8-22-2014 12:00 AM

Surgical Approach in Total Hip Arthroplasty: Patient Outcomes and Impact on Costs

Stephen M. Petis
The University of Western Ontario

Supervisor
Dr. Edward Vasarhelyi
The University of Western Ontario

Graduate Program in Surgery
A thesis submitted in partial fulfillment of the requirements for the degree in Master of Science

SURGICAL APPROACH IN TOTAL HIP ARTHROPLASTY: PATIENT OUTCOMES AND IMPACT ON COSTS

Integrated Article Format

by

Stephen Michael Petis

Graduate Program in Surgery

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Surgery

The School of Graduate and Postdoctoral Studies
Western University
London, Ontario, Canada

ABSTRACT

Total hip arthroplasty is often renowned as one of the most important surgical advances of the past century. Orthopaedic surgeons must choose a surgical approach to gain access to the hip joint in order to perform the reconstruction. There is debate in the literature as to which surgical approach optimizes patient outcomes, minimizes complications, and reduces costs to hospitals as a high volume procedure.

In the current studies, patient reported outcomes were compared at short-term follow-up using a prospective study design across the anterior, posterior, and lateral approach. A micro-costing method was used to acquire costs related to each procedure, as well as compare hospital metrics such as operating room time and hospital length of stay.

The anterior approach demonstrated superior functional outcomes at short-term follow-up, and significantly reduced costs from a hospital perspective. Further studies should compare objective assessments of function such as gait analysis, and cost-effectiveness from a societal perspective.

Keywords

Total hip arthroplasty, surgical approach, clinical outcomes, cost-analysis

Co-Authorship Statement

Chapter 1	Stephen Petis – Sole author
Chapter 2	Stephen Petis – Sole author
Chapter 3	Stephen Petis – Study design, patient recruitment, data collection, statistical analysis, manuscript preparation Edward Vasarhelyi – Study design, manuscript preparation James Howard – Study design, manuscript preparation Lyndsay Somerville – Study design, statistical analysis
Chapter 4	Stephen Petis – Study design, patient recruitment, data collection, statistical analysis, manuscript preparation Edward Vasarhelyi – Study design, manuscript preparation James Howard – Study design, manuscript preparation Jacquelyn Marsh – Study design, statistical analysis
Chapter 5	Stephen Petis – Sole author

Acknowledgements

This body of work would not have been possible without the help and support of a number of people.

Drs. Howard and Vasarhelyi – as members of my supervisory committee, you have both provided instrumental guidance and support throughout this process. Knowing how busy you both are with clinical and academic duties, I cannot thank you both enough for your contributions to this work. You are both mentors of mine and I look forward to working with both of you on future research endeavours.

Dr. Brent Lanting – Thank you for offering to participate as one of the surgeons in these studies. Without the help of you and your patients, these studies would not have been possible.

Drs. Lyndsay Somerville and Jacquelyn Marsh – Your expertise in clinical methodology and statistical analyses were integral parts of this project, so thank you for your contributions.

The Bourne-Rorabeck Joint Replacement Clinic staff – thank you for your patience and allowing me to attend follow-up appointments and run people through TUG tests in the middle of clinic. A special thanks to Meaghan Whalen for her tremendous efforts to ensure data collection was complete throughout the study.

Abigail Korczak – knowing how busy you are assisting with many other studies at University Hospital, it was difficult to ask for your help, but I greatly appreciate your contributions to ensuring the study protocol ran smoothly throughout.

TerryLyne McLaughlin and Maribeth Witteveen – your efforts to ensure the in-patient hospital data was complete are greatly appreciated.

My wife, Leanne – I cannot put into words how grateful I am for your unwavering support through the all stages of this thesis. The number of hours sacrificed on weekends seems countless, especially with the arrival of our beautiful son, Cole, 3-months ago, so I could not have done this without your love and understanding.

Table of Contents

List of Tables

List of Figures

Chapter 1

1 Introduction

This thesis aims to explore the role surgical approach in total hip arthroplasty has on patient reported outcomes and costs of the procedure from a hospital perspective. This chapter will review basic anatomy and principles of hip arthritis and total hip arthroplasty so that the context of the following chapters is clear. The anatomical and technical considerations for the anterior, posterior, and lateral approaches to the hip will be reviewed. This will facilitate understanding how subtle differences between the three approaches may impact clinical results.

1.1 The Hip

The hip is a ball-and-socket synovial joint formed through an articulation between the femoral head and the acetabulum of the pelvis. This articulation permits movement through the coronal, sagittal, and transverse planes [1]. A variety of muscles surround the hip joint, each with their own unique nervous innervation and action. The hip joint can be accessed surgically through various inter-nervous planes, as well as intra-muscular dissection [2].

1.1.1 Osteology

The two main bones of the hip include the proximal femur and the bony pelvis. The pelvis includes the fusion of three separate bony elements to create the acetabulum (Figure 1.1). Each bone has a unique set of bony prominences that serve as attachment sites for muscles and ligaments, as well as landmarks for planning surgical approaches [1, 2].

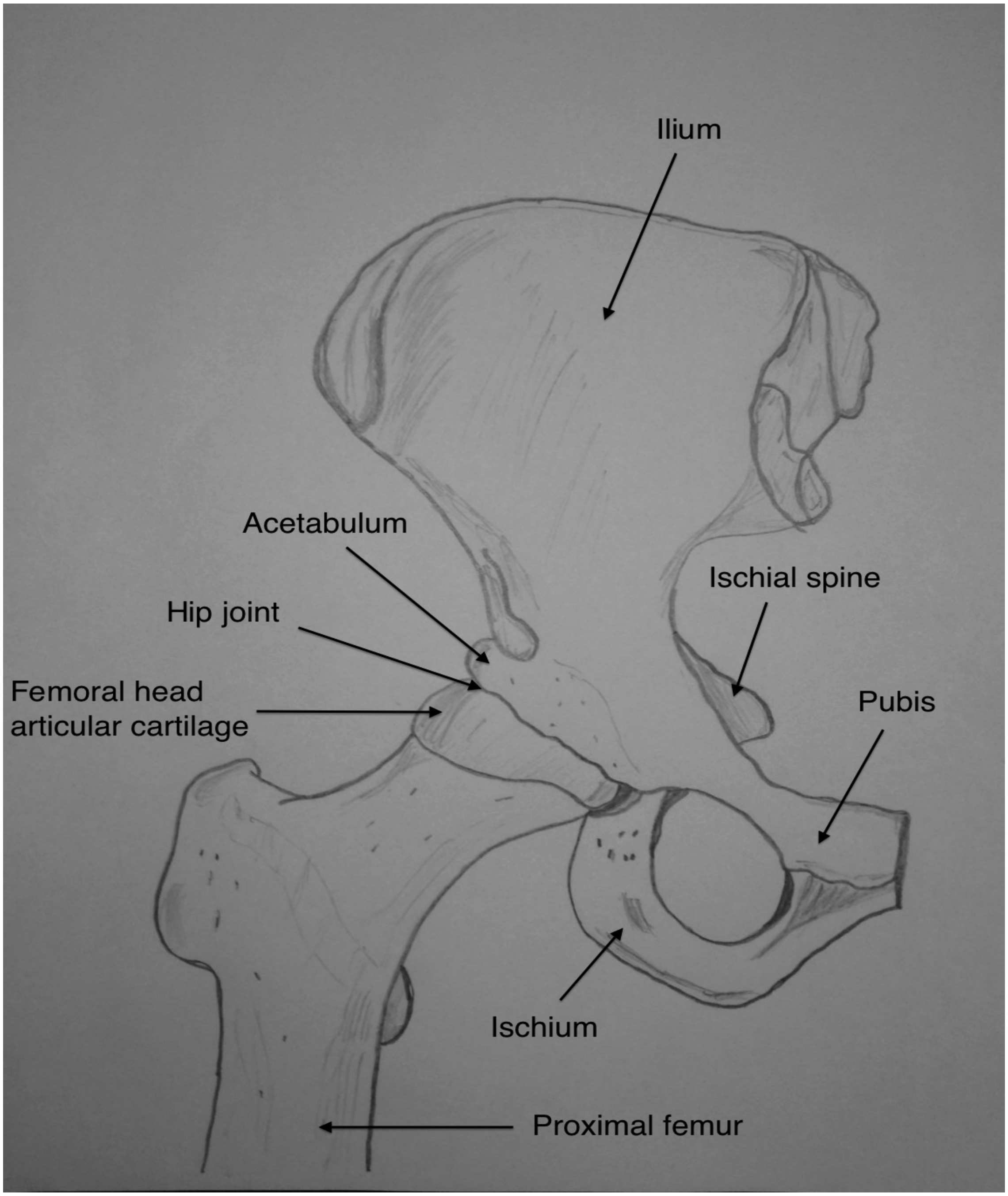

Figure 1.1 – Osteology of proximal femur and pelvis

A diagram demonstrating the main bony constituents of the hip joint and bony pelvis. The hip joint is represented by the articulation between the femoral head and acetabulum (S Petis).

1.1.1.1 Femur

The proximal femur consists of four main components – head, neck, and the greater and lesser trochanters [3]. The femoral head projects in a superomedial direction to articulate with the acetabulum [1]. The majority of its surface is covered with articular cartilage, which allows near frictionless and painless range of motion during daily activities such as gait [4].

The greater trochanter is a bony prominence located laterally and posteriorly on the proximal femur. The lesser trochanter is a smaller prominence located posteromedially at the neck-shaft junction [3]. They serve as important landmarks during surgical dissection, as well as attachment sites of numerous muscles around the hip [1-3].

The neck of the femur forms an angle with the femoral diaphysis of approximately 130 degrees in the coronal plane (Figure 1.2). Femoral anteversion refers to the angle formed when the femoral neck axis and the distal transverse condylar axis are superimposed [1]. This angle varies from 8-12 degrees anterior to the distal transverse condylar axis (Figure 1.3) [4]. Femoral retroversion occurs when the femoral neck version is directed posterior to the transverse condylar axis [1]. These angles are important to consider during reconstructive procedures such as total hip arthroplasty (THA).

1.1.1.2 Acetabulum

The acetabulum is the socket of the hip joint. It is formed by the fusion of the tri-radiate cartilage, which is the growth plate formed by the bony elements of the pelvis. These elements include the ischium, ilium, and pubis [1]. Approximately two-fifths of the acetabulum is contributed by the ilium and ischium, with the pubis comprising the remaining fifth. The acetabulum opens laterally, inferiorly, and anteriorly [5]. The degree of anterior inclination is referred to as acetabular anteversion, an angle typically measuring 15-23 degrees (Figure 1.3) [6, 7].

The rim of the acetabulum serves as an attachment site for the labrum, a fibro-cartilaginous structure that deepens the articular surface of the hip joint [5]. The femoral head is also supported within the acetabulum by the transverse acetabular ligament. This structure supports the most inferior aspect of the acetabulum, and is a useful landmark for determining acetabular anteversion during acetabular reconstructions [6].

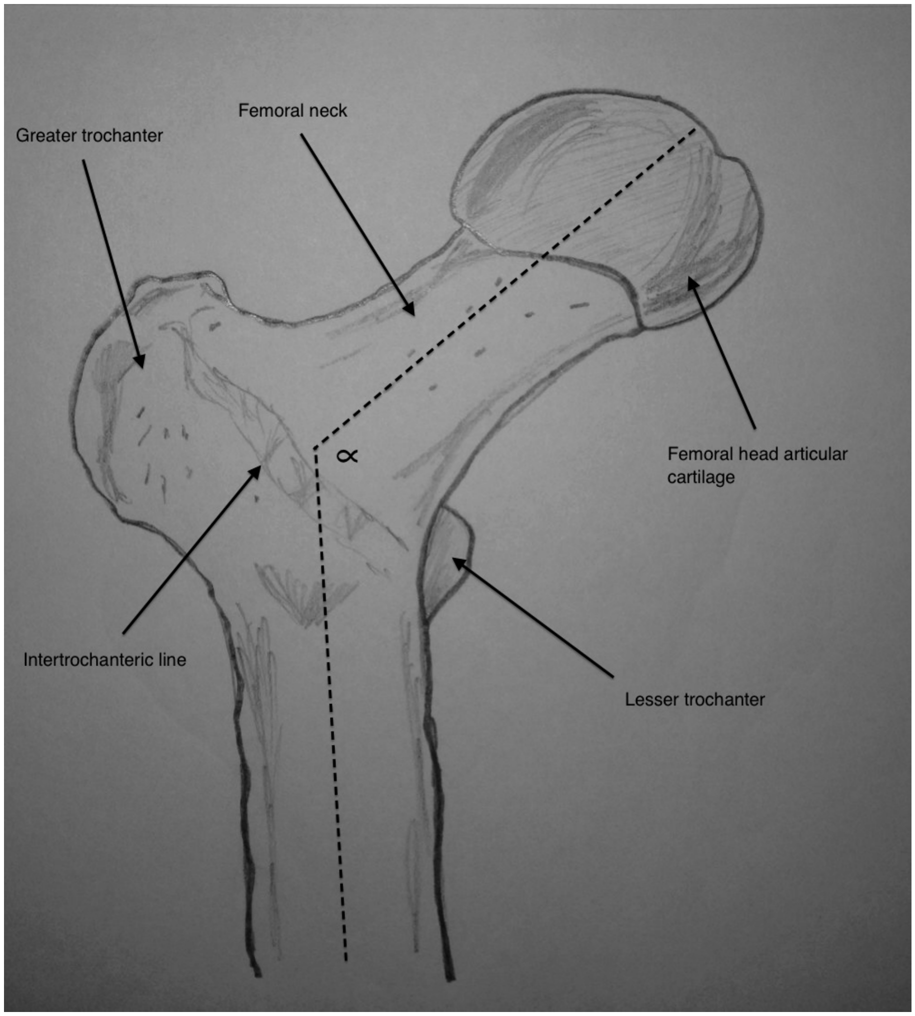

Figure 1.2 – Femoral neck-shaft angle

The angle subtended by α represents the neck-shaft angle of the proximal femur. This angle is normally 130 degrees in the coronal plane. Other important bony landmarks such as the greater and lesser trochanters serve as attachment sites for muscles and ligaments (S Petis).

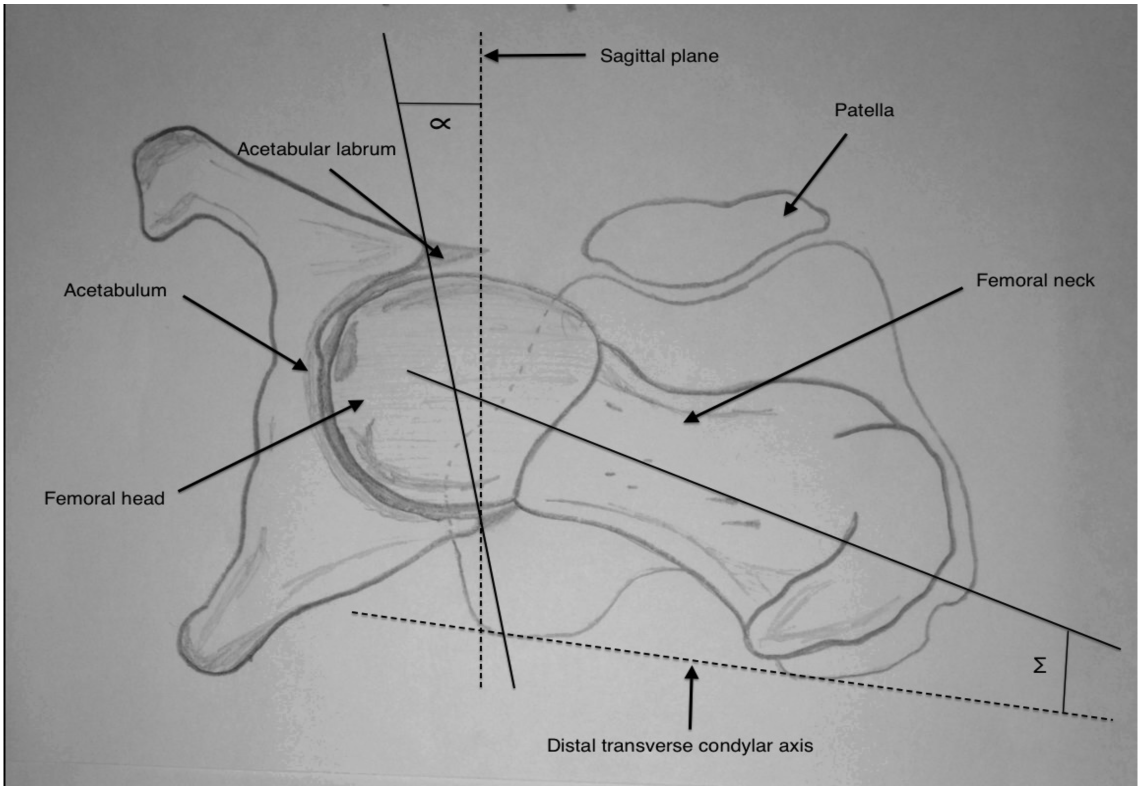

Figure 1.3 – Version of acetabulum and femoral neck

This axial cross-section of the hip joint demonstrates both acetabular and femoral neck version. Acetabular version, represented by angle α, is an angle formed by a line along the anterior and posterior aspect of the acetabulum intersecting a line in the sagittal plane. Normally, the acetabulum opens anteriorly, as demonstrated in this diagram, which is referred to as anteversion. If the acetabulum opens posteriorly, this is referred to as retroversion. Normal acetabular version is 15-23 degrees of anteversion. Femoral neck version, represented by angle Σ, is an angle formed by a line along the axis of the femoral neck and the distal transverse condylar axis of the knee. This angle is normally 8-12 degrees of femoral anteversion (S Petis).

1.1.2 Musculature around the hip

There are several muscles that surround the hip joint. Each muscle has its own bony or soft tissue origin and insertion, as well as nervous innervation. The nervous innervation of each muscle creates inter-nervous planes that are essential to understand when dissecting around the hip joint [2].

1.1.2.1 Sartorius

The sartorius is the longest muscle in the body. It originates off the anterior-superior iliac spine of the pelvis, and inserts on the proximal tibia as part of the pes anserine group. It is a weak hip flexor and external rotator, as well as a weak knee flexor and internal rotator [1]. It is innervated by the femoral nerve and serves as an important muscle during superficial dissection when using the anterior approach to the hip [8].

1.1.2.2 Tensor fascia latae

The tensor fascia latae is a more laterally based muscle originating from the anterior-superior iliac spine and inserting onto the iliotibial band. It assists in abduction, flexion, and internal rotation of the hip [1]. Innervated by the superior gluteal nerve, it forms a superficial inter-nervous plane with sartorius during the anterior approach to the hip [9].

1.1.2.3 Rectus femoris

The rectus femoris is a member of the quadriceps femoris group innervated by the femoral nerve. It is the only muscle in the group to cross both the hip and knee joints. This allows the muscle to contribute to flexion at the hip, and extension at the knee [1]. The muscle originates via a direct and indirect head; the direct head comes off of the anterior-inferior iliac spine, while the indirect head originates from the superior rim of the acetabulum and the anterior joint capsule (Figure 1.4) [1, 2]. This is important during an anterior approach to the hip, as both the direct and indirect head are retracted to improve visualization of the femur and acetabulum during reconstructive procedures [9-11].

1.1.2.4 Gluteus medius

The gluteus medius is a large, fan-shaped muscle often referred to as the “rotator cuff” of the hip [12]. It originates from the ilium between the anterior and posterior gluteal lines, splits into anterior, middle, and posterior portions, and inserts into two facets on the greater trochanter [1, 13]. Each portion of the gluteus medius is innervated by a branch of the superior gluteal nerve [12]. This muscle initiates hip abduction, produces subtle pelvic rotation to optimize gait efficiency, and helps stabilize the femoral head within the acetabulum during weight bearing [12, 14]. It is important to understand the anatomic boundaries of this muscle during a lateral approach to the hip [15].

1.1.2.5 Gluteus maximus

The gluteus maximus is a large muscle originating from the sacrum, ilium, and thoracolumbar fascia. It has upper and lower fibers inserting on the iliotibial band and gluteal tuberosity, respectively. This muscle is a powerful hip extensor and external rotator [1]. Innervated by the inferior gluteal nerve, many of the muscle fibers of gluteus maximus are split during a posterior approach to the hip [2].

1.1.2.6 Short external rotators

The group of muscles commonly referred to as the short external rotators includes piriformis, obturator internus, and the superior and inferior gemelli muscles (Figure 1.5). They originate from various bony landmarks including the sacrum, ischial spine and tuberosity, and the obturator foramen [1]. The gemelli form a conjoint tendon with obturator internus to insert on the medial aspect of the greater trochanter, whereas piriformis inserts at the apex of the greater trochanter [1, 2]. These muscles receive their nervous innervation from small branches of the sacral plexus, and they are weak contributors to hip external rotation. They are important landmarks during the posterior approach to the hip, and are often used to help identify and protect the sciatic nerve during this approach [2].

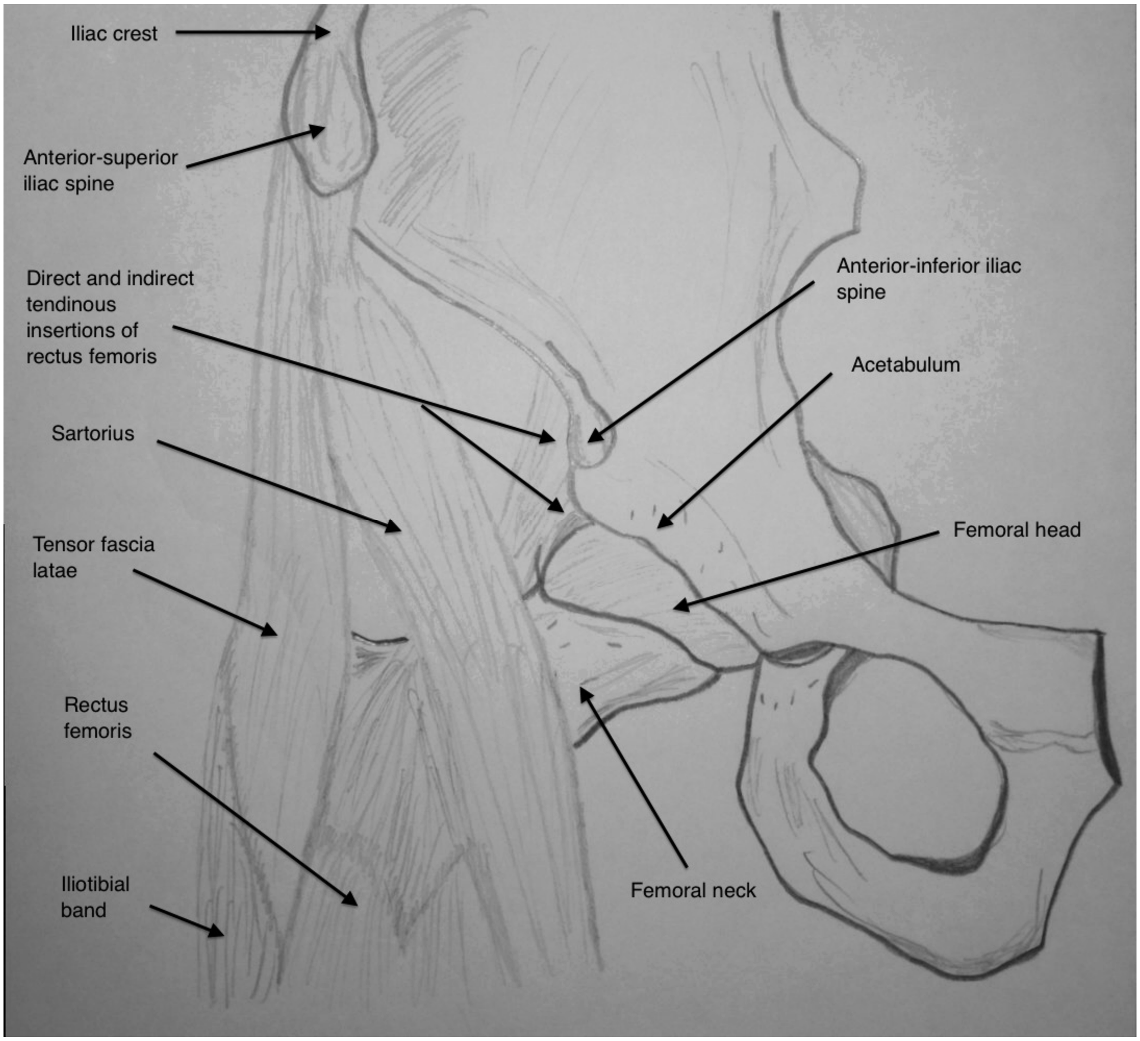

Figure 1.4 – Anterior muscles of the hip

There are several important muscles crossing the anterior aspect of the hip joint. These muscles form important inter-nervous planes that allow the surgeon to access the hip joint safely. The sartorius and tensor fascia latae form the superficial inter-nervous plane for an anterior approach to the hip. The rectus femoris forms the deep inter-nervous plane of the anterior approach with the gluteus medius. Note the two tendinous insertions of the rectus femoris (S Petis).

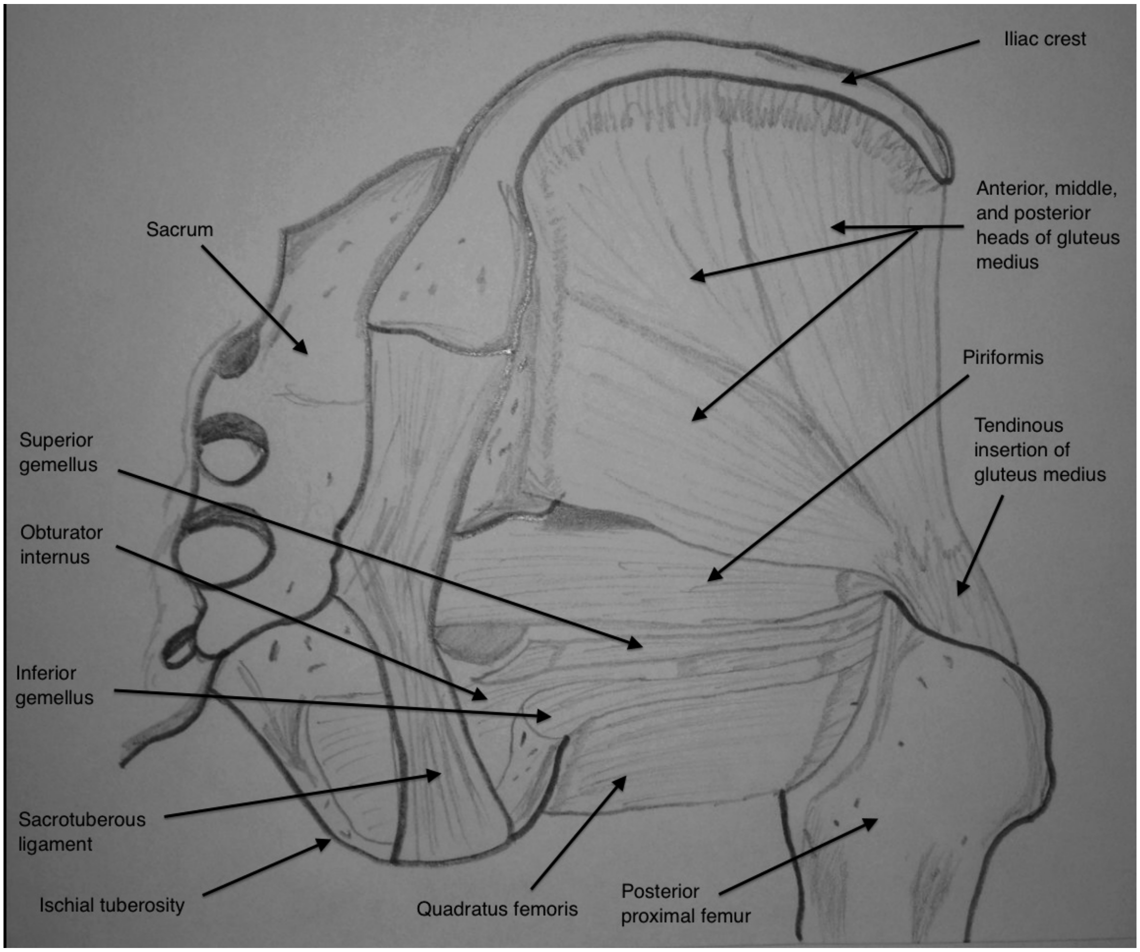

Figure 1.5 – Posterior muscles of the hip

This diagram depicts many muscles that cross the hip posteriorly and laterally. The tendinous insertion of the gluteus medius is split during a lateral approach to the hip. The superior and inferior gemelli and obturator internus form a conjoint tendon that is dissected off the proximal femur with the piriformis during a posterior approach to the hip (S Petis).

1.2 An overview of hip arthritis

The purpose of this section is to provide a brief overview of hip arthritis, its clinical features, and non-arthroplasty forms of treatment. The discussion will then describe total hip arthroplasty and its impact on patient outcomes. This will help demonstrate how the various surgical approaches to the hip can impact clinical outcomes.

1.2.1 Hip arthritis

Arthritis is a degenerative pathologic condition of the articular cartilage of synovial joints [16]. Damage and loss of articular cartilage leads to 4 cardinal changes within the joint: joint space narrowing, osteophytosis, subchondral bony sclerosis, and subchondral cyst formation (Figure 1.6) [17]. These changes cause debilitating musculoskeletal pain and psychological distress to those who have to live with the disease [18].

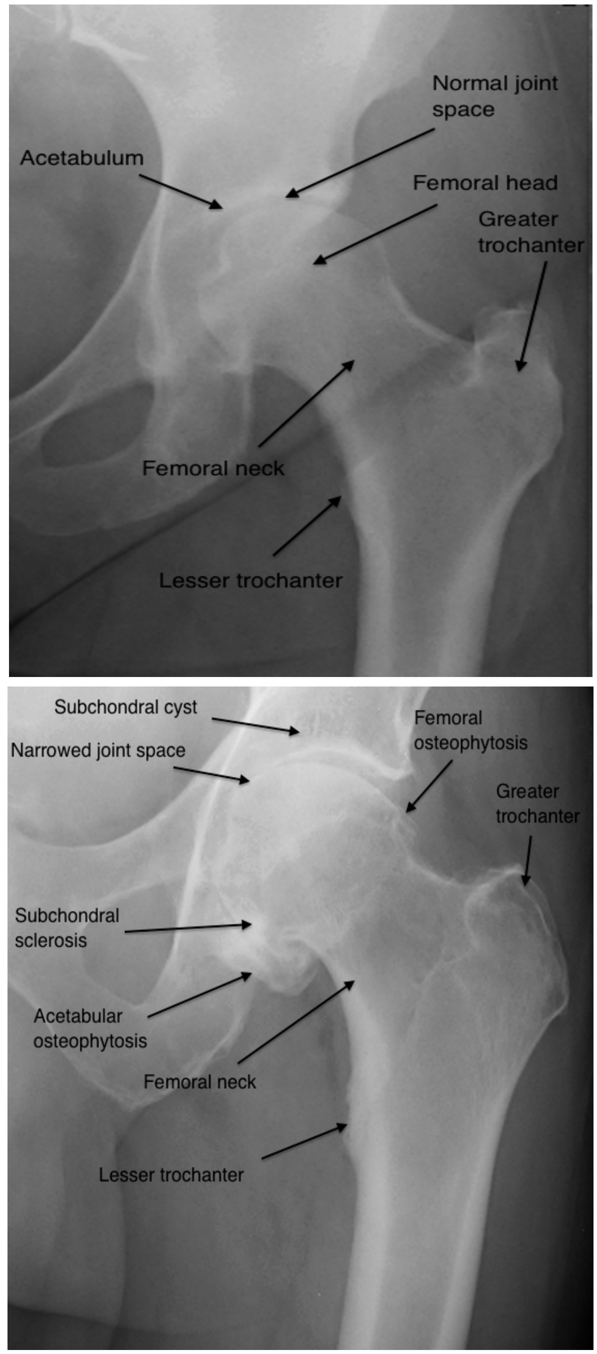

Figure 1.6 – The normal and arthritic hip joint

The top image is an anterior-posterior radiograph of a normal hip joint. The bottom image is an anterior-posterior radiograph of an arthritic hip joint. Note the cardinal signs of arthritis on the bottom radiograph: joint space narrowing, osteophyte formation, subchondral sclerosis, and cyst formation (S Petis).

1.2.1.1 Etiologies

Osteoarthritis is the most common cause of arthritis of the hip joint [16]. Primary osteoarthritis, or idiopathic arthritis, refers to cases where the cause of joint degeneration is unknown. Cases where there is an identifiable cause for the degenerative process are referred to as secondary osteoarthritis [19]. Several risk factors have been identified that may contribute to the development of osteoarthritis. Systemic factors include increased age, female sex and estrogen deficiency, increased bone density, poor nutrition, and genetics. Biomechanical risk factors include obesity, previous joint trauma, congenital joint deformities, certain vocations such as farming, sports participation, and surrounding muscle weakness [17, 20]. Other contributing factors include femoroacetabular impingement (FAI), developmental hip dysplasia, and slipped capital femoral epiphysis, although the details of each are beyond the scope of this discussion [16, 21, 22].

Other causes of joint degeneration within the hip are related to biological processes causing damage to the hyaline articular cartilage. Generally, these conditions expedite the degenerative process and cause much earlier debilitating pain and functional limitations [16]. Osteonecrosis of the femoral head, also known as avascular necrosis, is the result of ischemia to the subchondral bone, causing collapse of the supportive bony architecture and accelerated cartilage damage due to altered biomechanical stresses [23]. Legg-Calvé-Perthes disease is the childhood variant of idiopathic femoral head ischemia and necrosis leading to degenerative changes later in life [24]. Inflammatory arthritides are another cause of hip arthritis, examples of which include rheumatoid arthritis, ankylosing spondylitis, and systemic lupus erythematosus [16]. Joint destruction results from an aggressive inflammatory process driven by an autoimmune response to host biomarkers [25]. Finally, rapid and profound articular cartilage destruction is the devastating sequelae of untreated septic arthritis [26]. All of these conditions must be considered when consulting a patient regarding hip arthritis (Figure 1.7).

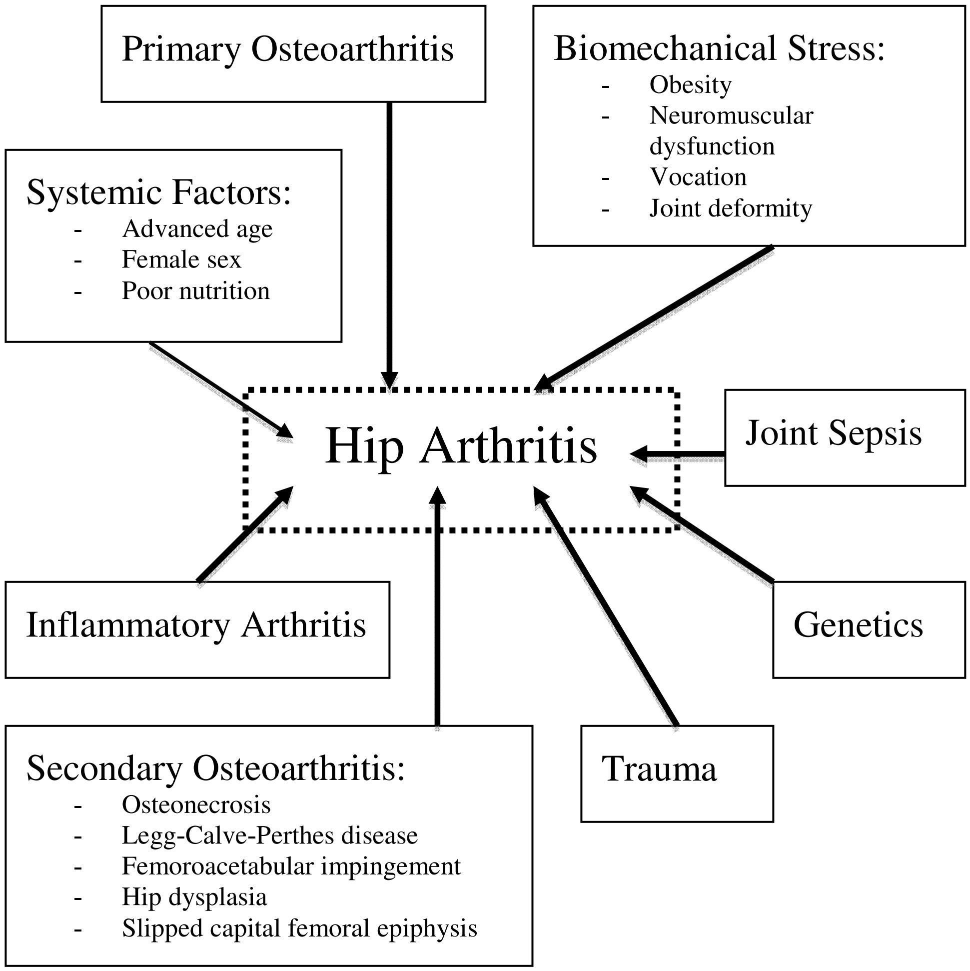

Figure 1.7 – Etiologies of hip arthritis

Several different factors contribute to the degenerative changes manifested as hip arthritis. The most common is primary, or idiopathic osteoarthritis. All other etiologies should be considered when acquiring a history from a patient with hip pain (S Petis).

1.2.1.2 Clinical features of hip arthritis

Patients presenting with hip arthritis will have a number of clinical features unique to this disease. The patient will often complain of groin pain, buttock pain, or pain around the greater trochanter [27]. The patient will often cup their hip with their hand when asked to locate the pain, which is known as the "C" sign. The pain may radiate to the inside of the knee due to irritation of the saphenous branch of the femoral nerve [28]. The pain is usually worse with activity, and abates with rest. Patients report that activities of daily living such as walking and self-hygiene have become cumbersome. Other associated symptoms include stiffness, joint instability, and motor weakness. Careful questioning should determine that the pain in the hip is not due to radiating patterns from the spine and knee as well [29].

A detailed physical examination is essential in confirming the diagnosis, and eliciting findings that may impact future reconstructive procedures [27]. Physical examination should begin by observing the patient's gait. A Trendelenburg gait and sign is a common physical finding resulting from abductor weakness [14]. The hip should be fully exposed to examine for bruising, swelling, erythema, or previous surgical scars. The examiner should note any leg length discrepancy that may impact future reconstructive procedures [27]. Range of motion and strength testing should document any limitations. Patients with hip arthritis typically have reduction in internal rotation and abduction, with pain in the groin elicited with internal rotation [29]. Pain produced in the groin with an active straight leg raise is often associated with hip arthritis, which is known as the Stinchfield test [30]. A complete neurovascular examination is critical to compare to any potential post-operative changes. Again, examination of the spine and knee are essential to ensure that the true source of functional limitation and pain is originating from the hip.

1.2.1.3 Epidemiology of hip arthritis

Hip arthritis has a tremendous impact on patient quality of life and level of functioning. By the year 2020, the World Health Organization projects that osteoarthritis is expected to become the 4th leading contributor to patient disability [31]. A recent systematic review suggests a prevalence of 10.9% for hip osteoarthritis for all-comers [32]. This prevalence differs for different countries around the world, as well as whether a clinical or radiographic definition is used to diagnose osteoarthritis [33]. Health care systems incur tremendous costs while patients live with debilitating hip arthritis. This is particularly true when patients are waiting for joint replacement surgery, a time when health related quality of life and functionality are presumed to be the lowest [34, 35]. As populations continue to live longer, more people will live with chronic disease such as arthritis, creating increased demand for both non-surgical and surgical modes of treatment [33].

1.2.1.4 Treatment of hip arthritis – Non-surgical

There are a variety of non-surgical treatment modalities available to mitigate the pain associated with arthritis. Treatment of hip arthritis should be tailored to patients' symptoms and previous therapies. Initially, treatment should begin with less invasive options and progress towards surgical intervention [29].

Early non-operative management includes exercise therapy. This has been shown to reduce pain early following the diagnosis of hip arthritis, and can contribute to weight-loss and muscle strengthening [36]. Weight-loss has been shown to reduce disability associated with osteoarthritis [37]. The use of a gait aid such as a cane or a walker can help produce an abductor moment to off-load the affected hip, particularly in the setting of abductor insufficiency. Patients may also need to avoid activities that exacerbate their hip pain, which sometimes includes taking time off of work if the individual is employed.

After these measures have failed, pharmacotherapy can effectively control pain associated with osteoarthritis. A Cochrane review has demonstrated that acetaminophen is better than placebo at controlling pain associated with osteoarthritis. Non-steroidal anti-inflammatory drugs (NSAIDs) may be more effective than acetaminophen at controlling painful osteoarthritis; however, there is an increased risk of gastrointestinal side effects, hypertension, and renal dysfunction with prolonged NSAID use [38]. Corticosteroid and visco-supplementation injections are also treatment options [29]. These injections are usually performed under radiographic or ultrasonographic guidance when used to treat painful osteoarthritis of the hip. Studies have demonstrated reduced pain and less reliance on other medications such as NSAIDs following visco-supplementation [39, 40].

1.2.1.5 Treatment of hip arthritis – Surgical

There are a number of surgical procedures available to treat patients with painful hip arthritis once non-surgical methods have become ineffective. Within the realm of surgical procedures, a number of non-arthroplasty options must be considered. Total hip arthroplasty will be discussed in greater detail in the following section.

Hip arthroscopy has become a popular procedure in the setting of the painful hip. Its utilization has steadily increased over the past decade as both a diagnostic and therapeutic procedure [41]. In the literature, indications include removal of intra-articular loose bodies, osteochondroplasty for painful impingement associated with FAI, grading the degree of articular cartilage degeneration, labral repair, synovectomy, irrigation of septic arthritis, extra-articular tendon releases, and debridement for osteoarthritis [16, 42]. However, there is a paucity of literature documenting the clinical efficacy of hip arthroscopy in treating pain due to hip arthritis at long-term follow-up. Therefore, managing patient expectations is very important when considering this surgical procedure [41].

Other surgical considerations are used for specific circumstances. The peri-acetabular osteotomy as described by Ganz can manage painful hip arthritis and limit the progression of degeneration in patients with mild to moderate acetabular dysplasia [43]. Proximal femoral osteotomies can correct deformities that create accelerated wear on articular cartilage from increased biomechanical stresses. Valgus- or varus-producing osteotomies, derotation osteotomies, and shortening osteotomies are used in conditions such as developmental dysplasia of the hip, Legg-Calve-Perthes disease, slipped capital femoral epiphysis, or post-traumatic arthritis [16, 27]. Hip arthrodesis, or fusion, is largely a historical procedure reserved for young patients with severe hip arthritis in order to delay the need for a reconstructive procedure (Figure 1.8) [16].

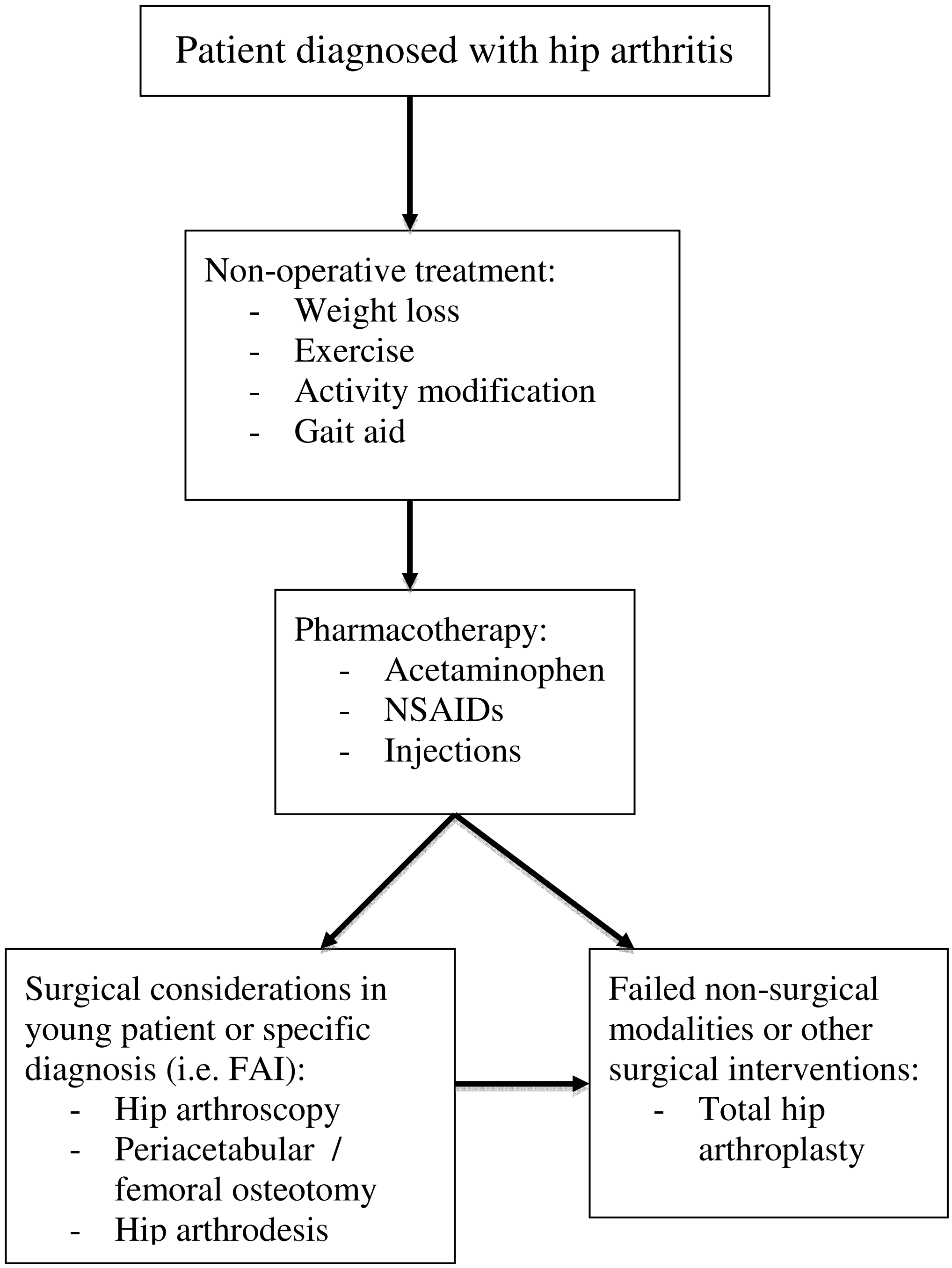

Figure 1.8 – Treatment algorithm for hip arthritis

This diagram represents a treatment algorithm for hip arthritis. Patients undergo a trial of non-operative management modalities such as gait aids and pharmacotherapy. If these fail, the treating surgeon considers surgical management tailored to each patient's underlying pathology (S Petis).

1.2.2 Total hip arthroplasty

Since its inception in the late 1950s, THA has revolutionized the treatment of painful hip arthritis [44]. The main constituents of the surgical reconstruction include a femoral stem, acetabular shell, and bearing articulation. This section will briefly outline the technical aspects of the procedure, as well as its clinical efficacy in the literature.

1.2.2.1 Femoral reconstruction

The goal of THA is to reproduce the native center of rotation of the femoral head [27]. This involves inserting a metal femoral stem into the proximal femur (Figure 1.9). The reconstruction begins by exposing the proximal femur through the chosen surgical approach. The femoral head is then dislocated from the acetabulum in a controlled manner. This will provide the surgeon with visualization of the femoral head, neck, and greater and lesser trochanters [16, 27].

Once the femoral neck is exposed, an oscillating saw is used to perform an osteotomy of the femoral neck. The location of this osteotomy is dependent on careful pre-operative templating [16]. Generally, this osteotomy is performed approximately 1 centimeter above the lesser trochanter, and perpendicular to the long axis of the femoral neck [45]. This will allow the surgeon to prepare the femoral intramedullary canal to receive the femoral stem implant.

The intramedullary canal is prepared using a series of graded reamers and broaches. These instruments are passed down the canal, and the broaches are often used as trial implants to represent the appropriately sized femoral implant. With the broach in-situ, a trial femoral head is placed on the neck of the femoral implant and reduced into a reconstructed acetabulum. This is when the surgeon decides to ask for the definitive implants, or make adjustments based on the following principles.

It is important that the surgeon matches the patient's femoral anteversion while broaching to prevent instability and impingement associated with an overly anteverted or retroverted implant [46]. The surgeon must be cognizant of the depth the femoral stem is implanted in order to maintain leg length equality and tensioning of the surrounding soft tissue including muscles and ligaments [27]. Soft tissue tensioning is also impacted by femoral offset, which is the distance from the center of the femoral head to the center of the femoral canal [47]. Restoring these anatomic variables will produce more efficient gait mechanics and limit excess biomechanical stresses across the implant [27].

Finally, the surgeon must then choose whether to use a cemented or cementless femoral stem. Cemented femoral stems are placed into a 2-4 millimeter polymethylmethacrylate polymer mantle that acts as a grouting material to interdigitate with the host bone [48, 49]. They are generally smooth, highly polished stems with no sharp edges to limit de-bonding from the cement mantle [50]. This form of fixation has several indications including profound osteopenia, irradiated bone, and unusual proximal femoral anatomy [27]. Cementless femoral stems rely on biological bony in-growth into a porous coating or bony on-growth onto a grit-blasted or hydroxyapatite surface [27, 51-53]. They are an attractive option because there is no need to use cement intra-operatively, resulting in shorter surgical times and reducing the theoretical risk of intra-operative hypotension caused by pressurizing cement into the femoral canal [54, 55]. Regardless of the mode of fixation, many femoral stems have excellent survivorship and clinical outcomes at long-term follow-up [56-61].

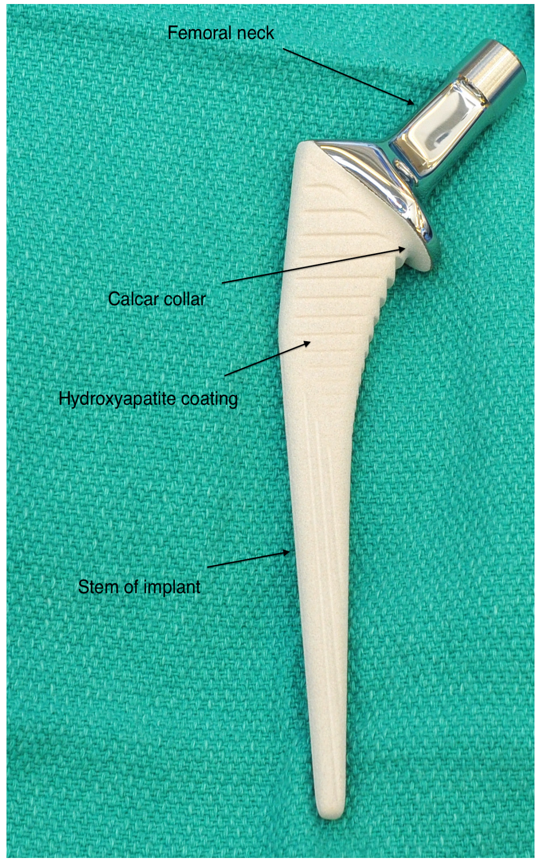

Figure 1.9 – Femoral stem

This is an example of the Corail ™ stem (DePuy Orthopaedics Inc., Warsaw, IN), a femoral stem used to reconstruct the proximal femur. It is an example of a cementless, hydroxyapatite-coated stem (S Petis).

1.2.2.2 Acetabular reconstruction

Acetabular reconstruction is the second constituent of a THA. As with femoral reconstructions, the goal of reconstructing the acetabulum is to reproduce the anatomic center of rotation to enable functional range of motion and stability [16, 62-64]. Pre-operative radiographs are useful in planning the positioning of acetabular component, as adequate medialization of the component to the acetabular floor limits biomechanical stresses and early implant failure [64, 65].

In order to ensure proper component positioning, the acetabulum must be adequately exposed through the chosen surgical approach [16, 27]. Surrounding soft tissue including joint capsule, labrum, and osteophytes are removed from the rim of the acetabulum. Acetabular reamers are then used to prepare the floor of the acetabulum to accept the acetabular implant. The size of the reamer incrementally increases until the size of the last reamer engages the anterior-posterior extent of the native acetabulum [27]. Throughout reaming, the surgeon is able to control the version and inclination of the acetabular reconstruction. Bony landmarks as well as soft tissue structures are used to assist the surgeon in reproducing anatomic acetabular anteversion [63, 66, 67]. Inclination is re-created by visualizing the position of the final reamer relative to the floor of the operating room, as well as a cup positioner or guide that accompanies many total hip implant systems [68, 69]. Acetabular inclination between 35-45 degrees has been shown to optimize range of motion, limit impingement on the femoral component, and lower the risk of hip dislocation [63, 70, 71]. As with femoral reconstructions, trial implants are available to allow the surgeon to reduce the reconstructed hip and assess range of motion and stability before definitive implant selection [27, 68, 69].

Once the surgeon is satisfied with the trial reconstruction, the definitive acetabular shell is chosen. Current generation acetabular shells are fabricated from titanium and are porous coated [16]. The porous coating allows biological bony in-growth that permits implant fixation. Once the shell is in-situ, several shell manufacturers allow for the insertion of screws to augment fixation into the bony pelvis [68, 69]. The decision to insert screws is based on the surgeon's assessment of the patient's bone quality and bony contact with the shell, co-morbid conditions that may preclude quality bony in-growth such as inflammatory arthropathy, and osteopenia [72, 73]. Current generation acetabular shells provide reliable long-term fixation and excellent clinical outcomes [74-76].

1.2.2.3 Bearing articulations

Once the femoral and acetabular reconstructions are complete, a bearing articulation must be chosen. Bearing articulations are composed of a femoral head, which attaches to the femoral stem via a Morse taper, and an articulating liner, which sits inside the acetabular shell. There are several options available when choosing a bearing articulation, each with theoretical advantages and disadvantages.

The acetabular liner can include polyethylene, ceramic, or metal [16]. Polyethylene is a plastic that is the most utilized lining surface in total hip arthroplasty [77]. The most concerning feature of polyethylene use is wear, resulting in particulate matter that causes phagocytosis of bone, osteolysis, and implant loosening [78, 79]. Biomedical engineers have constantly modified how polyethylene is manufactured in order to reduce wear and improve the longevity of the plastic. This includes sterilization in inert atmospheres such as ethylene oxide or gas plasma, re-melting versus annealing, and exposing the polyethylene to radiation [80]. Radiation has been shown to induce cross-linking at the molecular level, which improves the wear resistance of the plastic [81]. This has lead to improved wear resistance in-vivo with at least intermediate follow-up [82-84].

Metal is another consideration as an acetabular lining material. In simulator studies, metal has improved wear resistance over polyethylene [85, 86]. Metal is also less brittle compared to ceramic, reducing the risk of implant fracture [87]. However, studies have demonstrated that metal bearings can increase the generation of chromium and cobalt ions, which can leach into human serum and be excreted in urine [88, 89]. This may induce a T-cell mediated lymphocytic reaction referred to as an atypical lymphocytic vasculitis-associated lesion. These lesions may result in aseptic loosening and failure of metal-on-metal arthroplasties [90]. Pseudotumors are a localized granulomatous reaction to metal ions that can cause inflammation, pain, and the need for revision surgery for patients with metal-on-metal articulations [91]. Although there are concerns regarding increased carcinogenesis risk, nephrotoxicity, and neurotoxicity associated with elevated metal ion levels, these presumptions are poorly supported in the literature [79, 92, 93].

Ceramic was introduced as an acetabular liner in the 1970s [94]. The material has undergone several generational changes, resulting in a contemporary alumina composite material [95]. The advantages of ceramic materials are that they are extremely hard and scratch resistant, which amounts to reduced wears rates compared to other articulating bearings [96-98]. Ceramic also exhibits good biological inertness, reducing localized soft tissue reactivity [99]. The main disadvantages of ceramic materials are the risk of fracture due to increased brittleness, and squeaking due to edge loading in-situ. The risk of implant fracture has lessened significantly with the introduction of tougher alumina composites [94]. Edge loading and resultant squeaking are caused by poor component positioning, inability to restore leg-lengths and femoral offset, and implant impingement [100, 101]. Careful surgical technique can therefore ameliorate the risk of squeaking.

Once the acetabular liner has been chosen, the surgeon is left to choose a femoral head to articulate with the liner. Three main femoral head materials exist: metal, which is usually made from a cobalt chromium alloy, ceramic, and oxidized zirconium. Cobalt chrome is a long-standing femoral head bearing with the advantage of modularity, or availability of different implant specifications that allow the surgeon to better customize their reconstruction during THA [102]. Ceramic has demonstrated reduced wear rates when compared to cobalt chrome, both in simulation and clinical studies [103, 104]. However, the retained fragments of a fractured ceramic head can cause accelerated polyethylene wear, metallosis, and damage to the Morse taper located on the femoral stem (Figure 1.10) [105, 106]. Oxidized zirconium is a newer material composed of a metallic alloy center and an oxidized zirconium surface. It was designed to retain the exceptional wear rates seen with ceramic bearing surfaces, but reduce the risk of implant fracture [94]. Early clinical follow-up suggests reduced wear when compared to cobalt chromium [107]. This section clearly outlines the number of implant options available to the surgeon and the complexities of choosing the right combination of implants for each individual patient.

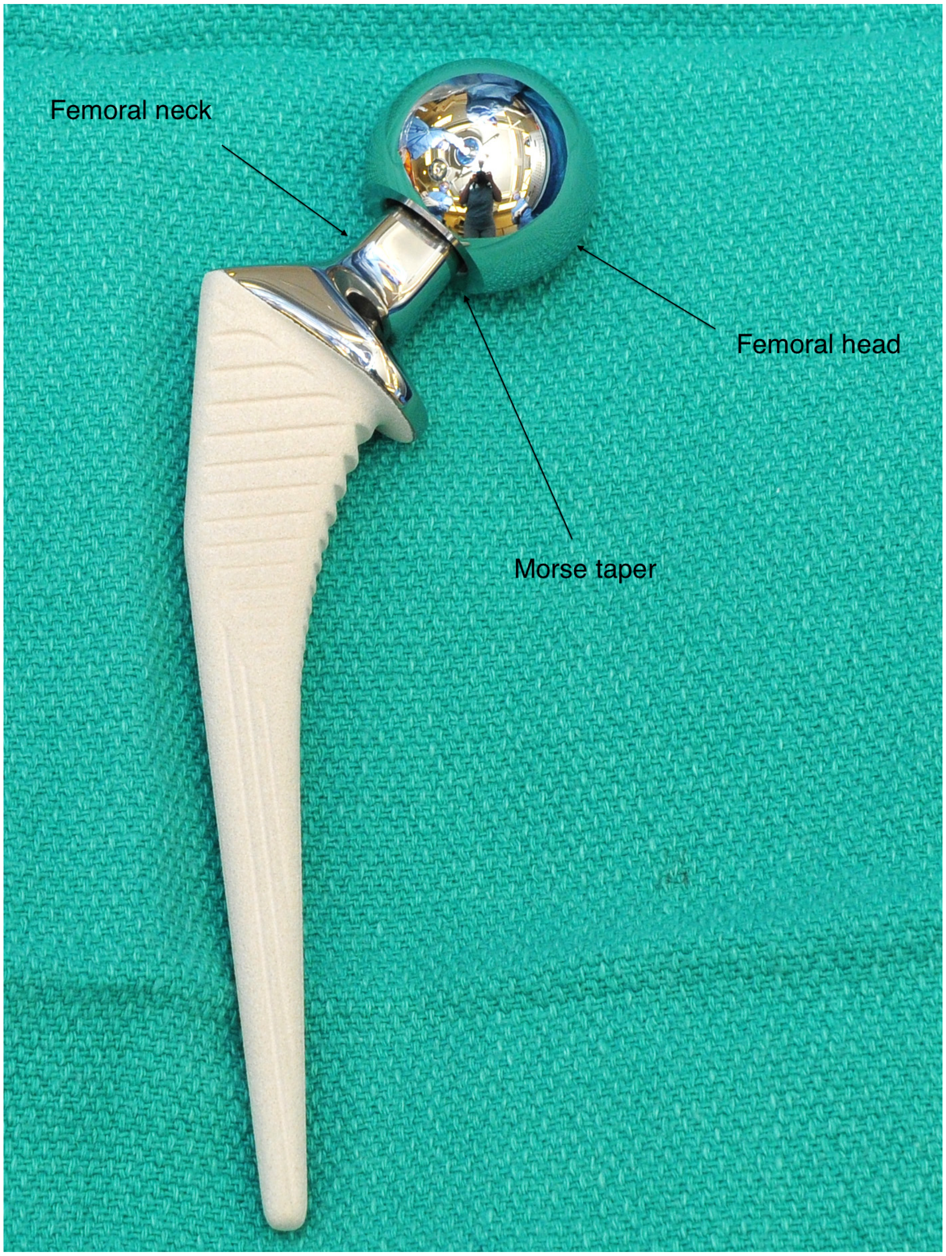

Figure 1.10 – Assembled femoral stem and head

The femoral head is engaged onto the femoral stem through a Morse taper. The femoral head is carefully seated on the femoral neck, followed by the surgeon impacting the head with a mallet to engage the taper (S Petis).

1.3 Surgical approaches for total hip arthroplasty

There are a variety of surgical approaches available to access the hip joint when performing a THA. Each approach demands a thorough understanding of human anatomy in order to optimize femoral and acetabular visualization, and minimize complications. This section will briefly outline the technical aspects of the anterior, lateral, and posterior approach, as well as a concise discussion of associated risks and benefits for each approach. A literature review will outline how the different approaches may impact patient outcomes and function following THA.

1.3.1 Anterior approach to the hip

The anterior approach to the hip was first described by Smith-Peterson in the 1940s and was later modified by Heuter in the 1950s [11]. In Canada, it is an approach utilized by less than 5 percent of orthopedic surgeons performing THA [108]. Advocates of this approach identify muscle-sparing intervals, earlier restoration of gait kinematics, and low dislocation rates as its main advantages [8, 109-112]. The anterior approach can be performed with and without the use of a specialized table [9, 10]. The use of a specialized table will be described in this section.

1.3.1.1 Anatomy and technical considerations

The procedure begins by positioning the patient supine on a specialized operating room table (Figure 1.11). Both feet are firmly secured to boots that are attached to lever arms that permit the application of traction to either limb. There is also a perineal post located between the legs that stabilizes the patient on the operating room table, and provides a point of counter-traction [9].

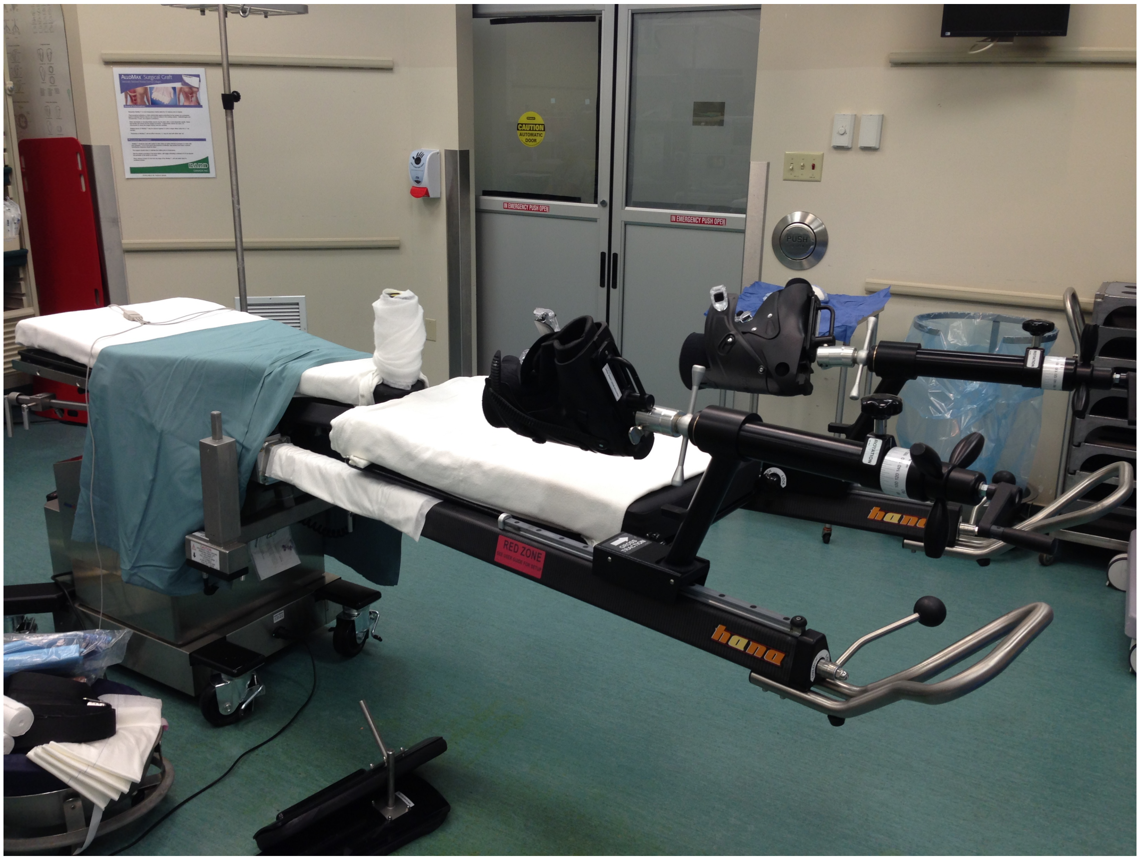

Figure 1.11 – Anterior approach traction table

An example of a traction table (Hana ™ fracture table, Mizuho OSI, Union City, CA) used for the anterior approach. Both legs are securely fastened in the boots provided, where traction, rotation, and angular motion can be applied to both limbs (S Petis).

The surgical incision begins just lateral to the anterior superior iliac spine of the pelvis. It is then carried distally for approximately 8 centimeters towards the patient's knee (Figure 1.12). The lateral femoral cutaneous nerve is identified, transposed medially, and protected. A plane is then developed between the tensor fascia latae and sartorius. The surgeon will then encounter the interval between rectus femoris and gluteus medius. The rectus femoris is retracted medially, and the gluteus medius is retracted laterally to expose the anterior joint capsule of the hip. The joint capsule is then incised along the length of the femoral neck from the acetabulum to the intertrochanteric line. Once traction is applied to the operative limb, external rotation can be used to dislocate the femoral head from the acetabulum [2, 9].

Once the femoral head is dislocated, a femoral neck osteotomy is performed at the desired level based on pre-operative planning. The femoral neck osteotomy can also be performed in-situ prior to dislocating the hip with careful soft tissue retraction. Intra-operative fluoroscopy is used during acetabular reaming to ensure adequate restoration of anteversion and inclination. Femoral preparation can be difficult due to limited proximal femoral exposure with this approach. The operative limb is generally placed in a position of extension, adduction, and external rotation in order to improve the accessibility of the proximal femur. Again, intra-operative fluoroscopy is used to help the surgeon determine accurate preparation of the femoral canal in order to restore version and offset (Figure 1.13). Once the final implants are in-situ and the hip is reduced, implant positioning is verified with fluoroscopy and the stability of the construct is assessed out of traction [2, 9, 10].

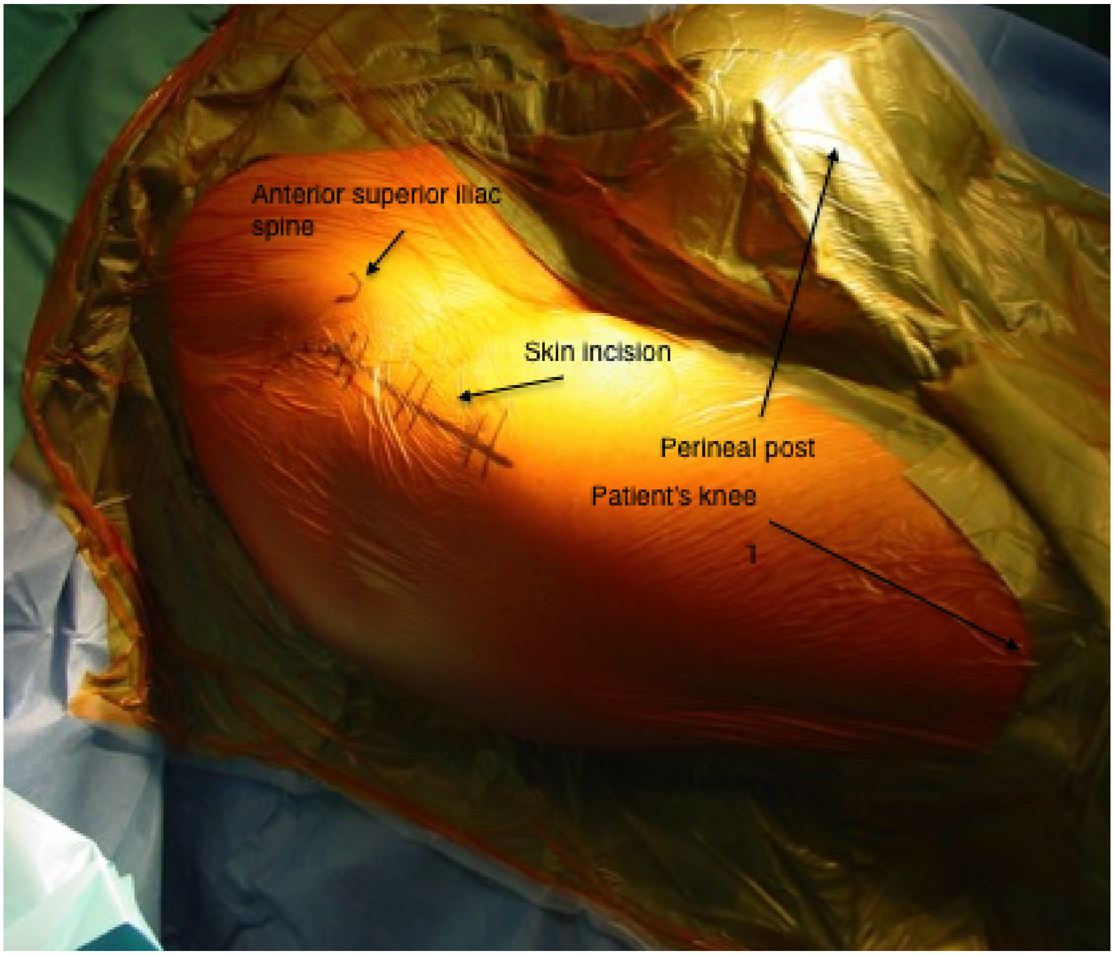

Figure 1.12 – Skin incision for the anterior approach

An intra-operative photograph of the skin incision used for the anterior approach. The incision starts at the anterior superior iliac spine and heads towards the lateral aspect of the patient's knee. A perineal post is used to secure both limbs to the traction table and provide a point of counter-traction (S Petis).

Figure 1.13 – Fluoroscopic C-arm

The fluoroscopic C-arm is a device used to attain x-rays during a surgical procedure. Many surgeons utilize intra-operative fluoroscopy during an anterior total hip arthroplasty in order to verify the position of the acetabular and femoral component (S Petis).

1.3.1.2 Risks of the anterior approach

There are risks associated with every surgical approach. Commonly cited risks of the anterior approach include proximal femur fractures, wound complications, lateral femoral cutaneous nerve palsies, and prolonged operative time due to the technically demanding nature of the procedure. Jewett and Collis reviewed 800 THAs performed through an anterior approach. They sited 19 intertrochanteric fractures (2.3%), 7 post-operative dislocations (0.88%), and 37 wound complications (4.6%). Most of the intertrochanteric fractures occurred during preparation of the femoral canal. Wound complications were attributed to the location of the incision, which is close to the groin area [113].

Another study by Woolson and colleagues retrospectively reviewed 247 THAs performed through an anterior approach in a community hospital. In 6.5% of cases there was an intra-operative proximal femur fracture. They also reported that 21% of cases had acetabular inclination angles greater than 50 degrees despite the use of intra-operative fluoroscopy [114]. This study, as well as results reported in a small series by Spaans et al., suggests longer operative time and increased blood loss associated with the anterior approach [114, 115]. However, these findings are likely related to surgeon experience, as Matta et al. reported much shorter operative time and less blood loss in 437 patients having an anterior approach [8].

Finally, neurpraxia of the lateral femoral cutaneous nerve can occur in up to 67% of patients having a THA through an anterior approach [116]. This is due to the nerve's variable course around the anterior superior iliac spine, and as it crosses the sartorial-tensor fascia latae plane more distally [2, 8]. Most of these neuropraxic injuries resolve without any long-term sequelae [8, 111].

1.3.2 Lateral approach to the hip

The lateral approach to the hip was described by Hardinge in the 1980s [15]. Approximately 60% of Canadian orthopedic surgeons perform THAs using a lateral approach [108]. This approach provides excellent exposure of both the proximal femur and acetabulum during reconstructive procedures [2]. A very low dislocation rate has also been reported in clinical follow-up [117, 118].

1.3.2.1 Anatomy and technical considerations

The procedure begins by positioning the patient in either the left of right lateral decubitus position for a right or left THA, respectively. The operative limb is draped freely to assist with dislocating the hip in order to expose the proximal femur and acetabulum. A longitudinal incision is made extending 3-5 centimeters proximal and approximately 5-8 centimeters distal to the tip of the greater trochanter (Figure 1.14). The fascia of the tensor fascia latae and gluteus maximus is then split in line with the skin incision. The surgeon will then encounter the tendon and muscle fibers of gluteus medius. These muscle fibers are split at the midway point between the most anterior and posterior extent of the muscle. The split is carried distally, leaving a cuff of gluteus medius tendon for repair following the procedure. The surgeon then incises the gluteus minimus and joint capsule overlying the neck of the femur. At this point, the surgeon is then able to dislocate the femoral head by externally rotating and flexing the hip. With the hip joint dislocated, the surgeon then performs a femoral neck osteotomy. This will provide the required exposure to complete both the femoral and acetabular reconstructions [2, 15].

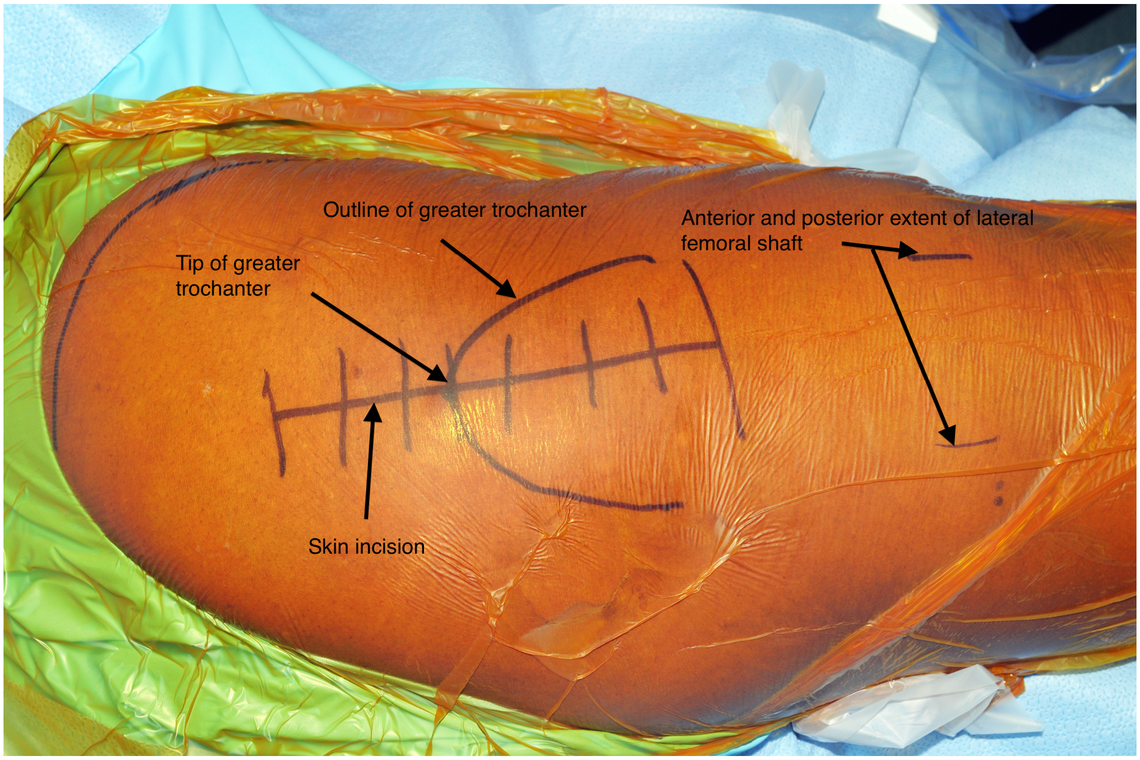

Figure 1.14 – Skin incision for the lateral approach

An intra-operative photograph of the skin incision used for the lateral approach. The patient is positioned in the left lateral decubitus position in preparation for a right total hip arthroplasty (S Petis).

1.3.2.2 Risks of the lateral approach

As with the anterior approach, the lateral approach has its own associated risks. These include abductor muscle insufficiency and a nerve palsy of the superior gluteal nerve or femoral nerve.

Abductor muscle insufficiency is a common clinical scenario following a lateral approach. It can cause abductor muscle weakness, a Trendelenburg gait or sign, inefficient gait mechanics, and peritrochanteric pain [14, 117, 119, 120]. The insufficiency likely results from an inadequate repair following a lateral approach, chronic degeneration of the gluteus medius tendon pre-operatively, or irreparable tears at the time of THA in up to 20% of patients undergoing THA [121, 122]. Masonis and Bourne reviewed over 2400 THAs having a lateral approach for THA and reported an incidence of 4-20% for abductor insufficiency post-operatively [117].

A superior gluteal or femoral nerve palsy is another potential complication following a lateral approach to the hip. The superior gluteal nerve passes between the gluteus medius and minimus muscles approximately 5 centimeters proximal to the greater trochanter [2]. Retrospective and prospective studies suggest an incidence of 2.2-42.5% for superior gluteal nerve injuries following reconstructive hip procedures using a lateral approach [123-125]. This nerve palsy can lead to abductor insufficiency and poorer functional outcomes following THA; fortunately, many cases improve spontaneously [125]. The femoral nerve is at risk with over-rigorous placement of soft tissue retractors over the anterior aspect of the acetabulum [2]. A study by Mulliken et al. did not identify any femoral nerve injuries in 770 consecutive lateral approaches to the hip [126]. The highest reported rate of femoral nerve palsy using a direct lateral approach was by Simmons and colleagues. They had 10 palsies in 440 hips with all cases having full functional recovery at 1 year post-operatively [127].

1.3.3 Posterior approach to the hip

The posterior approach to the hip was popularized by Moore in the 1950s [2]. A recent survey of surgeons from around the world suggests that the posterior approach is the most common surgical approach for THA internationally [128]. In Canada, approximately 36% of arthroplasty surgeons utilize the posterior approach [108]. It provides excellent visualization of both the acetabulum and femur during both primary and revision reconstructive procedures. The approach also spares the abductor muscles during surgical exposure of the acetabulum and femur [2].

1.3.3.1 Anatomy and technical considerations

Similar to the lateral approach, the patient is usually placed in the left or right lateral decubitus position. Again, the involved limb is draped freely to facilitate dislocating the hip, and to permit maneuverability of the limb to improve visualization throughout the case. The skin incision begins approximately 6 centimeters proximal and slightly posterior to the posterior aspect of the greater trochanter. The incision curves towards the greater trochanter and then extends down the femoral diaphysis for another 5 centimeters (Figure 1.15). The surgeon then incises the fascia overlying gluteus maximus and bluntly splits this bulk of muscle down to the short external rotators. The sciatic nerve is often draped over the short external rotators encased in adipose tissue. This structure must be carefully protected throughout this approach. The short external rotators and piriformis are then dissected off their insertion onto the greater trochanter. This will then expose the posterior joint capsule, which is incised to reveal the femoral neck and head. The surgeon is then able to dislocate the hip and begin the reconstruction [2].

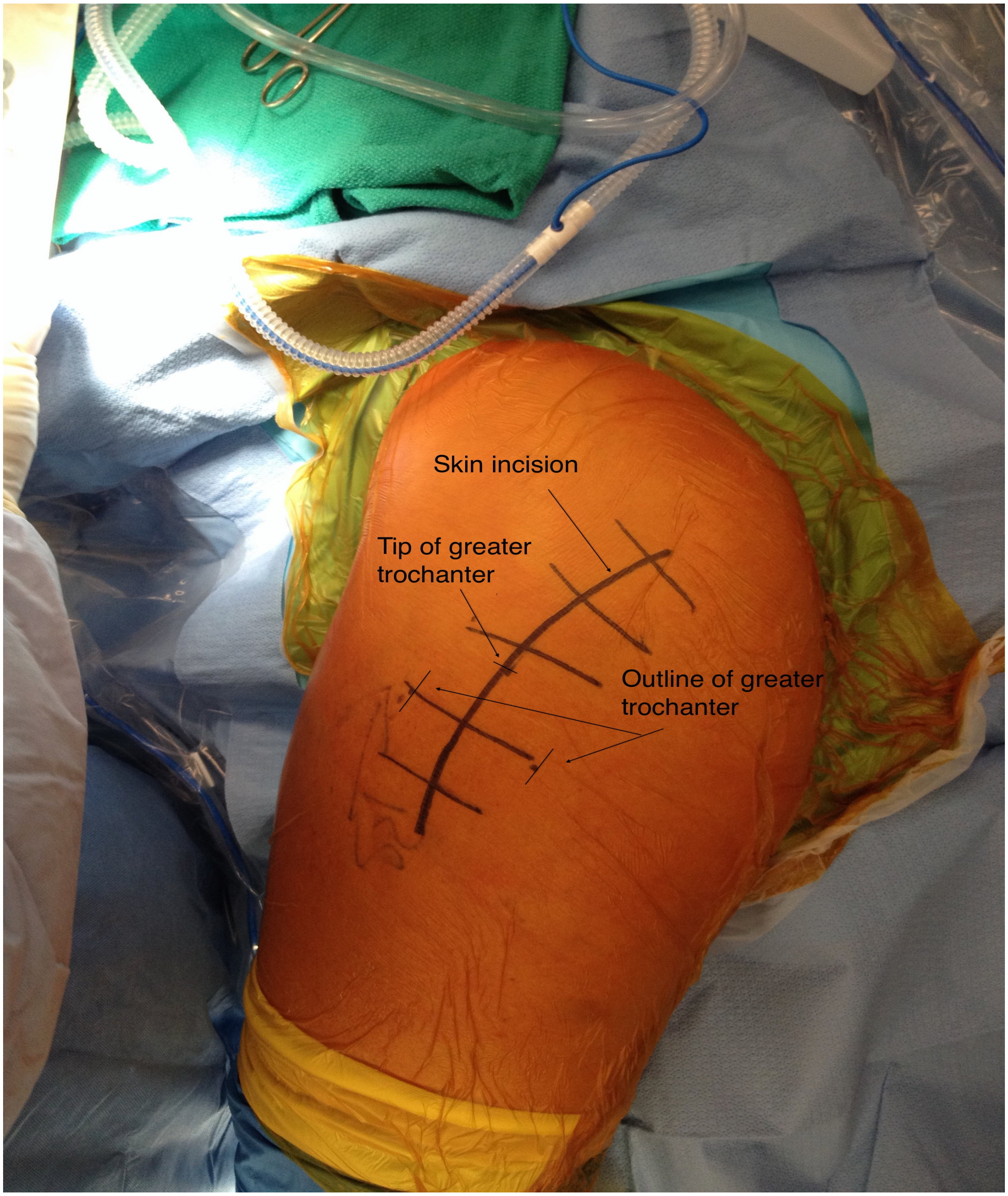

Figure 1.15 – Skin incision for the posterior approach

An intra-operative photograph of the skin incision used for the posterior approach to the hip. The patient is positioned in the lateral decubitus position. The incision curves posteriorly proximal to the greater trochanter. Alternatively, the incision can be made longitudinally with the hip flexed to 90 degrees (S Petis).

1.3.3.2 Risks of the posterior approach

A unique risk profile also exists for the posterior approach. Post-operative dislocations of the hip joint are a concern due to disruption of the posterior joint capsule [129]. By virtue of its proximity to the short external rotators, the sciatic nerve is vulnerable to injury during this approach [2]. These are the most commonly feared complications of the posterior approach.

The rate of hip dislocations following THA has been extensively studied. In the literature, reported dislocation rates vary anywhere between 1-5% [118, 130-133]. The reason for the increased incidence of dislocation is because when the hip is in a functional position of hip flexion and internal rotation, there is considerable tension on the posterior joint capsule of the hip. The femoral head then has a propensity to dislocate with inadequate repair of the posterior soft tissues [2, 118, 129]. Kwon et al. performed a meta-analysis to determine the rate of dislocations using a posterior approach with and without posterior soft tissue repair and found an 8 times greater relative risk of dislocation when soft tissue repair was not performed [118]. This finding is supported by a recent study by Ho and colleagues, who also determined that larger femoral head diameter also reduces the risk of hip dislocation in THA with a posterior approach [132]. This is because larger femoral heads have an increased jump distance, or the distance the component must travel before it dislocates over the rim of the acetabulum [27]. Using a larger femoral head diameter is a commonly cited preventative measure in patients at risk of dislocation following THA [134-136].

The sciatic nerve is a structure at risk of injury during the posterior approach. It can be damaged during soft tissue dissection, traction on the extremity, or during repair of soft tissues during closure [2, 137, 138]. A classic study by Schmalzried et al. reviewed over 3000 THAs and found an isolated sciatic nerve palsy incidence of 1.3% [139]. In most cases, sensory or motor deficits resolve spontaneously. However, preserving the integrity of the nerve in order to optimize patient outcomes following THA cannot be understated [138].

1.4 References

1. Schuenke M, Schulte E, Schumacher U. Atlas of anatomy: General anatomy and musculoskeletal system. New York, NY: Thieme New York; 2010.
2. Hoppenfeld S, DeBoer P, Buckley R. Surgical exposures in orthopaedics: The anatomic approach. Philidelphia, PA: Lippincott Williams and Wilkins; 2009.
3. Moore K, Dalley A. Clinically oriented anatomy, 4th Edition. 4th Edition ed. Philidelphia, PA: Lippincott Williams and Wilkins; 1999.
4. Yoshioka Y, Siu D, Cooke T. The anatomy and functional axes of the femur. J Bone Joint Surg Am. 1987;69:873-80.
5. Gray H. Anatomy of the human body. 20th Edition ed. Philidelphia, PA: Lea and Febiger; 2000.
6. Beverland D. The transverse acetabular ligament: Optimizing version. Orthopaedics. 2010;33:631.
7. Falliner A, Muhle C, Brossmann J. Acetabular inclination and anteversion in infants using 3D MR imaging. Acta Radiologica. 2002;43:221-4.
8. Matta J, Shahrdar C, Ferguson T. Single-incision anterior approach for total hip arthroplasty on an orthopaedic table. Clin Orthop Relat Res. 2005;441:115-24.
9. Horne P, Olson S. Direct anterior approach for total hip arthroplasty using the fracture table. Curr Rev Musculoskelet Med. 2011;4:139-45.
10. Lovell T. Single-incision direct anterior approach for total hip arthroplasty using a standard operating table. J Arthroplasty. 2008;23:64-8.
11. Light T, Keggi K. Anterior approach to hip arthroplasty. Clin Orthop Relat Res. 1980;152:255-60.
12. Gottschalk F, Kourosh S, Leveau B. The functional anatomy of tensor fasciae latae and gluteus medius and minimus. J Anat. 1989;166:179-89.

13. Robertson W, Gardner M, Barker J, Boraiah S, Lorich D, Kelly B. Anatomy and dimensions of the gluteus medius tendon insertion. Arthroscopy. 2008;24:130-6.
14. Lachiewicz P. Abductor tendon tears of the hip: Evaluation and management. J Am Acad Orthop Surg. 2011;19:385-91.
15. Hardinge K. The direct lateral approach to the hip. J Bone Joint Surg Br. 1982;64:17-9.
16. Brown T, Quanjun C, Mihalko W, Saleh K. Arthritis and Arthroplasty: The Hip, 1st Edition. 1st Edition ed. Philidelphia, PA: Saunders Elsevier; 2009.
17. Felson D, Lawrence R, Dieppe P, Hirsch R, Helmick C, Jordan J, et al. Osteoarthritis: New insights. Part 1: The disease and its risks factors. Ann Intern Med. 2000;133:635-46.
18. Summers M, Haley W, Reveille J, Alarcon G. Radiographic assessment and psychologic variables as predictors of pain and functional impairment in osteoarthritis of the knee or hip. Arthritis Rheum. 1988;31:204-9.
19. Mitchell N, Cruess R. Classification of degenerative arthritis. Can Med Assoc J. 1977;117:763-5.
20. Kuettner K, Goldberg V. Osteoarthritic disorders. Roemont, IL: American Academy of Orthopaedic Surgeons; 1995.
21. Beck M, Kalhor M, Leunig M, Ganz R. Hip morphology influences the pattern of damage to the acetabular cartilage: Femoroacetabular impingement as a cause of early osteoarthritis of the hip. J Bone Joint Surg Br. 2005;87:1012-8.
22. Leunig M, Casillas M, Hamlet M, Hersche O, Notzli H, Slongo T, et al. Slipped capital femoral epiphysis: Early mechanical damage to the acetabular cartilage by a prominent femoral metaphysis. Acta Orthop Scand. 2000;71:370-5.
23. Mont M, Hungerford D. Non-traumatic avascular necrosis of the femoral head. J Bone Joint Surg Am. 1995;77:459-74.

24. Yrjonen T. Long-term prognosis of Legg-Calve-Perthes disease: A meta-analysis. J Pediatr Orthop. 1999;8:169-72.
25. Ranawat C. Surgical management of the rheumatoid hip. Rheum Dis Clin North Am. 1998;24:129-41.
26. Manzotti A, Rovetta L, Pullen C, Catagni M. Treatment of the late sequelae of septic arthritis of the hip. Clin Orthop Relat Res. 2003;410:203-12.
27. Canale S, Beaty J. Campbell's Operative Orthopaedics, 12th Edition. Philidelphia, PA: Mosby, Inc.; 2012.
28. Khan A, McLoughlin E, Giannakas K, Hutchinson C, Andrew J. Hip osteoarthritis: Where is the pain? Ann R Coll Surg Engl. 2004;86:119-21.
29. Sinusas K. Osteoarthritis: Diagnosis and treatment. Am Fam Physician. 2012;85:49-56.
30. Maslowski E, Sullivan W, Harwood J, Gonzalez P, Kaufman M, Vidal A, et al. The diagnostic validity of hip provocation maneuvers to detect intra-articular hip pathology. PM R. 2010;2:174-81.
31. Woolf A, Pfleger B. Burden of major musculoskeletal conditions. Bull World Health Organ. 2003;81:646-56.
32. Pereira D, Peleteiro B, Araujo J, Branco J, Santos R, Ramos E. The effect of osteoarthritis definition on prevalence and incidence estimates: A systematic review. Osteoarthritis Cartilage. 2011;19:1270-85.
33. Nho S, Kymes S, Callaghan J, Felson D. The burden of hip osteoarthritis in the United States: Epidemiologic and economic considerations. J Am Acad Orthop Surg. 2013;21 Suppl:S1-6.
34. Fielden J, Cumming J, Horne J, Devane P, Slack A, Gallagher L. Waiting for hip arthroplasty: Economic costs and health outcomes. J Arthroplasty. 2005;20:990-7.
35. Rolfson O, Strom O, Karrholm J, Malchau H, Garellick G. Costs related to hip disease in patients eligible for total hip arthroplasty. J Arthroplasty. 2012;27:1261-6.

36. van Baar M, Dekker J, Oostendorp R, Bijl D, Voorn T, Bijlsma J. Effectiveness of exercise in patients with osteoarthritis of hip or knee: Nine months' follow-up. Ann Rheum Dis. 2001;60:1123-30.
37. Christensen R, Bartels E, Astrup A, Bliddal H. Effect of weight reduction in obese patients diagnosed with knee osteoarthritis: A systematic review and meta-analysis. Ann Rheum Dis. 2007;66:433-9.
38. Towheed T, Maxwell L, Judd M, Catton M, Hochberg M, Wells G. Acetaminophen for osteoarthritis. Cochrane Database Syst Rev. 2006.
39. Migliore A, Granata M, Tormenta S, Lagana B, Piscitelli P, Bizzi E. Hip viscosupplementation under ultra-sound guidance reduces NSAID consumption in symptomatic hip osteoarthritis patients in a long follow-up. Data from Italian registry. Eur Rev Med Pharmacol Sci. 2011;15:25-34.
40. van den Bekerom M, Lamme B, Sermon A, Mulier M. What is the evidence for viscosupplementation in the treatment of patients with hip osteoarthritis? Systematic review of the literature. Arch Orthop Trauma Surg. 2008;128:815-23.
41. Bozic K, Chan V, Valone III F, Feeley B, Vail T. Trends in hip arthroscopy utilization in the United States. J Arthroplasty. 2013;28:140-3.
42. Byrd J. Hip arthroscopy: Surgical indications. Arthroscopy. 2006;22:1260-2.
43. Ganz R, Klaue K, Vinh T, Mast J. A new periacetabular osteotomy for the treatment of hip dysplasias. Technique and preliminary results. Clin Orthop Relat Res. 1988;232:26-36.
44. Charnley J. Arthroplasty of the hip. A new operation. Lancet. 1961;1:1129-32.
45. Whiteside L, White S, McCarthy D. Effect of neck resection on torsional stability of cementless total hip replacement. Am J Orthop. 1995;24:766-70.

46. Karnezis I. A technique for accurate reproduction of the femoral anteversion during primary total hip arthroplasty. Arch Orthop Trauma Surg. 2001;121:343-5.
47. Johnston R, Brand R, Crowninshield R. Reconstruction of the hip: A mathematical approach to determine optimum geometric relationships. J Bone Joint Surg Am. 1979;61:639-52.
48. Askew M, Steege J, Lewis J, Ranieri J, Wixson R. Effect of cement pressure and bone strength on polymethylmethacrylate fixation. J Orthop Res. 1984;1:412-20.
49. Joshi R, Eftekhar N, McMahon D, Nercessian O. Osteolysis after Charnley primary low-friction arthroplasty: A comparison of two matched paired groups. J Bone Joint Surg Br. 1998;80:585-90.
50. Huiskes R, Verdonschot N, Nivbrant B. Migration, stem shape, and surface finish in cemented total hip arthroplasty. Clin Orthop Relat Res. 1998;355:103-12.
51. Jasty M, Bragdon C, Burke D, O'Connor D, Lowenstein J, Harris W. In-vivo skeletal responses to porous-surfaced implants subjected to small induced motions. J Bone Joint Surg Am. 1997;79:707-14.
52. Geesink R. Osteoconductive coatings for total joint arthroplasty. Clin Orthop Relat Res. 2002;395:53-65.
53. Engh C, Bobyn J, Glassman A. Porous-coated hip replacement: The factors governing bone ingrowth, stress shielding, and clinical results. J Bone JOint Surg Br. 1987;69:45-55.
54. Sherman R, Byrick R, Kay J, Sullivan T, Waddell J. The role of lavage in preventing hemodynamic and blood-gas changes during cemented arthroplasty. J Bone Joint Surg Am. 1983;65:500-6.
55. Barrack R, Castro F, Guinn S. Cost of implanting a cemented versus cementless femoral stem. J Arthroplasty. 1996;11:373-6.
56. Berry D, Harmsen W, Ilstrup D. The natural history of debonding of the femoral component from the cement and its effect on long-term survival

of Charnley total hip replacements. J Bone Joint Surg Am. 1998;80:715-21.

57. Older J. Charnley low-friction arthroplasty: A worldwide retrospective review at 15 to 20 years. J Arthroplasty. 2002;17:675-80.

58. Callaghan J, Templeton J, Liu S, Pedersen D, Goetz D, Sullivan P, et al. Results of Charnley total hip arthroplasty at a minimum of thirty years: A concise follow-up of a previous report. J Bone Joint Surg Am. 2004;86:690-5.

59. Williams H, Browne G, Gie G, Ling R, Timperley A, Wendover N. The Exeter universal cemented femoral component at 8 to 12 years: A study of the first 325 hips. J Bone Joint Surg Br. 2002;84:324-34.

60. Eskelinen A, Remes V, Helenius I, Pulkkinen P, Nevalainen J, Paavolainen P. Uncemented total hip arthroplasty for primary osteoarthritis in young patients: A mid- to long-term follow-up study from the Finnish Arthroplasty Register. Acta Orthop. 2006;77:57-70.

61. Kim Y. Titanium and cobalt-chrome cementless femoral stems of identical shape produce equal results. Clin Orthop Relat Res. 2004;2004:148-56.

62. Higa M, Tanino H, Abo M, Kakunai S, Banks S. Effect of acetabular component anteversion on dislocation mechanisms in total hip arthroplasty. J Biomech. 2011;44:1810-3.

63. Lewinnek G, Lewis J, Tarr R, Compere C, Zimmerman J. Dislocations after total hip-replacement arthroplasties. J Bone Joint Surg Am. 1978;60:217-20.

64. Della Valle V, Padgett D, Salvati E. Preoperative planning for primary total hip arthroplasty. J Am Acad Orthop Surg. 2005;13:455-62.

65. Inori F, Ohashi H, Yo H, Okajima Y, Matsui Y, Shintani K. Accuracy of cup height and medialization in THA for dysplastic hip osteoarthritis using an imageless navigation system. Orthopaedics. 2012;35:7-12.

66. Archbold H, Mockford B, Molloy D, McConway J, Ogonda L, Beverland D. The transverse acetabular ligament: An aid to orientaiton of the

acetabular component during primary total hip replacement: A preliminary study of 1000 cases investigating postoperative stability. J bone Joint Surg Br. 2006;88:883-6.

67. Maruyama M, Feinberg J, Capello W, D'Antonio J. The Frank Stinchfield Award: Morphologic features of the acetabulum and femur: Anteversion angle and implant positioning. Clin Orthop Relat Res. 2001;393:52-65.

68. Inc. SaN. R3 Acetabular System: Surgical Technique. Memphis, TN: Smith and Nephew, Inc.; 2010.

69. Inc. DO. Pinnacle Hip Solutions: Polyethylene Surgical Technique. Warsaw, IN: DePuy Orthopaedics, Inc.; 2013. 1-24 p.

70. Kummer F, Shah S, Iyer S, DiCesare P. The effect of acetabular cup orientations on limiting hip rotation. J Arthroplasty. 1999;14:509-13.

71. Paterno S, Lachiewicz P, Kelley S. The influence of patient-related factors and the position of the acetabular component on the rate of dislocation after total hip replacement. J Bone Joint Surg Am. 1997;79:1202-10.

72. Iorio R, Puskas B, Healy W, Tilzey J, Specht L, Thompson M. Cementless acetabular fixation with and without screws: Analysis of stability and migration. J Arthroplasty. 2010;25:309-13.

73. Hsu J, Lai K, Chen Q, Zobitz M, Huang H, An K, et al. The relation between micromotion and screw fixation in acetabular cup. Comput Methods Programs Biomed. 2006;84:34-41.

74. Chen C, Xenos J, McAuley J, Young A, Engh C. Second-generation porous-coated cementless total hip arthroplasties have high survival. Clin Orthop Relat Res. 2006;451:121-7.

75. Udomkiat P, Dorr L, Wan Z. Cementless hemispheric porous-coated sockets implanted with press-fit technique without screws: Average ten-year follow-up. J Bone Joint Surg Am. 2002;84:1195-200.

76. Valle A, Zoppi A, Peterson M, Salvati E. Clinical and radiographic results associated with a modern, cementless modular cup design in total hip arthroplasty. J Bone Joint Surg Am. 2004;86:1998-2004.

77. Bozic K, Kurtz S, Lau E, Ong K, Chiu V, Vail T, et al. The epidemiology of bearing surface usage in total hip arthroplasty in the United States. J Bone Joint Surg Am. 2009;91:1614-20.
78. Schmalzried T, Jasty M, Harris W. Periprosthetic bone loss in total hip arthroplasty: Polyethylene wear debris and the concept of the effective joint space. J Bone Joint Surg Am. 1992;74:849-63.
79. Learmonth I, Young C, Rorabeck C. The operation of the century: Total hip replacement. Lancet. 2007;370:1508-19.
80. Beaule P, Lamontagne M. Biomechanics and wear in joint arthroplasty. In: Lieberman J, editor. AAOS Comprehensive Orthopaedic Review. Rosemont, IL: American Academy of Orthopaedic Surgeons; 2009.
81. Ries M, Scott M, Jani S. Relationship between gravimetric wear and particle generation in hip simulators: Conventional compared with cross-linked polyethylene. J Bone Joint Surg Am. 2001;83:116-22.
82. McCalden R, MacDonald S, Rorabeck C, Bourne R, Chess D, Charron K. Wear rate of highly cross-linked polyethylene in total hip arthroplasty: A randomized controlled trial. J Bone Joint Surg Am. 2009;91:773-82.
83. Thomas G, Simpson D, Mehmood S, Taylor A, McLardy-Smith P, Gill H. The seven-year wear of highly cross-linked polyethylene in total hip arthroplasty: A double-blind, randomized controlled trial using radiostereometric analysis. J Bone Joint Surg Am. 2011;93:716-22.
84. Capello W, D'Antonio J, Ramakrishnan R, Naughton M. Continued improved wear with an annealed highly cross-linked polyethylene. Clin Orthop Relat Res. 2011;469:825-30.
85. Semlitsch M, Willert H. Clinical wear behaviour of ultra-high molecular weight polyethylene cups paired with metal and ceramic ball heads in comparison to metal-on-metal pairings of hip joint replacements. Proc Inst Mech Eng H. 1997;211:73-88.
86. Rieker C, Konrad R, Schon R. In-vitro comparison of the two hard-hard articulations for total hip replacements. Proc Inst Mech Eng H. 2001;215:153-60.

87. Fritsch E, Gleitz M. Ceramic femoral head fractures in total hip arthroplasty. Clin Orthop Relat Res. 1996;328:129-36.
88. Brodner W, Bitzan P, Meisinger V, Kaider A, Gottsauner-Wolf F, Kotz R. Elevated serum cobalt with metal-on-metal articulating surfaces. J Bone Joint Surg Br. 1997;79:316-21.
89. MacDonald S, McCalden R, Chess D, Bourne R, Rorabeck C, Cleland D, et al. Metal-on-metal versus polyethylene in hip arthroplasty: A randomized clinical trial. Clin Orthop Relat Res. 2003;406:282-96.
90. Delaunay C, Petit I, Learmonth I, Oger P, Vendittoli P. Metal-on-metal bearings total hip arthroplasty: The cobalt and chromium ions release concern. Orthop Traumatol Surg Res. 2010;96:894-904.
91. Glyn-Jones S, Pandit H, Kwon Y, Doll H, Gill H, Murray D. Risk factors for inflammatory pseudotumour formation following hip resurfacing. J Bone Joint Surg Br. 2009;91:1566-74.
92. Visuri T, Pukkala E, Pulkkinen P, Paavolainen P. Cancer incidence and causes of death among total hip replacement patients: A review based on Nordic cohorts with a special emphasis on metal-on-metal bearings. Proc Inst Mech Eng H. 2006;220:399-407.
93. Migaud H, Putman S, Combes A, Berton C, Bocquet D, Vasseur L, et al. Metal-on-metal bearing: Is this the end of the line? We do not think so. HSS J. 2012;8:262-69.
94. D'Antonio J, Sutton K. Ceramic materials as bearing surfaces for total hip arthroplasty. J Am Acad Orthop Surg. 2009;17:63-8.
95. Kuntz M. Validation of a new high-performance alumina matrix composite for use in total joint replacement. Semin Arthroplasty. 2006;17:141-5.
96. Clarke I. Role of ceramic implants: Design and clinical success with total hip prosthetic ceramic-to-ceramic bearings. Clin Orthop Relat Res. 1992;282:19-30.

97. Bohler M, Mochida Y, Bauer T, Salzer M, Plenk Jr H. Characterization of wear debris from alumina-on-alumina THA. J Bone Joint Surg Br. 2000;82:901-9.
98. Mochida Y, Bohler M, Salzer M, Bauer T. Debris from failed ceramic-on-ceramic and ceramic-on-polyethylene hip prostheses. Clin Orthop Relat Res. 2001;389:113-25.
99. Santavirta S, Bohler M, Harris W, Konttinen Y, Lappalainen R, Muratoglu O, et al. Alternative materials to improve total hip replacement tribology. Acta Orthop Scand. 2003;74:380-8.
100. Walter W, O'toole G, Walter W, Ellis A, Zicat B. Squeaking in ceramic-on-ceramic hips: The importance of acetabular component orientation. J Arthroplasty. 2007;22:496-503.
101. Walter W, Insley G, Walter W, Tuke M. Edge loading in third generation alumina ceramic-on-ceramic bearings: Stripe wear. J Arthroplasty. 2004;19:402-13.
102. Good V, Ries M, Barrack R, Widding K, Hunter G, Heuer D. Reduced wear with oxidized zirconium femoral heads. J Bone Joint Surg Am. 2003;85:105-10.
103. Clarke I, Gustafson A. Clinical and hip simulator comparisons of ceramic-on-polyethylene and metal-on-polyethylene wear. Clin Orthop Relat Res. 2000;379:34-40.
104. Zichner L, Willert H. Comparison of alumina-polyethylene and metal-polyethylene in clinical trials. Clin Orthop Relat Res. 1992;282:86-94.
105. Allain J, Roudot-Thoraval F, Delecrin J, Anract P, Migaud H, Goutallier D. Revision total hip arthroplasty performed after fracture of a ceramic femoral head: A multicenter survivorship study. J Bone Joint Surg Am. 2003;85:825-30.
106. Sharma V, Ranawat A, Rasquinha V, Weiskopf J, Howard H, Ranawat C. Revision total hip arthroplasty for ceramic head fracture: A long-term follow-up. J Arthroplasty. 2010;25:342-7.

107. Garvin K, Hartman C, Mangla J, Murdoch N, Martell J. Wear analysis in THA utilizing oxidized zirconium and crosslinked polyethylene. Clin Orthop Relat Res. 2009;467:141-5.
108. Burnett R. Total hip arthroplasty: Techniques and results. BCMJ. 2010;52:455-64.
109. Siguier T, Siguier M, Brumpt B. Mini-incision anterior approach does not increase dislocation rate: A study of 1037 total hip replacements. Clin Orthop Relat Res. 2004;426:164-73.
110. Kennon R, Keggi J, Wetmore R, Zatorski L, Huo M, Keggi K. Total hip arthroplasty through a minimally invasive anterior surgical approach. J Bone Joint Surg Am. 2003;85:39-48.
111. Nakata K, Nishikawa M, Yamamoto K, Hirota S, Yoshikawa H. A clinical comparative study of the direct anterior with mini-posterior approach: Two consecutive series. J Arthroplasty. 2009;24:698-704.
112. Mayr E, Nogler M, Benedetti M, Kessler O, Reinthaler A, Krismer M, et al. A prospective randomized assessment of earlier functional recovery in THA patients treated by minimally invasive direct anterior approach: A gait analysis study. Clin Biomech. 2009;24:812-8.
113. Jewett B, Collis D. High complication rate with anterior total hip arthroplasties on a fracture table. Clin Orthop Relat Res. 2011;469:503-7.
114. Woolson S, Pouliot M, Huddleston J. Primary total hip arthroplasty using an anterior approach and a fracture table: Short-term results from a community hospital. J Arthroplasty. 2009;24:999-1005.
115. Spaans A, van den Hout J, Bolder S. High complication rate in the early experience of minimally invasive total hip arthroplasty by the direct anterior approach. Acta Orthop. 2012;83:342-6.
116. Goulding K, Beaule P, Kim P, Fazekas A. Incidence of lateral femoral cutaneous nerve neuropraxia after anterior approach hip arthroplasty. Clin Orthop Relat Res. 2010;468:2397-404.

117. Masonis J, Bourne R. Surgical approach, abductor function, and total hip arthroplasty dislocation. Clin Orthop Relat Res. 2002;405:46-53.
118. Kwon M, Kuskowski M, Mulhall K, Macaulay W, Brown T, Saleh K. Does surgical approach affect total hip arthroplasty dislocation rates? Clin Orthop Relat Res. 2006;447:34-8.
119. Iorio R, Healy W, Warren P, Appleby D. Lateral trochanteric pain following primary total hip arthroplasty. J Arthroplasty. 2006;21:233-6.
120. Valente G, Taddei F, Jonkers I. Influence of weak hip abductor muscles on joint contact forces during normal walking: Probabilistic modeling analysis. J Biomech. 2013;46:2186-93.
121. Miozzari H, Dora C, Clark J, Notzli H. Late repair of abductor avulsion after the transgluteal approach for hip arthroplasty. J Arthroplasty. 2010;25:450-7.
122. Howell G, Biggs R, Bourne R. Prevalence of abductor mechanism tears of the hips in patients with osteoarthritis. J Arthroplasty. 2001;16:121-3.
123. Oldenburg M, Muller R. The frequency, prognosis and significance of nerve injuries in total hip arthroplasty. Int Orthop. 1997;21:1-3.
124. Ramesh M, O'Byrne J, McCarthy N, Jarvis A, Mahalingham K, Cashman W. Damage to the superior gluteal nerve after the Hardinge approach to the hip. J Bone Joint Surg Br. 1996;78:903-6.
125. Picado C, Garcia F, Marques W. Damage to the superior gluteal nerve after direct lateral approach to the hip. Clin Orthop Relat Res. 2007;455:209-11.
126. Mulliken B, Rorabeck C, Bourne R, Nayak N. A modified direct lateral appraoch in total hip arthroplasty: A comprehensive review. J Arthroplasty. 1998;13:737-47.
127. Simmons C, Izant T, Rothman R, Booth R, Balderston R. Femoral neuropathy following total hip arthroplasty: Anatomic study, case reports, and literature review. J Arthroplasty. 1991;6:57-66.

128. Chechik O, Khashan M, Lador R, Salai M, Amar E. Surgical approach and prosthesis fixation in hip arthroplasty world wide. Arch Orthop Trauma Surg. 2013;Epub.
129. Pellicci P, Potter H, Foo L, Boettner F. MRI shows biologic restoration of posterior soft tissue repairs after THA. Clin Orthop Relat Res. 2009;467:940-5.
130. Chiu F, Chen C, Chung T, Lo W, Chen T. The effect of posterior capsulorrhaphy in primary total hip arthroplasty: A prospective randomized study. J Arthroplasty. 2000;15:194-9.
131. Jolles B, Bogoch E. Posterior versus lateral surgical approach for total hip arthroplasty in adults with osteoarthritis. Cochrane Database Syst Rev. 2006;3.
132. Ho K, Whitwell G, Young S. Reducing the rate of early primary hip dislocation by combining a change in surgical technique and an increase in femoral head diameter to 36mm. Arch Orthop Trauma Surg. 2012;132:1031-6.
133. Sierra R, Raposo J, Trousdale R, Cabanela M. Dislocation of primary THA done through a posterolateral approach in the elderly. Clin Orthop Relat Res. 2005;441:262-7.
134. Saadat E, Diekmann G, Takemoto S, Ries M. Is an algorithmic approach to the treatment of recurrent dislocation after THA effective? Clin Orthop Relat Res. 2012;470:482-9.
135. Bistolfi A, Crova M, Rosso F, Titolo P, Ventura S, Massazza G. Dislocation rate after hip arthroplasty within the first postoperative year: 36mm versus 28mm femoral heads. Hip Int. 2011;21:559-64.
136. Howie D, Holubowycz O, Middleton R. Large femoral heads decrease the incidence of dislocation after total hip arthroplasty: A randomized controlled trial. J Bone Joint Surg Am. 2012;94:1095-102.
137. Lohana P, Woodnutt D, Boyce D. Sciatic nerve palsy - a complication of posterior approach using enhanced soft tissue repair for total hip arthroplasty. J Plast Reconstr Aesthet Surg. 2010;63:400-1.

138. DeHart M, Riley Jr. L. Nerve injuries in total hip arthroplasty. J Am Acad Orthop Surg. 1999;7:101-11.

139. Schmalzried T, Amstutz H, Dorey F. Nerve palsy associated with total hip replacement: Risk factors and prognosis. J Bone Joint Surg Am. 1991;73:1074-80.

Chapter 2

2 Literature Review

Chapter 1 introduced hip arthritis, the myriad of treatments available to treat the condition, and an overview of total hip arthroplasty (THA). It also discussed the three main surgical approaches used to perform a THA. The purpose of this literature review is to compare clinical performance in patients having a hip replacement through an anterior, posterior, or lateral approach. A discussion of economic analyses in the field of medicine and the economic impact of THA on health care systems will ensue. Finally, the impact of surgical approach on health economics and the paucity of literature in the setting of THA will be reviewed.

2.1 Comparing surgical approaches in total hip arthroplasty

There is a great debate in orthopedic surgery as to which surgical approach to the hip will produce the best clinical outcomes following a THA. Several studies have compared the different approaches using various methodologies. Currently, proponents of muscle-sparing approaches such as the anterior approach claim that using this approach will reduce post-operative pain, lower peri-operative blood loss, restore function sooner, and reduce length of stay in hospital [1]. This section will outline the literature to support or dispel these claims following a brief overview of the different outcome measures used to compare the approaches.

2.1.1 Clinical outcome questionnaires

There are a multitude of outcome questionnaires available to assess pain, mobility, level of functioning, and radiographic features associated with hip arthritis [2, 3]. These questionnaires are often scoring systems that allow physicians to objectively track patients' responses to surgical intervention such as THA [4]. The Harris Hip Score (HHS), Western Ontario and McMaster University Osteoarthritis Index (WOMAC), Short-Form 12 (SF-12), and EQ-5D questionnaires are common examples [5-8]. Ideally, these questionnaires assess disease-specific and overall aspects of the patient's health with proven validity, reliability, and responsiveness to clinical change (Figure 2.1) [3, 9, 10].

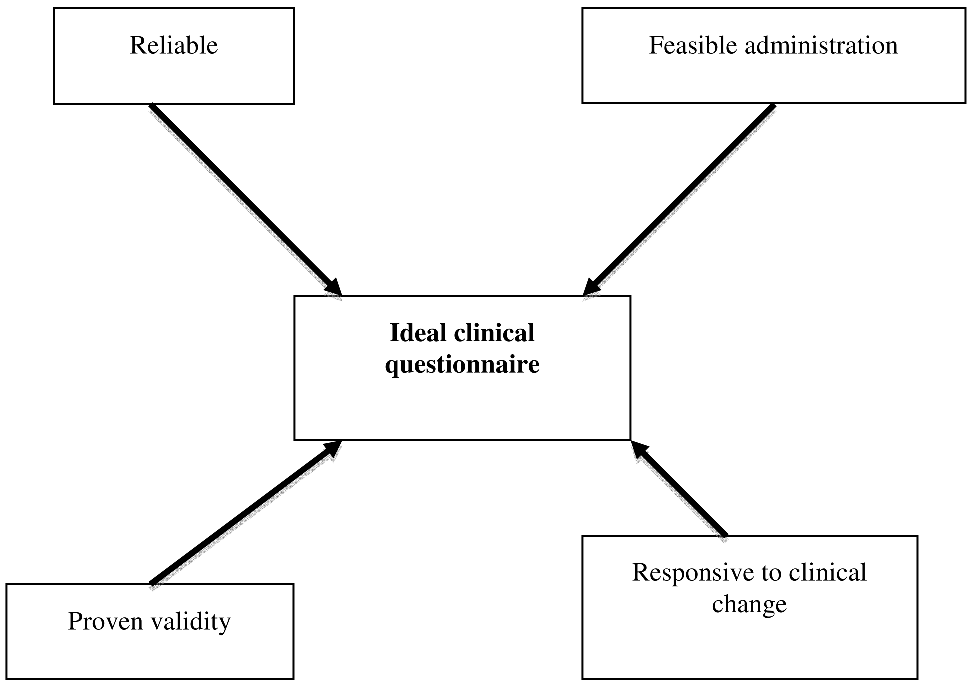

Figure 2.1 – Traits of an ideal clinical questionnaire

Reliability, validity, responsiveness, and the ability to administer a questionnaire in a timely manner with minimal costs are all considered when choosing a questionnaire for research purposes (S Petis).

2.1.1.1 Assessing clinical outcome questionnaires

There are several different characteristics used to describe outcome measures and assess their utility in determining patient outcomes. Questionnaires may be disease-specific, where the questionnaire explores specific complaints about a particular disease process, or generic, which are applicable to any intervention or disease and capture information about physical, social, emotional, and mental functioning. Disease processes such as hip arthritis can impact the elements assessed in generic scales, thus disease-specific and generic questionnaires are often employed together to determine a patient's response to an intervention [9, 11].

Validity is a crucial criterion of a useful outcome questionnaire. Valid questionnaires are those that measure what they intended to measure [9]. The COSMIN initiative (COnsensus-based Standards for the selection of health Measurement INstruments) concisely outlines the various domains within validity [10]. Content validity assesses the relevance of each item in a questionnaire and how well it addresses the constructs, or abstract variables of a questionnaire. Also important is criterion validity, which correlates the outcome score with a supposed "gold standard" assessment tool for a given condition [12]. An invalidated questionnaire will not be useful in determining patient's responses to an intervention in a specific patient population [3].

An applicable outcome questionnaire in clinical research should also be reliable. Reliability reflects a scale's ability to reproduce similar results when administered on more than one occasion [9]. There are several dimensions to reliability. Internal consistency refers to the redundancy of items in a questionnaire when assessing different constructs. Inter-rater reliability refers to achieving similar results on a questionnaire when administered by different people. Intra-rater reliability refers to getting similar results when either the same person is administering the test over and over, or is being completed by the same person on a different occasion. Test-retest reliability measures how stable outcomes are on a given questionnaire when tests are repeated after a short amount of time has elapsed [13]. Reliability is subject to measurement error, which can influence the true variability between patients completing an outcome questionnaire [14]. Using the standard error of measurement (SEM), the smallest detectable change (SDC) can be calculated. The SDC refers to a real change in the score not due to error in response to an intervention [15].

Another important consideration when choosing a questionnaire is how well it will detect important changes following some intervention, a term called responsiveness [11]. Generally, disease-specific scales are more responsive than generic scales [16-19]. This also relates to the minimal important difference (MID), which is the smallest difference in scores on an outcome questionnaire that the patient would perceive as important [20]. The MID can influence a clinician's decision to embrace or abandon a particular intervention [9]. Generally, the SDC should be less than the MID for this to be the case [15].

Finally, floor or ceiling effects are also considerations when choosing a questionnaire to measure health-related changes to an intervention. These phenomena occur if greater than 15% of respondents to a questionnaire attain the lowest (floor) or highest (ceiling) score. This suggests that the questionnaire may be missing items that assess the absolute best or worst possible clinical scenario or state of health [15]. All of the aforementioned qualities of a health-related outcome questionnaire should be considered when choosing which ones to include as part of a clinical research trial.

2.1.1.2 Harris hip score

The HHS was developed in the 1960s and was designed to assess pain and function in those individuals living with hip pathology, and to objectively ascertain their response to treatment [5]. It is a score out of 100, with pain (44 points) and function (47 points) receiving the highest contribution to the overall score. A high score represents a positive outcome. The functional scores assess daily activities, as well as the individual's gait. The remaining points are culminated by range of motion and the presence or absence of a fixed hip deformity. It was originally tested and validated in 39 patients undergoing hip arthroplasty for post-traumatic arthritis [21].

The HHS is an example of a disease-specific outcome measure. The questionnaire must be completed by a health professional as it includes objective assessments such as range of motion, deformity, and gait [3]. Since its inception in the 1960s, it is one of the most widely utilized outcome questionnaires in patients undergoing THA. Soderman and Malchau demonstrated that the HHS was a valid and reliable measure in a cohort of 344 patients who underwent THA [22]. Shi and colleagues showed that the HHS was more responsive to post-operative changes in pain and function following a THA than a generic questionnaire, particularly within the first year [23]. However, it should be noted that the HHS does not account for patient characteristics that may impact some of the scores (i.e. a patient with severe cardiorespiratory disease and their walking tolerance) [3]. As well, a systematic review suggests that the HHS may succumb to ceiling effects in younger patient populations undergoing THA such as those with a primary diagnosis of acetabular or femoral dysplasia [24].

2.1.1.3 Western Ontario and McMaster University Osteoarthritis Index

The WOMAC is another example of a disease-specific questionnaire. Developed in the 1980s, the questionnaire is completed by the patient and includes 24 questions to assess pain, stiffness, and physical function associated with hip arthritis [6]. Each question is assigned 0 to 4 points depending on the patient's response, and is then normalized to a score out of 100 [3]. Again, a higher score is a positive outcome. In the literature, it is a validated and reliable measure of assessing the response to intervention in patients with hip arthritis [6, 25-27]. A change score following an intervention of 9-12 points on the WOMAC is considered a MID [25].

2.1.1.4 Short-Form 12

The SF-12 questionnaire was derived from the Medical Outcomes Study 36-item Short-Form Health Survey (SF-36) [28]. The SF-36 is a validated and reliable generic health outcome questionnaire that assesses both physical and mental aspects of health through a Physical Component Summary (PCS) and Mental Component Summary (MCS) score, respectively [29]. The PCS and MCS are further broken down into 4 domains each. The goal of designing the SF-12 was to produce a self-administered health survey that was reliable, valid, could be published on a single page, and took less time to complete than the SF-36 [28].

The derivation of the SF-12 healthy survey occurred in the mid-1990s. Ware Jr. et al. chose 12 items from the SF-36 health survey to represent the PCS and MCS scores in the SF-12 survey. They found that the items selected were reliable predictors of the SF-36 scores in a United States population [28]. The survey has now been validated in several other countries around the world [30]. A change score of 3-5 points on the SF-12 is considered a MID [31]. It has become an important measure of health-related quality of life in joint replacement trials, as both the PCS and MCS scores are impacted substantially by hip arthritis [32, 33].

2.1.1.5 EQ-5D

The EQ-5D is another example of a generic health outcome questionnaire. Devised by the EuroQol Group in the 1980s, the EQ-5D consists of 5 questions and a visual analogue scale to assess health related quality of life. The 5 questions assess mobility, self-care, usual activities, pain, and anxiety/depression using three degrees of severity (no problems, some problems, severe problems). Each response is assigned a level from 1 to 3 for each question (level 1 = no problems, level 2 = some problems, level 3 = severe problems), creating a unique 5-digit health state. Therefore, there are 243 possible health states generated by using this questionnaire [8].

Once the 5-digit state has been determined, a summary index can be calculated. Each level is assigned a weighted value that has been determined from valuation studies in a given population [8]. This valuation is based on utility theory, where members of a population will have preferences regarding particular states of health. These preferences were weighted using a time-tradeoff method. During valuation of the ED-5D, community respondents were asked whether they would spend more time in a less desirable state of health followed by death, or less time in a more desirable state of health followed by death. The 5-digit state can then be used to calculate the summary index between -1 and 1, where 1 is perfect health, 0 is death, and any negative value is a state considered worse than death [13]. This index is useful in that it can be used to calculate Quality Adjusted Life Years (QALYs) in economic evaluations[3].

The EQ-5D has proven to be a valid and reliable measure in assessing quality of life adjustment following THA [34, 35]. A MID of 0.074 has been reported for the EQ-5D questionnaire [36]. A valuation study has been completed in Canada, providing useful information for determining summary indices in Canadian study populations [37].

2.1.2 The lateral versus posterior approach

The lateral and posterior approaches are fundamentally similar in that they are both muscle-splitting approaches to the hip [38]. However, as illustrated earlier, the surrounding anatomy and potential complications for each approach are much different. Therefore, it is worthwhile to review the literature to determine whether these differences influence patient outcomes.

A common discriminative endpoint used to determine the clinical effectiveness between the lateral and posterior approach is dislocation rate. Intuitively, patients are more satisfied with surgery and experience better quality of life if they do not experience a post-operative dislocation [39, 40]. After compiling studies that examined dislocation rate and surgical approach, a systematic review by Masonis and Bourne demonstrated a dislocation rate of 3.23% and 0.55% for the posterior and lateral approaches, respectively [41]. A review of over 78,000 THAs performed in Sweden suggested a slightly higher dislocation rate when hip replacements were performed through a posterior approach [42]. Conversely, a Cochrane Review in 2006 identified no difference in dislocation rate between the two approaches [43]. Another comprehensive review by Kwon et al. showed that with a careful soft tissue repair of the posterior joint capsule, the posterior approach has a similar dislocation rate to the lateral approach (0.49% vs. 0.43%) [44]. The literature suggests that with careful soft tissue closure and utilization of larger diameter femoral heads, the dislocation rate is similar between the two approaches [45-47].

Another common comparator between the posterior and lateral approach is the incidence of abductor insufficiency. Several studies have suggested the lateral approach has an increased incidence of abductor insufficiency following THA [41, 43, 48, 49]. However, there is tremendous heterogeneity in the methods used to diagnosis abductor insufficiency in many of these studies. Many studies use subjective findings to make the diagnosis, such as the presence of Trendelenburg gait or sign or lateral trochanteric pain, which may suffer from poor inter-rater reliability. Magnetic resonance imaging (MRI) is becoming a popular modality for assessing soft tissue pathology following THA [50-53]. Several studies have shown that metal suppression pulsed MRI sequences can identify abductor damage in patients with symptomatic abductor tears following THA [52-54]. Future prospective studies using MRI to assess soft tissue integrity post-operatively will provide a more objective measure of the incidence of abductor tears and clinical insufficiency.

The most important determinants of a successful THA are based on its indications: pain mitigation, improved quality of life, and restoration of function [1]. These measures are inferred by the use of the aforementioned questionnaires in clinical trials. An early study by Barber et al. prospectively followed 28 posterior and 21 lateral THAs for 2-years, each performed by a single surgeon. It should be noted the posterior joint capsule and short external rotators were not repaired in the THAs performed through the posterior approach. Both groups had similar improvements on the HHS at 2-year follow-up and had no observable differences in dislocations or the incidence of a Trendelenburg gait. The authors suggest that with meticulous surgical dissection, both the lateral and posterior approaches produce a THA with excellent patient outcomes and minimal sequelae at intermediate follow-up [55].

A more recent prospective study randomly assigned 60 patients to undergo a THA through either a posterior or lateral approach. Their primary end-point was the HHS at 12-week follow-up. They also captured data from the WOMAC and SF-36 questionnaires, as well as complications such as dislocations and peri-prosthetic fractures. Both approaches showed similar improvements across the HHS, WOMAC, and SF-36 questionnaires at multiple time points up to and including 12-weeks post-operatively. The rate of dislocation and fracture did not differ significantly between the groups [48].

There are surprisingly few clinical trials directly comparing clinical outcomes following THA using either of these two approaches [43]. The current study will compare these two approaches and add valuable patient reported outcome data to the literature.

2.1.3 The anterior versus lateral approach

The anterior approach is the preferred surgical approach of 10% of orthopedic surgeons performing THA [56]. Reduced blood loss, earlier functional recovery, low dislocation rates, and shorter stays in hospital have been attributed to the muscle-sparing properties of the anterior approach [57]. Current literature also suggests that minimizing muscle damage during surgery is a reason for patients to choose particular surgeons performing muscle-sparing techniques [58]. Thus, several recent studies have compared the anterior approach to both the lateral and posterior approaches.

From 2006 to 2009, Alecci et al. retrospectively reviewed peri- and intra-operative outcomes of THAs performed through either a lateral (n=198) or anterior (n=221) approach. Mean operative time was 8 minutes longer in the anterior group, which was a statistically significant difference between the groups. The lateral group observed increased peri-operative blood loss and increased number of blood transfusions compared to the anterior group. However, the pre-operative hemoglobin was lower in the lateral group, and they received significantly more fluid throughout each procedure, which may have contributed to hemo-dilution. Finally, length of stay in hospital was reduced significantly from 10 to 7 days when a THA was performed through an anterior approach [59].

A similar study by Restrepo et al. randomly assigned 100 patients to either the anterior or lateral approach before undergoing a THA. Interestingly, they found no significant differences in operative time, blood loss, need for blood transfusions, and length of stay in hospital between the two groups. The authors also examined patient outcome measures. The anterior group outperformed the lateral group for the HHS, SF-36, and WOMAC questionnaires at 6-weeks post-operatively. However, these significant differences in clinical outcomes abated when revisited at 2-years post-operatively [60]. This study suggests that the anterior approach may promote earlier patient satisfaction and restoration of function compared to a lateral approach cohort.

Earlier discharge from hospital using an anterior approach may be due to better pain mitigation following surgery. Goebel et al. retrospectively reviewed pain perception using a visual analogue scale (VAS), consumption of pain medication, and length of stay in hospital in 200 patients having either an anterior or lateral approach for THA. There was a significant reduction in perceived pain and consumption of pain medication in the anterior group during the first 24 hours post-operatively. The anterior group spent approximately 3 days less in hospital as well. Again, improved pain mitigation and earlier discharge were attributed to the muscle-sparing properties of the anterior approach [61]. However, the accuracy of this data is limited by the retrospective study design, as well as pain assessment using a VAS and multiple assessors.

There may be an anatomic aberrancy that can explain the discrepancy in perceived pain between the groups. Bremer et al. performed a MRI 1-year post-operatively in 50 patients having a THA through either an anterior or lateral approach. They noted significant increases in the number of abductor tears or detachments, greater trochanteric fluid collections, gluteus medius tendinosis, and fatty atrophy of the abductor muscles in the lateral group [62]. The abductor complex is a pain generator following the lateral approach and may explain differences in early pain perception between the groups [63]. However, a limitation of this study includes the absence of clinical outcome measures assessment. A pre-operative MRI was not performed, which could have identified patients with evidence of abductor pathology prior to THA, a common finding in patients with hip arthritis [64]. Future research should compare clinical outcomes and findings on advanced imaging modalities to explain discrepancies in pain and functional outcomes.

2.1.4 The anterior versus posterior approach

Several studies have also compared the anterior and posterior approaches using various outcomes. Length of stay in hospital, operative time, and clinical questionnaire scores such as the HHS are some examples of comparative outcomes. Recent literature has also examined the degree of muscle damage bestowed by each approach.

A prospective randomized trial by Barrett et al. compared 43 anterior and 44 posterior approaches to THA. The primary end-point was the ability to climb stairs and walk unlimited distances as assessed on the HHS at 6-weeks, 3-months, 6-months, and 12-months post-operatively. The authors also captured intra-operative data including total operative time, and post-operative data such as length of stay in hospital. Total operative time was 23.8 minutes longer in the anterior group ($p<0.05$). Length of stay in hospital was 2.28 days for the anterior group and 3.02 days for the posterior group ($p<0.05$). At the 6-week follow-up visit, significantly more patients were walking limitlessly, were able to climb stairs normally, and had a higher total HHS in the anterior group. These differences dissipated by the 3-month mark and remained insignificant up to and including 1-year post-operatively [65]. This study supports the claim that the anterior approach provides earlier restoration of function following THA.

Again, one of the purported benefits of the earlier functional return is earlier discharge from hospital. Martin et al. retrospectively reviewed 41 anterior and 47 posterior approaches for THA. Hospital length of stay was significantly shorter for the anterior group (2.9 versus 4.0 days). Mean operative time was significantly longer in the anterior approach cohort (141 versus 114 minutes). Both groups performed similarly on the SF-36 and WOMAC clinical outcome measures at 6-month follow-up. This study did suffer from selection bias, as the mean body mass index (BMI = kg/m^2) was significantly higher for the posterior approach group (34.1 versus 28.5 kg/m^2). The authors stated that many patients with obesity declined having an anterior approach when the surgeons conveyed that the procedure was more technically demanding in patients with a higher BMI. Anecdotally, patients with obesity do require more assistance with early mobilization, which may have explained the difference in length of stay between the groups [66].

There is considerable interest in the amount of muscle damage sustained during surgical approaches to the hip. An interesting study by Bergin et al. compared various blood markers indicative of muscle damage in patients undergoing a THA through either an anterior or posterior approach. This methodology has been used previously to justify the use of tissue-sparing techniques such as laparoscopy in other surgical subspecialties [67, 68]. The investigators measured pre- and post-operative values of various acute phase reactant proteins such as creatine kinase (CK), C-reactive protein, interleukin-6, tumor necrosis factor-alpha, and interleukin-1 in 57 patients undergoing THA. They found a significant rise in CK in the posterior approach group compared to the anterior approach group immediately following the procedure, as well as cumulatively after two days following THA. The other acute phase reactants did not change significantly between the groups [69]. However, the operative time in the posterior approach cohort was longer, with a mean of 118 minutes versus 78 minutes for the anterior group. A more prolonged period of immobilization on the operating room table could have contributed to accumulation of additional serum CK [70]. Serum CK clearance is also dependent on renal function, which was not accounted for in this study [71].

Another study examined the extent of gluteus medius/minimus, tensor fascia latae, rectus femoris, and short external rotator muscle damage in THAs performed on 12 cadaveric hips (6 anterior and 6 posterior approaches). Three different evaluators assessed the surface area of muscle damage from fixed bony landmarks. Minimal damage was sustained to the gluteus medius muscle through both approaches. The posterior approach caused more damage to the gluteus minimus muscle than the anterior approach (18% versus 8.5% of the mean surface area). The short external rotators were released in all posterior approach specimens and were damaged in 50% of the anterior approach specimens in order to improve visualization of the proximal femur. Using an anterior approach, 31% and 12% of the mean surface area of the tensor fascia latae and rectus femoris muscles, respectively, was damaged. No damage to either of these muscles was sustained using a posterior approach [72]. This study is limited by its use of cadaveric specimens, which would respond differently to physiologic loads during surgery in-vivo. As well, muscles are 3-dimensional structures, thus volume would have been a more accurate parameter of assessing muscle damage. This study challenges the claim that the anterior approach is truly a muscle-sparing approach. Future studies using gait analysis could elicit the clinical effects of this muscle damage.

This review has demonstrated that all three surgical approaches allow surgeons to perform a clinically effective THA procedure. The next step is to evaluate the cost of surgical interventions such as THA. It is important that surgical procedures be rigorously reviewed to determine whether the cost of treating each patient results in a justifiable accentuation of patient function and quality of life.

2.2 Health economics and total hip arthroplasty

Despite its technical and tribological intricacies, THA is often heralded as one of the most successful surgical interventions in medicine [4]. In 2005, approximately 21.4 million Americans were living with osteoarthritis. In 2030, that number is expected to rise to 41 million, largely attributable to improved management of chronic diseases and prolonged life [73]. Thus, the burden of hip arthritis may overwhelm the available resources within healthcare systems.

Therefore, it is important for physicians, patients, hospital administrators, and society at large to understand the costs of these procedures. Implants and surgical approaches used for THA are subject to new innovation, potentially resulting in increasing costs [74]. There are pressures to produce the best clinical outcome, while remaining cognizant of the costs associated with any intervention [13]. Total hip arthroplasty has been subjected to numerous cost analyses [75-80]. However, none of these analyses suggest whether surgical approach has a significant impact on health care costs. The purpose of this section is to provide a concise overview of cost-analysis and its use in THA.

2.2.1 Types of cost analyses in medicine

A variety of methods exist to evaluate the costs associated with medical interventions. These include cost-minimization/identification analysis, cost-consequence analysis, cost-benefit analysis, and cost-effectiveness analysis.

2.2.1.1 Cost-minimization analysis

Cost-minimization analysis is a type of cost-analysis. These analyses are useful when decisions are solely based on costs because the effectiveness between a new or experimental treatment is presumed to be equal to the comparator [13]. Therefore, cost-minimization analysis seeks to identify the cheapest means of attaining similar health outcomes across a treatment and its alternative [81].

2.2.1.2 Cost-consequence analysis

Cost-consequence analysis disseminates all costs and all outcomes associated with interventions and do not combine these parameters into a ratio [82]. Cost-consequence analysis expects a consumer to make value judgments on a list of costs and outcomes associated with an intervention and an alternative. Simply stated, the interpreter of the analysis creates their own list of pros and cons in order to choose the intervention that best suits their needs [13]. One advantage of this type of analysis is how the information can be presented to its users. The results of the study are often presented in a table format rather than ratios commonly cited in cost-analysis, which may increase the accessibility of the information [82].

2.2.1.3 Cost-benefit analysis

A cost-benefit analysis involves expressing both the costs and health outcomes associated with an intervention in dollars. The outcome measures are assigned a dollar value by using a willingness to pay value, which is usually inferred from surveys. This is one of the disadvantages of using a cost-benefit approach, as people often find it difficult to assign dollar values to intangibles such as health. If the health benefits valued in dollars less the cost of the intervention is positive, than that intervention is considered worthwhile. The cost information required to perform a cost-effectiveness analysis can also be used for cost-benefit analyses [13].

2.2.1.4 Cost-effectiveness analysis

At its roots, cost-effectiveness analysis relates the costs accrued during an intervention to health outcomes in the form an incremental cost-effectiveness ratio (ICER). This ratio can be generated and compared across various alternative forms of treatment to determine the lowest cost to achieve a desired health outcome. The ICER can also be used to compare interventions across different disease states to help payers determine which interventions are the least costly, yet achieve a desired health outcome (i.e. costs of statin therapy versus total hip arthroplasty in attaining QALYs) [13]. Incremental cost-effectiveness is different than marginal cost-effectiveness. Marginal cost-effectiveness disseminates the costs within a single intervention, such as the cost of adding or removing a day in hospital [83]. Several considerations need to be taken when designing any cost-analysis study.

2.2.1.5 Importance of perspective

When designing a study examining costs, it is imperative to understand how the target audience will use the information to facilitate decision-making regarding a particular intervention. The literature suggests that a societal perspective should be used when conducting a cost-analysis study in order to influence resource allocation [84]. This perspective ensures that any event that may affect a patient's health is included as either a cost or effect [84]. The societal perspective ensures that the cost-analysis captures many events that are apart of routine care, such as rehabilitation, educational programs, and other patient expenses. Other common perspectives include those of hospitals or clinics, insurance companies, and patients [13].

2.2.1.6 Setting boundaries

A term closely associated with perspective is the boundary imparted by the cost-analysis. Boundaries simply refer to the scope of patients and health outcomes that will be included, or excluded, in the analysis. In order for the analysis to exemplify society, a well-designed cost-analysis often has few exclusion criteria. Developing a cost-analysis with few exclusion criteria will capture various people living with the disease, living within the spectrum of that disease, and the individuals impacted by caring for an afflicted individual. The health outcome can be non-specific, such as life-years gained, or focus on constituents of health, such as physical pain, mental status, or functionality [13].

2.2.1.7 Determining the costs

There are a multitude of costs that should be compiled during a cost-analysis. Ideally, the data on cost is accumulated in a prospective study; however, many studies retrospectively retrieve data from databases. It is not uncommon for investigators to add a cost-analysis to an ongoing randomized-controlled trial (RCT), which is referred to as piggybacking. Although piggybacking may conduct a cost-analysis in a time efficient manner, the RCT protocol may impose additional costs to hospitals and patients that may not be representative of routine care. Additionally, these studies are often powered to demonstrate significance in clinical outcomes rather than cost-effectiveness. Finally, these piggyback studies may lack external validity as the patients selected for the study may not represent the general population, and they are being treated under restrictive circumstances. Thus, a more meaningful design includes cost-effectiveness as the primary outcome, thereby depicting routine clinical practice in costs and outcomes [13].

There are two methods of capturing costs included in a cost-analysis. One method is gross-costing, where estimates are used to derive a final cost. This is in contrast to micro-costing, which attempts to attach an exact cost to each resource consumed by each patient during an intervention. Immediacy of cost calculations is the major advantage of using a gross-costing method. Micro-costing is much more labour-intense, but if done well, would provide a gross-costing estimate for future studies. Although costs used for both methods can be acquired retrospectively, the analyst must consider the generalizability of the data used and whether it satisfies the chosen perspective [13].

2.2.1.7.1 Direct costs

Direct costs refer to the dollar amounts required to run an intervention or treatment algorithm in a cost-analysis [83]. These costs can be subdivided into direct medical/health care costs and direct nonmedical/non-health care costs. Direct medical/health care costs include expenditures such as inpatient hospitalization, medications, radiographs, laboratory investigations, or implants for a THA. Direct nonmedical/non-health care costs are other expenditures required for completion of an intervention, such as patient transportation, care on behalf of family members, gait aids, or home modifications. These direct costs are contained in the numerator of a cost-effectiveness ratio [13, 83].

When considering the societal perspective for a cost-analysis, it is sometimes difficult to account for direct costs such as time spent waiting for treatment or unpaid caretaking on behalf of family members (also known as home production). In general, most cost-analyses apply the average wage of a person of similar gender and age to those opportunity costs. In this way, the external validity of the costs contained in the numerator will be optimized [13].

2.2.1.7.2 Indirect/productivity costs

Indirect/productivity costs are other cost considerations for cost-analysis. The morbidity caused by an intervention may result in lost time to work, or the inability to partake in leisure activity. There is also lost productivity due to mortality associated with particular interventions or disease states [83]. The time lost to work or leisure activity during recovery from an intervention such as surgery would undoubtedly have financial implications for the patient, as well as impacting their health-related quality of life. In cost-analysis, these productivity costs are included in the denominator of a cost-effectiveness ratio and are reflected in health outcomes such as QALYs. Productivity costs can be monetized for the purposes of cost-benefit analysis when necessary [13].

2.2.1.8 Methods of assessing effectiveness

As mentioned earlier, cost-utility analysis is a type of cost-analysis. It is based on utility theory, which states that individuals place preference-weights on particular states of health [83]. Several questionnaires have been developed to capture a utility index, with values ranging from 1 (perfect health) to 0 (death), and any negative value representing states of health perceived to be worse than death [8, 13, 85-87]. As discussed in the section on the EQ-5D, this utility index allows the analyst to calculate QALYs [13].

Health-related quality of life determines each utility index. Several dimensions encompass health-related quality of life, such as physical function, psychological function, sensory impairment, social function, and pain. Again, questionnaires that allow derivation of a utility index are based on population studies where individuals have been asked to place preference weights on certain health states. The preference weights used in these questionnaires are typically derived from two methods: standard gamble or time-tradeoff (discussed earlier under EQ-5D) [13].

The standard gamble method literally asks respondents to gamble with various states of health. First, they are asked whether they would want to live indefinitely with an assigned state of health. If not, the individual can choose to gamble on achieving a full state of health or death. The probabilities of achieving the various health states are altered until the individual feels there is no difference between accepting the assigned state of health or gambling [88]. Many behavioural scientists contest that the general population may have difficulty gambling on states of health, thus limiting the utility of this approach [13].

Quality-adjusted life years are then calculated by multiplying the utility index by the length of time spent in that health state. The benefits of using QALYs are that they not only capture improvements in health-related quality of life while two cohorts are alive, but they also determine health-related quality of life from prolonged life if there is a mortality benefit from undergoing a particular intervention [13].

2.2.1.9 Time horizons

Cost-analysis involves time horizons. A time horizon refers to an interval of time required to observe potential health-related and economic implications of an intervention. In medicine, most investigators are interested in the lifelong effects of a treatment or procedure. Therefore, most prospective studies are not capable of capturing health and economic data with a time horizon equivalent to the length of a human life [13].

In order to accommodate for this, many studies use models to extrapolate cost and health effects of an intervention until a person's death. Many cost-analyses will report prospectively collected cost data using a short time horizon that includes the follow-up outlined in the study, and model a second set of data to include the longer time horizon [13].

2.2.2 Cost-analysis in total hip arthroplasty

Total hip arthroplasty has been subjected to cost-analysis, with the earliest studies dating back to the 1990s [75, 77]. Although THA is an effective treatment modality for debilitating hip arthritis, it is an expensive procedure performed more frequently each year [73, 89-92]. For example, the Canadian Institute for Health Information reported that the number of hip and knee replacements performed in Canada increased from 82,700 in 2007 to 93,450 in 2011. In the United States, some authors suggest that upwards of 500,000 THAs will be performed annually by 2030 [73]. These figures will undoubtedly place a tremendous burden on financial resources available for health-care administration. Therefore, it is important to understand the burden of hip osteoarthritis, and the cost associated with common procedures such as THA.

2.2.2.1 Economic burden of hip arthritis

Several studies have tried to capture the direct and indirect costs for patients living with arthritis. A Canadian study by Maetzel et al. determined that the costs incurred by patients living with osteoarthritis amounts to $5700 annually (1999 Canadian dollars). Sixty-nine percent of these costs are direct, such as hospitalization, drugs, and assistive devices, and 31% are indirect costs [93]. In Canada, the overall financial burden of osteoarthritis was estimated to be between 4.3 and 7.3 billion dollars (1994 Canadian dollars) [93]. A study in the United States by Leigh et al. quoted an annual cost of 89 billion dollars for all-comers with osteoarthritis (1994 US dollars) [94]. As life is prolonged through medical advancements, the number of individuals living with arthritis will rise and continue to incur tremendous health-care costs [73].

There are few studies capturing the costs incurred by patients living with hip arthritis. One study by Gupta et al. used questionnaires to acquire direct and indirect costs over 2 years in 1200 Canadians living with arthritis of their hip or knee. The WOMAC questionnaire was used to assign disease severity to each participant. Their perspective was that of the patient, thus they excluded several direct costs including hospital admissions, prescription drugs, and physiotherapy. They determined an average cost of $12,200 annually (2002 Canadian dollars), where approximately $10,000 of this total encompassed indirect costs (i.e. home-care programs, paid employment time lost, and costs of caregivers). Predictors of increasing costs were advanced age, more severe arthritis based on WOMAC performance, and lower socioeconomic status [95]. Unfortunately, these costs were not reported separately for hip and knee arthritis. The cost information was also dependent on patient recall, thereby limiting the accuracy of the aggregated cost [96].

Another study prospectively acquired direct medical costs of 70 Australians living with hip or knee arthritis. A customized cost questionnaire was distributed to study participants in 4 3-month intervals. The maximum annual direct medical costs incurred to patients in this study was $2,700 (1994 Australian dollars). Predictors of increased expenditures included female sex, age over 65, poorer performance on both the WOMAC and SF-36 questionnaires, and living with arthritis for a prolonged period of time [97]. Although this study captured many "out-of-pocket" costs that patients may encounter living with arthritis, it did not collect information on direct non-medical costs or indirect costs.

A more recent study by Rolfson et al. examined the costs of 2635 Swedish individuals with hip arthritis on the surgical waiting list for THA. A cost questionnaire was distributed to each patient, which outlined working status (i.e. working, retired, sick leave, or disability support pension), living situation, medications, community support, modifications made to living arrangements (i.e. wheelchair accessibility), transportation costs, and care from other individuals. The participants were asked to report information for the 12 months prior to receiving the questionnaire. Estimates were used to approximate costs of community home care and home modifications. Age and gender-specific mean incomes were used to estimate productivity losses for those taking time away from paid employment, as well as costs incurred to those providing informal care. The investigators also examined time spent waiting for both orthopedic consultation and the day of surgery [98].

The results of the study suggest an average annual cost of $7,666 for patients living with hip arthritis (2009 US dollars). Sixty-seven percent of the study population was retired at the time the questionnaire was distributed. Of those individuals not working, approximately 60% were on some form of sick leave or disability. Five percent of the cohort reported some form of home care, while 43% of respondents had some form of home modification because of hip arthritis. Almost one-quarter of the study population required informal assistance from another caregiver. The mean wait time for orthopedic consultation was 176 days, while the mean time to surgery following consultation was 144 days. The majority of the reported costs (61%) were due to productivity losses (indirect costs) [98]. This study provides useful information on many of the indirect costs incurred by patients living with hip arthritis in a publically funded health care system similar to Canada. Although the denominator of a cost-effectiveness ratio reflects productivity losses, this study illustrates the financial burden of hip arthritis for both patients and society [13].

2.2.2.2 Cost of total hip arthroplasty

Few studies have provided accurate estimations of the cost of THA. A multi-center study performed in Canada and the United States determined the mean direct costs of a THA to be $6,766 and $13,339, respectively (2001 US dollars). Interestingly, this difference was evident despite a significant difference in the mean length of stay between the two countries: 4.2 days for the United States centers and 7.2 days for the Canadian centers. There was also a marked difference in the cost of implants between the two nations, with medians costs of $8,017 and $1,695 for the United States and Canada, respectively (2001 US dollars). The cost of the implants, along with differences in overhead costs (administration, house-keeping, etc.), explained the cost disparity between the two countries [91]. This study provides useful information from a payer's perspective on how different health care budgeting frameworks can impact overall costs. However, it does not account for several other direct medical and non-medical costs associated with THA in the post-operative period.

Another study examined costs associated with undergoing either a hip or knee replacement in Canada. Hospital costs associated with the index procedure and post-operative direct medical and non-medical costs were aggregated up to 6-months following THA. The analysts determined a cost of $14,761 over the 6-month period (2007 Canadian dollars). Costs were not disseminated for hip and knee replacements separately. Also, it was unclear how they determined relevant outpatient rehabilitative costs [99].

2.2.2.3 Is total hip arthroplasty cost-effective?

It is clear from the discussion that THA is an expensive procedure to both the patient and the purveyor of health care resources. In Canada, with the number of THA procedures approaching 50,000 per year, millions of dollars will be spent to treat debilitating hip arthritis [90]. However, the pain mitigation and restoration of function attained following this procedure is almost incomparable [1, 4]. Although cost-analyses are sparse in the realm of THA, those that have been reported suggest it may be the most cost-effective procedure in all of medicine [1, 77].

The study composed by Chang and colleagues is considered the benchmark in cost-analysis and THA. Their goal was to determine the cost-effectiveness of THA versus no treatment for osteoarthritis of the hip. The analysts used a model to determine long-term costs and functional outcomes in these two cohorts. A stochastic tree was used to model transition rates between health states, such as undergoing a THA and then dying peri-operatively, and the risk of other related health events, such as peri-prosthetic infection, aseptic loosening, peri-prosthetic fracture, or death from unrelated causes. This analytic technique was also used to model non-operative management, which includes either further functional deterioration or death from unrelated causes. Probabilities of peri-operative and natural mortality and revision rates were acquired from published literature. A societal perspective was taken to allow for comparison against other medical interventions [77].

In order to measure effectiveness, they used the American College of Rheumatology (ACR) functional status classification. This classification ranges from I to IV, where class I would be the ability to complete all usual activities, and class IV is essentially being bed-ridden because of hip pain [100]. Class III on the ACR classification was the prerequisite for needing a THA in their model (the ability of the patient to perform little to none of their usual activities). The authors used expert consensus to determine which ACR class corresponded with Harris Hip and Mayo Hip scores in the literature. This allowed the authors to assign primary and revision THA procedures to a particular ACR class in their model. A standard gamble assessment was used to assign each ACR class a utility value to allow for the determination of QALYs [77].

Costs were tabulated for both THA and those patients treated conservatively without surgery. Most of the costs used in the analysis were direct medical costs, including hospital admissions, time spent in the operating room, costs of the implants, physiotherapy, physician billings, and investigations. The cost data was largely derived from a hospital accounting system and averages from reported health care institutions such as nursing homes [77].

With regards to their final analysis, the authors examined cost-effectiveness in men and women in 4 age categories: 60 years, 70 years, 80 years, and older than 85 year. At the extremes, THA was projected to be a cost-saving intervention in women aged 60 or younger. In men older than 85, the cost-effectiveness ratio was $6100/QALY (1991 US dollars). Their model suggested that THA was still cost-effective even when revision rates were increased and peri-operative mortality increased [77]. At that time, the only other comparable surgical intervention included coronary artery bypass graft for left main coronary artery disease, which had a reported cost-effectiveness ratio of $8100/QALY (1991 US dollars) [101].

Cost-analyses are undoubtedly important tools in implementing innovative medical technologies given finite resources. Since 1996, cost-analysis has been used in the realm of THA to assess new bearing surfaces, fixation methods, and prosthetic implants [78-80]. More recent cost-analysis studies have examined the cost-effectiveness of resurfacing hip arthroplasty versus conventional THA, and types of THA fixation [102, 103].

Surgical approach in THA is an area that warrants further investigation with regards to associated costs. This literature review outlines the differences in operating room time, length of stay in hospital, and time to functional recovery between the approaches. Each of these variables may have a significant impact on costs in THA, which is one of the rationales behind this thesis.

2.3 Rationale for thesis

This literature review has outlined some of the comparative studies examining surgical approach in total hip arthoplasty. There is still a paucity of robust prospective studies comparing the three most common surgical approaches used in THA. Many of the comparative studies failed to use validated outcome measures to determine effectiveness. As well, the lack of inclusion of generic clinical questionnaires such as the SF-12 prohibits any discussion on the psychological effect of surgical approach in THA. The first study of this thesis will include a prospective comparison between the three surgical approaches using various validated outcome questionnaires.

This chapter also reviewed the role cost-analysis has played in the arthroplasty literature. Surgical approach in THA has never been subjected to a cost-analysis. The second study will examine the impact of surgical approach on costs following THA. This will include a comparison of various metrics such as operating room time, length of stay in hospital, and complication rates, metrics which surgeons find valuable when choosing a surgical approach for THA.

2.4 Thesis objectives

This thesis has two primary objectives:

1. To compare various clinical outcomes across three different surgical approaches used for THA.
2. To determine the impact of surgical approach on costs following THA.

2.5 Thesis hypotheses

The hypotheses based on these objectives are:

1. There will be no difference on any of the validated outcome measures across surgical approaches at early follow-up.
2. Surgical approach will have no significant impact on the costs associated with THA.

2.6 References

1. Learmonth I, Young C, Rorabeck C. The operation of the century: Total hip replacement. Lancet. 2007;370:1508-19.
2. Canale S, Beaty J. Campbell's Operative Orthopaedics, 12th Edition. Philidelphia, PA: Mosby, Inc.; 2012.
3. Ahmad M, Xypnitos F, Giannoudis P. Measuring hip outcomes: Common scales and checklists. Injury. 2011;42:259-64.
4. Pivec R, Johnson A, Mears S, Mont M. Hip Arthroplasty. Lancet. 2012;380:1768-77.
5. Harris W. Traumatic arthritis of the hip after dislocation and acetabular fractures: Treatment by mold arthroplasty: An end-result study using a new method of result evaluation. J Bone Joint Surg Am. 1969;51:737-55.
6. Bellamy N, Buchanan W, Goldsmith C, Campbell J, Stitt L. Validation study of WOMAC: A health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. J Rheumatol. 1988;15:1833-40.
7. Jenkinson C, Layte R. Development and testing of the UK SF-12 (short form health survey). J Health Serv Res Policy. 1997;2:14-8.
8. EuroQol group. A new facility for the measurement of health-related quality of life. Health Policy. 1990;16:199-208.
9. Bryant D, Fernandes N. Measuring patient outcomes: A primer. Injury. 2011;42:232-5.
10. Mokkink L, Terwee C, Patrick D, Alonso J, Stratford P, Knol D, et al. The COSMIN checklist for assessing the methodological quality of studies on measurement properties of health status measurement instruments: An international Delphi study. Qual Life Res. 2010;19:539-49.
11. Wright J, Young N. A comparison of different indices of responsiveness. J Clin Epidemiol. 1997;50:239-46.

12. Martin D, Engelberg R, Agel J, Swiontkowski M. Comparison of the Musculoskeletal Function Assessment questionnaire with the Short-Form 36, the Western Ontario and McMaster Universities Osteoarthritis Index, and the Sickness Impact Profile Health-Status measures. J Bone Joint Surg Am. 1997;79:1323-35.
13. Gold M, Siegel J, Russell L, Weinstein M. Cost-effectiveness in Health and Medicine. New York, NY: Oxford University Press; 1996.
14. Scholtes V, Terwee C, Poolman R. What makes a measurement instrument valid and reliable. Injury. 2011;42:236-40.
15. Terwee C, Bot S, de Boer M, van der Windt D, Knol D, Dekker J, et al. Quality criteria were proposed for measurement properties of health status questionnaires. J Clin Epidemiol. 2007;60:34-42.
16. Stucki G, Liang M, Fossel A, Katz J. Relative responsiveness of condition-specific and generic health status measures in degenerative lumbar spinal stenosis. J Clin Epidemiol. 1995;48:1369-78.
17. Kantz M, Harris W, Levitsky K, Ware Jr J, Davies A. Methods for assessing condition-specific and generic functional status outcomes after total knee replacement. Med Care. 1992;30:240-52.
18. Jones C, Phoar S. Health-related quality of life after total joint arthroplasty: A scoping review. Clin Geriatr Med. 2012;28:395-429.
19. Collins N, Roos E. Patient-reported outcomes for total hip and knee arthroplasty: Commonly used instruments and attributes of a "good" measure. Clin Geriatr Med. 2012;28:367-94.
20. Schunemann H, Guyatt G. Commentary - Goodbye M(C)ID! Hello MID, where did you come from? Health Serv Res. 2005;40:593-7.
21. Larson C. Rating scale for hip disabilities. Clin Orthop Relat Res. 1963;31:85-93.
22. Soderman P, Malchau H. Is the Harris Hip Score system useful to study the outcome of total hip replacement? Clin Orthop Relat Res. 2001;384:189-97.

23. Shi H, Mau L, Chang J, Wang J, Chiu H. Responsiveness of the Harris Hip Score and the SF-36: Five years after total hip arthroplasty. Qual Life Res. 2009;18:1053-60.
24. Wamper K, Sierevelt I, Poolman R, Bhandari M, Haverkamp D. The Harris Hip Score: Do ceiling effects limit its usefulness in orthopaedics? A systematic review. Acta Orthop. 2010;81:703-7.
25. Ehrich E, Davies G, Watson D, Bolognese J, Seidenberg B, Bellamy N. Minimal perceptible clinical improvement with the Western Ontario and McMaster Universities osteoarthritis index quesionnaire and global assessments in patients with osteoarthritis. J Rheumatol. 2000;27:2635-41.
26. Davies G, Watson D, Bellamy N. Comparison of the responsiveness and relative effect size of the Western Ontario and McMaster Universities Osteoarthritis Index and the Short-Form Medical Outcomes Study survey in a randomized, clinical trial of osteoarthritis patients. Arthritis Care Res. 1999;12:172-9.
27. Sun Y, Sturmer T, Gunther K, Brenner H. Reliability and validity of clinical outcome measurements of osteoarthritis of the hip and knee - A review of the literature. Clin Rheumatol. 1997;16:185-98.
28. Ware Jr J, Kosinski M, Keller S. A 12-Item Short-Form Health Survey: Construction of scales and preliminary tests of reliability and validity. Med Care. 1996;34:220-33.
29. Ware Jr J, Kosinski M, Bayliss M, McHorney C, Rogers W, Raczek A. Comparison of methods for the scoring and statistical analysis of SF-36 health profile and summary measures: Summary of results from the Medical Outcomes Study. Med Care. 1995;33:264-79.
30. Gandek B, Ware Jr J, Aaronson N, Apolone G, Bjorner J, Brazier J, et al. Cross-validation of item selection and scoring for the SF-12 Health Survey in nine countries: Results from the IQOLA Project. J Clin Epidemiol. 1998;51:1171-8.

31. Drummond M. Introducing economic and quality of life measurements into clinical studies. Ann Med. 2001;33:344-9.
32. van der Waal J, Terwee C, van der Windt D, Bouter L, Dekker J. The impact of non-traumatic hip and knee disorders on health-related quality of life as measured with the SF-36 or SF-12. A systematic review. Qual Life Res. 2005;14:1141-55.
33. Bachmeier C, March L, Cross M, Lapsley H, Tribe K, Courtenay B, et al. A comparison of outcomes in osteoarthritis patients undergoing total hip and knee replacement surgery. Osteoarthritis Cartilage. 2001;9:137-46.
34. Ostendorf M, van Stel H, Buskens E, Schrijvers A, Marting L, Verbout A, et al. Patient-reported outcome in total hip replacement: A comparison of five instruments of health status. J Bone Joint Surg Br. 2004;86:801-8.
35. Dawson J, Firzpatrick R, Frost S, Gundle R, McLardy-Smith P, Murray D. Evidence for the validity of a patient-based instrument for assessment of outcome after revision hip replacement. J Bone Joint Surg Br. 2001;83:1125-9.
36. Walters S, Brazier J. Comparison of the minimally important difference for two health state utility measures: EQ-5D and SF-6D. Qual Life Res. 2005;14:1523-32.
37. Bansback N, Tsuchiya A, Brazier J, Anis A. Canadian valuation of EQ-5D health states: Preliminary value set and considerations for future valuation studies. PLoS One. 2012;7:e31115.
38. Hoppenfeld S, DeBoer P, Buckley R. Surgical exposures in orthopaedics: The anatomic approach. Philidelphia, PA: Lippincott Williams and Wilkins; 2009.
39. Forsythe M, Whitehouse S, Dick J, Crawford R. Functional outcomes after nonrecurrent dislocation of primary total hip arthroplasty. J Arthroplasty. 2007;22:227-30.
40. Enocson A, Pettersson H, Ponzer S, Tornkvist H, Dalen N, Tidermark J. Quality of life after dislocation of hip arthroplasty: A prospective cohort

study on 319 patients with femoral neck fractures with a one-year follow-up. Qual Life Res. 2009;18:1177-84.
41. Masonis J, Bourne R. Surgical approach, abductor function, and total hip arthroplasty dislocation. Clin Orthop Relat Res. 2002;405:46-53.
42. Hailer N, Weiss R, Stark A, Karrholm J. The risk of revision due to dislocation after total hip arthroplasty depends on surgical approach, femoral head size, sex, and primary diagnosis: An analysis of 78,098 operations in the Swedish Hip Arthroplasty Register. Acta Orthop. 2012;83:442-8.
43. Jolles B, Bogoch E. Posterior versus lateral surgical approach for total hip arthroplasty in adults with osteoarthritis. Cochrane Database Syst Rev. 2006;3.
44. Kwon M, Kuskowski M, Mulhall K, Macaulay W, Brown T, Saleh K. Does surgical approach affect total hip arthroplasty dislocation rates? Clin Orthop Relat Res. 2006;447:34-8.
45. Ho K, Whitwell G, Young S. Reducing the rate of early primary hip dislocation by combining a change in surgical technique and an increase in femoral head diameter to 36mm. Arch Orthop Trauma Surg. 2012;132:1031-6.
46. Pellicci P, Bostrom M, Poss R. Posterior approach to total hip replacement using enhanced posterior soft tissue repair. Clin Orthop Relat Res. 1998;355:224-8.
47. White R, Forness T, Allman J, Junick D. Effect of posterior capsular repair on early dislocation in primary total hip replacement. Clin Orthop Relat Res. 2001;393:163-7.
48. Witzleb W, Stephan L, Krummenauer F, Neuke A, Gunther K. Short-term outcome after posterior versus lateral surgical approach for total hip arthroplasty - A randomized clinical trial. Eur J Med Res. 2009;14:256-63.
49. Iorio R, Healy W, Warren P, Appleby D. Lateral trochanteric pain following primary total hip arthroplasty. J Arthroplasty. 2006;21:233-6.

50. Potter H, Nestor B, Sofka C, Ho S, Peters L, Salvati E. Magnetic resonance imaging after total hip arthroplasty: Evaluation of periprosthetic soft tissue. J Bone Joint Surg Am. 2004;86:1947-54.
51. Potter H, Foo L, Nestor B. What is the role of magnetic resonance imaging in the evaluation of total hip arthroplasty? HSS J. 2005;1:89-93.
52. Muller M, Thotz S, Springer I, Dewey M, Perka C. Randomized controlled trial of abductor muscle damage in relation to the surgical approach for primary total hip replacement: Minimally invasive anterolateral versus modified direct lateral approach. Arch Orthop Trauma Surg. 2011;131:179-89.
53. Pfirrmann C, Notzli H, Dora C, Hodler J, Zanetti M. Abductor tendons and muscles assessed at MR imaging after total hip arthroplasty in asymptomatic and symptomatic patients. Radiology. 2005;235:969-76.
54. Twair A, Ryan M, O'Connell M, Powell T, O'Byrne J, Eustace S. MRI of failed total hip replacement caused by abductor muscle avulsion. Am J Roentgenol. 2003;181:1547-50.
55. Barber T, Roger D, Goodman S, Schurman D. Early outcome of total hip arthroplasty using the direct lateral vs the posterior surgical approach. Orthopaedics. 1996;19:873-5.
56. Chechik O, Khashan M, Lador R, Salai M, Amar E. Surgical approach and prosthesis fixation in hip arthroplasty world wide. Arch Orthop Trauma Surg. 2013;Epub.
57. Matta J, Shahrdar C, Ferguson T. Single-incision anterior approach for total hip arthroplasty on an orthopaedic table. Clin Orthop Relat Res. 2005;441:115-24.
58. Dosanjh S, Matta J, Bhandari M. The final straw: A qualitative study to explore patient decisions to undergo total hip arthroplasty. Arch Orthop Trauma Surg. 2009;129:719-27.
59. Alecci V, Valente M, Crucil M, Minerva M, Pellegrino C, Sabbadini D. Comparison of primary total hip replacements performed with a direct

anterior versus the standard lateral approach: Perioperative findings. J Orthopaed Traumatol. 2011;12:123-9.
60. Restrepo C, Parvizi J, Pour A, Hozack W. Prospective randomized study of two surgical approaches for total hip arthroplasty. J Arthroplasty. 2010;25:671-9.
61. Goebel S, Steinert A, Schillinger J, Eulert J, Broscheit J, Rudert M, et al. Reduced post-operative pain in total hip arthroplasty after minimal-invasive anterior approach. Int Orthop. 2012;36:491-8.
62. Bremer A, Kalberer F, Pfirrmann C, Dora C. Soft-tissue changes in hip abductor muscles and tendons after total hip replacement: Comparison between the direct anterior and the transgluteal approaches. J Bone Joint Surg Br. 2011;93:886-9.
63. Lachiewicz P. Abductor tendon tears of the hip: Evaluation and management. J Am Acad Orthop Surg. 2011;19:385-91.
64. Howell G, Biggs R, Bourne R. Prevalence of abductor mechanism tears of the hips in patients with osteoarthritis. J Arthroplasty. 2001;16:121-3.
65. Barrett W, Turner S, Leopold J. Prospective randomized study of direct anterior vs posterolateral approach for total hip arthroplasty. J Arthroplasty. 2013;28:1634-8.
66. Martin C, Pugely A, Gao Y, Clark C. A comparison of hospital length of stay and short-term morbidity between the anterior and the posterior approaches to total hip arthroplasty. J Arthroplasty. 2013;28:849-54.
67. Grande M, Tucci G, Adorisio O, Barini A, Rulli F, Neri A, et al. Systemic acute-phase response after laparoscopic and open cholecystectomy. Surg Endosc. 2002;16:313-6.
68. Suter M, Martinet O, Spertini F. Reduced acute phase response after laparoscopic total extraperitoneal bilateral hernia repair compared to open repair with the Stoppa procedure. Surg Endosc. 2002;16:1214-9.
69. Bergin P, Doppelt J, Kephart C, Benke M, Graeter J, Holmes A, et al. Comparison of minimally invasive direct anterior versus posterior total

hip arthroplasty based on inflammation and muscle damage markers. J Bone Joint Surg Am. 2011;93:1392-8.

70. Khan F. Rhabdomyolysis: A review of the literature. Neth J Med. 2009;67:272-83.

71. Lappalainen H, Tiula E, Uotila L, Manttari M. Elimination kinetics of myoglobin and creatine kinase in rhabdomyolysis: Implications for follow-up. Crit Care Med. 2002;30:2212-5.

72. Meneghini R, Pagnano M, Trousdale R, Hozack W. Muscle damage during MIS total hip arthroplasty: Smith-Peterson versus posterior approach. Clin Orthop Relat Res. 2006;453:293-8.

73. Nho S, Kymes S, Callaghan J, Felson D. The burden of hip osteoarthritis in the United States: Epidemiologic and economic considerations. J Am Acad Orthop Surg. 2013;21 Suppl:S1-6.

74. Healy W, Iorio R. Implant selection and cost for total joint arthroplasty. Clin Orthop Relat Res. 2007;457:57-63.

75. Daigle M, Weinstein A, Katz J, Losina E. The cost-effectiveness of total joint arthroplasty: A systematic review of published literature. Best Pract Res Clin Rheumatol. 2012;26:649-58.

76. Brauer C, Neumann P, Rosen A. Trends in cost-effectiveness analyses in orthopaedic surgery. Clin Orthop Relat Res. 2007;457:42-8.

77. Chang R, Pellissier J, Hazen G. A Cost-effectiveness analysis of total hip arthroplasty for osteoarthritis of the hip. JAMA. 1996;275:858-65.

78. Bozic K, Morshed S, Silverstein M, Rubash H, Kahn J. Use of cost-effectiveness analysis to evaluate new technologies in orthopaedics: The case of alternative bearing surfaces in total hip arthroplasty. J Bone Joint Surg Am. 2006;88:706-14.

79. Marinelli M, Soccetti A, Panfoli N, de Palma L. Cost-effectiveness of cemented versus cementless total hip arthroplasty: A Markov decision analysis based on implant cost. J Orthopaed Traumatol. 2008;9:23-8.

80. McKenzie L, Vale L, Stearns S, McCormack K. Metal on metal hip resurfacing arthroplasty: An economic analysis. Eur J Health Econom. 2003;4:122-9.
81. Bozic K, Saleh K, Rosenberg A, Rubash H. Economic evaluation in total hip arthroplasty: Analysis and review of the literature. J Arthroplasty. 2004;19:180-9.
82. Mauskopf J, Paul J, Grant D, Stergachis A. The role of cost-consequence analysis in healthcare decision-making. Pharmacoeconomics. 1998;13:277-88.
83. Schulman K, Seils D. Clinical Economics. 2003. In: Symptom Research: Methods and Opportunities [Internet].
84. Weinstein M, Siegel J, Gold M, Kamlet M, Russell L. Recommendations of the panel on cost-effectiveness in health and medicine. JAMA. 1996;276:1253-8.
85. Furlong W, Feeny D, Torrance G, Barr R. The Health Utilities Index (HUI) system for assessing health-related quality of life in clinical studies. Ann Med. 2001;33:375-84.
86. Kaplan R, Ganiats T, Sieber W, Anderson J. The Quality of Well-Being Scale: Critical similarities and differences with SF-36. Int J Qual Health Care. 1998;10:509-20.
87. Hadorn D, Uebersax J. Large-scale health outcomes evaluation: How should quality of life be measured? Part 1 - Calibration of a brief questionnaire and search for preference subgroups. J Clin Epidemiol. 1995;48:607-18.
88. Gafni A. The standard gamble method: What is being measured and how it is interpreted. Health Serv Res. 1994;29:207-24.
89. Barber T, Healy W. The hospital cost of total hip arthroplasty. J Bone Joint Surg Am. 1993;75:321-5.
90. Hip and knee replacements in Canada: Canadian Joint Replacement Registry 2013 Annual Report. Canadian Institute for Health Information, 2013.

91. Antoniou J, Martineau P, Filion K, Haider S, Zukor D, Huk O, et al. In-hospital cost of total hip arthroplasty in Canada and the United States. J Bone Joint Surg Am. 2004;86:2435-9.
92. Rosenthal J, Lu X, Cram P. Availability of consumer prices from US hospitals for a common surgical procedure. JAMA Intern Med. 2013;173:427-32.
93. Maetzel A, Li L, Pencharz J, Tomlinson G, Bombardier C. The economic burden associated with osteoarthritis, rheumatoid arthritis, and hypertension: A comparative study. Ann Rheum Dis. 2004;63:395-401.
94. Leigh J, Seavey W, Leistikow B. Estimating the costs of job-related arthritis. J Rheumatol. 2001;28:1647-54.
95. Gupta S, Hawker G, Laporte A, Croxford R, Coyte P. The economic burden of disabling hip and knee osteoarthritis (OA) from the perspective of individuals living with this condition. Rheumatology. 2005;44:1531-7.
96. Goossens M, Rutten-van Molken M, Vlaeyen J, van der Linden S. The cost diary: A method to measure direct and indirect costs in cost-effectiveness research. J Clin Epidemiol. 2000;53:688-95.
97. Lapsley H, March L, Tribe K, Cross M, Brooks P. Living with osteoarthritis: Patient expenditures, health status, and social impact. Arthritis Rheum. 2001;45:301-6.
98. Rolfson O, Strom O, Karrholm J, Malchau H, Garellick G. Costs related to hip disease in patients eligible for total hip arthroplasty. J Arthroplasty. 2012;27:1261-6.
99. Hawker G, Badley E, Croxford R, Coyte P, Glazier R, Guan J, et al. A population-based nested case-control study of the costs of hip and knee replacement surgery. Med Care. 2009;47:732-41.
100. Steinbrocker O, Traeger C, Batterman R. Therapeutic criteria in rheumatoid arthritis. JAMA. 1949;140:659-62.
101. Weinstein M, Stason W. Cost-effectiveness of coronary artery bypass surgery. Circulation. 1982;66:56-66.

102. Pennington M, Grieve R, Sekhon J, Gregg P, Black N, van der Meulen J. Cemented, cementless and hybrid prostheses for total hip arthroplasty: Cost-effectiveness analysis. BMJ. 2013;346:1-14.
103. Edlin R, Tubeuf S, Achten J, Parsons N, Costa M. Cost-effectiveness of total hip arthroplasty versus resurfacing arthroplasty: Economic evaluation alongside a clinical trial. BMJ Open. 2012;2:1-8.

Chapter 3

3 Surgical approach in total hip arthroplasty: The impact on short-term patient outcomes

3.1 Introduction

Sir John Charnley revolutionized the treatment of hip arthritis forever in the 1960s. His low friction hip arthroplasty stood as the framework for the modern total hip arthroplasty (THA) [1]. Although several tribologic advances have been made in implant design and bearing articulations, THA remains the most effective treatment modality for hip arthritis and is often regarded as one of the most important surgical advances in all of history [2].

Basic science and clinical research remain integral components of improving the effectiveness of THA. Clinical trials allow clinicians to determine the impact of an intervention on a patient. These trials can also determine the indications and contra-indications for each intervention, factors that influence success and failure, and complications associated with a given procedure. Invaluable information is acquired from these studies when informing patients of the risks and benefits of any medical endeavor.

There are several methods of assessing the effectiveness of any intervention. In the orthopedic literature, many clinical studies rely on validated, disease-specific, and generic clinical questionnaires in order to document a patient's response to an intervention. Other outcome measures include metrics such as operating room time, functional outcomes such as gait analyses, and complication rates.

The impact of surgical approach on clinical outcomes in THA has been under scrutiny over the past decade. Prospective and retrospective studies have compared different surgical approaches in THA using a myriad of outcome measures. Very few studies have used validated clinical outcomes in their comparisons, and to our knowledge none of the studies have standardized the implants used at the time of the index procedure.

The primary objective of this study was to prospectively compare clinical outcomes across three different surgical approaches to the hip for THA, specifically the results on the Western Ontario and McMaster University Osteoarthritis Index (WOMAC). Using validated outcome measures, we look to elicit whether there is an early clinical benefit of performing a THA through an anterior approach. We will also compare complication rates between the approaches. We hypothesize that there will be no difference in clinical outcomes between the three different surgical approaches at short-term follow-up.

3.2 Materials and Methods

3.2.1 Study design, patient enrolment and selection

Institutional review board ethics approval was attained at Western University. The study design was a prospective cohort observation study from a single institution. Patients were first assigned to the clinic of one of three fellowship-trained arthroplasty surgeons at University Hospital at Western University. The surgeons were randomly assigned a day of the week to receive referrals from our central accepting database. Although not truly a randomized process, this is representative of usual clinical practice, thus strengthening the external validity of the study. Each surgeon performed only one of three surgical approaches to the hip: anterior (BL), posterior (JH), and lateral (EV). Informed consent for THA was attained for those patients whose hip arthropathy was deemed most appropriately treated with surgical intervention.

One hundred and seventy eight consecutive patients were then approached for study enrolment in the preadmission clinic prior to their procedure from September 2013 to July 2014. Patients were included if they consented for THA performed through either an anterior, posterior, or lateral approach, were older than 19 years of age, and did not meet any of the exclusion criteria (Table 3.1). A letter of information was provided for each patient screened, followed by voluntary consent for study participation.

Exclusion Criteria
Body Mass Index (BMI) > 40 kg/m^2
Legg-Calve-Perthes disease, slipped-capital femoral epiphysis, or developmental dysplasia of the hip (Crowe I or higher)
Post-traumatic or inflammatory arthropathy
Any previous hip surgery
Simultaneous bilateral THAs
Decision to change implants intra-operatively other than those approved for study
Cemented THA
Diagnoses that may preclude accurate completion of clinical questionnaires (i.e. Alcoholism, dementia, psychoses)
Non-English speaking
Inability to perform Timed Up-and-Go test (TUG)
Cases performed by trainees (residents or clinical fellows)

Table 3.1 – Study exclusion criteria

3.2.2 Patient demographics

At the time of enrolment, patient age, sex, and BMI were collected. The primary diagnosis causing arthropathy of the hip joint (i.e. osteoarthritis, avascular necrosis) was determined based on patient history and radiographic images. Surgical approach and operative side were also recorded.

3.2.3 Determining clinical outcomes

Pre-operatively, each patient completed 4 different clinical questionnaires: Harris hip score (HHS), WOMAC, Short-Form 12 (SF-12), and EQ-5D [3-6]. These questionnaires were administered at 6-weeks and 3-months following the index procedure for post-operative comparison. The WOMAC, SF-12, and EQ-5D are completed entirely by the patients and do not require any assistance from health care personnel. Unblinded physicians or health care personnel other than the treating surgeon completed the HHS. Any incomplete questionnaires were not included in final statistical analyses. An anterior-posterior pelvis and lateral hip radiograph were taken at the 6-week follow-up appointment to assess implant positioning, and document any peri-prosthetic concerns (i.e. fracture).

Each patient also completed a Timed up-and-go (TUG) test pre-operatively and at the 6-week and 3-month post-operative intervals. The test begins with the patient sitting in a chair with armrests. On the word “Go”, the patient walks to a 3-metre mark, turns, returns to the chair, and sits down [7]. The time from the word “Go” to the instant the patient’s buttock contacts the chair is recorded to the nearest tenth of a second. The patient performs the test in their normal footwear and is allowed to use an assisted device (i.e. cane). A time greater than 10 seconds pre-operatively correlates with requiring a gait aid at 6-months following THA [8]. A time of 10 seconds also correlates with increased risk of falls and inability to perform activities of daily living independently in patients with hip osteoarthritis [9]. A minimally important difference of 1.4 seconds has been reported in a population of patients living with hip arthritis [10].

Several other parameters will be compared between the surgical approaches. Post-operative infections, peri-prosthetic fractures and dislocations, wound complications, nerve palsies, and medical complications (i.e. myocardial infarction or pulmonary embolism) are examples of complications used to differentiate the three approaches. These were collected prospectively during each hospital stay by means of a standardized In-hospital Stay Data Collection Sheet (Appendix C).

3.2.4 Operative procedures

A single surgeon was designated to perform every case using one of the three surgical approaches. There were no cases performed by trainees (i.e. residents or fellows). Each patient received standardized implants: a hydroxyapatite-coated, cementless femoral stem (Corail ™ stem, DePuy Orthopaedics Inc., Warsaw, IN), a cementless acetabular cup (Pinnacle Sector II ™ acetabular cup, DePuy Orthopaedics Inc., Warsaw, IN), a highly cross-linked polyethylene liner (AltrX ™ polyethylene liner, DePuy Orthopaedics Inc., Warsaw, IN), and a cobalt chrome femoral head (Articul/eze ™ cobalt chrome, DePuy Orthopaedics Inc., Warsaw, IN). Cancellous screws (DePuy Orthopaedics Inc., Warsaw, IN) were inserted in order to augment acetabular fixation at the surgeon's discretion.

The anterior approach was performed using a modified Hueter approach [11]. The patient was positioned supine on a specialized operating table (Hana ™ fracture table, Mizuho OSI, Union City, CA). An incision was made 2 centimeters lateral to the anterior superior iliac spine, extending distally towards the superolateral patella for 8 to 10 centimeters. The superficial inter-nervous interval between tensor fascia latae and sartorius was incised, protecting the lateral femoral cutaneous nerve. The deep inter-nervous interval between gluteus medius and rectus femoris was then incised, exposing the anterior joint capsule. A longitudinal capsulotomy was performed along the long axis of the femoral neck, extending from the acetabulum to the intertrochanteric line. Using a reciprocating saw, a femoral neck osteotomy was performed with appropriate soft tissue retractors in place. A corkscrew was used to remove the femoral head, and a napkin ring osteotomy of the femoral neck was used as needed to facilitate femoral head removal. The operative leg was then carefully externally rotated to aid in visualizing the acetabulum. Intra-operative fluoroscopy was used to verify inclination and anteversion during acetabular reaming. For femoral preparation, the operative leg is carefully extended, adducted, and externally rotated. A femoral bone hook on a motorized bracket was used to aid in visualizing the proximal metaphysis during preparation. Intra-operative fluoroscopy was used to verify stem size, femoral offset, and restoration of leg lengths. The wound was irrigated and closed in layers.

The lateral approach was performed using the technique described by Hardinge [12]. The patient was positioned in the lateral decubitus position. An incision was fashioned centered over the tip of the greater trochanter, extending 3 centimeters proximally and 5 centimeters distally. The fascia latae was incised in line with the skin incision. A one-half anterior, one-half posterior split was made in the gluteus medius muscle. A tenotomy of the tendinous insertion of gluteus medius was performed, leaving a cuff of tissue for repair at the end of the case. The gluteus minimus and joint capsule were then dissected off the femoral neck in a single layer. The hip was then dislocated with the operative limb placed in a sterile bag. A femoral neck osteotomy was performed 1 centimeter proximal to the lesser trochanter. This then provided adequate visualization of both the acetabulum and femur for preparation, which were performed in the usual fashion. The wound is thoroughly irrigated and closed in layers. Careful attention was taken when closing the gluteus medius tenotomy to prevent post-operative abductor insufficiency.

The posterior approach utilized the technique popularized by Moore [13]. The patient was positioned in the lateral decubitus position. A skin incision extended along the posterior aspect of the greater trochanter, curving towards the posterior superior iliac spine. The fascia overlying the gluteus maximus was incised in line with the skin incision. The gluteus maximus was bluntly dissected down to the short external rotators. The surgeon protected the sciatic nerve with soft tissue retraction without formal exploration. The conjoint tendon (superior and inferior gemelli and obturator internus) and piriformis were dissected off the greater trochanter and tagged with a suture for later repair. A capsulotomy was performed, followed by femoral neck osteotomy. This provided adequate exposure to perform both the acetabular and femoral reconstructions. The joint capsule and short external rotators are repaired through trans-osseous tunnels in the greater trochanter. The remainder of the wound is closed in layers.

3.2.5 Post-operative care

Post-operatively, all patients were admitted to an orthopedic ward. Each patient received 24 hours of post-operative antibiotics, as well as prophylaxis against deep vein thrombosis. Analgesia was managed by our institution's acute pain service. All patients were permitted to weight-bear as tolerated with the use of a gait aid as needed. All patients received standardized, unblinded physiotherapy in accordance with our institution's hip arthroplasty discharge pathway.

3.2.6 Sample size calculation

There are few studies comparing validated clinical outcome measures using different surgical approaches in THA. Restrepo et al. found an effect size of 0.67 with the WOMAC questionnaire at 6-weeks as their primary endpoint between the anterior and lateral approach [14]. To take a conservative approach we used an effect size of 0.60, alpha set at 0.05, and a power of 0.80. This results in 36 participants in all groups. To account for attrition, we inflated the sample size by 10%. Therefore, we will enroll 40 patients per group.

3.2.7 Statistical analysis

The association between the anterior, posterior, and lateral approaches and demographic categorical data such as sex and operative side were evaluated by means of a nonparametric Pearson Chi-square. A one-way analysis of variance (ANOVA) was performed for continuous demographic variables such as age and BMI.

The mean ranks of the domains of the EQ-5D pre-operatively and at each follow-up time point was evaluated the Kruskal-Wallis test. Those comparisons demonstrating statistical significance were then followed by post hoc, pair-wise testing using the Mann-Whitney test.

A one-way ANOVA was used to compare pre-operative, 6-week, and 3-month outcome measures (HHS, WOMAC, SF-12, EQ-5D VAS and utility index, and TUG) across the 3 surgical approaches. Post-hoc analysis was performed using the Scheffé test to determine significant differences between the groups when necessary. Statistical significance was set at $p<0.05$. The SPSS® v.22 (SPSS Inc, Chicago, IL, USA) was used for all analyses.

3.3 Results

3.3.1 Patient demographics

Figure 3.1 represents a flow diagram outlining recruitment, patient exclusions, and follow-up. Sixty patients were excluded after random assignment for reasons listed in the flow diagram. All groups had complete pre-operative outcome measure data. Table 3.2 outlines the number of patients with missed follow-up at the 6-week and 3-month time-points, and reasons for the missed appointments.

Patient demographics of the 118 patients enrolled in the study are outlined in Table 3.3. There were no statistically significant differences between the groups with regards to age and BMI following a one-way ANOVA. Sex, operative side, and primary diagnosis distributions were also not statistically different following Pearson Chi-square analysis.

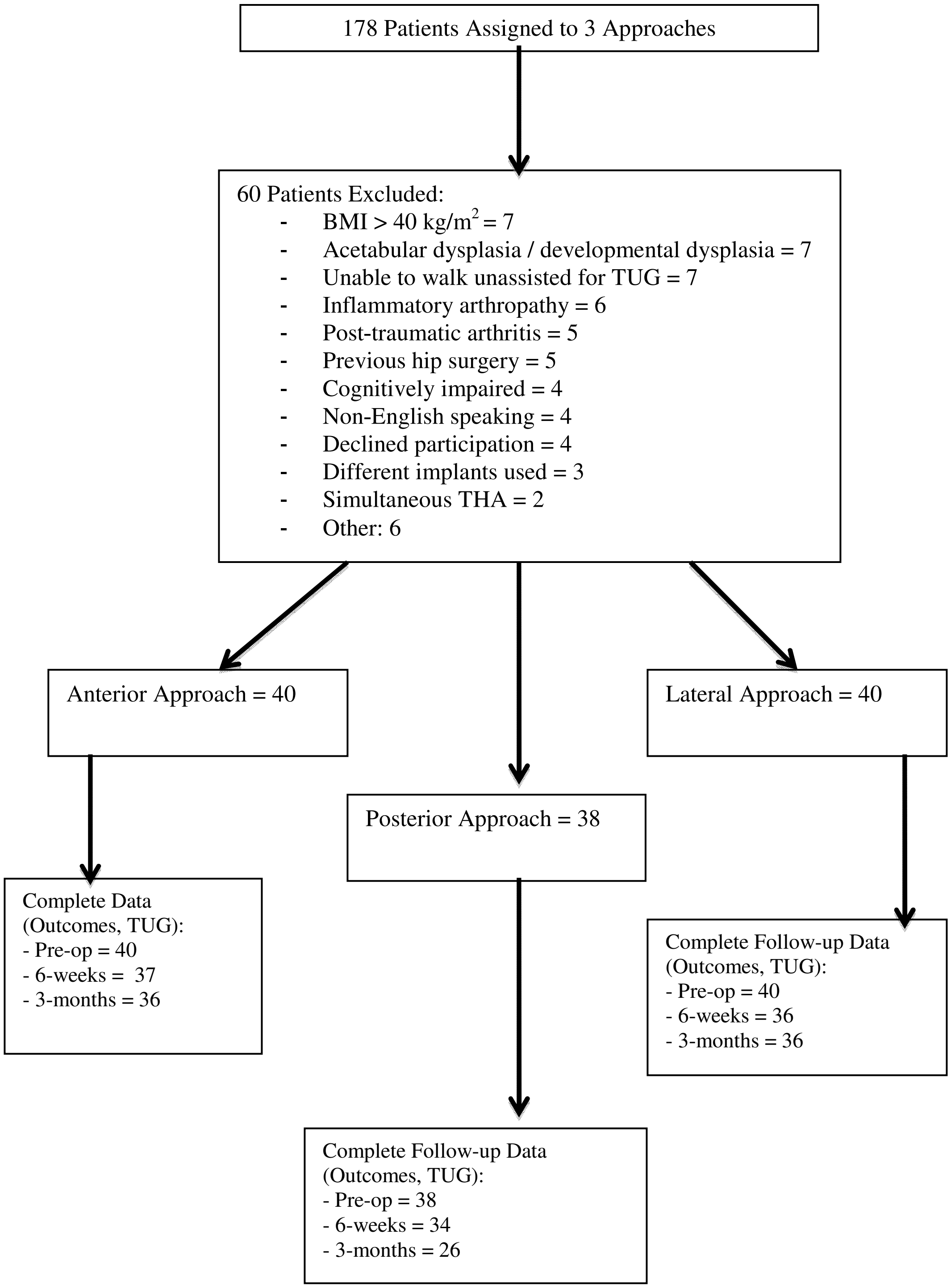

Figure 3.1 – Flow diagram for study

	Anterior Approach	Posterior Approach	Lateral Approach
Number of patients with missed 6-week data	n=3 Reason: - 2 due to travel - 1 patient could not be contacted	n=4 Reason: - 2 due to travel - 2 patients could not be contact	n=4 Reason: - 1 due to travel - 3 patients could not be contacted
Number of patients with missed 3-month data	n=4 Reason: - 3 patients still require 3-month follow-up - 1 patient could not be contacted	n=12 Reason: - 2 due to travel - 2 patients refused 3-month follow-up - 2 patients could not be contacted - 6 patients still require 3-month follow-up	n=4 Reason: - 2 due to travel - 2 patients could not be contacted

Table 3.2 – Missed follow-up appointments

An outline of the reasons for missing data at the 6-week and 3-month follow-up appointments.

Demographic	Anterior Approach	Posterior Approach	Lateral Approach	p-value
Age (years)	Mean = 66.9 Std. Dev. = 9.5 Range = 42 - 86	Mean = 66.7 Std. Dev. = 9.2 Range = 44 - 84	Mean = 65.5 Std. Dev. = 10.4 Range = 42 – 92	0.792
Sex	Female = 25 Male = 15	Female = 24 Male = 14	Female = 26 Male = 14	0.971
Body Mass Index (kg/m^2)	Mean = 27.9 Std. Dev. = 4.3 Range = 20.8 – 36.4	Mean = 28.2 Std. Dev. = 5.3 Range = 16.2 – 39.9	Mean = 29.1 Std. Dev. = 5.6 Range = 19.9 – 39.9	0.541
Operative Side	Left = 22 Right = 18	Left = 18 Right = 20	Left = 18 Right = 22	0.647
Primary Diagnosis	Osteoarthritis = 37 Avascular Necrosis = 3	Osteoarthritis = 33 Avascular Necrosis = 5	Osteoarthritis = 38 Avascular Necrosis = 2	0.418

Table 3.3 – Patient demographics

Sample demographics with means, standard deviations, and ranges for continuous variables.

3.3.2 Clinical outcome measures

3.3.2.1 Western Ontario and McMaster University Osteoarthritis Index

The results of the pre-operative, 6-week, and 3-month WOMAC can be found in Figure 3.3. The descriptive statistics from the comparison can be found in Table 3.5.

There were no statistically significant differences between the 3 groups for the pre-operative WOMAC pain, stiffness, function, and total score. At 6-weeks, there was a statistically significant difference between the groups for the function composite score, but not the pain, stiffness, and total score. Pair-wise post-hoc testing demonstrated that the anterior group scored higher than the lateral group on the 6-week function score (p=0.036). At 3-months, there were no statistically significant differences between groups for all of the WOMAC composite scores.

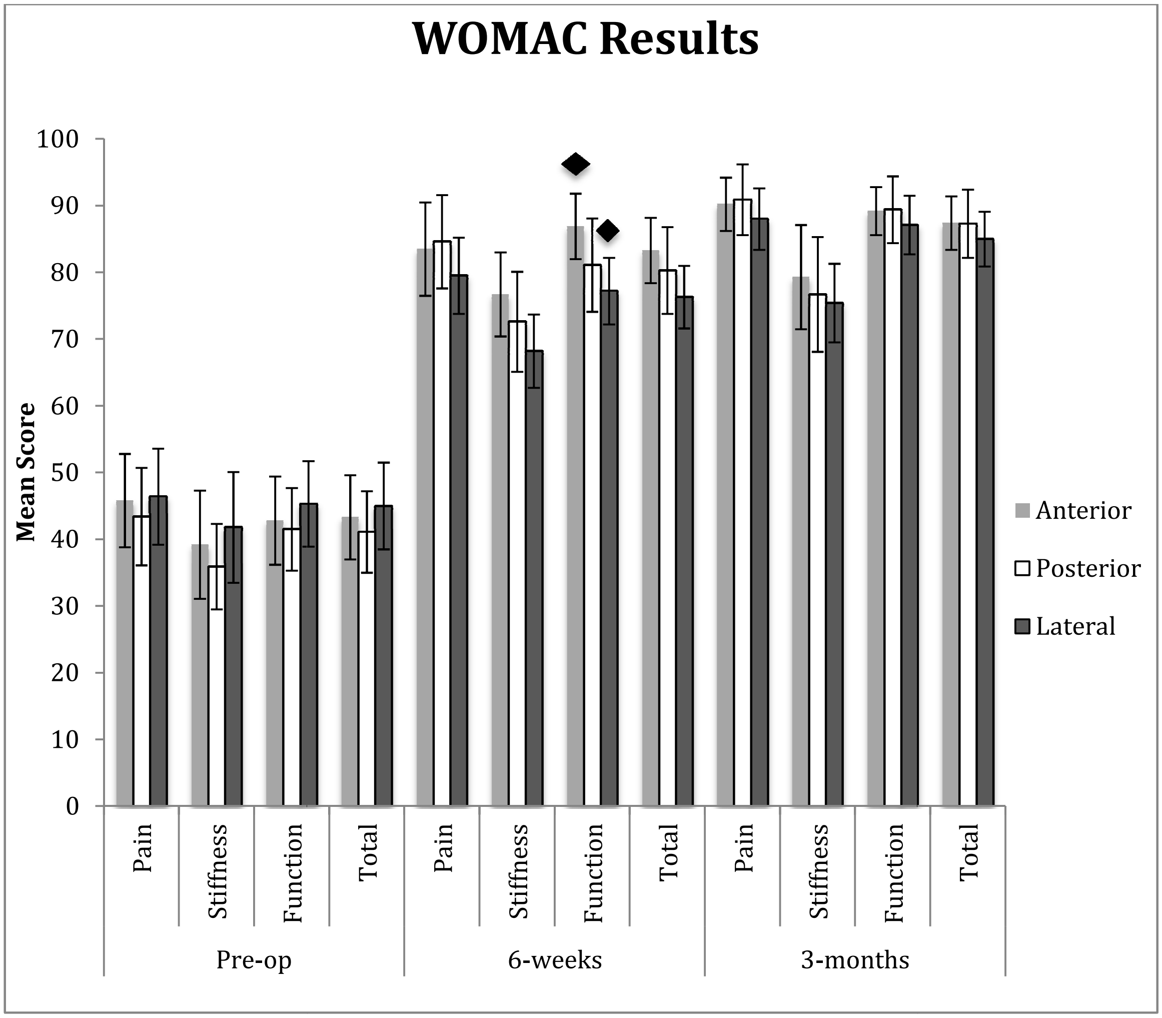

Figure 3.2 – Results of WOMAC

Mean scores for each component score for the WOMAC at all time points. Error bars represent 95% confidence intervals. Pair-wise comparisons reaching statistical significance for a given composite score are denoted by symbols.

	Anterior Approach (mean +/- SD)	Posterior Approach (mean +/- SD)	Lateral Approach (mean +/- SD)	p-value
Pre-operative WOMAC Pain	45.8 +/- 19.1	43.4 +/- 20.0	46.4 +/- 21.0	0.818
Pre-operative WOMAC Stiffness	39.2 +/- 22.3	35.9 +/- 17.7	41.8 +/- 24.1	0.536
Pre-operative WOMAC Function	42.8 +/- 18.1	41.5 +/- 17.0	45.3 +/- 18.8	0.684
Pre-operative WOMAC Total	43.3 +/- 17.2	41.1 +/- 17.1	45.0 +/- 18.9	0.661
6-week WOMAC Pain	83.5 +/- 15.6	84.6 +/- 17.2	79.5 +/- 16.0	0.444
6-week WOMAC Stiffness	76.7 +/- 16.7	72.6 +/- 18.7	68.2 +/- 15.7	0.139
6-week WOMAC Function	86.9 +/- 12.9	81.1 +/- 16.8	77.2 +/- 14.1	0.036
6-week WOMAC Total	83.3 +/- 13.2	80.3 +/- 15.8	76.3 +/- 13.2	0.141
3-month WOMAC Pain	90.2 +/- 11.2	90.9 +/- 11.9	88.0 +/- 13.0	0.646
3-month WOMAC Stiffness	79.3 +/- 21.7	76.7 +/- 19.4	75.4 +/- 16.4	0.715
3-month WOMAC Function	89.2 +/- 10.0	89.4 +/- 11.4	87.1 +/- 12.4	0.680
3-month WOMAC Total	87.4 +/- 11.1	87.3 +/- 11.7	85.0 +/- 11.7	0.638

Table 3.4 – Descriptive statistics for the WOMAC

Descriptive statistics including means and standard deviations are outlined in the table, as well as the p-values for the one-way, between-group ANOVA for the WOMAC.

3.3.2.2 Harris hip score

The results of the pre-operative, 6-week, and 3-month HHS can be found in Figure 3.2. The descriptive statistics for the ANOVA can be found in Table 3.4.

There were no statistically significant differences between the 3 groups for the pre-operative Harris hip pain, function, and total score. At 6-weeks, there was a statistically significant difference between the groups for the function score, but not the pain and total scores. Post-hoc pair-wise testing demonstrated that the posterior approach cohort scored significantly higher on the 6-week function score ($p=0.037$) than the lateral approach group. The 6-week functional score for the anterior approach group nearly reached statistical significance when compared to the lateral approach group ($p=0.057$). Finally, at 3-months, there were no statistically significant differences between the 3 groups for all of the HHS composite scores.

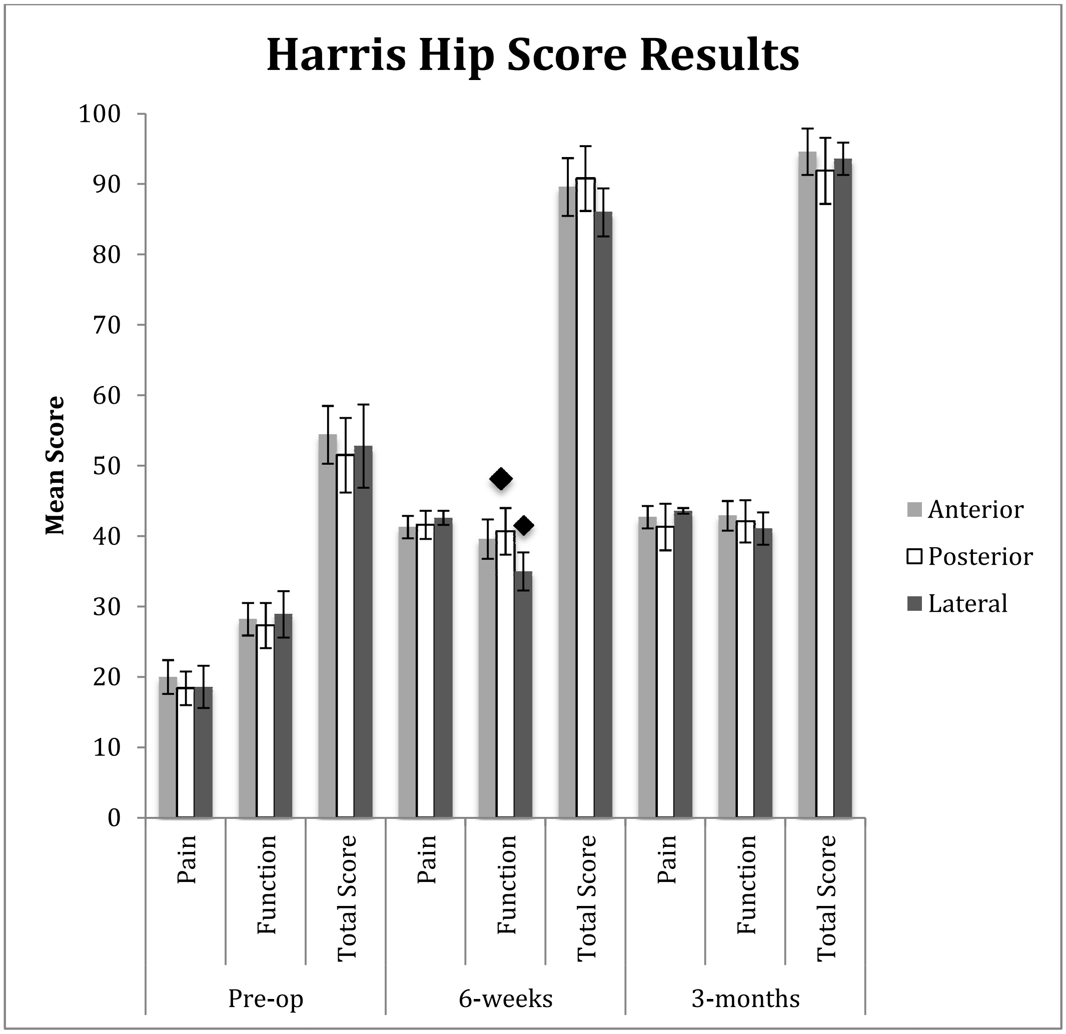

Figure 3.3 – Results of Harris hip score

Mean scores for each component score for the Harris hip score at all time points. Error bars represent 95% confidence intervals. Pair-wise comparisons reaching statistical significance for a given composite score are denoted by symbols.

	Anterior Approach (mean +/- SD)	Posterior Approach (mean +/- SD)	Lateral Approach (mean +/- SD)	p-value
Pre-operative HHS Pain	20.0 +/- 7.3	18.4 +/- 6.8	18.6 +/- 8.8	0.642
Pre-operative HHS Function	28.2 +/- 7.1	27.3 +/- 8.7	28.9 +/- 9.9	0.760
Pre-operative HHS Total	54.4 +/- 12.3	51.5 +/- 14.8	52.8 +/- 17.8	0.738
6-week HHS Pain	41.3 +/- 4.5	41.6 +/- 4.7	42.6 +/- 2.9	0.430
6-week HHS Function	39.6 +/- 7.6	40.7 +/- 6.9	35.0 +/- 6.8	0.017
6-week HHS Total	89.6 +/- 11.3	90.8 +/- 9.5	86.0 +/- 8.4	0.228
3-month HHS Pain	42.7 +/- 4.5	41.3 +/- 7.2	43.6 +/- 1.2	0.208
3-month HHS Function	42.9 +/- 5.7	42.1 +/- 6.6	41.1 +/- 6.4	0.494
3-month HHS Total	94.6 +/- 8.8	91.9 +/- 10.4	93.6 +/- 6.5	0.535

Table 3.5 – Descriptive statistics for Harris hip score

Descriptive statistics including means and standard deviations are outlined in the table, as well as the p-values for the one-way, between-group ANOVA for the HHS.

3.3.2.3 Short-form 12

The results of the pre-operative, 6-week, and 3-month SF-12 Mental and Physical Component Summary scores (MCS and PCS, respectively) can be found in Figure 3.4. The descriptive statistics for this comparison can be found in Table 3.6. There were no statistically significant differences between the groups for any time point for the MCS and PCS scores of the SF-12.

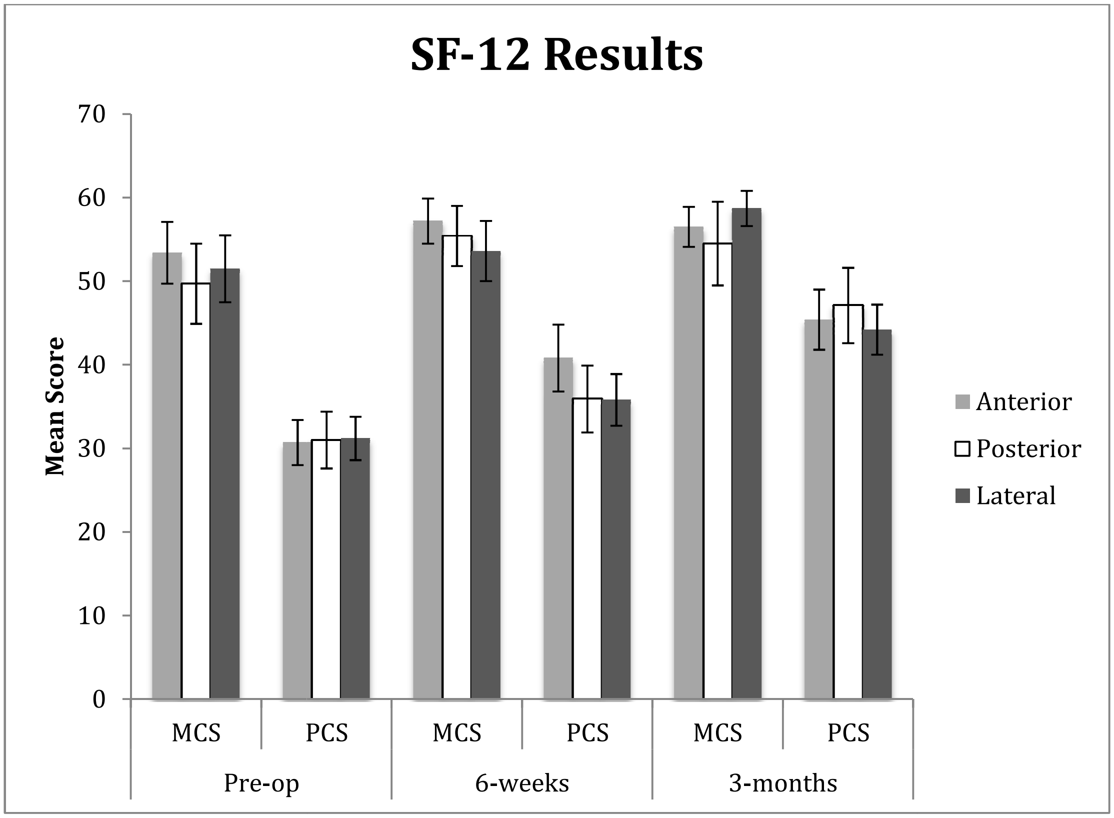

Figure 3.4 – Results of SF-12

Mean scores for each component score for the SF-12 at all time points. Error bars represent 95% confidence intervals.

	Anterior Approach (mean +/- SD)	Posterior Approach (mean +/- SD)	Lateral Approach (mean +/- SD)	p-value
Pre-operative SF-12 – MCS	53.4 +/- 10.2	49.7 +/- 13.2	51.5 +/- 11.5	0.468
Pre-operative SF-12 – PCS	30.7 +/- 7.4	31.0 +/- 9.1	31.2 +/- 7.8	0.975
6-week SF-12 – MCS	57.2 +/- 7.0	55.4 +/- 9.1	53.6 +/- 10.0	0.280
6-week SF-12 – PCS	40.8 +/- 10.4	35.9 +/- 9.8	35.8 +/- 8.8	0.087
3-month SF-12 – MCS	56.5 +/- 6.6	54.5 +/- 11.2	58.7 +/- 5.7	0.150
3-month SF-12 – PCS	45.4 +/- 9.9	47.1 +/- 10.2	44.2 +/- 8.3	0.554

Table 3.6 – Descriptive statistics for the SF-12

Descriptive statistics including means and standard deviations are outlined in the table, as well as the p-values for the one-way, between-group ANOVA for the SF-12.

3.3.2.4 EQ-5D

The results outlining the pre-operative, 6-week, and 3-month dimension distributions for the EQ-5D questionnaire can be found in Tables 3.7, 3.8, and 3.9, respectively. Pair-wise Mann-Whitney tests revealed that the pre-operative distribution of self-care was significantly different for the anterior versus posterior approach (p=0.008). At 6-weeks, the distribution of usual activities was significantly different for the anterior versus posterior (p=0.044) and anterior versus lateral (p=0.007) comparisons. At 3-months, the distribution of anxiety and depression was significantly different for the anterior versus lateral (p=0.018) and posterior versus lateral (p=0.004) comparisons.

The results of the pre-operative, 6-week, and 3-month EQ-VAS and EQ-5D utility index can be found in Figures 3.5 and 3.6. The descriptive statistics for these comparisons can be found in Tables 3.10 and 3.11. There were no statistically significant differences between the groups for any time point for EQ-VAS and utility index.

EQ-5D Dimension	Anterior Approach	Posterior Approach	Lateral Approach	Kruskal-Wallis test
Mobility				
Level 1	7.5%	11.1%	7.7%	0.887
Level 2	90.0%	86.1%	92.3%	
Level 3	2.5%	2.8%	0.0%	
Self-Care				
Level 1	45.0%	75.0%	56.4%	0.030
Level 2	55.0%	25.0%	43.6%	
Level 3	0.0%	0.0%	0.0%	
Usual Activities				
Level 1	7.5%	2.8%	10.3%	0.566
Level 2	77.5%	77.8%	74.4%	
Level 3	15.0%	19.4%	15.4%	
Pain / Discomfort				
Level 1	2.5%	2.8%	1.7%	0.713
Level 2	55.0%	50.0%	56.5%	
Level 3	42.5%	47.2%	41.7%	
Anxiety / Depression				
Level 1	57.5%	47.2%	64.1%	0.414
Level 2	40.0%	47.2%	28.2%	
Level 3	2.5%	5.6%	7.7%	

Table 3.7 – Pre-operative EQ-5D dimension distribution

Percent distributions across the 3 surgical approaches for pre-operative Level 1 (no problems), Level 2 (some problems), and Level 3 (severe problems) responses for the EQ-5D dimensions. Refer to the text for pair-wise comparisons when significance on the Kruskal-Wallis test is less than 0.05.

EQ5D Dimension	Anterior Approach	Posterior Approach	Lateral Approach	Kruskal-Wallis test
Mobility				
Level 1	64.9%	50.0%	55.6%	0.461
Level 2	35.1%	50.0%	44.4%	
Level 3	0.0%	0.0%	0.0%	
Self-Care				
Level 1	89.2%	80.0%	77.8%	0.403
Level 2	10.8%	20.0%	22.2%	
Level 3	0.0%	0.0%	0.0%	
Usual Activities				
Level 1	51.4%	26.7%	16.7%	0.017
Level 2	43.2%	63.3%	80.6%	
Level 3	5.4%	10.0%	2.8%	
Pain / Discomfort				
Level 1	2.5%	2.8%	1.7%	0.512
Level 2	55.0%	50.0%	56.5%	
Level 3	42.5%	47.2%	41.7%	
Anxiety / Depression				
Level 1	57.5%	47.2%	64.1%	0.383
Level 2	40.0%	47.2%	28.2%	
Level 3	2.5%	5.6%	7.7%	

Table 3.8 – 6-week EQ-5D dimension distribution

Percent distributions across the 3 surgical approaches for the 6-week Level 1 (no problems), Level 2 (some problems), and Level 3 (severe problems) responses for the EQ-5D dimensions. Refer to the text for pair-wise comparisons when significance on the Kruskal-Wallis test is less than 0.05.

EQ5D Dimension	Anterior Approach	Posterior Approach	Lateral Approach	Kruskal-Wallis test
Mobility				
Level 1	78.1%	83.7%	70.0%	0.577
Level 2	21.9%	16.3%	30.0%	
Level 3	0.0%	0.0%	0.0%	
Self-Care				
Level 1	96.4%	94.7%	89.7%	0.571
Level 2	3.6%	5.3%	10.3%	
Level 3	0.0%	0.0%	0.0%	
Usual Activities				
Level 1	67.9%	68.4%	65.5%	0.983
Level 2	32.1%	26.3%	34.5%	
Level 3	0.0%	5.3%	0.0%	
Pain / Discomfort				
Level 1	64.3%	68.4%	48.3%	
Level 2	35.7%	26.3%	51.7%	0.365
Level 3	0.0%	5.3%	0.0%	
Anxiety / Depression				
Level 1	82.1%	73.7%	100.0%	0.021
Level 2	17.9%	26.3%	0.0%	
Level 3	0.0%	0.0%	0.0%	

Table 3.9 – 3-month EQ-5D dimension distribution

Percent distributions across the 3 surgical approaches for 3- month Level 1 (no problems), Level 2 (some problems), and Level 3 (severe problems) responses for the EQ-5D dimensions. Refer to the text for pair-wise comparisons when significance on the Kruskal-Wallis test is less than 0.05.

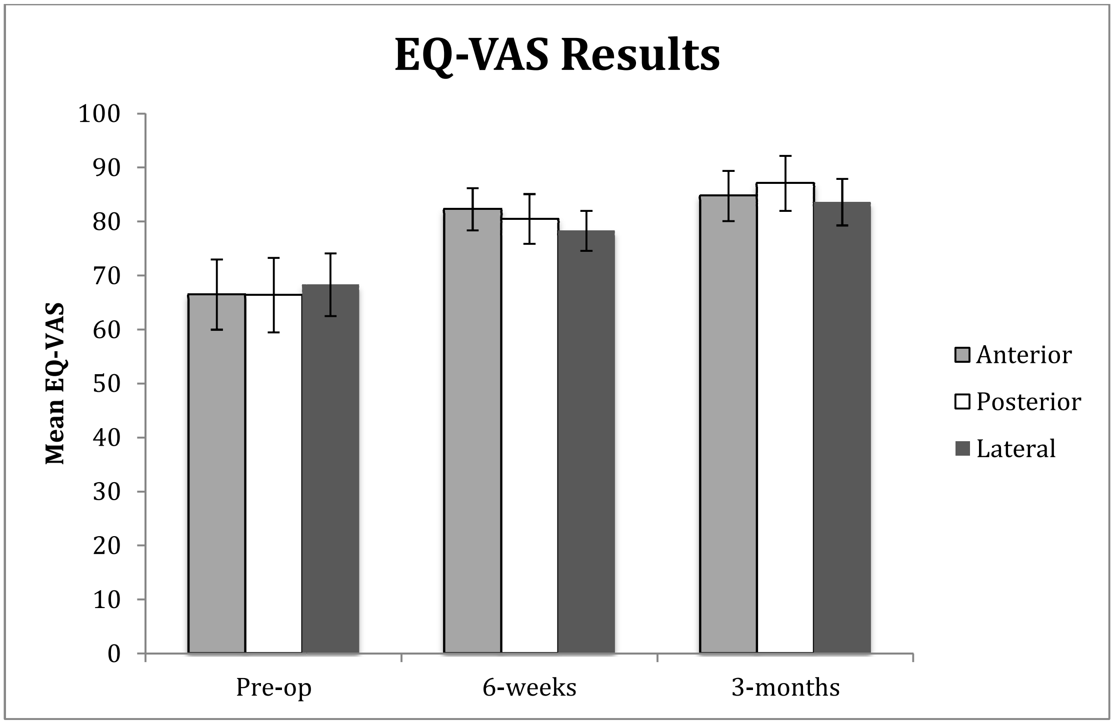

Figure 3.5 – Results of EQ-5D VAS

Mean scores for visual analogue scale of the EQ-5D at all time points. Error bars represent 95% confidence intervals.

	Anterior Approach (mean +/- SD)	Posterior Approach (mean +/- SD)	Lateral Approach (mean +/- SD)	p-value
Pre-operative EQ-VAS	66.5 +/- 20.4	66.4 +/- 20.6	68.3 +/- 17.9	0.889
6-week EQ-VAS	82.3 +/- 11.7	80.5 +/- 12.3	78.3 +/- 10.9	0.344
3-month EQ-VAS	84.8 +/- 12.0	87.1 +/- 10.6	83.6 +/- 11.4	0.576

Table 3.10 – Descriptive statistics for the EQ-VAS

Descriptive statistics including means and standard deviations are outlined in the table, as well as the p-values for the one-way, between-group ANOVA for the EQ-VAS.

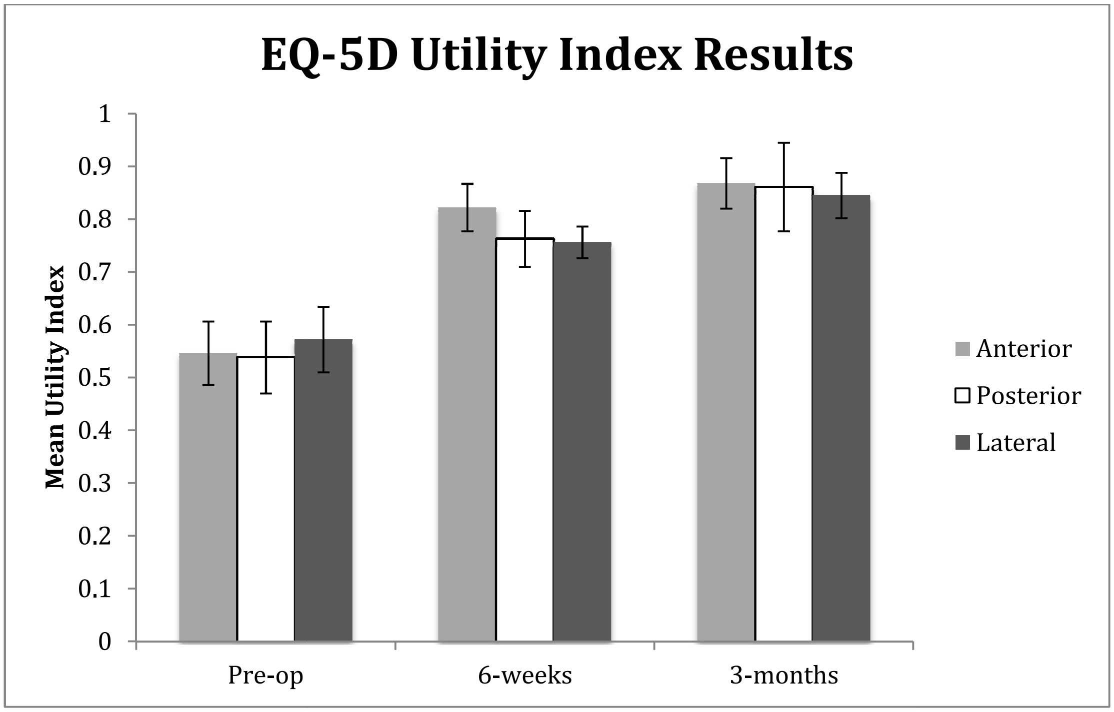

Figure 3.6 – Results of EQ-5D utility index

Mean scores for the EQ-5D utility index at all time points. Error bars represent 95% confidence intervals.

	Anterior Approach (mean +/- SD)	Posterior Approach (mean +/- SD)	Lateral Approach (mean +/- SD)	p-value
Pre-operative EQ-5D utility index	0.546 +/- 0.190	0.538 +/- 0.200	0.572 +/- 0.192	0.737
6-week EQ-5D utility index	0.822 +/- 0.136	0.763 +/- 0.142	0.756 +/- 0.086	0.051
3-month EQ-5D utility index	0.868 +/- 0.124	0.861 +/- 0.174	0.845 +/- 0.111	0.811

Table 3.11 – Descriptive statistics for the EQ-5D utility index

Descriptive statistics including means and standard deviations are outlined in the table, as well as the p-values for the one-way, between-group ANOVA for the EQ-5D utility index.

3.3.2.5 Timed up-and-go test

The results of the pre-operative, 6-week, and 3-month TUG tests can be found in Figure 3.7. The descriptive statistics for this comparison can be found in Table 3.12. There were no statistically significant differences following a one-way ANOVA between the groups for any time point for the TUG test. All group means fell under the 10-second benchmark predictive of performing activities of daily living independently after 3-months post-operatively [9].

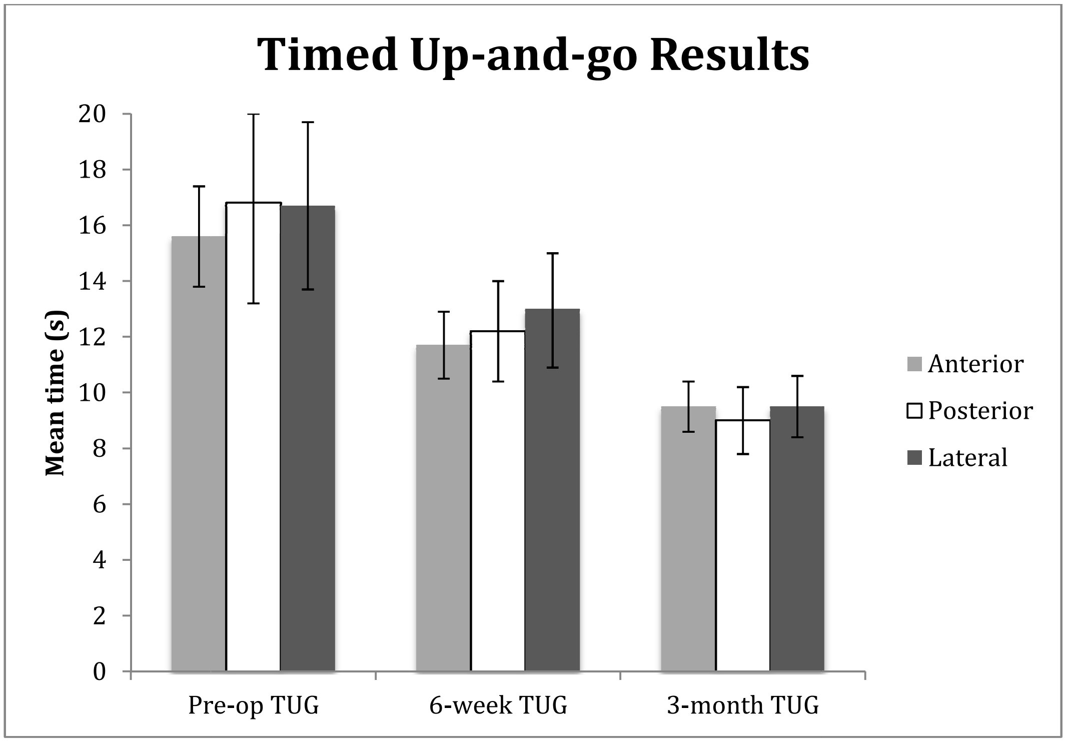

Figure 3.7 – Results of the TUG test

Mean times for the TUG test at all time points. Error bars represent 95% confidence intervals.

	Anterior Approach (mean +/- SD)	Posterior Approach (mean +/- SD)	Lateral Approach (mean +/- SD)	p-value
Pre-operative TUG test	15.6 +/- 5.7	16.8 +/- 10.6	16.7 +/- 9.3	0.783
6-week TUG test	11.7 +/- 3.5	12.2 +/- 5.0	13.0 +/- 6.3	0.559
3-month TUG test	9.5 +/- 2.4	9.0 +/- 2.4	9.5 +/- 3.0	0.802

Table 3.12 – Descriptive statistics for the TUG test

Descriptive statistics including means and standard deviations are outlined in the table, as well as the p-values for the one-way, between-group ANOVA for the TUG test.

3.3.3 Complications

Table 3.13 provides a summary of the complications documented across all three cohorts. There was a statistically significant difference in the number of nerve palsies observed in THAs performed through an anterior versus lateral or posterior approach ($p=0.001$). All 7 cases were injury to the lateral femoral cutaneous nerve resulting in symptomatic paresthesia. All cases resolved with expectant management at 3-month follow-up.

A single case of peri-prosthetic infection occurred in the anterior approach group. The patient was a 72 year-old male with a BMI of 35.56 kg/m^2 and a primary diagnosis of avascular necrosis. He had a persistently draining wound post-operatively that did not abate with community dressing changes. His initial investigations included a leukocyte count of 4.8×10^{9} / L, erythrocyte sedimentation rate (ESR) of 28 mm/h, and a C-reactive protein (CRP) of 2.3 mg/L. The infection was diagnosed 18 days post-operatively. The patient was admitted to hospital and treated with removal of the femoral stem, femoral head, and polyethylene liner, irrigation and debridement, followed by implantation of a new Corail ™ femoral stem, cobalt chrome femoral head, and highly cross-linked polyethylene liner. Intra-operative cultures grew Staphylococcus epidermidis. He received a 6-week course of intravenous cefazolin through a peripherally inserted central catheter. His latest ESR and CRP were 8 mm/h and 0.9 mg/L, respectively, 3-months following the irrigation and debridement.

The peri-prosthetic fracture occurred in a lady following a fall from standing height onto the operative hip 11-weeks post-operatively. Plain radiographs diagnosed a minimally displaced Vancouver A_L peri-prosthetic fracture based on the Vancouver classification [15]. The fracture was treated non-operatively with weight-bearing restrictions and went on to heal without further complication.

The wound complication in the anterior approach group was a stitch abscess diagnosed 4-weeks post-operatively. It was successfully treated with an incision and drainage, community dressing changes, and 2 weeks of oral cephalexin. The patient in the lateral approach group had a small dehiscence of the proximal aspect of their incision that required community dressing changes to allow for healing through secondary intent. This patient received 10 days of oral cephalexin and required no further intervention.

The complications occurring in the "Other" category were intra-operative injuries in the anterior approach group. One patient sustained an ipsilateral knee sprain during limb manipulation using the Hana ™ fracture table. A post-operative radiograph ruled out fracture around the knee, and magnetic resonance imaging (MRI) did not identify any intra-articular or soft tissue injury. The patient was successfully treated with rehabilitation. The second case was an intra-operative ankle sprain sustained during limb manipulation using the Hana ™ fracture table. Plain radiographs did not identify any fracture, and this patient also recovered well with rehabilitation. There were no medical complications throughout all three cohorts.

	Anterior Approach (n=40)	**Posterior Approach (n=38)**	**Lateral Approach (n=40)**	**Pearson Chi-square**
Nerve Palsy	7 (17.5%)	0	0	0.001
Dislocations	0	0	0	1.000
Peri-prosthetic Infections	1 (2.5%)	0	0	0.388
Peri-prosthetic Fracture	0	1 (2.7%)	0	0.332
Wound Complications	1 (2.5%)	0	1 (2.5%)	0.628
Other	2 (5.0%)	0	0	0.148

Table 3.13 – Summary of group complications

A summary of complications diagnosed across all three surgical approach cohorts during the course of the study. Significant differences between group complication rates were identified with a Pearson Chi-square.

3.4 Discussion

The purpose of this study was to determine whether surgical approach in THA has a significant impact on short-term clinical outcomes in a randomly assigned cohort. There were significant differences across the groups, primarily in functional composite scores, when comparing both disease-specific and generic clinical outcome measures. There were also significant differences in the complication rates post-operatively across the 3 surgical approaches.

The anterior approach demonstrated superior functional scores on both a disease-specific (WOMAC) and generic (EQ-5D, usual activities dimension) outcome measure at 6-weeks versus the lateral approach. Both the WOMAC and EQ-5D, unlike the HHS, are patient-reported outcome measures. This reduces the chance of expectation bias, and thus committing a type I error, associated with physician-reported outcome measures. Other studies in the literature have supported this finding when comparing 6-week functional composite scores or activities across the 3 different surgical approaches [14, 16]. Although the study was powered specifically on a WOMAC total score difference a priori, the WOMAC has demonstrated good content validity and internal consistency across the subscales (i.e. pain, stiffness, function), thus the differences are still clinically relevant [4].

There are several reasons as to why the anterior approach may provide earlier functional benefit following a THA. The anterior approach has been deemed a "muscle-sparing" approach by several authors, as it avoids the need for a large muscle tenotomy (i.e. gluteus medius in the lateral approach) or intra-muscular dissection (i.e. gluteus maximus in the posterior approach) [17, 18]. Cadaveric studies have demonstrated that less muscle damage occurs during an anterior versus posterior approach to the hip [19]. This study is limited by the use of cadaveric specimens as muscle tissue would respond differently in-vivo, particularly during soft tissue retraction to facilitate surgical exposure. Patients have reported that minimizing muscle damage during surgery would be a reason to choose a particular surgical approach over another [20]. Psychologically, this may motivate patients to get up and mobilize sooner. Knowing that they have less muscle damage to protect during daily activities may expedite functional improvement detected on clinical outcome measures.

Pain reduction following a THA performed through an anterior approach is another possible reason for earlier functional recovery. Goebel et al. studied pain perception, narcotic consumption, and length of stay in hospital in an anterior versus lateral THA cohort. They found that the anterior cohort reported significantly less post-operative pain on a visual analogue scale and less narcotic consumption following chart review, and shorter hospital stays [21]. However, our study demonstrated no difference in composite pain scores across all of the clinical outcome measures.

Another explanation for the difference may be related to the incidence of abductor tendon degeneration and atrophy following a THA through a lateral approach. Bremer et al. examined the abductor complex using MRI following THA and found a higher incidence of abductor tendinosis and gluteus medius muscle atrophy in patients having a lateral versus anterior approach at one-year post-operatively [22]. Abductor insufficiency can cause functional limitations and increased pain post-operatively [23, 24]. It is likely that the abductor insufficiency complicates certain functional activities (i.e. ascending and descending stairs), thus the discrepancy is reflected in early (6-week) functional scores rather than pain scores. This may explain why the posterior approach, which spares the abductor complex, also outperformed the lateral approach on a functional composite score. It is also important to note that 20% of patients with hip osteoarthritis may have abductor insufficiency at the time of THA [25], however, all cohorts performed similarly across pain and functional composite scores pre-operatively in our study. Finally, there were no significant differences at 3-

months, which may be because 3-months is the usual duration of musculo-tendinous healing [26], or patients have learned to adapt to functional limitations.

There were significantly more complications in the anterior approach cohort throughout the study. The incidence of 17.5% for lateral femoral cutaneous nerve palsies falls within ranges reported in the literature [27]. The high number of nerve palsies is likely due to the nerve's variable course around the anterior superior iliac spine during superficial dissection, resulting in iatrogenic injury, or during rigorous soft tissue retraction required during femoral or acetabular exposure, resulting in a tension neuropraxia [17]. Our study suggests that although injury to lateral femoral cutaneous nerve is common with an anterior approach, it has no detrimental effect on pain or function following a THA. As well, caution needs to be exercised when using a specialized table for the anterior approach. Two complications (an ankle and knee sprain) occurred as a direct result of limb manipulation using this table, which have also been described by other authors well versed in using the anterior approach [17].

Our study is not without limitations. It is difficult to perform a randomized, controlled trial using surgical procedures as the intervention. It would not of been ethical to randomize patients to one of the three approaches after they had established rapport with their assigned surgeon. This does introduce selection bias into the study design; fortunately, our groups were relatively homogeneous. This would require a multi-centre, multi-surgeon study where all surgeons were proficient in all three surgical approaches. Loss to follow-up is an obvious limitation, increasing the chance of a type II error, especially with a small sample size. However, we did account for 10% loss in our sample size calculation, which allowed for adequate numbers in the anterior and lateral groups at all time points. Every effort was taken to find out the reason for the missed appointment in order to complete the data. Once all patients have completed the required follow-up, imputation of mean values or regression will be used to complete missing data. The follow-up period was also relatively short. However, as discussed earlier, the purported functional advantages of the anterior approach occur in the first 6-weeks to 3-months in many studies, thus we felt this was a long enough time duration to satisfy our hypothesis. Lastly, the external validity of the study is limited by each approach being performed by a single surgeon from a single institution. This also introduces performance bias as some surgeons are more proficient at certain procedures than others; however, our study was designed to optimize internal validity.

Our study has several strengths. Perhaps the most important was that every patient in this study received standardized implants (see Appendix D). Femoral stem design, femoral and acetabular fixation (cementless versus cemented), and bearing surfaces can all influence clinical outcomes. For instance, cylindrical, extensively porous-coated femoral stems are known to cause an increased incidence of anterior thigh pain, which can then influence pain composite scores on various outcome measures [28, 29]. To our knowledge, standardization of all components has not been described in any other study examining the effects of surgical approach on THA outcomes. We also chose to use validated disease-specific and generic clinical outcome measures. This allowed us to gauge not only the effect of the intervention in mitigating pain and dysfunction associated with hip arthritis, but also the effect of the disease process and intervention on emotional and mental health.

3.5 Conclusion

This study examined the effect of surgical approach in THA on validated, disease-specific and generic clinical outcome measures using standardized implants. The anterior approach demonstrated superior functional outcomes at 6-weeks when compared to the lateral approach, but not the posterior approach. Complication rates, specifically lateral femoral nerve palsies, were significantly higher in the anterior approach group. Further research directions include using imaging modalities such as MRI to diagnose muscle damage and tendinosis following THA, and correlating these findings with changes seen in daily activities such as gait analysis. As well, the impact of surgical approach on component positioning and revision rates was not addressed in this study, but is an area of interest. All three surgical approaches produce positive changes that exceed the minimally important difference across various clinical outcome measures.

3.6 References

1. Charnley J. Arthroplasty of the hip. A new operation. Lancet. 1961;1:1129-32.
2. Learmonth I, Young C, Rorabeck C. The operation of the century: Total hip replacement. Lancet. 2007;370:1508-19.
3. Harris W. Traumatic arthritis of the hip after dislocation and acetabular fractures: Treatment by mold arthroplasty: An end-result study using a new method of result evaluation. J Bone Joint Surg Am. 1969;51:737-55.
4. Bellamy N, Buchanan W, Goldsmith C, Campbell J, Stitt L. Validation study of WOMAC: A health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. J Rheumatol. 1988;15:1833-40.
5. Jenkinson C, Layte R. Development and testing of the UK SF-12 (short form health survey). J Health Serv Res Policy. 1997;2:14-8.
6. EuroQol Group. A new facility for the measurement of health-related quality of life. Health Policy. 1990;16:199-208.
7. Podsiadlo D, Richardson S. The timed "Up & Go": A test of basic functional mobility for frail elderly persons. J AM Geriatr Soc. 1991;39:142-8.
8. Nankaku M, Tsuboyama T, Akiyama H, Kakinoki R, Fujita Y, Nishimura J, et al. Preoperative prediction of ambulatory status at 6 months after total hip arthroplasty. Phys Ther. 2013;93:88-93.
9. Arnold C, Faulkner R. The history of falls and the association of the timed up and go test to falls and near-falls in older adults with hip osteoarthritis. BMC Geriatr. 2007;17:1-9.
10. Wright A, Cook C, Baxter G, Dockerty J, Abbott J. A comparison of 3 methodological approaches to defining major clinically important improvement of 4 performance measures in patients with hip osteoarthritis. J Orthop Sports Phys Ther. 2011;41:319-27.

11. Light T, Keggi K. Anterior approach to hip arthroplasty. Clin Orthop Relat Res. 1980;152:255-60.
12. Hardinge K. The direct lateral approach to the hip. J Bone Joint Surg Br. 1982;64:17-9.
13. Hoppenfeld S, DeBoer P, Buckley R. Surgical exposures in orthopaedics: The anatomic approach. Philidelphia, PA: Lippincott Williams and Wilkins; 2009.
14. Restrepo C, Parvizi J, Pour A, Hozack W. Prospective randomized study of two surgical approaches for total hip arthroplasty. J Arthroplasty. 2010;25:671-9.
15. Brady O, Garbuz D, Masri B, Duncan C. Classification of the hip. Orthop Clin North Am. 1995;30:215-20.
16. Barrett W, Turner S, Leopold J. Prospective randomized study of direct anterior vs posterolateral approach for total hip arthroplasty. J Arthroplasty. 2013;28:1634-8.
17. Matta J, Shahrdar C, Ferguson T. Single-incision anterior approach for total hip arthroplasty on an orthopaedic table. Clin Orthop Relat Res. 2005;441:115-24.
18. Kennon R, Keggi J, Wetmore R, Zatorski L, Huo M, Keggi K. Total hip arthroplasty through a minimally invasive anterior surgical approach. J Bone Joint Surg Am. 2003;85:39-48.
19. Bergin P, Doppelt J, Kephart C, Benke M, Graeter J, Holmes A, et al. Comparison of minimally invasive direct anterior versus posterior total hip arthroplasty based on inflammation and muscle damage markers. J Bone Joint Surg Am. 2011;93:1392-8.
20. Dosanjh S, Matta J, Bhandari M. The final straw: A qualitative study to explore patient decisions to undergo total hip arthroplasty. Arch Orthop Trauma Surg. 2009;129:719-27.
21. Goebel S, Steinert A, Schillinger J, Eulert J, Broscheit J, Rudert M, et al. Reduced post-operative pain in total hip arthroplasty after minimal-invasive anterior approach. Int Orthop. 2012;36:491-8.

22. Bremer A, Kalberer F, Pfirrmann C, Dora C. Soft-tissue changes in hip abductor muscles and tendons after total hip replacement: Comparison between the direct anterior and the transgluteal approaches. J Bone Joint Surg Br. 2011;93:886-9.
23. Muller M, Thotz S, Springer I, Dewey M, Perka C. Randomized controlled trial of abductor muscle damage in relation to the surgical approach for primary total hip replacement: Minimally invasive anterolateral versus modified direct lateral approach. Arch Orthop Trauma Surg. 2011;131:179-89.
24. Lachiewicz P. Abductor tendon tears of the hip: Evaluation and management. J Am Acad Orthop Surg. 2011;19:385-91.
25. Howell G, Biggs R, Bourne R. Prevalence of abductor mechanism tears of the hips in patients with osteoarthritis. J Arthroplasty. 2001;16:121-3.
26. Maffulli N, Moller H, Evans C. Tendon healing: Can it be optimized? Br J Sports Med. 2002;36:315-16.
27. Goulding K, Beaule P, Kim P, Fazekas A. Incidence of lateral femoral cutaneous nerve neuropraxia after anterior approach hip arthroplasty. Clin Orthop Relat Res. 2010;468:2397-404.
28. Engh C, Bobyn J, Glassman A. Porous-coated hip replacement: The factors governing bone ingrowth, stress shielding, and clinical results. J Bone JOint Surg Br. 1987;69:45-55.
29. Nourbash P, Paprosky W. Cementless femoral design concerns: Rationale for extensive porous coating. Clin Orthop Relat Res. 1998;355:189-99.

Chapter 4

4 Surgical approach in total hip arthroplasty: A cost-analysis

4.1 Introduction

Total hip arthroplasty (THA) is a commonly performed surgical procedure for the treatment of hip arthritis. Approximately 50,000 THAs are performed on an annual basis in Canada [1]. The costs incurred to the healthcare system are tremendous, amounting to anywhere between 4.3 and 7.3 billion dollars each year (1994 Canadian dollars) [2]. Despite the substantial financial burden of THA on healthcare economics in Canada, few studies have provided accurate cost estimations of this procedure [2, 3].

Total hip arthroplasty has been the subject of cost-analysis studies. When comparing the procedure to non-operative treatment of hip osteoarthritis, THA is cost-effective, and in some instances, cost-saving [4]. Other studies have examined the impact of different bearing articulations, stem designs, and fixation methods on cost-effectiveness in THA [5-7]. However, these studies have relied on retrospective analyses of costs, and the perspective of the analyses has been unclear. Also, the impact of surgical approach on costs following THA has not been fully elucidated.

The purpose of this study was to determine the impact of surgical approach on costs in THA. This prospectively designed study will provide an accurate representation of costs following this intervention from a Canadian institution. Our hypothesis was that surgical approach would not result in significant differences in costs in patients undergoing THA.

4.2 Materials and Methods

4.2.1 Study framework

Institutional review board ethics approval was attained at Western University. Patients were recruited as per the patient enrolment and selection protocol outlined in Chapter 3. All patients were recruited from a single institution through University Hospital at Western University. A total of 118 patients were recruited to partake in the study. Patients were followed prospectively in order to provide accurate assessments of cost in patients undergoing a THA through either an anterior, posterior, or lateral approach. Each procedure was performed as outlined in Chapter 3, with all patients receiving standardized implants.

4.2.2 Study perspective

The goal of this study is to determine the impact of surgical approach on total costs for THA from a hospital, or ministry of health, perspective.

4.2.3 Boundaries of the analysis

This study's goal was to provide a cost-analysis that would impact clinical practice in both academic and community settings in Canada. Therefore, the inclusion and exclusion criteria (Table 3.1) were thought to represent the most common patient population undergoing a THA. Only THAs performed through either an anterior, posterior, or lateral approach were included.

4.2.4 Time horizon for the study

The time horizon for the cost-analysis included the time of admission to hospital to time of discharge from hospital following the procedure. The official time to admission and discharge was extracted from each patient's electronic medical record.

4.2.5 Determining costs

All costs throughout this study were acquired prospectively. A micro-costing method was used to determine all costs throughout the study. Dollar values are disseminated in 2013 Canadian dollars.

4.2.5.1 Operating room costs

The cost of the operating room time was calculated from the moment the patient entered the room, to the time they left the room to recover in the post-anesthetic care unit (PACU). A per minute direct and indirect operating room cost was acquired from the costing department at London Health Sciences Centre (LHSC). Costs applicable to the billing surgeon and anesthetist were acquired through the Ontario Ministry of Health's schedule of benefits [8]. The Inventory Control Clerk for LHSC provided the cost of implants and operating room supplies such as drapes and sutures.

There were some items that were utilized specifically for the anterior approach. Intra-operative fluoroscopy was monetized on a per minute basis, capturing the direct and indirect costs of the technician and use of the C-arm fluoroscopic machine. The cost of the radiologist reading the film post-operatively was acquired from the Ontario Ministry of Health's schedule of benefits [8]. Lead aprons were required during all anterior approach procedures in order to protect against fluoroscopic radiation. The cost of each lead apron was distributed on a per case basis using 1-year as the longevity of the item. At least seven personnel would require an apron during each case: surgeon, surgical assistant / clinical fellow, resident / medical student, anesthesia consultant, scrub nurse, circulating nurse, and x-ray technician. Approximately 130 anterior approach THAs are performed annually, resulting in the following calculation:

$700 per apron x 7 personnel = $4900 per year on aprons
$4900 per year / 130 anterior cases per year = $37.70 per case

The traction table (Hana ™ fracture table, Mizuho OSI, Union City, CA) was also incorporated into the final cost. The longevity of the table is 5-years as recommended by the manufacturer, resulting in the following calculation:

$120,000 per table / 5-year longevity = $24,000 per year
$24,000 per year / 130 anterior cases per year = $185 per case

Appendix E outlines an example of all of the costs captured during each operating room visit.

4.2.5.2 In-hospital costs

Following each operation, the patient would then be admitted to the PACU. Patient care and resource utilization costs in the PACU were represented on a per minute basis in consultation with the LHSC costing department. The length of each PACU admission was determined as the time leaving the operating room, to the time of admission to the inpatient ward. This information was gathered from paper and electronic chart review.

Following discharge from the PACU, the patient is admitted to the inpatient orthopedic ward. All patients received 24 hours of post-operative antibiotics, as well as deep vein thrombosis prophylaxis. Nursing care costs were based on an average per hour wage at LHSC. Administered medications, care items (i.e. dressing changes, urinary catheterizations), and investigations performed were recorded from paper and electronic chart review prospectively throughout each patient's admission using an In-hospital Stay Data Collection Sheet (see Appendix C). These costs were acquired from the costing department and pharmacy at LHSC. The Ministry of Health's schedule of benefits was used to determine costs for consultations from other physicians (i.e. acute pain services, internal medicine, infectious diseases, radiology). Allied health resources such as physiotherapy, occupational therapy, and social work were assigned a per-hour cost based on information from the costing department at LHSC. The time allotted for each allied health assessment was retrieved from paper chart review.

The total length of stay in hospital, including time in the operating room, was recorded from the patient's electronic chart. The in-hospital costs represented the sum of time spent in day surgery pre-operatively, time spent in PACU, plus time on the inpatient orthopedic ward. Appendix F provides a summary of the information captured during each hospital stay.

4.2.6 Statistical analysis

The association between the anterior, posterior, and lateral approaches and categorical data were evaluated by means of a nonparametric Pearson Chi-square. A one-way analysis of variance (ANOVA) was performed for continuous demographic variables such as age and body mass index (BMI).

A one-way ANOVA was used to compare various hospital metrics and cost data across the 3 surgical approaches, including operating room time, operating room costs, in-hospital costs, hospital length of stay, and total costs of the procedure. Post-hoc analysis was performed using the Scheffé test to determine significant differences between the groups when necessary. Statistical significance was set at $p<0.05$. The SPSS® v.22 (SPSS Inc., Chicago, IL, USA) was used for all analyses.

4.3 Results

4.3.1 Patient demographics

Figure 4.1 is a flow diagram outlining patient recruitment, exclusions, and completeness of intra-operative and in-hospital stay data. All 118 patients currently participating in the study had complete intra-operative and in-hospital data. Table 4.1 demonstrates patient demographics, including descriptive statistics for continuous variables. There were no statistically differences between the groups with regards to age and BMI following a one-way ANOVA. Sex, operative side, and primary diagnosis distributions were also not statistically different following Pearson Chi-square analysis.

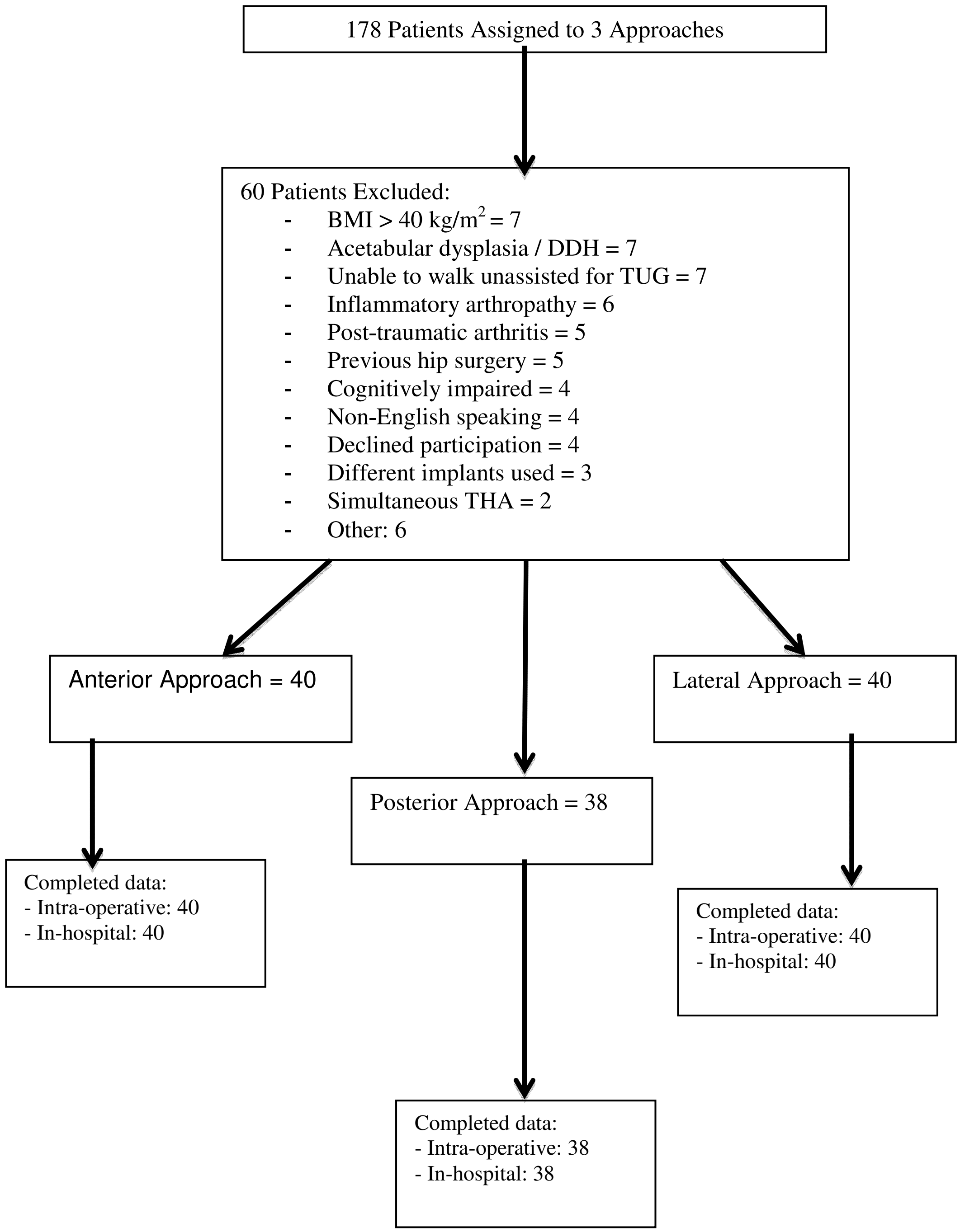

Figure 4.1 – Flow diagram for study

Demographic	Anterior Approach	Posterior Approach	Lateral Approach	p-value
Age (years)	Mean = 66.9 Std. Dev. = 9.5 Range = 42 - 86	Mean = 66.7 Std. Dev. = 9.2 Range = 44 - 84	Mean = 65.5 Std. Dev. = 10.4 Range = 42 – 92	0.792
Sex	Female = 25 Male = 15	Female = 24 Male = 14	Female = 26 Male = 14	0.971
Body Mass Index (kg/m^2)	Mean = 27.9 Std. Dev. = 4.3 Range = 20.8 – 36.4	Mean = 28.2 Std. Dev. = 5.3 Range = 16.2 – 39.9	Mean = 29.1 Std. Dev. = 5.6 Range = 19.9 – 39.9	0.541
Operative Side	Left = 22 Right = 18	Left = 18 Right = 20	Left = 18 Right = 22	0.647
Primary Diagnosis	Osteoarthritis = 37 Avascular Necrosis = 3	Osteoarthritis = 33 Avascular Necrosis = 5	Osteoarthritis = 38 Avascular Necrosis = 2	0.418

Table 4.1 – Patient demographics

Sample demographics with means, standard deviations, and ranges for continuous variables.

4.3.2 Intra-operative time and costs

The 3-group comparison for procedure time (time from cutting skin to wound closure) and total time in the operating room (time in room to time out of room) can be found in Figure 4.2. Descriptive statistics for procedure time, total time in the operating room, and time to position each patient in preparation for each procedure are included in Table 4.2.

One-way ANOVA testing revealed statistically significant differences between the groups for procedure time, total time in the operating room, and patient positioning time. Post-hoc testing demonstrated significantly shorter procedure time for the lateral versus anterior and posterior approach ($p=<0.001$ and $p<0.001$, respectively). The procedure time was also significantly shorter for the posterior versus anterior approach ($p=0.005$). Total time in the operating room was significantly shorter for the lateral versus anterior and posterior approach ($p<0.001$ and $p=0.008$, respectively). Positioning time was significantly shorter for the anterior versus posterior approach ($p=0.001$).

Intra-operative costs are disseminated in 2013 Canadian dollars for both the cost of the operating room time only (Figure 4.3), as well as the total procedural cost (Figure 4.4 and Table 4.3). A detailed breakdown of the costs acquired can be found in the Appendix C. One-way ANOVA testing revealed statistically significant differences between the groups for both operating room time costs and total procedural costs. Post-hoc testing determined that the cost of the operating room time was significantly less for the lateral versus anterior and posterior approach ($p<0.001$ and $p=0.008$, respectively). The total cost of the procedure was significantly less for the lateral versus anterior and posterior approach ($p<0.001$ and $p=0.001$, respectively), and the posterior versus anterior approach ($p=0.008$).

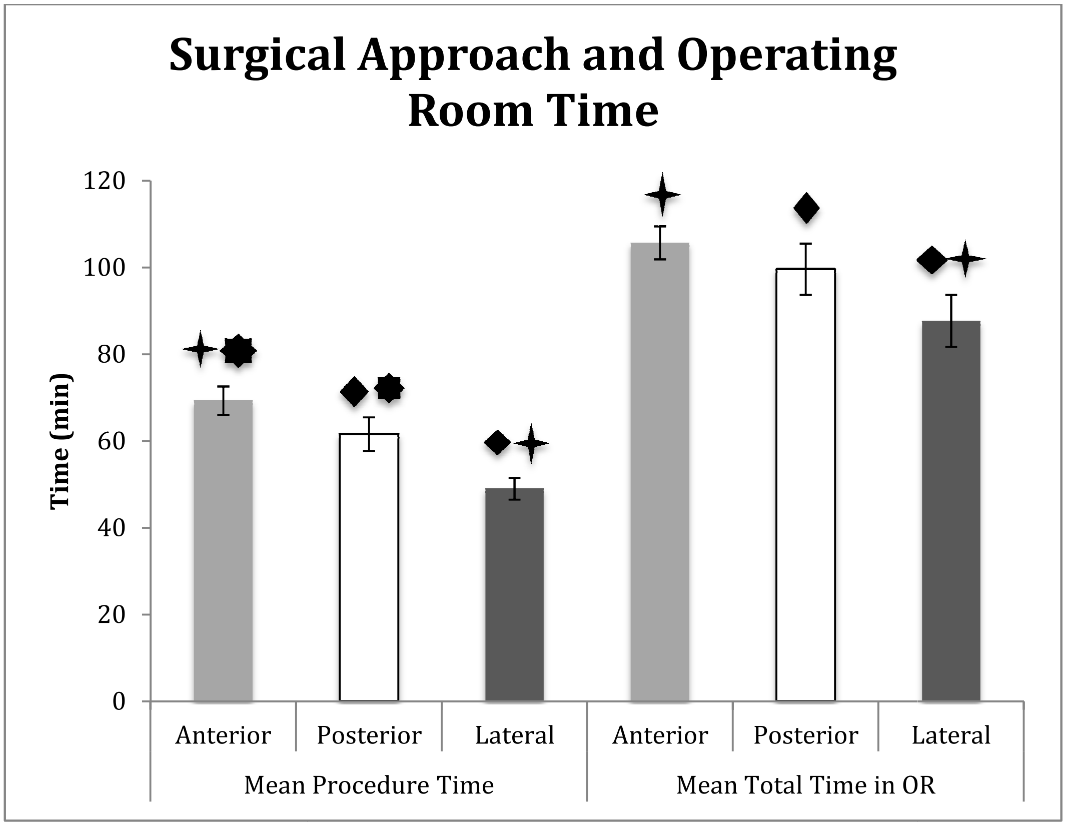

Figure 4.2 – Procedure time and total operating room time

Mean procedure time and total operating room times for each surgical approach. Error bars represent 95% confidence intervals. Pair-wise comparisons with statistical significance are denoted by symbols.

	Anterior Approach (mean +/- SD)	Posterior Approach (mean +/- SD)	Lateral Approach (mean +/- SD)	p-value
Procedure time (min)	69.3 +/- 10.1	61.6 +/- 11.9	49.0 +/- 8.1	<0.001
Total time in OR (min)	105.7 +/- 11.8	99.6 +/- 17.9	87.7 +/- 18.8	<0.001
Patient positioning time (min)	11.2 +/- 3.8	15.1 +/- 5.5	12.9 +/- 4.2	0.001

Table 4.2 – Descriptive statistics for intra-operative times

Descriptive statistics including means and standard deviations are outlined in the table, as well as the p-values for the one-way, between-group ANOVA for various operating room metrics.

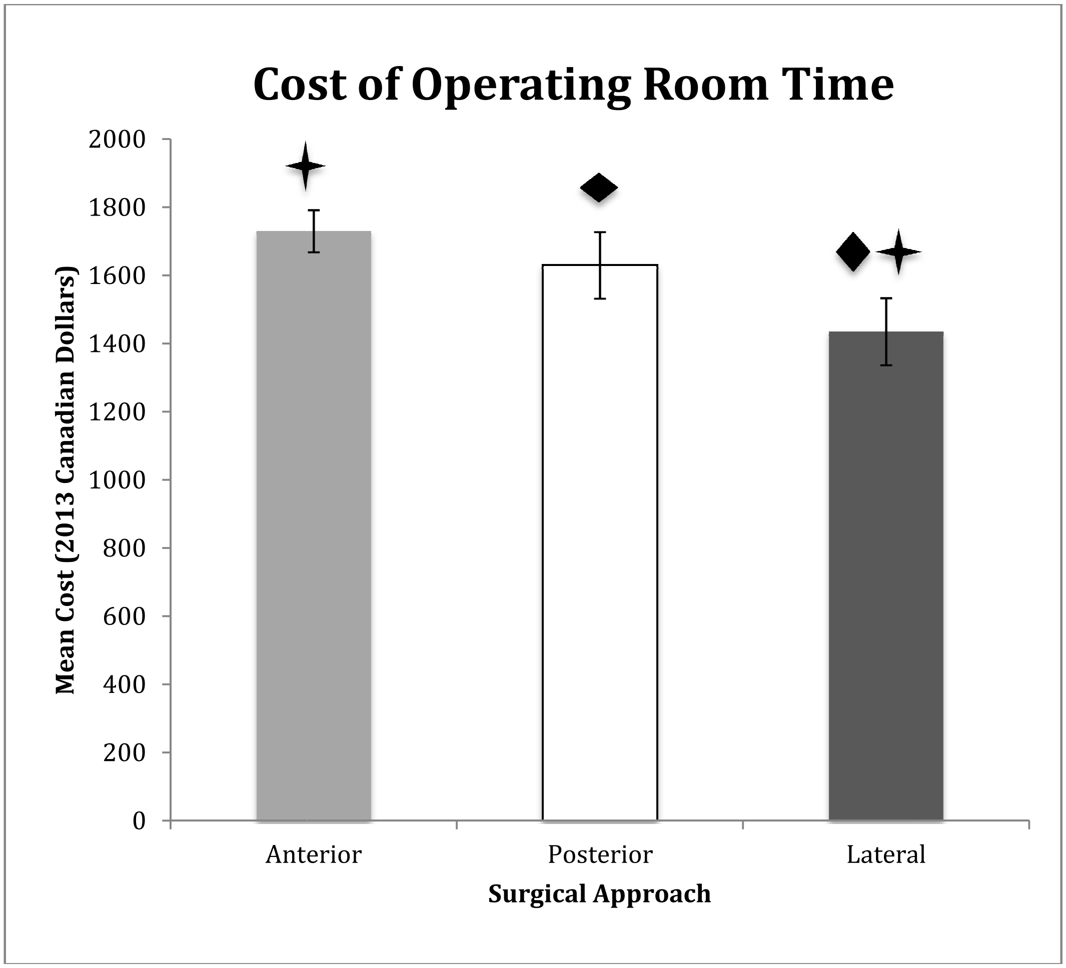

Figure 4.3 – Cost of operating room time

Mean cost of operating room time for each surgical approach. Error bars represent 95% confidence intervals. Pair-wise comparisons with statistical significance are denoted by symbols.

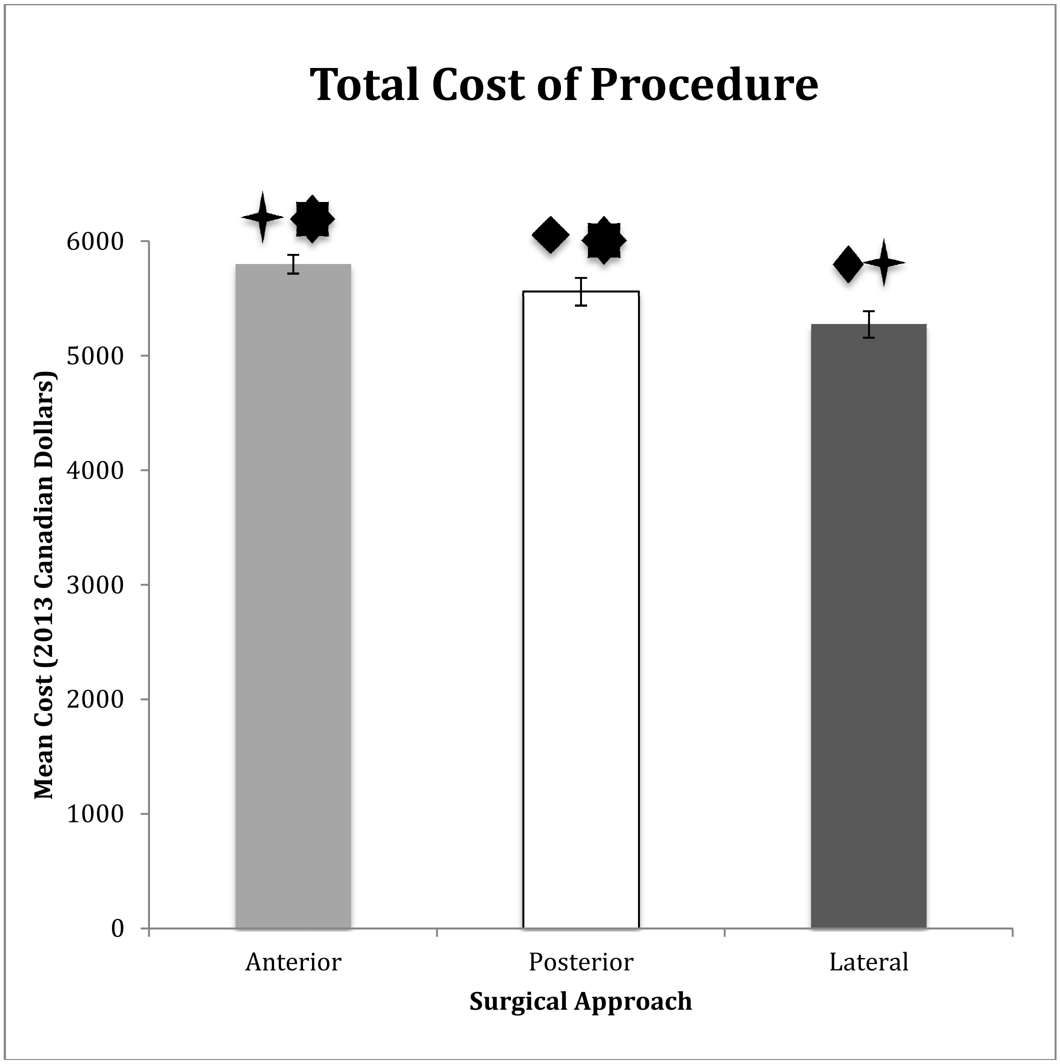

Figure 4.4 – Total procedural cost

Mean cost of the entire intra-operative procedure for each surgical approach. Error bars represent 95% confidence intervals. Pair-wise comparisons with statistical significance are denoted by symbols.

	Anterior Approach (mean +/- SD)	Posterior Approach (mean +/- SD)	Lateral Approach (mean +/- SD)	p-value
Cost of operating room time (2013 Canadian dollars)	\$1729.90 +/- 193.10 Range: \$1407.82 – 2062.62	\$1629.92 +/- 292.82 Range: \$1145.90 – 2553.72	\$1435.24 +/- 307.70 Range: \$965.83 – 2259.06	<0.001
Total cost of procedure (2013 Canadian dollars)	\$5799.79 +/- 254.12 Range: \$5412.19 – 6432.15	\$5560.24 +/- 362.36 Range: \$4959.43 – 6577.39	\$5274.39 +/- 362.22 Range: \$4735.21 – 6223.16	<0.001

Table 4.3 – Descriptive statistics for operating room costs

Descriptive statistics including means, standard deviations, and ranges are outlined in the table, as well as the p-values for the one-way, between-group ANOVA for operating room and procedural costs.

4.3.3 Hospital length of stay and costs

The 3-group comparison for hospital length of stay, as well as associated inpatient costs, can be found in Figures 4.5 and 4.6 and Table 4.4. One-way ANOVA testing demonstrated statistically significant group differences for hospital length of stay and total inpatient costs. Post-hoc testing revealed a statistically significant shorter length of stay for the anterior versus posterior and lateral approach ($p<0.001$ for both pair-wise comparisons). Length of stay was comparable between the posterior and lateral approach ($p=0.952$). The total inpatient costs were significantly less for the anterior versus lateral and posterior approach ($p<0.001$ for both pair-wise comparisons). Total inpatient costs were comparable between the posterior and lateral approach ($p=0.729$).

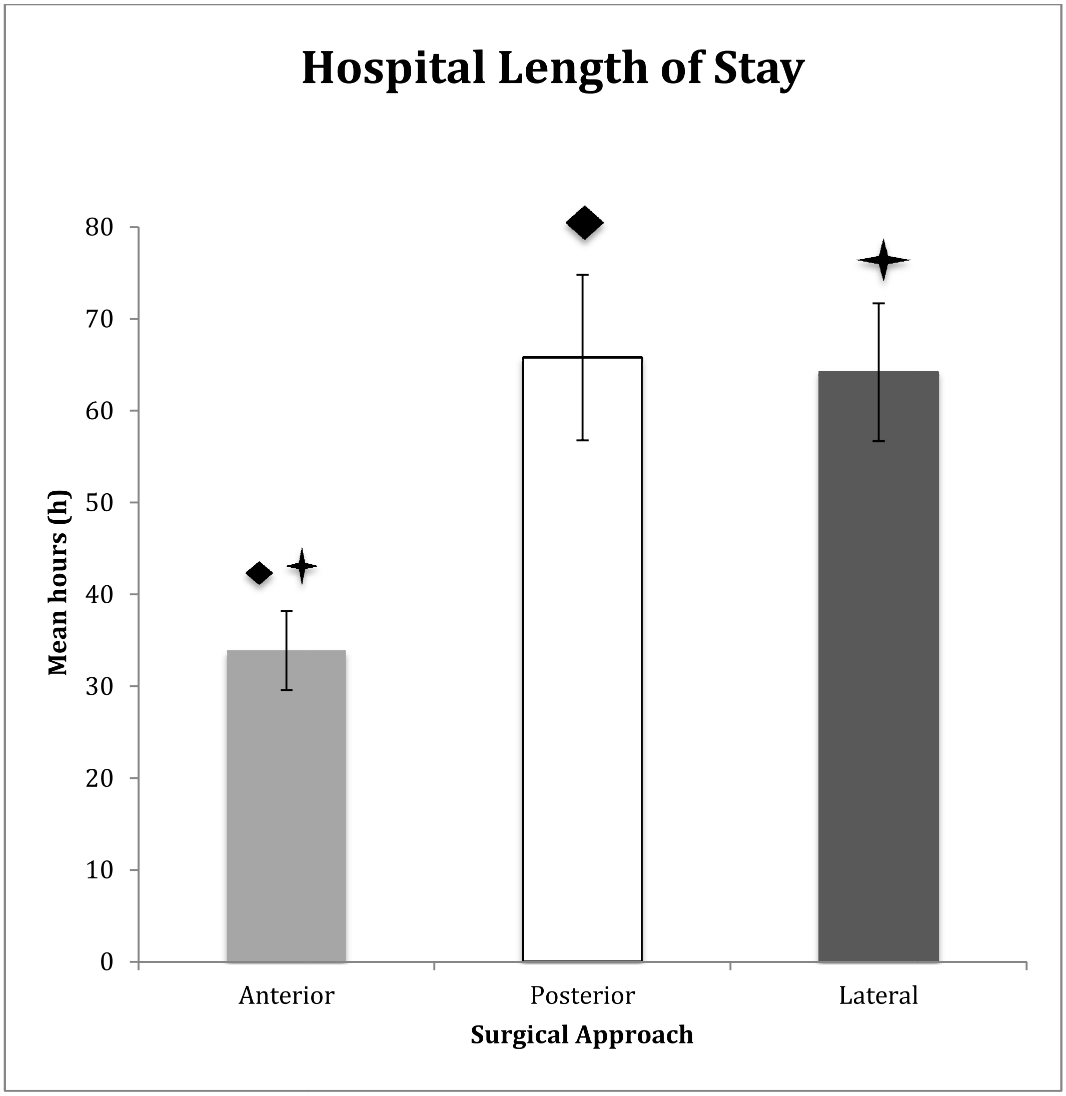

Figure 4.5 – Hospital length of stay

Mean hospital length of stay for each surgical approach. Error bars represent 95% confidence intervals. Pair-wise comparisons with statistical significance are denoted by symbols.

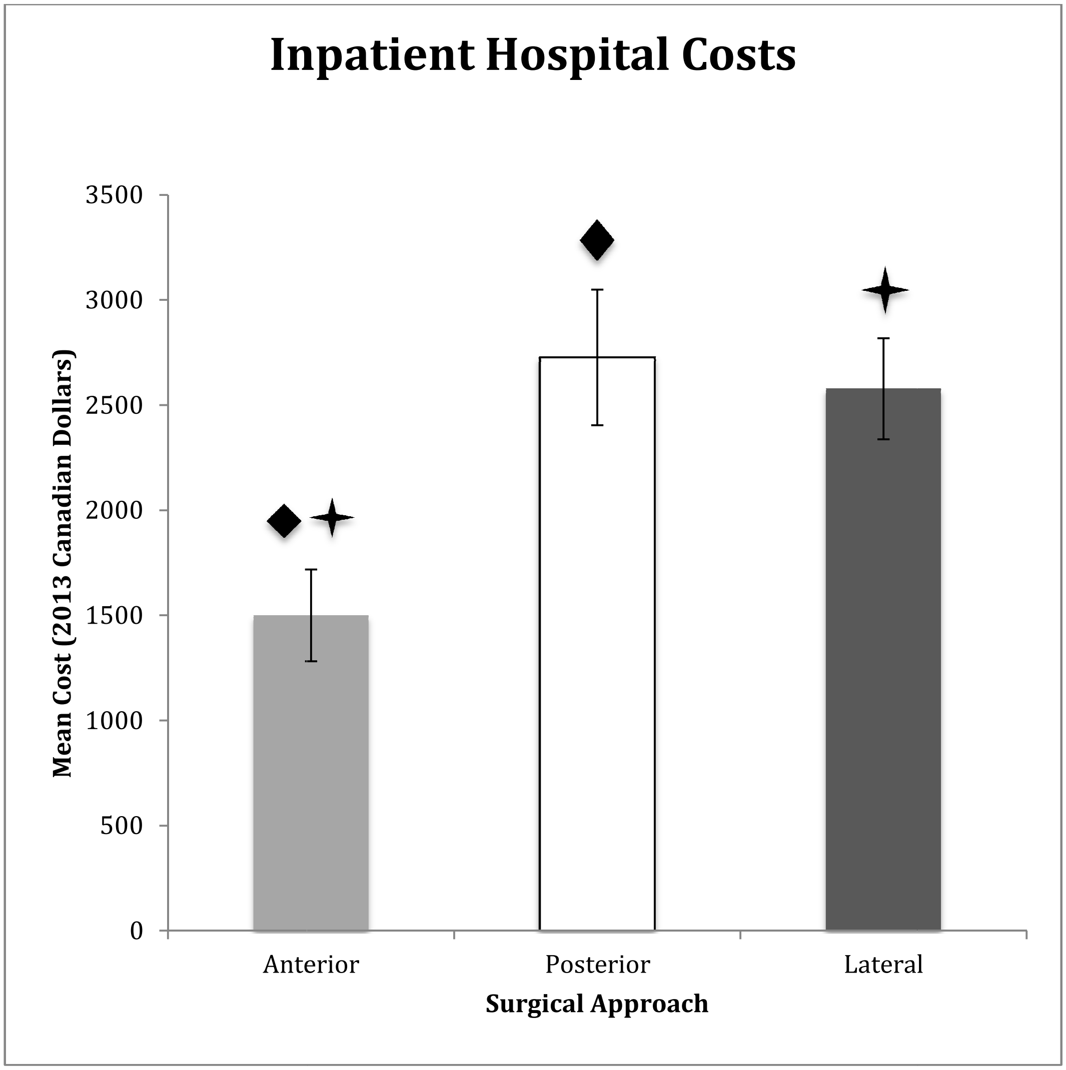

Figure 4.6 – Total inpatient hospital costs

Mean total inpatient costs for each surgical approach. Error bars represent 95% confidence intervals. Pair-wise comparisons with statistical significance are denoted by symbols.

	Anterior Approach (mean +/- SD)	Posterior Approach (mean +/- SD)	Lateral Approach (mean +/- SD)	p-value
Hospital length of stay (hours)	33.9 +/- 13.4 Range: 24.9 – 98.4	65.8 +/- 27.2 Range: 29.1 – 171.4	64.2 +/- 23.5 Range: 30.5 – 144.8	<0.001
Total cost of inpatient stay (2013 Canadian dollars)	$1500.43 +/- 683.59 Range: $1099.06 – 4994.27	$2727.22 +/- 998.28 Range: $1255.88 – 5865.66	$2578.71 +/- 751.38 Range: $1625.95 +/- 5008.66	<0.001

Table 4.4 – Descriptive statistics for length of stay and total inpatient costs

Descriptive statistics including means, standard deviations, and ranges are outlined in the table, as well as the p-values for the one-way, between-group ANOVA for hospital length of stay and total inpatient costs.

4.3.4 Total cost of total hip arthroplasty

Figure 4.7 and Table 4.5 outline the total costs of a THA from a hospital perspective. One-way ANOVA testing revealed statistically significant differences between the 3 surgical approaches for total THA costs. The anterior approach cost significantly less than both the posterior and lateral approach following post-hoc testing ($p<0.001$ and $p=0.031$, respectively). The difference in costs between the lateral and posterior approach was not significant ($p=0.124$).

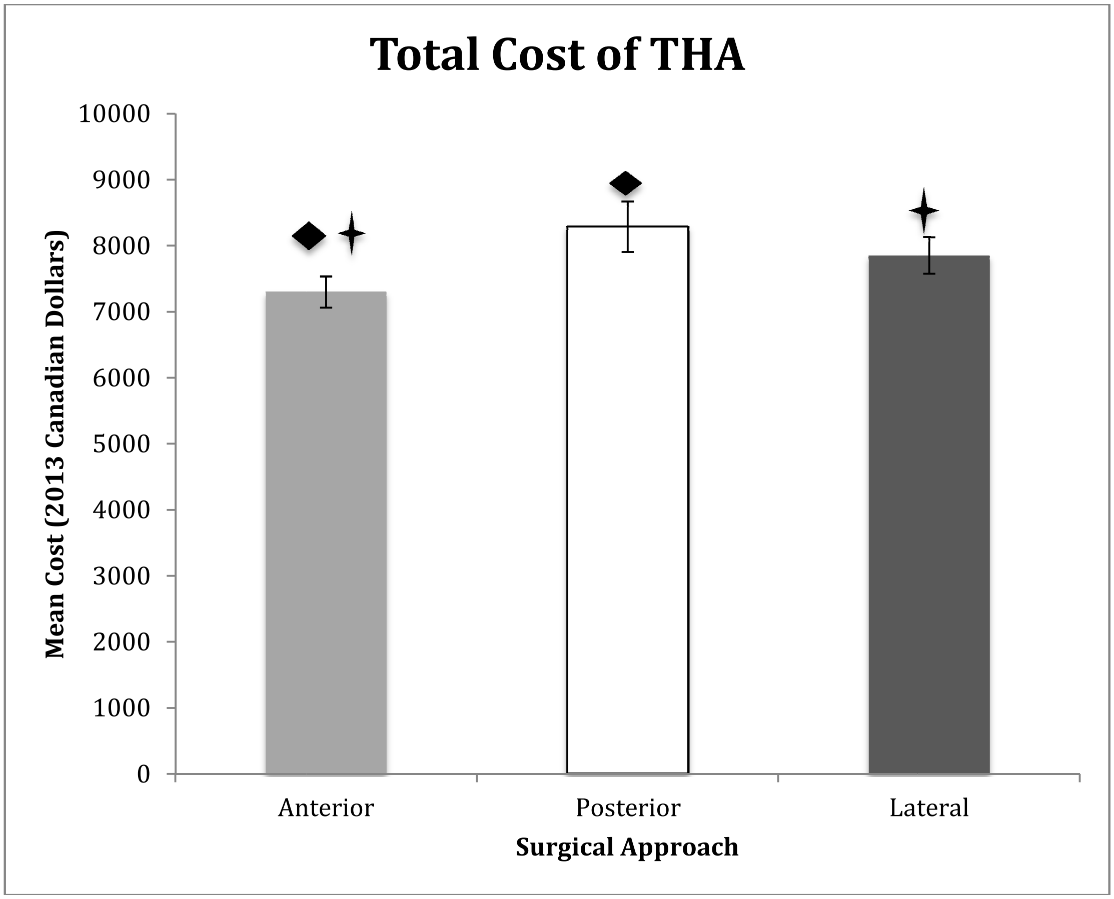

Figure 4.7 – Total cost of THA from hospital perspective

Mean total costs of THA for each surgical approach from a hospital perspective. Error bars represent 95% confidence intervals. Pair-wise comparisons with statistical significance are denoted by symbols.

	Anterior Approach (mean +/- SD)	**Posterior Approach (mean +/- SD)**	**Lateral Approach (mean +/- SD)**	**p-value**
Total cost of THA (2013 Canadian dollars)	$7300.22 +/- 737.08 Range: $6657.86 – 10677.25	$8287.46 +/- 1142.85 Range: $6797.83 – 12443.05	$7853.10 +/- 862.41 Range: $6587.21 – 10206.72	<0.001

Table 4.5 – Descriptive statistics for total cost of THA

Descriptive statistics including means, standard deviations, and ranges are outlined in the table, as well as the p-values for the one-way, between-group ANOVA for the total costs of a THA from a hospital perspective.

4.4 Discussion

The purpose of this study was to determine the impact of surgical approach on costs associated with a THA from the perspective of a hospital. A micro-costing method was used to accurately capture costs of the procedure, as well as the inpatient stay. There were statistically significant differences between the groups for procedural costs, inpatient costs, and overall costs. There were also statistically significant differences in various hospital metrics such as operating room time and length of stay in hospital.

The total cost of a THA from a hospital perspective was significantly less when performed using an anterior versus posterior or lateral approach. The mean cost savings per case when compared to the lateral and posterior groups amounts to approximately $550 to $1000, respectively. Over the course of a calendar year, that would amount to significant cost savings to a hospital.

Some of the purported disadvantages of the anterior approach are the added costs associated with using a specialized operating room table, such as the Hana TM fracture table in this study, as well as costs of using intra-operative fluoroscopy. These factors, along with prolonged mean operating room time, contributed to increased procedural costs observed in the anterior group. Hospital administrators may be reluctant to implement such a procedure due to the expensive up-front costs of the specialized table ($120,000 in 2013 Canadian dollars). Increased operating room time has been reported in other studies when comparing the anterior other surgical approaches [9, 10]. Again, administrators may find it difficult to implement this approach at the expense of potentially completing fewer cases, or running the risk of paying hospital staff overtime for prolonged cases.

However, a significant reduction in hospital length of stay translated into significant cost savings overall from a hospital perspective. Several other studies have found that having a THA performed through an anterior approach results in a significant reduction in days spent in hospital [9-12]. This may be due to many of the functional benefits of the anterior approach discussed in Chapter 3. Future studies should examine the effect of the earlier discharge from hospital from a societal perspective. Patients leaving hospital earlier may require dependence on several outpatient resources such as community care nurses for dressing changes, outpatient physiotherapy referrals, and time invested from alternative caregivers.

The mean costs reported in this study are higher than the previous reported mean costs of a THA performed in Canada by Antoniou in 2004. They reported mean costs of $6766 (2001 US dollars) from a hospital perspective, with implant costs contributing $1695 [3]. Interestingly, the mean length of stay was 7.2 days in that study. Unfortunately, a detailed breakdown of the costs were not disseminated in this study, therefore it is impossible to determine whether most of the costs were contributed through the procedure (i.e. operating room time) or inpatient stay in hospital. All of the implants were standardized in the current study, amounting to $2450 (2013 Canadian dollars) per case. It is clear from the micro-costing method utilized in this study that most of the overall costs are contributed by the total cost of the procedure.

Therefore, in order to reduce costs, hospital administrators need to look at either improving operating room efficiency or reducing the number of days patients spend in hospital. Examining the data closely, approximately 40 minutes were spent in the operating room not operating on patients. This time would include time to administer and reverse the anesthetic, and patient positioning. Literature suggests that dedicated operating room units (i.e. anesthesia and nursing staff facile in a certain procedure) can reduce operating room time and patient turnover [13]. Time spent waiting in the operating room due to patient turnover incurs tremendous costs, as the per minute rate for the operating room is substantially higher than that of the post-anesthetic care unit or orthopedic ward. Another factor to consider is day of surgery, as well as time of day when the surgery is performed. Surgery performed later in the day or on Fridays could reduce exposure to physiotherapy due to resource limitations. Dedicated rehabilitation protocols for specific procedures such as THA have been shown reduce length of stay [14]. Finally, procedures that permit earlier functional independence and reduce post-operative pain, such as the anterior approach for THA, can reduce hospital length of stay [12, 15].

The generalizability of the data is a limitation of this study. The cost data is taken from a single academic institution within a publically funded healthcare system, which would undoubtedly vary from one hospital to another and one healthcare model to another. As well, the anterior approach can be performed without the use of a specialized table or intra-operative fluoroscopy, which may have reduced costs even further [16]. Furthermore, a single surgeon from a single academic institution performed each surgical approach. Undoubtedly, other surgeons may use different instrumentation (i.e. the traction table for the anterior approach), or approach the hip differently than the steps outlined in our study. Another limitation is that the cost data is also presented using a small sample of patients with hip arthritis. Operating room time and length of stay in hospital may vary for other primary diagnoses, such as inflammatory arthropathy, post-traumatic arthritis, or developmental dysplasia of the hip. Finally, physiotherapy assessments and treatment was unblinded. This could have introduced expectation bias, thus influencing length of stay in hospital. However, weight-bearing status and discharge milestones were standardized as per our institution's discharge pathway.

Our study has several strengths. To our knowledge, this is the first study examining the impact surgical approach has on costs associated with THA. The prospective, micro-costing method ensured that cost data was captured accurately. Our hopes are that this study can then stand as a reference for gross-costing analyses in future cost-effectiveness analyses. Standardizing the implants, and thus standardizing the cost of the implants, eliminated the tremendous variability in implant costs from influencing the results [17]. Other institutions can then infer the impact on implant costs on their overall costs, assuming the other variables (operating room and inpatient costs) are similar. The detailed analysis regarding intra-operative time and inpatient length of stay will help decision makers determine where they can invest resources in order to improve cost-savings within their own institution.

4.5 Conclusion

This study examined the impact of surgical approach on costs in patients undergoing THA. The anterior approach group demonstrated significantly reduced overall costs compared to a lateral and posterior approach cohort. The cost-savings were largely amassed through a significant reduction in hospital length of stay. The micro-costing method provided an accurate estimation of THA costs from within a Canadian institution. Future studies should examine the impact of surgical approach on outpatient costs from a societal perspective, and combine effectiveness measures in a formal cost-effectiveness analysis.

4.6 References

1. Hip and knee replacements in Canada: Canadian Joint Replacement Registry 2013 Annual Report. Canadian Institute for Health Information, 2013.
2. Maetzel A, Li L, Pencharz J, Tomlinson G, Bombardier C. The economic burden associated with osteoarthritis, rheumatoid arthritis, and hypertension: A comparative study. Ann Rheum Dis. 2004;63:395-401.
3. Antoniou J, Martineau P, Filion K, Haider S, Zukor D, Huk O, et al. In-hospital cost of total hip arthroplasty in Canada and the United States. J Bone Joint Surg Am. 2004;86:2435-9.
4. Chang R, Pellissier J, Hazen G. A Cost-effectiveness analysis of total hip arthroplasty for osteoarthritis of the hip. JAMA. 1996;275:858-65.
5. Bozic K, Morshed S, Silverstein M, Rubash H, Kahn J. Use of cost-effectiveness analysis to evaluate new technologies in orthopaedics: The case of alternative bearing surfaces in total hip arthroplasty. J Bone Joint Surg Am. 2006;88:706-14.
6. Marinelli M, Soccetti A, Panfoli N, de Palma L. Cost-effectiveness of cemented versus cementless total hip arthroplasty: A Markov decision analysis based on implant cost. J Orthopaed Traumatol. 2008;9:23-8.
7. Briggs A, Sculpher M, Dawson J, Fitzpatrick R, Murray D, Malchau H. The use of probabilistic decision models in technology assessment: The case of total hip arthroplasty. Appl Health Econ Health Policy. 2004;3:79-89.
8. Ministry of Health and Long-term Care. Schedule of Benefits for Physician Services under the Health Insurance Act. 2013; Available from: http://www.health.gov.on.ca/english/providers/program/ohip/sob/physserv/physserv_mn.html.

9. Martin C, Pugely A, Gao Y, Clark C. A comparison of hospital length of stay and short-term morbidity between the anterior and the posterior approaches to total hip arthroplasty. J Arthroplasty. 2013;28:849-54.
10. Barrett W, Turner S, Leopold J. Prospective randomized study of direct anterior vs posterolateral approach for total hip arthroplasty. J Arthroplasty. 2013;28:1634-8.
11. Alecci V, Valente M, Crucil M, Minerva M, Pellegrino C, Sabbadini D. Comparison of primary total hip replacements performed with a direct anterior versus the standard lateral approach: Perioperative findings. J Orthopaed Traumatol. 2011;12:123-9.
12. Goebel S, Steinert A, Schillinger J, Eulert J, Broscheit J, Rudert M, et al. Reduced post-operative pain in total hip arthroplasty after minimal-invasive anterior approach. Int Orthop. 2012;36:491-8.
13. Small T, Gad B, Klika A, Mounir-Soliman L, Gerritsen R, Barsoum W. Dedicated orthopaedic operating room unit improves operating room efficiency. J Arthroplasty. 2013;28:1066-71.
14. Tayrose G, Newman D, Slover J, Jaffe F, Hunter T, Bosco J. Rapid mobilization decreases length-of-stay in joint replacement patients. Bull Hosp Jt Dis. 2013;71:222-6.
15. Restrepo C, Parvizi J, Pour A, Hozack W. Prospective randomized study of two surgical approaches for total hip arthroplasty. J Arthroplasty. 2010;25:671-9.
16. Lovell T. Single-incision direct anterior approach for total hip arthroplasty using a standard operating table. J Arthroplasty. 2008;23:64-8.
17. Healy W, Iorio R. Implant selection and cost for total joint arthroplasty. Clin Orthop Relat Res. 2007;457:57-63.

Chapter 5

5 General discussion and conclusions

The choice of surgical approach for total hip arthroplasty (THA) is an area of debate amongst orthopaedic surgeons. The distribution of surgical approach used for THA varies not only in Canada, but internationally [1, 2]. Several studies have sought to elicit the impact of surgical approach on clinical outcomes in THA with mixed methodologies. There is also a paucity of literature examining any financial implications of utilizing a particular surgical approach for THA from a hospital perspective. Thus, the objectives of this thesis were:

1. To compare various disease-specific and generic clinical outcome measures across the three commonest surgical approaches for THA.
2. To explore the impact of surgical approach on costs for THA.

Accordingly, our hypotheses were:

1. There will be no significant differences between the approaches across various clinical outcome measures at short-term follow-up.
2. There will be no significant differences in total costs from a hospital perspective dependent on which surgical approach was used for THA.

5.1 Surgical approach in total hip arthroplasty: The impact on short-term patient outcomes (Chapter 3)

This study examined the effect of surgical approach on a series of validated disease-specific and generic clinical outcome measures. We hypothesized that there would be no differences between the surgical approach at short-term follow-up. The results of the study rejected the hypothesis for the functional score of the Western Ontario and McMaster Osteoarthritis Index (WOMAC) questionnaire, and the usual activities dimension of the EQ-5D, at 6-weeks follow-up. The posterior approach also outperformed the lateral approach on the functional composite score of the Harris hip score (HHS). All other clinical outcome comparisons did not demonstrate statistical significance.

Several theories exist as to why the anterior approach may provide an earlier functional benefit over other surgical approaches. Commonly cited reasons include “muscle-sparing” intervals and reduced post-operative pain [3-6]. However, cadaveric studies have demonstrated that muscle damage is sustained during an anterior approach [7]. Additionally, our study did not demonstrate any significant differences in the pain composite scores across any of the outcome measures. It may be that the abductor tenotomy performed during a lateral approach produces enough abductor dysfunction to complicate some functional activities in the early post-operative course. This may explain why the posterior approach, which spares the abductor complex, outperformed the lateral approach on a functional composite score. In the future, dynamic kinematic studies can be used to demonstrate biomechanical differences during routine daily activities such as stairs and gait.

Attention needs to be given to the significantly higher complication rate observed in the anterior approach cohort. Injury to the lateral femoral cutaneous nerve resulted in symptomatic paresthesias in 17.5% of patients undergoing a THA through an anterior approach. Fortunately, injury to the nerve seemingly has no impact on clinical outcome scores following THA. This is likely because of the nerve's purely sensory innervation, resulting in no motor deficits and functional compromise following injury, and that the disease-specific outcome measures do not address nervous paresthesias in any of their questions. However, it is important that patients are made aware of this potential complication during informed consent, as complication rates of 17.5% are usually unacceptably high.

This prospective study demonstrated that there are clinical differences across the 3 main surgical approaches for THA. To our knowledge, it is the first study comparing these 3 approaches using standardized implants, the importance of which cannot be understated.

5.2 Surgical approach in total hip arthroplasty: A cost-analysis (Chapter 4)

This study examined the impact of surgical approach on costs for THA from a hospital perspective. To our knowledge, this is the first study of its kind performing a cost-analysis on surgical approach in THA. Previous cost-analyses from Canadian institutions used retrospective, database data to acquire costs for THA [8]. The prospective, micro-costing method used in this study provided accurate data that will prove useful in future cost-effectiveness analyses.

We were able to reject the hypothesis that there would be no cost differences between the 3 surgical approaches following THA. The anterior approach demonstrated significantly reduced overall costs from a hospital perspective. Despite increased procedural costs, the anterior approach reduces overall costs by significantly shortening hospital length of stay.

In order to reduce costs associated with operative procedures, hospital administrators should examine the operating room and hospital stay as two separate entities. The majority of the overall costs were incurred through the cost of the procedure. Improving operating room efficiency through the use of designated operating room units has been suggested [9]. Surgical and anesthetic expertise, competent support staff, and reducing patient turnover are all principles of this concept. The use of accelerated rehabilitation protocols and having adequate outpatient resources to support earlier hospital discharges are important considerations [10].

The use of a labour-intense, micro-costing method has provided accurate cost data comparing surgical approach for THA. Although the generalizability of the data can be questioned, the principles of cost reduction remain the same, as variables such as operating room time and length of stay in hospital are universal. Future directions include capturing outpatient cost data with long-term effectiveness measures (i.e. quality-adjusted life years) in order to perform a cost-effectiveness analysis from a societal perspective.

5.3 Conclusions

Total hip arthroplasty continues to be the cornerstone treatment modality for painful and functionally debilitating hip arthritis. The procedure produces tremendous clinically important differences in patient reported pain, function, and mental health, regardless of surgical approach. The choice of surgical approach can have a significant impact on patient reported functional outcomes, and costs from a hospital perspective.

5.4 References

1. Hip and knee replacements in Canada: Canadian Joint Replacement Registry 2013 Annual Report. Canadian Institute for Health Information, 2013.
2. Chechik O, Khashan M, Lador R, Salai M, Amar E. Surgical approach and prosthesis fixation in hip arthroplasty world wide. Arch Orthop Trauma Surg. 2013;Epub.
3. Barrett W, Turner S, Leopold J. Prospective randomized study of direct anterior vs posterolateral approach for total hip arthroplasty. J Arthroplasty. 2013;28:1634-8.
4. Restrepo C, Parvizi J, Pour A, Hozack W. Prospective randomized study of two surgical approaches for total hip arthroplasty. J Arthroplasty. 2010;25:671-9.
5. Matta J, Shahrdar C, Ferguson T. Single-incision anterior approach for total hip arthroplasty on an orthopaedic table. Clin Orthop Relat Res. 2005;441:115-24.
6. Goebel S, Steinert A, Schillinger J, Eulert J, Broscheit J, Rudert M, et al. Reduced post-operative pain in total hip arthroplasty after minimal-invasive anterior approach. Int Orthop. 2012;36:491-8.
7. Meneghini R, Pagnano M, Trousdale R, Hozack W. Muscle damage during MIS total hip arthroplasty: Smith-Peterson versus posterior approach. Clin Orthop Relat Res. 2006;453:293-8.
8. Antoniou J, Martineau P, Filion K, Haider S, Zukor D, Huk O, et al. In-hospital cost of total hip arthroplasty in Canada and the United States. J Bone Joint Surg Am. 2004;86:2435-9.
9. Small T, Gad B, Klika A, Mounir-Soliman L, Gerritsen R, Barsoum W. Dedicated orthopaedic operating room unit improves operating room efficiency. J Arthroplasty. 2013;28:1066-71.

10. Tayrose G, Newman D, Slover J, Jaffe F, Hunter T, Bosco J. Rapid mobilization decreases length-of-stay in joint replacement patients. Bull Hosp Jt Dis. 2013;71:222-6.

Appendix A: Glossary of terms

Abduction	Movement away from the center of the body
Abductor insufficiency	Weak abductor muscles around the hip causing either pain or changes in function and gait
Adduction	Movement towards the center of the body
Anteversion	Anatomic reference to something that is directed forward, or anteriorly
Arthropathy	Any condition causing articular cartilage damage resulting in joint arthritis
Arthroplasty	A surgical procedure where the articular surface of a joint is replaced by some other tissue or substance
Articulation	Contact made between two surfaces covered by articular cartilage
Capsulotomy	Incising through a joint capsule
Coronal	A vertical plane dividing the body into a front and back section
Cost-analysis	Determining the costs and financial risks and benefits of undergoing an intervention or procedure
Distal	Spatial relationship away from the trunk of the body

Extension	A straightening motion between two body parts that increases an angle formed by those two parts
External rotation	Rotation away from the center of the body
Flexion	A bending motion between two body parts that decreases an angle formed by those two parts
Fluoroscopy	The use of x-rays during a procedure
Idiopathic	Unknown pathogenesis of a disease process
Insertion	The more distal attachment site of a muscle or ligament
Internal rotation	Rotation towards the center of the body
Interval	In surgery, refers to a plane between the fascia of two different muscles, typically innervated by different nerves
Lateral	Away from the body's midline
Lateral decubitus	Patient position during surgery when they lie on their side
Medial	Closer to the body's midline
Micro-costing	A method of acquiring costs of health resources that involves attaching an exact cost to a resource consumed during an intervention

Muscle-sparing	Surgery that involves minimal dissection of muscular tissue
Neuropraxia	Injury to a nerve resulting in temporary loss of sensation or motor function supplied by that nerve
Origin	The more proximal attachment site of a muscle or ligament
Osteophytosis	Formation of osteophytes, or irregular bony prominences, as a consequence of arthritis
Osteotomy	Surgical cutting or removal of bone
Paresthesia	Sensory change, often describes as tingling or "pins-and-needles", in the distribution of a nerve due to injury or degeneration
Perspective	The targeted audience of a cost-analysis
Peri-prosthetic	Occurring around a prosthesis used during a joint replacement
Proximal	Spatial relationship towards the trunk of the body
Retroversion	Anatomical reference to something that is directed backward, or posteriorly
Sagittal	A vertical plane dividing the body into a right and left half

Subchondral cyst	A fluid-filled sac underlying a joint surface due to arthritis
Subchondral sclerosis	Thickening and hardening of the bone underlying articular cartilage due to arthritis
Surgical approach	Soft tissue dissection and working between inter-nervous or inter-muscular planes in order to reach a specific anatomic location (i.e. the hip joint)
Synovial joint	Articulation between two bones covered by articular cartilage and encapsulated by a joint capsule filled with synovial fluid
Tenotomy	Incising through or releasing a tendon from its insertion
Transverse	A horizontal plane dividing the body into an upper and lower section
Trendelenburg gait/sign	A gait pattern / physical exam finding due to weak abductor muscles where the center of gravity is shifted away from the affected leg to reduce load on the abductor muscles

Appendix B: Abbreviations list

ACR	American College of Rheumatology
ANOVA	Analysis of variance
BL	Brent Lanting
BMI	Body mass index
CK	Creatine kinase
CRP	C-reactive protein
ESR	Erythrocyte sedimentation rate
EV	Edward Vasarhelyi
FAI	Femoroacetabular impingement
HHS	Harris hip score
ICER	Incremental cost-effectiveness ratio
JH	James Howard
LHSC	London Health Sciences Centre
MCS	Mental component summary
MID	Minimally important difference

MRI	Magnetic resonance imaging
NSAID	Non-steroidal anti-inflammatory drug
PACU	Post-anesthetic care unit
PCS	Physical component summary
QALY	Quality-adjusted life year
RCT	Randomized-controlled trial
SDC	Smallest detectable change
SEM	Standard error of measurement
SF-12	Short-form 12 questionnaire
THA	Total hip arthroplasty
TUG	Timed up-and-go test
US	United States
VAS	Visual analogue scale
WOMAC	Western Ontario and McMaster Osteoarthritis Index

Appendix C: In-hospital Stay Data Collection Sheet

Surgical approach in total hip arthroplasty: Patient outcomes and impact on costs

In-hospital Stay Data Collection Sheet

Patient PIN:	
Surgeon:	JH ❑ EV ❑ BL ❑
Date of Surgery (DD/MM/YYYY):	
Date and Time of Admission (DD/MM/YYYY, HH:MM):	
Date and Time of Discharge (DD/MM/YYYY, HH:MM):	

Hospital Investigations:

Investigation	**Number of Tests**	**Date of Test (i.e. POD 1, 2, 3, etc.)**	**Other Information (i.e. +'ve/-'ve US, CT-PA to r/o PE)**
CBC			
Lytes			
BUN/Cr			
Extended Lytes			
Albumin			
LFTs			
CK/Trops			
Thyroid (TSH)			
Chest X-ray			
Abdo X-ray			
CT scan (chest, abdo, pelvis)			
Lower extremity Doppler U/S			
Urine R&M, C&S			
ECG			
Echocardiogram			
Pelvis X-ray / Hip X-ray			
Other:			
Other:			
Other:			
Other:			

Blood Transfusions: Yes ❑ No ❑ Number: ______________________

In-hospital Consultations:

Consulting Service	**Date of Consult**	**Number of Assessments**	**Intervention (i.e. additional surgery,**

			ICU admit, scope)
Internal Medicine			
Acute Pain Service (APS)			
Critical Care Team (CCOT)			
Gastroenterology (GI)			
General Surgery			
Other:			
Other:			
Other:			
Other:			

Allied-health Assessments:

Consulting Service	Date of Consult	Number of Assessments	Intervention (i.e. fit for walker/crutches, home adjustments by OT, dressing changes/home PT through CCAC, etc.)
Physiotherapy			
Occupational Therapy			
Social Work			
CCAC			
Other:			
Other:			

Dressing Changes:

Type of Dressing (i.e. Tegaderm, gauze)	Number of Dressing Changes

Complications:

Complication	Date of Complication	Intervention (i.e. antibiotics and for how long, surgery, medication, etc.)
Urinary tract infection		
Deep vein thrombosis		
Pulmonary embolism		
Pneumonia		
Wound infection		
Peri-prosthetic fracture		
Dislocated hip		
Nerve Palsy		

Urinary Retention (i.e. foley catheter/in-and-out)		
Other:		
Other:		
Other:		

Appendix D: Summary of implant selection

Study No.	*Surgical Approach*	*Acetabular Implant*	*Femoral stem Implant*
1	Anterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Standard, Collared
2	Anterior	DePuy 60mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 15 Coxa Vara Lateralized
3	Anterior	DePuy 56mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Coxa Vara Lateralized
22	Anterior	DePuy 50mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Standard Collared
24	Anterior	DePuy 54mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 9 Coxa Vara Lateralized
27	Anterior	DePuy 58mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Coxa Vara Lateralized
30	Anterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Standard Collared
31	Anterior	DePuy 54mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Standard Collared
32	Anterior	DePuy 56mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Standard Collared
34	Anterior	DePuy 60mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 14 Coxa Vara Lateralized
35	Anterior	DePuy 58mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 13 Coxa Vara Lateralized
36	Anterior	DePuy 56mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Standard Collared
37	Anterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 9 Coxa Vara Lateralized
42	Anterior	DePuy 56mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Standard Collared
51	Anterior	DePuy 62mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 15 Coxa Vara Lateralized
59	Anterior	DePuy 54mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Coxa Vara Lateralized
60	Anterior	DePuy 54mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Coxa Vara Lateralized
68	Anterior	DePuy 50mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 8 Standard Collared
70	Anterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 10 Standard Collared
79	Anterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 9 Coxa Vara Lateralized
80	Anterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 10 Coxa Vara Lateralized
87	Anterior	DePuy 58mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Standard Collared
88	Anterior	DePuy 58mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 9 Standard Collared
94	Anterior	DePuy 54mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 9 Standard Collared
95	Anterior	DePuy 60mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 14 Standard Collared
103	Anterior	DePuy 50mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 10 Standard Collared
104	Anterior	DePuy 50mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 8 Standard Collared
105	Anterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 10 Standard Collared
107	Anterior	DePuy 54mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 9 Coxa Vara Lateralized
113	Anterior	DePuy 54mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 9 Coxa Vara Lateralized
116	Anterior	DePuy 54mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 9 Standard Collared
132	Anterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 10 Coxa Vara Lateralized
138	Anterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Standard Collared
142	Anterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Standard Collared
146	Anterior	DePuy 58mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 10 Coxa Vara Lateralized
154	Anterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Standard Collared
156	Anterior	DePuy 48mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Standard Collared
157	Anterior	DePuy 48mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 8 Standard Collared
167	Anterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 8 Standard Collared
172	Anterior	DePuy 64mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 13 Coxa Vara Lateralized
5	Posterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 13 Standard Collared
10	Posterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Coxa Vara Lateralized
11	Posterior	DePuy 56mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Coxa Vara Lateralized
14	Posterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Standard Collared
17	Posterior	DePuy 50mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 8 Standard Collared
20	Posterior	DePuy 54mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 10 Standard Collared
33	Posterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Coxa Vara Lateralized
41	Posterior	DePuy 54mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 13 Standard Collared
43	Posterior	DePuy 64mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Standard Collared
45	Posterior	DePuy 50mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 10 Standard Collared
46	Posterior	DePuy 60mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Coxa Vara Lateralized
48	Posterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 9 Standard Collared
52	Posterior	DePuy 50mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 8 Standard Collared
53	Posterior	DePuy 60mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 13 Coxa Vara Lateralized
54	Posterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 10 Standard Collared
55	Posterior	DePuy 58mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Coxa Vara Lateralized
58	Posterior	DePuy 56mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Coxa Vara Lateralized
71	Posterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 9 Coxa Vara Lateralized

75	Posterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Standard Collared
76	Posterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 13 Standard Collared
98	Posterior	DePuy 50mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 9 Coxa Vara Lateralized
120	Posterior	DePuy 62mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Standard Collared
137	Posterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Standard Collared
139	Posterior	DePuy 56mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Standard Collared
147	Posterior	DePuy 50mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 10 Coxa Vara Lateralized
150	Posterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Standard Collared
155	Posterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 13 Standard Collared
159	Posterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Standard Collared
161	Posterior	DePuy 54mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 9 Standard Collared
162	Posterior	DePuy 54mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Coxa Vara Lateralized
166	Posterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Standard Collared
168	Posterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Standard Collared
173	Posterior	DePuy 58mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Coxa Vara Lateralized
176	Posterior	DePuy 54mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 10 Coxa Vara Lateralized
177	Posterior	DePuy 56mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Coxa Vara Lateralized
178	Posterior	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Standard Collared
128	Posterior	DePuy 54mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 9 Coxa Vara Lateralized
129	Posterior	DePuy 54mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 10 Standard Collared
6	Lateral	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Standard Collared
9	Lateral	DePuy 50mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 8 Standard Collared
12	Lateral	DePuy 56mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Standard Collared
15	Lateral	DePuy 50mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Standard Collared
19	Lateral	DePuy 56mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 9 Standard Collared
23	Lateral	DePuy 54mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 13 Standard Collared
25	Lateral	DePuy 58mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 10 Standard Collared
29	Lateral	DePuy 58mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 10 Standard Collared
38	Lateral	DePuy 64mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Coxa Vara Lateralized
47	Lateral	DePuy 58mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Coxa Vara Lateralized
49	Lateral	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 10 Standard Collared
61	Lateral	DePuy 56mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 10 Standard Collared
62	Lateral	DePuy 54mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Standard Collared
63	Lateral	DePuy 54mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 8 Standard Collared
64	Lateral	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 9 Standard Collared
65	Lateral	DePuy 50mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Standard Collared
66	Lateral	DePuy 50mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 9 Standard Collared
67	Lateral	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Standard Collared
72	Lateral	DePuy 54mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 8 Standard Collared
73	Lateral	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Standard Collared
77	Lateral	DePuy 54mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Coxa Vara Lateralized
81	Lateral	DePuy 56mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Standard Collared
89	Lateral	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 10 Standard Collared
90	Lateral	DePuy 58mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 13 Standard Collared
91	Lateral	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 8 Standard Collared
92	Lateral	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Standard Collared
93	Lateral	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 8 Standard Collared
99	Lateral	DePuy 50mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 8 Standard Collared
100	Lateral	DePuy 64mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 13 Standard Collared
101	Lateral	DePuy 54mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Standard Collared
102	Lateral	DePuy 60mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Coxa Vara Lateralized
106	Lateral	DePuy 60mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Standard Collared
112	Lateral	DePuy 60mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 13 Standard Collared
114	Lateral	DePuy 58mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Coxa Vara Lateralized
117	Lateral	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 12 Standard Collared
123	Lateral	DePuy 54mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 10 Standard Collared
130	Lateral	DePuy 54mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 10 Standard Collared
131	Lateral	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 10 Standard Collared
140	Lateral	DePuy 58mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Standard Collared
144	Lateral	DePuy 52mm Pinnacle Sector II Acetabular Cup	DePuy Corail Size 11 Standard Collared

Study No.	***Surgical Approach***	*Femoral head Implant*	*Polyethylene Implant*
1	Anterior	DePuy 32mm, plus 5.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
2	Anterior	DePuy 36mm, Plus 1.5 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
3	Anterior	DePuy 36mm, Plus 1.5 Articuleze Cobalt Chrome	DePuy 36mm Plus 4 Pinnacle Altrx Liner
22	Anterior	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Plus 4 Pinnacle Altrx Liner
24	Anterior	DePuy 32mm, Plus 9.0 Articuleze Cobalt Chrome	DePuy 32mm Plus 4 Pinnacle Altrx Liner
27	Anterior	DePuy 36mm, Plus 1.5 Articuleze Cobalt Chrome	DePuy 36mm Plus 4 Pinnacle Altrx Liner
30	Anterior	DePuy 32mm, plus 5.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
31	Anterior	DePuy 36mm, Minus 2.0 Articuleze Cobalt Chrome	DePuy 36mm Plus 4 Pinnacle Altrx Liner
32	Anterior	DePuy 36mm, Plus 8.5 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
34	Anterior	DePuy 36mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 36mm Plus 4 Pinnacle Altrx Liner
35	Anterior	DePuy 36mm, Plus 8.5 Articuleze Cobalt Chrome	DePuy 36mm Plus 4 Pinnacle Altrx Liner
36	Anterior	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Plus 4 Pinnacle Altrx Liner
37	Anterior	DePuy 32mm, Plus 9.0 Articuleze Cobalt Chrome	DePuy 32mm Plus 4 Pinnacle Altrx Liner
42	Anterior	DePuy 36mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
51	Anterior	DePuy 36mm, Minus 2.0 Articuleze Cobalt Chrome	DePuy 36mm Plus 4 Pinnacle Altrx Liner
59	Anterior	DePuy 32mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 32mm Plus 4 Pinnacle Altrx Liner
60	Anterior	DePuy 32mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
68	Anterior	DePuy 32mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
70	Anterior	DePuy 36mm, Minus 2.0 Articuleze Cobalt Chrome	DePuy 36mm Plus 4 Pinnacle Altrx Liner
79	Anterior	DePuy 32mm, Plus 9.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
80	Anterior	DePuy 32mm, plus 5.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
87	Anterior	DePuy 36mm, Minus 2.0 Articuleze Cobalt Chrome	DePuy 36mm Plus 4 Pinnacle Altrx Liner
88	Anterior	DePuy 36mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 36mm Plus 4 Pinnacle Altrx Liner
94	Anterior	DePuy 36mm, Plus 1.5 Articuleze Cobalt Chrome	DePuy 36mm Plus 4 Pinnacle Altrx Liner
95	Anterior	DePuy 36mm, Plus 8.5 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
103	Anterior	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Plus 4 Pinnacle Altrx Liner
104	Anterior	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Plus 4 Pinnacle Altrx Liner
105	Anterior	DePuy 36mm, Plus 8.5 Articuleze Cobalt Chrome	DePuy 36mm Plus 4 Pinnacle Altrx Liner
107	Anterior	DePuy 36mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 36mm Plus 4 Pinnacle Altrx Liner, 10 Degree
113	Anterior	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Plus 4 Pinnacle Altrx Liner
116	Anterior	DePuy 36mm, Plus 1.5 Articuleze Cobalt Chrome	DePuy 36mm Plus 4 Pinnacle Altrx Liner
132	Anterior	DePuy 32mm, Plus 9.0 Articuleze Cobalt Chrome	DePuy 32mm Plus 4 Pinnacle Altrx Liner
138	Anterior	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
142	Anterior	DePuy 36mm, Plus 1.5 Articuleze Cobalt Chrome	DePuy 36mm Plus 4 Pinnacle Altrx Liner
146	Anterior	DePuy 32mm, Plus 9.0 Articuleze Cobalt Chrome	DePuy 32mm Plus 4 Pinnacle Altrx Liner
154	Anterior	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
156	Anterior	DePuy 32mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
157	Anterior	DePuy 32mm, Plus 1.0, Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
167	Anterior	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Plus 4 Pinnacle Altrx Liner
172	Anterior	DePuy 36mm, Minus 2.0 Articuleze Cobalt Chrome	DePuy 36mm Plus 4 Pinnacle Altrx Liner
5	Posterior	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
10	Posterior	DePuy 32mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
11	Posterior	DePuy 36mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
14	Posterior	DePuy 32mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
17	Posterior	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
20	Posterior	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 54mm Pinnacle Altrx Liner
33	Posterior	DePuy 32mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
41	Posterior	DePuy 36mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
43	Posterior	DePuy 36mm, Plus 8.5 Articuleze Cobalt Chrome	DePuy 36mm Plus 4 Pinnacle Altrx Liner
45	Posterior	DePuy 32mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 32mm Plus 4 Pinnacle Altrx Liner
46	Posterior	DePuy 36mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 36mm Plus 4 Pinnacle Altrx Liner
48	Posterior	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
52	Posterior	DePuy 32mm, plus 5.0 Articuleze Cobalt Chrome	DePuy 32mm Plus 4 Pinnacle Altrx Liner
53	Posterior	DePuy 36mm, Plus 1.5 Articuleze Cobalt Chrome	DePuy 36mm Plus 4 Pinnacle Altrx Liner
54	Posterior	DePuy 36mm, Plus 1.5 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
55	Posterior	DePuy 36mm, Plus 8.5 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
58	Posterior	DePuy 36mm, Plus 1.5 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
71	Posterior	DePuy 36mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
75	Posterior	DePuy 36mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
76	Posterior	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner

98	Posterior	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Plus 4 Pinnacle Altrx Liner
120	Posterior	DePuy 36mm, Plus 1.5 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
137	Posterior	DePuy 32mm, Plus 1.0, Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
139	Posterior	DePuy 36mm, Plus 1.5 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
147	Posterior	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Plus 4 Pinnacle Altrx Liner
150	Posterior	DePuy 36mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
155	Posterior	DePuy 36mm, Plus 1.5 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
159	Posterior	DePuy 36mm, Plus 1.5 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
161	Posterior	DePuy 36mm, Plus 1.5 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
162	Posterior	DePuy 36mm, Plus 1.5 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
166	Posterior	DePuy 36mm, Plus 1.5 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
168	Posterior	DePuy 36mm, Plus 1.5 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
173	Posterior	DePuy 36mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 36mm Plus 4 Pinnacle Altrx Liner, 10 Degree
176	Posterior	DePuy 36mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
177	Posterior	DePuy 36mm, Plus 1.5 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
178	Posterior	DePuy 36mm, Plus 1.5 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
128	Posterior	DePuy 36mm, Plus 1.5 Articuleze Cobalt Chrome	DePuy 36mm Plus 4 Pinnacle Altrx Liner
129	Posterior	DePuy 36mm, Plus 1.5 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
6	Lateral	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
9	Lateral	DePuy 32mm, Plus 1.0, Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
12	Lateral	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
15	Lateral	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Plus 4 Pinnacle Altrx Liner
19	Lateral	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
23	Lateral	DePuy 32mm, Plus 9.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
25	Lateral	DePuy 36mm, Plus 1.5 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
29	Lateral	DePuy 36mm, Plus 1.5 Articuleze Cobalt Chrome	DePuy 36mm Plus 4 Pinnacle Altrx Liner
38	Lateral	DePuy 36mm, Plus 8.5 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
47	Lateral	DePuy 36mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 36mm Plus 4 Pinnacle Altrx Liner
49	Lateral	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
61	Lateral	DePuy 32mm, Plus 9.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
62	Lateral	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
63	Lateral	DePuy 32mm, plus 5.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
64	Lateral	DePuy 32mm, plus 5.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
65	Lateral	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Plus 4 Pinnacle Altrx Liner
66	Lateral	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
67	Lateral	DePuy 32mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
72	Lateral	DePuy 32mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
73	Lateral	DePuy 32mm, Plus 1.0, Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
77	Lateral	DePuy 32mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
81	Lateral	DePuy 36mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
89	Lateral	DePuy 32mm, Plus 9.0 Articuleze Cobalt Chrome	DePuy 32mm Plus 4 Pinnacle Altrx Liner
90	Lateral	DePuy 36mm, Plus 1.5 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
91	Lateral	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
92	Lateral	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
93	Lateral	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
99	Lateral	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
100	Lateral	DePuy 36mm, Plus 8.5 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
101	Lateral	DePuy 32mm, Plus 1.0, Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
102	Lateral	DePuy 36mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
106	Lateral	DePuy 36mm, Plus 1.5 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
112	Lateral	DePuy 36mm, Plus 8.5 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
114	Lateral	DePuy 36mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 36mm Pinnacle Altrx Liner
117	Lateral	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
123	Lateral	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
130	Lateral	DePuy 32mm, plus 5.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
131	Lateral	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
140	Lateral	DePuy 32mm, Plus 1.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner
144	Lateral	DePuy 32mm, Plus 5.0 Articuleze Cobalt Chrome	DePuy 32mm Pinnacle Altrx Liner

Appendix E: Summary of intra-operative costs

Study No.	*Time of Fluoroscopy (s)*	*Volume of irrigation per case*
Surgical Approach	*Procedure Time (min)*	*Cost of irrigation*
Surgeon	*Cost per min Fluoro machine and technician*	
Surgery Date	*Radiology Cost to read Xray*	*Type and Number of sutures*
Operative Side	*Cost of fluoroscopy*	*Cost of sutures*
Primary Diagnosis		
	Cautery	*Type of post-op dressing*
Procedure Time (min)	*Cost of cautery*	*Cost of dressings*
Total Time in OR (min)		
Direct cost per min OR	*Number of blood transfusions*	*Tubing*
Indirect cost per min OR	*Cost of blood transfusion*	*Cost of tubing*
Total cost per min OR		
Total Cost OR time	*Cement used? yes=1, no=0*	*Wraps*
	Cost of cement	*Cost of coban wrap*
Patient Set-up Time (min)		
Turnover time (min)		*Drape type*
	Acetabular Implant	*Cost of drapes*
Type of anesthesia	*Cost of acetabular implant*	
Spinal ($)		*Type of saw blade*
Total anesthesia time	*Femoral stem Implant*	*Cost of saw blade*
Time Units	*Cost of femoral stem*	
Basic Units (THA)		*Type of Linen*
Total Cost Anaesthesia	*Femoral head Implant*	*Cost of linen*
	Cost of femoral head	
Type of Local Anesthetic and Volume		*Type of sponge*
Cost of local anesthesia	*Polyethylene Implant*	*Cost of sponge*
	Cost of Polyethylene	
Foley catheter 1=yes, 0=no		*Gloves*
Cost of Foley	*Other Implant (s) - screws, wires*	*Cost of gloves*
	Cost of other implants	
Type of Surgical prep		*OHIP cost of THA*
Cost of prep	*Cost per case for Hana Table*	
	Cost per case for lead gowns	**Grand Total Cost of Procedure**

Appendix F: Summary of costs acquired for in-hospital stay

Study No.
Approach
Surgery Date
Date of Admission, HH:MM
Date of Discharge, HH:MM
Length of Stay (hrs)
Total PACU time (h)
Total PACU time (min)
Direct cost per min
Indirect cost per min
Total cost per min PACU
Total Cost PACU

Total OR Time (min)
Total OR Time (h)

Total inpatient time (h)
Total cost per hour
Total cost of meals
Total Cost Inpatient Time

Number of min Physiotherapy
Cost per min Physiotherapy
Cost of Physiotherapy

Number of min Social Work
Cost per min Social work
Cost of Social work

Internal Medicine (Consult, assessment)
Acute pain service (Consult, assessment)
Gastroenterology (Consult, assessment)
Infectious diseases (Consult, assessment)
Hematology (Consult, assessment)
Other (Consult, assessment)
Total cost of consultations

Number of min OT
Cost per min OT
Cost of OT

Number of blood transfusions
Cost per transfusion
Cost of transfusions

CBC tests
Cost per test
Cost of CBC

Lyte Tests
Cost per test
Cost of lyte tests

LFTs
Cost per test
Cost of LFT

BUN/Cr tests
Cost per test
Cost of BUN/Cr tests

CK/trop tests
Cost per test
Cost of CK/Trop tests

Arterial Gas tests
Cost per test
Cost of Arterial gases

INR/PTT tests
Cost per test
Cost of INR/PTT tests

Albumin tests
Cost per test
Cost of albumin tests

TSH tests
Cost per test
Cost of TSH tests

Urine R/M, C/S
Cost of Urine R/M, C/s

Foley Catheter
Cost per insertion
Cost of Foley Catheter

AP Pelvis
Cost per test
Cost of AP Pelvis

CXR tests
Cost per test
Cost of CXR tests

Ext Lyte Test

Cost per test
Cost of Ext Lyte Tests

HbA1c tests
Cost per test
Cost of HbA1c tests

Abxr Tests
Cost per test
Cost of Abxr tests

CT thorax tests
Cost per test
Cost of CT thorax tests

CT Abdo-pelvis tests
Cost per test
Cost of CT Abdo-pelvis tests

CT hip tests
Cost per test
Cost of CT hips tests

ECG
Cost per test
Costs of ECG

Bilateral US
Cost per test
Cost of Bilateral US

Knee XR
Cost per test
Cost of Knee XR

Echo
Cost per test
Cost of Echo

AP hip XR
Cost per test
Costs of AP hip XR

Unilateral U/s
Cost per test
Cost of unilateral US

Post op Abx
Cost per Dose
# of doses
Cost of Abx

DVT prophylaxis
Cost per dose
# of doses
Cost of DVT prophylaxis

Other costs

Grand Total Inpatient Costs

Curriculum Vitae

Stephen Michael Petis

Department of Surgery, Division of Orthopaedic Surgery
Western University
London, ON

Education

Master's of Science in Surgery Candidate 2014-present
Western University, London, ON

Orthopaedic Surgery Residency Training Program 2011-present
Western University, London, ON

Medical Degree 2008-2011
Michael G. DeGroote School of Medicine, McMaster University, Hamilton, ON

Honours BSciKin – Kinesiology 2004-2008
McMaster University, Hamilton, ON

Qualifications, Certifications, and Membership

Canadian Orthopaedic Association 2012-present

AO Trauma Membership 2012-present

Advanced Trauma Life Support (ATLS) Certification 2011-present

Advanced Cardiovascular Life Support (ACLS) Certification 2011-present

Licentiate of the Medical Council of Canada 2011-present

Basic Rescuer Cardiopulmonary Resuscitation 2008-present

Ontario Medical Association 2008-present

Canadian Medical Association 2008-present

Academic Awards and Accomplishments:

PSI Foundation Grant Recipient – A randomized trial comparing the direct lateral, anterior, and posterior approach: Imaging and gait analysis in total hip arthroplasty - $19,500 2013
Western University, London, ON

Lawson Health Research Institute Internal Research Fund Recipient – A 2013

randomized trial comparing the direct lateral, anterior, and posterior approach: Imaging and gait analysis in total hip arthroplasty - $20,000
Western University, London, ON

Winner of Sandy Kirkley Award for Best Clinical Science research paper at the 41st Annual Orthopaedic Surgery Residents' Research Day — 2013
Western University, London, ON

Nominated for Class of Meds '49 Award for Excellence in Teaching by Residents — 2012
Western University, London, ON

Nominated for Dr. Paul O'Byrne Achievement Award for outstanding performance during Medicine clerkship rotation — 2010
McMaster University, Hamilton, ON

Ivor Wynne Award – highest GPA in graduating kinesiology class — 2008
McMaster University, Hamilton, ON

Dr. Harry Lyman Hooker Scholarship (GPA > 3.90) — 2006-2007
McMaster University, Hamilton, ON

Dean's Honour List — 2005-2008
McMaster University, Hamilton, ON

Research Publications

Mundi, R., Petis, S., Kaloty, R., Shetty, V., and Bhandari, M. (2009). Low-intensity pulsed ultrasound: Fracture healing. *Indian Journal of Orthopaedics, 43,* 132-140.

Goldstein, C., Petis, S., Kowalchuk, M., Drew, B., Petrisor, B., and Bhandari, M. (2010). Radiologic assessment of lumbar spine fusion: Is it confused? *The Spine Journal, 10, pS71.*

Petis, S., Howard, J., Somerville, L., McCalden, R., MacDonald, S., Naudie, D., & McAuley, J. Comparing the long-term results of two uncemented femoral stems for total hip arthroplasty. *Journal of Arthroplasty, Epub.*

Petis, S., Vasarhelyi, E., Somerville, L., Howard, J. Mid-term comparison of cobalt chrome, ceramic, and Oxinium ™ on highly cross-linked polyethylene bearing surfaces in total hip arthroplasty. (accepted for podium presentation at COA annual meeting, 2013).

Podium Presentations

Petis, S., Howard, J., Somerville, L., McCalden, R., MacDonald, S., Naudie, D., & McAuley, J. Comparing the long-term results of two uncemented femoral stems for total hip arthroplasty. July 2013, Winnipeg, Manitoba. Canadian Orthopaedic Association Meeting.

Petis, S., Vasarhelyi, E., Somerville, L., Howard, J. Mid-term comparison of cobalt chrome, ceramic, and Oxinium ™ on highly cross-linked polyethylene bearing surfaces in total hip arthroplasty. July 2013, Winnipeg, Manitoba. Canadian Orthopaedic Association Meeting.