Title

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Introduction:

Osteoarthritis is the most common form of chronic arthritis, and the hip is the most common large joint affected.[1] Osteoarthritis is also the most common indication for joint replacement. It accounts for 95% of all Medicare funded hip and knee replacements.[2] Medicare spends more money on primary and revision joint replacements than any other inpatient procedure.[3] In addition, osteoarthritis is the leading cause of disability in the elderly.[4] While there is currently no cure for osteoarthritis, a variety of treatments exist to reduce pain and improve function. Total hip replacement can indeed alleviate pain and restore function; however, it is also associated with risks, complications, needs for revisions, added cost, and often does not prolong life.[5]

Non-surgical management consists of education, weight loss, physical therapy, acupuncture, electrotherapy, and anti-inflammatories. Anti-inflammatories include topical NSAIDs, acetominophen, oral NSAIDS, COX-2 inhibitors, and intra-articular corticosteroid injections. These interventions have all been shown to relieve pain and preserve function compared with placebo to varying degrees. [6] [7]

Total hip arthroplasty (THA) is often considered when non-surgical treatments fail. THA consists of a femoral stem, femoral head, acetabular liner, and acetabular shell. Long-term success of THA is dependent on prosthetic component fixation and the amount of wear and debris generated by the bearing surface. The femoral head is usually made of metal, and the acetabular liner is most commonly made of metal, polyethylene, or ceramic. Fixation is achieved with cement of porous material that encourages bony in growth.[8] Resurfacing hip arthroplasty is a procedure that preserves and resurfaces the arthritic femoral head and acetabular bearing surface. It is often used as an alternative to THA in younger patients.

As the population of the developed world ages, the number of elderly patients with osteoarthritis is increasing as well as their use of THA.[9] The increased use of THA in the treatment of osteoarthritis does not come free to society however. It is estimated that by 2030, Medicare may spend $50 billion dollars on joint replacements alone.[10] Different nations have approached this public health problem in different ways. The United Kingdom developed a National Joint Registry to track the success of joint replacements and has employed controlled and nationalized rationing of the supply of THA. In contrast, the United States has relied on localized and private joint registries to track the success of joint replacements. The United States has left the supply of THA up to market forces and allowed physicians and patients to be more autonomous in their decision to pursue joint replacement.

As the world's population ages and the developed world seeks to determine how to best care for its aging population, the determination of the value of total hip replacements is becoming more critical and pressing. This paper reviews the recent literature describing the indications, comparative cost effectiveness, and comparative effectiveness in reducing pain, prolonging survival, and improving function and quality

of life of THA in the treatment of osteoarthritis patients over age 65. This paper also compares the public health approach of the United States and United Kingdom in the treatment of osteoarthritis in their elderly population to shed light on different approaches to the same problem.

Methods:

A pubmed search of studies published from 1997 to present describing the treatments of osteoarthritis, indications for THA, effectiveness of osteoarthritis treatments, and cost effectiveness of osteoarthritis treatments was performed. A pubmed search of studies related to joint registries, overall use, cost, and inequality in use of THA in the United States and United Kingdom from 1997 to present was also performed. OECD's iLibrary was also used to estimate total numbers of THA performed in the elderly population in the United States and United Kingdom. The Dartmouth Atlas Study was referenced to determine regional variation in the use of THA in the United States.

Indications:

The indications for THA have generally been considered persistent pain and disability refractory to non-surgical interventions; however, it has been difficult to define more specific levels of pain and disability or timing in the course of osteoarthritis when THA is indicated. There is wide variation in the indications used for THA in the treatment of osteoarthritis amongst surgeons and referring physicians in practice.[11 12] Race, gender, socioeconomic status, access to care, willingness to undergo surgery, surgeon preference, and health care system have also been shown to play a role in the decision to use THA in the treatment of osteoarthritis.[13 14 15 16 17] Recently, some studies have suggested that THA may be more appropriate before osteoarthritis progresses to become severe; however, the evidence is not universally successful, and the complications associated with the procedure as well as the necessity for later revisions with early surgery have prevented this approach from becoming common practice.[18 19 20 21]

A recent large international observational study confirmed that presently there are very vague indications for THA in osteoarthritis. In 2004, an international working group was created by the Outcomes Measures in Rheumatology Clinical Trials (OMERACT) and Osteoarthritis Research Society International (OARSI) to create a composite index that could define states of osteoarthritis severity in hopes that outcomes to disease modifying osteoarthritis drugs could be measured. As part of their project, they sought to define pain and physical function endpoints that would, coupled with structural severity, define an equivalent measure of "need for joint replacement surgery" as an outcome. The group performed an international observational cross-sectional study amongst orthopedics departments of tertiary-care and secondary-care centers in Europe, North America, and Australia, amounting to a total of 779 patients with hip osteoarthritis. The data was compiled from the placebo arm of 8 randomized controlled trials assessing disease modifying osteoarthritis drugs. Level of pain and physical function were assessed as indications for THA, and the results were subsequently stratified on radiographic severity.[22] While patients recommended for THA had higher levels of pain

and worse disability levels, there was so much overlap in pain and disability level between patients with and without indication for THA that it was not possible to determine meaningful endpoints for pain and function to define a "theoretical indication for THA." The most discriminatory endpoint found was the least stringent criteria assessed [pain (0-100) + physical function (0-100) > 80 for more than 2 consecutive visits].[23]

The group found inconsistency between radiographic and clinical progression of osteoarthritis in the vast majority of patients, which hindered their ability to define indications for THA. The group found that only 2-12% of patients had both high levels of pain and disability in addition to radiographic progression of disease.[24] The degree of radiographic progression was not statistically significant as an indicator for THA; thus, when combined with symptomatic progression, it did not help discriminate between the endpoints of pain and physical function assessed. The study determined that a very large numbers of patients would be required to determine an indication for THA based on radiographic progression in combination with symptomatic progression of osteoarthritis.[25]

The study's primary limitation was its retrospective use of databases from randomized controlled trials. Randomized controlled trials for disease modifying osteoarthritis drugs tend to enroll patients with mild symptoms and slow progression of disease so that patients are less likely to drop out of the study due to pain. This may not be the best population to study indications for THA as it may miss many of the patients with severe symptoms. Furthermore, while all the studies included had regular follow-up of symptoms and radiographic progression, the time frame for this follow up, the inclusion criteria, and the patient specific characteristics such as rescue medication use differed significantly and could not be controlled for.[26] In addition, these results were not specific to the elderly population as most randomized trials included used age inclusion criteria greater than 40-45 years of age.[27]

While this study did have limitations, the weak correlation between radiographic progression of disease and level of pain and disability in osteoarthritis has been well recognized. In 2009, Paul Dieppe et al. published similar results in a prospective cohort study of 1520 patients with mean age of 69 across 20 orthopedic centers in Europe. The study found that the severity of pain and disability varies widely at the time of THA for osteoarthritis from mild to very severe disease. [28] In addition, while most patients had severe structural changes, clinical severity was not correlated with radiographic severity. They also reported that severity of symptoms at the time of surgery was associated with differences in educational status, employment status, age, sex, weight, and general health. They proposed that scores of pain and disability (WOMAC and K&L score for radiographic severity) do not accurately reflect the complex decision making that determines who should have a THA.[29] The findings were fairly consistent across the countries and centers studied. The study's weaknesses were that the orthopedic centers were self-selected, and thus, it may not have included a representative sample of patients. The variation in country and healthcare system amongst the population could have also introduced other variables unaccounted for.

Effectiveness:

In this section, the effectiveness of THA in improving pain, physical function, quality of life, and prolonging survival in elderly patients with osteoarthritis of the hip will be examined.

The goal of therapy for osteoarthritis is to relieve pain and preserve function, and while there is no cure for osteoarthritis, there are a variety of treatment options discussed in the introduction that attain these goals. THA has been well established as a safe, effective short-term treatment for healthy elderly patients through retrospective and prospective cohort studies despite longer recovery times; however, there have been no randomized controlled trials comparing it to more conservative treatments and few long-term studies. There have been few trials comparing different hip prostheses, and decisions regarding the superiority of different prostheses have largely been made based on retrospective data from joint registries. Current literature suggests that metal-on-polyethylene prostheses are the best choice in the elderly population. HRA should not be used in the elderly population because it has not been shown to provide significant benefit compared to traditional THA in the younger population and has not been studied in the elderly population.

There are many validated ways to measure quality of life. The most commonly used are the WOMAC and the SF-36. The WOMAC is a disease-specific measure that was developed for patients who have knee or hip osteoarthritis, and it measures pain, stiffness, and physical function. The SF-36 is a more generic quality of life outcome measure that measures physical function, role-physical, pain, general health, vitality, social functioning, role emotional, and mental health.

Pain, Physical Function, and Quality of Life: Short term

The consensus is that age should not be a barrier to THA in elderly patients that are good surgical candidates. The current literature suggests that increased co-morbidity rather than older age is associated with worse outcomes. The current literature based largely on prospective cohort studies consistently shows short-term (6 months-3 years) improvement in pain and health related quality of life with THA in the elderly population similar to that of younger populations. There is some evidence that gains in physical function may be more modest in the elderly population. Jones et al. showed comparable improvements in pain, physical function, and health related quality of life compared to younger cohorts (55-79 years of age) with equivalent co-morbid conditions. [30] Fitzgerald et al. found similar improvements in physical function in the elderly population above 75 years to that of the younger population 50-75 years of age when controlled for pre-operative physical function and co-morbid conditions. Their study found that pre-operative physical function was the greatest predictor of post-operative physical function. Furthermore, Fitzgerald et al. found that the elderly population had greater improvements in pain than the young population.[31] In contrast, AK. Nilsdotter and LS. Lohmander performed a prospective cohort study that matched pre-operative SF-36 and WOMAC scores and found that younger patients had greater improvements in physical function

than older patients; however, this study did not control for co-morbid conditions. The study found that both age groups had similar improvements in pain.[32]

Studies comparing the young elderly population and the older elderly population have found similar improvements in pain, health related quality of life, and physical function with THA. Hamel et al. found similar outcomes and recovery time in the 65-75 age group as the greater than 75 age group in a prospective cohort study of patients with severe OA of the hip or knee refractory to medical therapy.[33] Even in patients greater than 89 years of age, Berend et al. found significant improvements in pain, physical function, and health related quality of life short term after THA.[34] Berend et al. also found no increase in mortality between patients who underwent THA and a reference population of individuals in their 90s for 2.5 years after surgery.[35]

However, it must be noted, that many of these studies are limited in that the patients are not randomized but rather the elderly patients are selected for surgery. It is likely that only the elderly patients that are the best surgical candidates are undergoing THA in these studies. Thus, what can be concluded from current literature is that THA is an effective short-term treatment in the healthy elderly.

Elderly patients have been consistently shown to have longer recovery times after THA however. This has been quantified as longer lengths of stay, increased needs for rehabilitation facilities, or longer time to regain optimal physical function.[36] [37] [38] JN Katz et al. conducted a prospective cohort study of Medicare patients and found that the odds of hospitalization increased by 22% with every increase in 5 years of age, by 17% with each additional co-morbid condition, and by 14% with each 1 unit increase in activity limitation score.[39] Thus, elderly patients will likely require more resources and time to derive the same benefit from THA as a younger population.

Some studies argue that excellent short-term results are the most important in an elderly population that has a limited life span, and efforts should be focused on optimizing short-term outcomes. In a recent 12-year retrospective study of 51, 347 Medicare beneficiaries who had THA, the risk of dying was found to far exceed the risk of revision. The study found that because patients had a limited lifespan, they had very limited risks of revision. Patients aged 65-75 faced a 10% absolute risk of revision while patients aged above 75 faced a 6% absolute risk of revision.[40] This study was limited in that it did not identify patients who were in need of revision but unable to get it due to high peri-operative risk; however, it did not find a relationship between co-morbidity and risk of revision. It also did not address the physical functional status of patients.[41]

Pain, Physical Function, and Quality of Life: Long term

Despite proponents for maximizing short-term outcomes, others argue that increasing longevity among the elderly population demands an evaluation of the long-term outcomes of THA not only with regards to revision risk but also physical function outcome. Unfortunately, the studies of long-term effectiveness of THA in the elderly population are limited, and the results are conflicting. The literature consists of prospective cohort studies and epidemiological data that infrequently look specifically at the elderly population.

Bruyere et al. found that the short-term improvements in quality of life after joint replacement surgery were sustained 7 years later. Bruyere et al. conducted a prospective

cohort study examining health related quality of life in 22 patients who underwent THA and 17 patients who underwent TKA for osteoarthritis with mean age of 67.3 years for those who underwent THA.[42] The group found that pain and physical function, measured by both the WOMAC and SF-36 scores, were improved significantly 6 months after surgery. For 7 years post-operatively, SF-36 scores showed a significant improvement in physical function, role-physical, role-emotional while all WOMAC scores (pain, stiffness, and physical function) also improved. The group noted no statistical difference in WOMAC and SF-36 scores between the TKA and THA replacement groups.[43] This study has several limitations. It is a single center study with small sample sizes despite statistically significant results. In addition, it combines THA and TKA patients and does not separately address the elderly population.

Cushnaghan et al. found similar long-term benefits of THA in a prospective cohort study of 282 osteoarthritis patients from 2 English health districts with 8-year follow-up after THA. 295 controls were selected from the general population and the SF-36 questionnaire was used to assess quality of life. The study found that at baseline, the case group reported significantly worse physical functioning than the controls but similar vitality and mental health. By follow-up approximately 8 years later, the physical functioning of the cases had significantly improved while that of the controls had worsened.[44] However, vitality significantly deteriorated in the case group compared to the control group, and mental health improved to a similar extent in both groups. This study looked specifically at subjects with age $\geq$ 66.88, and found that older age was associated with poorer outcome in both case and control groups. Because of the poorer outcome in controls, the study concluded that older age did not indicate a worse response to surgery.[45] This study has several limitations. It is a cohort study; the subjects were not randomized, and the controls did not have osteoarthritis and were recruited from the general population. Thus, it can not be assumed that the cases' health related quality of life would have been similar to the controls had they not undergone surgery. Furthermore, there was incomplete follow up of cases and controls. The subjects lost to follow up in the case group were significantly older and had more deaths.[46]

In contrast, Rat et al. showed that health related quality of life gains in the short term after THA are time limited and that a high mean age at surgery may lead to a lower long-term quality of life. The study followed health related quality of life measurements in THA and TKA patients with mean age of 73 years for 3 or 10 years in two different cohorts compared to a reference population. The study found that quality of life significantly declined between 3 to 10 years after surgery. The study found that the SF-36 scores for the 3-year cohort improved as early as 6 months post-operatively and up to 1 year, and then plateaued at 3 years.[47] The study found that 3 years after joint replacement, the physical functioning and role dimensions of health related quality of life were limited compared to the reference population. At 10 years after joint replacement, the study found that all dimensions of health related quality of life were markedly lower than the reference population. In contrast to previous studies, this study also found that a high mean age at surgery was associated with lower quality of life at follow up controlling for co-morbidities.[48] However, this study also has limitations. The biggest being that the sample size of the 10-year cohort is too low to be statistically significant due to loss to follow up from death and migration. Furthermore, there are significant differences between the responders and non-responders in the 10-year cohort. In

addition, the cohorts were recruited at different times, completed difference quality of life questionnaires (SF-36 in the 3 year cohort and NHP in the 10 year cohort), and underwent joint replacement at different times.[49] The indications for THA may have changed across the two time periods with older patients and patients with less impaired quality of life likely undergoing arthroplasty with greater frequency in the later cohort.

Among the literature that suggests that THA may have long-term limitations is epidemiological literature. Most population studies suggest that a significant number of patients who have undergone past hip replacement have considerable pain in the replaced joint upon long-term follow up. In a study of 5500 Oxfordshire residents aged 65 years and older, Dawson et al. found that patients who had undergone past joint replacement surgery were twice as likely to report current joint pain.[50] In a cross-sectional survey of 5500 patients aged 65 years and older, Linsell et al. found that 35% of replaced hips are currently symptomatic.[51] These studies obviously have limitations because there is no data collected on how long ago the patients had their hips replaced, details of the surgery or prosthesis, or information on the improvement or worsening of their pain over time. However, a recent systematic review of prospective studies in unselected patients echoed the findings of these population based studies. It estimated that anywhere from 7%-23% of patients who undergo THA have chronic pain.[52]

There is consensus that THA is a safe procedure associated with a small increase in short-term mortality, and it seems that co-morbidity increases this short-term mortality more so than age. There is consensus that THA is associated with a small increase in short-term mortality within the first 20-30 days after surgery. [53] [54] [55] [56] Several observational studies have shown that this mortality increases with age; however, these studies did not control for co-morbidities.[57] [58] [59] Other studies that try to control for co-morbidities show that there is no increased mortality with age.[60] [61] [62] Thus, it seems that the consensus for patient selection is clinical judgment of the overall fitness, health, and co-morbidities of the patient.

The effects of THA on long-term mortality in the elderly population are less clear. A recent Danish epidemiological study evaluated long-term mortality after THA in osteoarthritis patients for up 12.7 years and found lower long-term mortality rates in the elderly population. This study was limited because its control group had significantly more co-morbidities than its THA group. The study ultimately concluded that the increased mortality associated with surgery must be offset by patient selection for surgery, arguing that it is very difficult to distinguish between the effects of the surgery, patient co-morbidity, age, and selection for surgery on mortality. In the first study to follow patients greater than 20 years, Visuri et al. found decreased mortality for the first two decades after THA, but increased mortality due to cardiovascular disease thereafter in the THA population compared to the general population. This study postulated that increased mortality may be due to metal debris deposited in the myocardium. While this study only included 2164 patients, it raises concerns about the effect of THA on long-term mortality, especially in a young elderly population who may live to feel these effects.[63]

With appropriate patient selection, THA is an effective and safe short-term treatment of osteoarthritis in the elderly population; however, more studies are needed to confirm its efficacy in the long term. While the revision rate is important, the functional status of the elderly after THA is also important because elderly are living longer and

more active lives. Currently, there is much conflicting literature made up largely of prospective and retrospective cohort studies, population based studies, and systemic reviews as to the long-term success of THA in the elderly. Because the health related quality of life in the elderly population is naturally deteriorating, it is difficult to assess whether THA slows that progression or contributes to it in some way. Randomized controlled trials with long-term follow up are needed to clarify whether the health related quality of life in the elderly who have undergone THA is better than that of their peers.

Compared to Other Treatments

Hip resurfacing arthroplasty (HRA) has not been sufficiently studied in the elderly population to make a compelling argument for its use. Do to the increasing popularity of HRA, its potential use in the elderly population will be briefly touched on. However, there is very little literature discussing the clinical performance of HRA versus THA in the elderly population. Furthermore, upon review of the literature, the consensus in the younger population seems to be that it is unclear whether HRA leads to better or similar quality of life outcomes as THA, but the markedly increased risk of revision and aseptic loosening make it an inferior option even in a younger population.[64] Costa et al. did show no significant difference in hip function or complication rate between THA and HRA after 12 months in a recent randomized control trial; however, this study was limited in that it had short follow-up.[65]

A retrospective cohort study of 434,560 hip replacements of which 31,932 were resurfacings from the National Joint Registry of England and Wales concluded that HRA offers no clear advantage over THA and is only an acceptable option in younger, active men with large femoral head sizes. Overall, HRA was associated with approximately double the 5-year revision rate compared to THA with 8 times the incidence of resurfacing for peri-prosthestic fracture, 10 times the incidence of revision for pain, and 4 times the incidence of revision for aseptic loosening.[66] Revision rates were unacceptably high in women and patients with small femoral heads. Furthermore, in the male group with large femoral heads, revision rates were equivalent to that of THA with uncemented ceramic-on-ceramic prosthesis and cemented metal-on-polyethylene prosthesis.[67] Age was found to be a significant predictor of an elevated risk of death but not revision, and only patients with a ASA score less than or equal to 2 were included in the study. ASA score was also associated with an increased risk of revision in men. The mean age in the resurfacing group was 54.1 while the mean age in the ceramic-on-ceramic and metal-on-polyethylene conventional THA groups were 59.6 and 72.7 respectively.[68] The Articular Surface Replacement (ASR) was excluded from the resurfacing analysis so as not to distort the results.[69] While the study did not evaluate the elderly population specifically, the results indicating that smaller femoral head size is associated with increased risk of revision, increased age is associated with increased risk of death, revision rates are unacceptably high in women and elevated in men with higher ASA score may indicate that HRA is not the best option in the elderly population who tend to have higher ASA scores and smaller build. However, this is a retrospective cohort study conducted from a national registry. Since the patients were not randomized and limited patient data on possible confounders was collected, it is difficult to definitely determine causality.

Furthermore, the patients who received HRA were younger and thus, their implants may have been predisposed to greater wear and associated with higher revision rates.

Between Prostheses

The type of prosthesis used in treatment of the elderly with osteoarthritis can markedly affect outcomes and cost. A comparison of the multitude of different types of prostheses is outside the scope of this paper, which has the goal of determining whether THR is an effective and reasonable procedure for osteoarthritis of the hip in the elderly population. However, it is important to emphasize that the type of prosthesis used is important to this question. Thus, this section will discuss several key differences between categories of commonly used prosthesis in hopes of illustrating that the ability of modern medicine to solve public health problems like osteoarthritis depends on many variables. Reliable, safe, and effective implants is one of those variables. Competent surgeons and anesthesiologists is another. Without reassurance of the excellence of these variables, modern medicine and particularly surgery have no business solving public health problems because misdirected medicine has too much potential to cause harm in the pursuit of healing.

The majority of evidence cited in the comparison of different prostheses is predominantly derived from observational studies of national joint registries. Few randomized control trials have directly compared different implants. While there are many differences between how prostheses are designed and surgically implanted such as cemented or cementless, our comparison will focus on 3 main broad categories: metal-on-polyethylene, metal-on-metal, and ceramic-on-ceramic. Each category is associated with complications that can cause the need for revision. Metal-on-polyethylene implants are associated with osteolysis and aseptic loosening. Metal-on-metal implants are associated with aseptic loosening and dislocation as well as complications from painful metal debris. Ceramic-on-ceramic implants are associated with ceramic liner fracture.

Metal-on-polyethylene implants are the appropriate choice of hip implant in the elderly population given current literature. There is very little literature comparing different prostheses in the elderly population; however, metal-on-polyethylene implants are the most studied and associated with the lowest revision rate and side effect profile. Hasegawa et al, Smith et al, and Gioe et al. all found that metal-on-polyethylene implants have lower or equivalent revision rates to newer ceramic-on-ceramic implants.[70 71 72] In a retrospective cohort study of elderly patients undergoing THA with the same acetabular and femoral components but different types of bearings, Milosev et al. found that the metal-on-polyethylene implants had significantly lower revision rates than ceramic-on-ceramic implants and metal-on-metal implants over 8 year follow up. Ceramic-on-ceramic implants had fewer revisions than the metal-on-metal implants, but this difference was not found to be significant.[73] The mean age of patients receiving metal-on-polyethylene implants was 71 years old whereas the mean age of patients receiving ceramic-on-ceramic and metal-on-metal implants was 60 years old. The mean postoperative activity level was 6 in the ceramic-on-ceramic group, 5 in the metal-on-metal group, and 4 in the metal-on-polyethylene group.[74] The limits of this study are that it is retrospective and does not directly compare the implants in the same elderly population. The elderly population is less active and thus, often has been shown to have

lower revision rates in general. It may be that the elderly population is not able to stress implants enough to extract meaningful differences between them. This study is also limited because not all the patients had osteoarthritis although the vast majority of them did. However, this study does confirm that metal-on-polyethylene implants have low revision rates in the elderly population.[75] In a short-term retrospective study of a Medicare population, Bozic et al. found that metal-on-polyethylene, metal-on-metal, and ceramic-on-ceramic implants have similar revision rates and complication profiles.[76] Nikolaou et al. found that ceramic-on-ceramic and metal-on-polyethylene have similar functional outcomes in a young population that is able to stress the implants, further supporting the reliability metal-on-polyethylene implants.[77]

Metal-on-metal hip resurfacing and conventional hip replacements fail faster and cause more complications than other models; the story surrounding these implants illustrates failures on the part of medical device manufacturers, federal regulatory agencies, and surgeons. With the push for use of THA in younger populations, its ultimate long-term problem, implant failure, has been an enlarging hurdle in establishing its use as a commonplace treatment. Younger patients are often more active, and thus, some studies estimate that little more than half of their implants last the duration of 15 years.[78] The leading causes of implant failure are aseptic loosening secondary to polyethylene wear and dislocation.[79] [80] The quest to overcome these complications popularized metal-on-metal large head implants over the more traditional metal-on–polyethylene implants. Large head sizes were thought to have lower risk of dislocation. Metal-on-metal bearing surfaces were found to be highly resistant to wear. Metal-on-metal seemed the perfect solution to the long-term failure of hip implants. Thus, under FDA rules, many all-metal devices were originally sold without testing in patients or without a requirement that producers track their performance.[81] The use of metal-on-metal implants grew to account for one third of hip replacements in the United States.[82] However, in 2010, there was a surge in reports of failing metal-on-metal implants. Metallic debris was found in the soft tissues surrounding the implants, often causing significant pain. Early implant failures with more challenging revisions were reported. The FDA ordered producers to study how often the devices were failing and what threats they caused to patients. Producers, however, found it difficult to recruit the large numbers of patients necessary to conduct the studies. They lacked joint registries and the metal-on-metal implants were associated with a growing stigma.[83] The Articular Surface Replacement made by Johnson and Johnson accounted for a significant portion of the complaints and was recalled by the company due to unpublished 2010 data from the National Joint Registry of England and Wales showing markedly elevated 5-year revision rates; however, the metal-on-metal implants as a whole were called into question.[84]

Observational studies from national joint registries have shown that metal-on-metal stem prostheses and resurfacing implants are associated with early implant failure and increased risk of complications from cobalt and chromium debris compared to other hip implants. Specific brands of metal-on-metal implants such as the Articular Surface Replacement made by Johnson and Johnson are particularly dangerous outliers of this group. In a single center prospective observational study with 2 year follow up, D.J. Langton et al. found a 25% failure rate for the ASR resurfacing implant and a 48.8% failure rate for the ASR total hip replacement at 6 years using Kaplan-Meier analysis.[85] These patients were all found to have significant implant wear on revision. The most

common finding at revision was joint effusion and soft tissue necrosis from metallic debris. Gross macroscopic metallosis was often encountered as well as some solid and cystic masses described as cystic tumors. In addition, 26.1% of patients were found to have blood levels of Co and Cr that were greater than 7ug/l, the level considered toxic, and 11.7% of patients had blood levels exceeding 20ug/l, the level associated with gross macroscopic metallosis.[86]

Although randomized controlled trials directly comparing different hip prostheses are lacking, retrospective observational studies from joint registries consistently find that metal-on-metal prostheses are associated with higher rates of failure, especially when used in combination with a larger head size. Retrospective analysis of the National Joint Registry in England and Wales between 2003 and 2011 of 40,1051 THA of which 31,171 utilized stemmed metal-on-metal prostheses revealed that metal-on-metal stemmed implants (6.2% 5-year revision rate) were associated with early failure compared to metal-on-polyethylene and ceramic-on-ceramic bearings (both <2% 5-year revision rate).[87] This study excluded the ASR metal-on-metal stemmed implant. The use of metal-on-metal implants with large femoral head size was associated with an especially high revision rate. In contrast, ceramic-on-ceramic implants had lower revision rates with larger femoral head size. Although the elderly population was not specifically analyzed in this study, the study was able to control for age and co-morbidity. The lowest revision rate for 60 year-old men and women was 1.8% with a 28mm metal-on-polyethylene implant.[88] While revision rate does not give us the whole clinical picture as to which implant is the best, it is a very good starting point for determining which implants are unacceptable.

Metal-on-metal prostheses are associated with local and whole body dissemination of metallic particles, and while they do not appear to increase all cause mortality, the long-term clinical effects of these metallic particles have not been determined. Small metal particles, most commonly cobalt and chromium are released into the tissues due to wear and corrosion of the implant. These metals are absorbed systemically and disseminated widely throughout the body, particularly to the liver, spleen, and bone marrow.[89 90 91] Metal-on-metal implants are estimated to generate 1000 times more of these particles than metal-on-polyethylene implants.[92] Metal-on-metal implants are also associated with markedly higher serum cobalt and chromium levels, which have been shown to cause chromosomal aberrations and DNA damage in a dose dependent manner.[93] It appears that local tissue sarcomas due to metal debris are rare. [94] The long term clinical effects associated with these metallic particles are unknown; however, in the limited studies available, these implants appear to be safe with no increase in all cause mortality.[95]

In a long-term retrospective cohort study of patients with first generation metal-on-metal and metal-on-polyethylene implants compared to the general population, Visuri et al. concluded that these implants are safe based on all cause mortality. Both cohorts had significantly decreased mortality during the first decade postoperatively, equal mortality during the 2nd decade, and significantly increased mortality greater than 20 years post-operatively due to cardiovascular disease compared to the general population. Neither group had a higher incidence of cancer than the general population, but the metal-on-polyethylene group had a significantly lower cancer mortality rate in the first two decades post-operatively compared to the metal-on-metal group.[96] It was noted that

osteoarthritis has a low rate of co-morbidity with cancer, which is a consideration that is difficult to control for. Interestingly, the increase in mortality in both THA groups after 20 years post-operation was due to increased risk of cardiovascular disease. Given the incidence of cardiomyopathy with heavy metal exposure, the authors emphasized that this finding should not be overlooked. The relationship between elevated serum chromium and cobalt concentrations and cardiomyopathy requires further study.[97] The first generation metal-on-metal implants examined in this study were associated with a higher systemic metal load than the later generations. Thus, as the authors note, future studies would be difficult as they would likely require longer follow-up to tease out the effects of newer metal-on-metal implants on mortality.

Ideal Timing, Population, Age

The best outcomes and best patient population in THA are difficult targets to define. From the available literature, it seems that the best predictor of post-operative quality of life scores are pre-operative quality of life scores.[98] Patients with severe osteoarthritis often experience the greatest improvements with THA. Cushnaghan et al. found that worse pre-operative physical function and radiographic osteoarthritis scores were associated with more improvement in physical functioning.[99] While their improvement may be great, there is a lower ceiling quality of life they can achieve with THA however. Patients with poor pre-operative quality of life are often not able to achieve the same quality of life as patients who undergo the procedure with a higher pre-operative quality of life. Fitzgerald et al. found that pre-operative physical function was the greatest predictor of post-operative physical function, and less severe pain before surgery was a strong predictor of less severe pain after surgery.[100] In a prospective cohort study with 222 patients who underwent hip or knee replacement for osteoarthritis, Fortin et al. found that elderly patients with worse pain and physical function pre-operatively have worse pain and physical function for 2 years post-operatively. [101] Nilsdotter et al. found that worse pre-operative pain predicted worse WOMAC score post-operatively at 3.6 years after THA in a prospective case control study of 219 osteoarthritis patients. [102] The clinical question remains as to whether patients should undergo THA earlier in the course of their disease or later.

This has implications for the elderly population, who in general, start with a lower quality of life than their younger counterparts. While elderly patients may not necessarily have more progression of their osteoarthritis, they may have other physical limitations and medical co-morbidities limiting their quality of life. Many studies have shown that the elderly population derives similar benefits from the procedure than their younger counterparts as discussed previously.[103] [104] However, their post-operative quality of life outcomes scores may still be worse. This is cited in many papers that show worse functional outcomes in elderly individuals, particularly in elderly women.[105] In a retrospective cohort study, Rat et al. found that higher age at surgery was associated with worse functional outcome. In addition, this study found that worse pre-operative physical function was associated with worse post-operative physical function at 3-year follow up but not 10-year follow up. The study concluded that long-term quality of life may be influenced more by general health rather than local disease. [106] In a prospective cohort study, Nilsdotter et al. found that both higher age and worse pre-operative pain were

independently associated with worse post-operative functional outcome.[107] AK Nilsdotter and LS Lohmander matched pre-operative SF-36 and WOMAC scores and found that elderly patients had smaller gains in physical function than younger patients. This study didn't look at co-morbid disease and suggested that other factors contributing to poor pre-operative quality of life could account for this difference.[108]

There is consistent evidence that revision rates in the elderly are lower than the general population who receives THA.[109] This is presumably because the elderly are less active and put less stress on their implants. This supports THA use in the elderly who get many more years out of their implant than the younger population.

The identification of the ideal patient population is further confounded by inconsistent, conflicting evidence on how patient characteristics affect outcomes. Some studies have shown that unfavorable environmental factors and living alone are associated with poorer outcomes.[110] In contrast, a recent review stated that there is limited evidence that psychosocial factors affect physical function outcomes after THA.[111] Still another review perhaps summed it up best by saying that there is "little consistent evidence on the nature and magnitude of the influence of patient characteristics on the outcomes of pain, revision, function, and mortality."[112]

Comparative Cost Effectiveness

The cost effectiveness of THA versus no surgery will be discussed in this section as well as the comparative cost effectiveness of different hip implants and THA versus HRA.

There has been little long-term economic proof of the cost-effectiveness of THA. While the longevity of the procedure seems to lend itself well to such studies, the difficulty in randomizing patients and the variability in implant models, surgical techniques, and surgeons make these studies difficult to complete. Many studies have relied on modeling to overcome these obstacles.

Most short-term studies come to the conclusion that THA with a reliable implant is a cost-effective treatment for osteoarthritis, but THA is more cost-effective in patients with worse pre-operative hip function scores and less cost-effective in the elderly. Richard Fordham et al. examined cost-effectiveness of the well-established and reliable Exeter implant for osteoarthritis retrospectively at the 5-year follow up stage using the Exeter Primary Outcomes Study. This was one of the largest longitudinal studies of a single prosthesis in the United Kingdom. The study compared the incremental quality of life, quality-adjusted life years (QALYs), and cost of THA in Exeter Primary Outcomes Study patients to those of a hypothetical no surgery osteoarthritis group. The study set the treatment costs of the no surgery group at zero. The SF-36 score was annually assessed and used to measure quality of life. QALY gains were calculated from a pre-operative baseline. Costs included implant costs and length of stay in the hospital. The study found that on average, patients gained approximately 0.8 QALYs over 5 years. The study found that older patients were associated with lower QALYs gained and higher costs due to higher lengths of stay.[113] The QALYs gained were highest from 23-49 years old (0.95), followed by 65-69 years old (0.88). After age 70, the QALYs gained dropped off significantly (0.71-0.72).[114] In addition, the study found that worse pre-operative Oxford Hip Score was associated with greater QALY gain. When costs were assessed,

the study found that over 85% of cases had a cost per QALY of 20,000 pounds or less, and 70% of cases had a cost per QALY of less than 10,000 pounds. Thus, the study found that THA with the Exeter implant was very cost-effective compared to no surgery by NICE standards.[115]

This study has several limitations. First, it used a hypothetical control group whose quality of life it assumed to be static and whose cost it set at zero. This could either strengthen or weaken the argument in favor of THA. The control group likely incurred costs associated with conservative treatment; however, the THA group likely also incurred such costs as we have seen that approximately 30% of THA patients continue to have pain at the replaced joint. Furthermore, it is unclear whether quality of life in the control patients would have, in reality, improved or worsened. It is likely that their osteoarthritis would have progressed and their quality of life deteriorated which further strengthens the study in favor of THA. However, it may be that these patients were seeking THA when their symptoms were at their worst, such as in a terrible flare up of their arthritis. In this case, their quality of life may have improved over time. This study is also limited in that it is retrospective. Furthermore, this study is limited in that it took place in the United Kingdom, so the conclusions made in this study may not be applicable to countries, where the costs of THA are much higher. Lastly, the study performed short-term follow up, and more studies are needed to assess the long-term cost-effectiveness of THA. As discussed previously, elderly patients are less likely to need revision, which is usually a more costly and invasive procedure than primary replacement. Thus, THA may, in fact, be much more cost-effective long-term in the elderly population than the younger population.

Metal-on-polyethylene is currently the most studied and cost-effective joint implant in the elderly population. The previous section comparing joint implants discussed this extensively. In addition, a recent retrospective cohort study examining whether "premium" joint implants add value found that ceramic-on-ceramic and metal-on-metal implants cost $1000 more than standard metal-on-polyethylene implants, but their revision rates are no different at 6 years. [116] This study is limited in that it does not identify and compare the proportion of patients with poor functional results. It does make a strong point for cost-effective prostheses in the context of prices in the United States however.

As was previously discussed, there is insufficient evidence for the use of HRA in the elderly population. Recently, an economic evaluation of a randomized controlled trial comparing metal-on-metal HRA with standard stemmed THA in a population greater than 18 years of age was published. The results are briefly mentioned here to further shed light on the topic. The study found that HRA provided a statistically insignificant QALY gain when patients were controlled for baseline characteristics. However, HRA was associated with a statistically significant cost within the first 12 months of surgery compared to standard THA. The costs of initial operation, inpatient care, post-discharge outpatient care, primary/community care, and medications/aids while in the community were included. HRA had higher implant costs, longer length of stay, and higher subsequent outpatient costs with more outpatient visits. When compared with metal-on-polyethylene standard implants, metal-on-metal HRA was not found to be cost-effective. However, when compared with ceramic-on-ceramic and metal-on-metal standard implants, metal-on-metal HRA was found to be cost-effective. Again, these results are

not statistically significant, but the trial was not designed with the power of cost-effectiveness in mind.[117] These results further emphasize the importance of implant and procedure choice when evaluating the cost-effectiveness of THA. HRA appears neither more effective nor cost-effective than standard stemmed metal-on-polyethylene THA in a young population. There is no evidence for its use in an elderly population.

The United States and the United Kingdom

The United States and the United Kingdom have different healthcare systems and approaches to joint replacement, but in both countries, similarly vague indications are employed and the use of THA amongst the elderly has been relatively stable in recent years. The United Kingdom is able to ration care based on the needs of the country and its ability to provide for those needs. The United States allows market forces to govern how much care and to a certain extent what care is delivered. The United Kingdom has a nationalized joint registry, whereas the United States relies on private joint registries of physicians and medical groups. The United Kingdom also appears plagued by a milder form of geographic, racial, and socioeconomic inequalities in THA compared to the United States.

The elderly in the United States and the United Kingdom are insured under very different nationalized healthcare systems: Medicare and the National Health Service, respectively. Under Medicare, most patients have co-payments and deductibles that they must contribute and many patients buy supplemental insurance to help cover these sometimes significant costs. The reimbursements rates for medical services under Medicare are set. During the time period when the body of literature analyzed in this paper was written, medical services were largely provided through a fee for service model that did not question or dictate the decisions of physicians. Thus, the provision of medical services was based on the clinical decisions and preferences of physicians and their patients. The healthcare system in the United Kingdom is more organized and there are regionalized centers where hip replacements are performed. Furthermore, physicians are salaried; thus, they do not get paid more for doing more operations. Decisions are still made in the clinical encounter. However, with this organization, comes the ability to ration the care determined necessary in the clinical encounter. Thus, the NHS can effectively determine the amount of hip replacements it is capable of performing each year, and if there are too many in need, make them wait until the next year. Like the United States, there is some degree of a two-tiered system. Those who do not wish to wait can buy their own private insurance and opt out of the system.

The utilization of primary THA in the United States and United Kingdom amongst the elderly population has been relatively stable in recent years; however, the United States has had difficulty adequately monitoring new prostheses and responding to inequalities in access to THA. According to OECD information databases, the elderly utilize more hip replacements in the United States compared to the United Kingdom; however, the utilization of these services has been relatively stable in the elderly population in recent years. In the United Kingdom, approximately 11 per 1000 people above the age of 65 per year have received hip replacements from 2007-2010.[118] The precise stability of 11 people in 1000 reflects the ability of the NHS to ration care in the United Kingdom. In the United States, 12 per 1000 people above the age of 65 per year

received hip replacements in 2007. This number steadily rose to 15.9 in 2009, and then stabilized at 15.5 in 2010.[119] While not completely stable, the use of THA has been relatively stable in the elderly population under the control of the haphazard American system largely based on market forces and the clinical encounter. By contrast, hip replacements have markedly increased in the younger population in the United States despite remaining stable in the United Kingdom.[120]

The attempt at national consensus on the indications for THA in the United States and United Kingdom have led to similarly unclear results; however, the consensus in the United Kingdom has been more responsive to new research and ideas within the field. The NIH last released a consensus statement on use of THA in the treatment of osteoarthritis in 1994. It states that the indications for THA are those with "radiographic evidence of joint damage and moderate to severe persistent pain or disability, or both, that is not substantially relieved by an extended course of non-surgical management."[121] Analgesic, non-steroidal anti-inflammatory drugs, physical therapy, walking aids, and rest are included in non-surgical management. The NIH states that there are few contraindications to THA other than local and systemic infections and other medical conditions that markedly increase the risk of peri-operative mortality. Most importantly, it recognizes that age is not a contraindication as poor outcomes appear to be related to co-morbidities rather than to age.[122]

The National Institutes for Health and Clinical Excellence last issued guidelines for the treatment of osteoarthritis in 2008. Their guidelines offer a more whole-istic approach consistent with research that the indications and outcomes of THA are multi-factorial. They suggest 3 core treatments: education, activity and exercise, and weight loss in the treatment of osteoarthritis.[123] Similar to the NIH, NICE states that THA is indicated when the patient has pain, stiffness, and reduced function that have a substantial impact on their quality of life and are refractory to non-surgical treatment. In addition, NICE lists similar non-surgical therapies as the NIH. However, NICE also states that referral should be made before there is prolonged and established functional limitation and severe pain, integrating into its guidelines recent research that suggests that outcomes may be better with earlier intervention in the course of disease. Furthermore, NICE states that patient specific factors (including age, gender, smoking, obesity, and co-morbidities) should not be barriers to referral for joint replacement surgery. Finally, NICE states that decisions on referral thresholds should be based on discussions between patient representatives, referring clinicians, and surgeons, rather than using current scoring tools for prioritization.[124]

Thus, both the NIH and NICE have reached consensus that age should not be a barrier to THA. NICE has integrated into its guidelines the plethora of research suggesting that the indications and outcomes of THA are multi-factorial and that scoring systems of hip function over simplify the decision to proceed with THA. They recognize that the details of the patient's life and their needs play an important role in the use of THA for the treatment of osteoarthritis, and these needs are best assessed on an individual basis. However, at the heart of both guidelines is the same vague indication: pain and functional limitation refractory to non-surgical therapies.

One of the major differences between the United States and United Kingdom in their approach to THA is the development of a national joint registry in the United Kingdom. The lack of a national joint registry has made it difficult for the United States

to anticipate problems and respond to recalls and advisories of new prostheses. The United States has thus had to rely on information from international joint registries in many instances. Many private hospitals, groups, and surgeons in the United States operate their own joint registries; however, their registries often lack the large numbers characteristic of national joint registries. There has been evidence that these registries have helped private groups better respond to recalls and advisories while also improving quality of care and cost-effectiveness.[125] [126]

The United States and United Kingdom both have geographic variation in the amount of THAs performed; however, the United States has more extreme variation. The Dartmouth Atlas Study performed in 2010 examined all THAs in the United States, and found marked variation across and within states that varied with time. For example, in 2000-2001, Alexandria, La had the lowest rate of hip replacement at 1.2 per 1000 beneficiaries. The rate in Boulder, CO was more than 5 times that at 6.7 per 1000 people. In 2005-2006 Bryan, TX had the nation's lowest rate at 1.8 per 1000 compared to Ogden, UT, which had the highest rate at 7.2 per 1000 people. There was even variation within states that changed across the time period. Rates of hip replacement in Los Angeles were 2.7 per 1000 people whereas in San Luis Obispo, they were 6.7 per 1000 people. [127]
This study did not have a clear explanation for the regional differences. It indicated that the most likely explanation is regional variation in the supply of surgeons and their preferences.[128] A recent study found that the United Kingdom has regional variation as well, but the variation is not as extreme and peaks at differences of 25-30%.[129] Furthermore, reasons for this variation were found. The proportion of elderly people in the area accounted for approximately half of the regional variation even though the data used was age standardized.[130] The authors of this study interpreted this to mean that regions with a higher proportion of elderly people had deliberately increased their provision of THR in hope of meeting the presumed need.[131]

The United States and United Kingdom both have history of inequalities in access to THA based on ethnicity and socioeconomic status; however, the United Kingdom has significantly improved these inequalities in comparison to the United States. In the 1990s, studies revealed socioeconomic inequalities in access to THA in both the United States and United Kingdom. The respective governments of both countries developed initiatives to resolve these inequalities, and have since been working to improve these disparities.[132] [133]

In the United States, African Americans, Hispanics, and low income patients have lower THA rates. Disparity in THA rates among elderly black patients has worsened, and low THA rates among Hispanic patients persist but appear to be more related to income and access inequality. In 2005, Jha et al. found that racial disparities in THA use among black and white elderly widened from 1992 to 2001. The study showed that in 17 out of 20 hospital referral regions examined, racial disparities in THA widened.[134] Similarly, Dunlop et al. found that there were inequalities in black versus white elderly in the use of THA. Elderly black patients were approximately half as likely to receive THA as elderly white patients.[135] Interestingly, they found these disparities were not present in the younger black population. Lower utilization rates among Hispanic compared to white patients were seen across all age groups. Lower utilization of THA in the Hispanic population was largely explained by less access to medical care; however, the lower utilization in the elderly black population persisted after controlling for medical access,

income, and education.[136] Other studies have documented inequality among the elderly Hispanic community in accessing THA independent of income as documented by Medicaid status.[137] Lower income elderly patients also have lower THA rates in the United States.[138] [139] Furthermore, black race and lower income have been associated with increased risk of adverse outcome after THA.[140]

The United Kingdom has been able to equalize waiting times for people of different socioeconomic status; however, the wealthy can opt out of the public system and get easy access to THA through the private system. The United Kingdom has a two tiered healthcare system with public insurance for all and private insurance for those that can afford it. The public system is associated with rationing of care and waiting for services. Thus, the overall rate of surgery must be evaluated between groups in addition to the waiting time. In a retrospective observational study, Cooper et al. found that there were longer waiting times for lower socioeconomic statuses in 1997-2000, but by 2005-2007, these differences had been successfully eliminated.[141] Several studies have found that less educated people have longer wait times and lower rates of THA, but there is no significant difference amongst patients of different socioeconomic status.[142] [143] Neither of these studies specifically looked at the elderly population or included the private healthcare market however. Studies looking at THA rates in the elderly population have found that lower income elderly people do have lower THA rates. Milner et al. published a study in 2004 displaying that there is increased unmet need in the elderly poor for THA. The study used a patient-completed questionnaire to assess patients in need of a hip replacement. The study found that there is a 3.4% unmet need for hip replacement in the elderly population above 65 years of age, and that the poorer elderly are more likely to have unment need.[144] Furthermore, the study found that only 10-16% of patients with unmet need were on the waiting list for THA even-though the majority were seeing their general practitioner.[145] The fact that patients in need are seeing their general practitioner but not being referred for hip replacement is indeed troubling, but it may also reflect limitations of the study. Even though the patient questionnaire was previously validated against clinical history and exam in determining need for THA, patient completed questionnaires still have limitations. These questionnaires may not reflect all of the important aspects of the clinical history, physical, and decision-making associated with a visit to one's general practitioner. Most importantly, the study did not exclude patients who needed hip replacement but did not want it.[146] The study did attempt to exclude patients who had too many co-morbidities to undergo THA however.[147] The disparities in the use of THA based on socioeconomic status may also reflect the ability of wealthier people to more readily obtain elective THA through the private healthcare system in the United Kingdom. Disparities due to the two-tiered system presumably exist but have not been quantified.

The population of the United Kingdom is less racially diverse, but studies show that there are similar racial disparities in THA use in the elderly population in the United Kingdom compared to the United States. There have been fewer studies of racial disparities in the United Kingdom presumably because there is less racial diversity. For example, cross sectional data on both need for and receipt of THA from the English Longitudinal Study of Aging showed variations in rates of hip or knee replacements by wealth, sex, and area of residence, but the sample did not have enough non-white residents to measure the effects of race.[148] However, in a study from 1998-2004, N Steel

et al. found whites were twice as likely as blacks to undergo joint replacement in the United Kingdom just as they are in the United States. This was after controlling for need, wealth, co-morbitidites, and access to care.[149]

Conclusion:

Osteoarthritis is the most common cause of disability, and a large portion of healthcare dollars is used to replace the hips of elderly in hopes of treating their osteoarthritis. As the population of the developed world ages and the elderly live longer, more active lives, osteoarthritis will become a more burdensome disease for the elderly and the societies that care for them. Currently, the most specific indications for THA in the treatment of osteoarthritis are pain and physical disability refractory to conservative treatment. More specific end points of physical function and pain have not been possible to define. Many factors have been recognized to significantly contribute to the decision to go forward with THA including quality of life, lifestyle, medical co-morbidities, and surgeon preferences. Current literature supports THA as an effective and safe short-term treatment for osteoarthritis in the elderly and displays marked improvements in quality of life comparable to that of younger populations. The long-term efficacy and safety of THA for treatment of osteoarthritis in the elderly population is more conflicting, and a definitive conclusion can not yet be drawn. Safety and efficacy vary significantly with implant. Metal-on-polyethylene implants are currently the most evidence based and cost-effective choice in the elderly population although few other varieties of implants have specifically been studied in the elderly population. Metal-on-metal prostheses are associated with earlier failure, increased risk of revision, and increased incidence of complications. These implants should be abandoned or significantly remodeled.

The ideal population for THA has been difficult to define; however, the elderly should not be excluded from THA use because of their age. Those with severe osteoarthritis often derive the most benefit from THA; however, those with better quality of life before THA achieve better quality of life after THA. The difficulty in determining the ideal patient population stems from this dichotomy. This dichotomy also makes cost-effectiveness arguments surrounding THA tricky. The elderly generally start with poorer quality of life, and thus, post-operatively, they never achieve the same quality of life that their younger counterparts enjoy. However, it has been shown that healthy elderly can benefit equivalently from THA as younger patients despite requiring longer recovery. In fact, the elderly have much in their favor as candidates for THA. They are not as active as younger patients, so they are less likely to wear out their implant and require revision. While they have longer lengths of stay and often require rehabilitation facilities post-operatively, their lower incidence of revision may actually make THA more cost-effective in the long run.

THA use in the elderly population has been relatively stable in both the United States and United Kingdom in recent years despite differences in how the two countries deliver osteoarthritis care. Both countries use the same vague indications for THA in the treatment of osteoarthritis. The United States and United Kingdom both have inequalities in how they deliver osteoarthritis treatments based on region, income, and race; however, these inequalities appear to be milder in the United Kingdom. The United Kingdom has developed a national joint registry, which allows them to track and respond to new

implants on the market more effectively than the United States. While the United States has many smaller private joint registries, it lacks the coordination and organization to nationally respond to public health disasters like the ASR hip implant. This appears to be one of the major advantages to nationalized healthcare in the United Kingdom.

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