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The Cost-Effectiveness of a Midvastus Versus Standard Medial Parapatellar Surgical Approach for Total Knee Arthroplasty

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Abstract

The minimally invasive midvastus (MMV) surgical approach for total knee arthroplasty (TKA) is a less invasive technique that has been proposed to accelerate recovery over standard TKA, however, advantages are not yet definitively established. We investigated the cost-effectiveness of MMV TKA versus the standard medial parapatellar (MPP) approach for TKA alongside a randomized controlled trial in patients with knee osteoarthritis. Patients reported resource use as well as indirect costs, and health outcomes were measured using the EQ-5D-5L and the Western Ontario and McMaster Universities Osteoarthritis Index over the 12-month study period. The results of our net benefit regression analysis suggest MMV TKA may be cost-effective compared to MPP TKA from the payer perspective at willingness-to-pay (WTP) values between $1000 and $2000, and WTP values between $2000 and $20,000 from the societal perspective.

Keywords

Total knee arthroplasty; cost-effectiveness; midvastus; medial parapatellar; osteoarthritis; cost; QALYs; WOMAC; minimally invasive; outpatient

Summary for Lay Audience

For patients with advanced knee osteoarthritis (OA), total knee replacement (TKR) is an established surgical procedure that has been shown to improve pain, function, and quality of life. Over the years, less invasive surgical approaches have been developed in efforts to improve short-term recovery, reduce complications, and shorten the length of stay in hospital following TKR. The midvastus approach is one such technique. The potential advantage of the midvastus approach over traditional approaches is that less soft tissue in the leg is cut during surgery, which may allow for faster recovery and thus reduce the length of stay in hospital.

A shorter length of stay may reduce the hospital costs of TKR, although it is unknown whether the potential financial savings will be outweighed by possible complications related to early discharge from the hospital.

Therefore, the aim of this study was to evaluate the clinical outcomes and costs of TKR using a midvastus surgical approach compared to the standard medial parapatellar approach in patients with knee OA. We randomly assigned consenting patients scheduled to have TKR to either surgical approach and followed them for 12-months.

Patients completed questionnaires on their health care resource use (e.g., number of physician visits, tests, medications) and indirect costs (e.g, time off work/volunteering) related to their surgery. They also completed surveys on health outcome measures such as health-related quality of life, pain, and movement before surgery, two-weeks, six-weeks, three-months, and 12-months

after surgery. We calculated the average total costs and health benefits incurred by patients in each group over the 12-month study period.

We found patients who had TKR with the midvastus approach experienced slightly greater health benefits than patients who had standard medial parapatellar TKR. Midvastus TKR patients also incurred fewer costs when considering societal costs which includes direct and indirect costs. Our findings highlight the importance of investigating patient-reported outcome measures and indirect costs. These results will help inform a future study evaluating the safety and cost-effectiveness of outpatient TKR, where patients are discharged from the hospital on the same day as their surgery.

Co-Authorship Statement

The randomized controlled trial was designed by Drs. Brent Lanting, Dianne Bryant, and Jacquelyn Marsh as part of a past student's doctoral thesis (Dr. Bryn Zomar). The present analysis was designed in collaboration with Dr. Marsh and Dr. Lanting. I was solely responsible for the collection of unit prices for all reported healthcare resource use, analyzing and interpreting the data, and writing the original draft of the thesis. Dr. Marsh contributed to data interpretation and reviewed and revised drafts of the thesis. Dr. Lanting also reviewed the manuscript and provided me with comments and suggestions to improve the final thesis submission.

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List of Abbreviations

ΔE	Incremental Effect
ΔC	Incremental Cost
AAC	Arthritis Alliance of Canada
ASA	American Society of Anesthetists
BMI	Body Mass Index
CEAC	Cost-Effectiveness Acceptability Curve
CI	Confidence Interval
FJS	Forgotten Joint Score
HCP	Healthcare Payer
ICER	Incremental Cost-Effectiveness Ratio
INB	Incremental Net Benefit
KSS	Knee Society Score
MCID	Minimally Clinically Important Difference
MICE	Multivariate Imputation using Chained Equations
MIS	Minimally Invasive Surgery
MMV	Minimally Invasive Midvastus
MOHLTC	Ministry of Health and Long-Term Care
MPP	Medial Parapatellar
NBR	Net Benefit Regression
OA	Osteoarthritis
PACU	Post-Anaesthesia Care Unit
PROM	Patient-reported Outcome Measure
PSI	Physicians' Services Incorporated
QALY	Quality Adjusted Life Year
RCT	Randomized Controlled Trial
ROM	Range of Motion
SD	Standard Deviation
SE	Standard Error
SOC	Societal Perspective

THA	Total Hip Arthroplasty
TJA	Total Joint Arthroplasty
TKA	Total Knee Arthroplasty
TKR	Total Knee Replacement
TUG	Timed Up and Go Test
VAS	Visual Analog Scale
WOMAC	Western Ontario and McMaster Universities Osteoarthritis Index
WTP	Willingness-To-Pay

Chapter 1

1.1 Introduction

Osteoarthritis (OA) is a degenerative joint disease often causing localized pain and reduced mobility (Woolf & Pfleger, 2003). This condition can significantly impact the physical and psychosocial well-being of patients (Sharma & Felson, 1998), and presents a substantial financial burden to healthcare systems and society as a whole (Gupta et al., 2005; Marshall et al., 2015). Nearly 1 in 3 people over the age of 65 are affected by OA, and the prevalence is expected to rise as risk factors for developing OA become more common (Arthritis Alliance of Canada [AAC], 2011; Hawker, 2019). Therefore, it is important to investigate the cost-effectiveness of treatments for OA to optimize health gains given the constraints on health care resources.

For patients with advanced knee osteoarthritis, total knee arthroplasty (TKA) is an established surgical procedure that has been shown to improve pain, function, and health-related quality of life (Pollock et al., 2016; Bourne et al., 2010). Over the years, less invasive surgical techniques, including the midvastus approach, have been developed in efforts to improve short-term recovery, reduce complications, and shorten the length of stay following TKA. The potential advantage of the midvastus approach is that a large portion of the insertion of the vastus medialis on the quadriceps tendon is preserved during surgery which may allow for accelerated recovery and thus a reduced length of stay in hospital following surgery (Haas et al., 2004; Berger et al, 2005; Laskin, 2005).

A shorter hospital stay is one means of reducing the overall costs of TKA. Although improved efficiency is important in healthcare delivery, we must also consider the safety, effectiveness, and patient satisfaction associated with new models of care. Further, it is unknown whether the potential financial savings of minimally invasive TKA will be outweighed by possible additional postoperative costs, such as increased readmissions and decreased quality of care.

Therefore, the objective of this study was to evaluate the cost-effectiveness of TKA using a minimally invasive midvastus (MMV) surgical approach compared to the standard medial parapatellar (MPP) approach in patients with knee OA based on a 12-month randomized controlled trial (RCT). Our findings will be used to inform the protocol of a future RCT investigating the safety and cost-effectiveness of outpatient total knee arthroplasty.

1.2 Literature Review

1.2.1 Osteoarthritis

Osteoarthritis is the most common type of arthritis (Murray et al., 1996), affecting nearly 1 in 3 people over the age of 65 (AAC, 2011). This degenerative musculoskeletal disease affects all structures within a joint (Felson et al., 2006) and is characterized by loss of joint cartilage that leads to localized pain, reduced joint range of motion and mobility, and lower quality of life (Hunter et al., 2008). In Canada, OA is one of the leading causes of disability, as well as a major economic burden (Marshall et al., 2015). The number of people living with OA is projected to double by 2040 as populations age and life expectancy extends (AAC, 2011). The increasing prevalence of OA risk factors, including obesity, physical inactivity, and joint injury, are also likely contributing to the rising rates of OA (Hawker, 2019; Puig-Junoy & Ruiz Zamora, 2015).

1.2.1.1 Disease burden in Canada

Studies on the prevalence of osteoarthritis have shown that approximately 3.9 million Canadians are living with symptomatic OA (PHAC, 2020). Osteoarthritis is not only responsible for a very high number of primary health care visits and overall hospital costs, but there is also a significant socio-economic burden (Li et al., 2006). A survey by Gupta et al. (2005) estimated Canadian patients over the age of 55 with hip or knee arthritis incurred $2300 in direct costs and $12,900 in indirect costs annually. These non-healthcare-related indirect costs took form in time lost from employment for patients and for unpaid informal caregivers, with caregiver time accounting for 40% of indirect costs. Another study by Xie et al. (2007) estimated the annual direct costs per patient to be US$2878 and the indirect costs to be US$9847 in Canada. As the Canadian population ages, osteoarthritis will become an increasing burden for individuals and the health care system (Birtwhistle et al., 2015). The direct costs of OA in Canada were projected to increase from $2.9 billion to $7.6 billion from 2010 to 2030, with hospitalizations for joint replacement accounting for the highest costs (Sharif et al., 2015).

1.2.1.2 Osteoarthritis of the Knee

Almost any synovial joint can be affected by osteoarthritis, although weight-bearing joints such as the knees and hips are the most commonly impacted (PHAC, 2010). Knee OA specifically impacts over 10% of the older adult population (AAC, 2011; Zhang & Jordan, 2010) and accounts for 83% of OA disability (Vos et al., 2012).

The lifetime risk of developing symptomatic OA in at least one knee is estimated to be 39.8% for men and 46.8% for women, with significantly higher odds seen in those who possessed risk factors including obesity and history of knee injury (Murphy et al., 2008). Other common risk factors for OA include age, sex, genetic predisposition, and mechanical factors, including malalignment and abnormal joint shape.

The course of the disease can vary but is often progressive. Over time the hyaline articular cartilage, which covers and protects the ends of bones, breaks down, and bony remodeling occurs. This breakdown was once thought to be caused by the wear and tear associated with aging, however, osteoarthritis is now understood to be the result of disruption of the natural cartilage remodeling process (PHAC, 2010; Kraus et al., 2015). As articular cartilage is lost, the subchondral bone becomes exposed, leading to joint space narrowing and bone-on-bone articulation. The continuous friction between the bones can cause excessive bone remodeling (formation of osteophytes and subchondral bone sclerosis) and thickening of the capsule (Lories & Luyten, 2011; Loeser et al., 2012). Inflammation of the synovium as well as overproduction of matrix-degrading enzymes, leading to destabilization of the joint, and abnormal joint loading are also often seen with knee osteoarthritis (Blagojevic et al., 2010; Felson et al., 2000; Felson, 2009; Troeberg & Nagase, 2012).

Knee OA is commonly clinically characterized by joint pain that is gradual in onset and worse with activity, tenderness, limitation of movement, crepitus, and variable degrees of local inflammation (Hunter et al. 2008; Kraus et al., 2015).

Progression of OA cannot be reversed, and no disease-modifying agents for the treatment of knee osteoarthritis currently exist, although interventions have been developed to reduce symptoms of knee OA and improve function (Woolf & Pfleger, 2003). Therapeutic exercise, weight management, and pain medications may help relieve symptoms (Dunlop et al., 2011; Bijlsma & Knahr, 2007; PHAC, 2010). In cases of severe osteoarthritis, when conservative management fails, surgical treatment, including knee arthroplasty, may be considered (Lützner et al., 2009).

1.2.2 Total Knee Arthroplasty

Total knee arthroplasty (TKA), also known as total knee replacement, is a surgical procedure to replace the arthritic parts of the bones at the knee joint (the tibia, femur, and sometimes the patella) with an orthopedic prosthesis. TKA is considered for patients with severe knee osteoarthritis, rheumatoid arthritis, avascular necrosis, bone tumors, and knee fracture, although osteoarthritis was the primary diagnosis for 99.4% of primary total knee arthroplasty patients in Canada from 2019-2020 (CIHI, 2021). The surgery has been shown to be highly effective, resulting in significant improvements in pain, functioning, and health-related quality of life (Brandes et al., 2011; Shan et al., 2015), but is also very costly. The average inpatient cost is more than $9,000 per procedure and accounts for more than 594,000 acute care bed days in Canada annually (CIHI, 2018). Total knee replacements are among the top 3 inpatient surgeries performed in Canada, and in the last five years, the number of TKAs performed has increased by 17.1% (CIHI, 2021). Given the frequency at which the procedure is performed, it is the focus of continuous analysis and improvement (King et al., 2011; Lan et al., 2020).

1.2.2.1 The Medial Parapatellar and Midvastus Surgical Approaches

Two commonly used surgical approaches that have been shown to be safe for TKA are the medial parapatellar and the midvastus approach.

The medial parapatellar approach is the most commonly used approach for total knee arthroplasty and is usually completed using an anterior incision approximately 18 cm long. With this approach, the quadriceps tendon is split in line with the fibers, leaving a cuff of tendon attached to the vastus medialis muscle, and the patella is everted (Laskin et al., 2004). This approach allows for excellent exposure of the joint and surgical visualization (Weinhardt et al., 2004, Migliorini et al., 2020), however, the damage on the insertion of the vastus medialis on the quadriceps tendon can result in a weakened extensor mechanism and unsatisfactory functional outcomes (Boerger et al., 2005; Haas et al., 2004). Additionally, with this approach, the patellar blood supply is disrupted, which may increase surgical complications such as button loosening, patellar dislocation, and anterior knee pain (Brick & Scott, 1988; Berger et al., 1998; Roysam & Oakley, 2001). Overall, the standard medial parapatellar approach for TKA has had excellent surgical results but can result in demanding and lengthy recovery periods, which may contribute to patient dissatisfaction (Laskin et al., 2004; King at al., 2007; Anderson et al., 1996; Maloney, 2002).

Aiming to reduce recovery time and achieve better postoperative results, less invasive approaches for TKA were developed (Tria & Scuderi, 2015). The midvastus approach is one surgical technique that was developed to reduce the injury to the quadriceps tendon and minimize the disruption to patellar blood supply (Haas et al., 2004). With this approach, the vastus medialis muscle is divided in the direction of its fibers, as opposed to the traditional method of splitting the quadriceps tendon above the patella (Engh & Parks, 1998). It was suggested that this might allow for patients to experience less pain, and early restoration of range of motion (ROM) and extensor mechanism strength, compared to the medial parapatellar approach (Haas at al., 2006; Bonutti et al., 2004). This accelerated recovery was also proposed to allow for a shorter hospital stay, although these theoretical advantages are still being evaluated in clinical practice (Tria & Coon, 2003; Haas et al., 2004; Berger et al., 2005; Laskin, 2005).

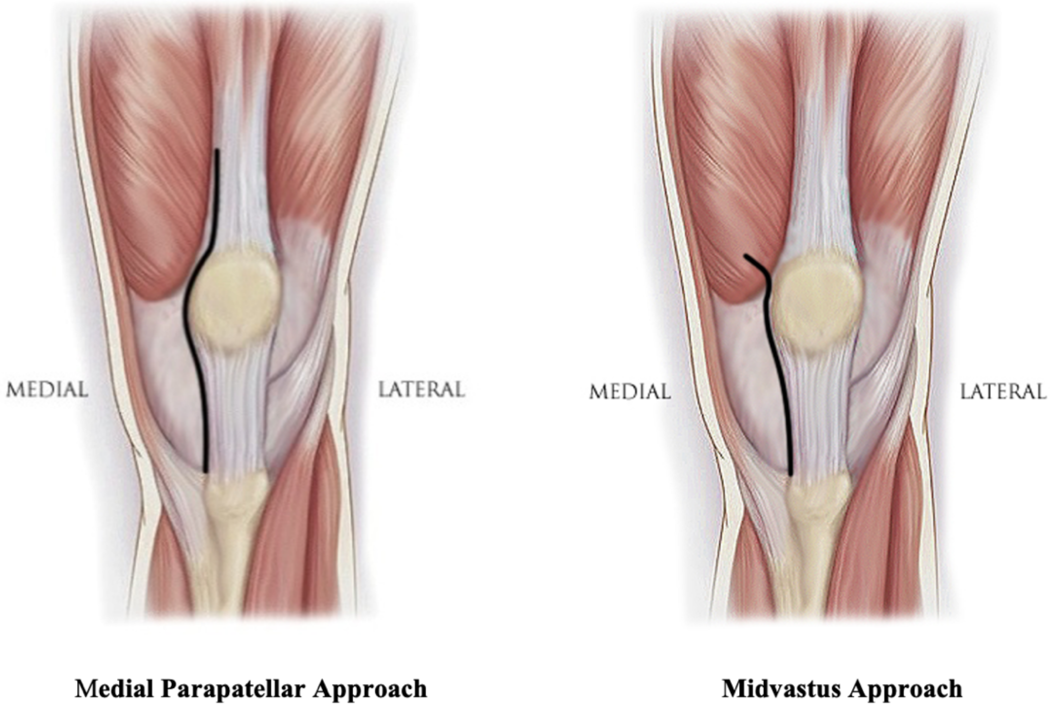


Figure 1.1: The standard medial parapatellar and midvastus approaches for total knee arthroplasty.

The definition of minimally invasive surgery (MIS) TKA is not yet standardized. Some authors have suggested MIS TKA generally involves a skin incision of less than 14 cm and incisions between 2-3 cm into the quadriceps muscle (Laskin et al., 2004; Tenholder et al., 2005; Tria & Scuderi, 2015). Others suggest MIS TKA includes a smaller incision, typically does not require eversion of the patella, and involves less quadriceps splitting (Leopold, 2009). The midvastus and medial parapatellar approaches can both be performed using either standard or minimally invasive techniques (Ongoo et al., 2020). However, the medial parapatellar approach is still the most commonly used standard approach for TKA, while the midvastus approach is often performed using minimally invasive techniques. In a meta-analysis comparing the midvastus and medial parapatellar approaches by Liu et al. (2014), 18 of the 22 included RCTs used minimally invasive techniques in the midvastus group, compared to standard medial parapatellar TKA. Xu et al. (2014) also conducted a meta-analysis including only studies that compared minimally invasive midvastus TKA with standard medial parapatellar TKA. In an earlier meta-analysis comparing midvastus TKA to standard medial parapatellar TKA by Alcelik et al. (2012), nine studies where minimally invasive techniques were used for midvastus TKA and nine studies where standard techniques was used for midvastus TKA were included. They found similar trends for all outcomes measured in a subgroup analysis comparing the minimally invasive approach to the standard approach for midvastus TKA.

Overall, these meta-analyses found the results from the studies analyzing the differences between midvastus and medial parapatellar TKA are conflicting. All authors have reported differences in short-term outcomes but a reduction in significant clinical advantages over time (Alcelik et al., 2012; Liu et al., 2014; Xu et al., 2014). The midvastus approach was associated with significantly improved knee range of motion and decreased anterior knee pain visual analog scale (VAS) scores at one to two weeks postoperative, however, there were no statistical differences in knee society score (KSS), VAS, or ROM beyond six weeks (Xu et al., 2014; Liu et al., 2014). Additionally, the midvastus approach has been associated with significantly longer operative time when compared to the standard medial parapatellar approach. This is possibly due to the greater surgical steps and reduced operation field required for less invasive techniques (Liu et al., 2014). Some investigators have raised questions about the risk of component malalignment and the learning curve associated with performing new minimally invasive techniques (Dalury and Dennis, 2005; King et al., 2007).

In terms of the time to perform straight leg raise, lateral retinacular release, blood loss, hospital stay, and postoperative complications (wound infection, deep vein thrombosis), no differences have been found between patients undergoing midvastus TKA compared to medial parapatellar TKA (Liu et al., 2014).

Other less invasive TKA approaches include the quadriceps-sparing approach, and the subvastus approach (Tenholder et al., 2005). Each approach has its advantages, however, due to the difficulty of the operations, limited visualization, and longer learning curve, these approaches have not gained as much popularity (Haas et al., 2004; Liu et al., 2014; Lin et al., 2020).

1.2.3 Outpatient Total Knee Arthroplasty

Overall improvements in surgical and anesthetic techniques, as well as accelerated clinical care pathways, have led to a reduction in the rate of complications and shorter lengths of stay following TKA. These clinical pathways involve the application of multidisciplinary strategies by various healthcare professionals, including extensive preoperative patient education, early mobilization, meticulous monitoring, and early preventive intervention for common postoperative medical complications (Pollock et al., 2016; Berger et al., 2009). Some authors have reported that reducing the length of stay in the hospital following joint arthroplasty can reduce costs without compromising patient outcomes (Bozic & Beringer, 2007; Teeny et al., 2005; Berger et al., 2009; Isaac et al., 2005). Today the average length of stay in the hospital following surgery is 3 days, although TKA is increasingly being performed as an outpatient surgery – where the patient is discharged from the hospital on the same day as their surgery (CIHI, 2021). Over the last five years, there has been over a 500% increase in the number of outpatient knee replacements performed in Canada, however outpatient procedures still only represent 1.3% of all total knee arthroplasties performed (CIHI, 2021). Initially, there was concern that patients who underwent outpatient total joint arthroplasty (TJA) may experience complications related to early discharge and require additional services post-discharge, however, studies have found that outpatient THA and TKA can be safe and effective when performed in appropriately selected patients (Berger et al, 2009; Berger et al., 2005; Kolisek et al., 2009; Pollock et al., 2016; Cassard et al., 2018; Mariorenzi et al., 2020). A systematic review of the literature by Pollock et al. (2016) found no increase in readmission rates or perioperative complications, and a high level of satisfaction among patients who underwent outpatient procedures.

No surgical approach is regarded as the standard for outpatient TKA, although most associate surgical approaches that minimize soft tissue damage with the ability to safely discharge patients home quicker (Berger et al., 2005; Berger et al., 2006). In an early study by Berger et al. (2005), a minimally invasive quadriceps-sparing approach was used to enable patients to go home the same day as their surgery. In a study by Kolisek et al. (2009), patients in both the inpatient and outpatient group received a TKA with medial parapatellar approach using a 10- to 13-cm incision, avoiding patella eversion. In this study, however, outpatients were defined as patients who were discharged within 23 hours of surgery rather than on the same day as surgery.

1.2.4 Health Economics

As healthcare costs rise and societal resources become more scarce, efficient allocation of healthcare dollars is crucial (Drummond et al., 2005). The constraints of the current fiscal climate require that decision-makers choose treatments that provide the best quality of care and optimize health benefits while minimizing costs. To better support these decisions, evidence-based research providing information on economic efficiency and value for money is necessary (Health Council of Canada, 2009).

Economic evaluation provides a method of comparing alternative courses of action in terms of costs and clinical consequences to help prioritize different healthcare strategies. These analyses help support investment in interventions that generate the greatest health value compared to a set of alternatives. With the growing burden of osteoarthritis as well as the high costs associated with total knee arthroplasty, it is important to investigate cost-effective strategies that optimize health gains given limited healthcare resources.

1.2.4.1 Cost-effectiveness of Midvastus Total Knee Arthroplasty

Several studies have evaluated the clinical effectiveness of midvastus TKA (Alcelik et al., 2012; Liu et al., 2014; Xu et al., 2014; Aslam et al., 2017; Lin et al., 2020), however, we found no studies that have investigated the economic implications of this approach.

A few authors have studied the costs associated with other minimally invasive approaches for TKA, although none have prospectively investigated costs after hospital discharge.
Coon et al. (2005) retrospectively reviewed the procedural charges of patients who received a minimally invasive TKA (with the MIS Mini-Incision™ or MIS Quadriceps-Sparing™ techniques), compared to standard TKA. They found the cost of MIS TKA to be on average US$8600 (26%) less compared to traditional TKA. They mention this cost-saving was seen

despite requiring a more expensive implant for MIS TKA and prolonged tourniquet times use due to an early learning curve, although they do not specify the source of the cost reduction. Additionally, this study only presented patient charges and not actual hospital costs and did not take post-discharge medication, rehabilitation, or time off work costs into consideration.

A study by King et al. (2011) also found MIS TKA to be associated with lower patient charges, although the magnitude of the difference was much smaller. They conducted a retrospective analysis on the inpatient charges of patients undergoing TKA with a minimally invasive quadriceps-sparing approach compared to the standard medial parapatellar approach and found MIS TKA patients to have slightly higher operating room costs but lower acute care costs resulting in a difference of US$1047 (7.2%) in the total inpatient charges.

These studies provide some evidence that minimally invasive TKA may be cost-saving in the peri-operative period from the payer perspective, however, there were some limitations to these studies that warrant further investigation.

These studies only considered the direct costs of the procedure or inpatient hospital charges; however, it is important to consider costs beyond hospital discharge. Potential financial savings in the hospital may be outweighed by additional postoperative costs, such as increased emergency room or physician visits, or decreased quality of care due to early discharge from the hospital. Given the proposed advantages of less invasive surgery such as earlier return to function, the costs associated with outpatient physical therapy and other rehabilitation costs, as well as indirect costs, should also be considered. Indirect costs include loss of wages or productivity losses, as well as time off for caregivers. Previous studies on the indirect costs associated with musculoskeletal disorders have estimated these costs may be three to five times greater than direct medical costs incurred by patients (Gupta et al., 2005; Leardini et al., 2004). The burden on caregivers is high in the early post-operative period following TKA (Zadzilka et al., 2018). Caregivers often assist with performing household chores, transportation, taking medication, and personal care for the first 7 to 30 days following surgery (Manohar et al., 2014; Zadzilka et al., 2018). With enhanced recovery care pathways and early discharge, more assistance may be required from caregivers as postoperative rehabilitation and care activities shift from the inpatient setting to the home. Thus, the potential impact on caregivers should also be considered as more responsibility is placed on them earlier (van den Berg et al., 2004; Zomar, 2020).

Additionally, as some studies have found minimally invasive TKA to be associated with component malalignment and an increase in the need for revision surgery (Dalury & Dennis, 2005; Barrack et al., 2009), analyzing direct medical costs over a longer time may influence results.

Another limitation of these studies was that they were non-randomized and included early learning curve patients with prolonged tourniquet times. Increased operation times have been associated with minimally invasive techniques; however, studies have shown operating times reduce as surgeons gain familiarity with the technique (King et al., 2007; Migliorini et al., 2020).

Finally, both studies analyzed costs separate from clinical outcomes and thus were not full economic evaluations which are required to inform decisions on value for care and changes to healthcare policy. To our knowledge, no studies to date have conducted full cost-effectiveness analysis comparing both costs and outcomes of midvastus TKA compared to medial parapatellar TKA.

A few authors have investigated the economic impact of outpatient total joint arthroplasty (Crawdord et al., 2015). Lovald et al. (2014) conducted a retrospective cost-analysis on the average medical costs of patients who had different lengths of stay following TKA and found those in the outpatient group incurred $8527 less in costs attributed to knee OA compared to the standard length of stay group over two years. They do not mention which surgical approach was used in the procedures, although they credit the move to outpatient procedures to the use of less invasive surgical techniques, regional as opposed to generalized anesthesia, and the implementation of enhanced recovery pathways.

The costs associated with a minimally invasive technique for outpatient total hip arthroplasty were compared to standard inpatient total hip arthroplasty in a study by Bertin (2005). The billed charges of patients undergoing minimally invasive outpatient THA were found to be approximately $4000 less compared to inpatient charges. A later study by Aynardi et al. (2014) also found outpatient THA to have significantly fewer billed charges. In this study, both groups underwent THA with a direct anterior approach which is a minimally invasive technique.

No full economic evaluations have yet been published on the cost-effectiveness of outpatient TKA using either a minimally invasive or standard surgical approach. Given the lack of scientific consensus on the benefits of different surgical approaches for TKA, further investigation into these techniques is warranted. The purpose of this trial was to inform the surgical protocol of a future randomized controlled trial to study the cost-effectiveness of outpatient TKA.

Chapter 2

2 Methods

2.1 Study Design

We conducted cost-effectiveness analyses comparing the medial parapatellar surgical approach to the midvastus surgical approach for TKA. In the trial, we randomized patients to either surgical approach, with or without the use of a tourniquet using a 2x2 factorial design. This randomization technique was used to allow us to explore surgical approach and tourniquet use efficiently and simultaneously by including all participants in both analyses (Lubsen & Pocock, 1994; Montgomery et al., 2003). Tourniquet use was expected to act independently from costs related to surgical approach, and results on clinical impact will be reported elsewhere. Here we present the results of cost-effectiveness comparisons between the surgical approach groups.

All patients underwent primary total knee arthroplasty at London Health Science's Centre, University Hospital between August 2017 and February 2020, using a cemented Triathlon™ (Stryker Orthopaedics, Mahwah, NJ, U.S.A.) implant by two fellowship-trained arthroplasty surgeons. We followed patients from their preoperative visit to 12 months post-surgery and collected data on healthcare resource use and clinical outcome measures at standard of care visits. The study was approved by the University of Western Ontario's Research Ethics Board for Health Sciences Research Involving Human Subjects and registered at clinicaltrials.gov (NCT03081663).

2.2 Eligibility Criteria

We included patients scheduled to undergo primary total knee replacement with osteoarthritis, varus knee alignment, and an American Society of Anesthetists (ASA) score of three or less. Patients were also required to be able to read and understand English (as printed instructions were provided in English only), have home or cell phone access, and have an adult to accompany them home and care for them post-operatively.

We excluded patients who were diagnosed with inflammatory arthritis, had a body mass index (BMI) greater than 40 or less than 18, were skeletally immature, had an active or suspected latent infection at or about the joint, had inadequate bone stock for support or fixation of the prosthesis, hardware precluding intramedullary instrumentation, prior osteotomies of the femur or tibia, had cognitive or neuromotor conditions, significant pain management issues, or had a family history of anesthesia-related complications (e.g. malignant hypothermia, pseudocholinesterase deficiency, airway difficulties, obstructive sleep apnea). Patients were also excluded if they lived more than 90 minutes from the hospital, were without access to caregivers, were unable to go directly to their home after surgery, or had significant psychological or social issues that would prevent them from managing at home safely.

We included patients who met these criteria, were willing and able to comply with follow-up requirements and self-assessments, and provided informed consent.

2.3 Randomization

Patients were enrolled in the trial at their preadmission visit to the hospital and were randomly allocated to one of four groups: midvastus TKA, with or without a tourniquet, or standard medial parapatellar TKA, with or without a tourniquet, via a web-based system. We used block randomization stratified by surgeon and patients previous experience with TKA (whether themselves or a family member/friend they cared for post-surgery). We kept patients and research staff blinded to group allocation until the final study visit.

2.4 Intervention

2.4.1 Operative Procedure

Both surgical approaches are currently used in the surgeons' normal practices and are completed using a straight anterior midline incision. Distally the approaches are the same, entering next to the patellar tendon to the tibia, avoiding the patella. With the midvastus surgical approach, proximally the incision extended obliquely from the superior-medial corner of the patella in line with the muscle fibers of the vastus medialis obliquus muscle belly, allowing the quadriceps tendon to remain intact. For the medial parapatellar approach, the quadriceps was split in line with the quadriceps tendon fibers, leaving a 5 mm cuff of tendon medially. An intramedullary femoral guide and extramedullary tibial guide were used for patients who were randomized to medial parapatellar TKA. The surgeons only used computer-assisted navigation for patients who received a TKA with the midvastus approach as implant malalignment has been a concern with this approach. All other aspects of the surgery were kept the same between the groups.

2.4.2 Postoperative Care

All participants had to pass physiotherapy discharge criteria and followed standard postoperative rehabilitation protocols. There was no difference in activity restrictions between both groups.

Patients returned to the orthopedic outpatient clinic for a follow-up visit with the surgeon at two weeks, six weeks, three months, and 12 months after surgery.

2.5 Outcome Measures

We collected outcome measures from patients at their preadmission appointment (no more than one month prior to surgery), on the day of discharge from hospital, and at two-weeks, six-weeks, three-months, and 12-months post-surgery. In addition to these time points, cost data were also collected at six and nine months. We used a secure web-based data management system (EmPower Health Research, Inc, www.empowerhealthresearch.ca) which allowed patients to complete questionnaires online. Patients also had the option of completing hard copies of the questionnaires at each follow-up.

2.5.1 Clinical Effectiveness

Information on clinical effectiveness was collected directly from study participants. Patients completed the self-reported questionnaires at or no earlier than one week before each study visit.

2.5.1.1 EQ-5D-5L

The EQ-5D-5L is a preference-based health-state measure used to collect quality of life data directly from patients (Fransen & Edmonds, 1999). Unique health states are described using a 5-digit number formed according to responses in five dimensions; mobility, self-care, usual activities, pain/discomfort, and anxiety/depression, each with five response levels (no problems, slight problems, moderate problems, severe problems, and unable to/extreme problems)

(Herdman et al., 2011; Janssen et al., 2013). Using a value set, which reflects the health preferences of the general public, health utility values can be derived from the EQ-5D-5L health states (Xie et al., 2016). Health utilities are required to estimate QALYs and are anchored at 0 (dead) and 1 (full health), although negative values are possible for health states worse than dead (Jenkins et al., 2013; Wolowacz et al., 2016).

The EQ-5D-5L has been shown to exhibit acceptable test-retest reliability in each domain (range 0.61-0.77) in OA patients undergoing TKA (Conner-Spady et al., 2015). When compared with the earlier EQ-5D-3L, the EQ-5D-5L has been found to have better responsiveness, stronger convergent construct validity, and stronger correlations with the Western Ontario McMaster Osteoarthritis Index, Oxford Knee Score, and Short Form-12 (Jin et al., 2019). Additionally, individual EQ-5D-5L dimension response levels collected through electronic versions of the tool have not been found to significantly differ when compared with paper versions (Mulhern et al., 2015).

2.5.1.2 Western Ontario McMaster Osteoarthritis Index

The Western Ontario McMaster Osteoarthritis Index (WOMAC) is a disease-specific questionnaire used to measure health status across three domains in patients with OA of the hip or knee (Bellamy & Buchanan, 1986). The tool is self-administered and comprised of 24 questions total across three domains: five items relating to pain, two to stiffness, and 17 to physical function. Each question is scored on a scale from 0 (none) to 4 (extreme). Domains can be assessed individually, or they can be combined to create a global score to evaluate function and health. WOMAC scores can be linearly transformed to a 0–100 scale, with lower scores indicating more severe impairment (Giesinger et al, 2014).

WOMAC is one of the most commonly used patient-reported outcome measures in patients with knee osteoarthritis and has been found to be valid, reliable, and responsive for detecting important health changes after total knee arthroplasty (White & Master, 2016; Walker et al., 2019). Overall, the WOMAC has high test-retest reliability for the physical function and pain subsections and has been found to be highly predictive for primary TKA treatment success at 12-months (Faucher et al., 2004; Giesinger et al., 2014). An electronic version of the WOMAC has been validated for use among joint replacement patients against the paper version (Marsh et al., 2014).

2.5.2 Costs

2.5.2.1 Surgical Costs

We collected data on health care resource use at the patient level. Patients' medical charts were reviewed from the time of admission for TKA to discharge to retrieve time spent in the post-anaesthetic care unit (PACU) and surgical inpatient ward following surgery. The cost per unit time spent in each department was obtained from our institution's case costing data and applied to each case.

The remaining average costs related to the TKA procedure, included the cost of food services, operating room, day surgery pre-and-post-operative care, clinical laboratory services, medical imaging, respiratory services, pharmacy costs, physiotherapy, and was obtained from hospital case costing data. Surgeon and anesthesiologist billing was also included in this total and valued from the Ontario Ministry of Health Schedule of Benefits (Ministry of Health and Long-Term

Care [MOHLTC], 2020). The cost of the prosthetic implant was not included as prosthesis costs vary widely and can largely influence TKA cost. All patients in the study had cemented Stryker Triathlon implant.

2.5.2.2 Healthcare Resource Use

Patients kept daily diaries for the first 14 days postoperative and completed self-reported cost questionnaires at two weeks, six weeks, three-, six-, nine-, and 12-months post-surgery. Resource use and costs were collected across 14 domains including visits to their family physician, surgeon, and other healthcare professionals (e.g., physical therapists, occupational therapists, etc.), information about hospitalizations and emergency room visits, diagnostics (e.g., imaging, laboratory), medications, calls to the surgeon's office, and any other related expenses.

To estimate costs directly covered by the provincial publicly funded healthcare, we applied the unit prices from provincial databases. We obtained the unit prices of physician services, including family physician and specialists from the Ontario Ministry of Health Schedule of Benefits (MOHLTC, 2020). We valued walk-in clinic costs at the family physician fee and valued calls to physicians or specialists which lasted at least 10 minutes as a partial assessment. The cost of a physiotherapist visit was taken from the Ontario Quality-Based Procedures Bundled Pricing (Health Quality Ontario & MOHLTC, 2013) if patients reported their visits were covered by the provincial insurance. Medication costs were obtained from the Ontario Drug Benefit Formulary (MOHLTC, 2021) or through a survey of local pharmacies.

Self-reported costs were used if patients reported that they paid for other healthcare professional visits or medications out-of-pocket or through private insurance.

2.5.2.3 Indirect Costs

Patients also reported information about indirect productivity losses such as the amount of time-off paid employment, homemaking, volunteer activities, and caregiving. We also requested patients report the number of hours of unpaid assistance received from friends or family, as well as the hours of paid assistance they received.

We used the average Canadian wage for individuals 25 years and older reported by Statistics Canada in June 2021 to place a monetary figure on time off from paid employment, for both patients and their caregivers (Statistics Canada, 2021). The current value of minimum wage in Ontario was used to value participants time away from volunteer or homemaking activities and unpaid assistance received (Government of Ontario, 2021). We estimated the total cost for each patient over the 12-month follow-up period and reported all costs in 2021 Canadian dollars. Resource use for unrelated conditions was not included.

2.6 Sample Size

A formal sample size calculation was not conducted as the main goal of this pilot study was to inform the surgical protocol of a future randomized trial investigating outpatient total knee arthroplasty. Based on the participating surgeons’ caseload, we estimated 80 participants could be recruited over the two-year study time frame.

2.7 Data Analysis

We analyzed data using Stata v. 11.2 (StataCorp LP, College Station, TX, USA) and all statistical tests were two-tailed at a significance level of 0.05.

All outcomes were tested for normality by looking at boxplots and assessing histograms for kurtosis and skewness. We used descriptive statistics to present the demographic and surgical characteristics for each group. We report means and standard deviation (SD) for all normally distributed continuous measures (age, height, operative time), and frequencies and proportions for categorical variables (sex, contralateral knee symptoms, ASA score). We reported the median and interquartile range for non-normally distributed continuous measures.

We used non-parametric bootstrapping with 1000 replications to estimate totals if data were skewed and presented 95% confidence intervals (CI) with standard errors (SE) (Efron, 1979; Briggs et al. 1997; Tambour & Zethraeus, 1998; Hesterberg, 2011). We conducted the primary analysis following the intention to treat principle.

2.7.1 Cost-effectiveness analyses

Costs are often categorized as direct medical costs, direct non-medical costs, and indirect costs. Direct medical costs refer to the costs associated with the health services (e.g., treatment and follow-ups, medications) which are relevant to the treatment option being considered. Direct non-medical costs include patient out-of-pocket expenses associated with the intervention (e.g., travel, house modifications, and informal caregiving), while indirect costs include productivity losses due to mortality or morbidity, (e.g., lost earnings and decreased capacity for leisure).

We conducted cost-effectiveness analyses from both the healthcare payer (HCP) and societal (SOC) perspectives. In Canada, we have a single-payer system where the funding and reimbursement decisions are made by provincial governments (e.g., the Ontario Ministry of Health and Long-Term Care) on behalf of the population covered. The HCP perspective includes direct costs covered by the Ontario Ministry of Health Insurance Plan (e.g., visits to healthcare professionals, procedures, tests, hospitalizations, and visits to emergency rooms). For patients aged 65 years and older, we also included prescription medications covered by the Ontario Drug Benefit in the HCP perspective.

The societal perspective included both direct and indirect costs (time-off paid employment, volunteer activities, homemaking, caregiving, and caregiver assistance), as well as out-of-pocket expenses to patients.

Once aggregated, we calculated incremental cost-effectiveness ratios (ICER) by taking the ratio of the mean values of incremental cost by the incremental effect between the MPP and MMV groups ($ICER = \Delta C/\Delta E$, C = cost, and E = effectiveness).

Cost-utility analyses were conducted using the difference in QALYs derived from EQ-5D-5L utility scores as the measure of effect. QALYs are a generic outcome metric which can reflect preference for different health effects and enables comparisons across health care interventions. QALYs were estimated by calculating the area under the curve, which can be thought of as the total time spent in each health state weighted by the health-related quality of life or utility value at that state (Drummond et al., 2015). We also conducted a cost-effectiveness analysis using WOMAC total score at 12-months as the measure of effect.

2.7.2 Net Benefit Regression (NBR)

We used a NBR framework to allow for consideration of incremental cost and effect of the intervention in addition to a willingness-to-pay (WTP) value (Hoch et al., 2002). A WTP value is the maximum acceptable amount one is willing-to-pay to achieve one additional unit improvement in effect.

Incremental net benefit (INB) was calculated using the equation: $INB = WTP^* \Delta E - \Delta C$
A positive INB, or INB>0, indicates the midvastus approach is more cost-effective than the medial parapatellar approach. Separate NBR models were developed for the HCP and societal perspectives, and a range of willingness–to-pay values from $0 – $50,000 were considered. We included age, sex, BMI, baseline utility, and WOMAC score as covariates in our model.

2.7.3 Uncertainty

Cost-effectiveness acceptability curves (CEAC) were also used to characterize the uncertainty around the cost-effectiveness estimates (Hoch et al., 2006). The CEACs graphically present the probability that TKA performed with the midvastus approach is cost-effective compared to the medial para-patellar approach over a wide range of willingness to pay values per outcome gained. We constructed CEACs from the healthcare payer and societal perspectives considering willingness to pay for either QALY or WOMAC point gained.

2.7.4 Sensitivity Analysis

We conducted one-way sensitivity analyses 1) analyzing participants who crossed over as treated and 2) removing outliers (residuals > 2 standard deviations) from both perspectives.

2.7.5 Missing Data

We used multivariate imputation using chained equations (MICE) methods to impute missing utility data and WOMAC scores. Estimates of total costs were also imputed for patients lost to follow-up at 12-months. We used predictive mean matching pulling from five nearest neighbors to generate 5 imputations which were pooled to create one final data set for analysis. To increase the accuracy of the imputed values, age, sex, BMI, previous TKA (yes or no), and smoking status (yes or no) were used as covariates.

2.8 Source of Funding

This study was supported by a grant from Stryker Canada and Physician Services Incorporated (PSI).

Chapter 3

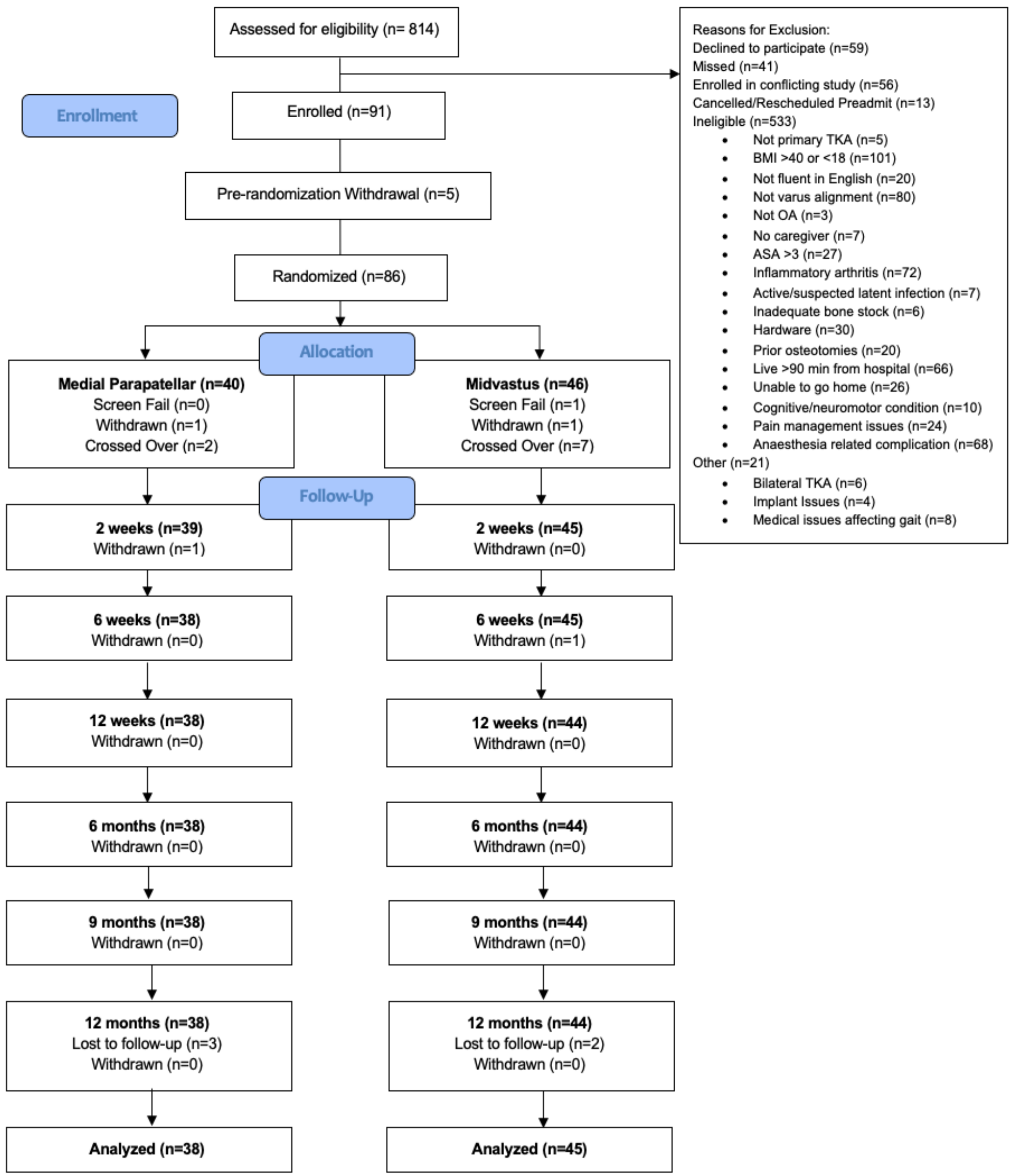
3 Results

3.1 Patient Flow

Eighty-six patients were randomized for this study, with 40 allocated to the standard medial parapatellar group (MPP), and 46 allocated to the minimally invasive midvastus (MMV) group (Figure 3.1). Following randomization, one participant was excluded as they no longer met the inclusion criteria (diagnosed with obstructive sleep apnea), and four patients requested to be withdrawn from the study. Two patients (MMV and MPP) withdrew at the baseline visit, one patient (MPP) withdrew at the two-week study visit, and one patient (MMV) requested to withdraw at the six-month visit. Nine participants crossed over, with two patients in the MPP group having TKA with a MMV approach, and seven patients in the MMV group having surgery with the standard MPP approach.

Due to COVID-19 restrictions, some patients were missed at the six-month follow-up (26 patients in the MPP group and 27 patients in the MMV group), and at the nine-month follow-up (15 patients in the MPP group and 24 patients in the MMV). We were able to contact the majority (95.4%) of patients missed at the 12-month follow-up and asked patients to report all relevant costs since their last study visit. Missing 12-month cost data values were imputed for 3 patients in the MPP group (7.9%) and 2 patients in the MMV group (4.5%). 4.6% of missing utility data and 13.3% of missing 12-month WOMAC data values were also imputed.

Figure 3.1: CONSORT diagram of participant flow through the study.



3.2 Demographics and Clinical Characteristics

Demographic and clinical characteristics were similar between the two groups across most measures with the exception of height (p = 0.044), weight (p = 0.001), and BMI (p = 0.014) which was significantly higher in the MPP group (Table 3.1). The mean age in the MPP group was 67 years compared to 70 years in the MMV group, and there was a greater percentage of male participants, although not significantly different. Majority of patients were considered to have a severe systemic disease according to their ASA score and had symptoms of osteoarthritis in their contralateral knee. There was also a lower proportion of patients with Charlson Comorbidity Index scores of two or greater in the MPP group compared to the MMV group.

Table 3.1. Baseline demographics and clinical characteristics.

Characteristic		MPP TKA (n=38) Mean (SD)	MMV TKA (n=45) Mean (SD)	*P* value
Height, cm		171.87 (10.51)	166.96 (11.18)	0.04
Weight, kg		96.53 (18.72)	84 (15.58)	>0.01
BMI, kg/m^2		32.47 (4.16)	30.07 (4.47)	0.01
Age, y		66.82 (7.53)	69.76 (7.29)	0.08
Sex (Male), n (%)		21 (55.26)	18 (40.00)	0.17
Other Knee Symptoms, n (%)		26 (68.42)	29 (64.44)	0.70
Previous TKA, n (%)		11 (28.95)	9 (20.00)	0.34
Surgery on Dominant Knee, n (%)		17 (44.74)	16 (35.56)	0.39
Smokers, n (%)				0.61
	0 (never smoked)	14 (36.84)	23 (51.11)	
	1 (quit >12 months)	20 (52.63)	19 (42.22)	
	2 (quit <12 months)	1 (2.63)	1 (2.22)	
	3 (yes)	3 (7.90)	2 (4.44)	
ASA Score, n (%)				0.48
	1	1 (2.63)	0	
	2	16 (42.11)	17 (37.78)	
	3	21 (55.26)	28 (62.22)	
Charlson Comorbidity Index				0.25
	0	24 (63.16)	29 (64.44)	
	1	11 (28.95)	7 (15.56)	
	2	3 (7.89)	8 (17.78)	
	3	0	1 (2.22)	

3.3 Surgical Characteristics

Surgical time and time in the Post Anesthesia Care Unit (PACU) was similar between the groups (Table 3.2). The majority of patients received spinal anesthesia while three patients in the MPP group and one patient in the MMV group received general anesthesia. There were two patients in the MPP group who were unable to pass physiotherapy discharge criteria after surgery and had to remain in hospital while waiting for a transfer to a rehabilitation facility. These patients had lengths of stays greater than 140 hours. Additionally, one participant in the MPP group was discharged from the hospital on the same day as their surgery. As this outcome was not normally distributed, we reported medians and interquartile ranges. The median length of stay in the MPP group was 44.5 hours compared to 44.0 hours in the MMV group (p = 0.22).

Table 3.2. Surgical characteristics.

	MPP TKA	MMV TKA	Mean Difference	*P* value
	Mean (SD unless stated)		(95% CI)	
Surgery Time, min	83.37 (14.45)	86.56 (17.72)	3.19 (-3.96, 10.34)	0.38
Procedure Time, min	55.0 (8.79)	58.2 (8.88)	3.2 (-0 .67, 7.07)	0.10
Tourniquet Time, min				
Standard Tourniquet	53.48 (8.72)	58.52 (8.72)	5.04 (-0.16, 10.25)	0.06
Minimal Tourniquet	8.24 (2.34)	13.35 (3.07)	5.12 (-2.95, 13.18)	0.21
Anaesthesia, n (%)				
Spinal	35 (92.11)	44 (97.78)		0.41
General	3 (7.90)	1 (2.22)		
Length of Stay, hrs, median, (IQR)	44.50 (26.0, 50.0)	44.00 (26.0, 48.0)		0.22
Admission to PACU, hrs	3.63 (0.91)	3.80 (0.70)	0.16 (.52, 0.19)	0.36
Time in PACU, hrs	2.65 (1.40)	2.70 (2.94)	0.05 (-1.00, 1.10)	0.94
Ward to Discharge, hrs, median, (IQR)	42.0 (23.0, 47.0)	40.0 (22.0, 45.0)		0.16

SD = standard deviation, CI = confidence interval, IQR = interquartile range, PACU = post anaesthesia care unit

3.4 Outcome Measures

3.4.1 Effectiveness Outcomes

Utility values were significantly higher in the MMV group compared to the MPP group at three-months postoperative, although there was no significant difference at 12-months (Table 3.3). WOMAC total scores were statistically significantly higher in the MMV group at both the three-month and 12-month visits. Both utility value and WOMAC total score were slightly higher in the MMV group at baseline, although the difference was not significant. Patients in both groups demonstrated improvements in total WOMAC score from baseline to 12-months however the difference in improvement did not the reach the minimally clinically important difference (MCID) of least 10 points (Clement, 2018).

Table 3.3. EQ-5D Utility Scores and WOMAC total scores measured from baseline to 12-months postoperative.

	MPP TKA Mean (SD)	MMV TKA Mean (SD)	Mean Difference (95% CI)	*P* value
EQ5D Utility Values				
Pre-operative	0.664 (0.028)	0.678 (0.034)	0.014 (-0.053, 0.080)	0.69
Two-week	0.649 (0.025)	0.680 (0.032)	0.030 (-0.032, 0.093)	0.34
Six-week	0.746 (0.016)	0.754 (0.023)	0.009 (-0.036, 0.054)	0.70
Three-month	0.794 (0.017)	0.850 (0.022)	0.057 (0.014, 0.100)	0.01
12-month	0.842 (0.019)	0.856 (0.023)	0.014 (-0.031, 0.059)	0.59
Mean QALYs gained from baseline	0.798 (0.015)	0.831 (0.019)	0.033 (-0.005, 0.071)	0.09
WOMAC Total Score				
Baseline	81.83 (0.90)	83.49 (1.17)	1.66 (-0.63, 3.96)	0.16
Six-week	87.57 (1.34)	89.34 (1.56)	1.77 (-1.30, 4.84)	0.26
Three-month	90.62 (0.99)	93.01 (1.20)	2.39 (0.04, 4.75)	0.05
12-month	93.90 (0.68)	96.15 (0.98)	2.26 (0.33, 4.19)	0.02

*values are reported as means with the bootstrap standard error which is the standard deviation of the bootstrap distribution – (Hesterberg, 2011)

3.4.2 Cost Outcomes

We calculated total costs over the 12-month study period, and also costs by category (Table 3.4). The categories with the largest differences in cost between the MPP and MMV groups were the cost of the inpatient hospital ward stay (mean difference = -385.46, 95% CI: -940.75, 169.94; p = 0.17), and paid caregiver assistance, which are higher in the MPP group. The difference in costs for other health care provider costs, including physical therapy and occupational therapy, was also large between the groups however these costs were higher in the standard group from the payer perspective, and higher in the midvastus group from a societal perspective (Table 3.4).

For the base-case analysis (participants analyzed according to intention to treat) there was a statistically significant difference in total costs from the societal perspective favoring the midvastus group (mean difference= -6980.95, 95% CI: -13988.45, 26.56; p = 0.05) (Table 3.5). Participants in the midvastus group also incurred fewer costs from the payer perspective although not statistically significant (mean difference = -463.94, 95% CI: -1110.32, 182.52; p = 0.16). When analyzed as treated, the difference in cost increases from both a payer and societal perspective with greater costs incurred by the MPP group. However, the difference from the payer perspective still does not reach statistical significance (mean difference = -529.20, 95% CI: -1116.84, 58.43; p = 0.08).

Table 3.4. Cumulative costs by categories for patients in the MPP and MMV groups (base case).

Costs	MPP TKA Mean (SD)	MMV TKA Mean (SD)	Mean Difference (95% CI)	*P* Value
Hospital Costs				
Average TKA Procedure	5878.36	5878.36	-	-
PACU	316.25 (27.91)	322.10 (61.47)	5.85 (-114.62, 126.33)	0.92
Ward	1493.68 (276.88)	1108.27 (283.34)	-385.46 (-940.75, 169.94)	0.17
Total Hospital Costs	7640.66 (292.14)	7245.16 (306.78)	(-996.77, 205.78)	0.20
Health Professionals				
Family Physician Visits	52.82 (19.57)	44.60 (26.01)	-8.22 (-59.18, 42.76)	0.75
Surgeon and Specialists	108.13 (17.74)	111.03 (19.94)	2.90 (-36.18, 41.98)	0.88
Other Health Care Professional - HCP	301.05 (19.91)	263.16 (26.58)	-37.90 (-89.99, 14.19)	0.15
Other Health Care Professional - SOC	544.15 (70.92)	742.18 (143.82)	198.03 (-83.87, 479.92)	0.17
Medication - HCP	42.94 (22.25)	56.58 (28.08)	13.64 (-41.39, 68.67)	0.63
Medication - SOC	78.37 (18.54)	109.02 (41.01)	30.6463 (-49.73, 111.02)	0.46
Tests and X-Rays	97.51 (7.75)	105.68 (11.62)	8.17 (-14.61, 30.95)	0.48
Emergency Visits and Hospitalizations	87.65 (37.67)	40.61 (41.99)	-47.04 (-129.34, 35.27)	0.26
Other Out-of-Pocket Expenses	1656.77 (1319.85)	680.01 (1352.68)	-976.75 (-3627.95, 1674.44)	0.47
Indirect Costs				
Paid Caregiver Assistance	660.11 (384.01)	120.52 (385.33)	-539.59 (-1294.82, 215.64)	0.16
Unpaid Caregiver Assistance	1135.77 (180.06)	984.75 (265.44)	-151.0195 (-671.26, 369.23)	0.57
Time-off Paid Employment	6698.95 (1868.39)	2671.25 (2011.48)	-4027.702 (-7970.13, -85.27)	0.05
Time-off Volunteer Activities	3317.25 (865.96)	2242.38 (925.42)	-1074.87 (-2888.66, 738.92)	0.25

*values are reported as means with the bootstrap standard error which is the standard deviation of the bootstrap distribution – (Hesterberg, 2011)

Table 3.5. Total costs with sensitivity analyses over the 12-month study period (2021 $CAD).

	MPP TKA Mean (SD)	MMV TKA Mean (SD)	Mean Difference (95% CI)	*P* value
Payer Perspective				
Base Case	8330.76 (307.08)	7866.82 (329.83)	-463.94 (-1110.32, 182.52)	0.16
As Treated	8334.27 (275.96)	7805.06 (299.82)	-529.20 (-1116.84, 58.43)	0.08
Outliers Removed	7905.95 (144.96)	7866.83 (186.08)	-39.12584 (-403.83, 325.57)	0.83
Societal Perspective				
Base Case	22078.13 (3446.42)	15097.19 (3575.32)	-6980.95 (-13988.45, 26.56)	0.05
As Treated	21877.39 (3085.75)	14440.36 (3263.55)	-7437.03 (-13833.47, -1040.59)	0.02
Outliers Removed	19116.11 (2007.89)	15097.18 (2302.51)	-4018.93 (-8531.77, 493.91)	0.08

*values are reported as means with the bootstrap standard error which is the standard deviation of the bootstrap distribution – (Hesterberg, 2011)

From the payer perspective, there were three outliers with residuals greater than two standard deviations in the MPP group; two patients who stayed greater than 140 in the hospital postoperative, and one patient who had extreme pain and reported visits to the emergency room at two-weeks and three-months. When these patients were removed from the analysis, there is no apparent difference in cost between groups.

From the societal perspective there was one patient in the MPP group that reported time off work from baseline to 12-months postoperative and the cost of hiring full time assistance. When removed as an outlier, a large difference in cost remained in favor of the MMV approach.

3.4.3 Cost-Effectiveness

The results of the cost-effectiveness analysis are reported in Table 3.6. From the base case cost-effectiveness analysis, the incremental cost from the societal perspective was -6980.95 and the incremental effect was 2.36, which indicates the midvastus approach dominates the standard medial parapatellar approach (less costs on average, and more effective on average). When patients were analyzed as treated from a societal perspective, the dominance was stronger. The midvastus approach remained dominated across all sensitivity analysis, although results were not statistically significant.

Table 3.6. Incremental Cost-Effectiveness of the midvastus versus medial parapatellar approach for TKA.

	Incremental Cost (95% CI)	Incremental Effect (95% CI)	ICER
QALYs			
Healthcare Payer Perspective			
Base Case	-463.94 (-1110.32, 182.52)	0.033 (-0.005, 0.071)	Dominated
As Treated	-529.20 (-1116.84, 58.43)	0.044 (0.008, 0.080)	Dominated
Outliers Removed	-39.12584 (-403.83, 325.57)	0.028 (-0.009, 0.065)	Dominated
Societal Perspective			
Base Case	-6980.95 (-13988.45, 26.56)	0.033 (-0.005, 0.071)	Dominated
As Treated	-7437.03 (-13833.47, -1040.59)	0.044 (0.008, 0.080)	Dominated
Outliers Removed	-4018.93 (-8531.77, 493.91)	0.031 (-0.007, 0.068)	Dominated
WOMAC			
Healthcare Payer Perspective			
Base Case	-463.94 (-1110.32, 182.52)	2.257 (0.328, 4.186)	Dominated
As Treated	-529.20 (-1116.84, 58.43)	1.908 (0.021, 3.795)	Dominated
Outliers Removed	-39.12584 (-403.83, 325.57)	1.877 (-0.109, 3.863)	Dominated
Societal Perspective			
Base Case	-6980.95 (-13988.45, 26.56)	2.257 (0.328, 4.186)	Dominated
As Treated	-7437.03 (-13833.47, -1040.59)	1.908 (0.021, 3.795)	Dominated
Outliers Removed	-4018.93 (-8531.77, 493.91)	2.092 (0.064, 4.121)	Dominated

3.4.3.1 Net Benefit Regression

From both the healthcare payer and societal perspectives, the incremental net benefit was greater than zero for all WTP values suggesting that the midvastus approach is cost-effective compared to the standard approach (Table 3.7).

Table 3.7. Base-case net benefit regression results.

	Healthcare Payer			Societal		
WTP	INB (SD)	95% CI	*P*	INB (SD)	95% CI	*P*
QALYs						
0	583.80 (421.92)	-243, 1410	0.17	4739.26 (3414.79)	-1953, 11432	0.17
1000	607.68 (429.15)	-233, 1448	0.16	4763.15 (3416.21)	-1932, 11458	0.16
2000	631.56 (437.12)	-225, 1488	0.15	4787.03 (3417.73)	-1911, 11485	0.16
3000	655.44 (445.79)	-218, 1529	0.14	4810.91 (3419.37)	-1890, 11512	0.16
4000	679.32 (455.13)	-212, 1571	0.14	4834.79 (3421.12)	-1870, 11540	0.16
5000	703.21 (465.09)	-208, 1614	0.13	4858.67 (3422.97)	-1850, 11567	0.16
10000	822.61 (522.92)	-202, 1847	0.12	4978.07 (3433.88)	-1752, 11708	0.15
20000	1061.42 (666.54)	-244, 2367	0.11	5216.88 (3463.76)	-1571, 12005	0.13
30000	1300.22 (830.97)	-328, 2928	0.12	5455.69 (3504.17)	-1412, 12323	0.12
40000	1539.03 (1006.06)	-432, 3510	0.13	5694.50 (3554.74)	-1272, 12661	0.11
50000	1777.84 (1187.10)	-548, 4104	0.13	5933.31 (3615.04)	-1152, 13018	0.10

	Healthcare Payer			Societal		
WTP	INB (SD)	95% CI	*P*	INB (SD)	95% CI	*P*
WOMAC						
0	583.80 (421.92)	-243, 1410	0.17	4739.26 (3414.79)	-1953, 11432	0.17
1000	2453.84 (1251.23)	1, 4906	0.05	6609.30 (3787.68)	-814, 14033	0.08
2000	4323.88 (2248.15)	-82, 8730	0.05	8479.34 (4374.17)	-93, 17052	0.05
3000	6193.92 (3262.49)	-200, 12588	0.06	10349.38 (5101.09)	351, 20347	0.04
4000	8063.95 (4281.88)	-328, 16456	0.06	12219.42 (5916.93)	622, 23816	0.04
5000	9933.99 (5303.42)	-460, 20328	0.06	14089.46 (6789.70)	781, 27397	0.04
10000	19284.19 (10421.17)	-1140, 39709	0.06	23439.65 (11535.4)	830.69, 46048	0.04
20000	37984.59 (20667.08)	-2522, 78491	0.07	42140.06 (21554.0)	-105, 84385	0.05
30000	56684.96 (30915.38)	-3908, 117270	0.07	60840.4 (31720.49)	-1330, 123011	0.06
40000	75385.35 (41164.28)	-5295, 156065	0.07	79540.8 (41927.42)	-2635, 161717	0.06
50000	94085.74 (51413.43)	-6682, 194854	0.07	98241.26 (52151.06)	-3972, 200455	0.06

*values are reported as means with the bootstrap standard error which is the standard deviation of the bootstrap distribution – (Hesterberg, 2011)

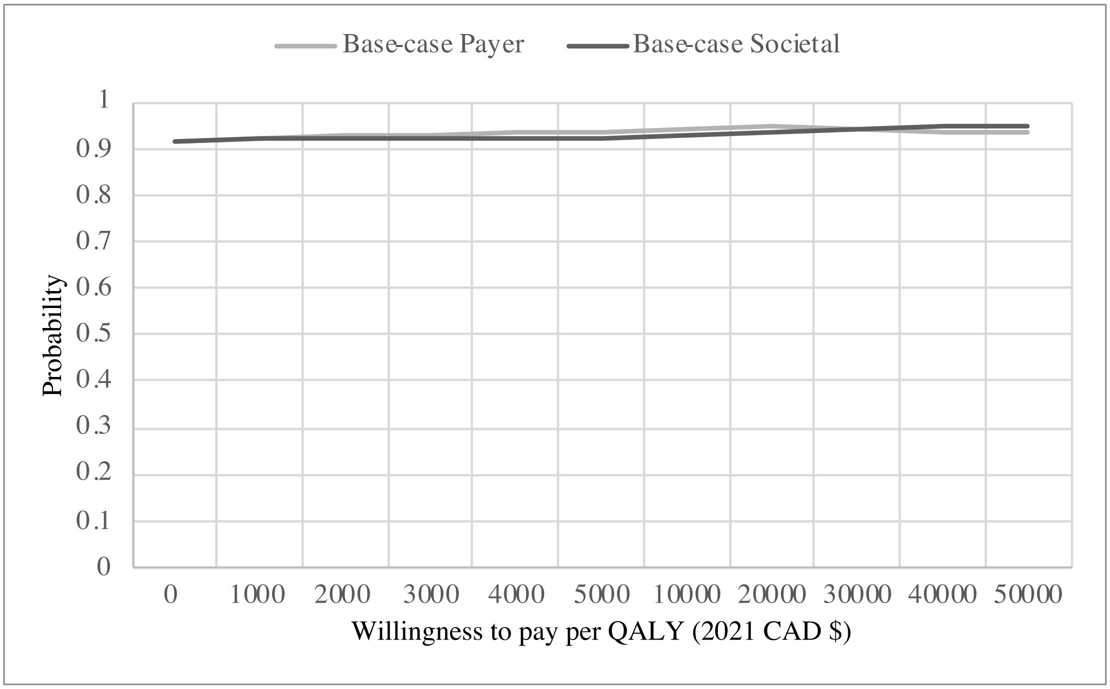
3.4.3.2 Cost Effectiveness Acceptability Curves

The probability of the midvastus approach for TKA being a cost-effective strategy at different willingness to pay thresholds is presented in Figure 3.2. At a willingness to pay of $0, there is a greater than 90% chance that the midvastus approach is cost-effective when considering improvements in QALYs or WOMAC total scores. When considering willingness to pay per QALY, from a payer perspective the probability the midvastus approach is cost-effective is 93.5% at a WTP value of $5000, while the probability is 92.0% at the same WTP value from the societal perspective.

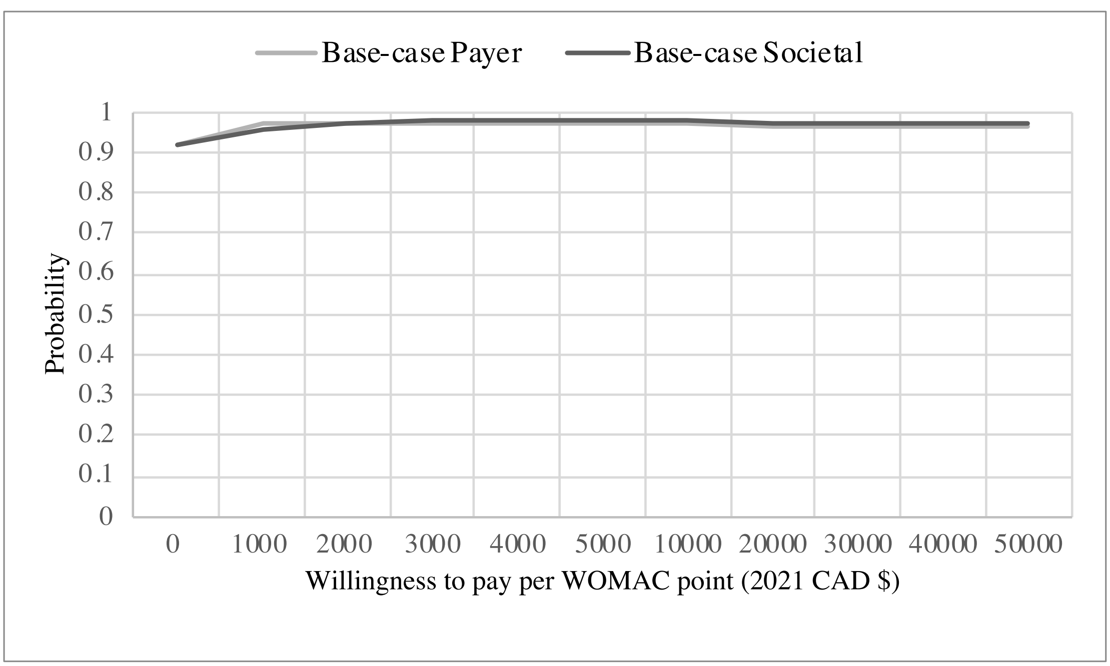
From the healthcare payer perspective if the willingness to pay value is $1000 per WOMAC outcome, the probability of cost-effectiveness is 97.5%, however as WTP goes up, the probability the approach is cost effective slightly decreases. At a WTP value of $2000/WOMAC the probability is 97.3%, at $5000/WOMAC it is 96.9%, and at $30000/WOMAC it is 96.5%. From a societal perspective, the probability the midvastus approach is cost-effective is 98.1% at a willingness to pay of $5000 per one point improvement in WOMAC total score and decreases at higher willingness to pay thresholds.

Figure 3.2: Base-case cost-effectiveness acceptability curve (CEACs) displaying the probability that MMV TKA is cost-effective compared to MPP TKA from the healthcare payer and societal perspectives, over a range of willingness to pay values A) for an additional QALY gained and B) for an additional one-point improvement in total WOMAC score at 12 months postoperative.

A)



B)



3.5 Sensitivity Analysis

In each of the sensitivity considerations, the INB was positive for all WTP values further suggesting the midvastus approach may be cost-effective compared to the standard medial parapatellar approach for TKA (Table 3.8). When analyzing patients as treated, at a willingness to pay value of $0, the probability the midvastus approach is cost-effective is 95.5% and 92.8% from the health care payer and societal perspectives respectively (Figure 3.3)

The probability the midvastus approach is cost-effective at a willingness to pay value of $0 decreases when analyzed with outliers removed. Although the incremental net benefit is greater than zero, the confidence intervals 95% CIs around the estimate are wide, and the probability of cost-effectiveness considering any outcome is estimated at 57.4% and 83.5% from the health care payer and societal perspectives respectively.

Table 3.8. Sensitivity analysis net benefit regression results.

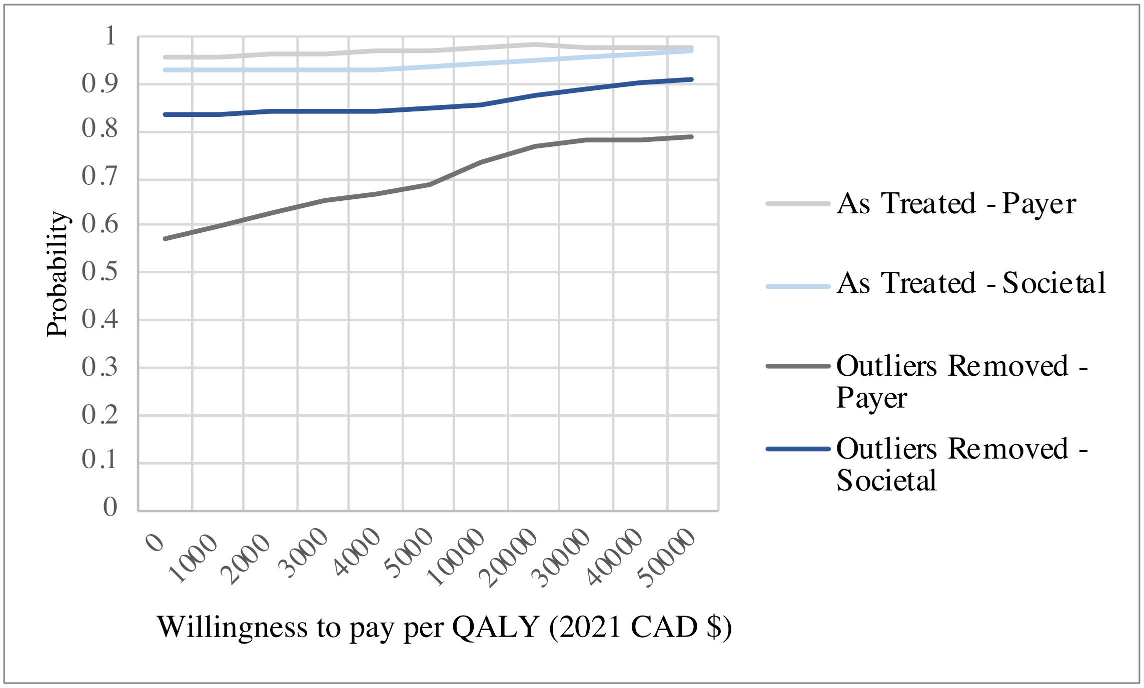
Healthcare Payer						
WTP	INB (SD)	95% CI	*P*	INB (SD)	95% CI	*P*
As Treated - QALYs				**Outliers Removed -QALYs**		
0	693.34 (409.29)	-108, 1495	0.09	33.94 (183.16)	-325, 392	0.85
1000	725.63 (415.92)	-89, 1540	0.08	49.62 (190.50)	-323, 423	0.80
2000	757.92 (423.37)	-71, 1587	0.07	65.29 (199.39)	-325, 456	0.74
3000	790.21 (431.61)	-55, 1636	0.07	80.97 (209.62)	329, 491	0.70
4000	822.50 (440.58)	-41, 1686	0.06	96.65 (221.01)	-336, 529	0.66
5000	854.79 (450.24)	-27, 1737	0.06	112.32 (233.39)	-345, 569	0.63
10000	1016.24 (507.44)	21, 2010	0.05	190.71 (305.60)	-408, 789	0.53
20000	1339.14 (652.55)	60, 2618	0.04	347.47 (474.58)	-582, 1277	0.46
30000	1662.04 (820.08)	54, 3269	0.04	504.24 (655.02)	-779, 1788	0.44
40000	1984.94 (998.72)	27, 3942	0.05	661.01 (839.57)	-984, 2306	0.43
50000	2307.83 (1183.53)	-11, 4627	0.05	817.77 (1026.01)	-1193, 2828	0.43
Societal						
WTP	INB (SD)	95% CI	*P*	INB (SD)	95% CI	*P*
As Treated - QALYs				**Outliers Removed -QALYs**		
0	4201.95 (2885.18)	-1452, 9856	0.15	1956.28 (2011.41)	-1986, 5898	0.33
1000	4234.24 (2887.19)	-1424, 9893	0.14	1979.72 (2014.74)	-1969, 5928	0.33
2000	4266.53 (2889.33)	-1396, 9929	0.14	2003.16 (2018.24)	-1952, 5958	0.32
3000	4298.82 (2891.61)	-1368, 9966	0.14	2026.60 (2021.90)	-1936, 5989	0.33
4000	4331.11 (2894.03)	-1341, 10003	0.14	2050.04 (2025.74)	-1920, 6020	0.31
5000	4363.39 (2896.57)	-1313, 10040	0.13	2073.48 (2029.74)	-1904, 6051	0.31
10000	4524.85 (2911.29)	-1181 10230	0.12	2190.69 (2052.21)	-1831, 6212	0.29
20000	4847.74 (2950.47)	-935, 10630	0.10	2425.09 (2109.00)	-1708, 6558	0.25
30000	5170.64 (3002.21)	-713, 11054	0.09	2659.50 (2180.54)	-1614, 6933	0.22
40000	5493.54 (3065.88)	-515, 11502	0.07	2893.91 (2265.42)	-1546, 7334	0.20
50000	5816.44 (3140.74)	-339, 11972	0.06	3128.31 (2362.22)	-1501, 7758	0.19

Healthcare Payer						
WTP	INB (SD)	95% CI	*P*	INB (SD)	95% CI	*P*
As Treated - WOMAC				**Outliers Removed -WOMAC**		
0	693.34 (409.29)	-108, 1495	0.09	33.94 (183.16)	-325, 392	0.85
1000	2116.26 (1299.17)	-430, 4662	0.10	1332.82 (1034.47)	-694, 3360	0.20
2000	3539.17 (2376.93)	-1119, 8197	0.14	2631.71 (2009.41)	-1306, 6570	0.19
3000	4962.08 (3471.79)	-1842, 11766	0.15	3930.59 (2989.38)	-1928, 9789	0.19
4000	6384.99 (4571.49)	-2574, 15344	0.16	5229.47 (3970.64)	-2552, 13011	0.19
5000	7807.91 (5673.21)	-3311, 18927	0.17	6528.36 (4952.44)	-3178, 16234	0.19
10000	14922.47 (11191.22)	-7011, 36856	0.18	13022.76 (9863.84)	-6310, 32355	0.19
20000	29151.59 (22236.93)	-14431, 72735	0.19	26011.6 (19689.05)	-12578, 64601	0.19
30000	43380.73 (33284.83)	-21856, 108617	0.19	39000.41 (29514.81)	-18847, 96848	0.19
40000	57609.85 (44333.29)	-29281, 144501	0.19	51989.24 (39340.71)	-25117, 129095	0.19
50000	71838.92 (55381.97)	-36707 180385	0.19	64978.06 (49166.66)	-31386, 161343	0.19
Societal						
WTP	INB (SD)	95% CI	*P*	INB (SD)	95% CI	*P*
As Treated - WOMAC				**Outliers Removed -WOMAC**		
0	4201.94 (2885.18)	-1452, 9856	0.15	1956.28 (2011.41)	-1986, 5898	0.33
1000	5624.86 (3296.19)	-835, 12085	0.09	3680.09 (2484.39)	-1189, 8549	0.14
2000	7047.77 (3980.84)	-754, 14850	0.08	5403.91 (3233.07)	-932, 11740	0.10
3000	8470.69 (4823.99)	-984, 17925	0.08	7127.72 (4109.42)	-926, 15182	0.08
4000	9893.60 (5756.42)	-1388, 21175	0.09	8851.54 (5047.38)	-1041, 18744	0.08
5000	11316.51 (6741.17)	-1895, 24528	0.09	10575.35 (6018.21)	-1220, 22370	0.08
10000	18431.07 (11983.45)	-5056, 41918	0.12	19194.42 (11056.4)	2475, 40864	0.08
20000	32660.22 (22870.14)	-12164, 77484	0.15	36432.58 (21350.67)	-5413, 78279	0.09
30000	46889.31 (33862.15)	-19479, 113257	0.17	53670.68 (31699.63)	-8459, 115800	0.09
40000	61118.44 (44882.16)	-26848, 149085	0.17	70908.84 (42062.95)	-11533, 153350	0.09
50000	75347.59 (55913.63)	-34241, 184936	0.18	88147.04 (52432.1)	-14617, 190912	0.09

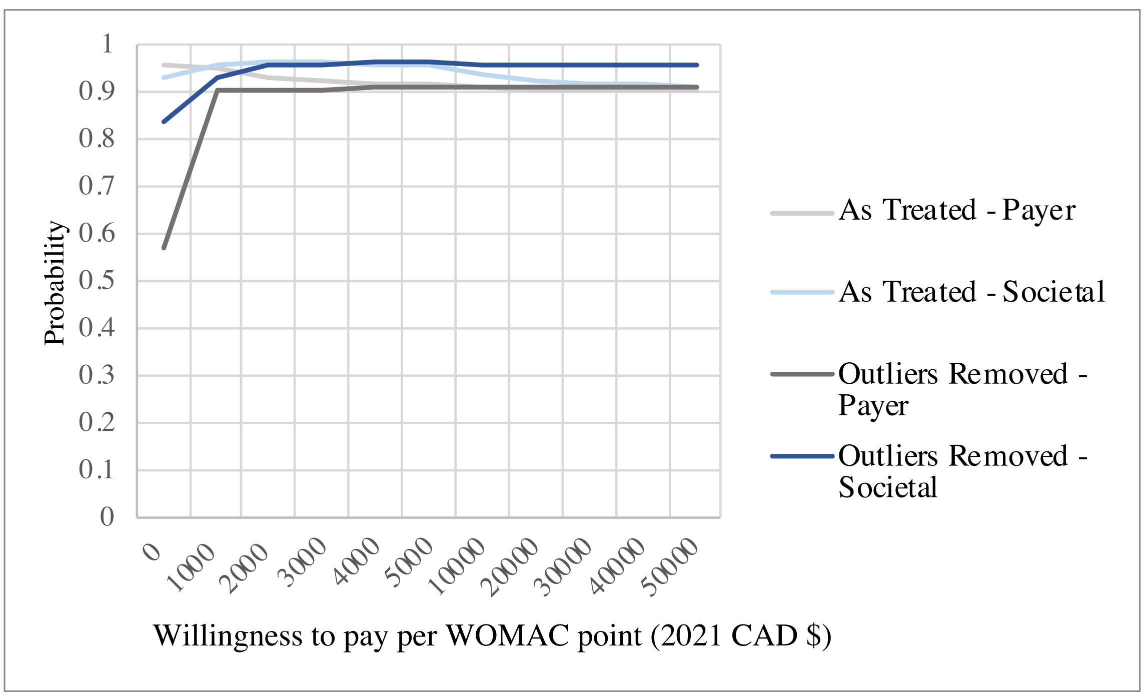
*values are reported as means with the bootstrap standard error which is the standard deviation of the bootstrap distribution – (Hesterberg, 2011)

Figure 3.3: Sensitivity analysis cost-effectiveness acceptability curves (CEAC) displaying the probability that MMV TKA is cost-effective compared to MPP TKA from the healthcare payer and societal perspectives with participants analyzed as treated, and with outliers removed, over a range of willingness to pay values A) for an additional QALY gained and B) for an additional one-point improvement in total WOMAC score at 12 months postoperative.

A)



B)



Chapter 4

4 Discussion

This study aimed to estimate the cost-effectiveness of a midvastus approach for TKA compared to the standard medial parapatellar surgical approach in patients with knee OA at 12-months postoperative. The results of our study suggest midvastus TKA may be cost-effective compared to medial parapatellar TKA from the payer perspective at WTP values between \$1000 and \$2000, and WTP values between \$2000 and \$20,000 from the societal perspective.

To our knowledge, this is the first full economic evaluation of midvastus TKA incorporating both direct and indirect costs alongside a randomized controlled trial with a 12-month follow-up. Previous studies evaluating the costs associated with minimally invasive TKA have focused on hospital costs and direct procedure-related costs covered by Medicaid or private insurance. Coon et al. (2005) found MIS TKA procedure charges to be US \$8600 (26%) less than standard TKA, while King et al. (2011) found the difference in procedure cost to be US \$1047 (7.2%) for minimally invasive TKA compared to traditional TKA. Similarly, we found the average hospital cost of patients in the MMV TKA group to be less than the hospital costs of the MPP group (mean difference = -\$395.49, 95% CI = -996.77, 205.78; $p = 0.20$), although the magnitude of the difference was smaller (5.2%) and not statistically significant. There was considerable uncertainty around our estimate, and calculation of hospital costs at the patient level is a noted limitation of this study.

In this study, we found the difference in overall costs from the payer perspective was -463.94 (95% CI: -1110.32, 182.52; $p = 0.16$) in favor of the midvastus group in the base case analysis. As there was a large variation in costs across individual patients, the 95% confidence intervals around our estimate did not provide the certainty to conclude whether MMV or MPP is cost-saving from this perspective. It is possible these results did not reach statistical significance due to the small sample size.

When we analyzed patients who crossed over in the group that they were treated, the differences in average costs from the health care payer and societal perspectives increase in favor of the midvastus group, with the 95% confidence intervals around our estimates suggesting significance although they remained similarly wide compared to the base case. Removing outliers from the analysis decreased the uncertainty around the cost estimates as the range of the 95% confidence intervals decreased from $1292.84 to $729.4, and $14015.01 to $9025.68 for the payer and societal perspective estimates, respectively. There were three outliers from the payer perspective and one outlier from the societal perspective, all in the medial parapatellar group. With these outliers removed, the difference in cost from the payer perspective greatly decreases, although due to the small sample size, and the related complications experienced by the outliers, this may be misleading.

Across all sensitivity analyses, the costs from the societal perspective remained substantially greater in the medial parapatellar group. The difference in societal costs, which includes indirect costs such as time off paid employment, volunteering, caregiving, and out-of-pocket expenses for the patient or private insurance, was $6980.95 (95% CI: -13988.45, 26.56; $p = 0.05$) in the base case analysis. The cost difference seen is largely due to less time off paid employment and volunteer activities experienced by the midvastus group. The cost incurred for paid caregivers was also substantially lower in the midvastus group (mean difference: -539.59; 95% CI: -1294.82, 215.64; $p = 0.16$). It is possible that the preservation of soft tissues with the midvastus approach enabled patients to return to work and activities of daily living sooner than MPP TKA patients, which is similar to what has been expected in the literature on less invasive surgical techniques (Berger et al., 2004; Bozic & Beringer, 2007). It is also possible that increased assistance and time off were required by the MPP TKA group as they experienced more knee pain following surgery (Zomar, 2020).

The results of our net benefit regression analysis (Table 3.7) and CEAC (Figure 3.2) further support this conclusion, as they suggest there is over a 90% chance the midvastus approach is cost-effective at a willingness-to-pay value of 0. When considering a one-point improvement in WOMAC total score, the probability the midvastus approach is cost-effective is over 97.5% at a WTP value between $1000 and $2000 from the payer perspective and between $2000 and $20,000 from the societal perspective. At willingness to pay values greater than this, however, the probability goes down due to the uncertainty surrounding the difference in outcome measures. The probability that either intervention is cost-effective from any explored WTP value considering QALYs gained as the primary outcome does not reach greater than 95% in the base case. This is explained by the insignificant difference in QALYs gained between the two treatment groups (mean difference: 0.033; 95% CI: -0.005, 0.071; p = 0.09).

Interestingly, the average cost incurred for other healthcare provider visits, such as physical therapy and occupational therapy visits, was greater in the midvastus group from the societal perspective. Based on the suggested quicker rehabilitation with less invasive surgical approaches, we expected to see fewer costs associated with physical therapy in the midvastus group.

Similarly, a reduction in the use of pain-relief medications has previously been reported in studies comparing minimally invasive joint arthroplasty to standard arthroplasty (Aslam et al., 2017; Laskin, 2005); however, few have investigated the long-term medication requirements or the costs associated. Our results indicate that over a 12-month time frame, the average cost of medications incurred by the MMV TKA group was higher than the MPP TKA group, although the difference was not significant. However, in our study, medications given prior to hospital discharge were not costed at the patient level. Medication use information was collected from patients following discharge, and the average cost of medications given to TKA patients in the hospital was used, which likely influenced results.

The average time in the PACU and the inpatient ward was not significantly different between groups. This is similar to findings on the length of stay in most meta-analyses comparing the medial parapatellar and midvastus surgical approaches. Liu et al. (2014) and Xu et al. (2014) included the results of five randomized controlled trials comparing the two approaches and found no significant difference in hospital stay ($p = 0.79$).

Unlike many studies, however, we did not find a statistically significant difference in operative and tourniquet times between the groups. Meta-analyses by Alcelik et al. (2012), Xu et al. (2014), and Liu et al. (2014) have all found significant differences ($p<0.05$) in the operative times between the two approaches, although there was significant heterogeneity among the studies included in all three analyses. These findings may be due to the inclusion of learning curve patients in included clinical studies. Studies investigating the learning curve associated with less invasive surgical approaches have found that operative times are substantially longer in the first 25 patients, however, once surgeons gain familiarity, operating times do decrease, and eventually, no differences in surgical time are found after surgeons received adequate training (Migliorini et al., 2020). A meta-analysis by Onggo et al. (2020) also found significantly increased operative times for the MMV approach, although they noted this might be due to a variety of administrative factors, skin closure technique, and surgeon factors within the operating room, rather than the direct result of the technical demands of the MMV surgical approach.

In both groups, there were improvements in WOMAC total scores relative to baseline at all follow-ups. Although the mean difference in total WOMAC score between groups at 12-months was statistically significant, it was not clinically significant. Clement et al. (2018) suggest a minimally clinically important difference (MCID) value of 10 for WOMAC total score after TKA. If considering a clinically important improvement of 10 points in WOMAC total score the midvastus approach is likely cost-effective at WTP values of $10000 from the payer perspective and between $30000 and $100000 from the societal perspective.

Compared to the literature, this study found that patients receiving MMV TKA had similar short-term outcomes but gains in WOMAC total and quality-of-life compared to MPP TKA patients farther out from surgery. In a study by Karpman & Smith (2009), 59 patients were randomized to receive MPP TKA, MMV TKA, or minimally invasive quadriceps sparing TKA and followed for two years. Although they found no difference in WOMAC scores in the MMV TKA group, compared to the MPP TKA group, they found the minimally invasive quadriceps sparing group demonstrated greater improvements in WOMAC pain and function scores up to three-months postoperative. Nestor et al. (2010) also found no difference in WOMAC or 12-Item Short Form Health Survey (SF-12) scores at any time from pre-operative to three-months postoperative, although their study was conducted with 27 patients undergoing bilateral TKA with the MMV versus MPP approaches.

Lin et al. (2020) recently compared the two approaches using the Forgotten Joint Score (FJS). The FJS is another patient-reported outcome measure (PROM) tool developed for THA and TKA patients to assess awareness of the artificial joint, which can reflect patient satisfaction (Behrend et al, 2012; Thienpont et al., 2014). They found significant differences between the groups in favor of the midvastus approach at all follow-ups during the three-year study period. Although the tools are not perfectly comparable, this further supports the notion that patients' priorities after TKA may not be reflected well in conventional outcomes (Lin et al., 2020).

Few other studies have reported on the long-term differences in PROMs, such as tools evaluating health-related quality-of-life between the surgical approaches. Most meta-analyses have focused on comparing the approaches using outcomes such as the visual analog scale, Knee Society Score, knee range of motion, time to straight leg raise, operative time, lateral retinacular release time, blood loss, hospital stay, and postoperative complications (Alcelik et al., 2012; Liu et al., 2014; Xu et al., 2019).

We have previously reported on the trajectory of pain, function using the timed up and go (TUG) test, motor power, and spatiotemporal gait outcomes experienced by our study population (Zomar, 2020). In these functional outcome measures, our findings were more in line with the existing literature (Alcelik et al., 2012; Liu et al., 2014; Xu et al., 2014; Aslam et al., 2019) as we found MMV TKA patients experience less pain early in the recovery period, although there was no difference in pain at two weeks and all outcomes at 12-weeks compared to MPP TKA patients.

4.1 Strengths and Limitations

There are several limitations to this study that should be acknowledged. Although this was a randomized trial and patient profiles were generally similar in both groups, there were a few differences in baseline characteristics (Table 3.1). Mean height ($p = 0.044$), weight ($p = 0.001$), and BMI ($p = 0.014$) were significantly higher in the MPP group when considering groups as randomized. When analyzing patients who crossed over in the group that they were treated, the difference in mean BMI reduces but remains significant ($p = 0.049$). In order to minimize the impact of these differences, we evaluated cost-effectiveness with adjustment for baseline variables (i.e., age, BMI, baseline WOMAC total score as covariates in the net benefit regression model).

One major limitation to this study was the small sample size. As the main purpose of the trial was to inform the surgical protocol of a future randomized controlled trial comparing outpatient to inpatient TKA, we recruited patients over two years to gain a preliminary understanding of functional recovery. We did not find significant differences in the trajectory of recovery at 12-weeks between MMV TKA and MPP TKA, suggesting either approach could be used to enable outpatient discharge. However, the results of this cost-effectiveness analysis indicate that over a one-year time period a difference in costs and outcomes may exist, although a larger sample size would provide greater certainty around estimates. The generalizability of this study may also be limited by the stringent inclusion criteria and the fact that all surgeries were performed at a single centre by arthroplasty surgeons who perform TKA at a high volume. Surgeon expertise may have resulted in improved surgical outcomes and lower complication rates.

Another limitation of this study was that all hospital costs could not be calculated at the patient level. In the present study, the same implant was used for patients in both groups, therefore implant costs should be equal. Computer-assisted navigation was used for the midvastus group however given the expected cost of navigation (approximately $100 to $150 per patient) it is unlikely to have a large impact on the overall costs at one-year postoperative. Although not required to perform the midvastus approach, new surgical instrumentation and implants, as well as navigation systems and patient-specific instrumentation, have been developed for minimally invasive TKA (Migliorini et al., 2020). Further investigation on the cost-effectiveness and clinical advantages of these new tools is needed as the uncertainty around them has discouraged many surgeons from using less invasive techniques for TKA (Karachalios et al., 2008; Migliorini et al., 2020).

Another possible limitation is the use of the self-reported resource utilization questionnaires administered at various intervals and missed check-ins due to COVID-19 restriction, making our data susceptible to recall bias. However, the demographics of those missed at six and nine months were not significantly different from the rest of the study population, and most were successfully contacted at the 12-month follow-up. Additionally, any limitations associated with the calculation of costs should apply equally to both study groups.

A strength of this study was the use of a patient-blinded randomized design. To limit possible bias, both participants and research staff were kept blinded to group allocation until the participants reached the final study visit. Additionally, our effectiveness measures were patient-reported, and no interpretation of data was required. We did have some cross-over between groups which is a noted limitation, although when analyzed in the group they were treated, results did not significantly change.

Another strength of this analysis was that we included indirect costs to patients and caregivers in the societal perspective. In a review on the economics of minimally invasive total joint arthroplasty, Bozic et al. (2007) highlights the importance of considering time to recovery and return to work. We are seeing the population of TKA patients getting younger, and the proportion of patients undergoing TKA who are active in the workforce is growing (Maradit Kremers et al., 2015). Additionally, as it is estimated that 80% of the overall costs related to OA are related to time off work and leisure activities for both patients and their caregivers (Gupta et al., 2005), understanding the costs related to productivity loss following TKA is important.

Possibly the greatest strength of this study was that costs were collected and analyzed simultaneously with both generic and disease-specific patient-reported outcome measures. Full economic evaluations are necessary to understand the value for money and ensure patients are getting the best care given available resources. Additionally, using the net benefit regression framework allowed us to determine the likelihood of cost-effectiveness across a range of willingness to pay values.

Chapter 5

5 Conclusion

At 1-year postoperative, midvastus TKA patients had higher WOMAC scores as well as lower average societal costs compared to medial parapatellar TKA patients. However, we cannot conclude with certainty that MMV TKA is cost-effective compared to MPP TKA. A long-term prospective study with an adequately powered sample size is necessary to determine the cost-effectiveness of MMV TKA and MPP TKA in the osteoarthritis patient population.

5.1 Future Directions

This analysis was conducted using data from a pilot study where the purpose was to inform the surgical protocol of a future randomized controlled trial investigating the clinical and cost-effectiveness of outpatient versus inpatient TKA. This trial will include more than 500 TKA and THA patients to estimate the safety and cost-effectiveness of outpatient arthroplasty over a 12-month follow-up period.

Establishing the safety and cost-effectiveness of outpatient TKA is essential as the prevalence of OA and the scarcity of healthcare resources continue to increase. Additionally, although reducing costs and freeing up hospital resources is a motivating factor for reducing the length of stay, existing literature also suggests that patients prefer to recover at home and have decreased length of rehabilitation (McDonald et al., 2014).

During the COVID-19 pandemic, many joint replacement surgeries were cancelled to provide additional hospital capacity to care for COVID-19 patients (CIHI, 2021). Delayed surgeries can significantly impact the quality of life of patients waiting for joint replacement, who have lived many years with the debilitating symptoms of OA. Outpatient total joint replacement is a possible solution to allow patients to receive timely treatment while reducing the need for inpatient hospital beds. Despite a lack of evidence supporting the safety and cost-effectiveness of outpatient arthroplasty, the number of outpatient TKAs performed doubled during the COVID-19 pandemic, although they still only represented 1.3% of all knee replacements (CIHI, 2021). High-quality randomized control trials with full economic evaluations are needed to fully evaluate outpatient total joint arthroplasty and increase implementation (Zomar et al., 2020).

The results of an earlier analysis on our study population found no significant differences in the trajectory of recovery between the MMV and MPP groups during the early postoperative period (Zomar, 2020). These findings were used to support the decision to use either surgical approach in outpatient TKA study patients.

As the medial parapatellar and midvastus surgical approaches are the two most commonly used approaches for TKA, not restricting surgeons to one approach increases the generalizability of future results. However, given the differences in cost and effect seen between patients in the MPP and MMV groups at 12-months, the effect of surgical approach on long-term outcomes and cost should be considered in the analysis of future studies.

This study highlights the importance of investigating patient-reported outcomes measures beyond the initial recovery period. Additionally, indirect costs should be considered along with resource use to get better estimates of the economic impact. Future studies with larger sample sizes can also provide more accurate estimates of patient-reported health outcomes and the cost-effectiveness of using different surgical approaches for TKA in osteoarthritis patients.

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Appendices

Appendix A: Ethics Approval

Western Research

Research Ethics

Western University Health Science Research Ethics Board
HSREB Delegated Initial Approval Notice

Principal Investigator: Dr. Brent Lanting
Department & Institution: Schulich School of Medicine and Dentistry\Orthopaedic Surgery, London Health Sciences Centre

Review Type: Full Board
HSREB File Number: 108949
Study Title: Cost and Patient Satisfaction after Total Knee Arthroplasty: Standard medial para-patellar versus quadriceps sparing mid-vastus surgical approach

HSREB Initial Approval Date: March 31, 2017
HSREB Expiry Date: March 31, 2018

Documents Approved and/or Received for Information:

Document Name	Comments	Version Date
Western University Protocol	Revised Protocol Clean	2017/03/20
Letter of Information & Consent	LOI Clean	2017/03/08
Sub-Study Letter of Information & Consent	Caregiver LOI	2017/02/15
Other	How to login to empower - Clean	2017/02/15
Instruments	Follow-Up Email Template - Clean	2017/02/15
Instruments	First Time Login Email Template - Clean	2017/02/15
Other	Evaluation Schedule-Received 20Jan2017	2017/01/20
Data Collection Form/Case Report Form	Gait Data Collection Form-Received 20Jan2017	
Data Collection Form/Case Report Form	Preoperative Visit Forms	2017/01/18
Data Collection Form/Case Report Form	Surgical Information Form	2017/01/18
Data Collection Form/Case Report Form	Discharge Visit Forms	2017/01/18
Data Collection Form/Case Report Form	2 Week Visit Forms	2017/01/18
Data Collection Form/Case Report Form	6 Month Visit Forms	2017/01/18
Data Collection Form/Case Report Form	3 Month Visit Forms	2017/01/18
Data Collection Form/Case Report Form	6 Week Visit Forms	2017/01/18
Data Collection Form/Case Report Form	Caregiver Preop Forms	2017/01/18
Data Collection Form/Case Report Form	1 Year Visit Forms	2017/01/18
Data Collection Form/Case Report Form	9 Month Visit Forms	2017/01/18
Data Collection Form/Case Report Form	Caregiver 6 Week Forms	2017/01/18
Data Collection Form/Case Report Form	Caregiver 2 Week Forms	2017/01/18

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above named study, as of the HSREB Initial Approval Date noted above.

HSREB approval for this study remains valid until the HSREB Expiry Date noted above, conditional to timely submission and acceptance of HSREB Continuing Ethics Review.

The Western University HSREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the International Conference on Harmonization of Technical Requirements for Registration of Pharmaceuticals for Human Use Guideline for Good Clinical Practice Practices (ICH E6 R1), the Ontario Personal Health Information Protection Act (PHIPA, 2004), Part 4 of the Natural Health Product Regulations, Health Canada Medical Device Regulations and Part C, Division 5, of the Food and Drug Regulations of Health Canada.

Members of the HSREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

[redacted]

Ethics Officer, on behalf of Dr. Doreen Matsui, HSREB Vice Chair
EO: Erika Basile ___ Nicole Kaniki ___ Grace Kelly ___ Katelyn Harris___ Nicola Morphet ✓ Karen Gopaul ___

Western University, Research, Support Services Bldg., Rm. 5150
London, ON, Canada N6G 1G9 [redacted]

LAWSON FINAL APPROVAL NOTICE

LAWSON APPROVAL NUMBER: R-17-063

PROJECT TITLE: Cost and Patient Satisfaction after Total Knee Arthroplasty: Standard medial para-patellar versus quadriceps sparing mid-vastus surgical approach

PRINCIPAL INVESTIGATOR: Dr. Brent Lanting

LAWSON APPROVAL DATE: June 23, 2017

Health Sciences REB#: 108949

Please be advised that the above project was reviewed by the Clinical Research Impact Committee and Lawson Administration and the project:

Was Approved

Please provide your Lawson Approval Number (R#) to the appropriate contact(s) in supporting departments (eg. Lab Services, Diagnostic Imaging, etc.) to inform them that your study is starting. The Lawson Approval Number must be provided each time services are requested.

Dr. David Hill
V.P. Research
Lawson Health Research Institute

All future correspondence concerning this study should include the Lawson Approval Number and should be directed to Sherry Paiva, Research Approval Officer, Lawson Health Research Institute, [redacted].

cc: Administration

Appendix B: EQ-5D-5L descriptive system

CAPS TKA Pilot

Database ID: __________
Date: ________________

EQ-5D

Under each heading, please tick the ONE box that best describes your health TODAY.

MOBILITY

I have no problems in walking about ☐
I have slight problems in walking about ☐
I have moderate problems in walking about ☐
I have severe problems in walking about ☐
I am unable to walk about ☐

SELF-CARE

I have no problems washing or dressing myself ☐
I have slight problems washing or dressing myself ☐
I have moderate problems washing or dressing myself ☐
I have severe problems washing or dressing myself ☐
I am unable to wash or dress myself ☐

USUAL ACTIVITIES *(e.g. work, study, housework, family or leisure activities)*

I have no problems doing my usual activities ☐
I have slight problems doing my usual activities ☐
I have moderate problems doing my usual activities ☐
I have severe problems doing my usual activities ☐
I am unable to do my usual activities ☐

PAIN / DISCOMFORT

I have no pain or discomfort ☐
I have slight pain or discomfort ☐
I have moderate pain or discomfort ☐
I have severe pain or discomfort ☐
I have extreme pain or discomfort ☐

ANXIETY / DEPRESSION

I am not anxious or depressed ☐
I am slightly anxious or depressed ☐
I am moderately anxious or depressed ☐
I am severely anxious or depressed ☐
I am extremely anxious or depressed ☐

Version: 06-Sep -2017

Appendix C: Western Ontario and McMaster Universities Osteoarthritis Index

CAPS TKA Pilot

Database ID: __________
Date: ________________

WOMAC

A. Think about the ***pain*** you felt in your hip/knee during the last 48 hours.

Question: How much pain do you have?	None	Mild	Moderate	Severe	Extreme
1. Walking on a flat surface	0	1	2	3	4
2. Going up or down stairs	0	1	2	3	4
3. At night while in bed, pain disturbs your sleep	0	1	2	3	4
4. Sitting or lying	0	1	2	3	4
5. Standing upright	0	1	2	3	4

B. Think about the ***stiffness*** (not pain) you felt in your hip/knee during the last 48 hours. Stiffness is a sensation of ***decreased*** ease in moving your joint.

	None	Mild	Moderate	Severe	Extreme
6. How ***severe*** is your ***stiffness after first awakening*** in the morning?	0	1	2	3	4
7. How ***severe*** is your stiffness after sitting, lying, or resting ***later in the day***?	0	1	2	3	4

C. Think about the ***difficulty*** you had in doing the following daily physical activities dues to your hip/knee during the last 48 hours. By this we mean your ***ability to move around and look after yourself***.

Question: What degree of difficulty do you have?	None	Mild	Moderate	Severe	Extreme
8. Descending stairs	0	1	2	3	4
9. Ascending stairs	0	1	2	3	4
10. Rising from sitting	0	1	2	3	4
11. Standing	0	1	2	3	4
12. Bending to the floor	0	1	2	3	4
13. Walking on a flat surface	0	1	2	3	4
14. Getting in and out of a car, or on or off a bus	0	1	2	3	4
15. Going shopping	0	1	2	3	4
16. Putting on your socks or stockings	0	1	2	3	4
17. Rising from bed	0	1	2	3	4
18. Taking off your socks or stockings	0	1	2	3	4
19. Lying in bed	0	1	2	3	4
20. Getting in or out of the bath	0	1	2	3	4
21. Sitting	0	1	2	3	4
22. Getting on or off the toilet	0	1	2	3	4
23. Performing heavy domestic duties	0	1	2	3	4
24. Performing light domestic duties	0	1	2	3	4

Appendix D: Cost Questionnaires

CAPS TKA Pilot Database ID: _______________

Daily Diary

1) Did you call the hospital for any reason related to your knee today?

◯ No ◯ Yes → ◯ Surgeon's office
◯ Resident on call
◯ Other (Please specify):

1b) Reason for call? ___________________________________

1c) Length of Call? ___________________________________

2) Please record what medications you have taken today:

Medication Name	Dose	Frequency (Dose/Day)

3) Have you received assistance from a relative or a friend for health care, personal care, shopping, household activities or transportation? (Only list assistance needed because of your knee)

◯ No ◯ Yes (Please Specify):

Health Care Activity	Number of hours of assistance	Number of hours that person took off paid employment
Taking Medications		
Exercises/Rehabilitation		
Dressing/Undressing		
Bathing/Showering		
Going to the bathroom		
Shopping		
Meal preparation		
Housework		
Finances		
Doctor appointments		
Driving		
Other:		

4) Did you incur any other expenses related to your knee, that we have not asked you about? Remember to include things like walking aids, gasoline, taxi, ambulance, parking, food, toiletries, etc)

◯ No ◯ Yes (Please Specify):

Expense	Cost ($)

5) How bad is your pain today? Please mark your pain with a slash across the line (/)

No Pain 0 ____ 100 Severe Pain

Version: 06-Sep-2017

CAPS TKA Pilot

Database ID: __________
Date: ________________

Emergency Room Visits and Hospitalizations

1. Since your last visit, have you visited an emergency room for any reason?

❑ No – Skip to **Question 2**
❑ Yes – How many times? ________ If yes, which hospital did you go to and why?

1	Reason:	
	Hospital:	
2	Reason:	
	Hospital:	

2. Since your last visit, have you been admitted to the hospital overnight for any reason (including overnight emergency room visits)?

❑ No – Skip to **Question 3**
❑ Yes – How many times? _______ Please complete the following:

Admission Date:		Discharge Date:	
Days in ICU/CCU:			
Major surgery / procedure if any:			
Reason:			
Hospital:			
Discharged to:			

Family Doctor Visits

3. Since your last visit, have you seen your family doctor for any reason?

❑I do not have a family physician - skip to **Question 4**
❑I have not attended an appointment with my family physician since my last visit (skip to **Question 4)**
❑Yes, I have attended an appointment with my family physician since my last visit.
Number of visits: _________

Version: 06-Sep-2017

CAPS TKA Pilot

Database ID: __________
Date: ________________

Visit 1: Reason: ____

❑Check this box if the reason for visit was related to your knee replacement

Visit 2: Reason: ____

❑Check this box if the reason for visit was related to your knee replacement

Specialist Visits and Outpatient Clinics

4. Since your last visit, have you visited a specialist for any reason (please include visits to the surgeon who performed your knee replacement)? If you are uncertain about the exact number of visits, please provide your best estimate.

❑ No – Skip to **Question 5**
❑ Yes – Complete the following:

How many specialists? _______________

1: Specialist Visited: ____

Number of Visits: ____

Please specify reason for visit: ____

2: Specialist Visited: ____

Number of Visits: ____

Please specify reason for visit: ____

5. Since your last visit, have you visited any clinics for any reason (for example walk-in or pain management clinics)? If you are uncertain about the exact number of visits, please provide your best estimate.

❑ No – Skip to **Question 6**
❑ Yes – Complete the following:

Type of clinic visited	**Reason for Visit**	**Number of visits**	**Number of visits relating to your knee replacement?**

CAPS TKA Pilot

Database ID: __________
Date: ________________

Other Health Care Professionals

6. Since your last visit, have you seen any other health professionals (like a physiotherapist, occupational therapist, etc)? If you are uncertain about the exact number of visits, please provide your best estimate.

❑ No – Skip to **Question 7**
❑ Yes – Complete the following:

Since your last visit, how many times have you visited a **physiotherapist**? ___________

Was this visit because of your knee replacement?	Cost of this visit	How was the visit paid for?
❑Yes ❑No	$	❑OHIP ❑Out of pocket ❑Private insurance
❑Yes ❑No	$	❑OHIP ❑Out of pocket ❑Private insurance
❑Yes ❑No	$	❑OHIP ❑Out of pocket ❑Private insurance
❑Yes ❑No	$	❑OHIP ❑Out of pocket ❑Private insurance

Since your last visit, how many times have you visited an **occupational therapist**? _______

Was this visit because of your knee replacement?	Cost of this visit	How was the visit paid for?
❑Yes ❑No	$	❑OHIP ❑Out of pocket ❑Private insurance
❑Yes ❑No	$	❑OHIP ❑Out of pocket ❑Private insurance

Since your last visit, how many **other health professionals** have you visited (for example a chiropractor, massage therapist or community nurse)? ___________

Specialist	Number of visits	Number of visits related to your knee replacement?	Cost of each visit	How was the visit paid for?
			$	❑OHIP ❑Private insurance ❑Out of pocket
			$	❑OHIP ❑Private insurance ❑Out of pocket
			$	❑OHIP ❑Private insurance ❑Out of pocket

CAPS TKA Pilot

Database ID: __________
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Tests, Procedures, and Surgeries

7. Since your last visit, have you had any tests, procedures, or surgeries for any reason (for example x-rays or blood tests)?

❑ No – Skip to **Question 8**
❑ Yes – Complete the following:

Test, procedure, or surgery	Number of tests	Number of tests related to your knee replacement?	Where did you receive this test or procedure?
			❑Emergency room ❑Hospital, inpatient ❑Hospital, outpatient ❑Rehab Centre ❑Other, specify:
			❑Emergency room ❑Hospital, inpatient ❑Hospital, outpatient ❑Rehab Centre ❑Other, specify:

Employment Status and Time-Off Work from Paid Employment

8. When you were enrolled in this study, were you actively employed?

❑ No - skip to **Question 10**
❑ Yes

9. Which of the following best describes your employment status or main activity at the time of study enrollment?

❑ Employed (full time)
❑ Employed (part time)
❑ Homemaking
❑ Student
❑ Volunteer
❑ Social Assistance
❑ Retired
❑ Accident Insurance
❑ Government
❑ WSIB
❑ Litigation
❑ Disability
❑ Temporary Sick Leave
❑ Self-Employed
❑ Other: ___________________

What was your occupation? ____

10. Has there been any change to your employment status since your last visit?

❑ No - skip to **Question 11**
❑ Yes – Please complete the following:

What is your current occupation? ____

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11. Since your last visit, how much time off paid employment did you take off as a result of your health? (includes hospitalization, doctor / emergency visits, treatment, and rehabilitation)

_____________ Days

_____________ Hours

❑None

12. What best describes your annual household income?

❑ <$20,000
❑ $20,000-$40,000
❑ $40,000-$60,000
❑ $60,000-$80,000
❑ $80,000-$100,000
❑ >$100,000

Homemaking and Volunteer Activities

13. Since your last visit, how much time off homemaking activities did you take off as a result of your health (including hospitalization, doctor / emergency visits, treatment, and rehabilitation)?

_____________ Days

_____________ Hours

❑None

14. Since your last visit, how much time off volunteer activities did you take off as a result of your health (including hospitalization, doctor / emergency visits, treatment, and rehabilitation)?

_____________ Days

_____________ Hours

❑None

15. This section is asking about your role as a primary caregiver.

Definition: Primary caregiver is an individual who is responsible for providing care assistance, companionship, and/or supervision to another person.

Since your last visit,

❑ I have not been a primary caregiver - skip to **Question 16**
❑ I have been a primary caregiver. My role has NOT changed

If you had to take days off from primary caregiving, how many days did you take off because of your knee (including hospitalizations, doctor visits, treatment and rehabilitation)?

_____________ Days

_____________ Hours

❑None

❑ I was a primary caregiver and now I am NO LONGER a primary caregiver

Date of change: |___|___|___|___|/|___|___|___|/|___|___|
yyyy / mmm / dd
Reason for no longer being a primary caregiver: ____________________

____

❑I was NOT a primary caregiver and now I AM a primary caregiver

Date of change: |___|___|___|___|/|___|___|___|/|___|___|
yyyy / mmm / dd
Reason for becoming a primary caregiver: __________________________

____

How many days of primary caregiving did you provide?

____________ Days

____________ Hours
❑None

<u>Assistive Living</u>

16. Since your last visit, has there been a change to your living status? (for example, did you move in with a relative, move into a rehabilitation facility or move back home?)

❑ No – Skip to **Question 17**
❑ Yes – Complete the following:

Is the change in living status related to your knee replacement?

❑ Yes ❑ No – skip to **Question 17**

If yes, which option best describes the change in your living status:

❑ Living in own home – no hired assistance

Date Changed: ___________________________________

❑ Living in own home – hired assistance required

Date Changed: ___________________________________
Please indicate the source of funding and total charge.
❑ Publicly funded $ ________________
❑ Insurance funded $ ________________
❑ Private funded $ ________________

❑ Living in relative's home – no hired assistance

Date Changed: ___________________________________

❑ Living in relative's home – hired assistance required

Date Changed: ___________________________________

Please indicate the source of funding and total charge.

❑ Publicly funded $ ________________

❑ Insurance funded $ ________________

❑ Private funded $ ________________

❑ Supportive housing / personal care home

Date Changed: ___________________________________

Type of assisted living:

❑ Assisted living (group home, retirement home)

❑ Residential care

❑ Long-term care facility, convalescent care, nursing home

Please indicate the source of funding and total charge.

❑ Publicly funded $ ________________

❑ Insurance funded $ ________________

❑ Private funded $ ________________

17. Did you incur any other expenses related to your knee replacement that we have not asked you about? (e.g. gasoline, walking aids, meals, accommodation, parking, etc)

❑ No
❑ Yes – please specify, with approximate cost:

Expense:__________________________________ $ cost: ____________

Expense:__________________________________ $ cost: ____________

Expense:__________________________________ $ cost: ____________

Expense:__________________________________ $ cost: ____________

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Medications

18. Since your last visit, have you taken any prescription or over-the-counter medications for your knee?

❑ No – Skip to **Question 19**
❑ Yes – Complete the following:

Yes No
❑ ❑ **Non-Steroidal Anti-Inflammatory Drugs (NSAIDs)**

Medication	**Dose (mcg, mg, g, other)**	**Pills/dose**	**Doses/day**	**How many days?**
❑Aspirin				
❑Celebrex				
❑Indomethacin				
❑Ibuprofen (Advil)				
❑Diclofenac (Arthrotec)				
❑Mobicox (Meloxicam)				
❑Naproxen (Naprosyn)				
❑Other, specify:				

Yes No
❑ ❑ **Steroids (please list)**

Name of steroid	**Dose (mcg, mg, g, other)**	**Pills/dose**	**Doses/day**	**How many days?**

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Yes No
❑ ❑ **Anti-Rheumatoid Drugs**

Medication	**Dose (mcg, mg, g, other)**	**Pills/dose**	**Doses/day**	**How many days?**
❑Plaquenil (hydroxychloraquine)				
❑Aralen (chloroquine)				
❑Arava (Leflunomide)				
❑Rheumatrex (Methotrexate)				
❑Azulfidine (Sulfasalazine)				
❑Remicade (Infliximab)				
❑Enbrel (Etanercept)				
❑Humira (Adalimumab)				
❑Other				

Yes No
❑ ❑ **Pain Killers**

Medication	**Dose (mcg, mg, g, other)**	**Pills/dose**	**Doses/day**	**How many days?**
❑Tylenol Regular Strength				
❑Tylenol Extra Strength				
❑Tylenol 2, 3				
❑Percocets				
❑Tramacet				
❑Hydromorphone (Dilaudid)				
❑Gabapentin				
❑Lyrica				
❑Oxycodone				
❑Other				

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19. Since your last visit, did you take any <u>other</u> medications? Examples would include antibiotics related to your knee replacement, or medications to prevent blood clots (i.e. Fragmin, Xeralto, Pradaxa).

❑ No – Skip to **Question 20**
❑ Yes – Please record the name of the medication or D.I.N. number (Drug Identification Number – found at the bottom of the prescription label on your medication bottle), number of pills per dose, doses per day, start date of the medication, and end date for each medication.

Medication /DIN	**Dose (mcg, mg, g, other)**	**Pills/dose**	**Doses/day**	**Start / End date**		**How did you pay for this medication?**
				Start:		❑OHIP ❑Private insurance ❑Out of pocket
				End:		
				Start:		❑OHIP ❑Private insurance ❑Out of pocket
				End:		
				Start:		❑OHIP ❑Private insurance ❑Out of pocket
				End:		
				Start:		❑OHIP ❑Private insurance ❑Out of pocket
				End:		

<u>Assistance from Others</u>

20. Since your last visit, have you received assistance from a relative or a friend for health care, personal care, shopping, household activities, or transportation because of your health?

❑ No
❑ Yes – Complete the following:

Health Care Activity	**Number of hours of assistance**	**Assistance needed because of <u>knee</u> replacement?**	**Number of hours off <u>paid</u> employment**
❑Taking Medications		❑Yes ❑No	
❑Exercises / Rehab		❑Yes ❑No	
❑ Other:___________		❑Yes ❑No	

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Personal Care Activity	Number of hours of assistance	Assistance needed because of knee replacement?	Number of hours off paid employment
❑ Dressing/Undressing		❑Yes ❑No	
❑ Bathing/Showering		❑Yes ❑No	
❑ Going to the bathroom		❑Yes ❑No	
❑Grooming (hair, shaving)		❑Yes ❑No	

Shopping/Home Activity	Number of hours of assistance	Assistance needed because of knee replacement?	Number of hours off paid employment
❑ Shopping (groceries)		❑Yes ❑No	
❑ Meal Preparation		❑Yes ❑No	
❑ Housework		❑Yes ❑No	
❑ Managing Finances		❑Yes ❑No	
❑ Other: __________		❑Yes ❑No	

Transportation to the…	Number of hours of assistance	Assistance needed because of knee replacement?	Number of hours off paid employment
❑ Doctor		❑Yes ❑No	
❑ Physiotherapist		❑Yes ❑No	
❑ Bank		❑Yes ❑No	
❑ Other: __________		❑Yes ❑No	

Curriculum Vitae

Ishita Joshi, BHSc

EDUCATION

Master of Science, Health and Rehabilitation Science, Measurement & Methods — Sept. 2019 – present
Collaborative Program in Musculoskeletal Health Research
Western University, London, Ontario, Canada

Bachelor of Health Science, Honours Specialization in Health Studies — Sept. 2015 – June 2019
Semester Exchange at the University of Copenhagen
Western University, London, Ontario, Canada

RESEARCH EXPERIENCE

Thesis Project — Sept 2020 – Apr 2021
Western University, London, ON
Supervisor: Dr. Jacquelyn Marsh; Advisory Committee: Dr. Dianne Bryant and Dr. Brent Lanting
Conducted a cost-effectiveness analysis on two different surgical approaches for total knee arthroplasty.
Responsible for ethics submission, patient recruitment, and data collection for a randomized controlled trial investigating outpatient total knee arthroplasty.

Undergraduate Student — 2019
The Center for Research on Health Equity and Social Inclusion, London, ON
Supervisor: James Shelley
Knowledge Translation Capacity Mapping at Western University.

Research Student, Li Ka Shing Knowledge Institute, Toronto, ON — 2016
Supervisor: Dr. Haibo Zhang
The role of fibroblasts in type II alveolar cell proliferation.

Research Student, Brookhaven National Laboratory — 2014
Supervisor: Dr. Alexei Soares
Reducing evaporation of crystallization droplets by using plate lids with apertures for adding liquids.

MANUSCRIPTS AND PUBLICATIONS

Primeau, C. A., Zomar, B. O., Somerville, L. E., Joshi, I., Giffin, J. R., & Marsh, J. D. (2021). Health Economic Evaluations of Hip and Knee Interventions in Orthopaedic Sports Medicine: A Systematic Review and Quality Assessment. *Orthopaedic journal of sports medicine*, *9*(3), 2325967120987241. https://doi.org/10.1177/2325967120987241

Primeau, C. A., Joshi, I., Zomar, B. O., Somerville, L. E., Philpott, H. T., McHugh, D. D., Lanting, B. A., Vasarhelyi, E. M., & Marsh, J. D. (2020). Cost-Effectiveness of Arthroplasty Management in Hip and Knee Osteoarthritis: A Quality Review of the Literature. *Current Treatment Options in Rheumatology*, *6*(3), 160–190. https://doi.org/10.1007/s40674-020-00157-8

Zipper, L. E., Aristide, X., Bishop, D. P., Joshi, I., Kharzeev, J., Patel, K. B., Santiago, B. M., Joshi, K., Dorsinvil, K., Sweet, R. M., & Soares, A. S. (2014). A simple technique to reduce evaporation of crystallization droplets by using plate lids with apertures for adding liquids. *Acta Crystallographica. Section F, Structural Biology Communications*, *70*(12), 1707–1713. https://doi.org/10.1107/S2053230X14025126

Under review: Marsh, J.D., Joshi, I., Somerville, L.E., Vasarhelyi, E.M., Lanting, B.A. (2021) Dissatisfied Patients Incur greater Costs Following Total Knee Arthroplasty. (Accepted, pending minor revisions - Canadian Journal of Surgery)

CONFERENCES AND PRESENTATIONS

Poster Presentation

Joshi I., Marsh J.D., Zomar B.O., Bryant D.M., Lanting B.A. Is Outpatient Total Knee Arthroplasty Cost-Effective? HRS Graduate Research Conference - London, ON, 2021.

Joshi, I., Uthayakumaran, M., Han, B., Khang, J., Xu, Y., Luo, A., Zhang, H. The role of fibroblasts in type II alveolar cell proliferation. Keenan Research Summer Student Conference - Toronto, ON, 2016.

Moderator

Moderator. Oral Sessions B-A. Health and Rehabilitation Sciences Graduate Research Conference – London, 2021

Moderator. Prevention Strategies Breakout Session. Bone and Joint Institute Research Retreat – London, 2021

TEACHING ASSISTANTSHIPS

Western University, London, ON

HS 2711B – Health Issues in Aging — Winter 2021
Professor: Stephen Lin

HS 2801A – Research Methods in Health Science — Fall 2020
Professor: Michael Robinson

HS 2300A/B – Systemic Approach to Functional Anatomy — Fall 2019 and Winter 2020
Professor: Jamie Melling

HONOURS & AWARDS

Western University, London, ON

Top MSK Masters Presentation (HRS Graduate Research Conference)	2021
Collaborative Program in Musculoskeletal Health Research Trainee Stipend	2020
Global Opportunity Award	2018
FHS and HSSA Student Opportunity Fund Awards	2018
Dean's Honor List	2016-2019