surgeon 2, and Surgeon 3. However, patients treated by the nine lower volume surgeons combined were, on average, at least 4.5 points below at baseline. Importantly, despite being fairly consistent with Surgeon 1 and Surgeon 2 in pre-operative PCS, patients treated by Surgeon 3 have significantly lower post-operative PCS scores and demonstrate less gain in physical functioning between pre- and post-operative assessments, after adjusting for all other model covariates. Further research is needed to determine why Surgeon 3's patients are reporting less gains in PCS over time compared to Surgeon 1, nearing the threshold for important clinical difference. According to volume thresholds, Surgeon 3's volume should be mitigating procedure-related effects, such as long tourniquet times, which has been reported to adversely impact functional outcomes [201].

Last, regarding change in PCS over time, as BMI increases, the magnitude of change in VR-12 PCS also increased. The magnitude of the association was consistent across PAM functional forms; for each 5-point increase in BMI, change in VR-12 PCS improves by 1.4 points, on average (95% CI = 0.64, 2.19, $p<0.0001$). For a normal weight person (< 25 BMI) compared to a patient with BMI > 35, which is roughly 25% of the study population, VR-12 PCS the magnitude of change is close to three points. The significant, positive relationship is contrary to current beliefs among orthopedic surgeons regarding the relationship between BMI and patient reported outcome measures. The general consensus in the literature is obese patients have lower pre-operative functional status and health-related quality of life pre-operatively, but gain equivalent improvement in PCS over time compared to non-obese patients [202, 203].

In contrast to the PCS models examined, the MCS 90-day post-operative models did not meet OLS assumptions. General heteroskedasticity persisted despite utilization of robust standard errors. Models also remained heteroskedastic after log-transforming the dependent variable when model building, which actually yielded a worse performing model overall than utilization of the raw MCS scores. Although there was no local heteroskedasticity detected among variables found to be significant in either PAM functional form models (score or level), caution should be used when drawing conclusions. The models do not produce the best linear unbiased estimators. Further investigation is warranted to mitigate the modeling specification issues for 90-day MCS. As per the PCS, MCS change over time likely carries more potential implications than 90-day score overall, and models examining MCS change were better specified, meeting basic OLS assumptions.

Patients at lower ends of activation (PAM Levels 1 – 3) demonstrated significantly better improvement in MCS over time compared to highly activated patients (Level 4). Recall PAM Level 4 patients also had baseline MCS scores nearing one standard deviation higher than Level 1 and 2 patients (8 points), and nearly five points higher than Level 3 patients. Results bring into question whether for acute post-surgical episodes regression to the mean may impact assessment of change over time in MCS. Pre-operatively, TKA patients in every Level are higher than the Medicare population mean (50.08) [198]. Rissman et al. (2016) reported 5.2 points of improvement in MCS between pre- and post-operative assessments, which is consistent with the magnitude of the coefficient differences between the lower levels of PAM compared to PAM Level 4.

Results from the current study clearly demonstrate patient activation is associated patient reported health related quality of life measures, even after adjusting for a number of known confounders. Patient activation level or score should likely be included in future research aimed at better predicting change in score over time and identifying patients at risk for poor self-reported outcomes post-operatively. There is room for improvement in the current PCS and MCS model specifications which will lead to more consistent and efficient estimates. It is also important to reiterate the response rate for post-operative assessments was low (48.8%) and the two highest volume surgeons in the study had a disproportionate amount of patients represented in the post-operative models. In addition, there may be reason to question whether the mode of administration, self-administered on iPads, impacted scores; however, research suggests computer-based administration imposes similar cognitive burden on patients as self-administration using paper and pencil [204]. The majority of comparisons available in the orthopedic literature map back to SF-36 or SF-12 scores, but the SF-12 averages only 0.06 and 0.31 points difference in PCS and MCS, respectively, in reported validation studies when compared to the longer SF-36 [128].

5.3.2 Functional status of the knee – Oxford Knee Score

In comparison to the VR-12, the Oxford Knee Score (OKS) captures more specific information about functional status and activities of daily life potentially limited by knee pain and disability. OKS has become one of the most widely studied patient reported outcome measures [31]. Mean baseline OKS score in the TKA study cohort was 23.8 (sd = 8.1), which varied significantly by PAM Level. Level 1 & 2 patients had lowest mean baseline OKS scores (21.9), Level 3 patients reported a mean of 24.0, and Level 4 patients were the highest at 24.7. These pre-operative scores are within the range of scores reported previously; roughly three-to-five points higher than baseline OKS reported by Klit et al. (2014) and Wood et al. (2016), respectively, and approximately four points lower than other recent reports [205-208].

Prior research has suggested the MCID in pre- to post-operative OKS is five points, when assessed at six months post-operatively [125]. The current study reports more than twice the MCID threshold with mean change at 90-days post-operatively of 11.4 points overall (sd = 8.7); however, there were no significant difference in mean change score by PAM Level. Klit et al. (2014) reported improvements in median OKS at three (OKS = 33) and six months (OKS = 36) post-operatively. Another report captured six-month OKS at mean of 37 (sd = 7.7), with continued increases in score at one and five years after surgery. In comparison, the current study population achieved a median three-month post-operative OKS equal to 37 (mean = 36.1, sd = 7.4), suggesting potential earlier gains in knee-specific functioning.

Results from Klit et al. (2014) did report significant differences in OKS pre- and post-operative scores, as well as change in score, between patients with and without depression as measured by the Major Depression Inventory (MDI). The OLS model aiming to predict 90-day OKS score in the current study remained heteroskedastic, generally, after employing robust standard errors, which extended to local heteroskedasticity in at least one significantly associated covariate. To improve the performance and consistency of estimates in statistical modeling, future assessment of OKS outcomes should control for the presence of depressive symptoms. It is possible the current models may be improved upon by including the pre-operative VR-12 MCS score as a covariate in future work utilizing the current dataset. Additional exploration, and perhaps extension of the study to include annual assessments to allow for application of a more ideal fixed-effects modeling approach, is may be necessary to better capture the association between PAM and post-operative OKS. In the current model, PAM score was significantly positively associated with OKS score at 90-days post-operatively. Further the direction of the coefficients in the cubic spline regression sensitivity analyses suggest the relationship may not be linear across PAM Levels.

The OLS model examining change in OKS score over time was better specified. Although there was no association between PAM Level or score and the magnitude of OKS change, there is a dose-response gradient noted; as PAM Level increased, OKS change also increased. Similar trends in significant predictors were uncovered in OKS change models as those previously reported for VR-12 PCS models. The magnitude of change for OKS increases as BMI increases, which between patients with a BMI of 25 compared to patients with a BMI over 40 (15 point difference at 1.9 points per 5-point change in BMI), crosses the threshold for MCID. Also similar to VR-12 PCS, the increased magnitude of change among obese patients is contrary to established knowledge. Morbidly obese patients (BMI = 40.0-60.0) as well as overweight and obese patients (BMI = 25.0-39.9) have previously demonstrated equivalent improvements in OKS when compared to a cohort with lower BMI (15.0-24.9) [203]. The contradictory findings warrant further exploration. Certainly, the current study does not support the rationale for withholding TKA for patients above certain BMI thresholds on the basis of poor performance on PROM.

The trend across PROM remains consistent in the OKS change model when predicting OKS score change by performing surgeon. Compared to Surgeon 1, Surgeon 3 again has consistently lower predicted improvement in OKS over time, which is lower than the threshold for clinical importance. A recent report of the association between surgeon factors including orthopedic specialty area, fellowship training, and TKA volume identifies higher volume, joint reconstruction specialists achieve superior OKS at 6-months post-operatively. In the current study, there was no significant difference in OKS at baseline; however, post-operative mean OKS scores and change in OKS score both varied significantly by provider, despite similar volumes, specialty, and training history. Recommendations for future investigation are consistent with those discussed regarding surgeon-specific factors for change in VR-12 PCS.

Finally, there may be one meaningful limitation in OKS reporting that impacts the generalizability of results. Throughout the duration of the study, impacting each study participant equally at pre- and post-operative assessments, the questions were presented out-of-order relative to the validated tool within the iPad application. Although questions are not progressive in nature or logically related conceptually, there is no way to determine the actually impact of this error on the actual pre- and post-operative scores. The OKS questions should have been presented to the patients in a manner identical to paper and pencil administration. The error was identified and allowed to persist throughout the data collection period, then changed immediately following the collection of final 90-day outcome data on study participants. Because the bias was consistent between patient groups and assessment period, it is unlikely the magnitude or direction of the coefficients would change. It may be difficult to publish and compare OKS outcome data as a result of the technical error.

5.3.3 Pain – Visual Analogue Pain Scale

There are many attempts to measure “success” in medical procedures, and in TJA populations specifically. PROMs ask patients about their ability to perform certain tasks, such as putting on socks and shoes, to walking up a flight of stairs, and even performing necessary tasks of community dwelling adults like grocery shopping. Really, at the end of the day, the ability of a person to perform tasks is driven by one factor – pain. Pain is what drives patients to elect major joint replacement surgery, yet up to one out of four TKA patients is reported to have persistent pain two years after surgery [209]. The Visual Analogue Pain Scale (VAS) utilized the current study is a commonly administered tool to evaluate pain on a simple 0-10 point scale. Overall, TKA patients reported a mean VAS score pre-operatively of 5.1 (sd = 2.8). Pre-operative pain rating was lower than previous reports examining TKA and pain, specifically, which indicate pain ratings closer to 6 and 7 [205, 209]. At three months post-operatively Forsythe et al. (2008) report VAS score declined to 3.3, and continued to drop over the first two years (24 month VAS = 2.2). van Hove et al. (2016) captured pre-operative scores at 4.9, more consistent with the current study population, and post-operative 6-month VAS at 2.6 (2.3 reduction). Similar to results for the OKS score, VAS scores in the current population trended toward faster reduction; mean VAS of 1.98 (sd = 1.94) at 3-months post-operatively, with a median of 2.0 and range from 0 to 9.

Patient activation level and score, separately, are significant associated with the magnitude of pain reduction experienced by study participants between pre- and post-operative assessments. These results include adjustment for covariates, such as comorbidity burden, which has been previously associated with self-reported pain [209]. Compared to patients in the highest level of activation (Level 4), Level 1 & 2 patients have VAS scores change scores 1.58 points higher (*less* pain reduction). These results were robust to excluding outliers; however, the direction of the coefficients on the cubic spline regression suggest the relationship may not be linear, although no significant associations were identified among the three spline coefficients. Kersten, White, and Tennant (2014) published a complex evaluation of the non-linearity of the VAS and caution the validity of utilizing raw VAS scores or change scores at previously established MCID thresholds, 3 points, or 30 mm [59, 137, 138].

The models examined for VAS pain do not include any covariates that capture differences in pain perceptions, attitudes, or behavior. In 2014, Gruber et al. published a study examining the association between patient activation, upper extremity specific PROM, and the Pain Self Efficacy Questionnaire (PSEQ). According to the authors, the PSEQ captures confidence to function day-to-day despite pain symptoms. PAM score was significantly and positively correlated with PSEQ, and negatively correlated with pain intensity utilizing an 11-point ordinal scale consistent to the VAS collected for TKA patients. Gruber et al. (2014) reported a consistent correlation between PAM at study enrollment and pain assessments at follow-up appointments (r = -0.055). In comparison, the correlation between pre-operative PAM score and post-operative pain on the VAS is -0.072 among TKA patients. Patients in the Gruber study were not diagnosis-specific; 112 patients presenting to the first time for upper extremity appointments were assessed [26].

Another tool that may help reduce potential endogeneity when assessing pain as a primary outcome is the degree to which patients exhibit catastrophizing behaviors. Wood et al. (2016) recently reported pre-operative predictors of pain catastrophizing, anxiety, and depression among TJA patients. Pain catastrophizing across three domains -- helplessness, rumination, and magnification – were predicted by higher subjective pre-operative pain. Wood suggests patients with pre-operative pain catastrophizing are more likely to be "disproportionately disabled subjectively with preserved objective clinical function (pp. 2753)." A literature search yield no results for studies jointly investigating patient activation and catastrophizing behavior. There is an opportunity to better understand the relationship between pain catastrophizing and patient activation, and their potential relationship together, or potentially as an effect modifier on subjective pain scores, such as the VAS.

Finally, the VAS assessment is ideally presented to the patient as a 0-10 point scale, but captured in millimeter increments to yield better sensitivity [132]. The current study utilized a 0-10 point scale, captured in single-point increments. Data were collected consistently across patients and time points; however, there is no way to determine whether pain scores may be over or under-inflated as a result of data capture methodology. There are a significant number of pain studies, or studies utilizing pain as a covariate in orthopedic research, that report on 0-10 point scales, thereby still allowing for reasonable comparisons to established literature.

5.3.4 Summary comparison to prior patient activation research in TJA populations

There remains only one other published study to assess patient activation in total joint arthroplasty populations. Ideally, the current study would have utilized identical patient reported outcome measures to allow for more direct comparisons; however, the Andrawis study (2015) was published after data collection on the current study had commenced. Instead of the OKS and VAS, pain and functional activity were assessed by the Knee Injury and Osteoarthritis Outcome Score (KOOS) and UCLA activity score. Health-related quality of life was measured with the SF-12v2, which can reasonably be compared to the VR-12 utilized in the current study. Finally, Andrawis et al. also collected a patient satisfaction metric (Hip and Knee Satisfaction Scale). All questionnaires were collected pre-operatively and at six-weeks, six-months and 12-months post-operatively.

Andrawis et al. reported a statistically significant association between patient activation and post-operative SF-12 mental health scores. For every 10-unit increase in PAM score, mental health score increased by 2.6 points, on average. The current study reports a smaller effect, after adjusting for more potential confounders, but also excluding patient level of education and insurance status; Model 28 reports a 10-unit increase in PAM score would increase VR-12 MCS score by 0.9 points. Recall, the MCS 90-day post model does not adhere to OLS assumptions for heteroskedasticity. Improvements in PCS were comparable between the two populations; Andrawis mean change was 10.6 versus 10.1. Andrawis reports no significant association between patient activation score and post-operative physical functioning (SF-12 PCS) at either follow-up assessment. In contrast, the current study reports a significant association between patient activation level and score, separately, on 90-day post-operative score. For every 10-point increase in PAM score, VR-12 PCS increase by 1 point. Further, the current study reports a significant dose-response effect between patient activation level and PCS, where patients at lower levels of activation report less change in PCS over time. In addition, after adjusting for all model covariates, the association between patient activation score and PCS change approached statistical significance (p=0.07). Finally, Andrawis also reports PAM score was positively associated with improved pain scores on the pain subsection of the KOOS six months after surgery. The current study failed to produce a 90-day VAS model that met OLS assumptions, which limits comparison between pain outcomes.

The current study improves upon the methodology employed by Andrawis et al. First, the study population is more homogeneous, including only TKA patients, and not combining TKA and THA, which have different surgical experiences and post-operative care plans. As discussed previously, the current study population is likely more representative of TJA populations nationally, as the Andrawis study reports more than half of patients earned collegiate or graduate school degrees. Second, the sample size in the current population is six-fold larger than the Andrawis study of combined hip and knee patients, presenting the opportunity to reduce endogeneity and model misspecification due to micronumerosity. Andrawis did elect to utilize a generalized linear model (GLM) with repeated measures over time, which may have been a more suitable approach reporting post-operative follow up measures for PROMs. The current study focused on only one time point within the global billing period, with little to no variability between assessment periods for covariate measures.

5.3.5 How well does PAM predict patient-reported outcomes following TKA?

Patient reported outcomes for models meeting OLS assumptions demonstrated a gradient effect between PAM Levels; the two lowest levels of PAM (1&2) had significantly less improvement over time in physical-health related quality of life (VR-12 PCS, Table 4.33) and higher self-assessed pain (VAS) compared to patients at PAM Level 4 (Table 4.34). Incremental improvements in PAM score were also significantly associated with every PROM, in either achievement of overall 90-day score, or change in score over time. It is interesting to note patients at the highest level of activation remain fairly stable in mental health related quality of life (Model 29 & 30), while patients in the two lower categories of activation levels achieve significant and clinically meaningful improvement in mental and emotional health over time. These gains were made despite the fact the cohort's baseline MCS was already higher than reported national averages [198].

There exists a body of literature regarding minimally clinically important differences for patient reported outcome measures in TKA, as well as established knowledge regarding the benefit of incremental improvements in VR-12 score on future healthcare costs. More investigation is needed to determine why general and, at times, local heteroskedasticity was detected in multivariate models predicting 90-day post-operative scores for MCS, OKS, and VAS. Further exploration of modeling approaches that may better account for potential group clustering by surgeon, for example, or patient characteristics may be warranted.

Currently, under MIPS, orthopedic surgeons submit a process measure indicating whether patient reported outcomes were assessed. There is currently no established outcome score or improvement threshold defining surgical "success." While patient activation level translates better to a clinical setting and development of targeted interventions, there may be additional opportunity to target increases in PAM score – to realize improvement in reimbursement when PROMs are included as part of future risk adjustment strategy. If reimbursement is to be weighted based on change in score over time, every point improvement could translate to increased reimbursement under bundled payment models.

5.4 Other Limitations and Considerations

The current study relied heavily on administrative billing data from up to four different entities. Both the sources and type of data being collected present sources of bias. First, there are two hospital entities representing five possible points of hospital-based service. One hospital system operates four hospitals included in the data; the other hospital is a single, community-based hospital. This study is not able to account for patients who may have utilized different hospital systems post-operatively. Similarly, for patients who reside out of the County, with emergency departments and hospitals more proximal to their place of residence, post-operative utilization was likely not captured. It is also possible patients with complications could be managed in a primary care setting, incurring additional utilization. The resulting bias toward under-reporting of utilization will impact study results. To help mitigate this particular bias, sensitivity analyses limiting the population to patients who reside within approximately 45 miles of the surgical hospitals, with the assumption geography will drive patient hospital preferences, was performed and reported.

Administrative billing data also present several limitations for use in research studies, predominantly because financial incentives drive the quantity and quality of documentation. Administrative data are prone to error based on clerical inaccuracy, which will likely vary based on place of service. The likely impact in the current study is in the computation of comorbidity indexes which rely on documentation of diagnosis codes. Stata user commands to calculate the Charlson Comorbidity Index were utilized; however, the study crossed the transition of ICD-9 to ICD-10 condition coding. ICD-10 provides a higher level of specificity compared to ICD-9, so it is possible patients in the last three months of the study period (October 2015 – December 2015) may have inflated Charlson scores compared to earlier populations. Because most hospital coding systems re-sort the ICD codes with the highest complexity to appear first, it is unlikely the major comorbidities captured by the Charlson were missed in either coding system.

Outpatient payments may be under-reported if bundled services were not billed with a qualifying HCPCS package code in the Outpatient Prospective Payment System. An investigation of 25 outpatient claims did not result in a single encounter in which a qualified package code was not identified; however, it is possible conditionally packaged laboratory tests or codes paid through a composite APC were not captured in the hospital billing data. Further, the current study assigned payment data to post-acute payments that are included under the hospital global DRG for post-acute services related to the original TKA procedure (e.g., manipulation in a day surgery center or ASC). The rationale driving inclusion of unpaid events was to accurately capture true predicted costs to the stakeholders who would be expected to participate in future bundled care initiatives. Although the payer may not have incurred additional expenditure as a result of the post-acute service, the facility used additional unreimbursed resource to provide necessary post-acute care.

Last, the current study did not have the ability to capture and report information regarding post-acute rehabilitation or skilled nursing center cost and utilization. In the current sample, two patients discharged to home were subsequently readmitted to the hospital inpatient rehabilitation center. These costs are consistent with the potentially avoidable utilization sought under bundled payment initiatives; however, inclusion of potential post-acute charges and utilization for the two patients would have introduced a significant measurement error. There is no feasible way to determine the proportion of patients who discharged to home, and were subsequently readmitted to inpatient rehabilitation centers not at the hospital. Patients may have elected to seek care at a private rehabilitation center. Because of the potential bias, data are limited to only patients who were readmitted to the inpatient setting, or accessed another hospital-based service. Future work should seek to better understand and capture the relationship between patient activation and the population who were likely the most expensive post-operatively – those who were admitted to skilled nursing or rehabilitation centers following a planned discharged to home.

CHAPTER SIX

Conclusion

6.1 Implications for policy and practice

The current study is the most comprehensive assessment of the role of patient activation within a defined orthopedic surgical episode of care, total joint arthroplasty. Results suggest patient activation plays a role in post-acute service utilization following an expensive, major surgical procedure, and further supports limited existing evidence that a patient's ability and confidence in managing their health and navigating the healthcare system is associated with post-operative patient reported outcomes following TKA. The orthopedic literature remains generally focused on medical and surgical predictors of "success" or "failure" following TJA. Yet, after adjusting for many of the known risk factors for post-surgical complications, a patient's level of activation – a measurement and patient characteristic unaddressed by the majority of orthopedic surgeons – explains additional differences in post-operative payments, utilization, and patient-reported health status.

Two incentives are driving provider and delivery system change around total knee replacement – federal mandates to participate in bundled care payment programs for lower extremity reconstruction and the opportunity to shift select patients to physician-owned outpatient ambulatory surgery centers. Both situations are propelling surgeons to adopt a population health framework for managing the TKA episode of care. For Medicare patients, poor alignment between physicians, hospitals, and post-acute care providers could lead to costly penalties if cost and utilization benchmarks be achieved. Under Medicare's Bundled Payments for Care Improvement (BPCI), the inpatient stay, post-acute care, and all related services through 90-days after discharge are benchmarked, at population level, against a target price determined by CMS based on the provider cohort's historical cost and utilization [210]. Early reports of BPCI interventions focused on care coordination and evidence-based care plans have reported declines in hospital length of stay and readmissions [145, 211].

Reducing length of stay and readmissions present the best opportunity currently to realize steep reductions against target price. It is probable, at some point in the future new target prices will be established, based on provider experiences during BPCI, moving the goal-post on stakeholders. As a result, providers may need to diversify strategies to impact post-acute therapy costs, use of durable medical equipment, and prescription drug use, for example.

Improved care coordination and management of the complete episode of care, however, is resource-intensive. Not all patients will require the same level of support to achieve quality outcomes. While targeting the medically complex patients for post-surgical optimization is an evidence-based strategy for managing post-acute costs, the current study suggests patient activation level provides would provide an additional piece of information to triage patients into risk-based care coordination pathways. After adjusting for the majority of known risk factors, including comorbidity burden, baseline physical and mental health functioning, smoking status, insurance type, BMI, and performing surgeon, patients who were not at the highest level of activation had significantly higher probability of accessing post-acute hospital services, and higher total post-acute payments across hospital and clinic settings combined.

This study further suggests a dose-response association between patient activation level and post-acute outpatient physical therapy utilization. As providers gain experience and demonstrated competency with outpatient total joint arthroplasty, payers will likely begin to pass along additional financial risk to surgeons under commercial bundled payment contracts. The opportunity maximize net revenue by controlling all components of the payment bundle may propel practices to vertically integrate the TKA episode of care. The increased risk will force surgeons to manage younger, commercial populations similar to Medicare beneficiaries under BPCI. Recently, a scoring tool for assessing eight modifiable risk factors for readmission was proposed. While the risk factors tool identifies assessment of pain catastrophizing -- a positive step toward branching out from the traditional medical assessments [212] -- the current study suggests patient activation level plays a role in identifying patients who have the confidence, ability, and self-management skills to be successful in a TJA outpatient setting. Better understanding specific risks associated with lower activation may help surgeons manage their own financial risk, in addition to making sure patients are positioned for quality outcomes.

The current CMS risk adjustment methodology, which relies heavily on administrative data and billing codes, does not sufficiently capture variability in the most economically important consequences of total joint replacement, post-acute services utilization [213]. In addition, there is growing consensus patient-reported functional status and health-related quality of life will be increasingly incorporated into clinical practice and carry more weight in value-based care models [196, 197, 213, 214]. The literature is robust with pre- to post-operative comparison across the myriad of tools used to measure changes in patient reported function and quality of life. Established tools including the Patient Reported Outcomes Measurement Information System (PROMIS) or VR-12, and the Knee Osteoarthritis Outcome Score (KOOS) will be used to develop a composite metric, which will ultimately inform risk adjustments for hospital performance evaluation [119]. The current study reports change in PROM scores between pre- and post-assessment, within the 90-day global period. Patients at lower levels of activation achieve less improvement from baseline compared to patients at the highest level of activation (Level 4) when assessing change in VR-12 PCS and self-reported pain (VAS). At the point CMS identifies benchmarks for post-operative quality metrics reliant upon patient self-report, orthopedic surgeons and their practices will benefit from knowing patient activation scores in advance of surgery scheduling. Patients at risk of achieving lower improvements in PROMs may require targeted interventions aimed at improving patient activation prior to surgery.

6.2 Future research and opportunities

Care of the total joint arthroplasty patient is multi-faceted. In order to achieve a successful outcome, one recent recommendation from Kim & Iorio (2017) suggests five clinical pillars of value under new bundled care models:

1) “Optimizing patient selection and comorbidities
2) Optimizing care coordination, patient education, shared decision-making, and patient expectations
3) Using a multi-modal pain management protocol and minimizing narcotic use to facilitate rapid rehabilitation
4) Optimizing blood management, and standardizing venous thromboembolic disease prophylaxis treatment by risk standardizing patients and minimizing use of aggressive anticoagulation
5) Minimizing post-acute facility and resource utilization, and maximizing home resources for patient recovery (pp. 2)”

The current study reports patient activation plays a role in optimizing patient selection and minimizing post-acute resource utilization. By extension, interventions aimed at increasing activation should be tested, and if demonstrated to be successful, incorporated into TKA care coordination and patient education. Whether patient activation is associated with post-operative intensity and duration of narcotic use presents an interesting opportunity to further the current work. Four out of the five pillars proposed above require patient engagement to optimize patients pre- and post-operatively. If patient activation helps quantifies future risk of poor surgical outcomes, post-acute resource utilization, pain management, and patient reported outcomes, surgeons will need to add screening for patient activation level into their pre-surgical optimization programs. Stratifying pre-surgical care pathways by activation level may present the best opportunity to manage patient through the TKA episode of care.

Impacts to care delivery based on patient level of activation may not be limited to billable events when defining resource utilization. There have been no previous studies examining how patient activation level or score may impact the entire care delivery team, including calls to the provider office and utilization of nurse triage lines. While effectively managing lower activated patients may reduce billable service utilization, it may not be without impact to clinical support staff. Within the current cohort, there exists the potential to extract counts of incoming and outgoing telephone calls between study patients and clinical team members, in addition to capturing the number of prescriptions written during the 90-day post-operative period.

Over time, key limitations identified could be addressed potentially within the existing data set, and by other researchers. The results of this study provide sound rationale for continuing to explore how patient activation influences patient experiences and outcomes for major elective surgical procedures, including TKA and more broadly TJA. Missing covariates such as marital status, education and income levels, employment status, and clinical depression could better inform predictive models and reduce endogeneity as a result of potential omitted variable bias. In addition, examining patient activation level prior to any patient education events or interventions, and capturing data regarding which patients attend educational opportunities, present prospects for improving upon the present approach.

Because the current study is the first comprehensive investigation into the role of patient activation on post-acute cost, utilization, and outcomes following TKA, it is too soon to propose patient activation level be considered as part of future reimbursement risk adjustment methodology. It is not hasty, however, to reaffirm the need to transition from a medical model, focused on individual physical and mental health risk factors, to an approach that incorporates population-based strategies for managing the behavioral characteristics of patients at variable levels of activation.

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APPENDICES

Appendix A: Patient Activation Measure*

Please note the PAM requires licensing for use through Insignia Health, LLC.

Below are some statements that people sometimes make when they talk about their health. Please indicate how much you agree or disagree with each statement as it applies to you personally by circling your answer. Your answers should be what is true for you and not just what you think others want you to say.

If the statement does not apply to you, circle N/A.

1. When all is said and done, I am the person who is responsible for taking care of my health	Disagree Strongly	Disagree	Agree	Agree Strongly	N/A
2. Taking an active role in my own health care is the most important thing that affects my health	Disagree Strongly	Disagree	Agree	Agree Strongly	N/A
3. I am confident I can help prevent or reduce problems associated with my health	Disagree Strongly	Disagree	Agree	Agree Strongly	N/A
4. I know what each of my prescribed medications do	Disagree Strongly	Disagree	Agree	Agree Strongly	N/A
5. I am confident that I can tell whether I need to go to the doctor or whether I can take care of a health problem myself	Disagree Strongly	Disagree	Agree	Agree Strongly	N/A
6. I am confident that I can tell a doctor concerns I have even when he or she does not ask	Disagree Strongly	Disagree	Agree	Agree Strongly	N/A
7. I am confident that I can follow through on medical treatments I may need to do at home	Disagree Strongly	Disagree	Agree	Agree Strongly	N/A
8. I understand my health problems and what causes them	Disagree Strongly	Disagree	Agree	Agree Strongly	N/A
9. I know what treatments are available for my health problems	Disagree Strongly	Disagree	Agree	Agree Strongly	N/A
10. I have been able to maintain (keep up with) lifestyle changes, like eating right or exercising	Disagree Strongly	Disagree	Agree	Agree Strongly	N/A
11. I know how to prevent problems with my health	Disagree Strongly	Disagree	Agree	Agree Strongly	N/A
12. I am confident I can figure out solutions when new problems arise with my health	Disagree Strongly	Disagree	Agree	Agree Strongly	N/A
13. I am confident that I can maintain lifestyle changes, like eating right and exercising, even during times of stress	Disagree Strongly	Disagree	Agree	Agree Strongly	N/A

Appendix B: Oxford Knee Score*
*Please note the use of the Oxford Knee Score requires licensing by Isis Innovations.

PROBLEMS WITH YOUR KNEE

Check (✓) one box for every question.

1. During the past 4 weeks...
How would you describe the pain you usually have from your knee?

None	Very mild	Mild	Moderate	Severe
☐	☐	☐	☐	☐

2. During the past 4 weeks...
Have you had any trouble with washing and drying yourself (all over) because of your knee?

No trouble at all	Very little trouble	Moderate trouble	Extreme difficulty	Impossible to do
☐	☐	☐	☐	☐

3. During the past 4 weeks...
Have you had any trouble getting in and out of a car or using public transportation because of your knee? (whichever you would tend to use)

No trouble at all	Very little trouble	Moderate trouble	Extreme difficulty	Impossible to do
☐	☐	☐	☐	☐

4. During the past 4 weeks...
For how long have you been able to walk before pain from your knee becomes **severe**? (with or without a cane)

No pain/more than 30 minutes	16 to 30 minutes	5 to 15 minutes	Around the house only	Not at all/severe pain when walking
☐	☐	☐	☐	☐

5. During the past 4 weeks...
After a meal (sitting at a table), how painful has it been for you to stand up from a chair because of your knee?

Not at all painful	Slightly painful	Moderately painful	Very painful	Unbearable
☐	☐	☐	☐	☐

6. During the past 4 weeks...
Have you been limping when walking because of your knee?

Rarely/ never	Sometimes, or just at first	Often, not just at first	Most of the time	All of the time
☐	☐	☐	☐	☐

7. During the past 4 weeks...

Could you kneel down and get up again afterwards?

Yes, easily	With little difficulty	With moderate difficulty	With extreme difficulty	No, impossible
☐	☐	☐	☐	☐

8. During the past 4 weeks...

Have you been troubled by <u>pain from your knee</u> in bed at night?

No nights	Only 1 or 2 nights	Some nights	Most nights	Every night
☐	☐	☐	☐	☐

9. During the past 4 weeks...

How much has <u>pain from your knee</u> interfered with your usual work (including housework)?

Not at all	A little bit	Moderately	Greatly	Totally
☐	☐	☐	☐	☐

10. During the past 4 weeks...

Have you felt that your knee might suddenly "give out" or let you down?

Rarely/ never	Sometimes, or just at first	Often, not just at first	Most of the time	All of the time
☐	☐	☐	☐	☐

11. During the past 4 weeks...

Could you do the grocery shopping <u>on your own</u>?

Yes, easily	With little difficulty	With moderate difficulty	With extreme difficulty	No, impossible
☐	☐	☐	☐	☐

12. During the past 4 weeks...

Could you walk down one flight of stairs?

Yes, easily	With little difficulty	With moderate difficulty	With extreme difficulty	No, impossible
☐	☐	☐	☐	☐

Finally, please check that you have answered each question.

Thank you very much.

Appendix C: Veteran's RAND 12-Item Health Survey (VR-12)*
*Please note the VR-12 requires licensing prior to use.

Instructions: This questionnaire asks for your views about your health. This information will help keep track of how you feel and how well you are able to do your usual activities.

Answer every question by marking the answer as indicated. If you are unsure how to answer a question, please give the best answer you can.

(Circle one number on each line)

1. In general, would you say your health is:

EXCELLENT	VERY GOOD	GOOD	FAIR	POOR
1	2	3	4	5

2. The following questions are about activities you might do during a typical day. Does **your health now limit you** in these activities? If so, how much?	YES, LIMITED A LOT	YES, LIMITED A LITTLE	NO, NOT LIMITED AT ALL
a. **Moderate activities,** such as moving a table, pushing a vacuum cleaner, bowling, or playing golf?	1	2	3
b. Climbing **several** flights of stairs?	1	2	3

3. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities **as a result of your physical health?**

	NO, NONE OF THE TIME	YES, A LITTLE OF THE TIME	YES, SOME OF THE TIME	YES, MOST OF THE TIME	YES, ALL OF THE TIME
a. **Accomplished less** than you would like.	1	2	3	4	5
b. Were limited in the **kind** of work or other activities.	1	2	3	4	5

4. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities **as a result of any emotional problems** (such as feeling depressed or anxious)?

	NO, NONE OF THE TIME	YES, A LITTLE OF THE TIME	YES, SOME OF THE TIME	YES, MOST OF THE TIME	YES, ALL OF THE TIME
a. **Accomplished less** than you would like.	1	2	3	4	5
b. Didn't do work or other activities as **carefully** as usual.	1	2	3	4	5

5. <u>During the past 4 weeks</u>, how much did **<u>pain</u>** interfere with your normal work (including both work outside the home and house work)?

NOT AT ALL	A LITTLE BIT	MODERATELY	QUITE A BIT	EXTREMELY
1	2	3	4	5

These questions are about how you feel and how things have been with you <u>during the past 4 weeks</u>. For each question, please give the one answer that comes closest to the way you have been feeling.

6. How much of the time <u>during the past 4 weeks</u>:

	ALL OF THE TIME	MOST OF THE TIME	A GOOD BIT OF THE TIME	SOME OF THE TIME	A LITTLE OF THE TIME	NONE OF THE TIME
a. Have you felt **calm and peaceful**?	1	2	3	4	5	6
b. Did you have **a lot of energy**?	1	2	3	4	5	6
c. Have you felt **downhearted and blue**?	1	2	3	4	5	6

7. <u>During the past 4 weeks</u>, how much of the time has your **<u>physical health or emotional problems</u>** interfered with your social activities (like visiting with friends, relatives, etc.)?

ALL OF THE TIME	MOST OF THE TIME	SOME OF THE TIME	A LITTLE OF THE TIME	NONE OF THE TIME
1	2	3	4	5

Now, we'd like to ask you some questions about how your health may have changed.

8. <u>Compared to one year ago</u>, how would you rate your **physical health** in general now?

MUCH BETTER	SLIGHTLY BETTER	ABOUT THE SAME	SLIGHTLY WORSE	MUCH WORSE
1	2	3	4	5

9. <u>Compared to one year ago</u>, how would you rate your **emotional problems** (such as feeling anxious, depressed or irritable) **now**?

MUCH BETTER	SLIGHTLY BETTER	ABOUT THE SAME	SLIGHTLY WORSE	MUCH WORSE
1	2	3	4	5