Applications of Operations Research and Decision Sciences Techniques on Policies and Issues Related to Obesity and Total Knee Arthroplasty

by

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ABSTRACT

Total Knee Arthroplasty (TKA) is one of the most commonly performed procedures in the United States every year. In 2014 alone, approximately three-quarters of a million were performed at a cost of nearly $40 billion. These figures are only expected to grow. Obesity is one factor influencing this growth. Obese patients are becoming a larger portion of those having TKA procedures and face different risks and benefits when doing so. Some have suggested that TKA be restricted in the obese population to either control spending or because obese patients do not see the same outcomes as nonobese patients. Given the substantial budget impact, it is important to understand the differences faced by obese patients.

This dissertation uses meta-analysis, cost-effectiveness analysis, and agent-based modeling to inform decision making about obese patients and TKA. The meta-analysis resolves some uncertainty in the current literature around complication and implant survival rates in individuals with different obesity classifications. Then, the cost-effectiveness analysis explores the relative costs and benefits of the TKA procedure by obesity class. Finally, a trend model is built in an agent-based framework to examine the volume of TKA procedures and the budget impact for the entire US population under different potential future scenarios.

These results show that even though obese patients do face higher rates of complications than their nonobese counterparts, this alone does not rule out TKA as a reasonable option for those patients. Even in the heaviest patients, TKA is cost-effective. The budget impact for restricting access to obese patients is minimal due to the offsetting rise in costs of living with osteoarthritis without surgical intervention. There are potential policy solutions to the large

expenditure on TKA and certain areas need further investigation before guidelines should be changed. Obesity does matter when considering TKA policies and outcomes, but outright bans on TKA in obese patients may not be the best policy solutions.

CHAPTER I:
Introduction

Total Knee Arthroplasty (TKA) is the most common inpatient surgery (excluding maternal and neonatal procedures) with 752,941 performed in 2014 alone at a rate of 237 per 100,000 (Healthcare Cost and Utilization Project (HCUP), 2017). This rate was virtually unchanged for 2015, the last year with data available (Healthcare Cost and Utilization Project (HCUP), 2017). According to a 2014 report, it is also in growing demand with the second greatest rate of increase among inpatient operative procedures having an average annual growth rate of 4.9% between 2003 and 2012 (Fingar, Stocks, Weiss, & Steiner, 2014). One controllable driver of this increased demand is obesity (Fehring, Odum, Griffin, Mason, & McCoy, 2007). Obesity is a risk factor for developing osteoarthritis (OA), the primary condition that leads to TKA, increasing risk by a factor of 3-4 (Webb, et al., 2004) which in turn contributes to the increased share of TKA patients who are obese nearly doubling between 1990 and 2005 (Fehring, Odum, Griffin, Mason, & McCoy, 2007). The share of TKA patients who are obese is also double the share of the general population who are obese (Fehring, Odum, Griffin, Mason, & McCoy, 2007). Taken together, TKA procedures are a significant and growing portion of the health care budget and rising obesity rates are both driving the rise in TKA and changing the makeup of the TKA population. It is less clear what effect this trend towards heavier patients is having on outcomes of the popular procedure.

Obesity is a major public health concern that now affects over 1/3 of the US population (Ogden, Carroll, Fryar, & Flegal, 2015). The definition of obesity varies in the current literature and this variation may explain some of the lack of consensus on whether obesity alone leads to poor surgical outcomes in TKA. Obesity can be classified in several ways, the most popular being to use Body Mass Index (BMI). BMI is simply defined as the body mass in kilograms divided by the square of height in meters. Obesity is almost always treated categorically (i.e. normal, overweight, obese), but the underlying value is continuous, a simple relationship between height and weight. The most familiar treatment of obesity is a binary variable in chart reviews or lists of comorbidities meaning the person is either above BMI 30 or not. Another important cutoff is morbid obesity defined as BMI $\geq$ 40, which now encompasses more than 5% of the US population (National Institute of Diabetes and Digestive and Kidney Diseases, 2012). The World Health Organization (WHO) classification system uses three smaller classifications of obesity by dividing the obese class in two halves: Class I with $30 \leq$ BMI < 35, Class II with $35 \leq$ BMI < 40, and Class III with BMI ≥ 40, identical to morbid obesity (Centers for Disease Control and Prevention, 2016). It is important to remember that because of the continuous nature of the underlying BMI value that an obese person with BMI of 30 may be more like the overweight group ($25 \leq$ BMI < 30), than an obese person with BMI of 39 than the categorical variable might otherwise suggest.

The TKA literature currently offers conflicting evidence on whether obese patients have poorer outcomes or whether to restrict surgical intervention in this patient population or some segment of it. Due to the growing share of obese patients receiving TKA, this is a popular subject in the literature, yet no clear consensus has been reached (Rodriguez-Merchan, 2015) (Alvi, et al., 2015) (Wallace, et al., 2014) (D'Apuzzo, Novicoff, & Browne, 2015) (Abdel, Ast, Lee, Lyman, & Gonzalez Della Valle, 2014) (Napier, et al., 2014) (Belmont, Goodman, Waterman, Bader, & Schoenfeld, 2014) (Baker, et al., 2013) (Issa, et al., 2013) (Issa, et al., 2013)

(Liabaud, Patrick, & Geller, 2013) (Collins, Walmsley, Amin, Brenkel, & Clayton, 2012) (Jarvenpaa, Kettunen, Soininvaara, Miettinen, & Kroger, 2012) (Yeung, et al., 2011) (Jarvenpaa, Kettunen, Kroger, & Miettinen, 2010) (Krushell & Fingeroth, 2007) (Amin, et al., 2006) (Foran, et al., 2004) (Spicer, et al., 2001) (Chesney, Sorth, Sales, Elton, & Brenkel, 2008) (Johnson, Worland, Keenan, & Norambuena, 2003) (Bordini, et al., 2009). When morbid obesity is used in the analysis, there is much more agreement in the literature that outcomes are worse for these patients (Amin, et al., 2006) (D'Apuzzo, Novicoff, & Browne, 2015) (Issa, et al., 2013) (Krushell & Fingeroth, 2007). Despite a variety of approaches and methodologies, the literature finds little common ground.

As the share of TKA patients who are obese grows, the question of whether obesity is a predictor of poor outcomes or even a disqualifying condition for surgery grows in importance for both individual patients and as a broader policy concern (Amin, et al., 2006) (Collins, Walmsley, Amin, Brenkel, & Clayton, 2012). A clear answer to the question of how obesity affects various outcomes is essential if policy makers are to develop guidelines in a systematic way. Attempts to establish guidelines or restrict access to TKA have been deemed arbitrary and judged to be solely based on financial considerations rather than patient care. In 2005, a local health trust in the United Kingdom (UK) banned knee replacement in any patient with a BMI over 30 unless all other options were exhausted and daily life was affected by the joint (Coombes, 2005). In this case, while clinicians supported the move based on the risk factors in this population, the motive is openly financial in a health system trying to close a budget deficit with a local National Health Service (NHS) official quoted as calling the move “unashamedly financial” while also admitting it was “unlikely to make big savings” (Carvel, 2005). An official from the national (UK) Department of Health noted in response to this policy, that “Any actions that trusts take to manage to reduce deficits should not lower the quality of care provided to NHS patients" indicating a more nuanced process is desirable (Carvel, 2005). In 2016, other NHS trusts also adopted a total restriction for routine surgeries, specifically including TKA, in obese patients until they lost 10% of body weight. Again, the motive is stated to be mainly financial with the NHS official referring to "severe pressure" when discussing cutting off payments for those not following the new policy, but this blanket ban has provoked more pushback from clinicians (Bodkin, 2016). In the American setting, the conversation includes more nuanced questions. These focus on areas like requiring weight loss before surgery in obese patients, how to effectively communicate the increased risk profile to patients, the ethics of withholding care from an otherwise eligible candidate, and who pays for any increased costs or burdens (Wooten & Curtin, 2016), (Martin, Jennings, & Dennis, 2017), (Li, et al., 2017), (Stickles, Phillips, Brox, Owens, & Lanzer, 2001), (Incavo & Derasari, 2014), (Kremers, Visscher, Kremers, Naessens, & Lewallen, 2014), (Gillespie & Porteous, 2007), (Bronson, et al., 2014). The American perspective takes a more individual focus on whether the surgery is worthwhile for that specific patient, including obesity as one factor in that calculus, rather than an evaluation of whether limited resources are used effectively at the system level as in the UK setting.

The literature is divided then in both what it measures in terms of outcomes, but also in what should be done with those results. Even though the morbidly obese have higher complication rates with some reasonable certainty, this does not lead to a consensus on whether this should preclude operations in the population. Due to its high demand, the cost implications of TKA mean that policy decisions are important at the national level. Having a clear evidence base to work from is therefore important. One option for developing this evidence base is a cost-effectiveness analysis. This approach can provide a structure for the differing costs and benefits across groups and place TKA in a broader healthcare context in terms of value for limited healthcare dollars.

The cost implications of refusing TKA to obese patients could be staggering. An analysis from 2012 showed that approximately 10% of all hospital stays involving operations paid for by either Medicare or private insurance were for TKA (Fingar, Stocks, Weiss, & Steiner, 2014) and there was a 13.8% increase in the discharge rate from 2007-2011 (Dreyer, Zhang, & Udow-Phillips, 2014). This translates into an estimated $38.5 billion USD in charges in 2011 alone (Dreyer, Zhang, & Udow-Phillips, 2014). The cost for TKA varies across and within markets, but nationally, the mean charge for a TKA is $54,158 (Dreyer, Zhang, & Udow-Phillips, 2014). The expectation is for continued growth as the population ages and becomes more obese. This makes it important to understand whether obese populations are in fact benefiting from this procedure and if TKA in obese populations is a valuable use of health care resources. The UK restrictions are explicitly focused on reducing expenditures in a cash-strapped system. The United States healthcare system, while different in many ways, is also not immune to budget constraints. Predicting volume and the commensurate costs is a valuable tool for budgeting of financial outlays and other resources like surgical capacity.

This dissertation adds to this policy conversation in several ways. First, the lack of consensus in the literature is addressed with a meta-analysis of implant failure rates and complications by obesity classifications. Next, a formal cost-effectiveness analysis (CEA) is undertaken focusing on TKA in different obesity classifications. Third, an agent-based model (ABM) is built to examine the trend in demand for TKA and several what-if scenarios relating to obesity are applied. The application of operations research and decision science techniques to this policy area can begin to remove some of the haphazard application of restrictions and reduce the ad hoc nature of the evidence base. For instance, the NHS official quoted above admitted uncertainty about seeing any budget savings despite the entire purpose of the guideline being a reduction of the financial burden of TKA. The ABM is able to easily quantify the budget impact in a variety of guideline scenarios with a reasonable level of confidence in the estimates. The impacts can be anticipated before policies are enacted thereby saving unnecessary disruption to patient care and upset among clinicians over policies that may not even achieve their goals. More generally, the modeling process can generate a framework for thinking about the issue that that helps to organize available information which in itself can be a useful exercise. The need for parameter values can draw attention to a lack of consensus in the literature and point to a need for meta-analysis or new studies about important topics. The act of developing a conceptual model and thinking through the entire process can point to unanticipated consequences of a policy decision that may be left out of more ad hoc decisions. In the case of TKA, the question at first seems to impact only the patients themselves and orthopedic surgery departments, but the conceptual model makes clear that those restricted patients remain with OA and this must be accounted for when considering a new policy. Thus, rheumatology and primary care departments are also impacted. Systems thinking provides policy insights and helps draw all stakeholders into the process. Finally, such techniques also provide evidence and concrete rationales to help dispel any upset over changes. Pointing to a CEA can help defend a policy against claims of unfairness in decision making processes as well as help to avoid biased decision making in the first place by forcing a different way of thinking about the issues. Policy making, then, can begin on a more solid footing, perhaps increasing uptake of proposed guidelines as appropriate.

Chapter II of this dissertation details the meta-analysis undertaken to rationalize the disparate literature on outcomes of TKA by obesity classifications. The literature has a wide variety of outcomes of interest, obesity designations, study designs, and sample size. The meta-analysis focuses on four outcomes of particular interest clinically: wound complications, venous thromboembolisms (VTE), deep infections, and survival of the implant. These parameters are also important in the development of the models used in Chapter III and IV. The lack of consensus in the literature is less pronounced when meta-analytic techniques are applied, but there are several areas that require more investigation in future research.

To address the arbitrary nature of existing guidelines, a cost-effectiveness analysis was performed using a compartmental model in Chapter III. The model follows the existing framework for the conceptual model from Losina, et al. (Losina, et al., 2009) to integrate the obesity findings into the existing literature on the cost-effectiveness of TKA. The parameters developed in Chapter II inform the risks associated with the different obesity classifications. This model formalizes the costs and benefits involved for different groups and provides metrics to examine the tradeoffs involved. The results reinforce the existing belief that TKA is generally cost-effective. The obesity results suggest that the lack of consensus around guidelines restricting access to TKA for obese patients is warranted.

Finally, a trend model is built using an ABM framework to incorporate other sources of heterogeneity into the population including time related trends in obesity, demand, and an aging population. This model is then used to examine several scenarios related to various guidelines as well as changes in population behavior relating to obesity and desire for TKA. The ABM follows the compartmental model in Chapter III as closely as possible in both form and parameterization. While the CEA focuses on individual level decisions, the ABM considers the

US population overall. The trend model closely follows the historical trajectory from 2000 until 2015 and provides an estimated volume for the subsequent 20 years. The model results focus on volume and budget impacts under the various scenarios considered. As expected from the results in Chapter III, the adoption of guidelines restricting access to TKA in obese populations is not clear cut. The results around changes in obesity patterns and modification of TKA uptake are more surprising.

The dissertation as a whole moves from a literature lacking consensus on whether outcomes are less favorable in obese patient populations and what to do with those poorer outcomes if they exist to a formal evaluation of the impact of obesity on TKA in terms of outcomes, budget impact, and projected volume. The dissertation makes use of several techniques new to this policy area. Literature reviews exist in the TKA complication domain, but formal meta-analytic techniques have not previously been applied to isolate the role of obesity in changed outcomes in TKA. Cost-effectiveness has looked at TKA generally as well as to examine the role of provider volume on outcome, but this is the first to include obesity in the analysis. The treatment of deep infections is also more detailed in this model than previous efforts. Finally, the application of an agent-based model to serve as an environment to explore what-if scenarios is a novel approach. The calibration necessary to do this also advanced new technique to ensure a well-matched synthetic population.

CHAPTER II:
Does Obesity Lead to Poorer Outcomes in Total Knee Arthroplasty? A Meta-Analysis

Background

Many studies have attempted to discover whether obesity leads to poorer surgical outcomes using various measures and study designs. Despite a large number of such studies, no consensus has been reached. Outcomes under consideration in existing literature include the failure rate of the implant (possibly due to faster deterioration due to increased stress on the joint), complications due to poorer overall health of obese patients, and various other markers of surgical improvement like functional knee score or range of motion after surgery. The most popular outcomes in the literature are the failure rate of implants and various complications, both short and long term.

The lack of consensus in the literature may have to do with several characteristics of the studies currently available. Small studies may be underpowered especially in the higher BMI range (Bordini, et al., 2009) (Krushell & Fingeroth, 2007) (Foran, et al., 2004). Two possibilities for the lack of power relate to the use of the binary obese designation that is readily available in charts and thus popular in retrospective studies. First, while this is convenient, it may lack accuracy if obese patients are not assigned obesity as a comorbidity in the chart or weights are out of date when assigning status. These clerical errors could mean that the nonobese control group actually contains many obese patients. The second issue with the binary designation is to do with a simple sharp divide into obese and nonobese. Because BMI is a continuous value, any categorization may conceal differences or a tipping point in the underlying population. It is possible that mild obesity is protective, part of the obesity paradox, while morbid obesity is problematic and that mixing all obese patients in a single group obscures the true nature of the relationship between BMI and complication rates. If the actual inflection point for obesity causing poorer outcomes is somewhere towards the middle of this divide, perhaps examining the existing literature with a finer classification system, including BMI as continuous value if possible, will provide clearer answers on the role of obesity on outcomes in TKA. Another reason for the disagreement in the literature is the wide variety of the complications considered and follow-up periods used. Failure rates are considered from 1 year to 15+ (Collins, Walmsley, Amin, Brenkel, & Clayton, 2012) (Foran, et al., 2004). Complications range from general body systems like cardiovascular to specific like VTE. This lack of consensus on even what complications are under consideration contributes to the lack of a clear conclusion in the literature. Finally, study designs range from case studies to retrospective chart review to long term prospective trials all with varying degrees of inclusion criteria.

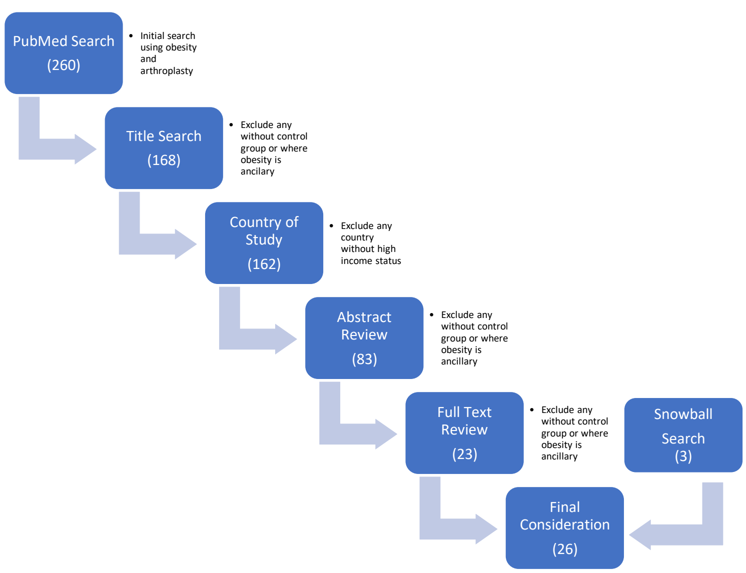
This review and meta-analysis of the literature on complications and revisions for TKA will examine the effect of obesity using several classification levels including binary obesity and the more granular WHO classification to help identify how obesity impacts a standardized set of outcomes and provide information to guide decision makers who are interested in understanding whether the impact of obesity on outcomes is great enough to merit establishing clinical exclusion criteria. The other goal is to examine a smaller subset of complications that are of most interest to orthopedic surgeons. Other literature reviews in this area are limited and focus either on a single outcome or are more qualitative in nature while this paper takes a full meta-analytic approach to a comprehensive set of outcomes.

Methods

Literature Search

A PubMed search with Medical Subject Headings (MeSH) terms was conducted to find all articles published relating obesity to total knee replacement outcomes. To be included in this review, the studies needed to have a nonobese control group for comparison purposes and the studies had to report outcomes of TKA stratified by the obesity designation of the patients under study. This excluded articles where the TKA outcomes were ancillary. After this initial refinement, four rounds of evaluation were conducted to ensure that papers included in the meta-analysis were a) focused on the entire population, b) from countries with health care systems comparable to the United States, c) original research and d) well-designed studies. These restrictions reduced the original sample from 260 prospective studies to 23. Secondarily, a snowball search was done using the literature reviews uncovered in the original search. This process generated a total of 26 papers for review (Figure II-1).

Figure II-1 Literature Search Review Steps



The literature review began with a PubMed search using two MeSH terms: “obesity” and “Arthroplasty, Replacement, Knee”. Entry terms for “Arthroplasty, Replacement, Knee” include appropriate variants for nomenclature combinations and total and partial procedures. This was further restricted to English only, but without publication date restrictions. This yielded 260 papers.

The titles were then examined for any dealing with specific subpopulations, those focused on partial replacements, and any papers that were not original research. Some were also excluded based on obesity-related outcomes of TKA not being the primary focus, such as studying anaesthesia techniques in obese patients undergoing joint replacements. After the title search, 168 papers remained leaving 65%.

Next, the country of the study population was extracted from PubMed. Only countries classified as High Income by the World Bank were included. It was believed that other countries would have fundamentally different health care systems and thus lack comparability across studies. Only 6 papers were excluded on this measure, retaining 96%. The excluded studies were conducted in China, Taiwan, Korea, and the Dominican Republic.

The abstracts were reviewed in the next stage of selecting articles. The search terms yielded a variety of papers including opinions, comments, and original research of which only original research findings were retained. Articles where obesity-related outcomes of TKA were not the primary objective of the paper were excluded. Another major exclusion was those that did not in fact have a comparison between nonobese and some obese classification in the study design. Studies that focused on specific procedures or implants were also excluded as were exclusively bilateral operations. This round yielded 83 papers or 51% retention.

Lastly, the full text was read with the same criteria. Again, a sizable portion of those excluded were those without control groups or where the effect of obesity on TKA outcomes was ancillary. Several were discarded when total joint replacements numbers rather than total knee replacements were reported. Others were discarded as being older studies with short follow-ups. Short term follow-up defined as 1 year or less and old being defined as operations performed prior to 2000. Long term follow-up studies were retained even with older procedures as the follow-up period requires time. Samples of convenience like the 50 heaviest patients seen at the hospital or those lacking control groups, for example, were excluded. This left 23 papers or 28%. This was an overall retention of 9%.

As a final step, the 9 literature reviews discovered in the initial search were examined for any papers missed in the original search strategy. Of the citations in these reviews, an additional 3 were discovered fitting the search criteria. Given the low yield, further snowball search was not done on the 23 retained papers.

The 26 papers were then reviewed for a final quality check. Using the criteria laid out in Egger (Egger, Davey-Smith, & Altman, 2001), eighteen categories were graded on a three-point scale: good, fair, bad (Table A-1). The criteria cover sample selection, follow-up period, outcome variable definition, prognostic variable selection, analysis methods, and treatment subsequent to inclusion. No papers had any categories judged bad. The categories most likely to see fair grades were dealing with treatment subsequent to inclusion or sample description. For treatment, this is mainly due to lack of detail in specific implant or surgical technique given in papers especially those from large claims databases. For the sample, some papers provide sparse demographic details and many of the single institution papers while representative of that patient population and well mixed in terms of gender and age, may not be representative of a larger national sample such as those studies that used claims data.

Data Collection

The final collection of 26 papers was then searched for any data points relating to survival of the implant or complications. During the initial search, the type of outcome data was not considered as part of exclusion criteria to avoid bias. During data collection, only the papers where the raw numbers were available were used. The full text as well as any tables or graphs were searched for this information. Two student reviewers conducted a second search. Conflicts in either inclusion or the specific values was decided by a third-party familiar with the project guidelines. Further details are available in Appendix A.

The two outcomes of interest are survival curves and complication rates. Due to the differences in presentation of the data, the extraction methods differed and are explained below.

Survival Curves

Survival curves were mainly presented in two ways in the literature. The graph of the curve itself was presented or a simple number was given. In the case of numbers, any that had a mixed age of implant survival at single time point were ignored. For instance, Pfefferle et al. collected information on patients who had surgery from 1998-2013 and reported revisions done as of March 26, 2013 as a single figure for survival (Pfefferle, Gil, Fening, & Dilisio, 2014). This was not included. For graphical presentations, Web Plot Digitizer was used to obtain the value at each year of survival independent of reporting increments used in the paper (Rohatgi, 2017). This was done to maximize the information compatibility across papers.

Complications

Complications of specific interest were wound, deep infection, and VTE. This group of complications was chosen as being of most interest to orthopedic surgeons as well as being the complications obesity most likely impacts (Hallstrom, 2017). They are also directly connected to the TKA procedure itself rather than more systemic issues related to health or surgery in general. Other groups of complications frequently mentioned in the literature were also examined. These were major and minor complications, surgical and medical complications, and overall complications. These groups were selected because they were a common theme across the literature, but they are not universal or particularly well defined. For example, the grouping of overall complications is meant to include any and all complications experienced, but if a study only reports complications of specific types ignoring rare or less specific complications in the report this will underestimate overall complications. Some papers chose to report complications by body system rather than individually. This schema may include major and minor complications meaning none can be included in either the major or minor counts for this study. If the grouping was used directly in a paper that number as a total was used. If not, individual complications that fit the category were summed. Any complications reported in groups were carefully considered to avoid double counting specific complications and to not include inappropriate complication types to fit into the defined category.

Only data presented in raw form was included, which excluded papers that only reported odds ratios developed from logistic regression. In most categories, this was one or no papers and at most two per category of complication. No two papers adjusted for all the same things and the papers that reported in the dominant format of contingency table had no adjustment. Thus, for comparability these were excluded at the data collection phase.

Statistical Methods

Survival Curves

With the collected data points taken at each year of follow-up, a weighted average was taken. The weight was the size of the studies as determined by the number of knees not patients. This weighted average was then graphed by BMI class using Microsoft Excel (Microsoft, 2016).

Complications

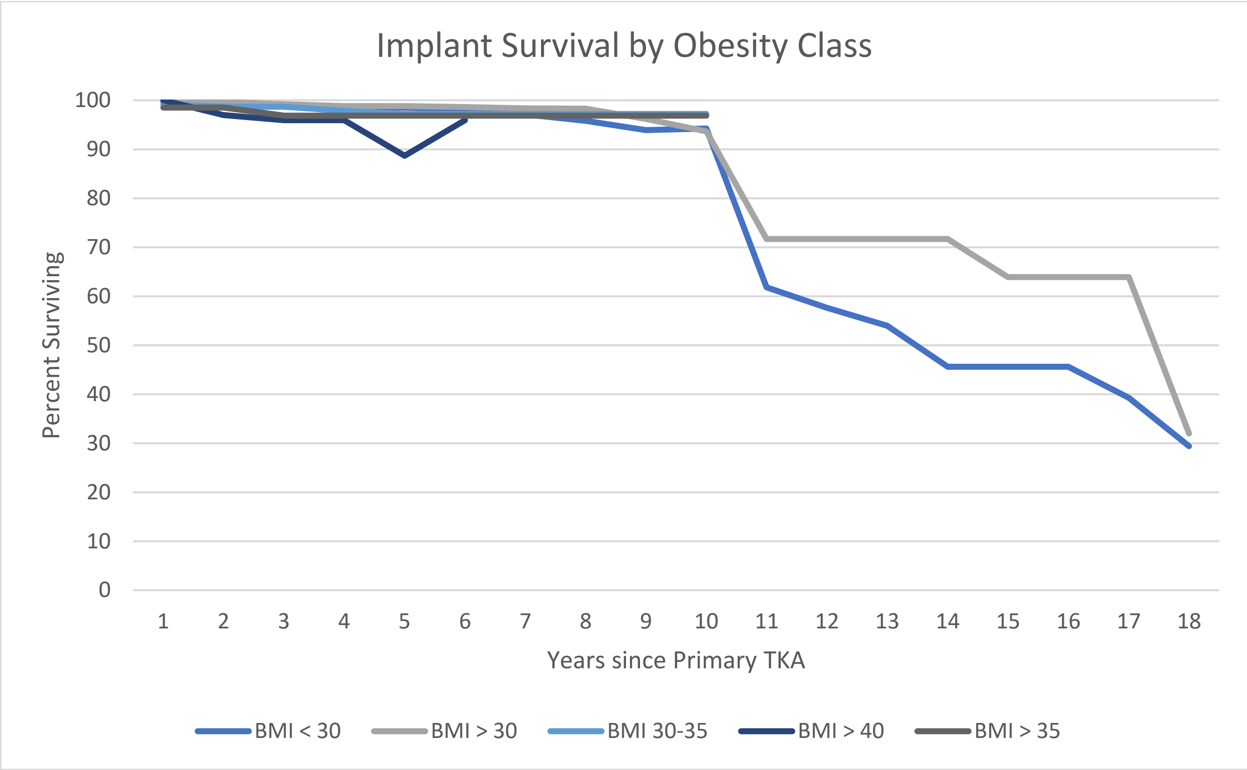
For complications, two ratios were calculated. A pooled odds ratio and a pooled relative risk were both undertaken using a fixed effects model using the inverse variance method. This approach favors larger studies with more weight in the point estimate (Sterne & Egger, 2001). Odds ratios and relative risk are both measures of association between an outcome and an exposure, but they address this relationship differently. The rationale for reporting both ratios is practical. Odds ratio is the dominant effect size reported in the existing literature, but relative risk is a more useful and intuitive number for understanding the probability of adverse effects based on obesity. The population of studies were carefully chosen to be of a homogenous underlying population. Any papers focusing on specific subpopulations were excluded as were countries with a different economic status. There is no theoretical basis to judge these studies to be examining heterogenous populations. However, for some categories, the heterogeneity tests did indicate some level of concern. This has been taken to be a result of the small sample size of some studies. Thus, a fixed effect model was used. The inverse variance method of pooling was selected based on including study quality in a quantifiable way. By weighting the studies with the smallest standard error most heavily, the high-quality studies are given the most impact (Barendregt & Doi, 2016). This method also allows a balance between the claims data and case control study designs. Lastly, a Peto model was determined to be inappropriate given the large effect sizes present.

Results

Survival Curves

The survival of the implant over time, the years past primary surgery without a revision operation, was combined from all studies reporting survival rates. The data from 9 studies was combined as described above. These aggregated survival rates over 20 years is displayed by different levels of BMI in Figure II-2. These curves show no significant difference between obesity classes through the first decade. Only a single study did longer follow-up. Foran et al. display a significant decline in survivorship after 10 years for all patients (Foran, et al., 2004). Of interest is the group with BMI over 30 is significantly better than nonobese in the period up to 18 years. While not included in the pooled results, the mixed duration survival numbers reported in the literature show similar results. A statistical difference is reported in Pfefferle, but it is of negligible practical difference (Pfefferle, Gil, Fening, & Dilisio, 2014). Spicer and Bordini reported no difference (Spicer, et al., 2001), (Bordini, et al., 2009). It is important to note that the number of studies and knees at each varies each year for each category with at most 6 studies and 684 knees to a low of a single study and 32 knees (Table A-2).

Figure II-2 Implant Survival by Obesity Class



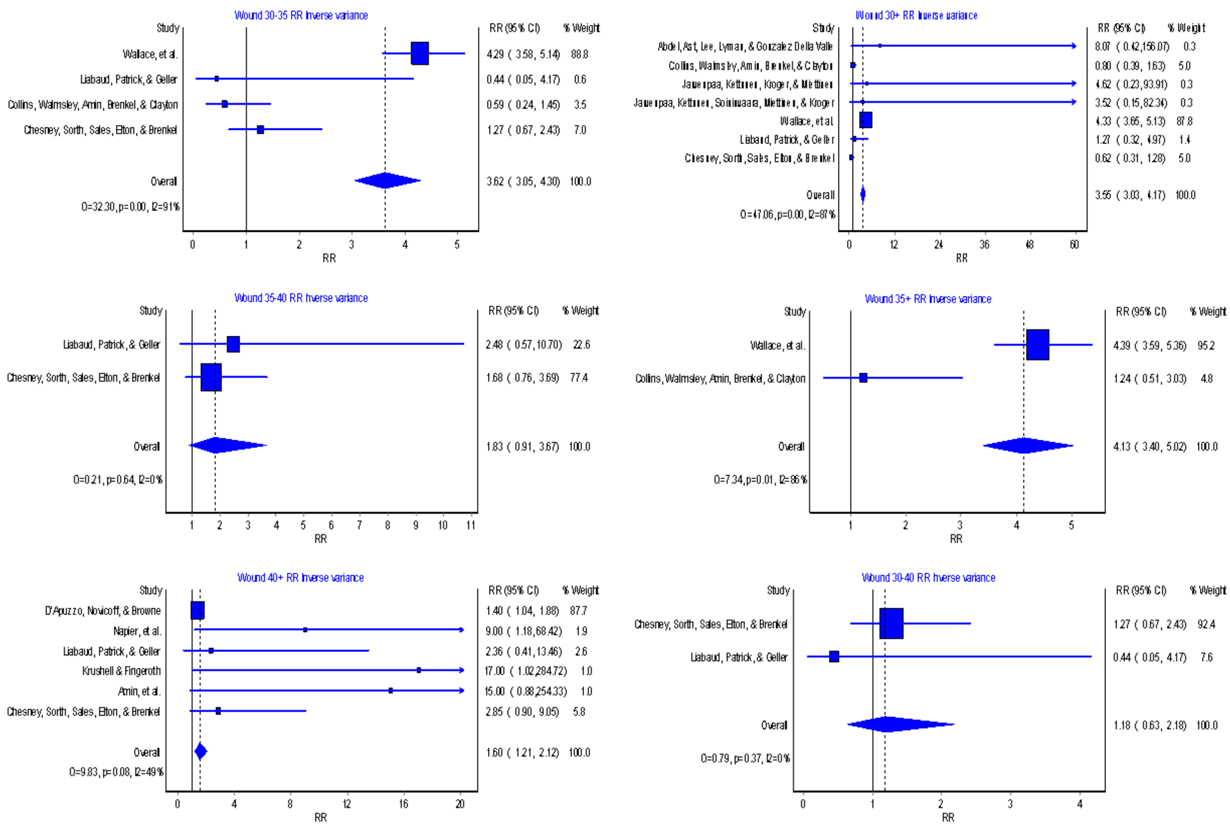
Complications

For complications, the pooled relative risk and odds ratio, both relative to the nonobese population (BMI <30) for various categorical designs are reported in Table II-1. Key findings are discussed below for specific complication types.

Wound

When looking at wound complications, obesity tends to increase the risk. While both Class I and Class III are significantly different from nonobese at 95% confidence level, the risk is more than double in Class I over Class III with OR of 3.748 and 1.605 respectively. It is also important to note that if this analysis focuses instead on just obesity defined as BMI between 30 and 40 the risks are higher than the nonobese, but not statistically significant. Obesity defined as any BMI greater than 30 more closely resembles Class I than Class III. Figure II - 3 shows the forest plots for the pooled relative risks of wound complications in each of the six obese categories under study.

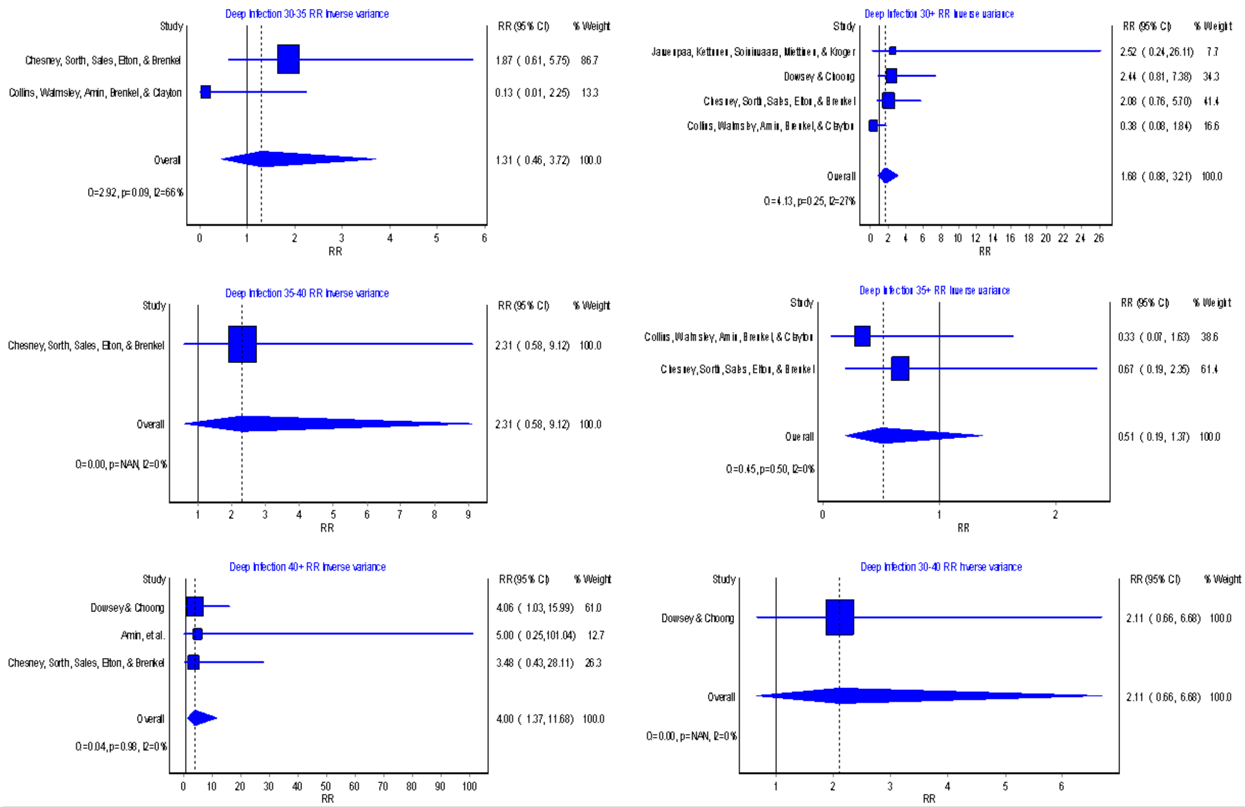
Figure II-3 Forest Plots for Wound Complications by Obesity Class



Deep Infection

This important complication involves major intervention to resolve and yet it is the least attested to in the literature searched. The point estimates indicate that at the granular level all obesity classes show increased risk of deep infection compared to nonobese, but statistically significant results were found only in Class III group. Relatively few studies were available for analysis, so perhaps a lower sample size led to the lack of statistically significant results. Figure II - 4 shows the forest plots for the pooled relative risks of deep infections in each of the six obese categories under study.

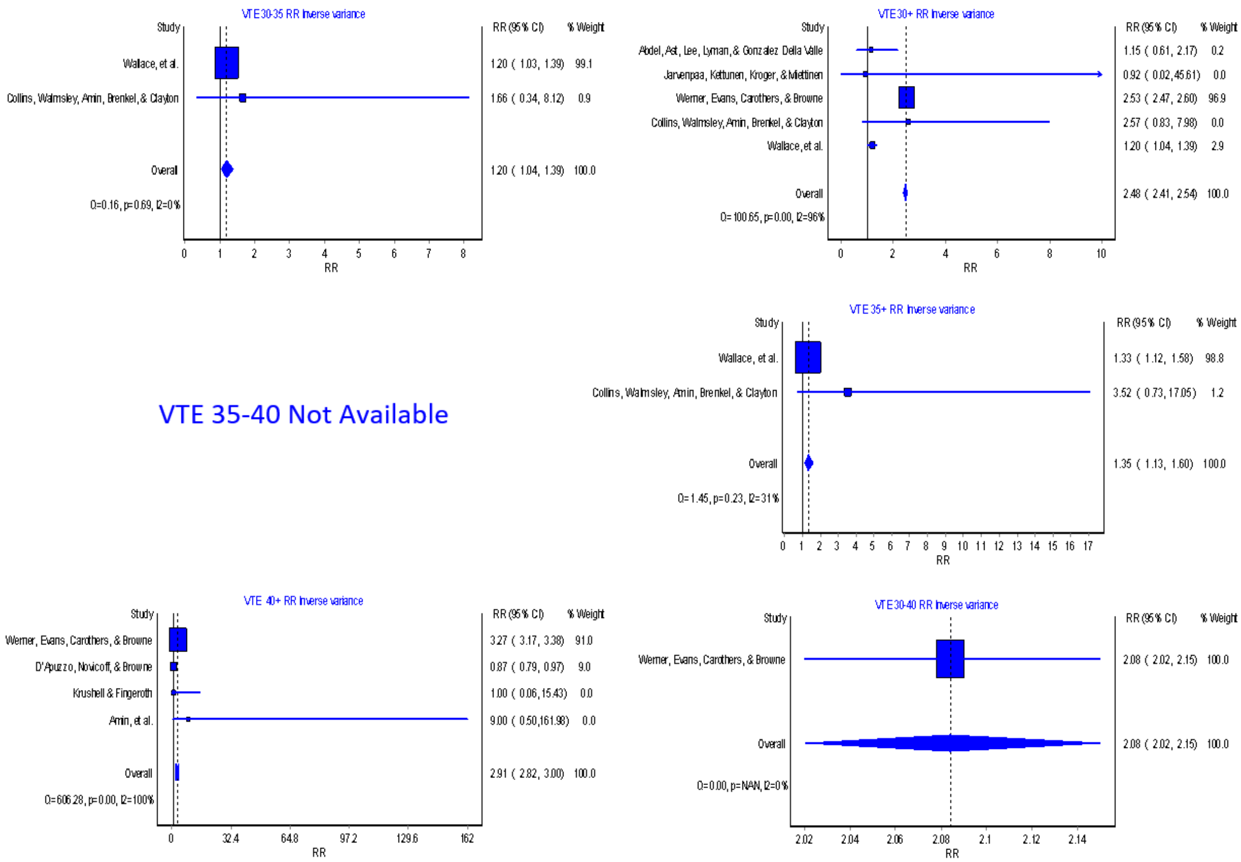
Figure II-4 Forest Plots for Deep Infection Complications by Obesity Class



VTE

In VTE, the higher risks observed for obese patients are statistically significant as compared to nonobese controls. Class I indicates a minor elevation of risk that barely reaches significance (OR 1.207, RR 1.200). No studies specifically studied VTE risk in Class II patients alone. As BMI exceeds 30, the risk is estimated to more than double relative to nonobese patients (OR 2.514, RR 2.476). When looking at obesity defined as BMI 30-40, we find a substantial and significant increased risk for this condition in this group (OR 2.106, RR 2.084). In the Class III group we see an increased risk approaching 3 (OR 2.957, RR 2.909). Using a binary indicator of obesity could obscure the difference between Class I and heavier patients. Figure II - 5 shows the forest plots for the pooled relative risks of VTE in each of the six obese categories under study.

Figure II-5 Forest Plots for VTE Complications by Obesity Class



Groupings

The five broad categories of complications investigated (medical, surgical, major, minor, and overall) are a more complex story that lack statistical significance in many cases. Obesity appears detrimental to most medical complications, but protective in surgical complications. The major and minor groupings lack power to make general conclusions. The overall complication rate shows conflicting results for different obesity levels. It is important to note that these groupings were selected to reflect some trends in the literature, but they are not necessarily found in the papers under study and included in these figures. Further, few studies reported results in a way that allowed for inclusion in these grouped results.

Table II-1 Pooled Odds Ratios and Relative Risks for Various Complications

			Obesity Class					
Significant, Increased Risk	Nonobese Rate	Nonobese	Class I	Class II	Class III	Obese	Obese	Obese
Significant, Decreased Risk	BMI < 30 Rate	BMI < 30	BMI 30-35	BMI 35-40	BMI > 40	BMI > 30	BMI 30-40	BMI > 35
Wound	0.25%							
Odds Ratio (95% CI)		*ref*	3.748 (3.148, 4.463)	1.882 (0.908, 3.9)	1.605 (1.211, 2.127)	3.682 (3.128, 4.335)	1.18 (0.621, 2.241)	4.296 (3.516, 5.249)
Relative Risk (95% CI)		*ref*	3.623 (3.054, 4.298)	1.832 (0.914, 3.671)	1.604 (1.212, 2.121)	3.552 (3.027, 4.169)	1.175 (0.633, 2.183)	4.132 (3.399, 5.022)
Total N		112023	9874	211	90337	17736	671	5618
No. Studies		11	4	2	6	7	2	4
Deep Infection	1.12%							
Odds Ratio (95% CI)		*ref*	1.305 (0.453, 3.763)	2.331 (0.577, 9.425)	4.114 (1.376, 12.3)	1.694 (0.878, 3.269)	2.126 (0.663, 6.822)	0.507 (0.187, 1.374)
Relative Risk (95% CI)		*ref*	1.307 (0.459, 3.723)	2.305 (0.583, 9.116)	4.001 (1.371, 11.681)	1.681 (0.88, 3.212)	2.107 (0.665, 6.678)	0.51 (0.19, 1.37)
Total N		1515	522	154	198	1515	592	255
No. Studies		5	2	1	3	4	1	2
VTE	0.95%							
Odds Ratio (95% CI)		*ref*	1.207 (1.036, 1.405)	-	2.957 (2.868, 3.05)	2.514 (2.45, 2.579)	2.106 (2.041, 2.174)	1.358 (1.138, 1.622)
Relative Risk (95% CI)		*ref*	1.2 (1.035, 1.392)	-	2.909 (2.823, 2.998)	2.476 (2.415, 2.539)	2.084 (2.02, 2.15)	1.347 (1.134, 1.599)
Total N		1323924	9414	0	267197	485889	291914	5343
No. Studies		8	2	0	4	5	1	2
Medical	3.09%							
Odds Ratio (95% CI)		*ref*	0.694 (0.621, 0.776)	-	5.043 (4.958, 5.13)	3.537 (3.489, 3.586)	2.892 (2.844, 2.941)	0.48 (0.409, 0.563)
Relative Risk (95% CI)		*ref*	0.709 (0.638, 0.788)	-	4.492 (4.423, 4.562)	3.282 (3.24, 3.325)	2.735 (2.693, 2.779)	0.497 (0.427, 0.58)
Total N		1239650	9272	0	177146	488831	294945	5276
No. Studies		4	1	0	2	4	2	1
Surgical	4.58%							
Odds Ratio (95% CI)		*ref*	0.326 (0.279, 0.38)	-	1.087 (0.341, 3.458)	0.471 (0.422, 0.526)	0.736 (0.503, 1.077)	0.581 (0.497, 0.68)
Relative Risk (95% CI)		*ref*	0.34 (0.292, 0.395)	-	1.085 (0.348, 3.385)	0.484 (0.435, 0.538)	0.739 (0.507, 1.076)	0.597 (0.514, 0.693)
Total N		26857	9272	0	172	19943	3031	2576
No. Studies		3	1	0	1	3	1	1
Major	2.00%							
Odds Ratio (95% CI)		*ref*	0.442 (0.16, 1.218)	-	15.197 (0.827, 279.287)	1.067 (0.726, 1.568)	-	1.642 (0.68, 3.963)
Relative Risk (95% CI)		*ref*	0.462 (0.175, 1.216)	-	13 (0.756, 223.501)	1.061 (0.731, 1.54)	-	1.566 (0.712, 3.44)
Total N		2803	142	0	41	2401	0	67
No. Studies		3	1	0	1	2	0	1
Minor	2.56%							
Odds Ratio (95% CI)		*ref*	-	-	1.002 (0.233, 4.312)	1.781 (1.285, 2.467)	-	-
Relative Risk (95% CI)		*ref*	-	-	0.956 (0.239, 3.829)	1.747 (1.274, 2.395)	-	-
Total N		2617	0	0	91	2192	0	0
No. Studies		3	0	0	2	1	0	0
Overall	9.76%							
Odds Ratio (95% CI)		*ref*	0.695 (0.64, 0.754)	0.83 (0.274, 2.519)	1.661 (1.013, 2.722)	0.712 (0.667, 0.76)	1.04 (0.855, 1.266)	0.54 (0.483, 0.605)
Relative Risk (95% CI)		*ref*	0.723 (0.671, 0.778)	0.845 (0.309, 2.314)	1.623 (1.036, 2.543)	0.733 (0.69, 0.778)	1.038 (0.86, 1.252)	0.575 (0.519, 0.638)
Total N		28047	9494	57	416	21086	3833	5343
No. Studies		10	3	1	5	7	3	2

Discussion

Several themes emerge from the results. One is that we generally see that obese patients have more complications than nonobese patients. Obese patients appear to be at higher risk of wound infections, deep infections, and VTEs when compared to nonobese patients following TKA. All definitions of obesity show higher risks of complications than nonobese patients, but some estimates of increased risk are not statistically significant. In addition, there is variability in increased risk for different definitions or categories of obesity.

It would be expected that if there was a detrimental effect of obesity in outcomes of TKA that a dose-response type effect would be observed with more dramatic obesity classification leading to more dramatic risk increases. We do not observe this.

One possible reason for the lack of dose-response effect is that, regardless of study design and controls, obese patients face different surgical criteria already (Kolata, 2016), (Yates, 2016). This would mean any observational design will fail to detect the true relationship between obesity and outcomes. If less healthy Class I patients are allowed surgery when Class III patients face more rigorous general health criteria before the patient can proceed to surgery, we would expect ancillary complications to be higher in the overall less healthy, but lighter group. Another manifestation of this explanation is found in the survival results. The endpoint used is not actually a failed implant but a revision operation. If obese patients are not given the option of reoperation, then they would not appear in this curve as a failure biasing the results towards no difference.

Another explanation for these somewhat counterintuitive results is that even if the selection is unbiased that the treatment plan or execution is different. This could explain why the risk of wound complications is highest in Class I patients. If following the current literature that Class III is a problem, but not simple obesity, these Class I patients may not be instructed as stringently on wound care or may see less intensive watching than their heavier counterparts.

An important consideration for these results is that by design they are unadjusted. In the literature search, papers that only reported adjusted odds ratios were discarded and in papers that reported both the contingency table and odds ratio only the contingency table’s raw numbers were used. This makes combining across papers appropriate given every paper adjusted for different things. It does however mean that any effect of age or comorbidities not addressed by a case control design is left in these figures. Papers that reported both adjusted odds ratios and raw numbers do not show a clear pattern of difference with some adjusted risks being much lower than the raw numbers suggest (Dowsey & Choong, 2009), others having nearly identical results in the adjusted and unadjusted risks, (D'Apuzzo, Novicoff, & Browne, 2015), and others having unadjusted risks half that suggested in the adjusted figure (Dowsey & Choong, 2009).

It is also apparent from examining both individual and grouped complications that granularity and agreement on which complications are of interest also matters. Studies that focus on grouped complications may find less of an effect of obesity than those examining specific complications of interest. This may be providing a false security to obese patients and their surgeons about their true risk profile. That is not to say groupings of complications are not of interest, but some effort should be made to design future groups to be more compatible with prior studies. Many studies were unable to be included in this meta-analysis because only grouped outcomes were reported and they were not defined either well enough to determine specific complications included or were entirely novel and unable to be grouped with any other studies. It is entirely possible that these seemingly conflicting results are really in agreement at a more granular level of single complications, but the different grouping systems yield different overall risk assessments.

The use of groups deserves further comment. As the results above suggest, using common and simple-sounding categories (such as “medical” and “surgical”) can be problematic. Firstly, the differing reporting style means that many of the studies that were otherwise of high quality could not be considered in this analysis because the complication outcome was entirely unable to be collapsed into a standard category or individual complication. Secondly, another issue, especially relating to the overall complication rate, has to do with which complications were included in the studies. Some chose a specific set to look for in charts that were deemed of interest or relevant to the procedure, but others chose to include any complication that occurred. These yielded two distinct types of “overall complication” numbers that are not measuring the same thing. In the same vein, some of the studies included in the "overall complication" results reported an overall number themselves while others are the sum of the individual complications reported in the papers that did not report overall rates on their own. Third, these groups may reflect something beyond obesity-related complications. A feedback loop may exist between major complications and surgical complications and surgeon quality, but surgeon quality may be a factor in which patients they choose to operate on. Much more clearly defined categories and complications to include needs to be agreed upon before these grouped results are considered for use in decision-making.

Future Research

Future research related to the effect of obesity on outcomes of TKA would benefit from several changes.   One would be moving away from a binary obesity classification culled from a single comorbidity and move towards measured BMI reported at a minimum using the WHO classification system or even a continuous BMI variable. It is clear that different classes behave differently in almost every complication examined. Adopting this more detailed approach may provide clarity to the debate in the literature about whether obesity increases the risk of complications currently observed or if there are certain obesity thresholds that are important to complication risk.

In the same spirit, more attention should be paid to consistent definitions of complications. Grouping complication by body system or severity or root cause is useful information, but without specific complication data the study is rendered less helpful in future meta-analyses. It may also be obscuring risk for some groups.

Finally, an effort should be made for more detailed description of patient selection and treatment protocols. While a randomized trial withholding care or inducing obesity is not possible, the standard matching on demographics may not suffice. Even matching or controlling for comorbidities may not suffice if these characteristics are evaluated differently in obese and nonobese populations. Treatment descriptions, if they exist, generally focus on type of implant or surgical approach used, but outcomes depend on the immediate follow-up period as well, which is nearly never described. While the claims data approach is an excellent way to add power and increase demographic generalizability, it may be obscuring key details on this account. Any designs that are not observational are to be pursued towards this end. A natural experiment using the NHS trusts that withheld TKA in some populations may be one possible setting for such a study.

It is also important that future research continues to report on both findings and non-findings in this area. Currently, no publication bias appears to exist as no consensus has yet been reached so individual studies are equally likely to report higher risk for obese patients as not. This is to be commended and continued.

Clinical Applications

Obese patients do face higher complication rates. This is most evident in looking at single complications. The grouped complications should not be used in evaluating risk at the current time. Careful attention should be paid to the postoperative regimen and aftercare instructions in all patients not just the morbidly obese. Informal heuristics may be ensuring that only the healthiest Class III patients are offered surgery while less healthy nonobese patients are routinely offered surgery. Therefore, it is important that the clinician does not consider only obesity in making treatment plans.

Methodological Advances

This study is the first formal meta-analytic evaluation of the impact on outcomes in TKA due to obesity. The focus on finer WHO classification for obesity is also a new approach. These techniques allow a fuller understanding of obesity ‘s impact on outcomes while making use of existing work.

CHAPTER III:
A Cost-Effectiveness Analysis of Total Knee Arthroplasty in Obese Populations

Background

The current literature has found some suggestions that the outcomes are different in obese populations but has not addressed quantitatively whether that is enough to withhold TKA. The meta-analysis in Chapter II also finds differences in complication rates. The previous studies have examined isolated factors including surgical time and certain complication rates. Rather than looking at simple differences in complication rates or patient satisfaction and extrapolating to a guideline, an analysis that combines all the available information in a systematic way and quantifies the value of TKA obtained in subpopulations based on their BMIs is needed. This study examines the entire experience holistically over time.

One approach to this broader policy question of whether obese patients should be offered elective TKA surgery is a cost-effectiveness framework. In this way, we can evaluate both the costs and benefits of proposed policies, such as a guideline restricting TKA to nonobese patients. CEA incorporates the value of treatment and a more long-term perspective than the simple cost-saving approach used in the UK in attempts to balance NHS trust budgets. Studies addressing complication rate differences amongst obesity groups have considered obesity guidelines to restrict access, but there has never been a formal examination of the cost-effectiveness of general guidelines.

While TKA in general has been judged cost-effective, no one has addressed this question specifically in obese populations. A cost-effectiveness analysis will incorporate both costs and quality of life information specific to patient obesity classifications to address this nascent policy issue. Current implementations of a ban as done in the UK are based on purely financial calculations, as admitted by the trusts involved in the UK guidelines, which raises the specter of unfairly rationing care at the expense of patient care. This study will attempt to answer whether TKA in obese populations is a worthwhile use of resources to society.

Methods

Overview of Model

To perform the CEA of TKA in obese populations, a Markov model was developed in Microsoft Excel 2016 and Visual Basic for Applications was used to perform sensitivity analysis (Microsoft, 2016). The basic model design, including the choice of health states, follows a similar model by Losina, et al. as closely as possible (Losina, et al., 2009). While Losina, et al. sought to understand the impact of hospital volume on patients, this model will instead examine the effect of obesity severity in patient outcomes. The overall patient journey from no surgery to final outcome is unchanged in the conceptual model. The choice to replicate the model design allows for cross model validation, furthers a single conceptual model of the progression from disease to knee replacements and outcomes in the literature, and eases verification of the model implementation (Rand & Wilensky, 2006). This analysis seeks to understand the role of obesity as defined in the WHO classification system. In this scheme, obesity has three classes based on BMI: : Class I with $30 \leq BMI < 35$, Class II with $35 \leq BMI < 40$, and Class III with $BMI \geq 40$, also known as morbid obesity (Centers for Disease Control and Prevention, 2016). The model therefore examines four groups of patients based on obesity status: those who are not obese ($BMI < 30$) and the three obesity classes. This replaces classifications of hospital volume and generic patient risk used in Losina, et al. The model also follows standard cost-effectiveness practice using a 3% discount rate (Gold, Siegel, Russell, & Weinstein, 1996) for both future costs and health related quality of life using a societal perspective.

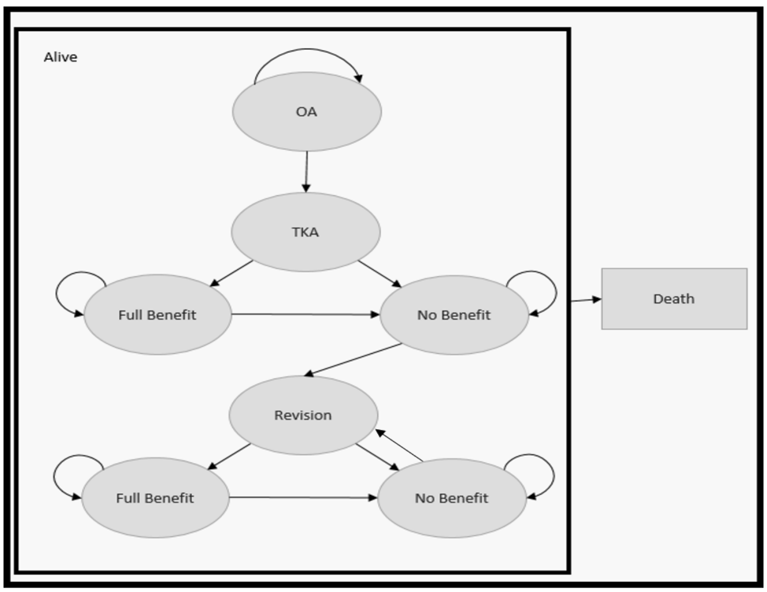
CEA Terminology

Several definitions specific to the cost-effectiveness domain are explained below. The incremental cost-effectiveness ratio (ICER) is a statistic defined as the difference in intervention and baseline costs divided by the difference in intervention and baseline QALYs providing a ratio of costs and benefits. This can then be compared to threshold values to assess the cost-effectiveness of an intervention. Net Monetary Benefit (NMB) is another summary statistic that incorporates the threshold value directly rather than a comparison as in the case of an ICER. In the US, the two commonly held thresholds for an intervention being considered cost-effective are $50,000 and $100,000 per QALY (Neumann, Cohen, & Weinstein, 2014). Thresholds are country but not disease specific. They serve as a benchmark of value for health care dollars across the whole of the system to aid in decision making among competing priorities. An intervention is said to be dominant if it is both less expensive and provides more health benefits than the status quo. Conversely, an intervention is dominated if it costs more to implement while providing less benefit than the alternative.

Model Structure

The model consists of 8 basic health states as shown in Figure III-1. All patients begin in end-stage OA of the knee, significant pain in and changes to the joint. From OA, patients may elect to undergo a TKA, the first of two acute states. The TKA may either result in a full benefit to the patient or no benefit. Full benefit means that the patient is now seeing an improvement over the preoperative state. No benefit means that the surgery did not improve the health state of the patient. This is a simplification from Losina, et al. where a limited benefit state exists as a precursor to failure. To accommodate more limited data on obese patients, this model collapsed those two states into a single full benefit state. For those who initially had a positive outcome, failure is still possible. Those who are in the no benefit state may choose to undergo a revision procedure, the second acute state. Revision leads to similar outcome states as those seen in the primary TKA. The final health state is death to which all other health states can transition.

Figure III-1 Simplified Compartmental Model Flow Chart



The time step of the model is one year. The two acute surgical states take zero time, but a health impact is assessed for passing through this state. In addition, patients who undergo surgery may also experience complications which add both cost and health penalties. Three specific complications are considered: wounds, VTEs, and deep infections. The last is of special interest given the intensity of treatment and possible long-term consequences. While the wound and VTE patients face one-time penalties in cost and Quality Adjusted Life Years (QALYs) for the year of the procedure, the deep infection complication patients move to a separate submodel for the duration. Following deep infection, patients permanently face different consequences and lower quality of life but follow a similar set of possible transitions. More specifically, a patient experiencing a deep infection has a second surgery the following year. There are still two possible outcomes of that surgery but the quality of life possible is lower than regular surgeries and the probability of each is specific to the deep infection module. The risk of complications is also different in the submodule. In some scenarios under consideration, OA patients may choose to have surgery or not at each time step, in others all patients receive TKA in the first year. For the benefit states, Figure III-1 is a simplification. The transition to failure is dependent on the age of the implant so these states are in fact a tunnel of health states where all patients move out of the state entirely or advance one year in the same state. In a similar way, the decision to revise or not is also time dependent with immediate failures undergoing revision more frequently than late failures.

Population

The model follows a cohort of patients. All patients begin the model at age 74 to match the average overall age of the Medicare population as used by Losina, et al. (Losina, et al., 2009). The model is flexible to evaluate other starting ages to incorporate the trend toward younger patients. The population is homogenous in all respects except for obesity. The four obesity groups – nonobese and Class I – III – run through the model separately using class specific parameters for some transitions and costs as defined below.

Alternative Strategies

The scenarios examined provide TKA to OA patients in different populations by obesity group. The alternative is supportive care for OA. Evaluation of the TKA strategy is done in two ways: in the base case, surgery occurs in the first year. In an alternative analysis, surgery occurs as a staggered patient choice with a percent of patients with OA opting in each year. The staggered start is used only for cross model comparison to Losina, et al. and the immediate TKA for the entire cohort is used for the rest of the analyses. In both cases, the comparison is between TKA and no TKA (OA with supportive care). The obesity groups considered are nonobese, Class I obesity, Class II obesity, and Class III obesity. Death rates vary by age as well as obesity classification. The obesity classification is unchanged for the duration of the model and the years spent as obese are not considered. Complication rates, surgical success (likelihood of full versus no benefit after surgery) and failure rates vary by obesity. Costs of surgery as well as overall quality of life are also dependent on the obesity classification.

Outcomes

The outcomes of interest include costs and QALYs, as well as the ICER and NMB. The model tracks the four obesity group outcomes separately. The overall outcomes are based on a weighted average of the four obesity groups where the weights are equal to the current share of the general population in each obesity group. In addition, the model considers two scenarios relative to no TKA, staggered TKA for cross model validation and all patients receiving TKA in the first year for policy recommendations. This provides 10 sets of outputs.

Data

Parameters fall into several broad categories including the likelihood of surgical outcomes for primary and revision TKAs, complication rates, implant failure rates, costs of treatment, and health outcomes measured in QALYs. The data to parameterize the model comes from a variety of sources with a focus on large population studies. Many data sources follow Losina, et al. with newer data used if available. Meta-analyses supplemented where needed particularly for complication and failure rates.

Transitions Between States

The primary transitions required for the Markov model (Table III-1) fall into several broad categories. Patient decisions to have TKA procedures are the first group and these rates follow existing literature. The staggered analysis requires a probability that a patient with end stage symptomatic knee OA will undergo TKA. That parameter uses the same parameter as Losina, et al which follows Holt, et al. who combine existing literature with observed utilization in the US and suggest a third of the symptomatic OA patients undergo surgery each year (Holt, et al., 2011). Both the immediate and staggered models use another patient decision: whether a failed surgery results in a revision. In this, the model follows that of Losina, et al. If a surgery is an immediate failure, all patients undergo revision surgery, but if it fails after the first year, then only half seek revision each year (Losina, et al., 2009). The next group of transitions relates to outcomes. The sources for these parameters are based in the literature. In Losina, et al., the model uses two states of improvement with a substantial improvement deemed full benefit and some improvement called limited benefit. In this model, a single state of full benefit conflates these so that any improvement qualifies as full benefit. Katz, et al. suggests that this figure is 90% following work done by Fortin, et al. (Katz, et al., 2004) (Fortin, et al., 2002). Lastly, revision outcomes follow a similar approach. A meta-analysis done by Saleh, et al. using patient reported Knee Scores found 77% good or excellent outcomes after revision (Saleh, et al., 2002). The final possible transition is that patients in any health state may die. Age dependent mortality rates come from US CDC life tables (Centers for Disease Control and Prevention, 2017). Relative risks for obesity are discussed in a later section.

Table III-1 Transition Parameters

Name	Base	Low	High	Distribution	Source (Base/ Range & Distribution)
Annual Probability OA has TKA	0.33	0.22	0.44	Normal (0.33, 0.06)	6/6
Probability of Full Benefit following TKA	0.9	0.1394	1	Beta (0.88, 0.12)	7/10a
Relative Risk for Nonobese (BMI <30)	1.0287	0.9765	1.0568	Normal (1.03, 0.02)	*
Relative Risk for Class I Obese (BMI 30-35)	0.9464	1.0438	0.894	Normal (0.95, 0.03)	*
Relative Risk for Class II Obese (BMI 35-40)	0.9464	1.0438	0.894	Normal (0.95, 0.03)	*
Relative Risk for Class III Obese (BMI > 40)	0.9464	1.0438	0.894	Normal (0.95, 0.03)	*
Probability of Revision after Early Failure	1	0	1	Beta (0.5, 0.5)	10/+
Probability of Revision after Late Failure	0.5	0	1	Beta (0.5, 0.5)	10/+
Probability of Full Benefit following Revision	0.77	0.1394	1	Beta (0.88, 0.12)	12/10c
Relative Risk for Nonobese (BMI <30)	1.0773	0.9369	1.1528	Normal (0.86, 0.05)	*
Relative Risk for Class I Obese (BMI 30-35)	0.8559	1.1178	0.715	Normal (0.86, 0.09)	*
Relative Risk for Class II Obese (BMI 35-40)	0.8559	1.1178	0.715	Normal (0.86, 0.09)	*
Relative Risk for Class III Obese (BMI > 40)	0.8559	1.1178	0.715	Normal (0.86, 0.09)	*
Annual Death Rate	1	1	1	Constant Value of 1	1/Not Tested
Relative Risk for Nonobese (BMI <30)	1	1	1	Constant Value of 1	3a
Relative Risk for Class I Obese (BMI 30-35)	1.0158	1.0106	1.021	Lognormal (0.02, 0)	3a
Relative Risk for Class II Obese (BMI 35-40)	1.0108	1.001	1.0207	Lognormal (0.01, 0)	3a
Relative Risk for Class III Obese (BMI > 40)	1.0923	1.0763	1.1085	Lognormal (0.09, 0.01)	3a
Probability of Best Case after Deep Infection Surgery	0.5	0	1	Beta (0.5, 0.5)	~/+
Relative Risk for Nonobese (BMI <30)	1.0773	0.9369	1.1528	Normal (0.86, 0.05)	*
Relative Risk for Class I Obese (BMI 30-35)	0.8559	1.1178	0.715	Normal (0.86, 0.09)	*
Relative Risk for Class II Obese (BMI 35-40)	0.8559	1.1178	0.715	Normal (0.86, 0.09)	*
Relative Risk for Class III Obese (BMI > 40)	0.8559	1.1178	0.715	Normal (0.86, 0.09)	*
Probability of Revision after Early Failure of Deep Infection Surgery	0	0	1	Beta (0.5, 0.5)	#/+
Probability of Revision after Late Failure of Deep Infection Surgery	0	0	1	Beta (0.5, 0.5)	#/+

#: In the base case, the worst-case scenario is amputation so there is no re-revision possible.

*: This parameter was unavailable in the literature. Relative risks of a poor outcome are approximately 2 for obese patients for observed parameters. The relative risks generally range from slightly protective to a relative risk of 4. This range was used as the basis for the unknown value here. The model is structured as a probability of a good outcome, so calculations were performed to make these observations compatible with the probability of the positive outcome of not failing.

~: Expert opinion for estimate

+: No information available for this range. A Beta (0.5,0.5) distribution was used to cover the full probability range with weight in center as best guess that explored full probability space.

1: Centers for Disease Control and Prevention

3: The Global BMI Mortality Collaboration a: The table data provided was used to construct relative risks and confidence intervals rather than the hazard ratios reported in the paper.

6: Holt, et al.

7: Katz, et al.

10: Losina, et al.

10: Losina, et al. a: The range used for limited benefit is taken as the complement of the full benefit desired for this model. The convention for defining a beta distribution was used.

10: Losina, et al. c: The rates given in the literature for success of revision surgery vary widely from less than 50% to nearly 90%. To ensure a wide range was explored, the same range from the primary surgery based in the Losina, et al. model was used here as well.

12: Saleh, et al.

Complications

A meta-analysis (Chapter II) was conducted to evaluate important complications by obesity class and those figures are used here to track VTE, wound complications and deep infections (Table III-2). For surgeries subsequent to a deep infection, the rates of wounds and VTE are the same but deep infection is ten times more likely. The meta-analysis results broadly indicate higher complication rates for obese patients for the VTEs, wound complications, and deep infections considered in the model. Depending on the exact definition of obesity used, the results showed some variability in magnitude and obtainment of statistical significance. Counterintuitively, no dose-response effect was observed as obesity increased for which several explanations are proposed in the meta-analysis.

Table III-2 Complication Parameters

Name	Base	Low	High	Distribution	Source (Base/ Range & Distribution)
VTE	0.0095	0	0.0279	Normal (0.01, 0.01)	4/4
Relative Risk for Nonobese (BMI <30)	1	1	1	Constant Value of 1	4/4a, b
Relative Risk for Class I Obese (BMI 30-35)	1.2005	1.0355	1.3918	Lognormal (0.18, 0.08)	4/4a, b
Relative Risk for Class II Obese (BMI 35-40)	2.0841	2.0202	2.15	Lognormal (0.73, 0.02)	4/4a, b
Relative Risk for Class III Obese (BMI > 40)	2.9088	0.5472	15.4612	Lognormal (1.07, 0.85)	4/4a, b
Wound	0.0025	0	0.0466	Normal (0, 0.02)	4/4
Relative Risk for Nonobese (BMI <30)	1	1	1	Constant Value of 1	4/4a, b
Relative Risk for Class I Obese (BMI 30-35)	3.6226	0.5798	22.6327	Lognormal (1.29, 0.93)	4/4a, b
Relative Risk for Class II Obese (BMI 35-40)	1.8316	0.914	3.6706	Lognormal (0.61, 0.35)	4/4a, b
Relative Risk for Class III Obese (BMI > 40)	1.6036	0.4971	5.173	Lognormal (0.47, 0.6)	4/4a, b
Deep Infection	0.0112	0	0.0363	Normal (0.01, 0.01)	4/4

Relative Risk for Nonobese (BMI <30)	1	1	1	Constant Value of 1	4/4a, b
Relative Risk for Class I Obese (BMI 30-35)	1.3066	0.076	22.4712	Lognormal (0.27, 1.45)	4/4a, b
Relative Risk for Class II Obese (BMI 35-40)	2.3052	0.5829	9.1164	Lognormal (0.84, 0.7)	4/4a, b
Relative Risk for Class III Obese (BMI > 40)	4.0014	1.3707	11.6813	Lognormal (1.39, 0.55)	4/4a, b
VTE after Deep Infection	0.0095	0	2	Normal (0.01, 0.01)	4c
Relative Risk for Nonobese (BMI <30)	1	1	1	Constant Value of 1	4c
Relative Risk for Class I Obese (BMI 30-35)	1.2005	1.0355	1.3918	Lognormal (0.18, 0.08)	4c
Relative Risk for Class II Obese (BMI 35-40)	2.0841	2.0202	2.15	Lognormal (0.73, 0.02)	4c
Relative Risk for Class III Obese (BMI > 40)	2.9088	0.5472	15.4612	Lognormal (1.07, 0.85)	4c
Wound after Deep Infection	0.0025	0	0.0466	Normal (0, 0.02)	4c
Relative Risk for Nonobese (BMI <30)	1	1	1	Constant Value of 1	4c
Relative Risk for Class I Obese (BMI 30-35)	3.6226	0.5798	22.6327	Lognormal (1.29, 0.93)	4c
Relative Risk for Class II Obese (BMI 35-40)	1.8316	0.914	3.6706	Lognormal (0.61, 0.35)	4c
Relative Risk for Class III Obese (BMI > 40)	1.6036	0.4971	5.173	Lognormal (0.47, 0.6)	4c
Subsequent Deep Infection	0.1122	0.0871	0.1373	Normal (0.11, 0.01)	4d
Relative Risk for Nonobese (BMI <30)	1	1	1	Constant Value of 1	4d
Relative Risk for Class I Obese (BMI 30-35)	1.3066	0.076	22.4712	Lognormal (0.27, 1.45)	4d
Relative Risk for Class II Obese (BMI 35-40)	2.3052	0.5829	9.1164	Lognormal (0.84, 0.7)	4d
Relative Risk for Class III Obese (BMI > 40)	4.0014	1.3707	11.6813	Lognormal (1.39, 0.55)	4d

4: Guiney
4: Guiney a: Inverse Variance Heterogeneity method used to parameterize the model over the values reported in this paper. This method accounts for more sources of heterogeneity which widens the confidence intervals to ensure the model encompasses the full range of values.

4: Guiney b: Using the reported confidence intervals, a lognormal distribution was fitted.

4: Guiney c: Unchanged from main model

4: Guiney d: Following expert opinion, the reoccurrence rate is ten times the primary rate.

Implant Failure Rates

Patients who initially have a positive outcome may still face implant failure over time. Each year after surgery, the probability of failure changes (Table III-3). The relative risks applied based on obesity follow in Table III-4. The meta-analysis conducted in Chapter II is the source for these annual rates in primary and revision surgeries. Failure rates subsequent to a deep infection are estimated at 50% each year. The ranges and relative risks are not year specific and are derived from the literature (Losina, et al., 2009) (Kerkhoffs, et al., 2012).

Table III-3 Annual Failure Parameters

Name	Base	Low	High	Distribution	Source (Base/ Range & Distribution)
TKA Failure - Year 1	0.0051	0	0.0764	Constant Value of 0	4, 10b
TKA Failure - Year 2	0.0107	0	0.0764	Constant Value of 0	4, 10b
TKA Failure - Year 3	0.0129	0	0.0764	Constant Value of 0	4, 10b
TKA Failure - Year 4	0.0128	0	0.0764	Constant Value of 0	4, 10b
TKA Failure - Year 5	0.0151	0	0.0764	Constant Value of 0	4, 10b
TKA Failure - Year 6	0.0181	0	0.0764	Constant Value of 0	4, 10b
TKA Failure - Year 7	0.0291	0	0.0764	Constant Value of 0	4, 10b
TKA Failure - Year 8	0.0423	0	0.0764	Constant Value of 0	4, 10b
TKA Failure - Year 9	0.0608	0	0.0764	Constant Value of 0	4, 10b
TKA Failure - Year 10	0.0578	0	0.0764	Constant Value of 0	4, 10b
Revision Failure - Year 1	0.0028	0	0.1673	Constant Value of 0	4, 10d
Revision Failure - Year 2	0.0033	0	0.1673	Constant Value of 0	4, 10d
Revision Failure - Year 3	0.0082	0	0.1673	Constant Value of 0	4, 10d
Revision Failure - Year 4	0.0122	0	0.1673	Constant Value of 0	4, 10d
Revision Failure - Year 5	0.0122	0	0.1673	Constant Value of 0	4, 10d
Revision Failure - Year 6	0.0139	0	0.1673	Constant Value of 0	4, 10d
Revision Failure - Year 7	0.0166	0	0.1673	Constant Value of 0	4, 10d
Revision Failure - Year 8	0.0172	0	0.1673	Constant Value of 0	4, 10d
Revision Failure - Year 9	0.038	0	0.1673	Constant Value of 0	4, 10d
Revision Failure - Year 10	0.0603	0	0.1673	Constant Value of 0	4, 10d
Failure After Deep Infection - Year 1	0.5	0	1	Constant Value of 0	~, +
Failure After Deep Infection - Year 2	0.5	0	1	Constant Value of 0	~, +
Failure After Deep Infection - Year 3	0.5	0	1	Constant Value of 0	~, +
Failure After Deep Infection - Year 4	0.5	0	1	Constant Value of 0	~, +
Failure After Deep Infection - Year 5	0.5	0	1	Constant Value of 0	~, +
Failure After Deep Infection - Year 6	0.5	0	1	Beta (0.5, 0.5)	~, +
Failure After Deep Infection - Year 7	0.5	0	1	Beta (0.5, 0.5)	~, +
Failure After Deep Infection - Year 8	0.5	0	1	Beta (0.5, 0.5)	~, +
Failure After Deep Infection - Year 9	0.5	0	1	Beta (0.5, 0.5)	~, +
Failure After Deep Infection - Year 10	0.5	0	1	Beta (0.5, 0.5)	~, +

~: Expert opinion for estimate

+: No information available for this range. A Beta (0.5,0.5) distribution was used to cover the full probability range with weight in center as best guess that explored full probability space.

4: Guiney

10: Losina, et al. b: For sensitivity analyses, Losina, et al. followed using single range for all years.

10: Losina, et al. d: To encompass the idea that revision sees lower success rates, the primary range was modified such that it is centered on a value twice as bad as that used in the primary distribution.

Table III-4 Obesity Adjustments for Failure Rates

Name	Base	Low	High	Distribution	Source (Base/ Range & Distribution)
TKA Failure					
Relative Risk for Nonobese (BMI <30)	1	1	1	Constant Value of 1	8a/8b
Relative Risk for Class I Obese (BMI 30-35)	1.7689	1.1494	2.7635	Lognormal (0.57, 0.22)	8a/8b
Relative Risk for Class II Obese (BMI 35-40)	1.7689	1.1494	2.7635	Lognormal (0.57, 0.22)	8a/8b
Relative Risk for Class III Obese (BMI > 40)	1.7689	1.1494	2.7635	Lognormal (0.57, 0.22)	8a/8b
Revision Failure					
Relative Risk for Nonobese (BMI <30)	1	1	1	Constant Value of 1	8a/8b
Relative Risk for Class I Obese (BMI 30-35)	1.7729	1.1479	2.7209	Lognormal (0.57, 0.22)	8a/8b
Relative Risk for Class II Obese (BMI 35-40)	1.7729	1.1479	2.7209	Lognormal (0.57, 0.22)	8a/8b
Relative Risk for Class III Obese (BMI > 40)	1.7729	1.1479	2.7209	Lognormal (0.57, 0.22)	8a/8b
Failure After Deep Infection					
Relative Risk for Nonobese (BMI <30)	1	1	1	Constant Value of 1	8a/8b
Relative Risk for Class I Obese (BMI 30-35)	1.7729	1.1479	2.7209	Lognormal (0.57, 0.22)	8a/8b
Relative Risk for Class II Obese (BMI 35-40)	1.7729	1.1479	2.7209	Lognormal (0.57, 0.22)	8a/8b
Relative Risk for Class III Obese (BMI > 40)	1.7729	1.1479	2.7209	Lognormal (0.57, 0.22)	8a/8b

8: Kerkhoffs, et al. a: Converted the odds ratio from Kerkhoffs, et al. to relative risk using RR = OR/(1-AbsRisk+(AbsRisk*OR)) with the Year 5 failure rate as the absolute risk as the original data was over 5-year period.
8: Kerkhoffs, et al. b: The high and low values used are derived using the same conversion from OR to RR as the base rate. To create a distribution, the event data in Figure 4 of Kerkhoffs, et al. were used to calculate a standard error with the formula: sqrt (1/event +1/event +1/total +1/total)

Costs

The costs (Table III -5), where possible, follow Losina, et al. Following the methodology of Losina, et al., the cost of the primary surgery is a combination of a Current Procedural Terminology (CPT) code (27447), a Diagnosis-related Group (DRG), and physical therapy costs (Losina, et al., 2009). The 2015 Medicare reimbursement rates were used rather than inflating the older costs used by Losina, et al. (Centers for Medicare & Medicaid Services, 2017), (Centers for Medicare & Medicaid Services, 2017). For the physical therapy component, after currency conversion, the inflation was done separately based on the figures from the Canadian study used by Losina, et al. This composite figure is the overall cost. Using population level obesity rates, the cost for the nonobese population was derived from this overall cost. The cost of revision followed a similar pattern. The CPT code (27487) and DRG changed and the in-home physical therapy care value was nearly tripled over primary surgery to account for the added intensity and duration required, which Losina did not incorporate (Losina, et al., 2009). The choice of DRG requires further discussion as it diverges from Losina, et al. For primary surgery, the DRG used was that for uncomplicated joint replacement, 470. Only major complications and comorbidities (MCC) justify the DRG 469 designation and the MCC list does not include obesity. Further, less than 5% of primary joint replacements are billed as 469 (Fontana, 2017) so the uncomplicated DRG was selected. In the case of revisions, three DRGs exist. Major complications (466) are again unlikely with less than 10% of joint revisions using this designation. For the remaining joint revisions, there is an almost even split between 467 for complications and comorbidities (CC) and 468 for uncomplicated (no MCC or CC). While the CC list includes BMI $\geq$ 40, the increased reimbursement between 467 and 468 is approximated by the obesity multiplier added in this model so DRG 468 was used in all obesity groups and independent of complication outcome. Another reason for these choices is that all five DRGs include both hips and knees. The share of knees in the higher DRG groups relative to the overall number reported is unclear and may not be the same as the overall billing pattern.

For the cost of complications, Losina, et al. uses a generic cost of complications (Losina, et al., 2009). This cost assignment method gives the costs associated with VTEs and wound complications. For deep infections, the model follows a two-stage surgical treatment. To reflect the nature of this complication and treatment plan, the cost of deep infection is the generic complication cost plus the cost of revision. Then, in the submodel for deep infections, the second phase surgery occurs, and a second revision cost incurred. This reflects the time lag and the multiple surgeries. The figures for treating OA, postoperative care for TKA patients, and care for failed surgeries are also simple inflations of Losina, et al. (Losina, et al., 2009).

Table III-5 Cost Parameters

Name	Base	Low	High	Distribution	Source (Base/ Range & Distribution)
TKA	$ 26,046	$13,023	$ 52,091	Lognormal (9.72, 0.35)	10,2/10e, f
Cost Multiplier for Nonobese (BMI <30)	1	1	1	Constant Value of 1	9a/9b
Cost Multiplier for Class I Obese (BMI 30-35)	1.03	1.02	1.05	Normal (1.03, 0.01)	9a/9b
Cost Multiplier for Class II Obese (BMI 35-40)	1.03	1.02	1.05	Normal (1.03, 0.01)	9a/9b
Cost Multiplier for Class III Obese (BMI > 40)	1.09	1.07	1.12	Normal (1.09, 0.01)	9a/9b
Revision	$ 52,307	$26,154	$104,615	Lognormal (10.8, 0.35)	10, 2/10g, f
Cost Multiplier for Nonobese (BMI <30)	1	1	1	Constant Value of 1	9a/9b
Cost Multiplier for Class I Obese (BMI 30-35)	1.03	1.02	1.05	Normal (1.03, 0.01)	9a/9b
Cost Multiplier for Class II Obese (BMI 35-40)	1.03	1.02	1.05	Normal (1.03, 0.01)	9a/9b
Cost Multiplier for Class III Obese (BMI > 40)	1.09	1.07	1.12	Normal (1.09, 0.01)	9a/9b
VTE	$ 15,296	$ 7,648	$ 30,593	Lognormal (9.58, 0.35)	10h/10f
Wound	$ 15,296	$ 7,648	$ 30,593	Lognormal (9.58, 0.35)	10h/10f
Deep Infection	$ 64,907	$32,454	$129,815	Lognormal (10.64, 0.35)	10i/10f
OA Treatment	$ 4,613	$ 2,307	$ 9,226	Lognormal (8.38, 0.35)	10h/10f
Successful TKA care	$ 250	$ 125	$ 500	Lognormal (5.46, 0.35)	10j/10f
Failed TKA care	$ 6,920	$ 3,460	$ 13,840	Lognormal (8.78, 0.35)	10k/10f
Revision after Deep Infection	$112,532	$56,266	$225,064	Lognormal (11.57, 0.35)	10p/10f
Cost Multiplier for Nonobese (BMI <30)	1	1	1	Constant Value of 1	9a/9b
Cost Multiplier for Class I Obese (BMI 30-35)	1.03	1.02	1.05	Normal (1.03, 0.01)	9a/9b
Cost Multiplier for Class II Obese (BMI 35-40)	1.03	1.02	1.05	Normal (1.03, 0.01)	9a/9b
Cost Multiplier for Class III Obese (BMI > 40)	1.09	1.07	1.12	Normal (1.09, 0.01)	9a/9b
VTE after Deep Infection	$ 15,296	$ 7,648	$ 30,593	Lognormal (9.57, 0.35)	10q
Wound after Deep Infection	$ 15,296	$ 7,648	$ 30,593	Lognormal (9.57, 0.35)	10q
Subsequent Deep Infection	$ 64,907	$32,454	$129,815	Lognormal (11.02, 0.35)	10q
Continuing Care for Best Case	$ 6,920	$ 3,460	$ 13,840	Lognormal (8.78, 0.35)	10r
Continuing Care for Worst Case	$ 30,000	$15,000	$ 60,000	Lognormal (10.25, 0.35)	@/10f

@: The figures for aftercare for amputation range from a few thousand to over $60,000 annually mostly to account for fitting and maintaining protheses. The value $30,000 was selected as a middle ground.

2: Centers for Medicare and Medicaid Services

9: Kim a: These are percent changes expressed as cost multipliers not relative risks.

9: Kim b: A normal distribution was fit to the confidence interval reported.

10: Losina, et al.

10: Losina, et al. e: The component pieces are 2015 rates of reimbursement for CPT 27447, 2015 reimbursement for DRG 470, and the inflated and converted value to USD 2015 from the Canadian study cited by Losina, et al. for the in-home physical therapy postoperative. This sum was then inflated to 2017 dollars.
10: Losina, et al. f: Following the convention of Losina, et al., a range from 50% to 100% of base costs is used. A lognormal distribution was selected for the probabilistic distribution.
10: Losina, et al. g: The component pieces are 2015 rates of reimbursement for CPT 27487, 2015 reimbursement for DRG 468, and the inflated and converted value from the Canadian study cited by Losina, et al. for the in-home physical therapy postoperative multiplied by 3 to reflect the more intensive treatment necessitated by revision. This sum was then inflated to 2017 dollars.
10: Losina, et al. h: The price given in Losina, et al. is inflated from 2006 to 2017 USD
10: Losina, et al. i: The complication cost from Losina, et al. is used to address the infection control and then the revision cost is added to reflect the first stage of the two-stage deep infection treatment.
10: Losina, et al. j: The postoperative treatment plan is reduced to include a single radiograph and office visit based on expert opinion.
10: Losina, et al. k: The 50% increase over OA treatment seen in Losina is applied here.
10: Losina, et al. p: The component pieces are 2015 rates of reimbursement for CPT 27487, 2015 reimbursement for DRG 468, and the inflated and converted value from the Canadian study cited by Losina, et al. for the in-home physical therapy postoperative multiplied by 3 to reflect the more intensive treatment necessitated by revision. This sum was then inflated to 2017 dollars. Then to account for the excess costs associated with the deep infection this is increased by 50%. Finally, to more accurately reflect the two-stage revision process a second round of physical therapy is added.
10: Losina, et al. q: Unchanged from main model
10: Losina, et al. r: Follows main model for failed TKA

QALYs

The model uses QALYs to account for health status and impacts (Table III-6). In the spirit of model replication, most QALYs follow Losina, et al. directly. For OA, the input assumption for the utility value is 0.69 and is taken directly from Losina, et al. (Losina, et al., 2009). For the condensed health state of full benefit, an average of the two health states in Losina, et al., weighted by likelihood of either outcome, generates a QALY of 0.826 (Losina, et al., 2009). Rather than a new QALY valuation, an increment is preferable so, taking the difference, the additional QALYs associated with the full benefit of TKA is set at 0.136. By using an incremental value over the OA QALY, sensitivity analyses provide more sensible results. If OA varies independently of the value of a beneficial TKA, it would be possible that a full benefit TKA left the patient worse off than OA. This violates the definition of full benefit procedures used in the model. For this reason, the benefit of TKA was set as an incremental benefit above OA state. Losina, et al. define failure QALYs as a 25% reduction from the preoperative state. This gives a QALY of 0.5175 (Losina, et al., 2009). Similarly, a decrement is preferable for use in the model and subtraction yields a decrement of 0.1725.

To account for the discomfort of surgery and the follow-up care, the model incorporates a QALY decrement in the year of surgery. This is taken to be the difference between subsequent year QALY and initial year as described in Monreal, et al. (Monreal, Brosa, Diamantopoulos, Folkerts, & Imberti, 2013). For wound and VTE complications the figures from Monreal, et al. become decrements by taking the first year QALY and subtracting the complication values. For both of these complications, this is approximately a 0.01 deduction (Monreal, Brosa, Diamantopoulos, Folkerts, & Imberti, 2013). In the case of deep infection, half of the wound decrement is added to the revision decrement to signify that a surgery occurs but there was an additional discomfort as well. In the second year, the revision decrement accrues again to reflect the second surgery. For deep revision, the QALY is anchored on the values of a normal revision. Even in the best-case, after a deep revision there is still a disability. To account for this, the QALY for best-case scenario is then equivalent to the failed state for a revision surgery. In the worst-case outcome, the QALY is set to 80% of the best-case scenario.

To account for loss of quality of life for those living with obesity, a decrement was developed from two pieces. WHO obesity classes are generally five BMI wide i.e. 30-35, 35-40. An increase of a single unit of BMI results in a decrement of 0.0017 (Hakim, Wolf, & Garrison, 2002). Thus, the single unit value is multiplied by half the width of a class (2.5) and this number serves as the basis of the QALY decrement for obesity, Class I once, Class II twice that value, and Class III trebled.

Table III-6 QALY Parameters

Name	Base	Low	High	Distribution	Source (Base/ Range & Distribution)
OA	0.69	0.4548	0.9252	Normal (0.69, 0.12)	10/10
Full Benefit Addition	0.136	0	0.3712	Normal (0.14, 0.12)	10l/10m
Failed TKA change	-0.1725	-0.4077	0	Normal (-0.17, 0.12)	10n/10m
TKA	0.15	0.0123	0.4145	Beta (1.5, 8.5)	11a/10o
Revision	0.15	0	0.9001	Beta (0.15, 0.85)	11a/10o
VTE	0.01	0	0.0808	Beta (0.01, 0.99)	11b/10o
Wound	0.0133	0	0.152	Beta (0.01, 0.99)	11b/10o
Deep Infection	0.1567	0.0001	0.9069	Beta (0.16, 0.84)	11c/10o
Obesity	0.0043	0	0.0084	Normal (0, 0)	5a/5b
Best Case	0.5175	0.2823	0.7527	Normal (0.52, 0.12)	10r/10m
Worst Case	0.414	0.1788	0.6492	Normal (0.41, 0.12)	&
Revision after Deep Infection	0.15	0	0.9001	Beta (0.15, 0.85)	10q
VTE after Deep Infection	0.01	0	0.0808	Beta (0.01, 0.99)	10q
Wound after Deep Infection	0.0133	0	0.152	Beta (0.01, 0.99)	10q
Subsequent Deep Infection	0.1567	0	0.9069	Beta (0.16, 0.84)	10q

&: This is estimated to be 80% of the best-case outcome

5: Hakim, Wolf, & Garrison a: The WHO classification system generally has a width of 5 BMI for the categories. The QALY/unit BMI of 0.017 is thus multiplied by half the width to create a BMI decrement by category of obesity.

5: Hakim, Wolf, & Garrison b: The class wide decrement was used as the mean of a normal distribution with half the mean used for a standard deviation

10: Losina, et al.

10: Losina, et al. l: A weighted average is constructed from full and limited benefit states in Losina, et al. From this, the OA QALY is subtracted to convert to an incremental gain.

10: Losina, et al. m: Following the convention of Losina, et al., a normal distribution is constructed with the mean equal to the base parameter and standard deviation of 0.12

10: Losina, et al. n: A 25% reduction from OA is used following Losina, et al. This is converted to a decrement.

10: Losina, et al. o: Following the convention of Losina, et al. a beta distribution is constructed where α is the baseline value and β is equal to $1-\alpha$

10: Losina, et al. q: Unchanged from main model

10: Losina, et al. r: Follows main model for failed TKA

11: Monreal, et al. a: A decrement was created by taking the difference between ongoing postsurgical value and the year of surgery value given by Monreal, et al.

11: Monreal, et al. b: The specific complication value listed by Monreal, et al. was subtracted from the first-year value to create a decrement for the complication

11: Monreal, et al. c: The wound complication decrement is halved and added to the surgical decrement to approximate the first stage of the two-stage deep infection treatment.

Obesity Adjustments

For several of the important parameters in the model, relative risks associated with the various obesity classes address the observed differences in certain transitions and outcome measures.

For probabilities of full benefit for each surgery, there is no suitable information available in the literature. Based on the other obesity relative risks, there is most often a doubled risk of a poor outcome. The range seen is a slight protective influence to about 4 times the risk of a poor outcome.

Another obesity adjustment applies to all-cause mortality rate. A meta-analysis done by an international consortium provides the adjustment factors (The Global BMI Mortality Collaboration, 2016). The duration of obesity is not taken into account. Hazard ratios were converted to relative risks and the reference group was changed to nonobese using the raw data provided in Table 1 of that paper (The Global BMI Mortality Collaboration, 2016). The confidence intervals required similar transformations.

Complication rate is a major source of difference between obesity classes. The relative risk for the various complications comes from the meta-analysis conducted in Chapter II. Confidence intervals on the relative risk were also constructed with the upper and lower bounds used as high and low values for the relative risk from the same source.

To address the added burden of obesity on costs of the procedure, the model includes a multiplier for surgical costs in lieu of the complicated coding rules of changing the DRG. Claims data analysis from Kim serves as the basis for this parameter (Kim, 2010). Kim found an increase in cost over the base price for both Class I and II as well as Class III. The confidence intervals provided by Kim are used to construct a normal distribution around this percentage increase (Kim, 2010).

Sensitivity Analysis Ranges and Distributions

In general, the distributions provided in the literature yielded 95% confidence intervals. The limits of those intervals were used to create a high and low value for univariate sensitivity analysis. In other cases, the literature supplied the upper and lower bounds and a distribution of an appropriate type was fitted. The beta distribution was used for probabilities to constrain values to the proper interval of 0 to 1 and the lognormal distribution for costs to address the long tail. A normal distribution was used for other parameters.

In transitions, the ranges are as follows. For OA to TKA, the range used matches that followed by Holt, et al. (Holt, et al., 2011). For any type of surgery to full benefit, the range set by Losina, et al. for probability of poor postoperative function is used (Losina, et al., 2009). A beta distribution centered on 0.5 accommodates uncertainty with a wide even range around both early and late revision choices by the patient. Base death rates do not undergo sensitivity analysis.

For complication rates, the meta-analysis in Chapter II provides confidence intervals directly. For purposes of this model, the inverse variance heterogeneity method gives the confidence intervals. This method developed by Doi, et al overcomes some known problems with both fixed and random effects models in dealing with heterogeneity in meta-analysis. Specifically, it deals with overconfident estimators (Barendregt & Doi, 2016). Consequently, the confidence intervals reported in the meta-analysis of Chapter II do not match those used here. This method derives larger confidence intervals because it accounts for several types of heterogeneity not addressed in the meta-analysis results. The point estimates are unchanged from those in Chapter II, but these larger ranges allow for more thorough examination in this model. There is no theoretical reason to believe that heterogeneity is an issue in the meta-analysis, but the sensitivity analyses can benefit from a wider exploration of relative risks.

For failure rates, a single adjustment factor was available. The value given by Losina, et al. for failure applies to each year and surgical category (Losina, et al., 2009).

All cost ranges follow the Losina, et al. suggestion of testing from 50% reduction to 100% increase (Losina, et al., 2009). Probabilistic analysis follows a log normal distribution fit to match the mean of the distribution to the base value.

For QALYs, when possible, the model follows Losina, et al. In general, Losina, et al. used normal distributions with standard deviations of 0.12 (Losina, et al., 2009). The model applies the same convention while using the bases as described above as the mean throughout for all QALY values. Except for obesity, QALY decrements also follow the convention of Losina, et al. while using the specific decrements from Monreal as baselines (Monreal, Brosa, Diamantopoulos, Folkerts, & Imberti, 2013). For decrements, the convention is to construct a beta distribution using the base as α and 1- α as β parameter (Losina, et al., 2009). For obesity decrements, the class decrement was used as the mean of a normal distribution with half the mean used for a standard deviation.

Sensitivity Analysis

Thorough sensitivity analyses were undertaken using five strategies. First, a one-way sensitivity analysis tested each parameter and relative risk separately at both the low and high values. For these results, tornado graphs display the most impactful parameters. Next, guided by the results of the one-way analysis, the costs of OA treatment compared to the costs of postoperative treatment for TKA patients with positive outcomes underwent a two-way sensitivity analysis. Third, a threshold analysis examined the impact of the size of the increment accrued for full benefit of TKA. Next, scenario analyses were performed in some key areas highlighted by either the literature or the one-way analysis: the relationship between OA and TKA costs and health states, complications, deep infection, and failure rates. Best- and worst-case scenarios were also considered where all parameters were set to favor TKA and OA respectively. To further explore the relationship between OA and TKA costs seen in the two-way analysis and the QALY increment in the threshold analysis, a scenario analysis expands the parameters included to encompass those related to failed procedures as well as the costs and decrements associated with the surgery itself. The literature implicates differential complication rates in differences between obesity class outcomes. To that end, scenarios explored various combinations of complication rates and the relative risks of experiencing those complications. Given the importance of deep infections and the particularly involved consequences, a set of scenarios involving only deep infection rate and relative risk was done as well. The one-way analysis along with the literature indicate failure rates are important.   This scenario led to a second threshold analysis where the annual failure rates were considered correlated and a range of change between no failure and twice the base rate of failure applied to each parameter. Finally, a probabilistic sensitivity analysis was conducted using the distributions described above and 10,000 iterations. Cost-effectiveness acceptability curves are the main outcome of this analysis.

Assumptions

Several important assumptions underlie the model design. Most important is the assumption that the population is a homogenous cohort of 74-year-olds undergoing a generic TKA procedure. There is no consideration for different implants or surgical approaches, all surgeons are equally competent, and patient demographics play no role in the outcomes. Second, the only comorbidity considered in the model is obesity. Any other potentially impactful comorbidities are not considered. The distribution of obesity is assumed to be identical in the TKA population as it is in the general population. The model allows for unlimited revisions in that any failed revision is allowed future revisions that face identical failure rates to first revisions. A final assumption is that the differential benefit in outcomes posited in the literature is implicit. The gain in QALYs is expected to be the same for all patients even if the starting point is lower. This is addressed by decrementing QALYs for obesity.

Verification and Validation

Verification was undertaken in several ways. The first was debugging the model to ensure proper formulas and data connections. The model structure incorporates error checking throughout the build. Where possible the transitions were built modularly to be transparent and intermediate summation was used to ensure that the model maintained a constant population, a sign that all transitions were accounted for correctly. Testing extreme cases in the one-way analysis ensured reasonableness. Finally, the model structure replicates Losina, et al. as closely as possible to verify the conceptual model (Losina, et al., 2009).

Validation also made use of the work of Losina, et al. The weighted average of the four obesity groups where primary TKA could be performed any year in the model was compared to results of that paper. There were very similar costs and QALYs, within 10% for each individual piece. Significant changes were made to the cost of postoperative care for successful procedures to reflect a change in treatment recommendations, so the cost is significantly lower in this model as is reflected in the ICER. A UK based trial setting yielded comparable results for the overall ICER (Dakin, et al., 2012). These results are also in line with the generally held belief that TKA is a cost-effective procedure. Further validation of the model comes from the one-way analysis. The direction and scale of movement fit within the expected changes. Finally, the model and its parameters were reviewed by an expert in TKA for face validity.

Results

Base Case

TKA is a cost-effective procedure when using baseline assumptions that all patients undergo TKA in the first year as seen in Table III-7. The overall population sees an ICER of $16,273/QALY, an excellent value by US standards. For nonobese patients, TKA is an even better value at $4,932/QALY. Class I and II see ICERs of $33,891 and $46,379 respectively. Class III sees a sharp rise in the ICER to $80,671/QALY.

Table III-7 Base Case Results

TKA Status by Obesity	Cost	QALY	ICER	NMB*
				Relative to No TKA
Overall				
No TKA	$ 49,071	7.31		
TKA	$ 65,151	8.30	$ 16,273	$ 33,326
Nonobese				
No TKA	$ 49,255	7.37		
TKA	$ 54,571	8.44	$ 4,932	$ 48,568
Class I Obese				
No TKA	$ 48,954	7.28		
TKA	$ 78,629	8.15	$ 33,891	$ 14,105
Class II Obese				
No TKA	$ 49,049	7.25		
TKA	$ 86,550	8.05	$ 46,379	$ 2,928
Class III Obese				
No TKA	$ 47,559	6.98		
TKA	$ 101,722	7.65	$ 80,671	$ (20,592)

*Net Monetary Benefit where QALYs are valued at $50,000

Sensitivity Analysis

The model is generally robust to parameter changes in the ranges considered when looking at TKA for the overall population. As obesity increases, TKA may no longer be consistently cost-effective. TKA for patients with Class III obesity may become very expensive under many different parameter assumptions. There are several categories of parameters that are most likely to weigh against TKA. Parameters related to OA (whether costs of treatment or health status) are important. The likelihood of successful surgery is also a key parameter to consider. Lastly, deep infection rates are also a major deciding factor in whether TKA is cost-effective for obese patients.

One-Way Sensitivity Analysis

One-way sensitivity analysis shows TKA is consistently cost-effective in the overall and nonobese populations. The model results are more likely to change as obesity class increases. This is most evident in the number of parameters that can make TKA look less cost-effective. In the overall population (Figure III-2), only three parameters would make TKA not look cost-effective at a willingness-to-pay threshold of $100,000 per QALY. If the initial success of either primary and revision surgery are poor, they can push the ICER over the $100,000 threshold. The maximum ICER is in the range of $125,000/QALY, a small amount relative to those observed in heavier groups. More interesting is the third parameter, the value of the utility increase from OA to full benefit after the surgery. In this case, when the value is at its lowest (no benefit over OA) TKA is dominated. Despite lower costs of continuing care, it is still necessary that health improves over the initial health state for TKA to be of value thus when this parameter is zero, TKA is dominated in all obesity groups. This relationship is explored further in other analyses. For the nonobese population (Figure III-3), when parameters are at their least favorable to TKA, the ICER of TKA never exceeds $100,000 per QALY and sometimes TKA may even become dominant. The exception is the utility increment of TKA benefit as noted above. In Class I obesity (Figure III-4), the situation is similar to the overall population with the addition that the utility associated with OA parameter can cause the ICER to exceed the $100,000 threshold. However, if the relative risk of deep infection is at its highest, TKA is dominated. Moving into a heavier population, Class II obesity (Figure III-5) sees six parameters capable of making the ICER for TKA exceed $100,000 per QALY. In addition to those seen in Class I, the decrement for having a revision surgery and the rate of deep infection can raise the ICER above $100,000 per QALY. Finally, in Class III obesity (Figure III-6), nineteen parameters can make TKA exceed this threshold.

It is also of interest to note that while the same parameters drive much of the change across these population groups that the magnitude of impact increases with obesity. A change in an important parameter in the nonobese makes TKA slightly more than the threshold at its worst, but in the Class III group that same change pushes the ICER into the millions of dollars. There are not only more parameters that matter in decision making, but those parameters also matter more.

Looking at the ten most impactful parameters in each obesity group and the overall population, only 16 unique parameters appear out of 248 possible. Six of those appear in all five lists. One interesting parameter that rises to importance in the overall population and even dominance in the nonobese is age. As the starting age of the population falls, the cost-effectiveness improves. This is most likely because there is more lifespan left to benefit from improved health. The trend toward younger patients is beneficial despite the increased likelihood of revision due to age of the implant.

The tornado graphs of the top ten most impactful parameters for each population group as well as the overall population are shown below (Figures III-2-6). Each parameter's range is centered about the baseline value (dashed line) for that population and the red line shows the $100,000 threshold. Full results are available in Appendix B.

Figure III-2 Tornado Graph of Top Ten Impactful Parameters for the Overall Population

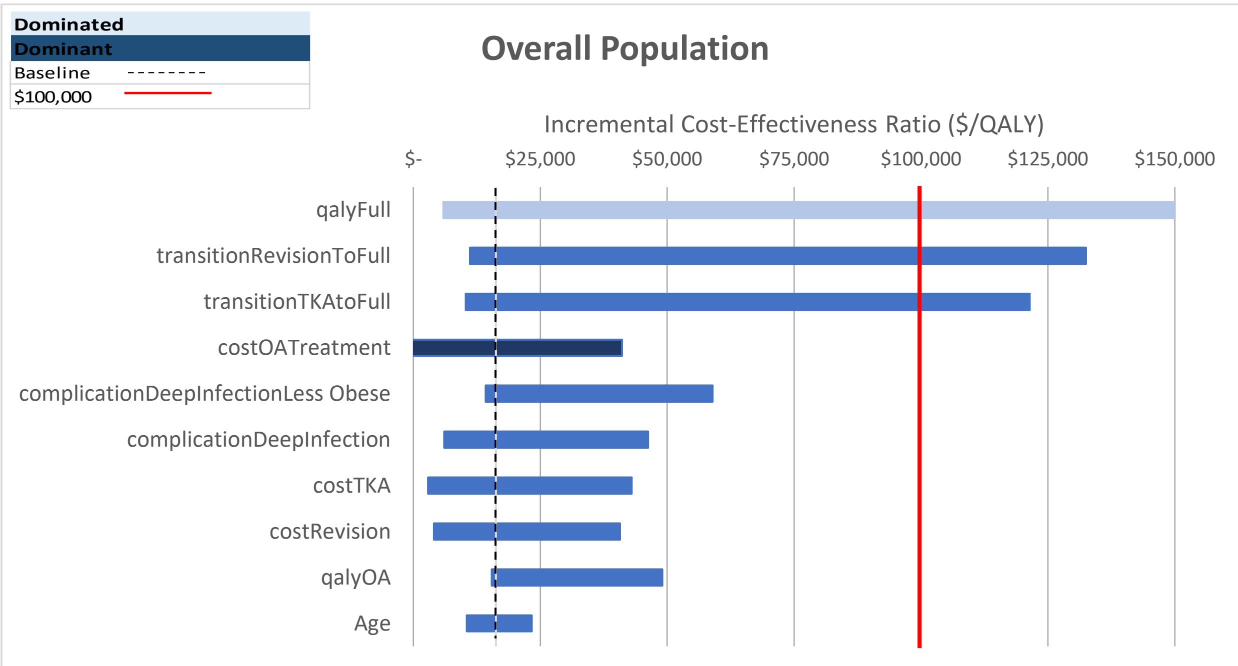


Figure III-3 Tornado Graph of Top Ten Impactful Parameters for the Nonobese Population

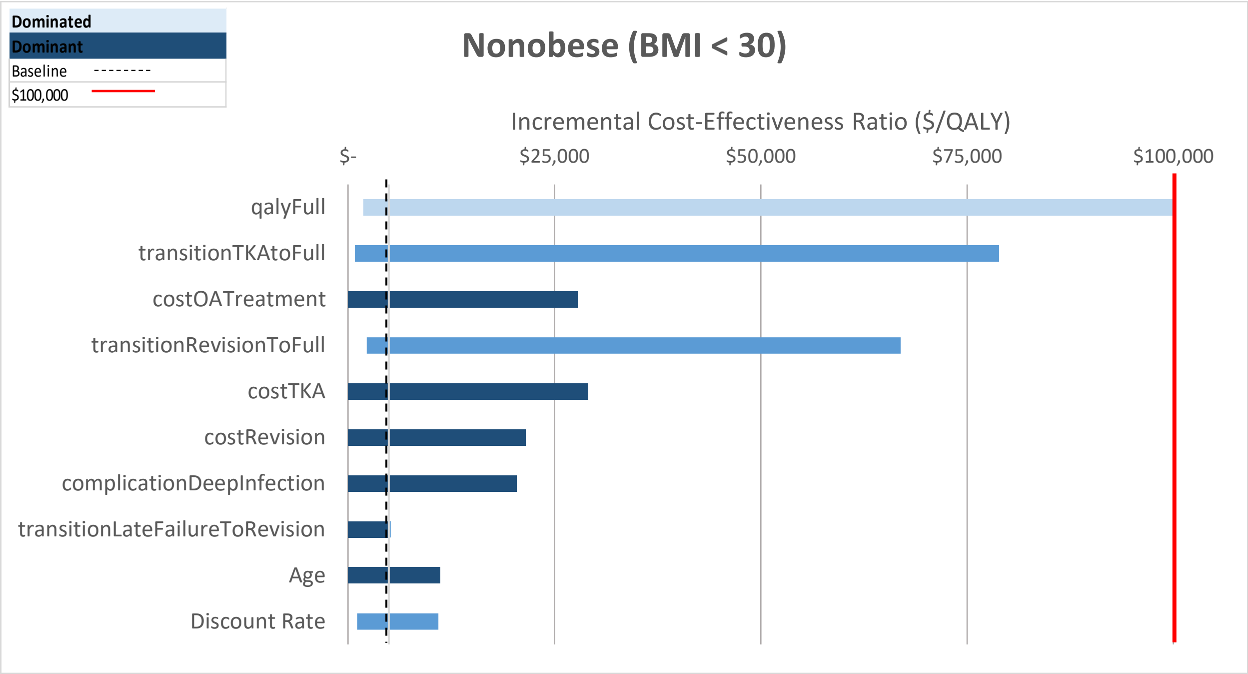


Figure III-4 Tornado Graph of Top Ten Impactful Parameters for the Class I Obese Population

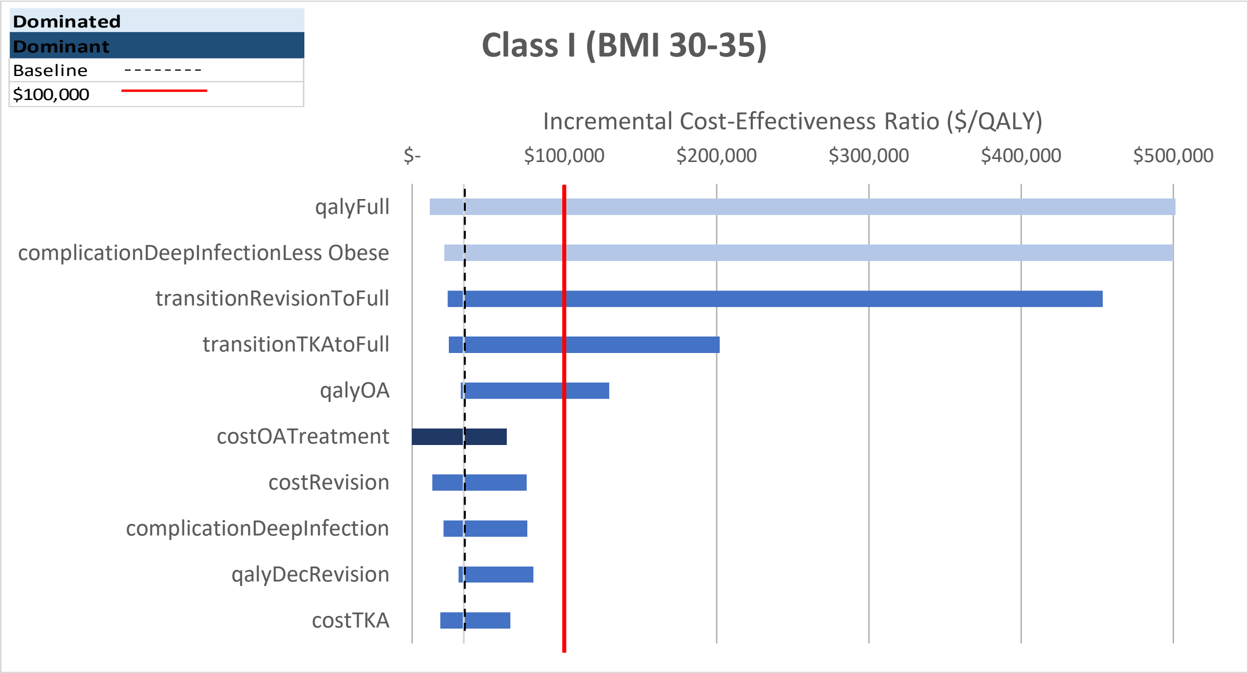


Figure III-5 Tornado Graph of Top Ten Impactful Parameters for the Class II Obese Population

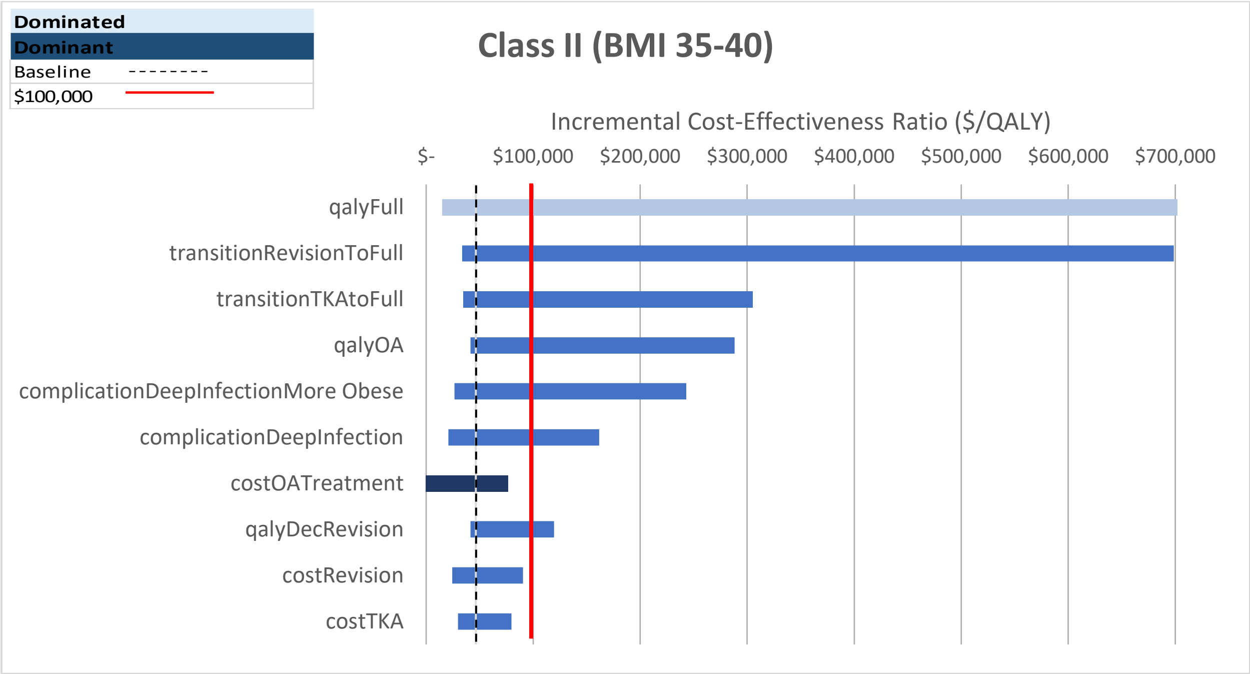
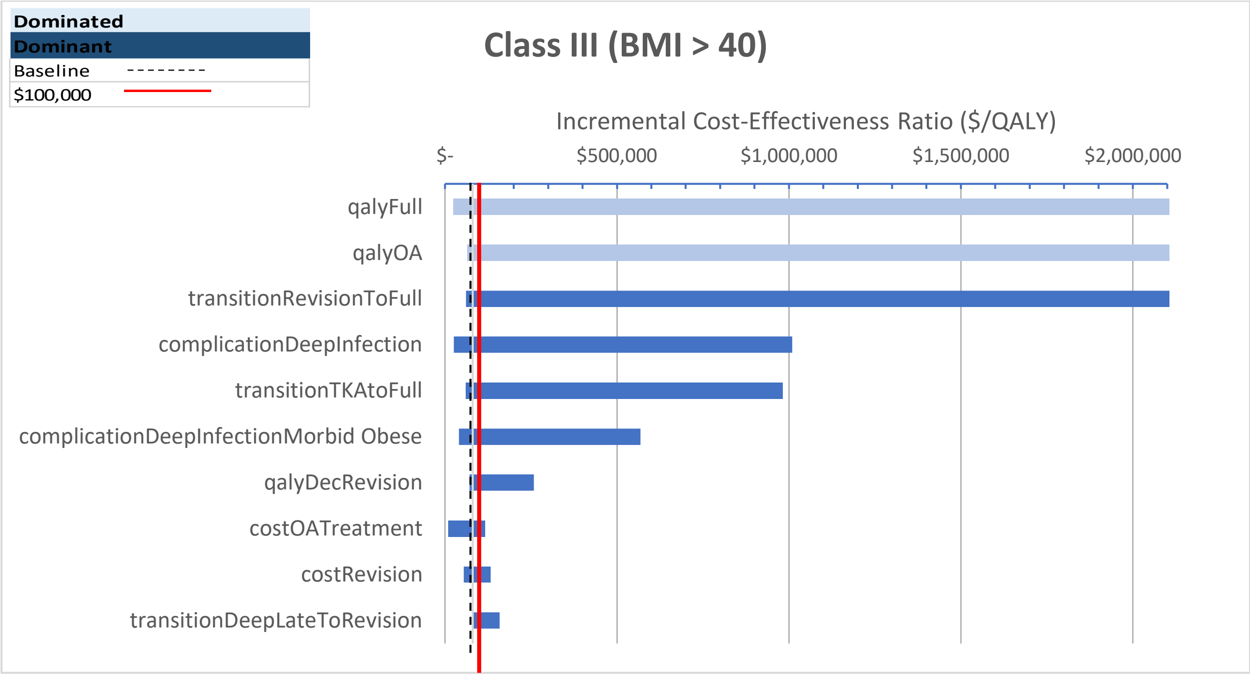


Figure III-6 Tornado Graph of Top Ten Impactful Parameters for the Class III Obese Population



Two-Way Sensitivity Analysis

The relationship between OA and postoperative health and costs was of import in the univariate analysis so further investigation using a two-way analysis explored this relationship.

The cost of OA treatment and the cost of continuing care after successful TKA were compared at various levels. For OA, the range was the same used in the univariate analysis (50%-200% of baseline). For successful TKA, the range was considerably wider. This reflects the much larger value used by Losina, et al. in their study while maintaining the base line value used in this model which reflects newer practice patterns of minimal contact once the implant is deemed a success. In that spirit, the range used is no cost for annual follow up care to the midpoint of the OA range which is roughly equal to baseline OA spending.

The results of the analysis are presented below using five tables, one for the overall population (Table III-8) followed by one for each obesity group (Tables III-9-12). The rows are different annual OA costs and the annual costs of continuing care for successful postoperative TKA are the columns. By applying conditional formatting such that red values have ICERs over the $100,000 threshold, yellow values are between the $50,000 and $100,000 thresholds and into green for values under the $50,000 threshold including zeroes for dominant combinations, the relationship between these two major cost components can be visualized. The base value of the continuing care of successful TKA is $250 per year and the annual cost of OA has a base value of $4613.20 and the red font represent these key values.

Table III-8 ICERs for Two-Way Sensitivity Analysis in the Overall Population

Overall Population

Annual Cost of Continuing Care for Successful TKA

Annual Cost of OA Treatment	$0	$250	$500	$1,000	$1,500	$2,000	$2,500	$3,000	$3,500	$4,000	$4,500	$5,000	$5,500	$6,000
$2,307	$38,894	$41,103	$43,312	$47,730	$52,148	$56,566	$60,984	$65,402	$69,820	$74,239	$78,657	$83,075	$87,493	$91,911
$2,500	$36,812	$39,021	$41,230	$45,648	$50,066	$54,484	$58,903	$63,321	$67,739	$72,157	$76,575	$80,993	$85,411	$89,829
$3,000	$31,430	$33,639	$35,848	$40,266	$44,684	$49,102	$53,520	$57,938	$62,356	$66,774	$71,192	$75,610	$80,028	$84,446
$3,500	$26,047	$28,256	$30,465	$34,883	$39,301	$43,720	$48,138	$52,556	$56,974	$61,392	$65,810	$70,228	$74,646	$79,064
$4,000	$20,665	$22,874	$25,083	$29,501	$33,919	$38,337	$42,755	$47,173	$51,591	$56,009	$60,427	$64,845	$69,263	$73,681
$4,500	$15,282	$17,491	$19,700	$24,119	$28,537	$32,955	$37,373	$41,791	$46,209	$50,627	$55,045	$59,463	$63,881	$68,299
$5,000	$9,900	$12,109	$14,318	$18,736	$23,154	$27,572	$31,990	$36,408	$40,826	$45,244	$49,662	$54,080	$58,498	$62,916
$5,500	$4,518	$6,727	$8,936	$13,354	$17,772	$22,190	$26,608	$31,026	$35,444	$39,862	$44,280	$48,698	$53,116	$57,534
$6,000	$0	$1,344	$3,553	$7,971	$12,389	$16,807	$21,225	$25,643	$30,061	$34,479	$38,897	$43,315	$47,733	$52,151
$6,500	$0	$0	$0	$2,589	$7,007	$11,425	$15,843	$20,261	$24,679	$29,097	$33,515	$37,933	$42,351	$46,769
$7,000	$0	$0	$0	$0	$1,624	$6,042	$10,460	$14,878	$19,296	$23,714	$28,132	$32,550	$36,968	$41,386
$7,500	$0	$0	$0	$0	$0	$660	$5,078	$9,496	$13,914	$18,332	$22,750	$27,168	$31,586	$36,004
$8,000	$0	$0	$0	$0	$0	$0	$0	$4,113	$8,531	$12,949	$17,367	$21,785	$26,203	$30,621
$8,500	$0	$0	$0	$0	$0	$0	$0	$0	$3,149	$7,567	$11,985	$16,403	$20,821	$25,239
$9,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$2,184	$6,602	$11,020	$15,438	$19,856
$9,226	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$4,165	$8,583	$13,001	$17,419

Table III-9 ICERs for Two-Way Sensitivity Analysis in the Nonobese Population

Nonobese (BMI < 30)

Annual Cost of Continuing Care for Successful TKA

Annual Cost of OA Treatment	$0	$250	$500	$1,000	$1,500	$2,000	$2,500	$3,000	$3,500	$4,000	$4,500	$5,000	$5,500	$6,000
$2,307	$25,701	$27,785	$29,868	$34,035	$38,202	$42,368	$46,535	$50,702	$54,868	$59,035	$63,202	$67,368	$71,535	$75,702
$2,500	$23,785	$25,869	$27,952	$32,119	$36,285	$40,452	$44,619	$48,785	$52,952	$57,119	$61,286	$65,452	$69,619	$73,786
$3,000	$18,832	$20,915	$22,998	$27,165	$31,332	$35,498	$39,665	$43,832	$47,998	$52,165	$56,332	$60,499	$64,665	$68,832
$3,500	$13,878	$15,961	$18,045	$22,211	$26,378	$30,545	$34,711	$38,878	$43,045	$47,211	$51,378	$55,545	$59,712	$63,878
$4,000	$8,924	$11,008	$13,091	$17,258	$21,424	$25,591	$29,758	$33,924	$38,091	$42,258	$46,424	$50,591	$54,758	$58,925
$4,500	$3,971	$6,054	$8,137	$12,304	$16,471	$20,637	$24,804	$28,971	$33,137	$37,304	$41,471	$45,637	$49,804	$53,971
$5,000	$0	$1,100	$3,184	$7,350	$11,517	$15,684	$19,850	$24,017	$28,184	$32,350	$36,517	$40,684	$44,850	$49,017
$5,500	$0	$0	$0	$2,396	$6,563	$10,730	$14,897	$19,063	$23,230	$27,397	$31,563	$35,730	$39,897	$44,063
$6,000	$0	$0	$0	$0	$1,609	$5,776	$9,943	$14,110	$18,276	$22,443	$26,610	$30,776	$34,943	$39,110
$6,500	$0	$0	$0	$0	$0	$822	$4,989	$9,156	$13,323	$17,489	$21,656	$25,823	$29,989	$34,156
$7,000	$0	$0	$0	$0	$0	$0	$35	$4,202	$8,369	$12,536	$16,702	$20,869	$25,036	$29,202
$7,500	$0	$0	$0	$0	$0	$0	$0	$0	$3,415	$7,582	$11,749	$15,915	$20,082	$24,249
$8,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$2,628	$6,795	$10,962	$15,128	$19,295
$8,500	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$1,841	$6,008	$10,175	$14,341
$9,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$1,054	$5,221	$9,388
$9,226	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$2,978	$7,144

Table III-10 ICERs for Two-Way Sensitivity Analysis in the Class I Obese Population

Class I Obesity (BMI 30-35)

Annual Cost of Continuing Care for Successful TKA

Annual Cost of OA Treatment	$0	$250	$500	$1,000	$1,500	$2,000	$2,500	$3,000	$3,500	$4,000	$4,500	$5,000	$5,500	$6,000
$2,307	$59,446	$61,846	$64,246	$69,047	$73,847	$78,648	$83,448	$88,249	$93,049	$97,850	$102,650	$107,451	$112,251	$117,052
$2,500	$57,102	$59,502	$61,902	$66,703	$71,503	$76,304	$81,104	$85,905	$90,705	$95,506	$100,306	$105,107	$109,907	$114,708
$3,000	$51,042	$53,442	$55,842	$60,643	$65,443	$70,244	$75,044	$79,845	$84,645	$89,446	$94,246	$99,047	$103,847	$108,648
$3,500	$44,982	$47,382	$49,783	$54,583	$59,384	$64,184	$68,985	$73,785	$78,586	$83,386	$88,187	$92,987	$97,788	$102,588
$4,000	$38,922	$41,323	$43,723	$48,523	$53,324	$58,124	$62,925	$67,725	$72,526	$77,326	$82,127	$86,927	$91,728	$96,528
$4,500	$32,863	$35,263	$37,663	$42,464	$47,264	$52,065	$56,865	$61,666	$66,466	$71,267	$76,067	$80,868	$85,668	$90,469
$5,000	$26,803	$29,203	$31,603	$36,404	$41,204	$46,005	$50,805	$55,606	$60,406	$65,207	$70,007	$74,808	$79,608	$84,409
$5,500	$20,743	$23,143	$25,544	$30,344	$35,145	$39,945	$44,746	$49,546	$54,347	$59,147	$63,948	$68,748	$73,549	$78,349
$6,000	$14,684	$17,084	$19,484	$24,284	$29,085	$33,885	$38,686	$43,486	$48,287	$53,087	$57,888	$62,688	$67,489	$72,289
$6,500	$8,624	$11,024	$13,424	$18,225	$23,025	$27,826	$32,626	$37,427	$42,227	$47,028	$51,828	$56,629	$61,429	$66,230
$7,000	$2,564	$4,964	$7,364	$12,165	$16,965	$21,766	$26,566	$31,367	$36,167	$40,968	$45,768	$50,569	$55,369	$60,170
$7,500	$0	$0	$1,305	$6,105	$10,906	$15,706	$20,507	$25,307	$30,108	$34,908	$39,709	$44,509	$49,310	$54,110
$8,000	$0	$0	$0	$45	$4,846	$9,646	$14,447	$19,247	$24,048	$28,848	$33,649	$38,449	$43,250	$48,050
$8,500	$0	$0	$0	$0	$0	$3,587	$8,387	$13,188	$17,988	$22,789	$27,589	$32,390	$37,190	$41,991
$9,000	$0	$0	$0	$0	$0	$0	$2,327	$7,128	$11,928	$16,729	$21,529	$26,330	$31,130	$35,931
$9,226	$0	$0	$0	$0	$0	$0	$0	$4,384	$9,185	$13,985	$18,786	$23,586	$28,387	$33,187

Table III-11 ICERs for Two-Way Sensitivity Analysis in the Class II Obese Population

Class II Obesity (BMI 35-40)

Annual Cost of Continuing Care for Successful TKA

Annual Cost of OA Treatment	$0	$250	$500	$1,000	$1,500	$2,000	$2,500	$3,000	$3,500	$4,000	$4,500	$5,000	$5,500	$6,000
$2,307	$74,148	$76,710	$79,272	$84,396	$89,520	$94,645	$99,769	$104,893	$110,017	$115,142	$120,266	$125,390	$130,514	$135,639
$2,500	$71,605	$74,167	$76,729	$81,853	$86,977	$92,102	$97,226	$102,350	$107,474	$112,599	$117,723	$122,847	$127,971	$133,096
$3,000	$65,030	$67,592	$70,154	$75,278	$80,402	$85,527	$90,651	$95,775	$100,899	$106,024	$111,148	$116,272	$121,396	$126,521
$3,500	$58,455	$61,017	$63,579	$68,703	$73,828	$78,952	$84,076	$89,200	$94,325	$99,449	$104,573	$109,697	$114,822	$119,946
$4,000	$51,880	$54,442	$57,004	$62,129	$67,253	$72,377	$77,501	$82,626	$87,750	$92,874	$97,998	$103,123	$108,247	$113,371
$4,500	$45,305	$47,867	$50,430	$55,554	$60,678	$65,802	$70,927	$76,051	$81,175	$86,299	$91,424	$96,548	$101,672	$106,796
$5,000	$38,730	$41,293	$43,855	$48,979	$54,103	$59,227	$64,352	$69,476	$74,600	$79,724	$84,849	$89,973	$95,097	$100,221
$5,500	$32,156	$34,718	$37,280	$42,404	$47,528	$52,653	$57,777	$62,901	$68,025	$73,150	$78,274	$83,398	$88,522	$93,647
$6,000	$25,581	$28,143	$30,705	$35,829	$40,954	$46,078	$51,202	$56,326	$61,451	$66,575	$71,699	$76,823	$81,948	$87,072
$6,500	$19,006	$21,568	$24,130	$29,255	$34,379	$39,503	$44,627	$49,752	$54,876	$60,000	$65,124	$70,249	$75,373	$80,497
$7,000	$12,431	$14,993	$17,555	$22,680	$27,804	$32,928	$38,052	$43,177	$48,301	$53,425	$58,549	$63,674	$68,798	$73,922
$7,500	$5,856	$8,419	$10,981	$16,105	$21,229	$26,353	$31,478	$36,602	$41,726	$46,850	$51,975	$57,099	$62,223	$67,347
$8,000	$0	$1,844	$4,406	$9,530	$14,654	$19,779	$24,903	$30,027	$35,151	$40,276	$45,400	$50,524	$55,648	$60,773
$8,500	$0	$0	$0	$2,955	$8,080	$13,204	$18,328	$23,452	$28,577	$33,701	$38,825	$43,949	$49,074	$54,198
$9,000	$0	$0	$0	$0	$1,505	$6,629	$11,753	$16,877	$22,002	$27,126	$32,250	$37,374	$42,499	$47,623
$9,226	$0	$0	$0	$0	$0	$3,652	$8,776	$13,900	$19,025	$24,149	$29,273	$34,397	$39,522	$44,646

Table III-12 ICERs for Two-Way Sensitivity Analysis in the Class III Obese Population

Class III Obesity (BMI >40)

Annual Cost of OA Treatment	Annual Cost of Continuing Care for Successful TKA													
	$0	$250	$500	$1,000	$1,500	$2,000	$2,500	$3,000	$3,500	$4,000	$4,500	$5,000	$5,500	$6,000
$2,307	$113,185	$116,089	$118,993	$124,802	$130,611	$136,419	$142,228	$148,036	$153,845	$159,653	$165,462	$171,270	$177,079	$182,887
$2,500	$110,215	$113,119	$116,024	$121,832	$127,641	$133,449	$139,258	$145,066	$150,875	$156,683	$162,492	$168,301	$174,109	$179,918
$3,000	$102,538	$105,442	$108,346	$114,155	$119,963	$125,772	$131,580	$137,389	$143,197	$149,006	$154,814	$160,623	$166,431	$172,240
$3,500	$94,860	$97,764	$100,669	$106,477	$112,286	$118,094	$123,903	$129,711	$135,520	$141,328	$147,137	$152,945	$158,754	$164,562
$4,000	$87,182	$90,087	$92,991	$98,799	$104,608	$110,417	$116,225	$122,034	$127,842	$133,651	$139,459	$145,268	$151,076	$156,885
$4,500	$79,505	$82,409	$85,313	$91,122	$96,930	$102,739	$108,547	$114,356	$120,165	$125,973	$131,782	$137,590	$143,399	$149,207
$5,000	$71,827	$74,731	$77,636	$83,444	$89,253	$95,061	$100,870	$106,678	$112,487	$118,295	$124,104	$129,913	$135,721	$141,530
$5,500	$64,150	$67,054	$69,958	$75,767	$81,575	$87,384	$93,192	$99,001	$104,809	$110,618	$116,426	$122,235	$128,043	$133,852
$6,000	$56,472	$59,376	$62,281	$68,089	$73,898	$79,706	$85,515	$91,323	$97,132	$102,940	$108,749	$114,557	$120,366	$126,174
$6,500	$48,794	$51,699	$54,603	$60,411	$66,220	$72,029	$77,837	$83,646	$89,454	$95,263	$101,071	$106,880	$112,688	$118,497
$7,000	$41,117	$44,021	$46,925	$52,734	$58,542	$64,351	$70,159	$75,968	$81,777	$87,585	$93,394	$99,202	$105,011	$110,819
$7,500	$33,439	$36,343	$39,248	$45,056	$50,865	$56,673	$62,482	$68,290	$74,099	$79,907	$85,716	$91,525	$97,333	$103,142
$8,000	$25,762	$28,666	$31,570	$37,379	$43,187	$48,996	$54,804	$60,613	$66,421	$72,230	$78,038	$83,847	$89,655	$95,464
$8,500	$18,084	$20,988	$23,893	$29,701	$35,510	$41,318	$47,127	$52,935	$58,744	$64,552	$70,361	$76,169	$81,978	$87,786
$9,000	$10,406	$13,311	$16,215	$22,023	$27,832	$33,641	$39,449	$45,258	$51,066	$56,875	$62,683	$68,492	$74,300	$80,109
$9,226	$6,930	$9,834	$12,739	$18,547	$24,356	$30,164	$35,973	$41,781	$47,590	$53,398	$59,207	$65,015	$70,824	$76,632

For the overall population, even in the worst pairing for TKA, TKA does not exceed the $100,000 threshold. Examining by obesity classification, the tables tell a similar story with a decreasing number of combinations being dominant and an increasing share exceeding that threshold. In the nonobese population, few combinations are not cost-effective at $50,000 and none exceed $100,000 with many others being dominant. The least cost-effective occur in the upper right where postoperative care for successful TKA is very (perhaps unrealistically) expensive and cost of OA treatment is minimal. Conversely, TKA is dominant when OA is expensive and continuing care is minimal as found to the lower left. In Class I, these numbers shift towards the worst and less realistic situations for TKA exceeding the $100,000 as well as fewer being dominant in the opposite corner. For Class II, this pattern continues with a larger area around the extreme corner failing at the highest threshold and smaller area at the opposite extreme being dominant. In Class III, TKA does not fare as well when costs turn against TKA. It is no longer possible to see TKA as dominant. Regardless, looking at areas where Class III is most cost-effective, it is easy to think of situations where these conditions exist, high intensity health care users where successful surgery seems probable. It is much harder to imagine situations in the opposite direction where treating OA is minimal cost but TKA expenses for continuing care will be more than 20 times the base value.

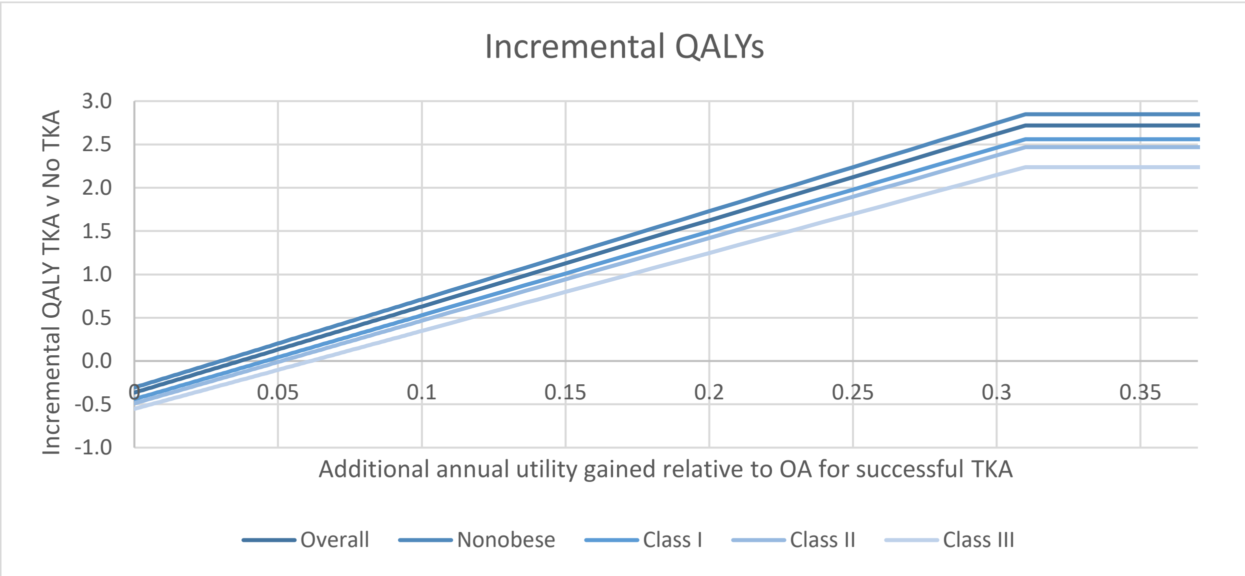
This last group also illustrates the importance of the relative relationship between OA and TKA as well as what is still missing in this two-way analysis. In the top left corner of the Class III table, TKA continuing care is no cost, there is no additional cost beyond the initial surgery and any complications for patients remaining in the successful TKA state. Patients who never return to the surgeon after the immediate postoperative appointments because they and their implant are doing well would accrue no costs for continuing care. This fairly likely situation is still not cost-effective until OA treatment costs over $3,000 annually. The simple costs of OA and postoperative treatments are less important than the relationship between them and should not be considered in isolation.

Utility Threshold Analysis

A threshold analysis for the incremental improvement in quality of life after successful TKA surgery relative to living with OA was done to further explore the effects of the relationship between OA and successful TKA. In this analysis, the magnitude of this improvement of quality of life following successful TKA relative to OA was varied between no change and 0.37. The baseline value of utility for living with OA is 0.69 and is maintained throughout this analysis. The maximum possible utility for any patient is 1 so the increment size is constrained when it pushes the total utility over this boundary of perfect health.

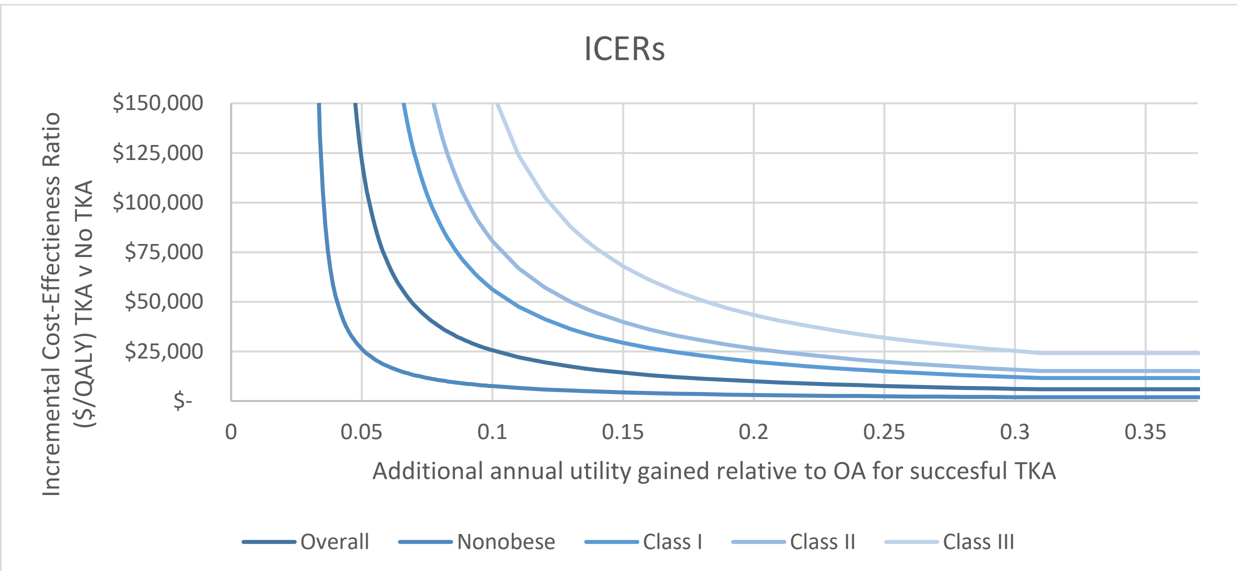
There are two interesting ways to examine the effect of this maximum benefit size for successful TKA. The first is to look at just the change in incremental utility for TKA relative to no TKA. The incremental QALY graph (Figure III-7) shows the additional utility gained per year by someone in the successful TKA state relative to living with OA on the horizontal axis. The vertical axis shows the difference in QALYs over the patient life span between TKA and no TKA. Each line depicts one population group. The other is to look at the overall outcome of interest, the ICER (Figure III-8). In that graph, the horizontal axis is the same, but the vertical is the incremental cost-effectiveness ratio (which is the incremental cost [which remains unchanged in this analysis] divided by the incremental QALYs that are examined alone in the previous graph).

Figure III-7 Incremental QALYs by Obesity Class



Looking at just the incremental QALYs illustrates two things. The first is the previously discussed maximum benefit ceiling. For all population groups, at 0.31 the incremental benefit flattens out. This is because while OA is at baseline, the maximum improvement possible is the gap between perfect health and OA (1-0.69 = 0.31). The lines reach this maximum at different levels of incremental benefit in lifetime QALYs due to other factors in the model such as the obesity penalty and different complication rates assessing QALY penalties. At the other end of the spectrum, every obesity classification as well as the nonobese can result in net losses in lifetime QALYs when the benefit of successful TKA is low enough. This result may appear surprising. However, this parameter is not the only one determining overall lifetime QALYs. To experience the benefit of successful TKA, a patient must first face the surgery itself (a decrement of 0.15 for that first year). Additionally, patients face complications which may also lower quality of life experienced in both the short and long term for deep infections. Implants may also fail which is a worse health state than OA. Revisions may also occur with a further surgical decrement and accompanying risks. The higher quality of life associated with a successful surgery must outweigh all these risks and experiences. For each obesity group there is a floor at which the benefit of the best outcome does not outweigh the rest of the process. The accompanying table (Table III-13) displays those floors.

Figure III-8 ICERs by Obesity Class



The graph of ICERs demonstrates another key factor in the overall results. While the cost portion of the ICER is unchanged in this analysis, the ratio is significantly impacted by the change in benefit relative to the OA utility. This graph shows the ICERs in a reasonable window of willingness to pay (WTP). To the left the impact of this single parameter on the overall results is clear from the rate at which the ICER is falling. The difference in benefit needed to move between dominated and cost-effectiveness at reasonable thresholds is small. The effect of the same increase in benefit at larger benefit levels is minimal.

Table III-13 below shows the increase in utility associated with successful TKA relative to OA required for TKA to not be dominated by no TKA along with the increase required to be cost-effective at the two most common thresholds used in the US setting. As seen on the graphs, Class III patients require a much larger benefit to reach a cost-effectiveness threshold that is considered appropriate in the US. The baseline value is 0.136 which is just beyond the increment required to reach $50,000 per QALY. The nonobese group on the other hand only requires a third of that value to be cost-effective at the same threshold. This difference in required benefit highlights the differences between groups. While the same net benefit is had from the surgery, the overall risk profile limits the overall impact surgery has on heavier groups. The best-case scenario needs to have greater impact for the heavier groups to get enough benefit from surgery to be worthwhile.

Table III-13 Minimum Utility Benefit of TKA Required at Baseline

Population Group		Cost-effective at WTP	
	Not Dominated	$100,000	$50,000
Overall	0.036	0.053	0.068
Nonobese	0.030	0.035	0.040
Class I	0.045	0.076	0.100
Class II	0.051	0.090	0.120
Class III	0.061	0.120	0.180

Scenario Analysis

OA and Postoperative Costs and QALYs

This scenario extends the two analyses conducted to work jointly among all the parameters on the postoperative side including procedure costs in addition to the continuing care as well as combining the effects of costs and QALYs simultaneously. Table III-14 presents these results.

First, biasing all costs against TKA by setting TKA costs to their highest values and simultaneously setting OA cost to its lowest, the nonobese population is cost-effective at the $100,000 level. None of the obese classes would be considered cost-effective. Next, the scenario was reversed to bias all costs in favor of TKA. In this scenario, all subpopulations and the overall population show TKA as dominant. The two-way analysis showed that, at the extreme favorability for just two of the costs, dominance was likely. This extends that to Class III by incorporating all the costs faced on the operative side.

Similarly, biasing all QALY measures against TKA, the results are as suggested by the threshold analysis in Table III-13. In all obesity groups and overall, TKA is dominated. The cost remains unchanged, but the QALYs show no improvement over the no TKA scenario. In the reverse case, the large gains in health while costs are unchanged make the extra expense well worth the cost in all groups.

Combining the costs and QALYs, when OA is favored all groups see TKA dominated. When TKA is favored, all groups see TKA dominant.

The full picture of postoperative health and costs extends the earlier analyses by showing that the relative relationship between OA and postoperative experience are more important than the absolute values.

Table III-14 CEA Results of OA and TKA Scenarios

TKA Status by Obesity	Cost	QALY	ICER	NMB*	TKA Status by Obesity	Cost	QALY	ICER	NMB*
TKA Favored					**OA Favored**				
				Relative to No TKA					*Relative to No TKA*
Overall					**Overall**				
Costs Only					Costs Only				
No TKA	$ 98,142	7.31			No TKA	$ 24,536	7.31		
TKA	$ 33,670	8.30	Dominant	$113,878	TKA	$128,112	8.30	$ 104,822	$ (54,171)
QALY Only					QALY Only				

No TKA	$ 49,071	4.81			No TKA	$ 49,071	9.82		
TKA	$ 65,151	7.52	$ 5,940	$119,261	TKA	$ 65,151	9.66	Dominated	$ (23,868)
Cost & QALY					Cost & QALY				
No TKA	$ 98,142	4.81			No TKA	$ 24,536	9.82		
TKA	$ 33,670	7.52	Dominant	$199,812	TKA	$128,112	9.66	Dominated	$(111,365)
Nonobese					**Nonobese**				
Costs Only					Costs Only				
No TKA	$ 98,510	7.37			No TKA	$ 24,628	7.37		
TKA	$ 27,953	8.44	Dominant	$124,441	TKA	$107,805	8.44	$ 77,182	$ (29,293)
QALY Only					QALY Only				
No TKA	$ 49,255	4.86			No TKA	$ 49,255	9.88		
TKA	$ 54,571	7.79	$ 1,809	$141,624	TKA	$ 54,571	9.76	Dominated	$ (11,068)
Cost & QALY					Cost & QALY				
No TKA	$ 98,510	4.86			No TKA	$ 24,628	9.88		
TKA	$ 27,953	7.79	Dominant	$217,496	TKA	$107,805	9.76	Dominated	$ (88,930)
Class I Obese					**Class I Obese**				
Costs Only					Costs Only				
No TKA	$ 97,909	7.28			No TKA	$ 24,477	7.28		
TKA	$ 40,492	8.15	Dominant	$101,197	TKA	$154,904	8.15	$ 148,957	$ (86,647)
QALY Only					QALY Only				
No TKA	$ 48,954	4.78			No TKA	$ 48,954	9.77		
TKA	$ 78,629	7.15	$ 12,538	$ 88,668	TKA	$ 78,629	9.57	Dominated	$ (39,628)
Cost & QALY					Cost & QALY				
No TKA	$ 97,909	4.78			No TKA	$ 24,477	9.77		
TKA	$ 40,492	7.15	Dominant	$175,759	TKA	$154,904	9.57	Dominated	$(140,380)
Class II Obese					**Class II Obese**				
Costs Only					Costs Only				
No TKA	$ 98,098	7.25			No TKA	$ 24,525	7.25		
TKA	$ 45,346	8.05	Dominant	$ 93,181	TKA	$168,957	8.05	$ 178,628	$(104,004)
QALY Only					QALY Only				
No TKA	$ 49,049	4.75			No TKA	$ 49,049	9.75		
TKA	$ 86,550	7.01	$ 16,587	$ 75,539	TKA	$ 86,550	9.50	Dominated	$ (49,786)
Cost & QALY					Cost & QALY				
No TKA	$ 98,098	4.75			No TKA	$ 24,525	9.75		
TKA	$ 45,346	7.01	Dominant	$165,792	TKA	$168,957	9.50	Dominated	$(156,718)
Class III Obese					**Class III Obese**				
Costs Only					Costs Only				
No TKA	$ 95,119	6.98			No TKA	$ 23,780	6.98		

TKA	$ 54,680	7.65	Dominant	$ 74,009	TKA	$195,805	7.65	$ 256,221	$(138,456)
QALY Only					QALY Only				
No TKA	$ 47,559	4.56			No TKA	$ 47,559	9.41		
TKA	$101,722	6.57	$ 26,976	$ 46,227	TKA	$101,722	9.10	Dominated	$ (69,749)
Cost & QALY					Cost & QALY				
No TKA	$ 95,119	4.56			No TKA	$ 23,780	9.41		
TKA	$ 54,680	6.57	Dominant	$140,828	TKA	$195,805	9.10	Dominated	$(187,613)
*Net Monetary Benefit where QALYs are valued at $50,000									

<u>All Complications</u>

Complication rates are frequently discussed in the literature as a reason to withhold surgery in obese patients or at least something to consider when deciding whether surgical intervention is appropriate. Complications were considered in three ways: base rates, relative risks, and rates and risk together (Table III-15).

When only the base rates of complications were considered at their lowest value, TKA becomes dominant in the nonobese population. Even Class III becomes very cost-effective with an ICER under $25,000/QALY. At the opposite extreme, the overall population is still cost-effective but not at $50,000 and neither is Class I obesity. Class II and III obesity are not cost-effective even at the higher $100,000 threshold with Class III showing an untenable $1.5 Million/QALY.

The real debate though may not be what the base rate is, but the impact of obesity on the complication rate. To that end, relative risks for each obesity group for each complication were also considered at high and low values. When all are set to low values, the results are similar to low base rates. All population groups are cost-effective at $50,000. The overall value is not cost-effective at even the $100,000 level when all relative risks are set to high. Class II and III obesity are very much not cost-effective with Class III almost a million dollars per QALY. Class

I is actually dominated. This is not surprising because for Class I obesity, the upper bound for the relative risk is set to 22. The much wider range on this relative risk is a result of limited literature that deals with deep infection rates.

Combining these scenarios, when the base rate and the relative risks are both low, for overall population we see cost savings and even Class III is very cost-effective. At the opposite end of the range, TKA is dominated in all obese groups and overall. TKA remains highly cost-effective in the nonobese population.

Table III-15 CEA Results of Complication Rates Scenarios

TKA Status by Obesity	Cost	QALY	ICER	NMB*	TKA Status by Obesity	Cost	QALY	ICER	NMB*
Complication Low					**Complication High**				
			Relative to No TKA					*Relative to No TKA*	
Overall					**Overall**				
Base Rates Only					Base Rates Only				
No TKA	$49,071	7.31			No TKA	$ 49,071	7.31		
TKA	$55,257	8.39	$ 5,738	$47,720	TKA	$ 91,735	8.10	$ 54,109	$ (3,240)
Relative Risks Only					Relative Risks Only				
No TKA	$49,071	7.31			No TKA	$ 49,071	7.31		
TKA	$60,774	8.34	$ 11,394	$39,654	TKA	$112,854	7.94	$ 101,460	$ (32,350)
Base & Risks					Base & Risks				
No TKA	$49,071	7.31			No TKA	$ 49,071	7.31		
TKA	$55,257	8.39	$ 5,738	$47,720	TKA	$248,935	7.13	Dominated	$(209,160)
Nonobese					**Nonobese**				
Base Rates Only					Base Rates Only				
No TKA	$49,255	7.37			No TKA	$ 49,255	7.37		
TKA	$48,036	8.51	Dominant	$58,202	TKA	$ 71,339	8.31	$ 23,529	$ 24,845
Relative Risks Only					Relative Risks Only				
No TKA	$49,255	7.37			No TKA	$ 49,255	7.37		
TKA	$54,571	8.44	$ 4,932	$48,568	TKA	$ 54,571	8.44	$ 4,932	$ 48,568
Base & Risks					Base & Risks				
No TKA	$49,255	7.37			No TKA	$ 49,255	7.37		
TKA	$48,036	8.51	Dominant	$58,202	TKA	$ 71,339	8.31	$ 23,529	$ 24,845

Class I Obese					**Class I Obese**				
Base Rates Only					Base Rates Only				
No TKA	$48,954	7.28			No TKA	$ 48,954	7.28		
TKA	$68,311	8.25	$ 19,992	$29,055	TKA	$107,673	7.95	$ 87,896	$ (25,316)
Relative Risks Only					Relative Risks Only				
No TKA	$48,954	7.28			No TKA	$ 48,954	7.28		
TKA	$69,163	8.24	$ 20,992	$27,926	TKA	$275,015	6.69	Dominated	$(255,447)
Base & Risks					Base & Risks				
No TKA	$48,954	7.28			No TKA	$ 48,954	7.28		
TKA	$68,311	8.25	$ 19,992	$29,055	TKA	$685,859	4.08	Dominated	$(796,567)
Class II Obese					**Class II Obese**				
Base Rates Only					Base Rates Only				
No TKA	$49,049	7.25			No TKA	$ 49,049	7.25		
TKA	$68,412	8.22	$ 19,956	$29,151	TKA	$135,977	7.70	$ 191,648	$ (64,249)
Relative Risks Only					Relative Risks Only				
No TKA	$49,049	7.25			No TKA	$ 49,049	7.25		
TKA	$73,303	8.18	$ 26,106	$22,199	TKA	$143,622	7.58	$ 281,498	$ (77,775)
Base & Risks					Base & Risks				
No TKA	$49,049	7.25			No TKA	$ 49,049	7.25		
TKA	$68,412	8.22	$ 19,956	$29,151	TKA	$325,494	6.33	Dominated	$(322,366)
Class III Obese					**Class III Obese**				
Base Rates Only					Base Rates Only				
No TKA	$47,559	6.98			No TKA	$ 47,559	6.98		
TKA	$70,474	7.92	$ 24,425	$23,994	TKA	$188,803	7.08	$1,450,938	$(136,377)
Relative Risks Only					Relative Risks Only				
No TKA	$47,559	6.98			No TKA	$ 47,559	6.98		
TKA	$80,746	7.83	$ 39,195	$ 9,149	TKA	$170,837	7.14	$ 761,469	$(115,183)
Base & Risks					Base & Risks				
No TKA	$47,559	6.98			No TKA	$ 47,559	6.98		
TKA	$70,474	7.92	$ 24,425	$23,994	TKA	$626,850	5.51	Dominated	$(653,056)

*Net Monetary Benefit where QALYs are valued at $50,000

Deep Infection

In the one-way analysis, the only complication to appear in the most important parameters list for any of the subpopulations is deep infection. A scenario similar to the complications was done to isolate the effect of this single complication as a result (Table III-16).

When the deep infection rate is low, TKA is cost-saving in the nonobese population. All three obesity classes now have ICERs well under the $50,000 threshold. If instead deep infection is set at its highest rate, the nonobese cease to be cost-saving, but do remain cost-effective with an ICER under $50,000. Class I obesity is acceptable at $100,000 level, but BMI greater than 35 is no longer cost-effective. Class III sees an ICER over a million dollars.

Looking instead at the relative risks of deep infection, overall and each of the obesity groups are cost-effective even at $50,000. Conversely, when relative risks are high, the overall figure is not even cost-effective at $100,000. Class II and III are not cost-effective at any reasonable level. Class I, as with all complications, is dominated driven by the high value tested for deep infection in this group.

When both the base rate and the relative risks are considered simultaneously, low values show the same pattern to base rate alone being low because this is equivalent to no complications occurring. When both are set to high, all three obesity classes and the overall population show TKA as dominated.

Table III-16 CEA Results of Deep Infection Rates Scenarios

TKA Status by Obesity	Cost	QALY	ICER	NMB*	TKA Status by Obesity	Cost	QALY	ICER	NMB*
Deep Infection Low					Deep Infection High				
			Relative to No TKA					*Relative to No TKA*	
Overall					**Overall**				
Base Rates Only					Base Rates Only				
No TKA	$49,071	7.31			No TKA	$ 49,071	7.31		

TKA	$55,630	8.39	$ 6,085	$47,334	TKA	$ 85,967	8.11	46,549	$ 2,735
Relative Risks Only					Relative Risks Only				
No TKA	$49,071	7.31			No TKA	$ 49,071	7.31		
TKA	$60,868	8.34	$ 11,486	$39,557	TKA	$112,361	7.94	$ 100,614	$ (31,838)
Base & Risks					Base & Risks				
No TKA	$49,071	7.31			No TKA	$ 49,071	7.31		
TKA	$55,630	8.39	$ 6,085	$47,334	TKA	$213,093	7.15	Dominated	$(172,065)
Nonobese					**Nonobese**				
Base Rates Only					Base Rates Only				
No TKA	$49,255	7.37			No TKA	$ 49,255	7.37		
TKA	$48,283	8.51	Dominant	$57,946	TKA	$ 68,562	8.31	$ 20,527	$ 27,722
Relative Risks Only					Relative Risks Only				
No TKA	$49,255	7.37			No TKA	$ 49,255	7.37		
TKA	$54,571	8.44	$ 4,932	$48,568	TKA	$ 54,571	8.44	$ 4,932	$ 48,568
Base & Risks					Base & Risks				
No TKA	$49,255	7.37			No TKA	$ 49,255	7.37		
TKA	$48,283	8.51	Dominant	$57,946	TKA	$ 68,562	8.31	$ 20,527	$ 27,722
Class I Obese					**Class I Obese**				
Base Rates Only					Base Rates Only				
No TKA	$48,954	7.28			No TKA	$ 48,954	7.28		
TKA	$68,841	8.24	$ 20,547	$28,506	TKA	$100,100	7.95	$ 75,895	$ (17,451)
Relative Risks Only					Relative Risks Only				
No TKA	$48,954	7.28			No TKA	$ 48,954	7.28		
TKA	$69,401	8.24	$ 21,244	$27,677	TKA	$273,639	6.69	Dominated	$(254,012)
Base & Risks					Base & Risks				
No TKA	$48,954	7.28			No TKA	$ 48,954	7.28		
TKA	$68,841	8.24	$ 20,547	$28,506	TKA	$616,549	4.14	Dominated	$(724,653)
Class II Obese					**Class II Obese**				
Base Rates Only					Base Rates Only				
No TKA	$49,049	7.25			No TKA	$ 49,049	7.25		
TKA	$69,041	8.22	$ 20,614	$28,500	TKA	$124,412	7.71	163,263	$ (52,283)
Relative Risks Only					Relative Risks Only				
No TKA	$49,049	7.25			No TKA	$ 49,049	7.25		
TKA	$73,379	8.17	$ 26,189	$22,121	TKA	$143,482	7.58	280,981	$ (77,629)
Base & Risks					Base & Risks				
No TKA	$49,049	7.25			No TKA	$ 49,049	7.25		

TKA	$69,041	8.22	$ 20,614	$28,500	TKA	$290,112	6.35	Dominated	$(285,777)
Class III Obese					**Class III Obese**				
Base Rates Only					Base Rates Only				
No TKA	$47,559	6.98			No TKA	$ 47,559	6.98		
TKA	$71,278	7.92	$ 25,296	$23,163	TKA	$166,146	7.09	$1,053,501	$(112,959)
Relative Risks Only					Relative Risks Only				
No TKA	$47,559	6.98			No TKA	$ 47,559	6.98		
TKA	$81,390	7.83	$ 39,975	$ 8,484	TKA	$167,449	7.15	$ 730,309	$(111,681)
Base & Risks					Base & Risks				
No TKA	$47,559	6.98			No TKA	$ 47,559	6.98		
TKA	$71,278	7.92	$ 25,296	$23,163	TKA	$351,718	5.69	Dominated	$(368,859)

*Net Monetary Benefit where QALYs are valued at $50,000

Failure Rates

Failure rates are likely to be correlated across time so were tested as sets to capture this (Table III-17). In the one-way analysis, the later failure rates sometimes appeared as a top parameter of interest in some of the obesity classes and deserve further investigation. Three scenarios were considered at both high and low values. These values are derived from the bounds of 95% confidence intervals around the base to cover the full spectrum of likely values. The first is the failure rate for each year in both primary and revision procedures. Second, only failure rates of the primary surgery were considered. Third, only failure rates for revision were considered with revision done normally and subsequent to a deep infection considered at once.

When all failure rates were set to lowest value, TKA is dominant in all obesity subpopulations and overall except Class III. Conversely, when all failure rates were set to highest value, TKA is dominated in all groups.

More interesting is when just TKA failure rates are considered. Because there is little opportunity for revision when the primary rarely fails, results are quite comparable to the results when all failure rates are changed. When failure rates are low, only Class III obesity fails to be cost-saving and even that is highly cost-effective. When TKA failure rates are all set to high values, TKA is no longer cost-effective for any group at $50,000 and only nonobese has an ICER less than $100,000. This reflects the importance placed on the initial failure rate of TKA shown in all groups in the one-way analysis.

Looking just at revision, the results for low failure rates are quite favorable for TKA. The nonobese group is cost-saving and the three obesity classes are all cost-effective at $50,000. When the revision failure rate is high, TKA in obese groups instead are dominated because the health toll of multiple surgeries and increased exposure to complications plus the added costs of those repeated surgeries drops the QALY below the no TKA values while increasing costs. The nonobese population sees an ICER of over $100,000/QALY and overall ICER is over $200,000/QALY.

Table III-17 CEA Results of Implant Failure Rates Scenarios

TKA Status by Obesity	Cost	QALY	ICER	NMB*	TKA Status by Obesity	Cost	QALY	ICER	NMB*
Failure Rates Low					**Failure Rates High**				
			Relative to No TKA					*Relative to No TKA*	
Overall					**Overall**				
Primary and Revision					Primary and Revision				
No TKA	$49,071	7.31			No TKA	$ 49,071	7.31		
TKA	$34,505	8.54	Dominant	$76,039	TKA	$376,883	5.47	Dominated	$(420,242)
Primary Only					Primary Only				
No TKA	$49,071	7.31			No TKA	$ 49,071	7.31		
TKA	$38,383	8.52	Dominant	$71,111	TKA	$117,630	7.83	$ 134,119	$ (43,000)
Revision Only					Revision Only				
No TKA	$49,071	7.31			No TKA	$ 49,071	7.31		
TKA	$53,880	8.38	$ 4,492	$48,718	TKA	$137,059	7.64	$ 270,490	$ (71,723)
Nonobese					**Nonobese**				
Primary and Revision					Primary and Revision				
No TKA	$49,255	7.37			No TKA	$ 49,255	7.37		

TKA	$31,447	8.63	Dominant	$80,875	TKA	$346,702	5.75	Dominated	$(378,519)
Primary Only					Primary Only				
No TKA	$49,255	7.37			No TKA	$ 49,255	7.37		
TKA	$33,829	8.62	Dominant	$77,932	TKA	$103,249	8.00	$ 85,857	$ (22,550)
Revision Only					Revision Only				
No TKA	$49,255	7.37			No TKA	$ 49,255	7.37		
TKA	$47,288	8.50	Dominant	$58,497	TKA	$110,353	7.92	$ 110,845	$ (33,538)
Class I Obese					**Class I Obese**				
Primary and Revision					Primary and Revision				
No TKA	$48,954	7.28			No TKA	$ 48,954	7.28		
TKA	$37,091	8.49	Dominant	$72,263	TKA	$424,482	5.04	Dominated	$(487,268)
Primary Only					Primary Only				
No TKA	$48,954	7.28			No TKA	$ 48,954	7.28		
TKA	$42,075	8.45	Dominant	$65,718	TKA	$134,887	7.65	$ 231,847	$ (67,401)
Revision Only					Revision Only				
No TKA	$48,954	7.28			No TKA	$ 48,954	7.28		
TKA	$62,264	8.28	$ 13,279	$36,805	TKA	$180,996	7.22	Dominated	$(134,997)
Class II Obese					**Class II Obese**				
Primary and Revision					Primary and Revision				
No TKA	$49,049	7.25			No TKA	$ 49,049	7.25		
TKA	$40,714	8.41	Dominant	$66,727	TKA	$434,644	4.94	Dominated	$(500,924)
Primary Only					Primary Only				
No TKA	$49,049	7.25			No TKA	$ 49,049	7.25		
TKA	$48,023	8.37	Dominant	$57,294	TKA	$146,617	7.51	$ 362,847	$ (84,123)
Revision Only					Revision Only				
No TKA	$49,049	7.25			No TKA	$ 49,049	7.25		
TKA	$66,867	8.20	$ 18,713	$29,791	TKA	$188,859	7.13	Dominated	$(145,647)
Class III Obese					**Class III Obese**				
Primary and Revision					Primary and Revision				
No TKA	$47,559	6.98			No TKA	$ 47,559	6.98		
TKA	$49,063	8.04	$ 1,424	$51,296	TKA	$457,829	4.64	Dominated	$(527,166)
Primary Only					Primary Only				
No TKA	$47,559	6.98			No TKA	$ 47,559	6.98		
TKA	$59,993	7.98	$ 12,472	$37,409	TKA	$170,761	7.06	$1,512,011	$(119,127)
Revision Only					Revision Only				
No TKA	$47,559	6.98			No TKA	$ 47,559	6.98		

TKA	$77,221	7.82	$ 35,598	$12,000	TKA	$202,081	6.80	Dominated	$(163,514)
*Net Monetary Benefit where QALYs are valued at $50,000									

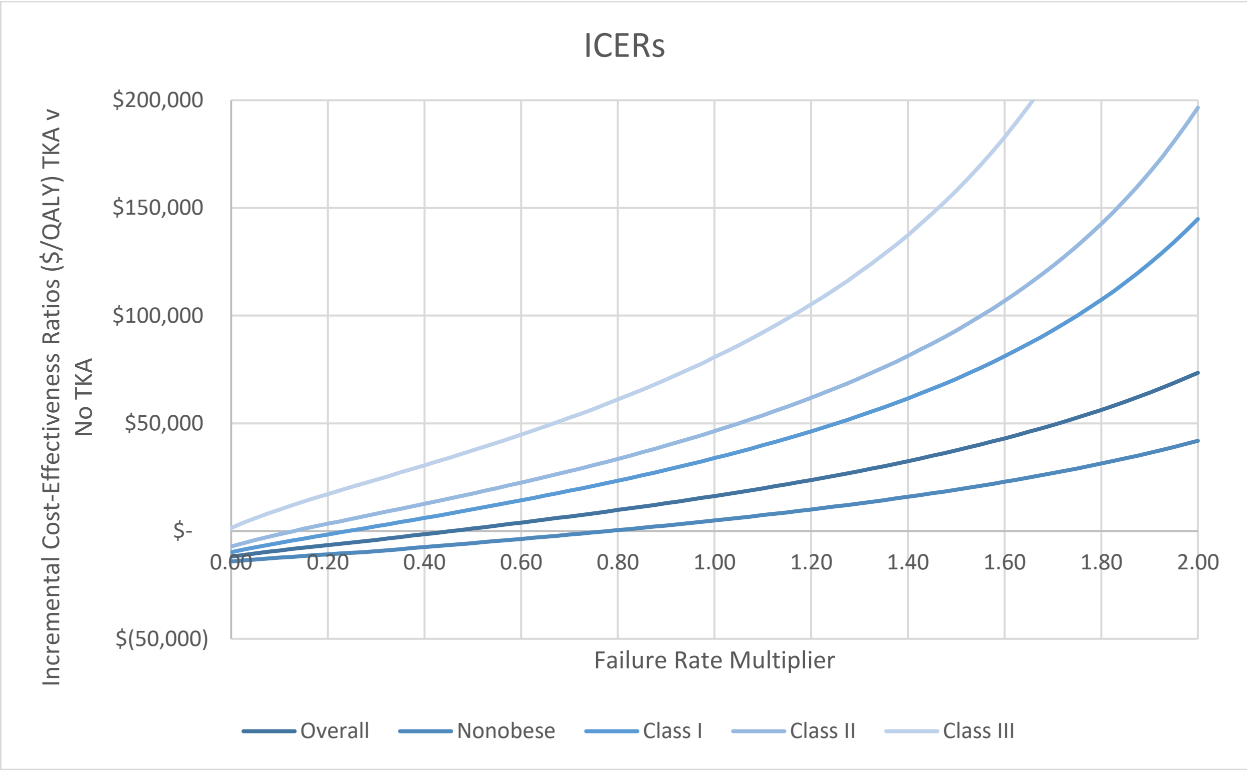
A best- and worst-case scenario analysis was also conducted. Unsurprisingly, the best case shows TKA dominant in all groups and the worst case shows it dominated in all groups.

Threshold Analysis for Failure Rates

The failure rates scenario analysis suggested that failure rates deserve more attention. The scenario treated each year alike, but this analysis maintains the differences between rates by the number of years postoperative. The assumption that the rates are correlated is also maintained. For this analysis, the failure rates for primary and revision surgeries are multiplied by a factor ranging from 0 for no failure to 2 for a 100% increase in the failure rates.

Figure III-9 shows the ICERs relative to the multipliers across a reasonable range of WTP. The impact of failure rates as well as the difference between obesity groups is clear. Class III obesity is never cost-saving even when failure rates are zero. The nonobese group is cost-saving until nearly 80% of baseline rate. TKA for individuals in Class I and II obesity remain dominant until approximately 25% and 15% respectively. At the opposite end of the range, even when failure rates double, the nonobese population is still cost-effective. Class III obesity cannot tolerate even a 15% increase in failure rates if it is to remain cost-effective. Class I and II can both see more than 50% increase and remain cost-effective at $100,000/QALY.

Figure III-9 ICERs by Obesity Class for Failure Rate Multipliers

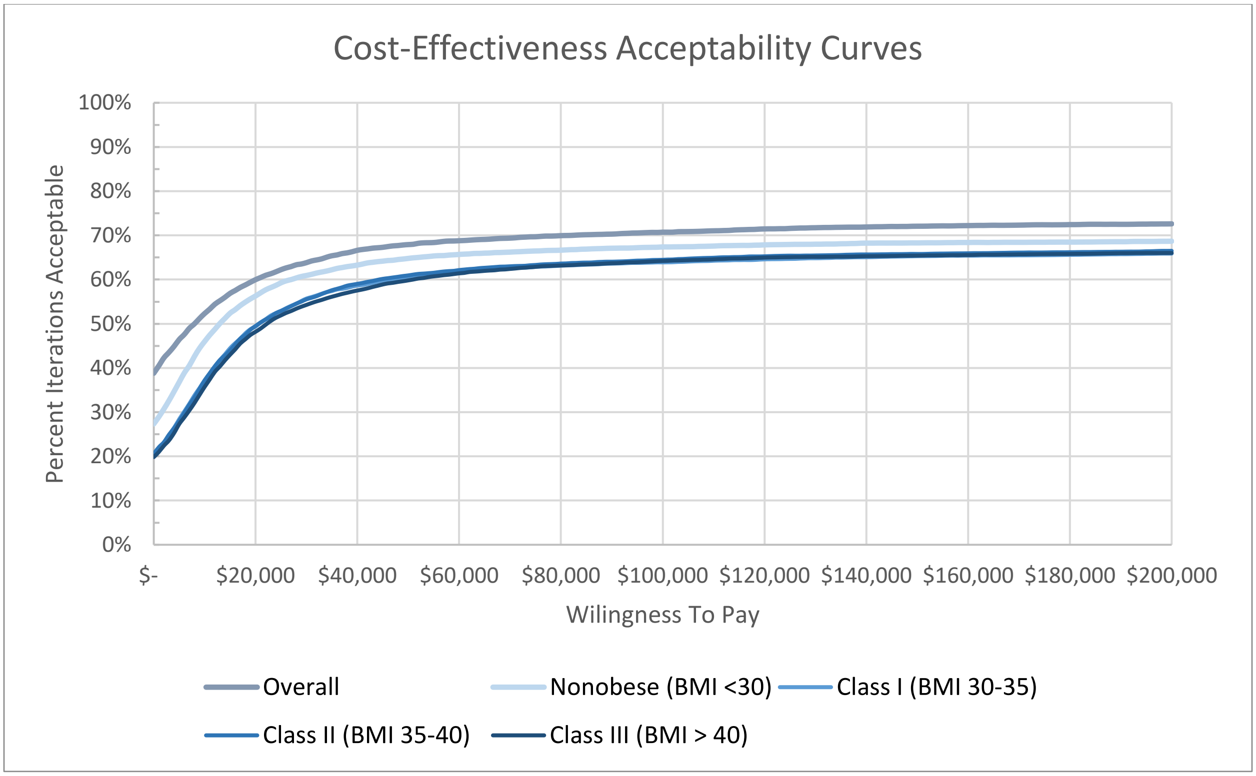


The margin of error in parameters for Class III obesity is once again much finer than other groups. Nonobese is again more robust to changes in parameter valuation.

Probabilistic Sensitivity Analysis

A probabilistic sensitivity analysis was conducted using Monte Carlo simulation to explore the impact of uncertainty in multiple parameters simultaneously. The model was run using the probability distributions described above for 10,000 iterations. Then cost-effectiveness acceptability curves were constructed (Figure III-10). The acceptability curve displays the percent of simulation iterations that would be preferred at various levels of WTP for a QALY. The x-axis is these WTP values. There are two things to note about the model design. The overall population figure is an average of the four obesity groups not a distinct model setting. Second, each iteration makes a single draw from each parameter distribution so that each obesity group faces the same value for that iteration excepting the relative risks that are unique to each subgroup.

Figure III-10 Acceptability Curves by Obesity Class



Looking at just the overall population, about 25% of the time TKA is dominated and 40% of the time it is dominant. Using a WTP of $50,000, TKA is preferred about two thirds of the time. Increasing the WTP to $100,000, about 72% of the time TKA is preferred.

Looking at the specific obesity groups similar results are found across all groups as detailed in Table III-18. In each obesity class about 34% of the time TKA is dominated and TKA is dominant about 20%. Using a WTP of $50,000 about 60% of the time TKA is preferred and this increases to 64% when the WTP rises to $100,000.

Table III-18 Key Values for Probabilistic Sensitivity Analysis

	Willingness to Pay			
	Dominant	$ 50,000	$ 100,000	Dominated
Overall	39%	68%	71%	~27%
Nonobese	27%	65%	67%	~31%
Class I	20%	60%	64%	~34%
Class II	21%	61%	64%	~34%
Class III	20%	60%	64%	~34%

The parameter related to the utility gained following successful TKA alone accounts for much of the probability that TKA would be dominated. This parameter has a wide distribution. The probability distribution for the incremental utility associated with postoperative success is frequently less than the threshold of being dominated (Table III-13). If all other parameters were kept at their base values, Table III-19 shows the probability that TKA would be dominated solely due to the QALYs gained from TKA not being high enough. Finally, the last column shows that the incremental utility parameter explains 60-80% of the iterations where TKA is dominated. The remaining dominated iterations are explainable by the other ways that the overall QALYs can be lowered e.g. increased failure rates driving more revisions and poorer outcomes, higher penalties for surgeries and complications, and higher likelihood of those complications.

Table III-19 Probability of TKA Domination and QALY Increment of Successful TKA

Population	Dominated	Predicted by Incremental Utility Gained by Successful TKA	Share explained
Overall	~27%	20.23%	76%
Nonobese	~31%	18.85%	60%
Class I	~34%	22.41%	66%
Class II	~34%	23.94%	71%
Class III	~34%	27.15%	80%

The similarity across obesity classifications for the PSA seems to contradict the univariate results where many more parameters had much larger effects in higher obesity classes. However, the threshold analysis of the incremental utility gain over OA can explain this apparent contradiction. That single parameter has such a large influence that any impact of other parameters is often subsumed in the dominated simulations. With that single parameter explaining about two-thirds of the dominated simulations, many of the sensitivity analyses showing high ICERS disappear into the dominated runs. Because of this strong influence by the incremental utility from successful TKA, only 2% of iterations are both not dominated and above acceptable thresholds. All variation seen in the univariate analysis on other parameters can only express differences in this small number of the iterations. The extreme ICERs seen in the univariate analyses, especially in Class III obesity, disappear when combined with perturbations in the overall quality of life benefit of successful TKA.

Also of note, the overall population is less likely to be dominated because it is a weighted average of the subpopulations rather than an independent analysis. A common set of parameters is used for each obesity group so in order to be dominated, all four obesity groups must have been assigned unfavorable relative risks simultaneously. In this average population result, the more favorable relative risks in some groups may compensate for even the most unfavorable relative risk and base rate combinations in another.

Discussion

The analyses show that the cost-effectiveness of TKA varies across the spectrum of BMI, with a range from very cost-effective in the nonobese population to Class III obesity requiring the higher US threshold of $100,000 to be considered cost-effective. These results fit in the general thought that TKA is a very cost-effective procedure, but that obesity, especially higher levels of obesity, may undermine that. Even at the worst, Class III obesity with an ICER of $80,671 is much more cost-effective than Vioxx was in the treatment of arthritis relative to other

NSAID and Vioxx was widely prescribed before its withdrawal from the market on safety grounds (Maetzel, Krahn, & Naglie, 2003).

The question of whether TKA should be withheld in obese patients or in some subset of obese patients is of great interest and has been implemented for budgetary reasons in some places. The results of this study indicate that obese patients do benefit from TKA even with lower functionality scores, but that the absolute benefit is low and drives TKA in a Class III obese population to be of marginal cost-effectiveness. If restriction of TKA to obese patients is based on budgetary caution, perhaps there is a rationale for implementing such guidelines. The model shows the higher BMI categories have extremely large consequences compared to less obese populations. These could be costly errors. It is also important to consider that the share of the population in these higher obesity classes is also increasing so the overall budgetary implications will only grow as the population shifts.

Patient satisfaction surveys after TKA indicate 10-30% of patients are not satisfied with their outcomes (Bourne, Chesworth, Davis, Mahomed, & Charron, 2010). The authors also examined specific factors that predicted dissatisfaction including complications, low improvement after surgery, and unmet expectations (Bourne, Chesworth, Davis, Mahomed, & Charron, 2010). These are all factors that contribute to the occurrence of dominated results in the PSA. The role of unmet patient expectations observed in the patient surveys and the important effect of the QALY increment for successful TKA on whether TKA is dominated hold an interesting parallel. Managing patient expectations or discouraging surgery for those with unrealistic expectations may improve both patient satisfaction scores and improve resource allocation by limiting the patient population to those who will get the most benefit. Patients who believe that a TKA will return them to perfect health with no limitations will never meet that goal, regardless of how well the procedure goes. When patients expect too much, satisfaction scores will be low. The expectations can either be managed or patients who are not anticipated to see much improvement can be denied surgery as not worth the risk for the expected gains. The QALY increment's importance works in a similar way. When the QALY gain for a successful TKA is low, the surgery is not worth the risk and costs, no matter how many successful surgeries occur.

Class III or morbid obesity is the most frequent target of guidelines withholding treatment based on increased complications or decreased benefit after the procedure. While it is true that this population does have increased complications and decreased benefits, that alone is not enough to argue from a cost-effectiveness standpoint to issue such a guideline. The interaction of those facts with the other influential aspects of the situation needs consideration. The overall number of QALYs gained may be smaller but there is still an incremental benefit that may offset the increased cost of the TKA procedure. If cost-effectiveness is meant to be an impartial judgment, then by this standard even the patients with the highest BMIs are still cost-effective at the $100,000 threshold. The two-way sensitivity analysis further this argument showing that with just an average expectation of benefit, this group will be cost-effective at the even lower threshold of $50,000. It does not take much to make this worthwhile. The threshold analysis does indicate that the required improvement is larger than for nonobese patients, but that alone should not be disqualifying so long as that floor is expected to be exceeded.

Complication rates may be what is behind the focus on Class III obesity. This group does face increased, sometimes greatly, risk compared to nonobese groups, but not necessarily more than less obese groups. The complication rates are shown to matter a great deal in the scenario analysis and deep infection especially as evidenced by the one-way analysis. The results of the meta-analysis indicate that the data on these specific complications by obesity class could be improved to tighten up the relative risks associated with obesity and improve the results of this study. This is particularly true of deep infection and Class I obesity as shown by TKA being dominated when relative risk is set to high as discussed above. The conclusions are tentative, but these are clearly important parameters that require more specific obesity focused research.

Future Research

Complication rates and the relative risk by obesity needs further exploration as discussed above. These parameters proved important across the board in the univariate analysis and the scenario analyses further demonstrated that the extreme values could change the decision regarding TKA.

Another group of parameters that also need further investigation are failure rates. First, these failure rates are taken from implant survival analysis which are better described as revision rates rather than failure rates. This measure does not account for patients who choose not to undergo a subsequent procedure or those who are not even offered such surgery. The stratification by obesity classification is also not explored in the literature on failure rate to any great extent. These two factors may also interact if heavier patients are less likely to be offered revision for instance. The scenario and threshold analyses indicate that failure rates can alter the recommendation for or against TKA and so this is a key area to explore.

Another major area for further study is the ethics of guidelines and withholding treatment from certain groups. The difference in reaction from the two NHS bans illustrate the need for this exploration. In the earlier decision, the procedure was not banned in patients but only to be used as a last resort. In the later decision, the ban was absolute until a weight loss goal had been met. The results of this study indicate that at any level there is still benefit to the procedure and may be cost-effective at any weight. There may be other related benefits to losing weight, but whether that should be tied to the ability to have surgery is debatable. There is also the question of whether this decision is really a financial cover for moralizing against obesity.

A final major area for further study is found in the next chapter which examines population level dynamics and budget impact of TKA in growing obese populations.

Clinical Applications

The evidence against TKA in obese patients as a group is scant, but in specific circumstances the procedure may not be the best decision. The results of the sensitivity analysis suggest a few key values to consider when considering surgery for an obese patient. First, the heavier a patient the more improvement relative to current health is needed to make surgical intervention worthwhile. A nonobese patient who is clinically expected to improve enough to start walking unaided is likely to benefit from TKA. That same expectation in a morbidly obese patient may not be sufficient to offset the costs and the increased risk of complications. While nonobese and obese patients expect to see the same relative level of improvement to their quality of life, nonobese patients can still be cost-effective with much smaller improvements. Heavier patients who for whatever reasons are expected to see a below average improvement are unlikely to be good surgical candidates.

In terms of complications, any suspicion that deep infection is more likely than average is a major caution especially in the Class I obese population where the relative risk is least well defined. Deep infections are a costly and time-consuming complication that can easily prevent TKA from being cost-effective. When other risk factors for deep infection are present extra care should be taken before offering the TKA.

Failure rates are similar to deep infection. Class III obese patients where failure rate is suspected to be higher than average should be offered nonsurgical alternatives. Only a 15% increase in failure rate can be tolerated in this group before TKA no longer remains cost-effective.

No blanket ban is supported by this analysis, but certain patients will not be cost-effective. Focusing on likelihood to gain at least an average level of health improvement, no other risk factors for deep infections, and no increased risk for implant failure are good places to focus attention when evaluating an obese patient for TKA.

Methodological Advances

This is the first CEA done in TKA for obese populations. It adds to the conversation that TKA is a good value for money, but also puts the increased complication rates for obese patients into perspective. The conceptual model is also an advancement on the current literature. The importance of deep infection complications is more fully incorporated by using the submodule to address the lifetime differences of patients experiencing this involved complication.

CHAPTER IV:
Total Knee Arthroplasty and Obesity: Predicting Trends From 2015 To 2035 and an Examination of Guidelines Restricting Access in Obese Populations with an Agent-Based Model

Background

There is broad agreement that demand is growing for TKA procedures (Kurtz S. , Ong, Lau, Mowat, & Halpern, 2007), (Kurtz S. M., Ong, Lau, & Bozic, 2014). Age and obesity seem to be important drivers of this increased demand (Fehring, Odum, Griffin, Mason, & McCoy, 2007), (Wilson, Schneller, Montgomery, & Bozic, 2008), (Losina, Thornhill, Rome, Wright, & Katz, 2012), (Weinstein, et al., 2013), (Derman, Fabricant, & David, 2014), (Iorio, et al., 2008), (Odum, Springer, Dennos, & Fehring, 2013). The aging of the population cannot be modified. This leaves obesity as a possible lever to control the costs of and demand for TKA.

There are several ways that the future volume of TKA procedures and the budget and health impacts of that volume relate to obesity. First, if the future volume of TKA depends at least in part on whether those obese patients are to be offered surgery, then total volume, budget and health impacts are directly impacted by obesity. If surgical intervention for OA is restricted for these obese patients, the volume of TKA procedures will be lower in future than the current trend would suggest. Second, the obesity in the population can be modified such as a public health campaign that broadly reduces obesity. This could change the TKA volume predictions given that so many patients are obese even compared to the population. Last, obesity is one factor that could change the decision making around surgical uptake. For instance, surgical device development tracks could be reprioritized. The focus could shift to making implants more suited to obese patients' particular needs because of increasing obesity in the population or instead to focus on implants that are more durable and long-lasting resulting in fewer revisions for implant failure in younger patients. The trend model in this chapter will be exposed to each of these areas to explore the impact obesity has on TKA.

Understanding future volume and the drivers underlying the trend is an essential element in policy making. This demand has two important sets of consequences – budget impact and medical staff planning. These areas both require projections of volume that incorporate potential future conditions to help policy makers plan in these important domains.

The share of health care spending on TKA is already quite large and only predicted to grow. Health care dollars are a finite resource that should be allocated in a way that provides value for the money spent. Understanding the budget impact for obese patients access to TKA is important for future planning. The existing financial calculations seem focused on the lower benefit to obese patients compared to the nonobese population. Because obesity is a modifiable risk factor, unlike age, the thinking is that cost savings are had by reducing the risk factor before surgery is allowed to proceed. This approach does not focus on the broader systemic question of whether withholding surgery has a positive budget impact given that the lack of surgical access does not mean the cost of treating the underlying disease and disability is zero.

Another consideration is that as demand grows, orthopedic surgeons will be needed in larger numbers to absorb this demand. Workforce planning is also a long-term project. Residents need to be trained now if demand continues to rise in order to accommodate all the future patients. Understanding future demand can also suggest the risk factor modification to focus on with primary prevention such as obesity reduction programs.

A trend model was developed to address the planning issues and to explore the effects of various policy levers related to obesity, including implementing the restrictions on TKA for obese populations. The trend model develops a synthetic population and is parameterized to fit the historical data on TKA volume and population characteristics. The future volume is predicted under existing trends. Then, guidelines restricting access to TKA for obese groups are implemented in the simulation. Third, the pattern of obesity in the population's effect on TKA is explored. Lastly, the propensity of patients to undergo TKA is changed. In all these environments, the impact to health care budget, volume predictions, and health outcomes are considered with an eye toward policy decisions.

Methods

Overview

A trend model was constructed in AnyLogic using an ABM framework (The AnyLogic Company, 2018). The model begins with a population of 250,000 agents representative of the United States population in 1995. Agents are assigned age, gender, an obesity class, and OA status based on historic conditions. The model runs for 40 years until 2035. The basic model design, including the choice of health states, follows a similar model by Losina, et al. as closely as possible (Losina, et al., 2009) including the same modifications to Losina, et al. used in the compartmental model in Chapter III insofar as possible. The overall patient journey from no surgery to final outcome is unchanged in the conceptual model, but this model begins with healthy patients who progress first to OA then to possible surgery.

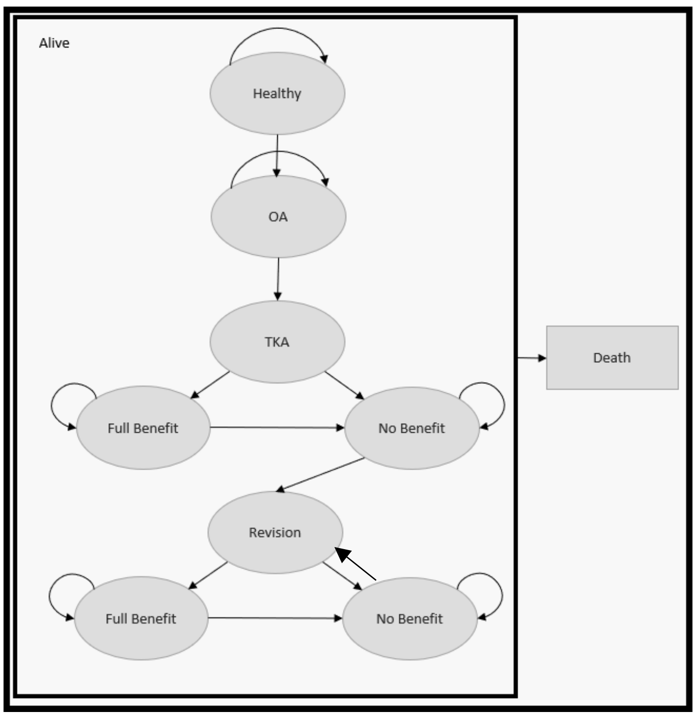
An ABM was selected to easily incorporate heterogeneity into the population under study. This framework uses a population of low-level agents, individual patients, and allows them to make individual choices that shape the top-level behavior observed (TKA uptake). Each agent follows a set of behavior independently that allows macrolevel outcomes to emerge. This more closely aligns with how patients and providers generate discharges for TKA in the real world than other modeling paradigms. Given the patient's individual characteristics, disease progresses. There is then a decision made, in consultation with their medical providers, about whether to pursue surgical intervention. Again, based on their individual characteristics different outcomes are more or less likely. The ABM also allows for interaction by the agents with their environment. In this model, that will include the presence or absence of guidelines restricting agents to certain classes of obesity.

This trend model will be used to address several different questions. First, the trend model will be used to predict TKA discharges from 2015-2035 assuming current conditions persist. Second, guidelines restricting access to primary TKA surgeries depending on obesity level will be considered. This will directly address the proposed restrictions and consider the budgetary impact as well as applying cost-effectiveness measures to the results. Third, another means to reduce the growing demand for TKA is to change the trajectory for obesity in the population as, according to a large registry, much of the increased volume in younger patients is not among healthy active patients but is instead obesity related (UMass Medical School Communications Staff, 2013). The trend model will be applied to a world where obesity trends are modified to understand the effect of larger changes in the population at large on TKA discharges. Last, TKA rates may change due to changes in medical science like a new nonsurgical intervention for OA of the knee or limited surgical capacity. To that end, the uptake of the procedure will be modified in the trend model.

Model Structure

The model consists of 9 basic health states as shown in Figure IV-1. The population now includes a healthy state, a key difference from Figure III-1 and the 8 health states in the compartmental model of Chapter III. From healthy, some patients develop OA. The remaining transitions are the same as described in the Methods section of Chapter III.

Figure IV-1 Simplified ABM Flow Chart



As with the compartmental model, the time step of the model is one year. The ABM is designed to use discrete time in this implementation to maintain similarity to the Markov process used in the compartmental model. As before, the two acute surgical states take zero time, but a health impact is assessed for passing through this state. In addition, patients who undergo surgery may also experience complications which add both cost and health penalties. Deep infections are still treated differently from other complications, but they are not moved out of the population in the ABM as they were in the compartmental implementation. OA patients may choose to have surgery or not at each time step based on demographic characteristics. Unlike the compartmental model, the four obesity groups – nonobese and Class I – III – run through the model together using class specific parameters. The overall numbers are not weighted averages, but the overall population in the model.

Population

The model follows a cross-section of patients starting in 1995. The model begins with agents matching the age and gender distribution according to Census estimates in that year and no birth occurs in the model (Day, 1996). Race is not considered in this model as the racial component of OA in the knee, surgical uptake patterns, or outcomes is not well explored in the literature. The overall population is a closed cohort, however, the portion of the population likely to use TKA is an open cohort as the younger ages in 1995 come of age.

Obesity is not considered until agents reach the age of 20 to reflect that BMI is used differently in children (Centers for Disease Control and Prevention, 2018). On model creation, for agents over the age of 20, 1995 obesity estimates were used to assign an obesity class for the model outset. In subsequent years of the model, the changing obesity prevalence observed since 1995 is reflected in the model's obesity design. The likelihood of an agent changing obesity classes in the model reflects the changes in obesity seen in National Health and Nutrition Examination Survey (NHANES) data (Flegal, Carroll, Ogden, & Johnson, 2002), (Wang & Beydoun, 2007), (Ogden, Carroll, & Curtin, Prevalence of Overweight and Obesity in the United States, 1999-2004, 2006), (Ogden, Carroll, McDowell, & Flegal, 2007), (Flegal, Carroll, Ogden, & Curtin, Prevalence and Trends in Obesity Among US Adults, 1999-2008, 2010), (Flegal, Carroll, Kit, & Ogden, 2012), (Ogden, Carroll, Kit, & Flegal, 2014), (Flegal, Kruszon-Moran, Carroll, Fryar, & Ogden, 2016). Throughout the model, adults may change obesity class by becoming more obese. There is no decrease in obesity class for two reasons. First, fluctuation is already accounted for in a reasonable range. Depending on height, each of these BMI classes is approximately 30 pounds. Second, even after TKA, most patients do not lose weight despite the theoretical ability to do so because of increased activity and mobility (Hospital for Special Surgery, 2014), (Schwartsmann, et al., 2017). Both age and gender are considered in determining obesity status.

OA is not considered until agents reach the age of 40 to reflect long term studies of OA population estimates (Murphy & Helmick, 2012). Similar to obesity, those over the age of 40 are assigned an OA status to match the prevalence in the population in 1995. As with obesity, age and gender are considered in determining OA risk. Obesity is an additional risk factor included in the model. Throughout the model, healthy agents may acquire OA.

Model Purpose

The scenarios examine providing TKA to patients in different populations by obesity group. The first purpose is to predict the volume of TKA until 2035 and the role that obese patients have in driving that. The obesity groups considered are nonobese with BMI < 30, Class I with $30 \leq$ BMI < 35, Class II with $35 \leq$ BMI < 40, and Class III with BMI ≥ 40. Many of the model parameters are dependent on obesity classification to this end. Evaluation of the TKA strategy is surgery occurring as a staggered patient choice with a percent of patients with OA opting in each year based on their demographic characteristics. OA itself is partially determined by obesity. Death rates vary by age and gender as well as obesity classification. Complication rates, surgical success (likelihood of full versus no benefit after surgery) and failure rates vary by obesity. Costs of surgery as well as overall quality of life are also dependent on the obesity classification.

Next, several what-if scenarios are constructed to understand some possible ways to impact volume and burden of TKA. First, guidelines restricting access to TKA in obese populations are considered. Specifically, the budget implications and the effect on volume by excluding these populations are examined. Second, the upward trend in TKA volume anticipated by most may be dampened or heightened depending on the trend in the obesity prevalence in the population and this will also be considered. Third, the volume trend is considered in light of TKA uptake changes. Uptake is a combination of supply and demand pressures in the broader environment. Demand may be reduced based on new medical treatments for OA or economic considerations by the patient, but supply may also be impacted if the population desirous of surgery outstrips the providers available to operate on them. For purposes of this model, both these changes can be treated as a change in the propensity for OA patients to receive a TKA. As with the obesity trend, the uptake trend is considered at heightened and dampened level and the budget and volume impacts are of special interest.

Outcomes

The outcomes of interest focus on the number of procedures performed annually from 2015 -2035 in the United States. The role of obesity class is broken out for special analysis. This procedure volume is also translated into an overall budget impact to understand the financial implications of the uptake of TKA.

Data

Because the conceptual model is the same in the ABM and the compartmental model in Chapter III, the data needed to parameterize the models are nearly identical. With few exceptions, the parameters used are identical between the two models. Exceptions are noted below and details of the parameters are not repeated.

Transitions Between States

There are three transitions that see different parameters in the ABM. First, the ABM introduces a healthy state that does not exist in the compartmental model. So, the first new parameter is disease development relating to the transition between the healthy and OA states. This is done following relative risks for age, gender, and obesity status from a large study on OA and a large systematic review for OA risk factors (Zhang, et al., 2011), (Silverwood, et al., 2015). In the compartmental model, the main analysis assumed everyone had a TKA the same year and relied on the value used in Losina, et al. for replicating the staggered surgery for validation. The ABM though requires a probability that a patient with end stage OA will in fact undergo TKA in a given year to match historic data on volume, a key parameter in the ABM implementation. For this now key transition a combination of historic data and calibration, which is further discussed below, is used. The final changed transition is that to do with death. The ABM has heterogeneity in agents not present in the compartmental model. Rather than CDC death rates by age, the ABM uses age and gender dependent mortality rates from US CDC life tables (Centers for Disease Control and Prevention, 2017). The relative risks for obesity are the same but applied to a different base rate. Otherwise, transition probabilities are unchanged, and details are found in Table III-1.

Complications

Complication rates see no changes in the ABM implementation from that of Table III-2.

Implant Failure Rates

Implant failure rates are also unchanged from the compartmental implementation and details are found in Tables III-3 and 4.

Costs

The costs follow the same parameters as the compartmental model. The minor change is to do with how deep infections are treated in the model. There is no submodel where deep infections are removed from the population in the ABM. The idea is the same, however. The year after a deep infection, the cost of the second phase surgery is assessed. Otherwise, refer to Chapter III for details.

QALYs

QALYs remain the same as those described in Chapter III and detailed in Table III-6.

Obesity Adjustments

Obesity Adjustments follow the methods described in Chapter III.

Population Construction and Verification

Construction

The model uses a representative US population reflecting trends and demographics for age, gender, obesity classification and OA status. This begins with the 1995 US Census estimate for age and gender makeup by converting population estimates into a joint probability for age and gender (Day, 1996). A total population of 250,000 agents is constructed and simulated following this distribution. Next, an obesity classification is assigned to all agents 20 years or older based on age and gender. This follows the 1994 NHANES obesity data (Flegal, Carroll, Ogden, & Johnson, 2002), (Wang & Beydoun, 2007), (Ogden, Carroll, & Curtin, Prevalence of Overweight and Obesity in the United States, 1999-2004, 2006), (Ogden, Carroll, McDowell, & Flegal, 2007), (Flegal, Carroll, Ogden, & Curtin, Prevalence and Trends in Obesity Among US Adults, 1999-2008, 2010), (Flegal, Carroll, Kit, & Ogden, 2012), (Ogden, Carroll, Kit, & Flegal, 2014), (Flegal, Kruszon-Moran, Carroll, Fryar, & Ogden, 2016). The beginning values for 1995 are in Table IV-1 below.

Table IV-1 Obesity Prevalence in 1995

Obesity Class	Male			Female		
	20-39	40-59	60+	20-39	40-59	60+
Nonobese - BMI < 30	82.020%	72.008%	73.914%	76.112%	67.255%	69.931%
Class I Obesity - BMI 30-35	14.114%	15.077%	14.385%	6.731%	14.032%	24.127%
Class II Obesity - BMI 35-40	0.375%	10.293%	11.314%	12.725%	12.743%	0.832%
Class III Obesity - BMI >= 40	3.491%	2.622%	0.386%	4.432%	5.969%	5.110%

In each subsequent year, agents may move into a heavier weight class. NHANES data is available in every odd year from 1999-2013. In some years, Class I and II are not available separately. A transition probability was fitted for each of the six age/gender groups for advancing an obesity class annually. These trend parameters were optimized using Excel to best fit the available data points from NHANES in this 14-year period. The NHANES figures are reported in three age groups by gender. For each of the six groups, all data points available were arranged by obesity class and year for a total of 19. A simple simulation was designed to set the probability that a person in one group will move to the next highest obesity class for a set of three for each of the six groups. Excel's Solver add-in determined the three values that minimized the mean squared error between the NHANES data and the simulation results across all 19 data points. This was done independently for each of the six groups. The trend of annual transitions to higher BMI groups within each group is considered constant over the time under study (Table IV-2). Childhood obesity statistics are less available and BMI is less useful in children, so the model considers all patients under 20 to be nonobese. This, however, does not reflect the nature of obesity in the population. To account for this, in the year an agent reaches age 20 an initial prevalence boost is modeled by immediately assigning a portion to Class I Obesity.

Table IV-2 Obesity Transitions

Obesity Class	Male				Female			
	20	20-39	40-59	60+	20	20-39	40-59	60+
Nonobese - BMI < 30	8.770%	1.137%	1.005%	0.912%	16.877%	0.939%	0.831%	0.825%
Class I Obesity - BMI 30-35		2.770%	0.011%	0.000%		0.000%	0.009%	3.415%
Class II Obesity - BMI 35-40		2.181%	1.642%	2.637%		2.373%	2.354%	1.601%
Number denotes the probability of exiting that class into the next higher classification as optimized by Solver								

For OA, relative risks based on a large OA study and systematic review were used as the basis of a simple simulation. The base category used was a nonobese 40-year-old male. Because OA cannot exist prior to age 40 in the model, prevalence and incidence are the same for 40-year-olds. Murphy and Helmick report an incidence of 1 in 1,000 for symptomatic knee OA in 40-49-year-old males (Murphy & Helmick, 2012). The base probability of having OA is then set at 0.001. The odds ratio from a logit model in the study was converted to 1.525 relative risk of being female and similarly obesity (BMI ≥ 30) has a relative risk of 2.13. For each year of age over 40, an additional probability of 0.056 is added to the base. The initial prevalence in 1995 for those over age 40 and the relative risks are shown in Table IV-3. These parameters are also the basis of assigning OA from healthy for the rest of the model. OA prevalence may be increasing but we assume the risk factors underlying that change have not changed. OA rises predictably as the population makeup relative to age, gender, and obesity status change following the same parameters.

Table IV-3 Osteoarthritis Parameters

Name	Value
Prevalence Nonobese 40-year-old Male	0.001
Additional Risk for year over age 40	0.056
Relative Risk – Female	1.525
Relative Risk – Obese - BMI > 30	2.130

Verification

The population demographics were verified against historic data to ensure that the population retains the appropriate mix for the United States population from 1995 up to 2015. Census estimates were used for verifying the age and gender makeup of the population as time progressed. The 2010 Census and the 2015 estimate based on the 2010 Census were used for comparison data (U.S. Census Bureau, Population Division, 2016). Because of the closed cohort design, certain age segments of the population cease to be present in the model over time. In 2010, this is 0-15-year-olds and in 2015 it is 0-20-year-olds. To account for this, a joint probability of age and gender was calculated after eliminating the dropped age groups from the Census figures. These joint probabilities were multiplied by the current number of living agents in the model at the same time points to generate the expected number of agents in each age gender group. These expected values were then compared to the actual observed size of the population in those age gender groups. The age distribution for each gender closely follows the age distribution in the Census (See Appendix C).

Next, the obesity distribution in the population was compared against NHANES data and trends in obesity. The last year available that included Class I and Class II obesity reported individually is 2011. The 1995 starting obesity distribution is compared against the 1995 starting figures in the model, the 2003 NHANES data to get a middle point estimate and then 2011 as the last point all three groups appear. The obesity prevalence by group is also well matched (See Appendix C).

Finally, the OA prevalence was verified. OA prevalence is difficult to estimate with precision as symptomatic versus radiographic versus doctor diagnosed figures vary widely. Figures available also often include all joints not the knee specifically and sometimes even all types of arthritis not just osteoarthritis. Verification for OA prevalence was done in two ways to accommodate this uncertainty. First, an examination of the trends and relative risk of OA was considered. The share of the population over age 40 suffering from OA is the metric in this verification. The prevalence remains relatively stable over the course of the 40 years which fits the expectation that while risk factors for OA do not change the underlying population that has them does. This should leave a relatively stable prevalence in the middle age and older portion of the population despite the population aging overall, but obesity is rising driving some upward trend. Throughout, the prevalence of OA in female is approximately 1.5 times higher than men and obese is approximately twice the nonobese prevalence. Both are close to the relative risks observed in the large population studies described above. The second verification test is also based on the assumption of relative stability. In 1995, the only year with an age standardized population available, prevalence is roughly 5%. This is a match for the estimate found in the Framingham study for symptomatic OA of the knee (Zhang & Jordan, 2010). Thus, with a stable trend and a starting point equivalent to Framingham that result from a relative risk model derived from a large-scale study of OA, the rates of OA in the model can be deemed suitably representative of the US population. Further detail is available in Appendix C.

Model Output

The AnyLogic model output undergoes extensive data processing. The AnyLogic model is run on 10,000 agents 25 times for each scenario for a total population of 250,000 agents per scenario. Each model run creates an Excel file containing the patient demographics, the surgical and complication events, and the patient state information each year. This information is combined into a single scenario file with a structure appropriate for analysis using PivotTables in Excel by using the pandas library in Python. Excel files were generated for each scenario. Those scenario files are then used as the basis for the final output which is organized by outcome of interest. Extensive data validation was undertaken at each step in the process to ensure data fidelity. Further details are provided in Appendix D.

Cross Model Validation

The model structure itself was validated in several ways. First, the model structure is designed to follow Losina, et al. The compartmental model also did this in Chapter III. The structure of the ABM was tested directly by comparing output with the compartmental model using a population cohort of 10,000 74-year-olds with OA. The ABM was run once for each of the four obesity groups, with and without TKA, for a period of 25 years and the undiscounted costs and QALYs streams were compared to the compartmental results over the same time. These are the same conditions used in the compartmental design. In all 8 scenarios, the results were quite similar (See Appendix E). The average over the 25 years in costs is within 5% and for QALYs within an average of 10%. The model structure that defines agent behavior then is sound.

Calibration

The final model design aspect is the probability that a patient with OA of the knee will choose to have TKA in a given year. This probability is allowed to vary based on patient characteristics related to age and gender and incorporates the underlying trend towards more TKAs observed in the population. This TKA uptake probability encompasses more than the simple choice of the patient to have surgery. To have a TKA, a healthy person must first develop OA, the patient must then seek medical care for the OA which incorporates access to, affordability of, and availability of health care services. Third, it includes the willingness of a surgeon to offer TKA as a viable medical procedure for that patient. This includes any medical or social conditions that would make the patient a bad surgical risk as well as patient severity of OA. Lastly, it includes the patient wanting to take a surgical intervention for whatever reasons of personal circumstances. This uptake probability then encompasses both supply and demand constraints on whether an individual patient undergoes a TKA.

TKA uptake is designed in the model as a baseline probability for uptake as well as trend parameters to capture the increasing demand for TKA in younger patients (45-64) as well as the portion of trend that is not attributable to age and obesity shifts in the population (Ravi, et al., 2012). Finally, to capture the differing preferences and suitability for surgery among age and gender groups multiplicative factors are applied to that trend line. These factors use males age 45-64 as the reference group. The general equation for uptake is $BaseProbability * (1 + Trend)^{Year-1995} * RelativeRisks$, where the trend and relative risks applied dependent on the age and gender group.

The calibration of these parameters was done against TKA discharges from the Healthcare Costs and Utilization Project (HCUP) database (Healthcare Utilization Project, 2018).

The data on discharges for the ICD-9 code for Total Knee Replacement (81.54) from the inpatient setting in the years 1997 – 2014 was available for use as the target values for the model. The revision code and its inclusion criteria changed in the middle of this period and was therefore ignored for calibration purposes. Discharge data is not available for 2015. Data is available in the following age groups: under 1, 1-17, 18-44, 45-64, 65-84, and older than 85. Data is also available for female, male, and overall number of discharges. Because only a small number of less than 45-year-olds receive TKA at all and most are not due to OA these groups are ignored in this analysis. For 2012-2014, data is also available jointly for the same age groups and gender.

Population estimates for the US by age, gender and obesity were required annually for the calibration period. The model starts with a population of 250,000 agents representative of the entire US population on age, gender, and obesity. When available, CDC Wonder data was used for population statistics as that is what HCUP uses to estimate populations (Centers for Disease Control and Prevention, 2016). This was supplemented, when necessary. Census Bureau figures were chosen when available and alternatively from a website based on otherwise unavailable Census estimates (Centers for Disease Control and Prevention), (US Census Bureau), (Population Pyramid, n.d.). When age groups of five years were used in the source, population was assumed to be evenly distributed across the individual ages. Obesity assignment for the population was allocated according to the obesity distribution observed in the model population for the age and gender group for each year. The total US population discharge estimates were constructed by scaling the model results up to the US population size. The number of primary discharges is divided by the number of agents living to obtain the incidence probability and then this is multiplied by the size of the US population at that point for that population subgroup. Thus, if 100 primary surgeries occurred while 1,000 agents were living that year and the US population was 50,000, then those 100 primary surgeries in the model would equate to 5,000 procedures in the US population as a whole.

The HCUP population estimates for the age brackets, genders, and totals for 2000-2014 were used to allow for a burn in period. In the model, there was no initial prevalence of individuals having had TKA, so a burn-in period of 5 years was used to allow the initial population to reach a steady level of rates of TKA procedures. In addition, the rates of TKA for sub-populations defined by age and sex were used in the three years they are available. This led to a total of 108 datapoints available for calibration (See Appendix F). Standard errors are not provided by HCUP for the joint age and gender datapoints.

Due to randomness in the stochastic model, logarithmic regression was used to smooth the trend line of predicted discharge levels for calibration purposes. This also provided 95% confidence intervals around the predicted trend line. The same approach was used to create confidence intervals for the joint age and gender HCUP estimates. A logarithmic model was chosen as the best fit for the data points with adjusted R^2 well above 0.9 and because it accommodates the increasing rate of discharge observed in the population.

An iterative process was used to select the final parameter set. Parameters were adjusted based on the previous iteration's fit according to the calibration criteria selected. The calibration made use of three different objectives to determine best fit using a holistic approach. For all three objectives, the age and gender groups were considered together. The 12 age, gender, age/gender groups and overall data reporting categories were given equal importance for goodness of fit measures. The primary objective was to maximize the number of years within each category for which the confidence intervals from the simulation trend line and confidence intervals from HCUP overlapped. A secondary criterion was to maximize the number of data points where the trend line was inside the HCUP confidence intervals. This narrower definition helped to tighten the calibration to the data without being overly constraining initially. Finally, a visual inspection of the trend lines was employed as an objective to verify the two lines were generally similarly oriented. The conventional approach would have been to minimize the mean squared errors (MSE) of the 12 age by gender groups or the sum of those 12 figures as a total MSE. The MSEs were calculated across iterations within each group and as a sum of all 12 for a total MSE. However, this approach was noisy and less informative for parameter selection than the objectives used. The final parameter set selected does in fact have the lowest total MSE for over all the iterations examined. By keeping the individual years as part of the decision making, the size and direction of adjustments between iterations were easier to discern. Additionally, calibration parameters impact multiple groups at the same time adding interactions between the MSE figures that are not easy to parse when looking at the MSE for a whole data group rather than years. Further details are available in Appendix F.

Model Assumptions

There are some important assumptions relating to parameter choice and model structure. While obesity is frequently discussed in the literature as a driving force behind the increased volume of TKAs and a possible negative outcome predictor, there is not a great deal of obesity-specific information. The relative risks of complications are built on a literature review of available data. The calibration is done without regard to obesity in the HCUP data so estimates of diverted TKAs must bear that in mind. TKA uptake only considers obesity in an oblique way in that surgical offers by physicians may be more limited to those groups, but this is not modeled directly. Comorbidities that may influence that offer of surgery are also only considered in this same parameter. Any effect of comorbidities other than obesity are ignored in the complication or outcomes entirely.

The model also simulates a general TKA procedure.   There is no consideration of approaches or implant types. Any variability in physician expertise or hospital volume that may influence outcomes are also not considered. Most importantly, once a patient has a TKA there is no difference in trajectory of the process outside of obesity-related complication rates and costs. Revisions are done at the same rate regardless of age. These are all important considerations, but there is a lack of detailed data related to obesity to parameterize these factors, so these considerations were not included in the model design.

Bilateral or second knee replacements are also not considered. A patient could have exactly one primary surgery and revisions only on that knee. Further, revisions are capped at 3 in this model. It is possible that more could be done in practice, but without some cap patients in the model showed up to 8 procedures in their lifetimes which seems highly unlikely in practice.

As previously discussed, TKA uptake is a composite likelihood function of both patients and providers preferences that get packaged into a single likelihood. This means that supply and demand cannot be parsed from this output. There is also no crowd out or competition from other patients for surgical appointments with surgeons or for surgeons to get operative time in a crowded hospital. Insofar as that effects surgical choices being presented to a patient, that is represented in surgical uptake for purposes of this model. Willingness to operate on less healthy patients does not deny surgical resources to other patients in this model but may drive some part of decision making in practice.

OA risk factors are assumed to be time invariant. Prevalence may change in the population due to demographics, but the drivers are assumed unchanged. Any injury or occupational based risk factors are also considered out of scope leaving only age, gender, and obesity included here. This is why socioeconomic factors and race are not part of the model. It is also why only those over 45 are considered in calibration. These are not well understood or documented in the literature for the role in TKA or OA development.

A further assumption has to do with agent behavior respective to the larger environment. Regardless of the environment, patient motivations do not change. It is possible that an obese patient facing an absolute choice of no surgery or losing weight will in fact lose weight to become eligible. This is not currently observed to be the case, but the presence of a guideline may change that behavior. As the magnitude of such a potential change is unknowable, this behavior is not modeled.

Insurance status was not considered in the model design. The main reason is that most patients are over 65 and thus Medicare eligible making insurance status a moot point. A second reason is for simplicity and parameter availability. The behavior of uninsured patients may well be different. OA does partially depend on occupational hazards. Those same manual labor type occupations that increase the risk of OA may systematically affect insurance status and willingness/ability to forgo work to seek surgical intervention. The socioeconomic factors are complex and intertwined with insurance status, type of job, and obesity. For this reason, insurance status was left out of the model.

Results

The results from the various scenarios are presented below. The model is based on a stochastic process and some random variation is to be expected. Unlike with the calibration procedure above no smoothing was performed on the following results.

Calibration

The annual probability for any OA patient to undergo a TKA in any given year is calibrated as described above using 7 parameters to incorporate demographic and trend conditions as well as an underlying base probability. Initial parameter values were selected based on relative risks calculated from the HCUP data and iteratively changed to find the best fit to the observed volume. The final parameter set (Table IV-4) has 97% overlapping confidence intervals and 71% model means contained in HCUP confidence intervals. A visual inspection reveals the trend lines appear to have a similar trajectory as the HCUP observed volume. The OA to TKA rate parameter used in the CEA in Chapter III is 0.33 is large compared to the base value used here for TKA uptake of 0.03. The origin of the 0.33 is from a Canadian survey on whether patients with disabling arthritis in the hip or knee were willing to consider surgical interventions in a survey format (Hawker, Wright, Badley, & Coyte, 2004). But the base probability only applies to 1995 and increases over time. The probability of moving from OA to TKA is larger once the trend and relative risks are applied. Further details are available in the Appendix F.

Table IV-4 Calibrated TKA Uptake Parameters

Name	Value
Base Uptake (P(TKA | OA) each year)	0.030
Trend – Under 45 or 65 years and older	0.090
Trend – 45-64 years old	0.115
Relative Risk – Female	0.750
Relative Risk – Under 45	0.090
Relative Risk – 65-84 years old	1.100
Relative Risk – 85 years and older	0.070

Trend Prediction

The future demand for the twenty-year period from 2015 to 2035 was predicted along with the budget impact for the TKA procedure being offered in current patterns with no regard for obesity restrictions. To do this, the model was run from 1995-2035 for 250,000 agents. The output was converted in the same manner as with the calibration to make results applicable to the entire US population according to relative weight in the population. The number of discharges and complications as well as costs and QALYs were recorded. Costs were assessed in 2015 USD.

Considering all TKAs, primary and revisions, the number of procedures increases by about 80% from just under a million to nearly 2 million in the 20 years (Figure IV-2). Just considering primary surgeries this is almost 50% growth from just under 750,000 to almost 1.1 million procedures. In part, this reflects the obesity in the population, but as seen by looking at the population divided into obesity classes all groups see a rising trend and obesity alone cannot explain this growth (Figure IV-3). The heavier groups are increasing at a slower rate than the Class I obesity group and the nonobese. One retrospective study on the role of obesity in TKA found that in 2005, the share of TKA patients who were obese was 52.1% (Fehring, Odum, Griffin, Mason, & McCoy, 2007). In this model, the share of obese patients in the same year was slightly lower at 49.2%. That study found a sharp rise from 30.4% in 1990 which is outside the scope of this model.

Figure IV-2 Total Surgeries Predicted by Year

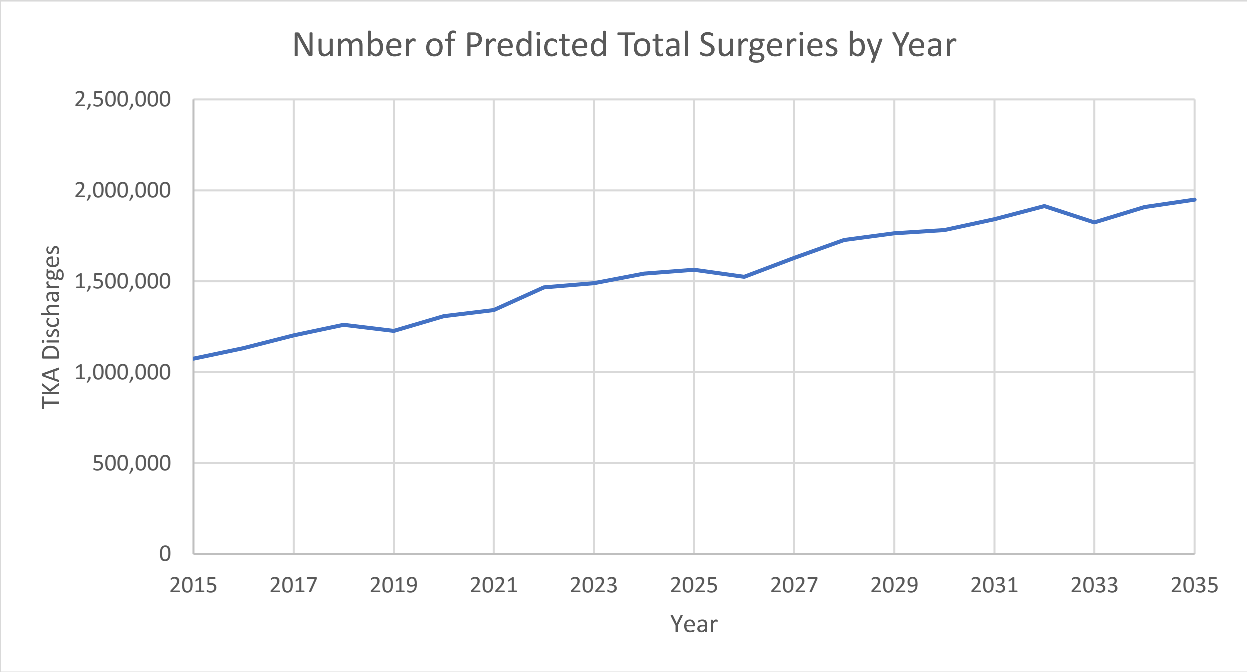
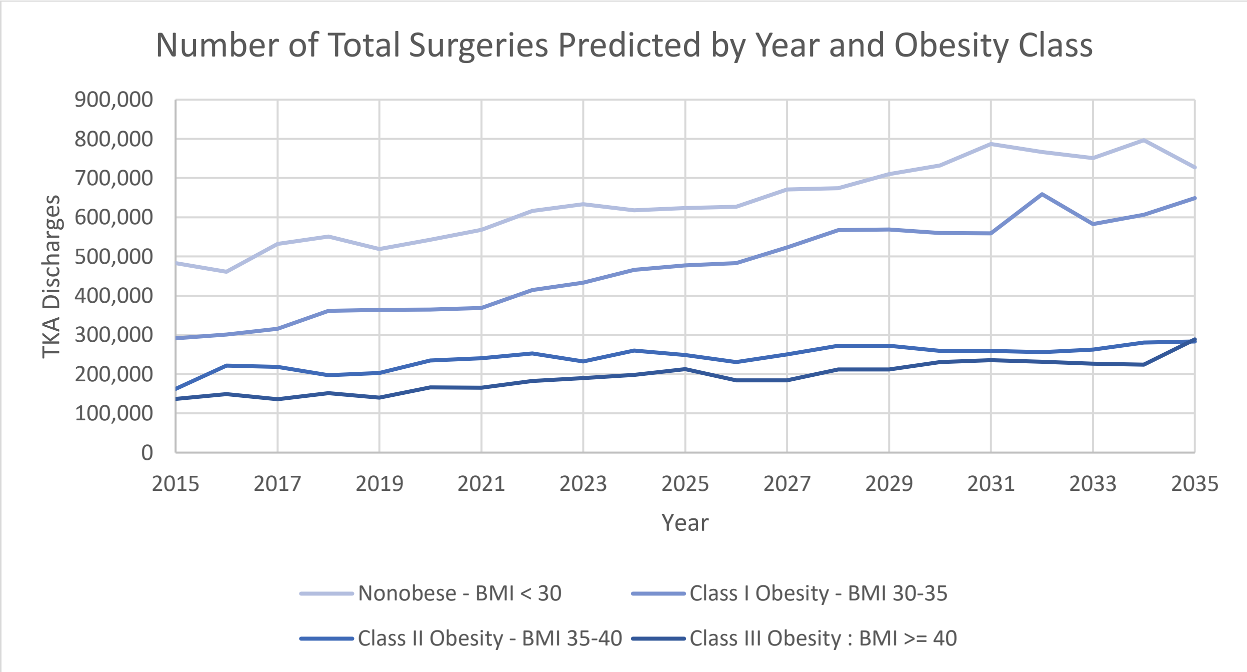


Figure IV-3 Total Surgeries Predicted by Year and Obesity Class



These trend predictions are in line with the findings from other models. A linear regression model predicted growth of similar magnitude and a 2030 estimate of 1.28 million primary TKA, a slightly higher figure than that predicted here (Sloan, Premkumar, & Sheth, 2018). These are both much lower than another projection undertaken in 2007 which overshot 2010 and 2015 estimates substantially and estimated 678% growth between 2005 and 2030 (Kurtz S. , Ong, Lau, Mowat, & Halpern, 2007). There was a large uptick in volume in the years just prior to that study that has since settled down which likely explains the discrepancy from the earlier estimate.

These discharges translate to a substantial budget impact for the healthcare system. Over the two decades under consideration, the estimated burden for the US population is nearly 2 trillion dollars. Of this, nearly $50 billion is spent on complications. Of the $1.2 trillion spent on surgery, primary surgery accounted for almost $700 million or 48.6%, revision surgeries cost over $600 million or 45.8%, and deep infection related surgeries about $75 million for just 5.6% of the total. Even with this number of discharges, the cost of treating the OA in the population is almost half a billion dollars.

Obesity Restrictions

The suggestion that TKA be withheld in obese patients is generally based on financial considerations when put in use as in the NHS. In addition, there is evidence of higher complication rates and poorer outcomes. There is however no clear answer to the budget impact of implementing such restrictions. Obese patients still exist and still require medical treatment for OA. To understand the budget impact of such guidelines, the model was run withholding treatment from obese patients in several severity groups. First, only morbidly obese were denied surgical intervention. Next, patients with a BMI greater than 35 (Class II and III) and finally, all obese patients (BMI $\geq$ 30, Class I -III) were barred from receiving a primary TKA. Patients who received a primary either when in a lower weight class or before the restrictions were implemented in 2015 were allowed to receive revision procedures under these hypothetical guidelines.

There are several ways to consider the effectiveness of the guidelines. The simplest is number of procedures averted from baseline. This basic measure can help with planning demand for surgical time and workforce planning, but it cannot suggest whether it is the best financial choice. Another is to consider the budget impact in isolation. This number accounts for the fact that those denied surgery still must live with OA and thus incur lifelong costs for pain and treatment associated with that disease burden. Again, this is not the full picture as even increased costs may be offset by quality of life concerns, so a cost-effectiveness approach is warranted as well.

The number of averted cases is large. Even including revisions, the total number of surgeries falls and nearly flattens in the most restrictive scenario (Figure IV-4). It drops to zero when only considering primary surgeries (not shown). Over the course of the two decades after 2015, just restricting access to the morbidly obese averts 10% of primary surgeries, but an even greater share of deep infection revisions is averted (Table IV-5). This is increased to 50% if all obese patients are barred from surgery. Even though obese people are not half the population they make up a large share of the TKA surgical pool and many cases can be averted by restricting access. This is especially true in the expensive Deep Infection Revision category of surgery.

Figure IV-4 Total Surgeries Predicted by Year and Guideline Scenario

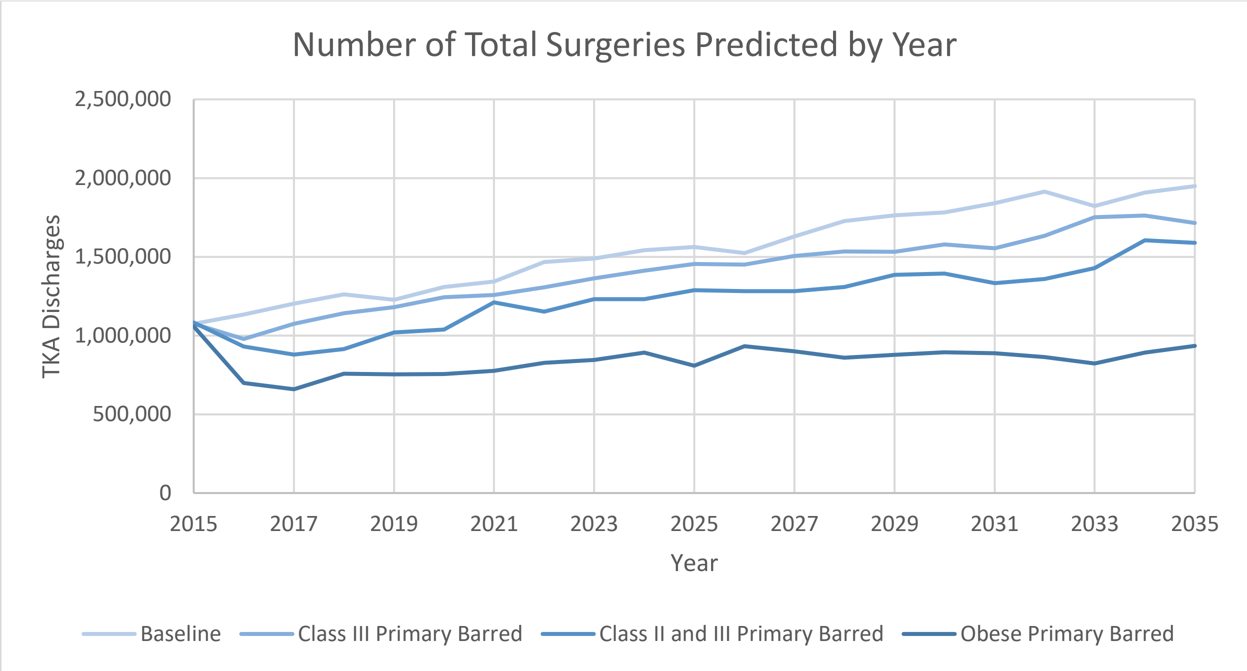


Table IV-5 Averted Surgeries (in Thousands)

Scenario	Total Surgery	Primary	Revision	Deep Revision
Baseline	32471	20212	11689	570
Class III Primary Barred	29504	18136	10922	446
Averted	2967	2077	767	123
Percent Averted	9%	10%	7%	22%
Class II and III Primary Barred	25942	15786	9797	359
Averted	6529	4427	1892	210
Percent Averted	20%	22%	16%	37%
Obese Primary Barred	17696	10079	7371	246
Averted	14775	10134	4318	323
Percent Averted	46%	50%	37%	57%

The budget impact can be considerable in scale at first glance, but the tradeoffs are stark (Table IV-6). Only barring the heaviest patients saves 10% of surgical costs but saves only 4.2% in terms of total costs which include the costs of surgery, complications, and OA treatment as well as the postoperative costs (which in successful cases are minimal). This does include a large decrease in complication costs owing to the high rates of complication in this population, but costs of general OA treatment increase to offset most of these savings. In the most extreme restriction, the cost savings overall near $400 million (a 16% savings). This comes at the expense of nearly doubling the cost associated with OA but nearly halves the surgical and complication costs. It is possible to drastically decrease the budget impact of TKA surgeries directly, but the indirect total cost consequences of treating OA limit the overall budget impact.

Table IV-6 Averted Costs (in Billions)

Scenario	Total Costs	Surgical Costs	Complication Cost	OA Cost
Baseline	$2223.501	$1234.004	$46.547	$461.292
Class III Primary Barred	$2129.865	$1115.633	$36.230	$542.931
Cost Difference	$93.636	$118.371	$10.316	-$81.639
Percent Saved	4%	10%	22%	-18%
Class II and III Primary Barred	$2049.454	$981.226	$29.943	$648.195
Cost Difference	$174.047	$252.778	$16.603	-$186.903
Percent Saved	8%	20%	36%	-41%
Obese Primary Barred	$1860.130	$684.793	$19.642	$856.662
Cost Difference	$363.372	$549.211	$26.904	-$395.371
Percent Saved	16%	45%	58%	-86%
*Undiscounted 2015 USD				

One way to put these costs into perspective is to use a cost-effectiveness framework. The costs are considered along with the health benefits of that policy. Looking first at the health benefits, many agents spend much more time living with OA when restrictions are in place, as is to be expected when reducing access to surgical intervention. Class III Barred, as compared to the Baseline with no restrictions, sees 18% more QALYs from OA, an undesirable health state. When surgical access is limited, the life years spent with debilitating arthritis rises. In the most restrictive guideline where no obese patients are allowed primary TKA that number is 86%. The health decrements faced from surgeries and complications do fall in these restrictive environments. In the scenario barring only the morbidly obese, surgical decrements decrease by 9% and complication decrements by 24%. The most restrictive scenario is more dramatic with 46% and 60% respectively. These health decrements, though, are fleeting, a onetime burden to, hopefully, live a fuller life without the limitations of OA. These two competing pressures, longer time spent with a debilitating disease and less exposure to surgical risk and hassle, balance out to basically zero or model noise. Surgical burden falls, but the long-term burden of unrelieved OA rises dramatically. When considering the overall population, overall health may not change with reduced access to surgery for some groups, but the type of care and resource mix required does change.

The ICER balances the cost difference against the health benefit difference. Discounted figures are used to account for the time at which these costs and benefits occur. While there is no clear standard in the United States, a figure under $50,000 per QALY gained is considered money well spent and even $100,000 may be worthwhile to pursue. ICERs were computed for the analysis of these guideline proposals.

For the overall population, the guidelines show a cost savings but a loss in health benefit across all three restrictions (Table IV-7). The values differ from the values shown above due to discounting. The surgical values are a one-time event, but the OA costs and QALYs are ongoing into the future so the benefits are valued less in this analysis. This analysis can be thought of as a series of hypothetical restrictions being in place and then being lifted. The current baseline is then an expansion of care to allow obese patients of various classes access to TKA once again. Under the standards of the United States, “lifting” these restrictions on TKA for obese groups of any severity are generally considered cost-effective. For instance, if Class III primary TKA went from unavailable to available costs and QALYs would change at a rate of about $60,000/QALY.

Table IV-7 Guideline ICERs

TKA Status by Obesity	Cost	QALY	ICER
Relative to Baseline			
Overall			
Class III Primary Barred			
Baseline	$ 1,645,345,069,196	2,716,748,706	
Restricted	$ 1,576,843,381,318	2,715,592,594	$ 59,252
Class II and III Primary Barred			
Baseline	$ 1,645,345,069,196	2,716,748,706	
Restricted	$ 1,520,172,760,400	2,714,012,307	$ 45,743
Obese Primary Barred			
Baseline	$ 1,645,345,069,196	2,716,748,706	
Restricted	$ 1,382,837,832,573	2,712,601,442	$ 3,296
**Discounted at 3%*			

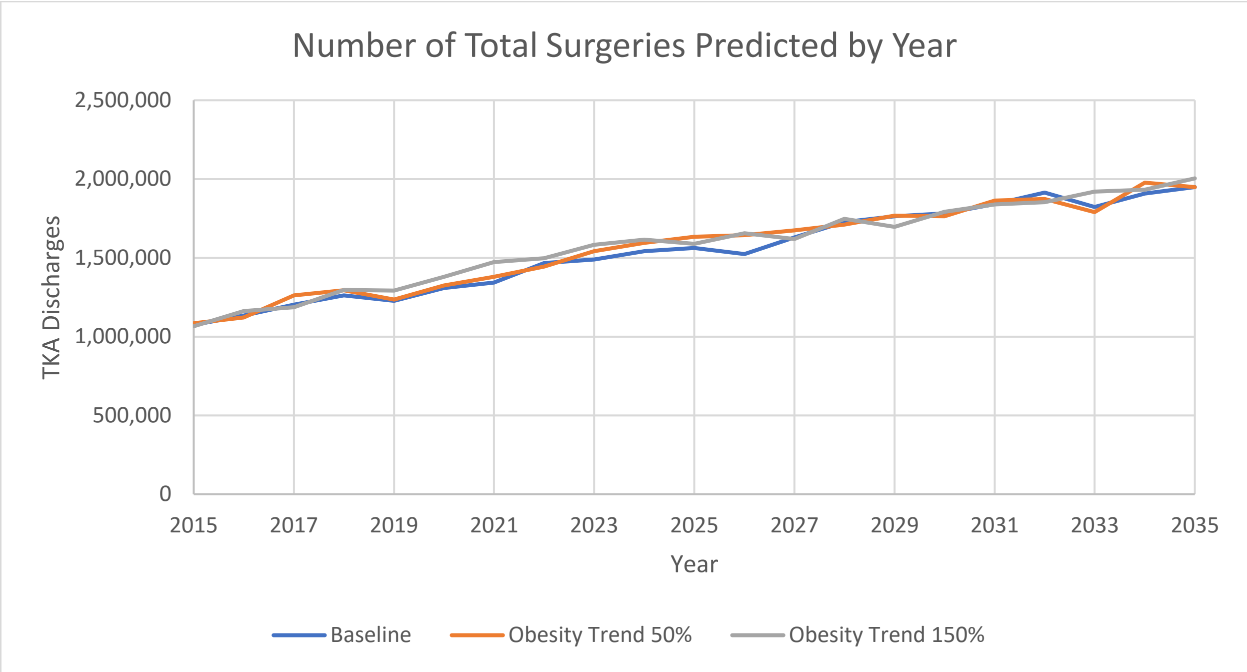
In comparison to the compartmental model done in Chapter III, the figure for Class III Primary Barred is of most interest. In that analysis TKA was compared to no TKA by obesity classification. This is not exactly analogous in that this analysis allows for revisions for those who had surgery when not subject to the restriction, but it is a similar situation for Class III obese patients. The mixed age cohort here also allows for much longer life expectancy than the 74-year-olds examined in the compartmental model so costs and benefits can both accrue for longer periods. The compartmental model found an ICER of $82,635 for Class III TKA versus no TKA. In this analysis, a similar value of $59,252 was found in the overall population for barring Class III primary surgeries. These are both above the most conservative threshold but well under the higher $100,000/QALY. There is agreement that even in the most obese patients, TKA is cost-effective.

Obesity Trend

There is much discussion in the literature about either limiting access for these groups or intervening to combat obesity before surgical options are offered. It would then be expected that modifying the obesity rate in the population would alter the volume of TKAs observed and the costs associated with TKA. This model considers obesity to be an increasing trend in the population to continue as it has since 1995. The currently observed pattern may change in the future due to outside factors including successful public health interventions dampening the trend towards obesity and the possibility that the drivers of the obesity epidemic have not yet reached their peak influence. Obesity is a major driver in healthcare costs generally and as such is a focus of many prevention programs. To see what influence such programs may have on TKA usage specifically, the trend for obesity after 2015 is manipulated. In the earlier prediction and guideline scenarios, the trend towards heavier population was considered to be growing at a stable rate. A proportion of the population would increase their obesity level each year. This analysis tests what effect a 50% decrease to a 50% increase in that rate has on the budget impact of TKA. It does not change the existing prevalence, those who are already obese will not lower their BMI but will be less likely to advance into a heavier class. This analysis gives insights into how obesity prevention strategies may affect outcomes for this specific procedure.

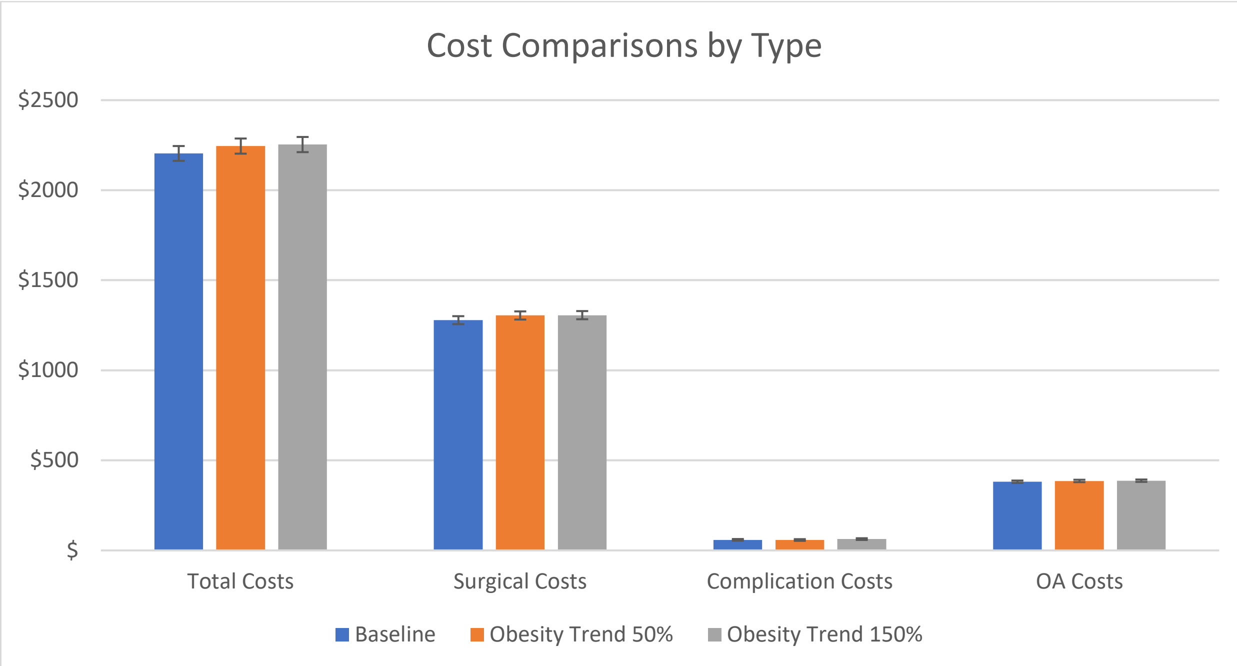
Discharges for TKA do not show much change in this analysis (Figure IV-5). The numbers also suggest that the noise in the stochastic process is driving the minimal difference more than any obesity trend modifications.

Figure IV-5 Total Surgeries Predicted by Year and Obesity Trend



The budgetary impact is also minimal. No practically significant difference is seen in the expected total costs at either extreme trend modification (Figure IV-6). Reducing obesity by half does not make a difference in this key element suggests that the obesity trend is not a place to focus immediate energy to modify the costs and surgical burden related to TKA.

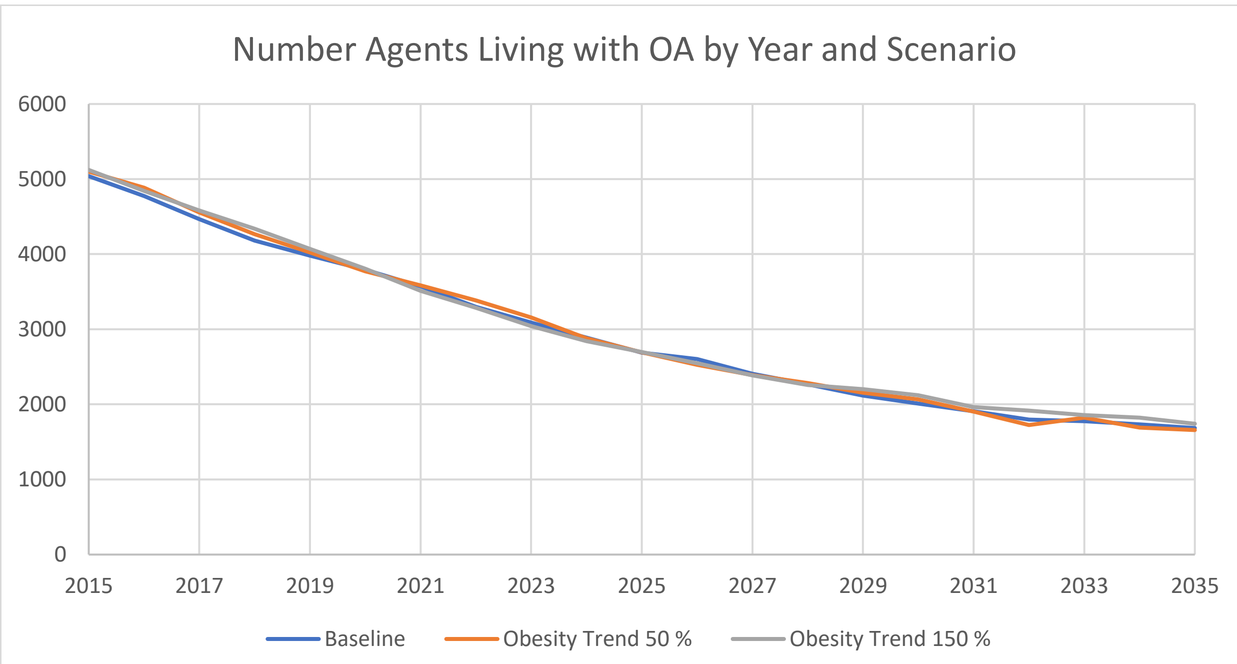
Figure IV-6 Costs in Billions by Obesity Trend



As a whole, there is not much difference made in TKA even at extreme and unlikely changes in obesity patterns. While this, at first, seems a surprising result given the known health burden of obesity and the increased complication rates in TKA, a consideration of the disease course makes it less so. The medical history leading up to TKA is not an instant process. After patients become obese or increase their obesity level (a slow process), patients must then develop OA and then sufficiently damage the knee joint before surgical intervention is pursued. None of this happens instantaneously. While obesity increases the risk of developing OA, age is also a major factor in developing OA. This does not change existing obesity, OA (even that caused by obesity), or the aging of the population. Because these rate changes are slow and long-term, we do not see a discernable impact over 20 years.

Looking at the number of agents with OA across the same time period suggests that this is predictable (Figure IV-7). Those living with OA, the candidate pool for TKA, is virtually unchanged by the obesity trend modifications. The decline in number of agents with OA is due to the closed cohort model design and not a decline in OA prevalence. It takes time to develop OA and while the benefits of reducing obesity burden may bear fruit in the TKA domain in later years, the 20 years under study here are not enough to accrue any benefit from such reduction or conversely suffer if obesity burden rises dramatically. While modifying the trend towards obesity may have immediate impacts on other disease processes where losing weight yields immediate health benefits, TKA and the long progression of OA does not work in the same way. Nor should it really be expected to do so. Curbing the obesity epidemic will not be a magic wand to lower the TKA burden on the US health system in the near future.

Figure IV-7 Agents Living with OA by Year and Obesity Trend



Uptake of TKA Procedures

TKA uptake is dependent on many things that may be subject to change. These include orthopedic workforce size, orthopedic techniques, implant quality, surgical recovery on the part of the medical intervention itself, but also patient perception of pain and quality of life with and without surgery, the sense of desirability of TKA as a treatment option, and many others on the part of the patient. Many things could influence this parameter that are unknowable in the present like a new everlasting implant that makes surgery more desirable to younger or heavier patients or conversely a public scandal about medical devices such as implants causing some long-term consequences that causes patients to stop seeking surgical intervention. The newly available option for outpatient TKA as a billable procedure may increase demand by making the surgery seem less onerous to patients as well, or it could drive down surgeon availability because of reimbursement patterns. Regardless of the reasons, surgical uptake may change in the future. Like the obesity design above, surgical uptake is tested at a 50% decrease to a 50% increase to understand what might happen in those unknown future situations. This is parameterized as a change to the rate at which OA patients get TKA.

Predicted discharges for TKA follow an interesting pattern. In 2015, there is a dramatic shift for both demand changes, but as time advances both return towards the baseline values. This suggests there is some sort of equilibrium in the population for demand (Figure IV-8). Again, the OA in the model population is suggestive of the reason for this pattern (Figure IV-9). This can be thought of in the framework of a susceptible – infected model. The OA group is the susceptible population and in the increased uptake scenario it initially exhausts more quickly than in baseline, but over time the susceptible pool recovers as new people develop OA. The opposite occurs in the decreased uptake scenario. At first, the susceptible group is much larger, but over time they are eventually ‘infected’ with TKA as well and the pool starts to decrease towards the same levels seen in the baseline scenario. The population is larger, so despite the lower rate, a similar level of TKA discharges per year eventually emerges.

Figure IV-8 Number of Total Surgeries Predicted by Year and Uptake Trend

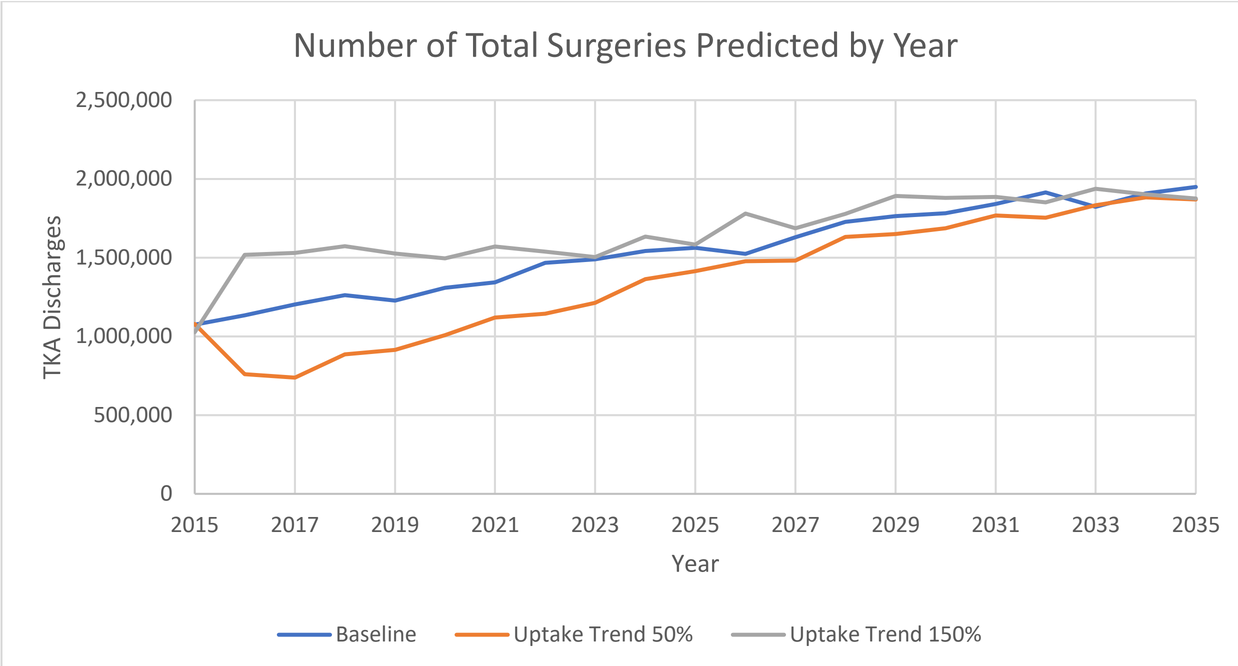
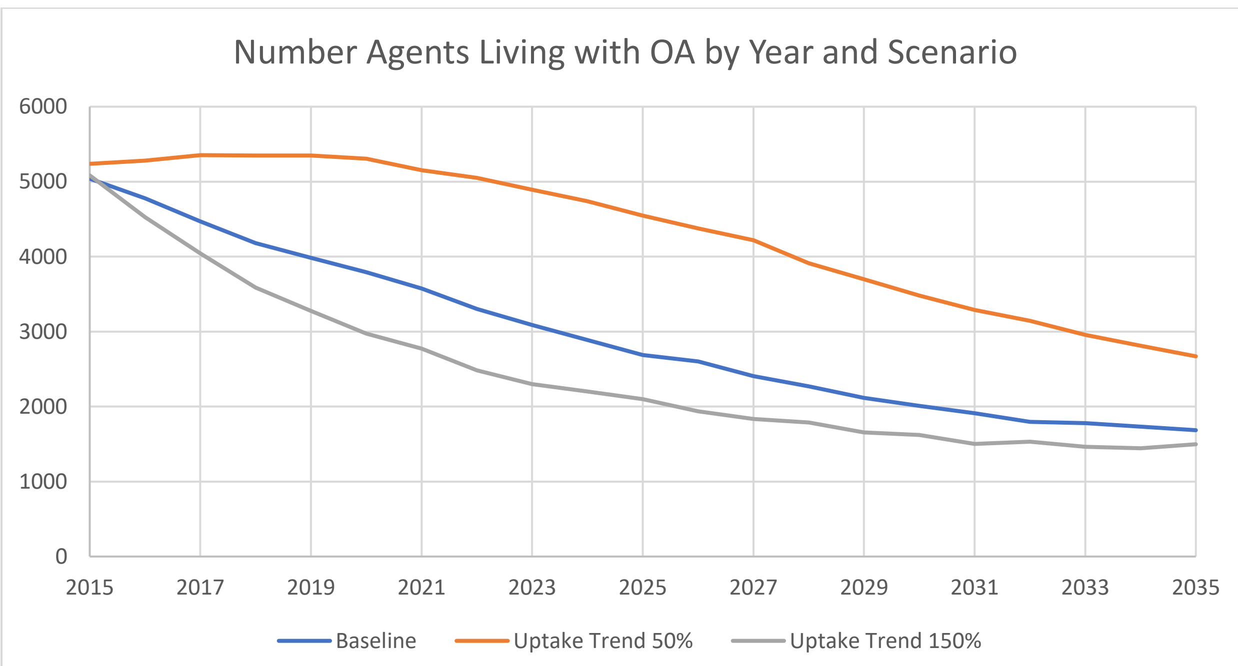


Figure IV-9 Agents Living with OA by Year and Uptake Trend



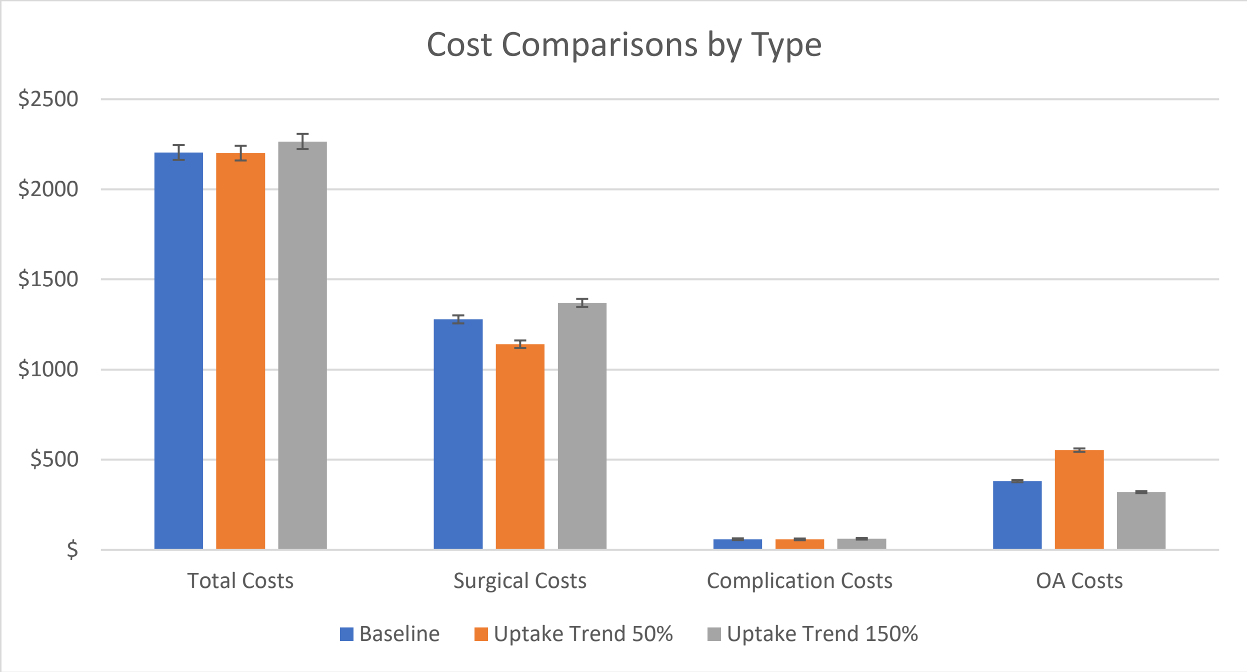
Looking at the number of discharges, the impact of the early trajectory changes is more apparent. The impact is slight in comparison. Halving the uptake of TKA results in about 12% fewer discharges total and barely changes deep revision rates (Table IV-8). Increasing the uptake by half on the other hand increases discharges by about 8% overall. In this case deep revision also moves a similar amount. Overall, it takes a great deal to change the number of procedures performed each year in the long-term.

Table IV-8 Averted Surgeries by Uptake Trend (in Thousands)

Scenario	Total Surgery	Primary	Revision	Deep Revision
Baseline	32471	20212	11689	570
Uptake Trend 50%	28673	17903	10217	553
Averted	3798	2310	1472	17
Percent Averted	12%	11%	13%	3%
Uptake Trend 150%	34966	21572	12781	613
Averted	-2495	-1360	-1092	-43
Percent Averted	-8%	-7%	-9%	-8%

Despite the vastly different discharge trajectories, the total budget impact is small as expected seeing the averted discharges. It is more interesting to see how that budget is allocated as the surgical and OA costs are quite different (Figure IV-10). There are meaningful differences in how resources should be allocated if the uptake patterns change even if the overall budget is not impacted. As with the tradeoffs in the guideline scenarios, the number of discharges averted does not offset the increased burden of living with OA to a great extent.

Figure IV-10 Costs in Billions by Uptake Trend



Discussion

TKA is already a large cost center in health care system. It is only expected to rise given current patterns. These results are similar to other studies showing increases in the number of TKA procedures performed annually in the United States. The rapid growth in demand for TKA and its large economic impact suggest that further study is warranted. The large share of obese patients and the higher complication rates experienced in those groups suggest the guideline restrictions imposed in NHS and proposed for the US may be worthy of additional study. These trillions of dollars of budget impact are a large drain on resources that could possibly be spent elsewhere if obese patients were denied surgery or obesity patterns changed in theory. However, the budget impact is closer to cost neutral when the resulting increase in OA is accounted for. Ways to shift down uptake are also minimally impactive on the overall budget and lead more to a reallocation of dollars rather than a cost savings.

This is not to say these are not ideas worth pursuing, but not from the perspective of the overall health budget. This may change in a longer time frame, however. The effects of an obesity intervention may be more impactful if the timeline was expanded beyond 20 years. There may also be lessons in the steady state that is seen in the uptake changes. OA is a process and the population is still aging. Short term budget planning may require different approaches than longer term planning. Workforce planning may be a challenge given the lengthy process of medical training and the conflicting needs of the short and long term. In the short term, reducing TKA uptake would need fewer orthopedic surgeons. Within the space of a decade the volume trends back up and there would be a problematic shortage of trained surgeons. The budget projections suggest that both short- and long-range perspectives need to be considered in terms of the resource allocation before any policy implementation.

There are further workforce issues to consider. The obesity restrictions and the uptake increase do reduce the surgical burden, but they also increase the OA burden as a result. These are different resources and do save operating theaters for other purposes and suggest that training in different specialties could be pursued. Other shared hospital resources such as surgical nurses or office space could also be impacted. This reduction in TKA demand for surgical resources may free these valuable resources up for other departments with different impacts on population health.

Guidelines restricting access to obese patients may be a strategy that would substantially reduce the volume of TKA procedures. There is however no clear rationale to do so. The total budget is virtually unchanged and the cost-effectiveness is within generally reasonable American standards. The ethical questions raised in the UK about denying access are not easily set aside by the results of this analysis. This calculus may be different in other healthcare systems if wait times and constrained resources are considered. The complication rate differences observed are important to consider, but do not alone change the efficacy of the procedure in obese patients.

Future Research

This analysis did not consider crowding out of healthy patients by obese patients. In reality, there are a limited number of surgeons and operative time available that could make prioritizing rather than banning certain groups a different calculus. A networked analysis incorporating the constraints on the system would be beneficial in addressing this question. Wait times in other healthcare systems in particular would benefit from such an addition to the model. Reducing wait times for nonobese patients may be enough to change the cost-effectiveness of the guidelines.

The obesity parameters are also simple extrapolations. In this model implementation, weight does not fluctuate in individual patients. Nor does OA develop more in the heaviest patients. More weight is not more damaging to knees, artificial or otherwise, according to this model. Although there is some evidence that more weight may be damaging to knees we do not have sufficient levels of detail on the progression of OA and obesity or the detriment of knee joint mechanics under extreme weight for precisely parameterizing this model so these simplifications were used (Cicuttini , Baker, & Spector, 1996), (Landsmeer, et al., 2018). Better, more detailed parameters would fine tune these estimates and the benefits and costs of the heaviest patients could be explored more deeply. Before any restrictions are imposed a better understanding of the effect of specific levels of obesity in specific outcomes and disease progression is warranted.

The model also makes use of a generic TKA process that does not vary for patient characteristics. The scope of the model was limited to a generic total replacement without regard for surgical details or provider volume. Different surgical approaches or implant types may be more or less suitable for obese patients and that is not considered here. Hospital and surgeon volume are known to impact outcomes. Another simplification in the model is that revision rates are not age dependent. This may introduce systematic error into the total surgery estimates in either direction. If heavier patients are also younger this could lead to even higher revision burden than predicted here. If instead heavier patients are forced to wait longer for surgery in attempts to lose weight before intervention, then the revision burden may be inflated because the heavier patients are actually older and less likely to live long enough to require revision. Introducing these details into the surgical process could provide important nuance to the model results.

This analysis does not incorporate the introduction of bundled payments or the new rules allowing the procedure to be done on an outpatient basis. Both changes could dramatically change the availability of surgeons in either direction. The bundled payment may discourage use of TKA by being priced too low and becoming unprofitable for hospitals or conversely may create financial incentives to focus on the procedure. It could encourage providers to focus more on lower risk, lower weight patients. The outpatient change could drive demand by patients up by appearing as a more minor procedure to fix their knee pain or could cause surgeons to limit surgery as an option to only the healthiest patients. One estimate suggests that an outpatient TKA will be reimbursed at a rate 18% less than an inpatient procedure (Rovinsky, Looby, & Zacchigna, 2018). This could tend to lower surgeon participation or organization promotion of TKA as a profit center by reducing profitability. The lower margins could cause only the healthiest patients to be offered TKA to minimize risk so that costs remain lower than the lesser reimbursement rate. A best practices group estimates that almost half of the current uncomplicated cases done in hospital could potentially be eligible for outpatient surgery (Fontana, Members Ask: How many Medicare TKA cases could shift outpatient?, 2017). The obese, among other chronic conditions and advanced age, were excluded from their analysis. With so many cases moved out of the inpatient setting, obese patients may be welcomed by hospitals trying to maintain a profit center in orthopedics. Alternatively, with that much of the volume moved to an outpatient setting, the number of joint replacement surgeons working out of a hospital may reduce dramatically leaving no surgical capacity for obese patients. These changes in payment structure are indirectly considered in the uptake analysis, but future research should directly include these changes.

Overall, TKA procedures are expected to increase dramatically in the next 20 years. Although obesity appears to be driving this increase, changes in the rates of obesity growth over time may not be sufficient to see a noticeable change in the number of TKA procedures. Of all the policies evaluated, a strict prohibition on TKAs for obese individuals was the only policy that substantially altered the volume of TKA procedures performed, but this may not be an ethical or cost-effective policy choice.

Future research may evaluate the impact of other policies including different impacts and effects over a longer time horizon.

Clinical Applications

Restrictions on access to TKA for obese patients would function more like a budget reallocation than overall cost savings. The largest lesson from this model is that OA is also a large part of the story of TKA. Rheumatology and primary care providers who treat and refer patients for surgery should work together with orthopedic surgeons to develop an idea of what makes a good candidate. Rather than working in isolation, these groups of doctors should collectively consider risk factors as discussed in Chapter III before scarce resources are spent in referrals unlikely to be good candidates.

Methodological Advances

This is the first study to make use of an agent-based model to understand the budget impacts of OA and TKA in the population level. The calibration required to ensure the volume predictions followed existing conditions made use of a novel combination of techniques. The use of logarithmic regressions on the stochastic model results allowed for better calibration with fewer costly stochastic simulation runs. The choice to use relationships of confidence intervals rather than a traditional mean squared error approach to the objective function also allowed a more holistic choice with regards to the trend in the data.

CHAPTER V:
Conclusion

The goal of this dissertation was to apply operations research and decision science techniques to the policy conversation around obesity and TKA. Currently, the conversation centers on possibly increased complication rates in obese populations and possible implementation of guidelines restricting access to surgery in certain groups. The large volume of TKAs and the growing share of obese patients make this an important topic in terms of individual patient outcomes and as a large item in the national healthcare budget. These studies affirm that obesity does matter, but not always in the anticipated manner.

The general consensus is, that by American standards, TKA is a cost-effective procedure is repeated and expanded to include even the morbidly obese. Being a good value for money does not necessarily translate to inexpensive. The budget impact is large and expected to rise. Better understanding of what does and does not drive the process and costs can inform policy makers as they attempt to plan, budget, and influence the future volume of this popular procedure.

The meta-analysis in Chapter II helped reduce the conflicting data relating to complication rates in obese populations. The results suggest that obesity does increase complication rates for important individual complications. It does not find a dose-response relationship which suggests that other factors besides obesity itself are driving at least some of the observed difference. Postoperative care or informal preoperative criteria may be creating differences in the complication rates not readily apparent in the existing studies. The seeming lack of consensus in the current literature is less of an issue than it appears when looking at individual studies. Taken together, there is much more agreement at least in those areas where the same outcomes were considered. An effort towards a standard set of complications and a more detailed approach to obesity definitions is still needed to fully understand the role of obesity in outcomes of TKA.

The CEA in Chapter III provides a systematic way to consider whether TKA should be offered to patients with various levels of obesity. Guidelines currently implemented in the UK are not based on a rigorous calculation of benefit, but purely a cost-savings experiment based on the notion that obese patients benefit less from surgery than others. This analysis demonstrated that even the heaviest patients still meet US standards of cost-effectiveness. The sensitivity analyses also point to several key areas for possible policy levers. Failure and complication rates mattered greatly and are both potentially modifiable with innovation in medical devices, surgical techniques, postoperative instructions, or other policy changes. The results also suggest that the concerns around the morbidly obese are not without merit. It is quite difficult to create a scenario that nonobese patients are not cost-effective, but simple to create one that is wildly expensive for Class III patients.

Chapter IV explicitly examined several potential policy levers and at the population level. The predicted volume of TKA procedures is expected to grow, but obesity is only part of that story. Obese patients do continue to be a growing share of TKA patients, but the volume is trending upwards independent of that change in patient demographics. Guidelines restricting access to TKA were explicitly modeled and, similar to the CEA results, the case for restricting access is not clear cut. Restricting access to TKA would have a noticeable impact on reducing overall volumes of TKA procedures. However, large numbers of people have OA of the knee regardless of whether TKA is an option to alleviate pain and immobility. Controlling the volume of TKA does not control the budget impact of OA. The guideline experiments demonstrate the need for tradeoffs in healthcare decision making. Policy makers need to plan workforce sizes and training priorities as well as budgetary concerns. The impact of reducing obesity in the population through broader public health initiatives is minimal in this specific domain, at least over the next 20 years. The damage to knees is a long-term process and will not be reversed in the short term. The ability to bend the demand for the procedure appears to be a temporary influence. The levels of OA in the population are much more powerful than policies or events that influence desirability of TKA. Obesity plays a role in the development of OA, so any actions need to be focused upstream on the development of the underlying disease rather than TKA usage itself.

These results also give some clinical insights. First, risk factors for deep infection and failure besides obesity should be strong markers against offering TKA in obese populations. Second, the suspicion that quality of life improvement will be less than average due to temperament or lifestyle of the patient should also give pause to surgeons considering obese patients for surgery. Third, the limited resources of the orthopedic staff need to be considered in light of rheumatology and primary care burdens of OA and these departments should discuss who make good surgical candidates before not after referrals occur to better use everyone's time.

Methodologically, this dissertation expanded the knowledge base around obesity and TKA by applying existing techniques to the new policy area and by also by using novel techniques when needed to better use models to answer these policy questions.

Two broad themes are found in these studies. The current data on obesity and TKA outcomes is limited. Better information can change policy recommendations as seen in the CEA and should be easily obtainable if a consensus is reached on what outcomes matter. The sheer volume of TKA procedures make any investment in obtaining more precise estimates of the impact of obesity on TKA outcomes worth pursuing. The other theme is that an application of decision science techniques to this area can add an important amount of fairness into this conversation. As seen in the UK, the idea of limiting care can elicit pushback from the public and from providers, an effect more pronounced in the American setting where rationing is not a welcome part of any health care conversation. Adding the charged topic of obesity to the mix does not calm these concerns. The models in Chapter III and IV show that while TKA is a generally a good value for money it is less so for the heaviest patients while also highlighting the tradeoffs in different treatment decisions and potential modifiable factors, short of restricting access to obese patients, that can make an impact on this large cost center in the American healthcare landscape.

APPENDICES

APPENDIX A:
Literature Search Details

After the 26 papers were selected for inclusion, the data was extracted in a three-phase process. As a first step, I read all papers and developed an Excel workbook to record the various reporting styles in the studies. Generally, each row was a single study and columns were arranged in sets according to obesity classification. Obesity classifications were as specific as the papers reported. They include the WHO classifications and thresholds such as BMI $\geq$ 35. Each set included any of the reported figures. For survival rates, this included all postoperative years up to the longest study of 18 years. The complication rates recorded odds ratios, values from contingency tables, and confidence intervals.

In the second phase, two master's students served as reviewers. The first reviewer did 11 papers, index numbers from 103-238 in the Table A-1. Table A-1 is also available in the Study Quality tab of the workbook MetaAnalysisExclusionAndDataFinal included in the supplementary materials available on the Drive for easier viewing. The second reviewer did the remaining 15 papers after the first graduated. There was no overlap between the two reviewers. Each was given a basic description of the project and the outcomes under consideration. The variety of outcome reporting styles was explained as was the graphing tool for extracting values from survival curve graphs. The instruction document attempted to balance detailed instructions with wide latitude to use own judgement to preserve the independence of the second review. The instructions also asked for recording of page or table number to easily find the source within the paper.

Considering the two student reviewers as one, agreement was 29.9%. For the first reviewer, it was 33.9% and the second saw 25%. This low rate of agreement can be explained partially by the very loose definitions in the grouped complications. Excluding those from the calculation sees overall agreement rise to 35.7% and the two reviewers to 40.6% and 29.2% respectively.

The third phase involved David Hutton as arbiter between differing results both in terms of finding any number at all and in disagreement of specific values in the same paper. He and I walked through each of the papers and value. Prof. Hutton then made the final decision on whether to include a value or not. For instance, the first reviewer included many values for survival of revision operations. Yet all 7 of the papers he found were only about the revision of primary surgeries and they were not included in the analysis. Other sources of disagreement related to definition of complications or groupings in the primary papers. For instance, some papers discussed pulmonary embolism and deep vein thrombosis separately but together they are venous thromboembolism so with some simple addition can be made a part of the analysis. There were also several that were simply overlooking a table not mentioned inline or vice versa on my part that the reviewers found.

After this process, consensus was achieved on which values to include and that all possible data was extracted. From this base, the analysis continued as described above.

Table A-1 Study Quality Analysis

Green = Good, Yellow = Fair, Red = Bad																		
														Chart report only is yellow. In person measure is green.			Must define type of TKR/approach for green.	Same or mostly same implant process for green.
Index	**Sample - Inclusion Criteria Defined**	**Sample - Sample Selection Explained**	**Sample - Adequate Description of diagnostic criteria**	**Sample - Cinical and Demographics Fully Described**	**Sample - Representative**	**Sample - Assembled at a common point in disease**	**F/U - Sufficiently Long**	**Outcome- Objective**	**Outcome - Unbiased**	**Outcome - Fully defined**	**Outcome - Appropriate**	**Outcome- Known for high share**	**Prognostic Var - Fully defined**	**Prognostic Var - Precisely Measured**	**Prognostic Var - Avail for high share**	**Ax- Good procedures**	**Treatment subsequent to inclusion - fully described**	**Treatment sub - Treatment standardized or randomized**
32	Green	Green	Green	Yellow	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Yellow	Green	Green	Yellow	Yellow
37	Green	Green	Green	Green	Green	Green	Green	Green	Green	Yellow	Green	Green	Green	Green	Green	Green	Yellow	Yellow
38	Green	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Yellow	Green	Green	Yellow	Green	Yellow	Yellow	Yellow
46	Green	Green	Green	Yellow	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Yellow	Green	Green	Yellow	Yellow
59	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Yellow	Green	Green	Green	Green	Green	Yellow	Yellow
61	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Yellow	Green	Green	Yellow	Yellow
73	Green	Green	Green	Green	Yellow	Green	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Green	Yellow	Yellow
76	Green	Green	Green	Yellow	Yellow	Green	Green	Green	Green	Green	Yellow	Green	Green	Yellow	Green	Green	Green	Green
78	Green	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Yellow	Green	Green	Yellow	Green	Green	Green	Green	Yellow	Yellow
81	Green	Green	Green	Green	Green	Green	Green	Green	Green	Yellow	Green	Green	Yellow	Yellow	Green	Green	Yellow	Yellow
100	Green	Green	Green	Yellow	Yellow	Green	Yellow	Green	Green	Green	Yellow	Green	Green	Green	Green	Green	Yellow	Yellow
103	Green	Green	Green	Yellow	Yellow	Green	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
113	Green	Green	Green	Yellow	Yellow	Green	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
117	Yellow	Green	Green	Yellow	Yellow	Green	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Green	Yellow	Yellow
124	Green	Green	Green	Green	Yellow	Green	Green	Green	Green	Green	Green	Yellow	Green	Yellow	Green	Green	Green	Green
126	Green	Green	Green	Yellow	Yellow	Green	Green	Green	Green	Green	Green	Yellow	Green	Green	Green	Green	Green	Yellow
172	Green	Green	Green	Green	Yellow	Green	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
174	Green	Green	Green	Green	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Yellow	Green	Green	Green	Green
195	Green	Green	Green	Yellow	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
206	Green	Green	Green	Yellow	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
224	Green	Green	Green	Yellow	Yellow	Green	Yellow	Green	Green	Green	Green	Green	Green	Yellow	Green	Green	Green	Green
238	Green	Green	Green	Yellow	Yellow	Green	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Green	Yellow	Yellow
253	Green	Green	Green	Yellow	Yellow	Green	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Yellow
L1	Green	Green	Green	Yellow	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Yellow	Green	Green	Green	Yellow
L3	Green	Green	Green	Yellow	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Yellow	Green	Green	Yellow	Yellow
L5	Green	Green	Green	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Green	Yellow	Green	Green	Yellow	Yellow

Table A-2 Number of Studies and Knees by Year and Obesity Class

Number of Knees (Number of Studies)					
Year	BMI < 30	BMI > 30	BMI 30-35	BMI > 40	BMI > 35
1	561	479	187	684	187
	5	6	3	3	3
2	561	479	187	684	187
	5	6	3	3	3
3	561	479	187	684	187
	5	6	3	3	3
4	561	479	187	684	187
	5	6	3	3	3
5	602	479	187	684	187
	6	6	3	3	3
6	561	479	187	684	187
	5	6	3	3	3
7	269	269	187	602	187
	3	5	3	2	3
8	269	269	187	602	187
	3	5	3	2	3
9	269	269	187	602	187
	3	5	3	2	3
10	269	269	325	602	187
	3	5	4	2	3
11	32	32	0	0	0
	1	1	0	0	0
12	32	32	0	0	0
	1	1	0	0	0
13	32	32	0	0	0
	1	1	0	0	0
14	32	32	0	0	0
	1	1	0	0	0
15	32	32	0	0	0
	1	1	0	0	0
16	32	32	0	0	0
	1	1	0	0	0
17	32	32	0	0	0
	1	1	0	0	0
18	32	32	0	0	0
	1	1	0	0	0

APPENDIX B:
Full Sensitivity Analysis Results

The full univariate sensitivity analysis results for all 248 parameters are shown below. The four obesity groups (Table B-2 – 4) form the basis of the weighted average shown as overall in Table B-1. Red values have been artificially inflated to reflect that the value was changed from a negative ICER due to dominance. Yellow cells are highlighted negative values that reflect domination.

Table B-1 Full Univariate Sensitivity Analysis Results for Overall Population

Overall					
Base	**$**				**16,272.89**
Parameter Name	**Low**	**High**	**Min**	**Max**	**Gap**
qalyFull	$ (44,076.85)	$ 5,913.62	$ 150,000.00	$ 5,913.62	$ 144,086.38
transitionRevisionToFull	$ 132,497.56	$ 11,154.97	$ 11,154.97	$ 132,497.56	$ 121,342.59
transitionTKAtoFull	$ 121,413.85	$ 10,327.51	$ 10,327.51	$ 121,413.85	$ 111,086.34
costOATreatment	$ 41,103.36	$ (33,388.07)	$ (33,388.07)	$ 41,103.36	$ 74,491.43
complicationDeepInfectionLess Obese	$ 14,221.18	$ 58,909.95	$ 14,221.18	$ 58,909.95	$ 44,688.77
complicationDeepInfection	$ 6,084.82	$ 46,240.60	$ 6,084.82	$ 46,240.60	$ 40,155.78
costTKA	$ 2,905.72	$ 43,007.22	$ 2,905.72	$ 43,007.22	$ 40,101.50
costRevision	$ 4,056.95	$ 40,704.76	$ 4,056.95	$ 40,704.76	$ 36,647.81
qalyOA	$ 15,465.50	$ 49,058.97	$ 15,465.50	$ 49,058.97	$ 33,593.47
Age	$ 10,512.95	$ 23,297.86	$ 10,512.95	$ 23,297.86	$ 12,784.92
Discount Rate	$ 11,889.78	$ 23,227.34	$ 11,889.78	$ 23,227.34	$ 11,337.56
transitionDeepLateToRevision	$ 16,272.89	$ 27,057.79	$ 16,272.89	$ 27,057.79	$ 10,784.91
transitionTKAFullToNo10	$ 7,615.39	$ 18,361.94	$ 7,615.39	$ 18,361.94	$ 10,746.55
qalyDecRevision	$ 15,227.32	$ 24,781.57	$ 15,227.32	$ 24,781.57	$ 9,554.25
costsDeepContinuingWorst	$ 13,373.31	$ 22,072.03	$ 13,373.31	$ 22,072.03	$ 8,698.72
qalyDecTKA	$ 14,282.08	$ 22,220.05	$ 14,282.08	$ 22,220.05	$ 7,937.97
transitionRevisionFullToNo1	$ 16,179.97	$ 23,210.63	$ 16,179.97	$ 23,210.63	$ 7,030.66
transitionTKAFullToNo1	$ 15,830.88	$ 22,703.27	$ 15,830.88	$ 22,703.27	$ 6,872.40
complicationDeepInfectionMore Obese	$ 14,892.90	$ 21,744.65	$ 14,892.90	$ 21,744.65	$ 6,851.76
transitionTKAFullToNo2	$ 15,446.17	$ 21,575.27	$ 15,446.17	$ 21,575.27	$ 6,129.10
transitionRevisionFullToNo2	$ 16,177.66	$ 21,947.81	$ 16,177.66	$ 21,947.81	$ 5,770.15
complicationDeepInfectionMorbid Obese	$ 14,843.11	$ 20,371.11	$ 14,843.11	$ 20,371.11	$ 5,528.00

transitionTKAFullToNo3	$ 15,385.23	$ 20,816.05	$ 15,385.23	$ 20,816.05	$ 5,430.82
transitionLateFailureToRevision	$ 11,350.11	$ 16,283.48	$ 11,350.11	$ 16,283.48	$ 4,933.37
transitionTKAFullToNo4	$ 15,496.77	$ 20,270.83	$ 15,496.77	$ 20,270.83	$ 4,774.07
transitionRevisionFullToNo3	$ 16,074.18	$ 20,786.69	$ 16,074.18	$ 20,786.69	$ 4,712.51
transitionTKAFullToNo5	$ 15,468.93	$ 19,636.90	$ 15,468.93	$ 19,636.90	$ 4,167.97
costsDeepRevision	$ 14,920.62	$ 18,977.42	$ 14,920.62	$ 18,977.42	$ 4,056.80
transitionRevisionFullToNo4	$ 16,023.82	$ 19,864.65	$ 16,023.82	$ 19,864.65	$ 3,840.84
transitionTKAFullToNo6	$ 15,435.97	$ 19,043.19	$ 15,435.97	$ 19,043.19	$ 3,607.23
transitionRevisionFullToNo10	$ 14,576.88	$ 17,961.36	$ 14,576.88	$ 17,961.36	$ 3,384.48
costPostOpTKA	$ 15,168.38	$ 18,481.90	$ 15,168.38	$ 18,481.90	$ 3,313.51
qalyFailed	$ 18,321.45	$ 15,039.54	$ 15,039.54	$ 18,321.45	$ 3,281.91
transitionTKAtoFullNon Obese	$ 18,405.13	$ 15,155.92	$ 15,155.92	$ 18,405.13	$ 3,249.21
transitionRevisionFullToNo5	$ 16,065.63	$ 19,178.16	$ 16,065.63	$ 19,178.16	$ 3,112.53
transitionTKAFullToNo7	$ 15,104.17	$ 18,214.78	$ 15,104.17	$ 18,214.78	$ 3,110.62
transitionRevisionToFullLess Obese	$ 14,544.33	$ 17,631.55	$ 14,544.33	$ 17,631.55	$ 3,087.22
costFailure	$ 15,371.46	$ 18,075.73	$ 15,371.46	$ 18,075.73	$ 2,704.27
transitionTKAFullToNo8	$ 14,810.04	$ 17,474.22	$ 14,810.04	$ 17,474.22	$ 2,664.17
transitionRevisionToFullNon Obese	$ 18,097.19	$ 15,464.87	$ 15,464.87	$ 18,097.19	$ 2,632.32
transitionRevisionFullToNo6	$ 16,077.69	$ 18,582.35	$ 16,077.69	$ 18,582.35	$ 2,504.66
transitionTKAFullToNo9	$ 14,466.12	$ 16,743.20	$ 14,466.12	$ 16,743.20	$ 2,277.09
costDeepInfection	$ 15,514.99	$ 17,788.67	$ 15,514.99	$ 17,788.67	$ 2,273.68
transitionDeepEarlyToRevision	$ 16,272.89	$ 18,497.93	$ 16,272.89	$ 18,497.93	$ 2,225.04
transitionTKAtoFullLess Obese	$ 14,860.36	$ 17,045.63	$ 14,860.36	$ 17,045.63	$ 2,185.27
transitionRevisionFullToNo7	$ 16,083.73	$ 18,081.44	$ 16,083.73	$ 18,081.44	$ 1,997.70
complicationWound	$ 16,174.11	$ 18,000.64	$ 16,174.11	$ 18,000.64	$ 1,826.53
qalyDeepWorstDecrement	$ 17,099.62	$ 15,522.41	$ 15,522.41	$ 17,099.62	$ 1,577.22
transitionRevisionFullToNo8	$ 16,116.44	$ 17,687.05	$ 16,116.44	$ 17,687.05	$ 1,570.62
transitionRevisionToFullMore Obese	$ 15,413.15	$ 16,935.92	$ 15,413.15	$ 16,935.92	$ 1,522.77
transitionTKAFullToNo10Less Obese	$ 15,666.65	$ 17,002.12	$ 15,666.65	$ 17,002.12	$ 1,335.47
transitionRevisionFullToNo9	$ 15,995.29	$ 17,240.70	$ 15,995.29	$ 17,240.70	$ 1,245.41
complicationDeepVTE	$ 16,267.40	$ 17,427.01	$ 16,267.40	$ 17,427.01	$ 1,159.61
transitionTKAtoFullMore Obese	$ 15,553.17	$ 16,663.28	$ 15,553.17	$ 16,663.28	$ 1,110.12
transitionRevisionToFullMorbid Obese	$ 15,649.01	$ 16,746.48	$ 15,649.01	$ 16,746.48	$ 1,097.47
transitionTKAtoFullMorbid Obese	$ 15,708.25	$ 16,578.49	$ 15,708.25	$ 16,578.49	$ 870.24
complicationVTE	$ 15,994.82	$ 16,813.19	$ 15,994.82	$ 16,813.19	$ 818.36
complicationDeepSubsequentDeepLess Obese	$ 16,228.10	$ 17,044.61	$ 16,228.10	$ 17,044.61	$ 816.51

transitionTKAFullToNo10More Obese	$ 15,971.33	$ 16,634.10	$ 15,971.33	$ 16,634.10	$ 662.77
costsDeepSubsequentDeep	$ 16,112.93	$ 16,592.81	$ 16,112.93	$ 16,592.81	$ 479.88
transitionTKAFullToNo10Morbid Obese	$ 16,058.82	$ 16,531.98	$ 16,058.82	$ 16,531.98	$ 473.17
tranistionEarlyFailureToRevision	$ 16,718.67	$ 16,272.89	$ 16,272.89	$ 16,718.67	$ 445.78
transitionTKAFullToNo9Less Obese	$ 16,114.45	$ 16,528.02	$ 16,114.45	$ 16,528.02	$ 413.57
costVTE	$ 16,135.29	$ 16,548.07	$ 16,135.29	$ 16,548.07	$ 412.78
transitionDeepBestToFail1	$ 16,028.01	$ 16,404.46	$ 16,028.01	$ 16,404.46	$ 376.45
transitionRevisionFullToNo10Less Obese	$ 16,107.04	$ 16,471.08	$ 16,107.04	$ 16,471.08	$ 364.05
complicationDeepSubsequentDeepMorbid Obese	$ 16,180.81	$ 16,541.89	$ 16,180.81	$ 16,541.89	$ 361.08
qalyDecDeepInfection	$ 16,213.60	$ 16,563.08	$ 16,213.60	$ 16,563.08	$ 349.48
qalyDeepRevisionDecrement	$ 16,216.08	$ 16,563.01	$ 16,216.08	$ 16,563.01	$ 346.93
transitionTKAFullToNo8Less Obese	$ 16,142.89	$ 16,482.11	$ 16,142.89	$ 16,482.11	$ 339.23
complicationWoundLess Obese	$ 16,233.78	$ 16,517.27	$ 16,233.78	$ 16,517.27	$ 283.49
transitionDeepRevisionToBest	$ 16,423.32	$ 16,140.67	$ 16,140.67	$ 16,423.32	$ 282.65
transitionTKAFullToNo7Less Obese	$ 16,167.50	$ 16,442.42	$ 16,167.50	$ 16,442.42	$ 274.92
complicationDeepSubsequentDeepMore Obese	$ 16,220.78	$ 16,479.07	$ 16,220.78	$ 16,479.07	$ 258.28
complicationVTEMorbid Obese	$ 16,237.28	$ 16,462.19	$ 16,237.28	$ 16,462.19	$ 224.91
transitionTKAFullToNo3Less Obese	$ 16,188.28	$ 16,408.95	$ 16,188.28	$ 16,408.95	$ 220.67
transitionTKAFullToNo2Less Obese	$ 16,193.28	$ 16,400.89	$ 16,193.28	$ 16,400.89	$ 207.60
costRevisionLess Obese	$ 16,204.03	$ 16,410.60	$ 16,204.03	$ 16,410.60	$ 206.57
transitionTKAFullToNo9More Obese	$ 16,193.87	$ 16,399.93	$ 16,193.87	$ 16,399.93	$ 206.06
transitionTKAFullToNo6Less Obese	$ 16,196.44	$ 16,395.80	$ 16,196.44	$ 16,395.80	$ 199.36
transitionTKAFullToNo5Less Obese	$ 16,198.30	$ 16,392.80	$ 16,198.30	$ 16,392.80	$ 194.50
transitionTKAFullToNo4Less Obese	$ 16,199.90	$ 16,390.22	$ 16,199.90	$ 16,390.22	$ 190.32
transitionRevisionFullToNo10More Obese	$ 16,191.97	$ 16,369.45	$ 16,191.97	$ 16,369.45	$ 177.48
transitionTKAFullToNo8More Obese	$ 16,207.97	$ 16,377.24	$ 16,207.97	$ 16,377.24	$ 169.27
costTKALess Obese	$ 16,221.75	$ 16,375.16	$ 16,221.75	$ 16,375.16	$ 153.41
transitionTKAFullToNo9Morbid Obese	$ 16,214.16	$ 16,367.27	$ 16,214.16	$ 16,367.27	$ 153.11
complicationDeepSubsequentDeep	$ 16,198.61	$ 16,347.19	$ 16,198.61	$ 16,347.19	$ 148.58
costWound	$ 16,224.18	$ 16,370.29	$ 16,224.18	$ 16,370.29	$ 146.10
transitionTKAFullToNo7More Obese	$ 16,220.19	$ 16,357.57	$ 16,220.19	$ 16,357.57	$ 137.38
transitionTKAFullToNo8Morbid Obese	$ 16,224.29	$ 16,350.98	$ 16,224.29	$ 16,350.98	$ 126.70
qalyDeepBestCase	$ 16,335.90	$ 16,210.35	$ 16,210.35	$ 16,335.90	$ 125.55
transitionDeepBestToFail2	$ 16,206.09	$ 16,327.82	$ 16,206.09	$ 16,327.82	$ 121.72
transitionRevisionFullToNo10Morbid Obese	$ 16,219.50	$ 16,337.00	$ 16,219.50	$ 16,337.00	$ 117.51
transitionTKAFullToNo1Less Obese	$ 16,230.09	$ 16,341.66	$ 16,230.09	$ 16,341.66	$ 111.57

transitionTKAFullToNo3More Obese	$ 16,230.36	$ 16,341.22	$ 16,230.36	$ 16,341.22	$ 110.86
transitionTKAFullToNo2More Obese	$ 16,232.83	$ 16,337.25	$ 16,232.83	$ 16,337.25	$ 104.43
transitionTKAFullToNo7Morbid Obese	$ 16,233.18	$ 16,336.68	$ 16,233.18	$ 16,336.68	$ 103.51
costRevisionMorbid Obese	$ 16,231.83	$ 16,334.46	$ 16,231.83	$ 16,334.46	$ 102.63
transitionTKAFullToNo6More Obese	$ 16,234.61	$ 16,334.38	$ 16,234.61	$ 16,334.38	$ 99.76
transitionTKAFullToNo5More Obese	$ 16,235.50	$ 16,332.96	$ 16,235.50	$ 16,332.96	$ 97.46
costRevisionMore Obese	$ 16,240.76	$ 16,337.14	$ 16,240.76	$ 16,337.14	$ 96.39
transitionTKAFullToNo4More Obese	$ 16,236.25	$ 16,331.74	$ 16,236.25	$ 16,331.74	$ 95.49
transitionTKAFullToNo3Morbid Obese	$ 16,240.20	$ 16,325.39	$ 16,240.20	$ 16,325.39	$ 85.18
transitionRevisionFullToNo9Less Obese	$ 16,239.81	$ 16,323.28	$ 16,239.81	$ 16,323.28	$ 83.47
costTKAMorbid Obese	$ 16,239.67	$ 16,322.70	$ 16,239.67	$ 16,322.70	$ 83.03
transitionTKAFullToNo2Morbid Obese	$ 16,241.98	$ 16,322.53	$ 16,241.98	$ 16,322.53	$ 80.55
transitionRevisionFullToNo4Less Obese	$ 16,242.04	$ 16,320.04	$ 16,242.04	$ 16,320.04	$ 78.00
transitionTKAFullToNo6Morbid Obese	$ 16,243.88	$ 16,319.48	$ 16,243.88	$ 16,319.48	$ 75.60
transitionTKAFullToNo5Morbid Obese	$ 16,244.40	$ 16,318.64	$ 16,244.40	$ 16,318.64	$ 74.24
transitionTKAFullToNo4Morbid Obese	$ 16,244.85	$ 16,317.92	$ 16,244.85	$ 16,317.92	$ 73.07
qalyDeepSubsequentDeepDecrement	$ 16,260.33	$ 16,333.28	$ 16,260.33	$ 16,333.28	$ 72.95
costTKAMore Obese	$ 16,248.64	$ 16,321.39	$ 16,248.64	$ 16,321.39	$ 72.75
transitionRevisionFullToNo5Less Obese	$ 16,247.40	$ 16,311.79	$ 16,247.40	$ 16,311.79	$ 64.39
transitionRevisionFullToNo3Less Obese	$ 16,248.21	$ 16,310.56	$ 16,248.21	$ 16,310.56	$ 62.35
transitionRevisionFullToNo6Less Obese	$ 16,249.04	$ 16,309.24	$ 16,249.04	$ 16,309.24	$ 60.20
transitionRevisionFullToNo7Less Obese	$ 16,249.97	$ 16,307.80	$ 16,249.97	$ 16,307.80	$ 57.84
transitionTKAFullToNo1More Obese	$ 16,251.32	$ 16,307.52	$ 16,251.32	$ 16,307.52	$ 56.19
costsDeepContinuingBest	$ 16,254.51	$ 16,309.63	$ 16,254.51	$ 16,309.63	$ 55.12
transitionDeepBestToFail3	$ 16,246.92	$ 16,297.61	$ 16,246.92	$ 16,297.61	$ 50.69
transitionRevisionFullToNo8Less Obese	$ 16,254.14	$ 16,301.41	$ 16,254.14	$ 16,301.41	$ 47.26
transitionTKAFullToNo1Morbid Obese	$ 16,256.19	$ 16,299.69	$ 16,256.19	$ 16,299.69	$ 43.50
transitionRevisionFullToNo9More Obese	$ 16,256.74	$ 16,297.48	$ 16,256.74	$ 16,297.48	$ 40.74
transitionRevisionFullToNo4More Obese	$ 16,257.79	$ 16,295.95	$ 16,257.79	$ 16,295.95	$ 38.16
qalyDecObesity	$ 16,289.97	$ 16,256.18	$ 16,256.18	$ 16,289.97	$ 33.80
transitionRevisionFullToNo5More Obese	$ 16,260.42	$ 16,291.90	$ 16,260.42	$ 16,291.90	$ 31.49
transitionRevisionFullToNo3More Obese	$ 16,260.80	$ 16,291.32	$ 16,260.80	$ 16,291.32	$ 30.52
complicationDeepWound	$ 16,271.24	$ 16,301.69	$ 16,271.24	$ 16,301.69	$ 30.45
transitionRevisionFullToNo2Less Obese	$ 16,261.05	$ 16,290.89	$ 16,261.05	$ 16,290.89	$ 29.83
transitionRevisionFullToNo6More Obese	$ 16,261.23	$ 16,290.65	$ 16,261.23	$ 16,290.65	$ 29.42
transitionRevisionFullToNo1Less Obese	$ 16,261.30	$ 16,290.51	$ 16,261.30	$ 16,290.51	$ 29.21

transitionRevisionFullToNo7More Obese	$ 16,261.69	$ 16,289.94	$ 16,261.69	$ 16,289.94	$ 28.26
transitionRevisionFullToNo9Morbid Obese	$ 16,261.87	$ 16,289.65	$ 16,261.87	$ 16,289.65	$ 27.78
transitionRevisionFullToNo4Morbid Obese	$ 16,262.29	$ 16,289.07	$ 16,262.29	$ 16,289.07	$ 26.79
costsDeepRevisionMorbid Obese	$ 16,262.48	$ 16,288.50	$ 16,262.48	$ 16,288.50	$ 26.02
transitionDeepRevisionToBestNon Obese	$ 16,289.03	$ 16,264.21	$ 16,264.21	$ 16,289.03	$ 24.82
qalyDecVTE	$ 16,269.96	$ 16,293.63	$ 16,269.96	$ 16,293.63	$ 23.67
transitionRevisionFullToNo8More Obese	$ 16,263.73	$ 16,286.81	$ 16,263.73	$ 16,286.81	$ 23.08
transitionDeepBestToFail4	$ 16,261.45	$ 16,284.19	$ 16,261.45	$ 16,284.19	$ 22.74
transitionDeepBestToFail1Less Obese	$ 16,256.43	$ 16,278.86	$ 16,256.43	$ 16,278.86	$ 22.43
transitionRevisionFullToNo5Morbid Obese	$ 16,264.17	$ 16,286.17	$ 16,264.17	$ 16,286.17	$ 22.00
transitionDeepBestToFail1Morbid Obese	$ 16,257.09	$ 16,278.63	$ 16,257.09	$ 16,278.63	$ 21.54
transitionRevisionFullToNo3Morbid Obese	$ 16,264.36	$ 16,285.89	$ 16,264.36	$ 16,285.89	$ 21.53
transitionRevisionFullToNo6Morbid Obese	$ 16,264.78	$ 16,285.23	$ 16,264.78	$ 16,285.23	$ 20.45
transitionRevisionFullToNo7Morbid Obese	$ 16,265.15	$ 16,284.67	$ 16,265.15	$ 16,284.67	$ 19.52
complicationWoundMorbid Obese	$ 16,268.42	$ 16,287.29	$ 16,268.42	$ 16,287.29	$ 18.87
transitionDeepBestToFail1More Obese	$ 16,259.20	$ 16,277.86	$ 16,259.20	$ 16,277.86	$ 18.66
complicationVTELess Obese	$ 16,264.96	$ 16,282.07	$ 16,264.96	$ 16,282.07	$ 17.11
tranistionToDeathMorbid Obese	$ 16,281.40	$ 16,264.42	$ 16,264.42	$ 16,281.40	$ 16.98
complicationWoundMore Obese	$ 16,267.33	$ 16,284.02	$ 16,267.33	$ 16,284.02	$ 16.69
costsDeepRevisionLess Obese	$ 16,267.47	$ 16,283.71	$ 16,267.47	$ 16,283.71	$ 16.23
transitionRevisionFullToNo8Morbid Obese	$ 16,266.60	$ 16,282.45	$ 16,266.60	$ 16,282.45	$ 15.85
qalyDecWound	$ 16,271.51	$ 16,287.27	$ 16,271.51	$ 16,287.27	$ 15.76
transitionRevisionFullToNo2More Obese	$ 16,267.09	$ 16,281.70	$ 16,267.09	$ 16,281.70	$ 14.61
transitionRevisionFullToNo1More Obese	$ 16,267.21	$ 16,281.52	$ 16,267.21	$ 16,281.52	$ 14.31
costsDeepRevisionMore Obese	$ 16,268.39	$ 16,281.88	$ 16,268.39	$ 16,281.88	$ 13.49
transitionDeepBestToFail5	$ 16,267.70	$ 16,278.06	$ 16,267.70	$ 16,278.06	$ 10.35
transitionRevisionFullToNo2Morbid Obese	$ 16,268.78	$ 16,279.13	$ 16,268.78	$ 16,279.13	$ 10.35
transitionRevisionFullToNo1Morbid Obese	$ 16,268.85	$ 16,279.03	$ 16,268.85	$ 16,279.03	$ 10.18
complicationDeepVTEMorbid Obese	$ 16,271.29	$ 16,281.38	$ 16,271.29	$ 16,281.38	$ 10.10
costsDeepVTE	$ 16,270.17	$ 16,278.31	$ 16,270.17	$ 16,278.31	$ 8.14
transitionDeepBestToFail6	$ 16,270.53	$ 16,275.24	$ 16,270.53	$ 16,275.24	$ 4.71
tranistionToDeathMore Obese	$ 16,275.22	$ 16,270.58	$ 16,270.58	$ 16,275.22	$ 4.64
transitionDeepRevisionToBestLess Obese	$ 16,270.00	$ 16,274.44	$ 16,270.00	$ 16,274.44	$ 4.44
transitionDeepRevisionToBestMorbid Obese	$ 16,270.11	$ 16,274.38	$ 16,270.11	$ 16,274.38	$ 4.27
complicationDeepWoundLess Obese	$ 16,272.31	$ 16,276.47	$ 16,272.31	$ 16,276.47	$ 4.16
transitionDeepRevisionToBestMore Obese	$ 16,270.48	$ 16,274.18	$ 16,270.48	$ 16,274.18	$ 3.70

complicationVTEMore Obese	$ 16,271.44	$ 16,274.38	$ 16,271.44	$ 16,274.38	$ 2.94
costsDeepWound	$ 16,272.07	$ 16,274.51	$ 16,272.07	$ 16,274.51	$ 2.44
transitionDeepBestToFail2Less Obese	$ 16,271.16	$ 16,273.51	$ 16,271.16	$ 16,273.51	$ 2.35
transitionDeepBestToFail2Morbid Obese	$ 16,271.23	$ 16,273.49	$ 16,271.23	$ 16,273.49	$ 2.25
transitionDeepBestToFail7	$ 16,271.82	$ 16,273.95	$ 16,271.82	$ 16,273.95	$ 2.14
transitionDeepBestToFail2More Obese	$ 16,271.45	$ 16,273.41	$ 16,271.45	$ 16,273.41	$ 1.95
tranistionToDeathLess Obese	$ 16,272.00	$ 16,273.79	$ 16,272.00	$ 16,273.79	$ 1.79
transitionDeepBestToFail8	$ 16,272.40	$ 16,273.37	$ 16,272.40	$ 16,273.37	$ 0.96
complicationDeepWoundMorbid Obese	$ 16,272.69	$ 16,273.53	$ 16,272.69	$ 16,273.53	$ 0.85
transitionDeepBestToFail10	$ 16,272.30	$ 16,272.98	$ 16,272.30	$ 16,272.98	$ 0.68
qalyDeepVTEDecrement	$ 16,272.83	$ 16,273.29	$ 16,272.83	$ 16,273.29	$ 0.47
complicationDeepWoundMore Obese	$ 16,272.74	$ 16,273.17	$ 16,272.74	$ 16,273.17	$ 0.43
transitionDeepBestToFail9	$ 16,272.67	$ 16,273.10	$ 16,272.67	$ 16,273.10	$ 0.43
qalyDeepWoundDecrement	$ 16,272.86	$ 16,273.13	$ 16,272.86	$ 16,273.13	$ 0.26
complicationDeepVTELess Obese	$ 16,272.77	$ 16,273.02	$ 16,272.77	$ 16,273.02	$ 0.25
transitionDeepBestToFail3Less Obese	$ 16,272.71	$ 16,272.95	$ 16,272.71	$ 16,272.95	$ 0.25
transitionDeepBestToFail3Morbid Obese	$ 16,272.71	$ 16,272.95	$ 16,272.71	$ 16,272.95	$ 0.23
transitionDeepBestToFail3More Obese	$ 16,272.74	$ 16,272.94	$ 16,272.74	$ 16,272.94	$ 0.20
complicationDeepVTEMore Obese	$ 16,272.85	$ 16,272.92	$ 16,272.85	$ 16,272.92	$ 0.08
transitionDeepBestToFail4Less Obese	$ 16,272.87	$ 16,272.89	$ 16,272.87	$ 16,272.89	$ 0.03
transitionDeepBestToFail4Morbid Obese	$ 16,272.87	$ 16,272.89	$ 16,272.87	$ 16,272.89	$ 0.02
transitionDeepBestToFail4More Obese	$ 16,272.87	$ 16,272.89	$ 16,272.87	$ 16,272.89	$ 0.02
transitionDeepBestToFail5Less Obese	$ 16,272.88	$ 16,272.89	$ 16,272.88	$ 16,272.89	$ 0.00
transitionDeepBestToFail5Morbid Obese	$ 16,272.88	$ 16,272.89	$ 16,272.88	$ 16,272.89	$ 0.00
transitionDeepBestToFail5More Obese	$ 16,272.88	$ 16,272.89	$ 16,272.88	$ 16,272.89	$ 0.00
transitionDeepBestToFail6Less Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 0.00
transitionDeepBestToFail6Morbid Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 0.00
transitionDeepBestToFail6More Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 0.00
transitionDeepBestToFail7Less Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 0.00
transitionDeepBestToFail7Morbid Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 0.00
transitionDeepBestToFail7More Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 0.00
transitionDeepBestToFail8Less Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 0.00
transitionDeepBestToFail8Morbid Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 0.00
transitionDeepBestToFail8More Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 0.00
transitionDeepBestToFail9Less Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 0.00
transitionDeepBestToFail9Morbid Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 0.00

transitionDeepBestToFail9More Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 0.00
transitionDeepBestToFail10Less Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 0.00
transitionDeepBestToFail10Morbid Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 0.00
transitionDeepBestToFail10More Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 0.00
transitionOAtoTKA	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionTKAFullToNo1Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionTKAFullToNo2Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionTKAFullToNo3Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionTKAFullToNo4Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionTKAFullToNo5Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionTKAFullToNo6Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionTKAFullToNo7Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionTKAFullToNo8Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionTKAFullToNo9Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionTKAFullToNo10Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionRevisionFullToNo1Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionRevisionFullToNo2Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionRevisionFullToNo3Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionRevisionFullToNo4Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionRevisionFullToNo5Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionRevisionFullToNo6Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionRevisionFullToNo7Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionRevisionFullToNo8Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionRevisionFullToNo9Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionRevisionFullToNo10Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
tranistionToDeath	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
tranistionToDeathNon Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
complicationVTENon Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
complicationWoundNon Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
complicationDeepInfectionNon Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
costTKANon Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
costRevisionNon Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
complicationDeepVTENon Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
complicationDeepWoundNon Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
complicationDeepSubsequentDeepNon Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionDeepBestToFail1Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -

transitionDeepBestToFail2Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionDeepBestToFail3Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionDeepBestToFail4Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionDeepBestToFail5Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionDeepBestToFail6Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionDeepBestToFail7Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionDeepBestToFail8Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionDeepBestToFail9Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
transitionDeepBestToFail10Non Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -
costsDeepRevisionNon Obese	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ 16,272.89	$ -

Table B-2 Full Univariate Sensitivity Analysis Results for Nonobese Population

Nonobese					
Base	$				4,932.35
Parameter Name	Low	High	Min	Max	Gap
qalyFull	$ (17,349.50)	$ 1,866.09	$ 100,000.00	$ 1,866.09	$ 98,133.91
transitionTKAtoFull	$ 78,887.45	$ 855.73	$ 855.73	$ 78,887.45	$ 78,031.72
costOATreatment	$ 27,784.77	$ (40,772.51)	$ (40,772.51)	$ 27,784.77	$ 68,557.29
transitionRevisionToFull	$ 66,968.36	$ 2,247.12	$ 2,247.12	$ 66,968.36	$ 64,721.24
costTKA	$ (7,151.78)	$ 29,100.60	$ (7,151.78)	$ 29,100.60	$ 36,252.38
costRevision	$ (3,372.68)	$ 21,542.40	$ (3,372.68)	$ 21,542.40	$ 24,915.08
complicationDeepInfection	$ (853.20)	$ 20,438.97	$ (853.20)	$ 20,438.97	$ 21,292.17
transitionLateFailureToRevision	$ (433.82)	$ 5,156.17	$ (10,000.00)	$ 5,156.17	$ 15,156.17
Age	$ (648.55)	$ 11,174.35	$ (648.55)	$ 11,174.35	$ 11,822.89
Discount Rate	$ 1,084.80	$ 10,932.80	$ 1,084.80	$ 10,932.80	$ 9,847.99
transitionTKAFullToNo10	$ (1,348.06)	$ 6,546.84	$ (1,348.06)	$ 6,546.84	$ 7,894.90
qalyOA	$ 4,778.35	$ 12,650.90	$ 4,778.35	$ 12,650.90	$ 7,872.55
costsDeepContinuingWorst	$ 3,184.54	$ 8,427.96	$ 3,184.54	$ 8,427.96	$ 5,243.42
transitionDeepLateToRevision	$ 4,932.35	$ 9,769.29	$ 4,932.35	$ 9,769.29	$ 4,836.95
transitionTKAFullToNo1	$ 4,658.75	$ 8,850.04	$ 4,658.75	$ 8,850.04	$ 4,191.29
transitionTKAtoFullNon Obese	$ 7,680.10	$ 3,508.30	$ 3,508.30	$ 7,680.10	$ 4,171.79
transitionTKAFullToNo2	$ 4,414.91	$ 8,205.43	$ 4,414.91	$ 8,205.43	$ 3,790.51
transitionTKAFullToNo3	$ 4,369.63	$ 7,778.29	$ 4,369.63	$ 7,778.29	$ 3,408.66
transitionRevisionToFullNon Obese	$ 7,276.80	$ 3,903.04	$ 3,903.04	$ 7,276.80	$ 3,373.75
costPostOpTKA	$ 3,890.67	$ 7,015.69	$ 3,890.67	$ 7,015.69	$ 3,125.02
transitionTKAFullToNo4	$ 4,433.15	$ 7,477.94	$ 4,433.15	$ 7,477.94	$ 3,044.79

transitionRevisionFullToNo1	$ 4,890.03	$ 7,831.46	$ 4,890.03	$ 7,831.46	$ 2,941.43
transitionTKAFullToNo5	$ 4,407.25	$ 7,110.95	$ 4,407.25	$ 7,110.95	$ 2,703.70
transitionRevisionFullToNo2	$ 4,888.64	$ 7,365.59	$ 4,888.64	$ 7,365.59	$ 2,476.95
transitionTKAFullToNo6	$ 4,376.40	$ 6,759.69	$ 4,376.40	$ 6,759.69	$ 2,383.29
costsDeepRevision	$ 4,146.00	$ 6,505.04	$ 4,146.00	$ 6,505.04	$ 2,359.04
qalyDecTKA	$ 4,373.39	$ 6,536.43	$ 4,373.39	$ 6,536.43	$ 2,163.04
costFailure	$ 4,221.33	$ 6,354.38	$ 4,221.33	$ 6,354.38	$ 2,133.06
transitionTKAFullToNo7	$ 4,143.14	$ 6,236.07	$ 4,143.14	$ 6,236.07	$ 2,092.93
transitionRevisionFullToNo3	$ 4,840.39	$ 6,912.54	$ 4,840.39	$ 6,912.54	$ 2,072.15
transitionRevisionFullToNo10	$ 4,070.67	$ 5,925.78	$ 4,070.67	$ 5,925.78	$ 1,855.11
transitionTKAFullToNo8	$ 3,927.38	$ 5,753.76	$ 3,927.38	$ 5,753.76	$ 1,826.38
qalyDecRevision	$ 4,708.09	$ 6,474.42	$ 4,708.09	$ 6,474.42	$ 1,766.33
transitionRevisionFullToNo4	$ 4,816.01	$ 6,542.12	$ 4,816.01	$ 6,542.12	$ 1,726.11
transitionTKAFullToNo9	$ 3,671.08	$ 5,259.40	$ 3,671.08	$ 5,259.40	$ 1,588.32
transitionRevisionFullToNo5	$ 4,834.42	$ 6,263.11	$ 4,834.42	$ 6,263.11	$ 1,428.68
costDeepInfection	$ 4,478.79	$ 5,839.46	$ 4,478.79	$ 5,839.46	$ 1,360.67
transitionRevisionFullToNo6	$ 4,838.93	$ 6,012.69	$ 4,838.93	$ 6,012.69	$ 1,173.76
transitionRevisionFullToNo7	$ 4,840.47	$ 5,796.66	$ 4,840.47	$ 5,796.66	$ 956.19
complicationWound	$ 4,884.01	$ 5,777.13	$ 4,884.01	$ 5,777.13	$ 893.11
transitionDeepEarlyToRevision	$ 4,932.35	$ 5,768.37	$ 4,932.35	$ 5,768.37	$ 836.03
transitionRevisionFullToNo8	$ 4,854.91	$ 5,624.62	$ 4,854.91	$ 5,624.62	$ 769.71
qalyFailed	$ 5,343.36	$ 4,668.94	$ 4,668.94	$ 5,343.36	$ 674.42
transitionRevisionFullToNo9	$ 4,792.98	$ 5,414.55	$ 4,792.98	$ 5,414.55	$ 621.56
complicationVTE	$ 4,751.36	$ 5,283.94	$ 4,751.36	$ 5,283.94	$ 532.58
complicationDeepVTE	$ 4,930.31	$ 5,359.36	$ 4,930.31	$ 5,359.36	$ 429.05
transitionDeepBestToFail1	$ 4,778.41	$ 5,086.49	$ 4,778.41	$ 5,086.49	$ 308.08
transitionDeepRevisionToBest	$ 5,090.46	$ 4,797.28	$ 4,797.28	$ 5,090.46	$ 293.18
qalyDeepWorstDecrement	$ 5,079.25	$ 4,793.70	$ 4,793.70	$ 5,079.25	$ 285.54
costVTE	$ 4,842.14	$ 5,112.77	$ 4,842.14	$ 5,112.77	$ 270.63
tranistionEarlyFailureToRevision	$ 5,104.08	$ 4,932.35	$ 4,932.35	$ 5,104.08	$ 171.73
costsDeepSubsequentDeep	$ 4,881.45	$ 5,034.13	$ 4,881.45	$ 5,034.13	$ 152.68
transitionDeepBestToFail2	$ 4,861.03	$ 5,003.71	$ 4,861.03	$ 5,003.71	$ 142.68
costWound	$ 4,908.28	$ 4,980.47	$ 4,908.28	$ 4,980.47	$ 72.19
costsDeepContinuingBest	$ 4,909.75	$ 4,977.53	$ 4,909.75	$ 4,977.53	$ 67.78
transitionDeepBestToFail3	$ 4,899.42	$ 4,965.28	$ 4,899.42	$ 4,965.28	$ 65.86
qalyDecDeepInfection	$ 4,921.58	$ 4,984.61	$ 4,921.58	$ 4,984.61	$ 63.03

qalyDeepRevisionDecrement	$ 4,922.03	$ 4,984.60	$ 4,922.03	$ 4,984.60	$ 62.57
complicationDeepSubsequentDeep	$ 4,909.33	$ 4,955.36	$ 4,909.33	$ 4,955.36	$ 46.03
qalyDeepBestCase	$ 4,948.71	$ 4,916.09	$ 4,916.09	$ 4,948.71	$ 32.62
transitionDeepRevisionToBestNon Obese	$ 4,952.93	$ 4,921.28	$ 4,921.28	$ 4,952.93	$ 31.65
transitionDeepBestToFail4	$ 4,917.20	$ 4,947.49	$ 4,917.20	$ 4,947.49	$ 30.28
transitionDeepBestToFail5	$ 4,925.41	$ 4,939.28	$ 4,925.41	$ 4,939.28	$ 13.87
complicationDeepWound	$ 4,931.80	$ 4,941.82	$ 4,931.80	$ 4,941.82	$ 10.01
qalyDeepSubsequentDeepDecrement	$ 4,931.13	$ 4,938.16	$ 4,931.13	$ 4,938.16	$ 7.02
transitionDeepBestToFail6	$ 4,929.19	$ 4,935.51	$ 4,929.19	$ 4,935.51	$ 6.32
qalyDecVTE	$ 4,931.76	$ 4,936.47	$ 4,931.76	$ 4,936.47	$ 4.70
costsDeepVTE	$ 4,931.33	$ 4,934.37	$ 4,931.33	$ 4,934.37	$ 3.04
transitionDeepBestToFail7	$ 4,930.91	$ 4,933.78	$ 4,930.91	$ 4,933.78	$ 2.87
qalyDecWound	$ 4,932.14	$ 4,934.50	$ 4,932.14	$ 4,934.50	$ 2.36
transitionDeepBestToFail8	$ 4,931.70	$ 4,932.99	$ 4,931.70	$ 4,932.99	$ 1.29
transitionDeepBestToFail10	$ 4,931.57	$ 4,932.47	$ 4,931.57	$ 4,932.47	$ 0.91
costsDeepWound	$ 4,932.08	$ 4,932.89	$ 4,932.08	$ 4,932.89	$ 0.81
transitionDeepBestToFail9	$ 4,932.06	$ 4,932.64	$ 4,932.06	$ 4,932.64	$ 0.58
qalyDeepVTEDecrement	$ 4,932.34	$ 4,932.39	$ 4,932.34	$ 4,932.39	$ 0.05
qalyDeepWoundDecrement	$ 4,932.34	$ 4,932.37	$ 4,932.34	$ 4,932.37	$ 0.03
transitionOAtoTKA	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAtoFullLess Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAtoFullMore Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAtoFullMorbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo1Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo1Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo1More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo1Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo2Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo2Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo2More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo2Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo3Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo3Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo3More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo3Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo4Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -

transitionTKAFullToNo4Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo4More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo4Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo5Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo5Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo5More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo5Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo6Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo6Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo6More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo6Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo7Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo7Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo7More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo7Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo8Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo8Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo8More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo8Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo9Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo9Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo9More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo9Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo10Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo10Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo10More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionTKAFullToNo10Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionToFullLess Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionToFullMore Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionToFullMorbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo1Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo1Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo1More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo1Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo2Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo2Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -

transitionRevisionFullToNo2More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo2Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo3Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo3Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo3More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo3Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo4Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo4Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo4More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo4Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo5Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo5Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo5More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo5Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo6Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo6Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo6More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo6Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo7Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo7Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo7More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo7Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo8Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo8Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo8More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo8Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo9Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo9Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo9More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo9Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo10Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo10Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo10More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionRevisionFullToNo10Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
tranistionToDeath	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
tranistionToDeathNon Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -

tranistionToDeathLess Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
tranistionToDeathMore Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
tranistionToDeathMorbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
complicationVTENon Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
complicationVTELess Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
complicationVTEMore Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
complicationVTEMorbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
complicationWoundNon Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
complicationWoundLess Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
complicationWoundMore Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
complicationWoundMorbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
complicationDeepInfectionNon Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
complicationDeepInfectionLess Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
complicationDeepInfectionMore Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
complicationDeepInfectionMorbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
costTKANon Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
costTKALess Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
costTKAMore Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
costTKAMorbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
costRevisionNon Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
costRevisionLess Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
costRevisionMore Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
costRevisionMorbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
qalyDecObesity	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
complicationDeepVTENon Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
complicationDeepVTELess Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
complicationDeepVTEMore Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
complicationDeepVTEMorbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
complicationDeepWoundNon Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
complicationDeepWoundLess Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
complicationDeepWoundMore Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
complicationDeepWoundMorbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
complicationDeepSubsequentDeepNon Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
complicationDeepSubsequentDeepLess Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
complicationDeepSubsequentDeepMore Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
complicationDeepSubsequentDeepMorbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -

transitionDeepRevisionToBestLess Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepRevisionToBestMore Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepRevisionToBestMorbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail1Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail1Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail1More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail1Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail2Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail2Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail2More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail2Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail3Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail3Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail3More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail3Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail4Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail4Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail4More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail4Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail5Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail5Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail5More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail5Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail6Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail6Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail6More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail6Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail7Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail7Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail7More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail7Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail8Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail8Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail8More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail8Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail9Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -

transitionDeepBestToFail9Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail9More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail9Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail10Non Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail10Less Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail10More Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
transitionDeepBestToFail10Morbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
costsDeepRevisionNon Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
costsDeepRevisionLess Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
costsDeepRevisionMore Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -
costsDeepRevisionMorbid Obese	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ 4,932.35	$ -

Table B-3 Full Univariate Sensitivity Analysis Results for Class I Obese Population

Class I Obesity					
Base	$ 33,891.07				
Parameter Name	Low	High	Min	Max	Gap
qalyFull	$ (67,282.49)	$ 11,591.18	$ 550,000.00	$ 11,591.18	$ 538,408.82
complicationDeepInfectionLess Obese	$ 21,258.22	$ (373,698.53)	$ 500,000.00	$ 21,258.22	$ 478,741.78
transitionRevisionToFull	$ 453,601.46	$ 23,330.37	$ 23,330.37	$ 453,601.46	$ 430,271.09
transitionTKAtoFull	$ 201,993.13	$ 24,351.88	$ 24,351.88	$ 201,993.13	$ 177,641.25
qalyOA	$ 31,929.87	$ 129,377.64	$ 31,929.87	$ 129,377.64	$ 97,447.78
costOATreatment	$ 61,845.91	$ (22,018.60)	$ (22,018.60)	$ 61,845.91	$ 83,864.51
costRevision	$ 13,263.46	$ 75,146.29	$ 13,263.46	$ 75,146.29	$ 61,882.82
complicationDeepInfection	$ 20,546.95	$ 75,606.00	$ 20,546.95	$ 75,606.00	$ 55,059.05
qalyDecRevision	$ 30,399.38	$ 79,621.50	$ 30,399.38	$ 79,621.50	$ 49,222.11
costTKA	$ 18,571.87	$ 64,529.48	$ 18,571.87	$ 64,529.48	$ 45,957.61
transitionRevisionToFullLess Obese	$ 23,137.09	$ 43,403.09	$ 23,137.09	$ 43,403.09	$ 20,266.00
qalyDecTKA	$ 29,284.48	$ 48,557.58	$ 29,284.48	$ 48,557.58	$ 19,273.10
transitionRevisionFullToNo1	$ 33,676.71	$ 51,458.79	$ 33,676.71	$ 51,458.79	$ 17,782.08
transitionTKAFullToNo10	$ 20,490.38	$ 36,869.51	$ 20,490.38	$ 36,869.51	$ 16,379.13
transitionRevisionFullToNo2	$ 33,672.11	$ 47,953.55	$ 33,672.11	$ 47,953.55	$ 14,281.44
transitionTKAtoFullLess Obese	$ 25,009.28	$ 39,165.54	$ 25,009.28	$ 39,165.54	$ 14,156.27
transitionDeepLateToRevision	$ 33,891.07	$ 47,915.03	$ 33,891.07	$ 47,915.03	$ 14,023.95
Age	$ 28,249.08	$ 41,722.69	$ 28,249.08	$ 41,722.69	$ 13,473.61
Discount Rate	$ 28,981.32	$ 41,965.20	$ 28,981.32	$ 41,965.20	$ 12,983.88
transitionTKAFullToNo1	$ 33,094.28	$ 45,837.86	$ 33,094.28	$ 45,837.86	$ 12,743.59

qalyFailed	$ 41,765.56	$ 29,773.89	$ 29,773.89	$ 41,765.56	$ 11,991.66
transitionRevisionFullToNo3	$ 33,436.03	$ 44,862.82	$ 33,436.03	$ 44,862.82	$ 11,426.79
transitionTKAFullToNo2	$ 32,415.29	$ 43,607.91	$ 32,415.29	$ 43,607.91	$ 11,192.63
costsDeepContinuingWorst	$ 30,414.40	$ 40,844.41	$ 30,414.40	$ 40,844.41	$ 10,430.01
transitionTKAFullToNo3	$ 32,323.52	$ 42,096.70	$ 32,323.52	$ 42,096.70	$ 9,773.17
transitionRevisionFullToNo4	$ 33,323.19	$ 42,476.05	$ 33,323.19	$ 42,476.05	$ 9,152.86
transitionTKAFullToNo10Less Obese	$ 30,003.54	$ 38,786.33	$ 30,003.54	$ 38,786.33	$ 8,782.79
transitionTKAFullToNo4	$ 32,537.37	$ 40,998.50	$ 32,537.37	$ 40,998.50	$ 8,461.13
transitionRevisionFullToNo5	$ 33,420.95	$ 40,728.03	$ 33,420.95	$ 40,728.03	$ 7,307.08
transitionTKAFullToNo5	$ 32,508.08	$ 39,771.20	$ 32,508.08	$ 39,771.20	$ 7,263.12
transitionRevisionFullToNo10	$ 30,187.06	$ 37,236.24	$ 30,187.06	$ 37,236.24	$ 7,049.19
transitionTKAFullToNo6	$ 32,473.94	$ 38,644.24	$ 32,473.94	$ 38,644.24	$ 6,170.30
transitionRevisionFullToNo6	$ 33,451.01	$ 39,246.73	$ 33,451.01	$ 39,246.73	$ 5,795.72
transitionTKAFullToNo7	$ 31,943.88	$ 37,161.73	$ 31,943.88	$ 37,161.73	$ 5,217.85
complicationWound	$ 33,616.20	$ 38,712.40	$ 33,616.20	$ 38,712.40	$ 5,096.20
complicationDeepSubsequentDeepLess Obese	$ 33,620.01	$ 38,604.61	$ 33,620.01	$ 38,604.61	$ 4,984.59
costsDeepRevision	$ 32,270.00	$ 37,133.21	$ 32,270.00	$ 37,133.21	$ 4,863.21
transitionRevisionFullToNo7	$ 33,467.81	$ 38,024.96	$ 33,467.81	$ 38,024.96	$ 4,557.14
transitionTKAFullToNo8	$ 31,495.80	$ 35,875.55	$ 31,495.80	$ 35,875.55	$ 4,379.75
qalyDeepWorstDecrement	$ 35,988.36	$ 32,024.77	$ 32,024.77	$ 35,988.36	$ 3,963.58
costFailure	$ 32,584.93	$ 36,503.36	$ 32,584.93	$ 36,503.36	$ 3,918.44
transitionTKAFullToNo9	$ 30,981.08	$ 34,654.00	$ 30,981.08	$ 34,654.00	$ 3,672.92
transitionLateFailureToRevision	$ 36,584.39	$ 32,972.64	$ 32,972.64	$ 36,584.39	$ 3,611.75
costPostOpTKA	$ 32,690.95	$ 36,291.32	$ 32,690.95	$ 36,291.32	$ 3,600.37
transitionRevisionFullToNo8	$ 33,544.44	$ 37,073.38	$ 33,544.44	$ 37,073.38	$ 3,528.94
tranistionEarlyFailureToRevision	$ 37,260.51	$ 33,891.07	$ 33,891.07	$ 37,260.51	$ 3,369.44
transitionDeepEarlyToRevision	$ 33,891.07	$ 36,985.31	$ 33,891.07	$ 36,985.31	$ 3,094.23
transitionRevisionFullToNo9	$ 33,280.94	$ 36,042.84	$ 33,280.94	$ 36,042.84	$ 2,761.90
costDeepInfection	$ 32,983.29	$ 35,706.64	$ 32,983.29	$ 35,706.64	$ 2,723.35
transitionTKAFullToNo9Less Obese	$ 32,859.65	$ 35,575.69	$ 32,859.65	$ 35,575.69	$ 2,716.03
transitionRevisionFullToNo10Less Obese	$ 32,811.20	$ 35,197.72	$ 32,811.20	$ 35,197.72	$ 2,386.51
transitionTKAFullToNo8Less Obese	$ 33,043.89	$ 35,270.52	$ 33,043.89	$ 35,270.52	$ 2,226.63
transitionTKAFullToNo7Less Obese	$ 33,203.65	$ 35,007.43	$ 33,203.65	$ 35,007.43	$ 1,803.78
complicationWoundLess Obese	$ 33,660.18	$ 35,335.61	$ 33,660.18	$ 35,335.61	$ 1,675.43
transitionTKAFullToNo3Less Obese	$ 33,338.53	$ 34,786.40	$ 33,338.53	$ 34,786.40	$ 1,447.87
transitionTKAFullToNo2Less Obese	$ 33,371.07	$ 34,733.22	$ 33,371.07	$ 34,733.22	$ 1,362.15

transitionTKAFullToNo6Less Obese	$ 33,391.87	$ 34,699.23	$ 33,391.87	$ 34,699.23	$ 1,307.36
transitionTKAFullToNo5Less Obese	$ 33,403.96	$ 34,679.50	$ 33,403.96	$ 34,679.50	$ 1,275.54
transitionTKAFullToNo4Less Obese	$ 33,414.34	$ 34,662.58	$ 33,414.34	$ 34,662.58	$ 1,248.25
costRevisionLess Obese	$ 33,490.54	$ 34,692.14	$ 33,490.54	$ 34,692.14	$ 1,201.61
complicationDeepVTE	$ 33,886.10	$ 34,936.85	$ 33,886.10	$ 34,936.85	$ 1,050.75
complicationVTE	$ 33,552.02	$ 34,549.94	$ 33,552.02	$ 34,549.94	$ 997.93
costTKALess Obese	$ 33,593.61	$ 34,485.99	$ 33,593.61	$ 34,485.99	$ 892.38
qalyDecDeepInfection	$ 33,743.30	$ 34,617.55	$ 33,743.30	$ 34,617.55	$ 874.25
qalyDeepRevisionDecrement	$ 33,749.47	$ 34,617.36	$ 33,749.47	$ 34,617.36	$ 867.89
transitionTKAFullToNo1Less Obese	$ 33,611.10	$ 34,342.67	$ 33,611.10	$ 34,342.67	$ 731.57
transitionRevisionFullToNo9Less Obese	$ 33,674.80	$ 34,221.57	$ 33,674.80	$ 34,221.57	$ 546.77
transitionRevisionFullToNo4Less Obese	$ 33,689.34	$ 34,200.28	$ 33,689.34	$ 34,200.28	$ 510.94
costVTE	$ 33,725.18	$ 34,222.85	$ 33,725.18	$ 34,222.85	$ 497.66
transitionRevisionFullToNo5Less Obese	$ 33,724.34	$ 34,146.08	$ 33,724.34	$ 34,146.08	$ 421.74
transitionRevisionFullToNo3Less Obese	$ 33,729.64	$ 34,138.06	$ 33,729.64	$ 34,138.06	$ 408.41
costWound	$ 33,757.54	$ 34,158.14	$ 33,757.54	$ 34,158.14	$ 400.60
costsDeepSubsequentDeep	$ 33,757.97	$ 34,157.26	$ 33,757.97	$ 34,157.26	$ 399.29
transitionRevisionFullToNo6Less Obese	$ 33,735.11	$ 34,129.37	$ 33,735.11	$ 34,129.37	$ 394.26
transitionRevisionFullToNo7Less Obese	$ 33,741.15	$ 34,119.94	$ 33,741.15	$ 34,119.94	$ 378.79
transitionDeepBestToFail1	$ 33,599.90	$ 33,928.41	$ 33,599.90	$ 33,928.41	$ 328.51
transitionRevisionFullToNo8Less Obese	$ 33,768.44	$ 34,077.96	$ 33,768.44	$ 34,077.96	$ 309.52
qalyDeepBestCase	$ 33,998.01	$ 33,784.80	$ 33,784.80	$ 33,998.01	$ 213.21
transitionRevisionFullToNo2Less Obese	$ 33,813.64	$ 34,009.01	$ 33,813.64	$ 34,009.01	$ 195.37
transitionRevisionFullToNo1Less Obese	$ 33,815.27	$ 34,006.53	$ 33,815.27	$ 34,006.53	$ 191.26
transitionDeepRevisionToBest	$ 33,970.50	$ 33,811.86	$ 33,811.86	$ 33,970.50	$ 158.65
transitionDeepBestToFail1Less Obese	$ 33,788.35	$ 33,928.41	$ 33,788.35	$ 33,928.41	$ 140.06
complicationDeepSubsequentDeep	$ 33,826.74	$ 33,955.42	$ 33,826.74	$ 33,955.42	$ 128.69
qalyDeepSubsequentDeepDecrement	$ 33,869.31	$ 33,995.67	$ 33,869.31	$ 33,995.67	$ 126.36
complicationVTELess Obese	$ 33,844.46	$ 33,945.11	$ 33,844.46	$ 33,945.11	$ 100.64
costsDeepRevisionLess Obese	$ 33,859.59	$ 33,954.03	$ 33,859.59	$ 33,954.03	$ 94.43
qalyDecWound	$ 33,883.20	$ 33,973.35	$ 33,883.20	$ 33,973.35	$ 90.15
tranistionToDeathLess Obese	$ 33,848.18	$ 33,934.23	$ 33,848.18	$ 33,934.23	$ 86.05
qalyDecObesity	$ 33,928.73	$ 33,854.25	$ 33,854.25	$ 33,928.73	$ 74.48
complicationDeepWound	$ 33,887.04	$ 33,961.48	$ 33,887.04	$ 33,961.48	$ 74.44
qalyDecVTE	$ 33,883.72	$ 33,943.17	$ 33,883.72	$ 33,943.17	$ 59.45
transitionDeepRevisionToBestLess Obese	$ 33,866.81	$ 33,904.13	$ 33,866.81	$ 33,904.13	$ 37.32

transitionDeepBestToFail2	$ 33,860.56	$ 33,894.98	$ 33,860.56	$ 33,894.98	$ 34.42
complicationDeepWoundLess Obese	$ 33,887.69	$ 33,912.23	$ 33,887.69	$ 33,912.23	$ 24.54
transitionDeepBestToFail2Less Obese	$ 33,880.31	$ 33,894.98	$ 33,880.31	$ 33,894.98	$ 14.67
costsDeepContinuingBest	$ 33,886.21	$ 33,900.79	$ 33,886.21	$ 33,900.79	$ 14.58
costsDeepVTE	$ 33,888.64	$ 33,895.94	$ 33,888.64	$ 33,895.94	$ 7.30
costsDeepWound	$ 33,889.11	$ 33,894.99	$ 33,889.11	$ 33,894.99	$ 5.87
transitionDeepBestToFail3	$ 33,887.89	$ 33,891.48	$ 33,887.89	$ 33,891.48	$ 3.59
transitionDeepBestToFail3Less Obese	$ 33,889.95	$ 33,891.48	$ 33,889.95	$ 33,891.48	$ 1.53
complicationDeepVTELess Obese	$ 33,890.39	$ 33,891.86	$ 33,890.39	$ 33,891.86	$ 1.48
qalyDeepWoundDecrement	$ 33,890.96	$ 33,892.27	$ 33,890.96	$ 33,892.27	$ 1.32
qalyDeepVTEDecrement	$ 33,890.96	$ 33,891.83	$ 33,890.96	$ 33,891.83	$ 0.87
transitionDeepBestToFail4	$ 33,890.74	$ 33,891.11	$ 33,890.74	$ 33,891.11	$ 0.37
transitionDeepBestToFail4Less Obese	$ 33,890.95	$ 33,891.11	$ 33,890.95	$ 33,891.11	$ 0.16
transitionDeepBestToFail5	$ 33,891.04	$ 33,891.08	$ 33,891.04	$ 33,891.08	$ 0.04
transitionDeepBestToFail5Less Obese	$ 33,891.06	$ 33,891.08	$ 33,891.06	$ 33,891.08	$ 0.02
transitionDeepBestToFail6	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 0.00
transitionDeepBestToFail6Less Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 0.00
transitionDeepBestToFail7	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 0.00
transitionDeepBestToFail7Less Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 0.00
transitionDeepBestToFail8	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 0.00
transitionDeepBestToFail8Less Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 0.00
transitionDeepBestToFail9	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 0.00
transitionDeepBestToFail10	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 0.00
transitionDeepBestToFail9Less Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 0.00
transitionDeepBestToFail10Less Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 0.00
transitionOAtoTKA	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAtoFullNon Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAtoFullMore Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAtoFullMorbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo1Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo1More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo1Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo2Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo2More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo2Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo3Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -

transitionTKAFullToNo3More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo3Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo4Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo4More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo4Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo5Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo5More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo5Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo6Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo6More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo6Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo7Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo7More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo7Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo8Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo8More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo8Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo9Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo9More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo9Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo10Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo10More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionTKAFullToNo10Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionToFullNon Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionToFullMore Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionToFullMorbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo1Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo1More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo1Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo2Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo2More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo2Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo3Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo3More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo3Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo4Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -

transitionRevisionFullToNo4More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo4Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo5Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo5More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo5Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo6Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo6More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo6Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo7Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo7More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo7Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo8Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo8More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo8Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo9Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo9More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo9Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo10Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo10More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionRevisionFullToNo10Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
tranistionToDeath	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
tranistionToDeathNon Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
tranistionToDeathMore Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
tranistionToDeathMorbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
complicationVTENon Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
complicationVTEMore Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
complicationVTEMorbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
complicationWoundNon Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
complicationWoundMore Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
complicationWoundMorbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
complicationDeepInfectionNon Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
complicationDeepInfectionMore Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
complicationDeepInfectionMorbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
costTKANon Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
costTKAMore Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
costTKAMorbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -

costRevisionNon Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
costRevisionMore Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
costRevisionMorbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
complicationDeepVTENon Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
complicationDeepVTEMore Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
complicationDeepVTEMorbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
complicationDeepWoundNon Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
complicationDeepWoundMore Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
complicationDeepWoundMorbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
complicationDeepSubsequentDeepNon Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
complicationDeepSubsequentDeepMore Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
complicationDeepSubsequentDeepMorbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepRevisionToBestNon Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepRevisionToBestMore Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepRevisionToBestMorbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail1Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail1More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail1Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail2Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail2More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail2Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail3Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail3More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail3Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail4Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail4More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail4Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail5Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail5More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail5Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail6Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail6More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail6Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail7Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail7More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail7Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -

transitionDeepBestToFail8Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail8More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail8Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail9Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail9More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail9Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail10Non Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail10More Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
transitionDeepBestToFail10Morbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
costsDeepRevisionNon Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
costsDeepRevisionMore Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -
costsDeepRevisionMorbid Obese	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ 33,891.07	$ -

Table B-4 Full Univariate Sensitivity Analysis Results for Class II Obese Population

Class II Obesity					
Base	**$ 46,378.84**				
Parameter Name	**Low**	**High**	**Min**	**Max**	**Gap**
qalyFull	$ (76,711.56)	$ 15,191.59	$ 750,000.00	$ 15,191.59	$ 734,808.41
transitionRevisionToFull	$ 698,500.30	$ 33,560.76	$ 33,560.76	$ 698,500.30	$ 664,939.53
transitionTKAtoFull	$ 305,261.61	$ 34,508.85	$ 34,508.85	$ 305,261.61	$ 270,752.77
qalyOA	$ 41,521.07	$ 288,083.10	$ 41,521.07	$ 288,083.10	$ 246,562.04
complicationDeepInfectionMore Obese	$ 26,346.74	$ 243,132.13	$ 26,346.74	$ 243,132.13	$ 216,785.39
complicationDeepInfection	$ 20,613.69	$ 161,751.67	$ 20,613.69	$ 161,751.67	$ 141,137.97
costOATreatment	$ 76,709.77	$ (14,283.01)	$ (14,283.01)	$ 76,709.77	$ 90,992.78
qalyDecRevision	$ 41,321.65	$ 119,526.47	$ 41,321.65	$ 119,526.47	$ 78,204.82
costRevision	$ 24,399.73	$ 90,337.07	$ 24,399.73	$ 90,337.07	$ 65,937.33
costTKA	$ 29,789.62	$ 79,557.28	$ 29,789.62	$ 79,557.28	$ 49,767.66
transitionDeepLateToRevision	$ 46,378.84	$ 76,346.31	$ 46,378.84	$ 76,346.31	$ 29,967.47
qalyDecTKA	$ 39,628.32	$ 68,922.20	$ 39,628.32	$ 68,922.20	$ 29,293.88
transitionRevisionToFullMore Obese	$ 33,327.40	$ 58,039.07	$ 33,327.40	$ 58,039.07	$ 24,711.67
transitionRevisionFullToNo1	$ 46,120.09	$ 67,755.64	$ 46,120.09	$ 67,755.64	$ 21,635.55
costsDeepContinuingWorst	$ 39,753.70	$ 59,629.12	$ 39,753.70	$ 59,629.12	$ 19,875.42
transitionTKAFullToNo10	$ 30,190.08	$ 50,027.86	$ 30,190.08	$ 50,027.86	$ 19,837.78
transitionTKAtoFullMore Obese	$ 35,319.02	$ 53,048.87	$ 35,319.02	$ 53,048.87	$ 17,729.85
qalyFailed	$ 58,031.48	$ 40,425.32	$ 40,425.32	$ 58,031.48	$ 17,606.16
transitionRevisionFullToNo2	$ 46,114.72	$ 63,451.36	$ 46,114.72	$ 63,451.36	$ 17,336.64

transitionTKAFullToNo1	$ 45,389.13	$ 61,410.69	$ 45,389.13	$ 61,410.69	$ 16,021.56
Discount Rate	$ 40,702.46	$ 55,880.17	$ 40,702.46	$ 55,880.17	$ 15,177.71
transitionLateFailureToRevision	$ 58,972.85	$ 44,691.09	$ 44,691.09	$ 58,972.85	$ 14,281.77
Age	$ 41,042.30	$ 55,297.29	$ 41,042.30	$ 55,297.29	$ 14,254.99
transitionTKAFullToNo2	$ 44,549.63	$ 58,557.38	$ 44,549.63	$ 58,557.38	$ 14,007.75
transitionRevisionFullToNo3	$ 45,830.34	$ 59,672.16	$ 45,830.34	$ 59,672.16	$ 13,841.82
transitionTKAFullToNo3	$ 44,438.91	$ 56,631.10	$ 44,438.91	$ 56,631.10	$ 12,192.19
transitionRevisionFullToNo4	$ 45,694.78	$ 56,763.14	$ 45,694.78	$ 56,763.14	$ 11,068.36
transitionTKAFullToNo10More Obese	$ 41,644.77	$ 52,386.71	$ 41,644.77	$ 52,386.71	$ 10,741.94
transitionTKAFullToNo4	$ 44,705.71	$ 55,234.96	$ 44,705.71	$ 55,234.96	$ 10,529.25
qalyDeepWorstDecrement	$ 52,171.10	$ 41,744.22	$ 41,744.22	$ 52,171.10	$ 10,426.88
costsDeepRevision	$ 43,301.72	$ 52,533.09	$ 43,301.72	$ 52,533.09	$ 9,231.37
transitionTKAFullToNo5	$ 44,672.15	$ 53,685.01	$ 44,672.15	$ 53,685.01	$ 9,012.86
transitionRevisionFullToNo5	$ 45,812.87	$ 54,637.70	$ 45,812.87	$ 54,637.70	$ 8,824.82
transitionRevisionFullToNo10	$ 41,946.72	$ 50,401.24	$ 41,946.72	$ 50,401.24	$ 8,454.52
transitionTKAFullToNo6	$ 44,632.79	$ 52,268.64	$ 44,632.79	$ 52,268.64	$ 7,635.85
transitionRevisionFullToNo6	$ 45,849.37	$ 52,840.53	$ 45,849.37	$ 52,840.53	$ 6,991.16
transitionDeepEarlyToRevision	$ 46,378.84	$ 52,864.26	$ 46,378.84	$ 52,864.26	$ 6,485.42
transitionTKAFullToNo7	$ 43,984.69	$ 50,419.24	$ 43,984.69	$ 50,419.24	$ 6,434.56
transitionRevisionFullToNo7	$ 45,869.89	$ 51,361.01	$ 45,869.89	$ 51,361.01	$ 5,491.13
transitionTKAFullToNo8	$ 43,439.66	$ 48,823.38	$ 43,439.66	$ 48,823.38	$ 5,383.73
tranistionEarlyFailureToRevision	$ 51,597.49	$ 46,378.84	$ 46,378.84	$ 51,597.49	$ 5,218.65
costDeepInfection	$ 44,655.68	$ 49,825.16	$ 44,655.68	$ 49,825.16	$ 5,169.48
transitionTKAFullToNo9	$ 42,815.31	$ 47,316.08	$ 42,815.31	$ 47,316.08	$ 4,500.77
transitionRevisionFullToNo8	$ 45,962.26	$ 50,210.43	$ 45,962.26	$ 50,210.43	$ 4,248.16
costFailure	$ 44,980.65	$ 49,175.22	$ 44,980.65	$ 49,175.22	$ 4,194.57
costPostOpTKA	$ 45,097.78	$ 48,940.97	$ 45,097.78	$ 48,940.97	$ 3,843.19
complicationDeepSubsequentDeepMore Obese	$ 45,639.44	$ 49,326.41	$ 45,639.44	$ 49,326.41	$ 3,686.96
complicationDeepVTE	$ 46,362.33	$ 49,857.91	$ 46,362.33	$ 49,857.91	$ 3,495.58
transitionTKAFullToNo9More Obese	$ 45,113.73	$ 48,450.00	$ 45,113.73	$ 48,450.00	$ 3,336.27
transitionRevisionFullToNo9	$ 45,646.12	$ 48,966.88	$ 45,646.12	$ 48,966.88	$ 3,320.76
transitionRevisionFullToNo10More Obese	$ 45,084.40	$ 47,947.73	$ 45,084.40	$ 47,947.73	$ 2,863.33
complicationWound	$ 46,227.72	$ 49,024.40	$ 46,227.72	$ 49,024.40	$ 2,796.69
transitionTKAFullToNo8More Obese	$ 45,337.87	$ 48,077.18	$ 45,337.87	$ 48,077.18	$ 2,739.31
qalyDecDeepInfection	$ 45,996.48	$ 48,303.00	$ 45,996.48	$ 48,303.00	$ 2,306.53
qalyDeepRevisionDecrement	$ 46,012.38	$ 48,302.50	$ 46,012.38	$ 48,302.50	$ 2,290.11

transitionTKAFullToNo7More Obese	$ 45,532.67	$ 47,755.25	$ 45,532.67	$ 47,755.25	$ 2,222.58
complicationVTE	$ 45,740.61	$ 47,619.80	$ 45,740.61	$ 47,619.80	$ 1,879.20
transitionTKAFullToNo3More Obese	$ 45,694.37	$ 47,489.52	$ 45,694.37	$ 47,489.52	$ 1,795.16
transitionTKAFullToNo2More Obese	$ 45,733.70	$ 47,425.07	$ 45,733.70	$ 47,425.07	$ 1,691.37
transitionTKAFullToNo6More Obese	$ 45,763.26	$ 47,376.62	$ 45,763.26	$ 47,376.62	$ 1,613.37
transitionTKAFullToNo5More Obese	$ 45,777.22	$ 47,353.80	$ 45,777.22	$ 47,353.80	$ 1,576.58
transitionTKAFullToNo4More Obese	$ 45,789.12	$ 47,334.35	$ 45,789.12	$ 47,334.35	$ 1,545.23
costsDeepSubsequentDeep	$ 45,933.12	$ 47,270.30	$ 45,933.12	$ 47,270.30	$ 1,337.18
costRevisionMore Obese	$ 45,952.06	$ 47,232.40	$ 45,952.06	$ 47,232.40	$ 1,280.34
costTKAMore Obese	$ 46,056.72	$ 47,023.08	$ 46,056.72	$ 47,023.08	$ 966.36
costVTE	$ 46,068.99	$ 46,998.55	$ 46,068.99	$ 46,998.55	$ 929.56
transitionTKAFullToNo1More Obese	$ 46,030.91	$ 46,940.49	$ 46,030.91	$ 46,940.49	$ 909.58
transitionRevisionFullToNo9More Obese	$ 46,119.06	$ 46,775.95	$ 46,119.06	$ 46,775.95	$ 656.89
transitionDeepBestToFail1	$ 45,799.57	$ 46,453.22	$ 45,799.57	$ 46,453.22	$ 653.64
transitionRevisionFullToNo4More Obese	$ 46,135.81	$ 46,751.45	$ 46,135.81	$ 46,751.45	$ 615.65
qalyDeepSubsequentDeepDecrement	$ 46,279.27	$ 46,861.71	$ 46,279.27	$ 46,861.71	$ 582.44
qalyDeepBestCase	$ 46,657.44	$ 46,103.55	$ 46,103.55	$ 46,657.44	$ 553.89
transitionRevisionFullToNo5More Obese	$ 46,178.09	$ 46,685.94	$ 46,178.09	$ 46,685.94	$ 507.86
transitionRevisionFullToNo3More Obese	$ 46,184.23	$ 46,676.65	$ 46,184.23	$ 46,676.65	$ 492.42
transitionRevisionFullToNo6More Obese	$ 46,191.17	$ 46,665.65	$ 46,191.17	$ 46,665.65	$ 474.48
transitionRevisionFullToNo7More Obese	$ 46,198.55	$ 46,654.14	$ 46,198.55	$ 46,654.14	$ 455.60
complicationDeepSubsequentDeep	$ 46,157.47	$ 46,600.43	$ 46,157.47	$ 46,600.43	$ 442.96
qalyDecObesity	$ 46,575.78	$ 46,187.46	$ 46,187.46	$ 46,575.78	$ 388.32
transitionRevisionFullToNo8More Obese	$ 46,231.45	$ 46,603.51	$ 46,231.45	$ 46,603.51	$ 372.06
transitionDeepRevisionToBest	$ 46,562.75	$ 46,195.90	$ 46,195.90	$ 46,562.75	$ 366.84
transitionDeepBestToFail1More Obese	$ 46,174.34	$ 46,453.22	$ 46,174.34	$ 46,453.22	$ 278.87
transitionRevisionFullToNo2More Obese	$ 46,285.44	$ 46,521.14	$ 46,285.44	$ 46,521.14	$ 235.70
transitionRevisionFullToNo1More Obese	$ 46,287.34	$ 46,518.23	$ 46,287.34	$ 46,518.23	$ 230.90
complicationWoundMore Obese	$ 46,303.12	$ 46,530.62	$ 46,303.12	$ 46,530.62	$ 227.49
costWound	$ 46,306.20	$ 46,524.13	$ 46,306.20	$ 46,524.13	$ 217.93
tranistionToDeathMore Obese	$ 46,288.63	$ 46,470.22	$ 46,288.63	$ 46,470.22	$ 181.60
costsDeepRevisionMore Obese	$ 46,319.09	$ 46,498.34	$ 46,319.09	$ 46,498.34	$ 179.25
qalyDecVTE	$ 46,360.06	$ 46,512.20	$ 46,360.06	$ 46,512.20	$ 152.14
transitionDeepRevisionToBestMore Obese	$ 46,322.75	$ 46,409.04	$ 46,322.75	$ 46,409.04	$ 86.28
complicationDeepWound	$ 46,374.93	$ 46,447.13	$ 46,374.93	$ 46,447.13	$ 72.19
transitionDeepBestToFail2	$ 46,318.05	$ 46,386.63	$ 46,318.05	$ 46,386.63	$ 68.58

qalyDecWound	$ 46,372.99	$ 46,440.03	$ 46,372.99	$ 46,440.03	$ 67.04
complicationVTEMore Obese	$ 46,359.27	$ 46,399.03	$ 46,359.27	$ 46,399.03	$ 39.76
transitionDeepBestToFail2More Obese	$ 46,357.41	$ 46,386.63	$ 46,357.41	$ 46,386.63	$ 29.22
costsDeepContinuingBest	$ 46,369.62	$ 46,397.30	$ 46,369.62	$ 46,397.30	$ 27.68
costsDeepVTE	$ 46,370.83	$ 46,394.87	$ 46,370.83	$ 46,394.87	$ 24.04
transitionDeepBestToFail3	$ 46,372.50	$ 46,379.66	$ 46,372.50	$ 46,379.66	$ 7.16
complicationDeepWoundMore Obese	$ 46,376.88	$ 46,382.77	$ 46,376.88	$ 46,382.77	$ 5.88
costsDeepWound	$ 46,376.96	$ 46,382.60	$ 46,376.96	$ 46,382.60	$ 5.64
qalyDeepVTEDecrement	$ 46,378.36	$ 46,382.28	$ 46,378.36	$ 46,382.28	$ 3.93
transitionDeepBestToFail3More Obese	$ 46,376.61	$ 46,379.66	$ 46,376.61	$ 46,379.66	$ 3.05
qalyDeepWoundDecrement	$ 46,378.69	$ 46,380.42	$ 46,378.69	$ 46,380.42	$ 1.73
complicationDeepVTEMore Obese	$ 46,378.34	$ 46,379.37	$ 46,378.34	$ 46,379.37	$ 1.03
transitionDeepBestToFail4	$ 46,378.18	$ 46,378.93	$ 46,378.18	$ 46,378.93	$ 0.74
transitionDeepBestToFail4More Obese	$ 46,378.61	$ 46,378.93	$ 46,378.61	$ 46,378.93	$ 0.32
transitionDeepBestToFail5	$ 46,378.77	$ 46,378.85	$ 46,378.77	$ 46,378.85	$ 0.08
transitionDeepBestToFail5More Obese	$ 46,378.82	$ 46,378.85	$ 46,378.82	$ 46,378.85	$ 0.03
transitionDeepBestToFail6	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 0.01
transitionDeepBestToFail6More Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 0.00
transitionDeepBestToFail7	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 0.00
transitionDeepBestToFail7More Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 0.00
transitionDeepBestToFail8	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 0.00
transitionDeepBestToFail8More Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 0.00
transitionDeepBestToFail9	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 0.00
transitionDeepBestToFail10	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 0.00
transitionDeepBestToFail9More Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 0.00
transitionDeepBestToFail10More Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 0.00
transitionOAtoTKA	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAtoFullNon Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAtoFullLess Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAtoFullMorbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo1Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo1Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo1Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo2Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo2Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo2Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -

transitionTKAFullToNo3Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo3Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo3Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo4Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo4Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo4Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo5Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo5Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo5Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo6Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo6Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo6Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo7Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo7Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo7Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo8Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo8Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo8Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo9Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo9Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo9Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo10Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo10Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionTKAFullToNo10Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionToFullNon Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionToFullLess Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionToFullMorbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo1Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo1Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo1Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo2Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo2Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo2Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo3Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo3Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo3Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -

transitionRevisionFullToNo4Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo4Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo4Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo5Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo5Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo5Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo6Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo6Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo6Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo7Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo7Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo7Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo8Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo8Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo8Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo9Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo9Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo9Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo10Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo10Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionRevisionFullToNo10Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
tranistionToDeath	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
tranistionToDeathNon Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
tranistionToDeathLess Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
tranistionToDeathMorbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
complicationVTENon Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
complicationVTELess Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
complicationVTEMorbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
complicationWoundNon Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
complicationWoundLess Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
complicationWoundMorbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
complicationDeepInfectionNon Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
complicationDeepInfectionLess Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
complicationDeepInfectionMorbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
costTKANon Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
costTKALess Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -

costTKAMorbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
costRevisionNon Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
costRevisionLess Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
costRevisionMorbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
complicationDeepVTENon Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
complicationDeepVTELess Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
complicationDeepVTEMorbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
complicationDeepWoundNon Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
complicationDeepWoundLess Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
complicationDeepWoundMorbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
complicationDeepSubsequentDeepNon Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
complicationDeepSubsequentDeepLess Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
complicationDeepSubsequentDeepMorbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepRevisionToBestNon Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepRevisionToBestLess Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepRevisionToBestMorbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail1Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail1Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail1Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail2Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail2Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail2Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail3Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail3Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail3Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail4Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail4Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail4Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail5Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail5Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail5Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail6Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail6Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail6Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail7Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail7Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -

transitionDeepBestToFail7Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail8Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail8Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail8Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail9Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail9Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail9Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail10Non Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail10Less Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
transitionDeepBestToFail10Morbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
costsDeepRevisionNon Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
costsDeepRevisionLess Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -
costsDeepRevisionMorbid Obese	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ 46,378.84	$ -

Table B-5 Full Univariate Sensitivity Analysis Results for Class III Obese Population

Class III Obesity					
Base	$				80,670.88
Parameter Name	Low	High	Min	Max	Gap
qalyFull	$ (97,999.80)	$ 24,206.66	$ 2,500,000.00	$ 24,206.66	$ 2,475,793.34
qalyOA	$ 65,447.03	$ (1,522,558.19)	$ 2,500,000.00	$ 65,447.03	$ 2,434,552.97
transitionRevisionToFull	$ 2,109,925.01	$ 61,457.00	$ 61,457.00	$ 2,109,925.01	$ 2,048,468.01
complicationDeepInfection	$ 25,296.31	$ 1,009,654.42	$ 25,296.31	$ 1,009,654.42	$ 984,358.11
transitionTKAtoFull	$ 981,470.25	$ 61,494.83	$ 61,494.83	$ 981,470.25	$ 919,975.42
complicationDeepInfectionMorbid Obese	$ 40,604.37	$ 568,115.45	$ 40,604.37	$ 568,115.45	$ 527,511.09
qalyDecRevision	$ 70,919.20	$ 258,208.62	$ 70,919.20	$ 258,208.62	$ 187,289.42
costOATreatment	$ 116,089.19	$ 9,834.27	$ 9,834.27	$ 116,089.19	$ 106,254.92
costRevision	$ 54,538.25	$ 132,936.15	$ 54,538.25	$ 132,936.15	$ 78,397.90
transitionDeepLateToRevision	$ 80,670.88	$ 158,810.17	$ 80,670.88	$ 158,810.17	$ 78,139.29
qalyDecTKA	$ 66,938.55	$ 133,100.32	$ 66,938.55	$ 133,100.32	$ 66,161.77
costTKA	$ 59,528.60	$ 122,955.44	$ 59,528.60	$ 122,955.44	$ 63,426.84
transitionLateFailureToRevision	$ 120,321.80	$ 76,877.81	$ 76,877.81	$ 120,321.80	$ 43,443.99
costsDeepContinuingWorst	$ 67,537.35	$ 106,937.96	$ 67,537.35	$ 106,937.96	$ 39,400.62
qalyDeepWorstDecrement	$ 103,486.08	$ 66,098.41	$ 66,098.41	$ 103,486.08	$ 37,387.66
transitionRevisionToFullMorbid Obese	$ 61,110.69	$ 98,483.60	$ 61,110.69	$ 98,483.60	$ 37,372.91
qalyFailed	$ 104,212.89	$ 69,204.73	$ 69,204.73	$ 104,212.89	$ 35,008.16
transitionRevisionFullToNo1	$ 80,287.68	$ 112,774.41	$ 80,287.68	$ 112,774.41	$ 32,486.73

transitionTKAtoFullMorbid Obese	$ 62,774.98	$ 91,856.69	$ 62,774.98	$ 91,856.69	$ 29,081.71
transitionTKAFullToNo10	$ 57,483.76	$ 86,116.36	$ 57,483.76	$ 86,116.36	$ 28,632.61
transitionTKAFullToNo1	$ 79,070.22	$ 105,729.65	$ 79,070.22	$ 105,729.65	$ 26,659.42
transitionRevisionFullToNo2	$ 80,281.48	$ 106,084.69	$ 80,281.48	$ 106,084.69	$ 25,803.21
transitionTKAFullToNo2	$ 77,729.35	$ 100,767.05	$ 77,729.35	$ 100,767.05	$ 23,037.70
Discount Rate	$ 72,406.32	$ 94,775.16	$ 72,406.32	$ 94,775.16	$ 22,368.84
transitionRevisionFullToNo3	$ 79,866.19	$ 100,299.21	$ 79,866.19	$ 100,299.21	$ 20,433.02
transitionTKAFullToNo3	$ 77,565.75	$ 97,444.08	$ 77,565.75	$ 97,444.08	$ 19,878.33
costsDeepRevision	$ 74,045.03	$ 93,922.58	$ 74,045.03	$ 93,922.58	$ 19,877.55
Age	$ 75,010.93	$ 94,450.14	$ 75,010.93	$ 94,450.14	$ 19,439.22
transitionTKAFullToNo4	$ 78,004.37	$ 95,046.93	$ 78,004.37	$ 95,046.93	$ 17,042.56
transitionDeepEarlyToRevision	$ 80,670.88	$ 97,221.73	$ 80,670.88	$ 97,221.73	$ 16,550.85
transitionRevisionFullToNo4	$ 79,672.39	$ 95,891.46	$ 79,672.39	$ 95,891.46	$ 16,219.07
transitionTKAFullToNo10Morbid Obese	$ 73,736.53	$ 89,686.98	$ 73,736.53	$ 89,686.98	$ 15,950.46
transitionTKAFullToNo5	$ 77,965.28	$ 92,431.39	$ 77,965.28	$ 92,431.39	$ 14,466.11
transitionRevisionFullToNo5	$ 79,849.10	$ 92,693.44	$ 79,849.10	$ 92,693.44	$ 12,844.34
transitionTKAFullToNo6	$ 77,919.06	$ 90,070.15	$ 77,919.06	$ 90,070.15	$ 12,151.10
transitionRevisionFullToNo10	$ 74,667.01	$ 86,254.66	$ 74,667.01	$ 86,254.66	$ 11,587.66
tranistionEarlyFailureToRevision	$ 91,466.04	$ 80,670.88	$ 80,670.88	$ 91,466.04	$ 10,795.15
costDeepInfection	$ 77,164.72	$ 87,683.22	$ 77,164.72	$ 87,683.22	$ 10,518.51
complicationDeepVTE	$ 80,622.96	$ 90,807.22	$ 80,622.96	$ 90,807.22	$ 10,184.26
transitionTKAFullToNo7	$ 76,925.77	$ 87,055.55	$ 76,925.77	$ 87,055.55	$ 10,129.78
transitionRevisionFullToNo6	$ 79,906.42	$ 90,014.32	$ 79,906.42	$ 90,014.32	$ 10,107.90
complicationDeepSubsequentDeepMorbid Obese	$ 78,210.12	$ 87,997.32	$ 78,210.12	$ 87,997.32	$ 9,787.20
qalyDecDeepInfection	$ 79,329.06	$ 87,786.32	$ 79,329.06	$ 87,786.32	$ 8,457.26
qalyDeepRevisionDecrement	$ 79,384.43	$ 87,784.36	$ 79,384.43	$ 87,784.36	$ 8,399.94
transitionTKAFullToNo8	$ 76,109.82	$ 84,495.28	$ 76,109.82	$ 84,495.28	$ 8,385.46
transitionRevisionFullToNo7	$ 79,940.48	$ 87,826.65	$ 79,940.48	$ 87,826.65	$ 7,886.17
transitionTKAFullToNo9	$ 75,189.42	$ 82,121.92	$ 75,189.42	$ 82,121.92	$ 6,932.50
transitionRevisionFullToNo8	$ 80,076.96	$ 86,135.90	$ 80,076.96	$ 86,135.90	$ 6,058.94
complicationVTEMorbid Obese	$ 79,804.82	$ 85,290.06	$ 79,804.82	$ 85,290.06	$ 5,485.24
transitionTKAFullToNo9Morbid Obese	$ 78,718.45	$ 83,882.68	$ 78,718.45	$ 83,882.68	$ 5,164.24
costsDeepSubsequentDeep	$ 79,096.60	$ 83,819.46	$ 79,096.60	$ 83,819.46	$ 4,722.86
transitionRevisionFullToNo9	$ 79,633.81	$ 84,334.36	$ 79,633.81	$ 84,334.36	$ 4,700.55
costFailure	$ 79,110.35	$ 83,791.94	$ 79,110.35	$ 83,791.94	$ 4,681.59
costPostOpTKA	$ 79,218.75	$ 83,575.15	$ 79,218.75	$ 83,575.15	$ 4,356.40

transitionTKAFullToNo8Morbid Obese	$ 79,050.87	$ 83,324.88	$ 79,050.87	$ 83,324.88	$ 4,274.01
transitionRevisionFullToNo10Morbid Obese	$ 78,902.36	$ 82,832.66	$ 78,902.36	$ 82,832.66	$ 3,930.30
qalyDeepSubsequentDeepDecrement	$ 80,062.50	$ 83,717.67	$ 80,062.50	$ 83,717.67	$ 3,655.18
transitionTKAFullToNo7Morbid Obese	$ 79,344.01	$ 82,836.76	$ 79,344.01	$ 82,836.76	$ 3,492.74
complicationVTE	$ 79,604.25	$ 82,746.37	$ 79,604.25	$ 82,746.37	$ 3,142.11
complicationWound	$ 80,511.34	$ 83,463.96	$ 80,511.34	$ 83,463.96	$ 2,952.62
transitionTKAFullToNo3Morbid Obese	$ 79,572.84	$ 82,458.36	$ 79,572.84	$ 82,458.36	$ 2,885.53
transitionTKAFullToNo2Morbid Obese	$ 79,631.20	$ 82,362.16	$ 79,631.20	$ 82,362.16	$ 2,730.96
transitionTKAFullToNo6Morbid Obese	$ 79,698.91	$ 82,250.46	$ 79,698.91	$ 82,250.46	$ 2,551.55
transitionTKAFullToNo5Morbid Obese	$ 79,715.36	$ 82,223.47	$ 79,715.36	$ 82,223.47	$ 2,508.11
transitionTKAFullToNo4Morbid Obese	$ 79,729.26	$ 82,200.66	$ 79,729.26	$ 82,200.66	$ 2,471.40
costRevisionMorbid Obese	$ 79,711.89	$ 82,109.38	$ 79,711.89	$ 82,109.38	$ 2,397.49
qalyDecObesity	$ 81,701.14	$ 79,686.16	$ 79,686.16	$ 81,701.14	$ 2,014.98
qalyDeepBestCase	$ 81,662.85	$ 79,702.73	$ 79,702.73	$ 81,662.85	$ 1,960.13
costTKAMorbid Obese	$ 79,895.02	$ 81,834.68	$ 79,895.02	$ 81,834.68	$ 1,939.66
complicationDeepSubsequentDeep	$ 79,831.82	$ 81,512.80	$ 79,831.82	$ 81,512.80	$ 1,680.98
costVTE	$ 80,163.95	$ 81,684.75	$ 80,163.95	$ 81,684.75	$ 1,520.80
transitionDeepBestToFail1	$ 79,347.80	$ 80,841.18	$ 79,347.80	$ 80,841.18	$ 1,493.38
transitionTKAFullToNo1Morbid Obese	$ 80,107.50	$ 81,581.87	$ 80,107.50	$ 81,581.87	$ 1,474.37
transitionDeepRevisionToBest	$ 81,230.08	$ 80,117.63	$ 80,117.63	$ 81,230.08	$ 1,112.45
transitionRevisionFullToNo9Morbid Obese	$ 80,303.20	$ 81,232.95	$ 80,303.20	$ 81,232.95	$ 929.76
transitionRevisionFullToNo4Morbid Obese	$ 80,316.08	$ 81,214.98	$ 80,316.08	$ 81,214.98	$ 898.90
transitionRevisionFullToNo5Morbid Obese	$ 80,379.36	$ 81,116.89	$ 80,379.36	$ 81,116.89	$ 737.54
transitionRevisionFullToNo3Morbid Obese	$ 80,385.33	$ 81,107.96	$ 80,385.33	$ 81,107.96	$ 722.63
transitionRevisionFullToNo6Morbid Obese	$ 80,399.90	$ 81,085.04	$ 80,399.90	$ 81,085.04	$ 685.14
transitionRevisionFullToNo7Morbid Obese	$ 80,412.13	$ 81,066.01	$ 80,412.13	$ 81,066.01	$ 653.88
transitionDeepBestToFail1Morbid Obese	$ 80,203.13	$ 80,841.18	$ 80,203.13	$ 80,841.18	$ 638.05
costsDeepRevisionMorbid Obese	$ 80,427.73	$ 81,035.61	$ 80,427.73	$ 81,035.61	$ 607.88
transitionRevisionFullToNo8Morbid Obese	$ 80,460.74	$ 80,991.21	$ 80,460.74	$ 80,991.21	$ 530.47
complicationWoundMorbid Obese	$ 80,560.80	$ 81,026.15	$ 80,560.80	$ 81,026.15	$ 465.35
qalyDecVTE	$ 80,617.45	$ 81,051.07	$ 80,617.45	$ 81,051.07	$ 433.62
tranistionToDeathMorbid Obese	$ 80,473.44	$ 80,872.78	$ 80,473.44	$ 80,872.78	$ 399.34
transitionRevisionFullToNo2Morbid Obese	$ 80,533.16	$ 80,880.72	$ 80,533.16	$ 80,880.72	$ 347.56
transitionRevisionFullToNo1Morbid Obese	$ 80,535.35	$ 80,877.37	$ 80,535.35	$ 80,877.37	$ 342.02
transitionDeepRevisionToBestMorbid Obese	$ 80,500.94	$ 80,762.49	$ 80,500.94	$ 80,762.49	$ 261.55
complicationDeepVTEMorbid Obese	$ 80,631.98	$ 80,877.72	$ 80,631.98	$ 80,877.72	$ 245.74

costWound	$ 80,596.33	$ 80,819.99	$ 80,596.33	$ 80,819.99	$ 223.66
transitionDeepBestToFail2	$ 80,532.04	$ 80,688.68	$ 80,532.04	$ 80,688.68	$ 156.64
complicationDeepWound	$ 80,663.72	$ 80,796.02	$ 80,663.72	$ 80,796.02	$ 132.30
qalyDecWound	$ 80,660.43	$ 80,780.11	$ 80,660.43	$ 80,780.11	$ 119.68
costsDeepVTE	$ 80,648.12	$ 80,716.41	$ 80,648.12	$ 80,716.41	$ 68.28
transitionDeepBestToFail2Morbid Obese	$ 80,621.92	$ 80,688.68	$ 80,621.92	$ 80,688.68	$ 66.76
costsDeepContinuingBest	$ 80,652.15	$ 80,708.36	$ 80,652.15	$ 80,708.36	$ 56.21
complicationDeepWoundMorbid Obese	$ 80,665.94	$ 80,686.83	$ 80,665.94	$ 80,686.83	$ 20.89
qalyDeepVTEDecrement	$ 80,668.48	$ 80,687.88	$ 80,668.48	$ 80,687.88	$ 19.39
transitionDeepBestToFail3	$ 80,656.42	$ 80,672.74	$ 80,656.42	$ 80,672.74	$ 16.32
costsDeepWound	$ 80,667.54	$ 80,677.58	$ 80,667.54	$ 80,677.58	$ 10.04
transitionDeepBestToFail3Morbid Obese	$ 80,665.78	$ 80,672.74	$ 80,665.78	$ 80,672.74	$ 6.95
qalyDeepWoundDecrement	$ 80,670.41	$ 80,675.78	$ 80,670.41	$ 80,675.78	$ 5.37
transitionDeepBestToFail4	$ 80,669.38	$ 80,671.08	$ 80,669.38	$ 80,671.08	$ 1.69
transitionDeepBestToFail4Morbid Obese	$ 80,670.36	$ 80,671.08	$ 80,670.36	$ 80,671.08	$ 0.72
transitionDeepBestToFail5	$ 80,670.73	$ 80,670.90	$ 80,670.73	$ 80,670.90	$ 0.17
transitionDeepBestToFail5Morbid Obese	$ 80,670.83	$ 80,670.90	$ 80,670.83	$ 80,670.90	$ 0.07
transitionDeepBestToFail6	$ 80,670.87	$ 80,670.89	$ 80,670.87	$ 80,670.89	$ 0.02
transitionDeepBestToFail6Morbid Obese	$ 80,670.88	$ 80,670.89	$ 80,670.88	$ 80,670.89	$ 0.01
transitionDeepBestToFail7	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 0.00
transitionDeepBestToFail7Morbid Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 0.00
transitionDeepBestToFail8	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 0.00
transitionDeepBestToFail8Morbid Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 0.00
transitionDeepBestToFail9	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 0.00
transitionDeepBestToFail10	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 0.00
transitionDeepBestToFail9Morbid Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 0.00
transitionDeepBestToFail10Morbid Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 0.00
transitionOAtoTKA	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAtoFullNon Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAtoFullLess Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAtoFullMore Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo1Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo1Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo1More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo2Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo2Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -

transitionTKAFullToNo2More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo3Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo3Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo3More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo4Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo4Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo4More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo5Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo5Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo5More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo6Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo6Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo6More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo7Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo7Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo7More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo8Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo8Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo8More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo9Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo9Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo9More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo10Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo10Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionTKAFullToNo10More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionToFullNon Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionToFullLess Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionToFullMore Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo1Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo1Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo1More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo2Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo2Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo2More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo3Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo3Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -

transitionRevisionFullToNo3More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo4Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo4Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo4More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo5Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo5Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo5More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo6Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo6Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo6More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo7Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo7Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo7More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo8Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo8Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo8More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo9Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo9Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo9More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo10Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo10Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionRevisionFullToNo10More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
tranistionToDeath	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
tranistionToDeathNon Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
tranistionToDeathLess Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
tranistionToDeathMore Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
complicationVTENon Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
complicationVTELess Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
complicationVTEMore Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
complicationWoundNon Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
complicationWoundLess Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
complicationWoundMore Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
complicationDeepInfectionNon Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
complicationDeepInfectionLess Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
complicationDeepInfectionMore Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
costTKANon Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -

costTKALess Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
costTKAMore Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
costRevisionNon Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
costRevisionLess Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
costRevisionMore Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
complicationDeepVTENon Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
complicationDeepVTELess Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
complicationDeepVTEMore Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
complicationDeepWoundNon Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
complicationDeepWoundLess Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
complicationDeepWoundMore Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
complicationDeepSubsequentDeepNon Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
complicationDeepSubsequentDeepLess Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
complicationDeepSubsequentDeepMore Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepRevisionToBestNon Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepRevisionToBestLess Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepRevisionToBestMore Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail1Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail1Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail1More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail2Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail2Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail2More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail3Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail3Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail3More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail4Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail4Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail4More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail5Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail5Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail5More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail6Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail6Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail6More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail7Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -

transitionDeepBestToFail7Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail7More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail8Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail8Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail8More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail9Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail9Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail9More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail10Non Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail10Less Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
transitionDeepBestToFail10More Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
costsDeepRevisionNon Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
costsDeepRevisionLess Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -
costsDeepRevisionMore Obese	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ 80,670.88	$ -

APPENDIX C:
Verification of Population

The population used in the ABM was synthetically created to match the US population on age, gender, obesity, and OA. The 1995 population was created and allowed to age and die. OA and obesity trends were also applied. Given the available data, these model population demographics were periodically checked against the historical patterns. The following graphs were used to verify that the population design reasonably reflected the population it was meant to represent (Figures C-1 - 12).

Age and Gender

Figure C-1 Female 1995 Population by Age: Census Expected versus Model Observed

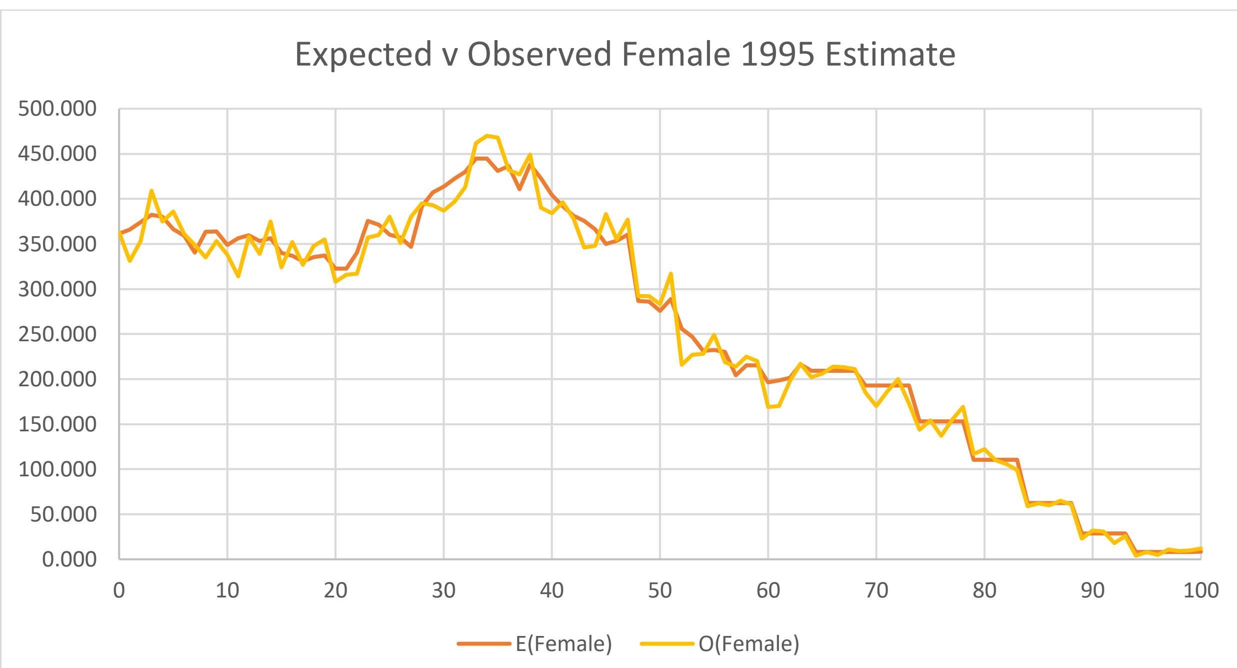


Figure C-2 Male 1995 Population by Age: Census Expected versus Model Observed

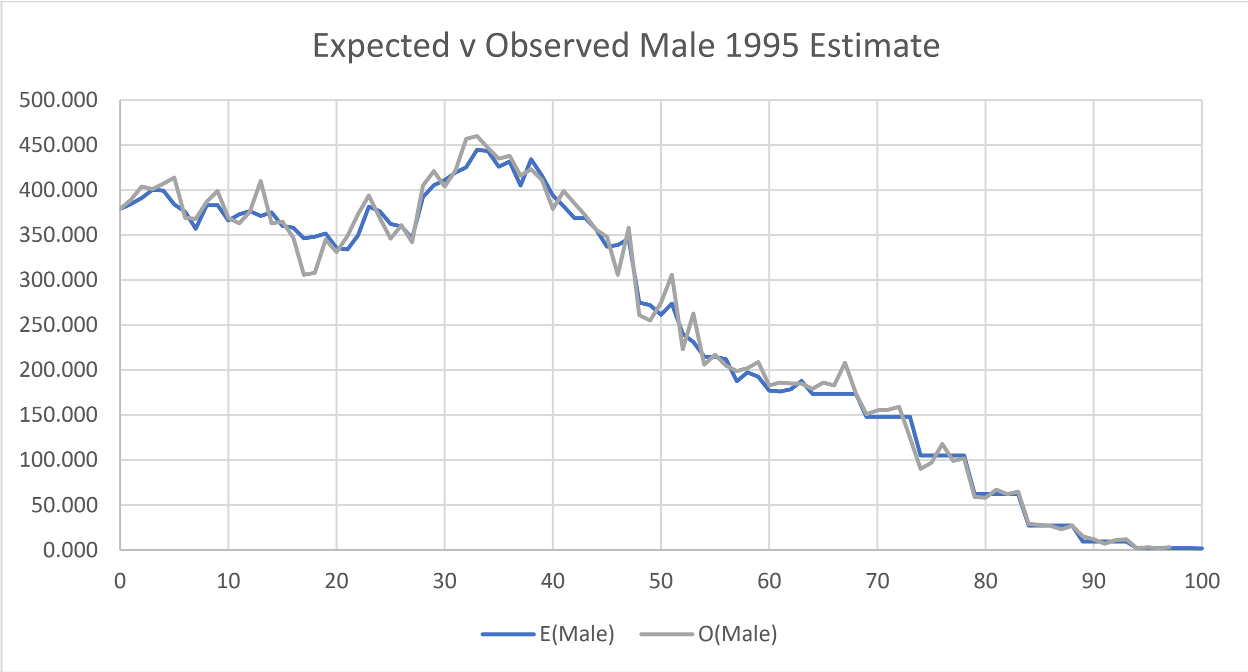


Figure C-3 Female 2010 Population by Age: Census Expected versus Model Observed

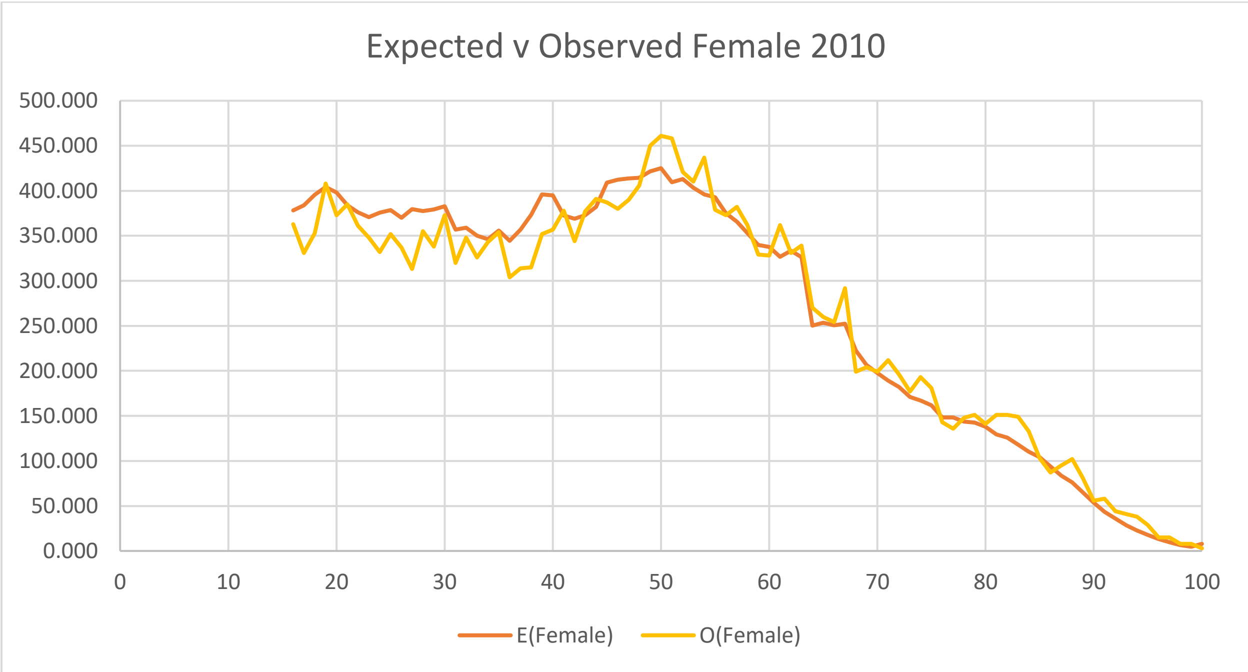


Figure C-4 Male 2010 Population by Age: Census Expected versus Model Observed

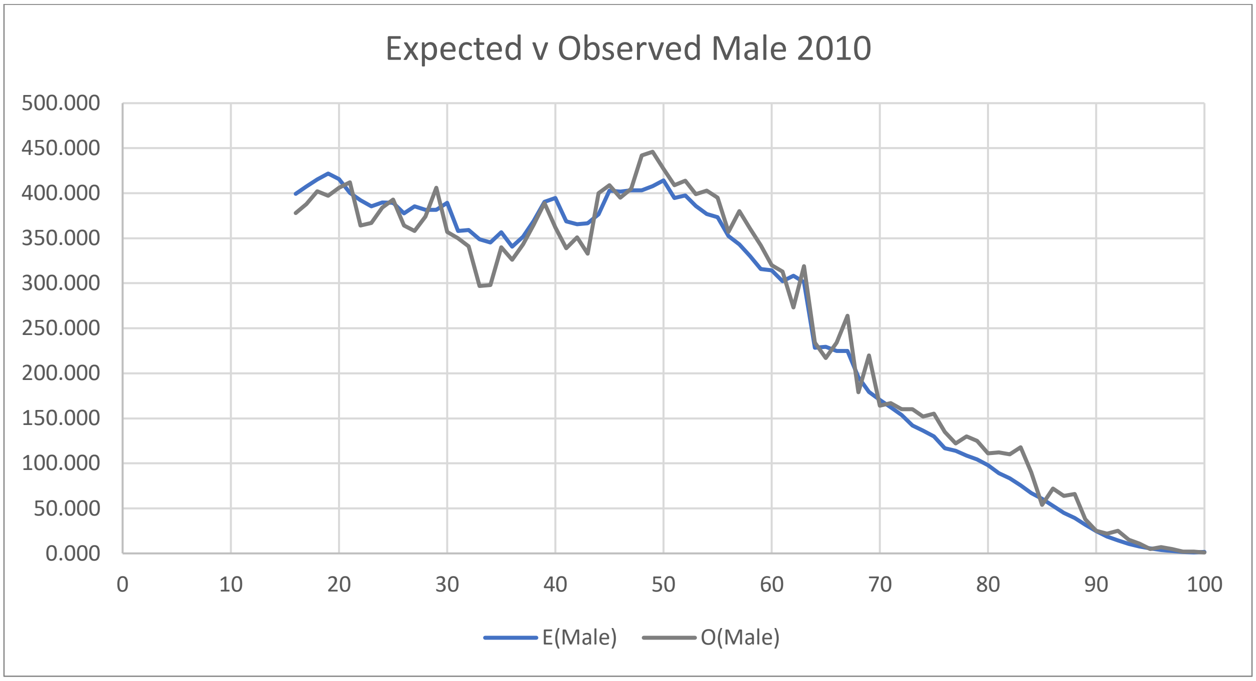


Figure C-5 Female 2015 Population by Age: Census Expected versus Model Observed

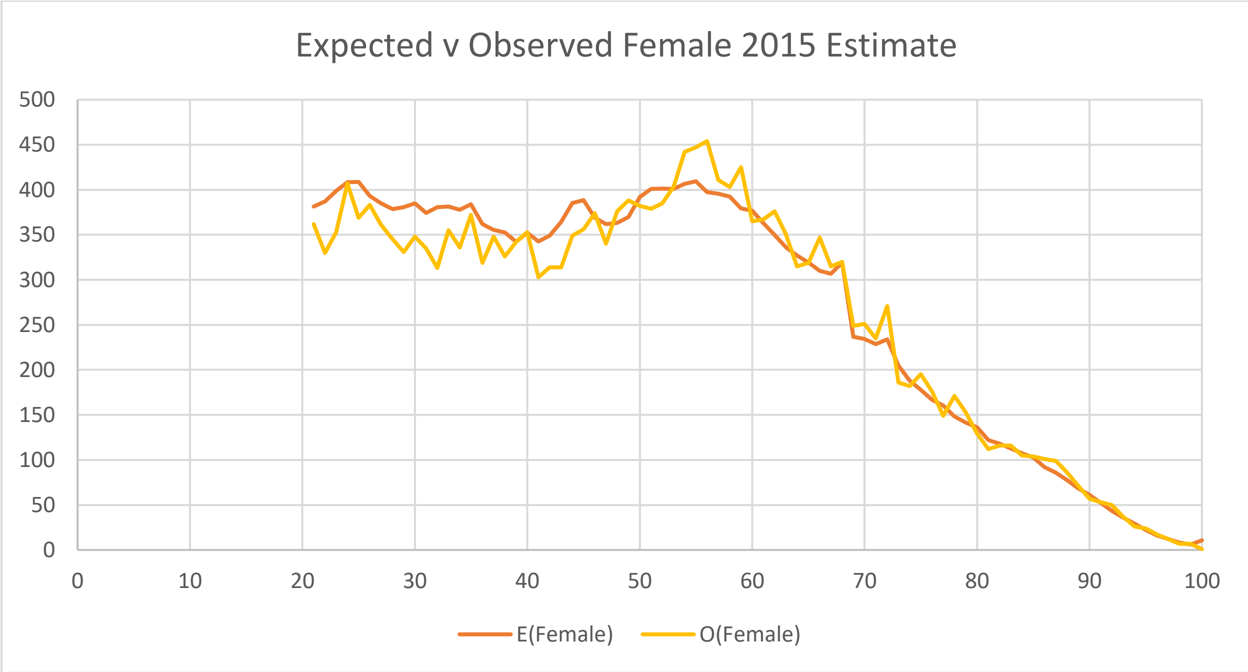
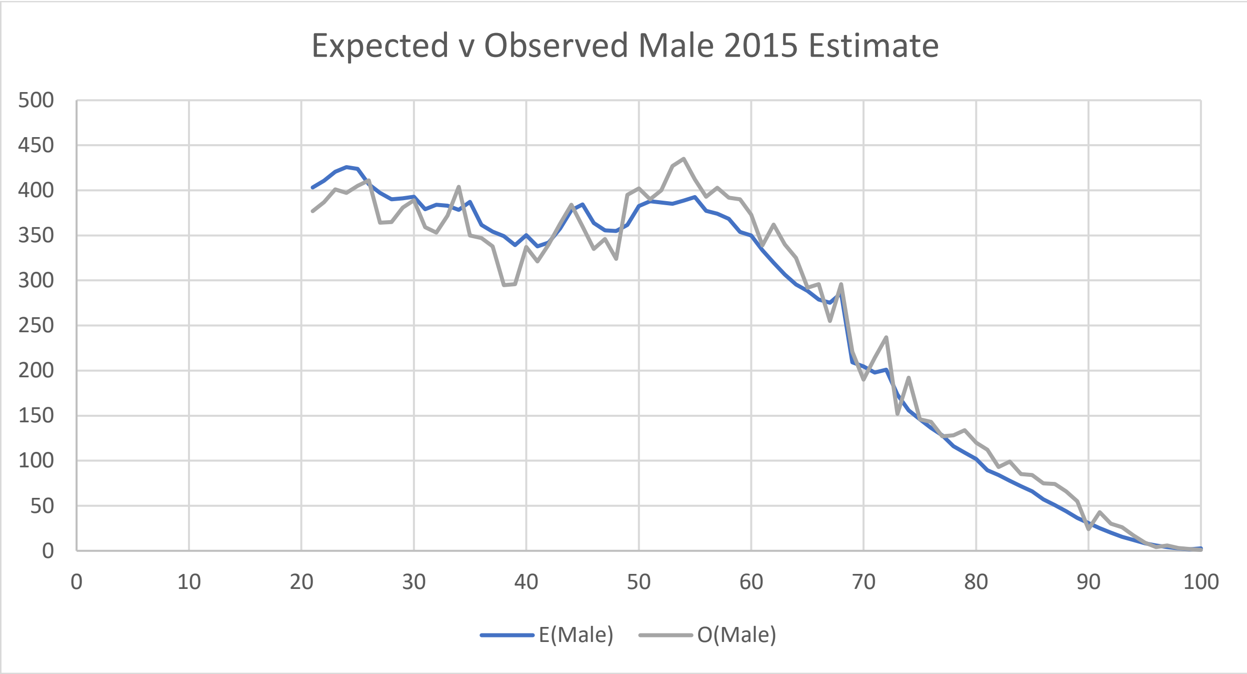


Figure C-6 Male 2015 Population by Age: Census Expected versus Model Observed



Obesity

Figure C-7 Obesity Class by Age and Gender in 1995: NHANES Expected versus Model Observed

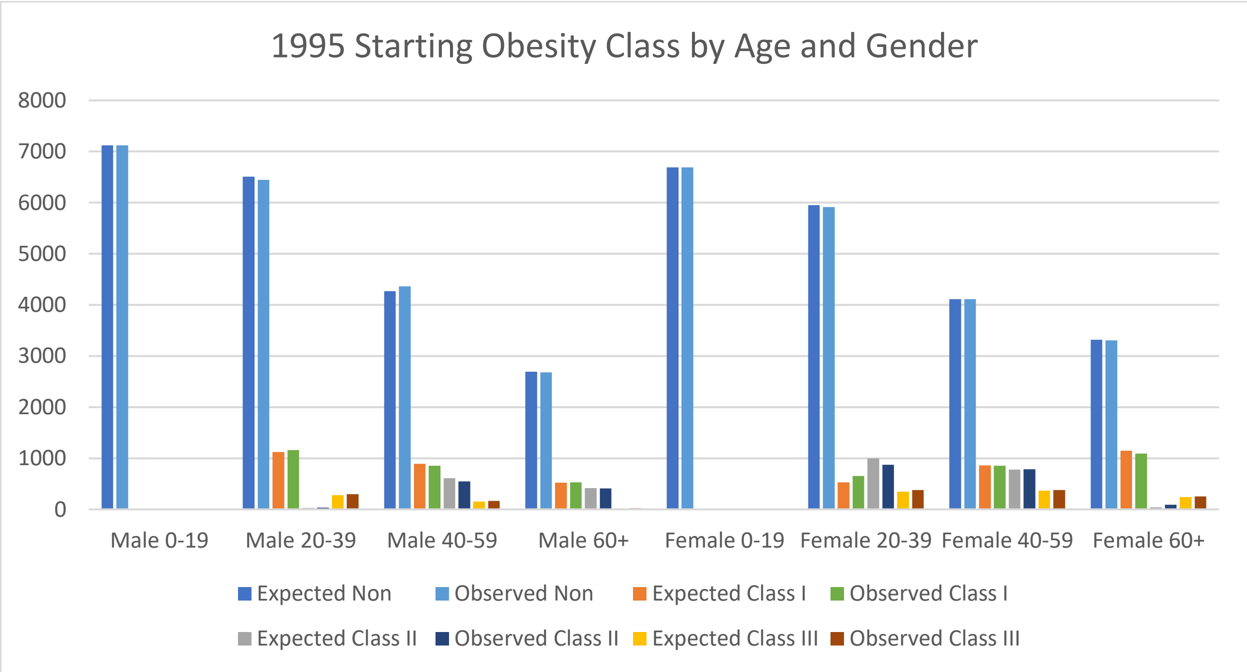


Figure C-8 Obesity Class by Age and Gender in 2003: NHANES Expected versus Model Observed

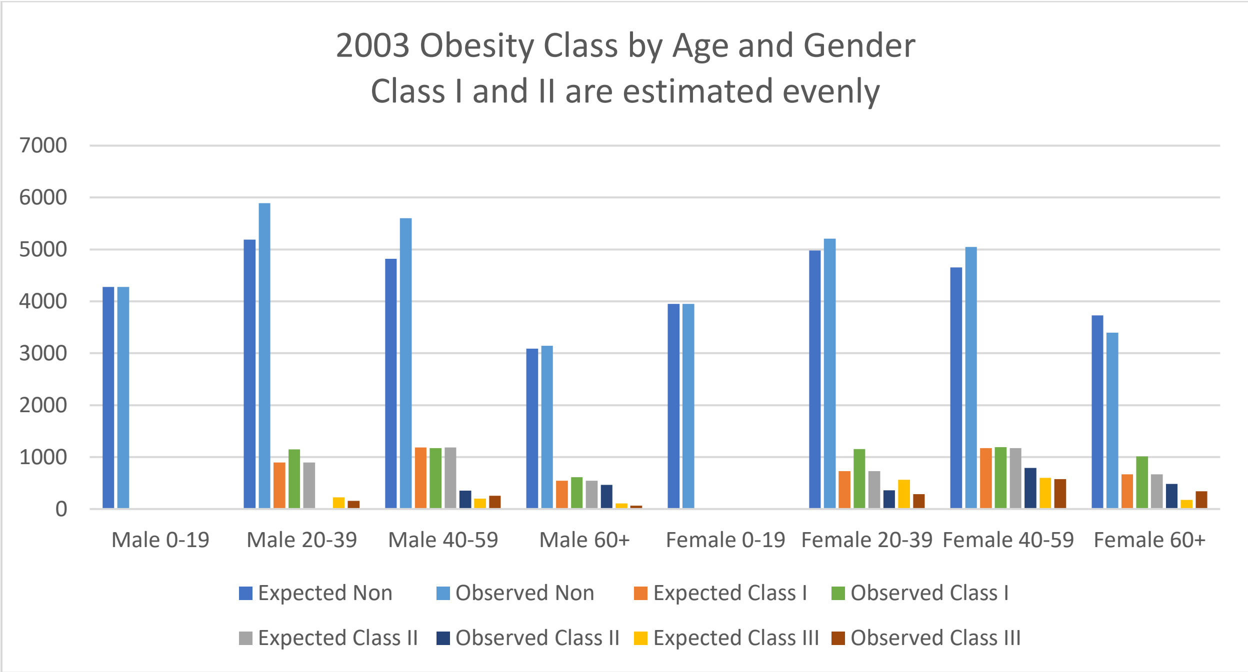
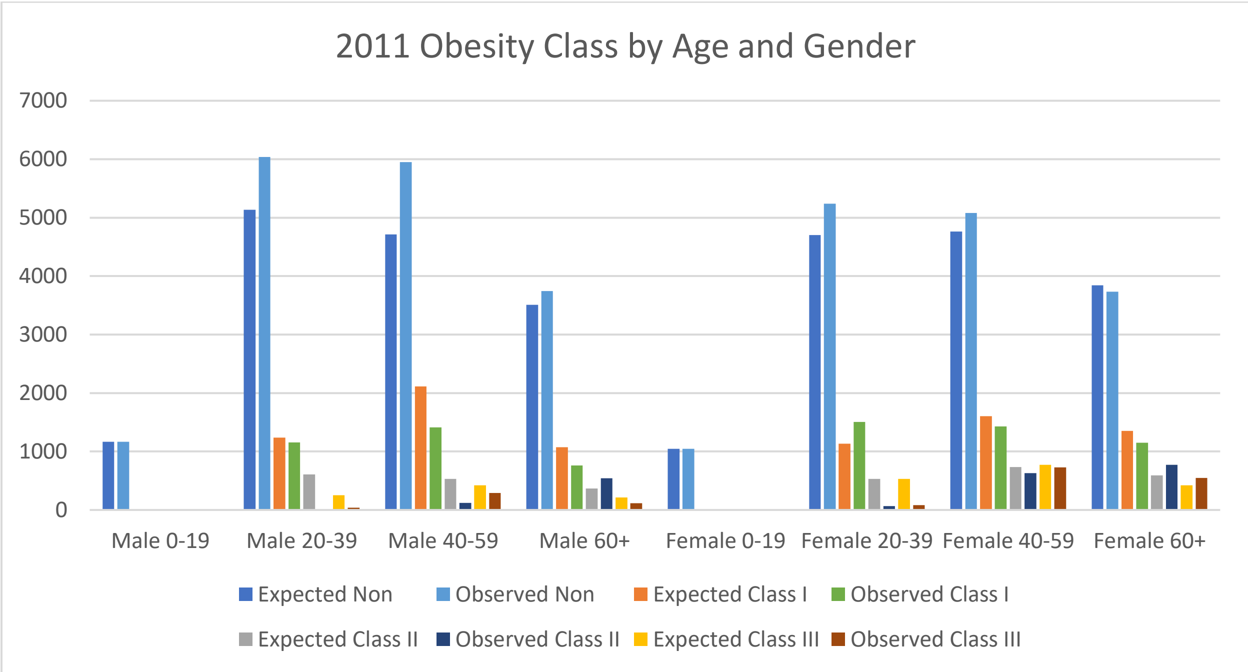


Figure C-9 Obesity Class by Age and Gender in 2011: NHANES Expected versus Model Observed



OA

Figure C-10 Osteoarthritis Prevalence in Population Over Age 40

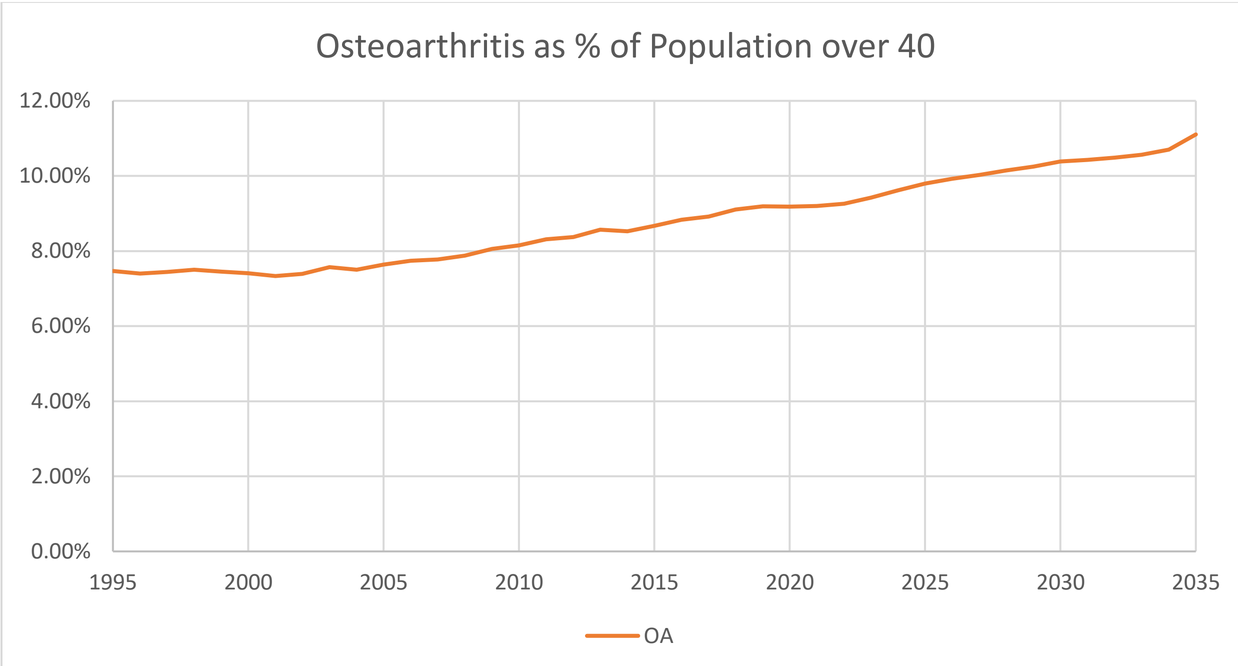


Figure C-11 Osteoarthritis Prevalence in Population Over Age 40 by Obesity

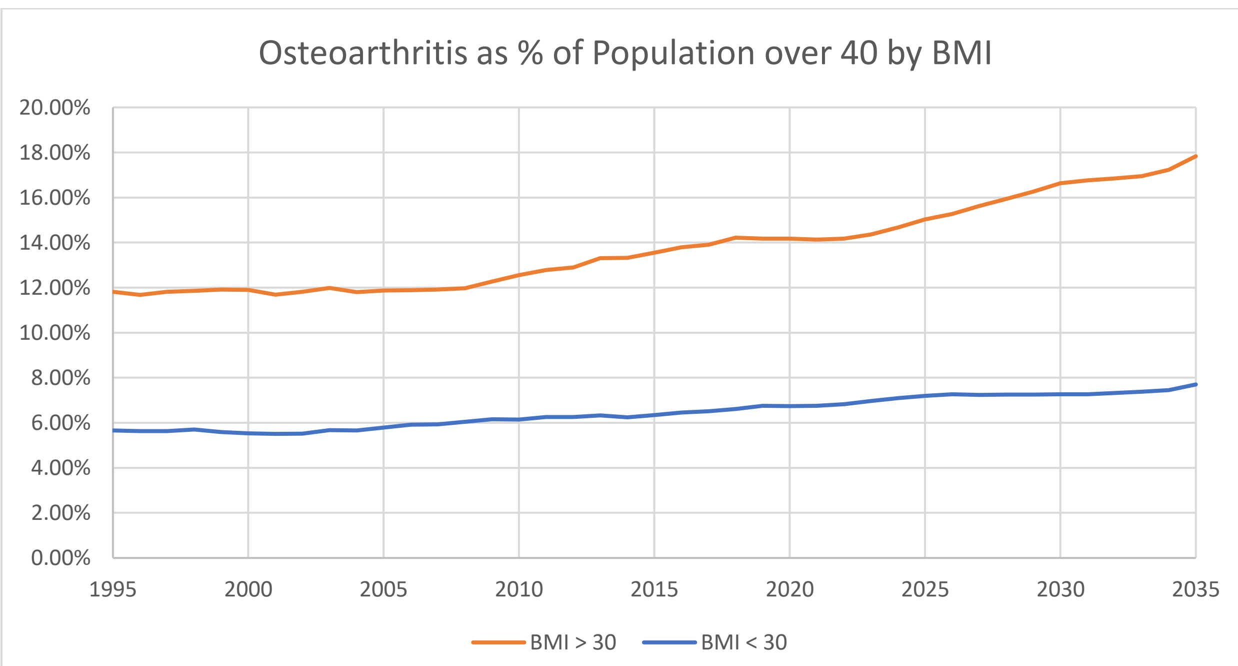
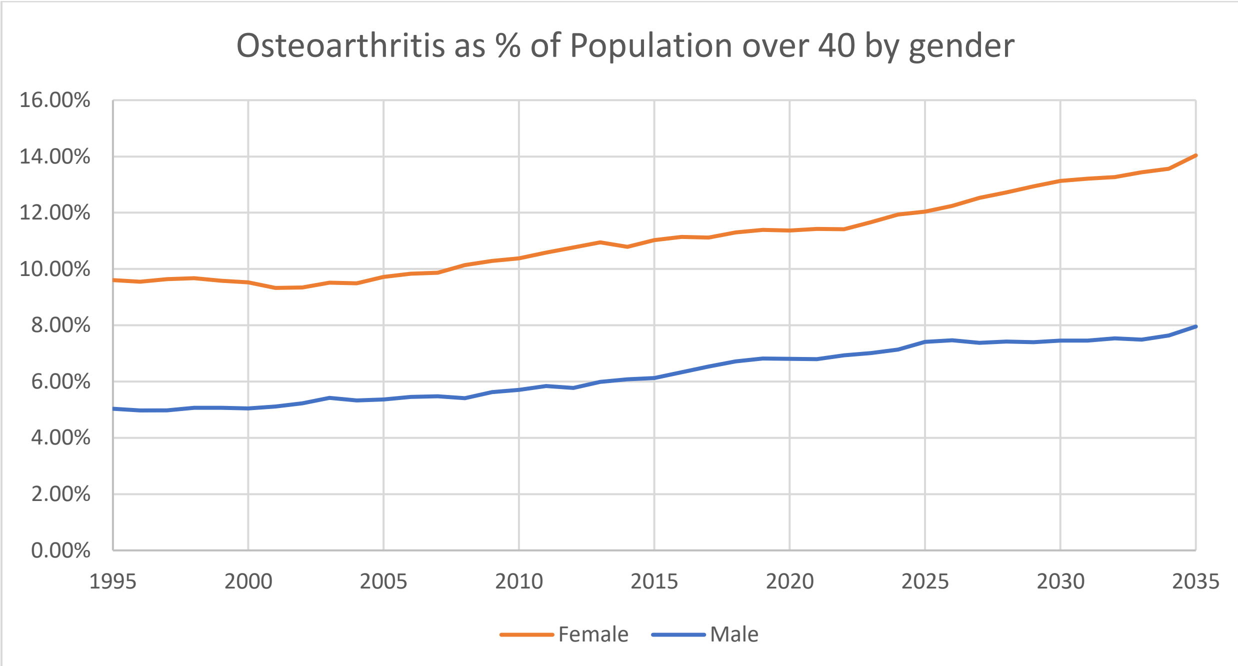


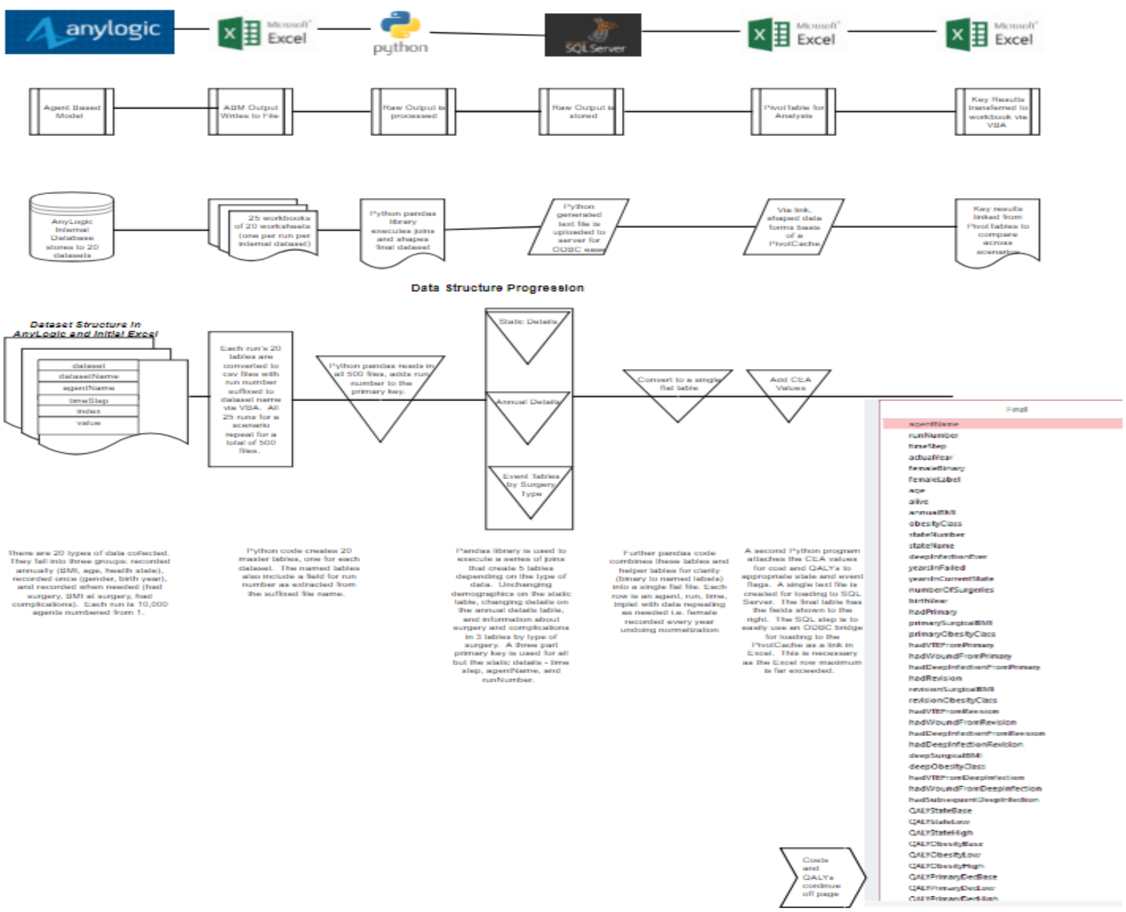
Figure C-12 Osteoarthritis Prevalence in Population Over Age 40 by Gender



APPENDIX D:
Database Implementation

The model required extensive data processing before analysis. Much of this was required due to the limitations of Excel in terms of maximum rows. Processing the agents in smaller segments also significantly reduced model run time in AnyLogic. This was a multiphase process requiring several pieces of software in several coding languages. The process is described below and graphically represented in the attached figure (Figure D-1).

Figure D-1 Schematic of Database Implementation from Raw Output to Final Analysis



AnyLogic has an internal database system. On runtime, the output variables were stored to an internal dataset. A total of 20 datasets, which are briefly described in the table below, are included in the AnyLogic database (Table D-1). Each dataset follows the same structure – the name of the dataset, the agentName (a unique identifier for each agent), the time step, an index, and the numeric value recorded.

Table D-1 AnyLogic Dataset Descriptions

Category	Name	Description
Static Demographics	Female	This shows value of 1 if female, 0 if male
	Patient Birth Year	Records the birth year of the agent based on age in 1995
Annual Demographics	Years in Current Health States	Records the number of years spent in the current health state
	Years in Failed Health States	Records the number of years spent in the current health state if it is one of the three failed states
	Age	The current age based on starting age in 1995
	Alive	This shows value of 1 if alive in the current year, 0 if patient has died
	Health State (Numeric)	Records which of the 12 health states the patient is in via numeric code
	Obesity Classification at time of surgery	If a surgery occurred, the current obesity class (0-3) is recorded permanently
	Number of Surgeries undergone	A running count of the number of surgeries a patient has undergone
	Obesity Classification Annual	Records the current obesity class (0-3)
	Had Deep Infection Ever	A permanent flag for anyone that has ever experienced a deep infection
Event Flags	Had Primary Surgery	A onetime flag when primary surgery occurred
	Had Revision Surgery	A onetime flag when revision surgery occurred
	Had Deep Revision Surgery	A onetime flag when deep revision surgery occurred
	Had Wound	A onetime flag if a wound complication occurred in either a primary or revision surgery
	Had VTE	A onetime flag if a VTE complication occurred in either a primary or revision surgery
	Had Deep Infection	A onetime flag if a deep infection complication occurred in either a primary or revision surgery
	Had Wound from Deep Infection Surgery	A onetime flag if a wound complication occurred in deep revision surgery
	Had VTE From Deep Infection Surgery	A onetime flag if a VTE complication occurred in deep revision surgery
	Had Subsequent Deep Infection	A onetime flag if a deep infection complication occurred in deep revision surgery

On each model run, the datasets were exported to an Excel workbook. Each dataset was written to its own worksheet with the name of the dataset given to the worksheet. Each workbook was saved with the run number attached as a suffix. Due to the upper limit of rows in Excel, the AnyLogic runs had to be split into smaller batch sizes.

For each scenario, a run of 10,000 agents was repeated 25 times for a total of 250,000 agents. All files were saved in a single folder with the name of the scenario. Upon completion of the 25 runs, a VBA macro was run to extract the worksheets from the individual files as comma separated value (csv) files. This macro was coded such that the name of the csv file was the name of the worksheet and the run number from the workbook name. Each csv file then was named for the data type contained and the run number. This created a total of 500 files. The files were spot checked for fidelity to the original Excel output. The csv files significantly reduced the file size and the processing time for the next step.

The Spyder development environment for Python was used for the shaping of the data. In addition to basic Python, the panda's library was used for data manipulation (pandas, n.d.). This is the Python Data Analysis Library and makes use of standard database techniques like inner and outer joins on specific values between data tables. The Python was executed in two steps to accommodate the kernel timing out on the full process due to the file size. In the first step, the 500 csv files were read into Python. In this step, a run number field was added to the table with the run number value taken from the file name. Additionally, the files corresponding to each dataset were merged into a single table. Thus, on read in the Python code converts 500 files to 20 tables with run number added as a field. The new tables were also visually inspected for fidelity to the original data for both correctness of insertion of run numbers and for the values recorded.

Assistive tables were also read in at this time. These files served to make the AnyLogic numeric output more readable. The time step was converted to the real-world year it corresponds to and the binary female was changed to text labels. Obesity class names were also added.

With these tables created, the joining process with the panda's library commenced. Five tables were needed to deal with the variable nature of the data. First, static demographics were grouped together. This contains the unchanging year of birth and gender. The composite key for this table was agent name and runs number. Second, annual demographics made the largest table. Every year, health state, age, obesity class and years in the current state were recorded for every agent who was alive. Additionally, the number of surgeries received and a permanent flag if deep infection had ever been experienced were included. Third, a series of three tables contained surgical and complication event flags organized by type of surgery: primary, revision and deep revision. As appropriate the assistive tables were attached for clarity in the file dataset. The final four tables used a three-part composite key of agent name, run number, and time step. Samples from each of these five tables were then compared to raw output to ensure that the joins accurately reflected the original raw output.

These five tables were then combined into a single flat table that was denormalized. The ultimate goal for the data is as the basis of a PivotTable which requires such a format. To accomplish this, the five tables created above were also joined on the three-part composite key. This table was written to a text file to be used in the second step of the Python process.

In the second step of the Python data processing, the costs and QALYs associated with health states and events were attached to the flat table created in the first phase. A series of tables containing specific cost and QALY events was attached based on the event flags or health state. The final table was again exported as a txt file.

SQL Server Express was used as an intermediary between the Python output and the Excel PivotCache. The file was imported to a database in SQL Server. The file was otherwise unchanged. Using several SELECT queries, the final table was tested against the raw output to ensure data fidelity for a final check of the extensive process of data manipulation.

Finally, an ODBC bridge was created between Excel and the SQL Server database. This link served as the basis of a PivotCache. Various PivotTables were created based on this data link. The data never comes into Excel itself because the Excel maximum row limit was still exceeded.

APPENDIX E:
Cross Model Validation Results

The model structure was validated by comparing results to the compartmental model that used the same design for the disease process. The starting conditions were set to identical values and heterogeneity was removed from the ABM population design. The outcomes tracked in the compartmental model focused on the costs and QALYs associated with two scenarios – no TKA and TKA occurring for an entire population in the first year – in four obesity classes. For comparison, the total costs and total QALYs were compared on an annual basis between the two models for all 8 scenarios. The results of those comparisons are presented below as 16 graphs – one for each scenario for costs and QALYs (Figures E-1 -16). The output tracks closely across all groups in both measures.

Figure E-1 Undiscounted Costs by Year: Nonobese – Year 1 TKA

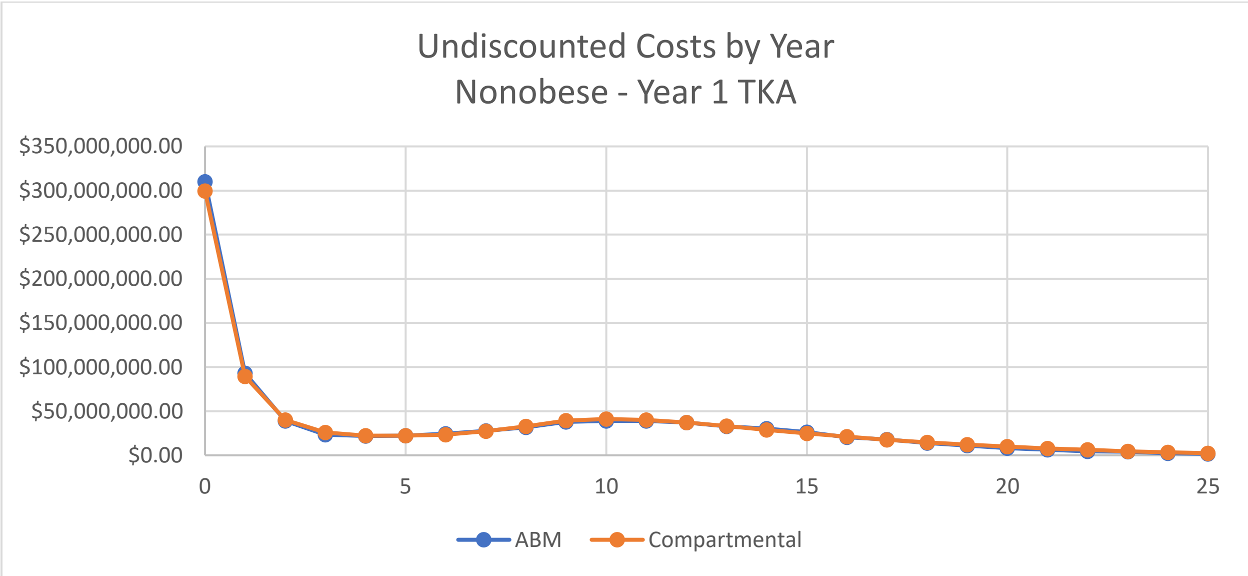


Figure E-2 Undiscounted QALYs by Year: Nonobese – Year 1 TKA

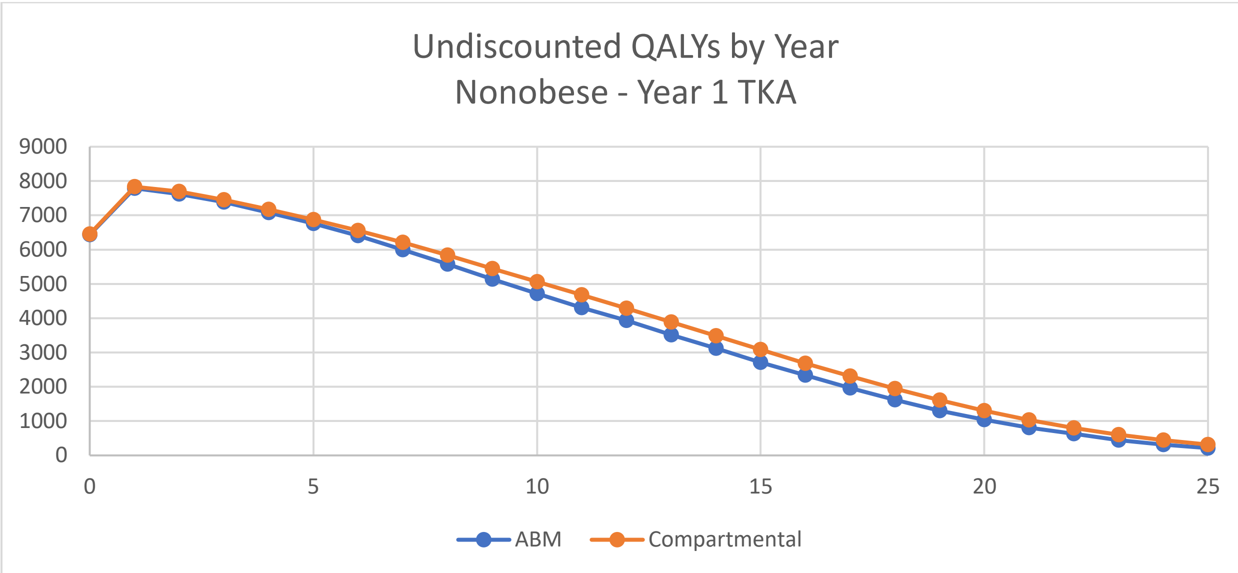


Figure E-3 Undiscounted Costs by Year: Class I Obesity– Year 1 TKA

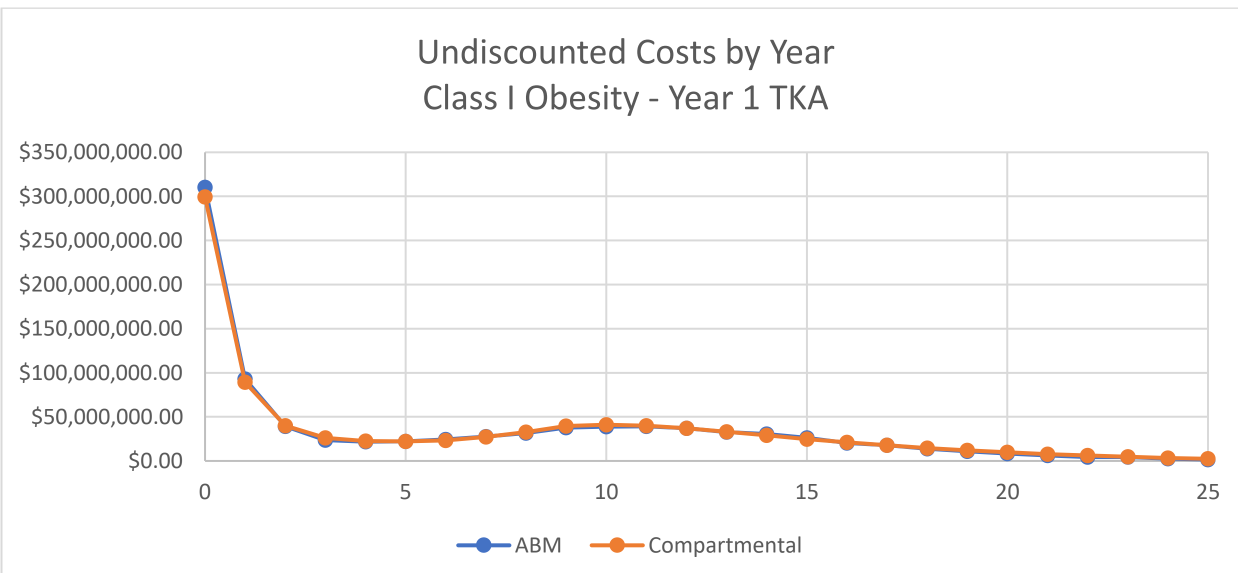


Figure E-4 Undiscounted QALYs by Year: Class I Obesity– Year 1 TKA

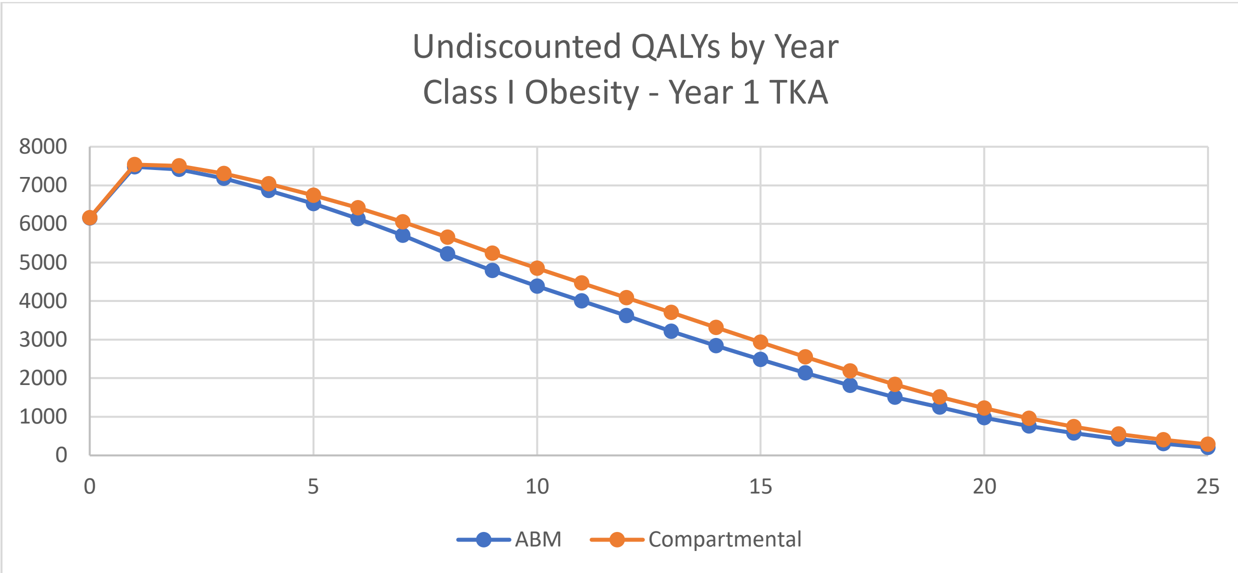


Figure E-5 Undiscounted Costs by Year: Class II Obesity– Year 1 TKA

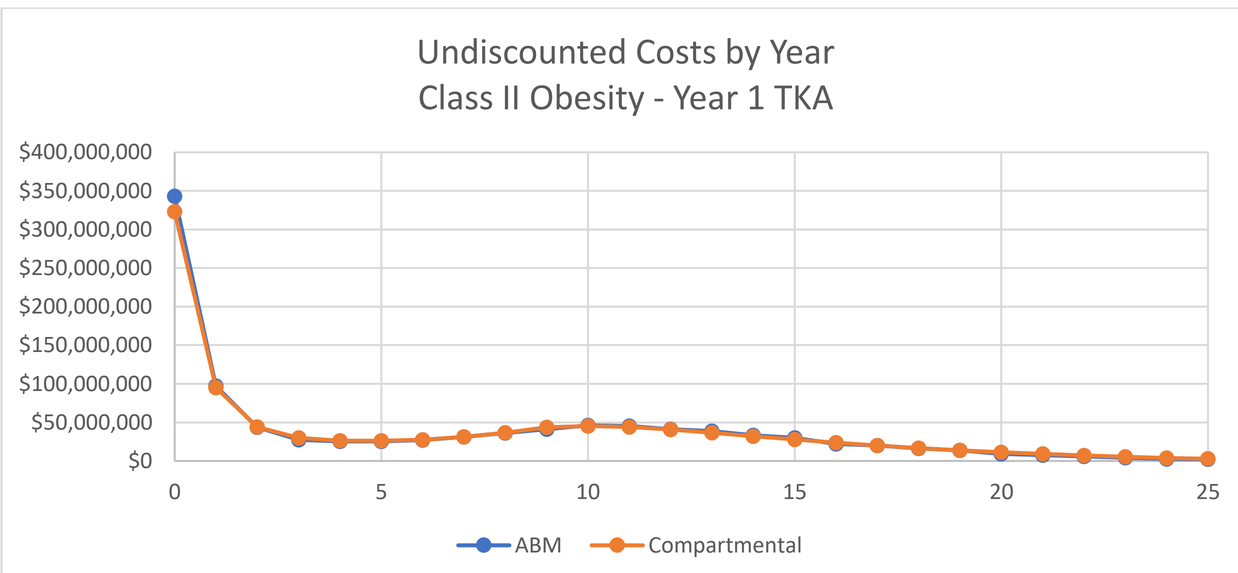


Figure E-6 Undiscounted QALYs by Year: Class II Obesity– Year 1 TKA

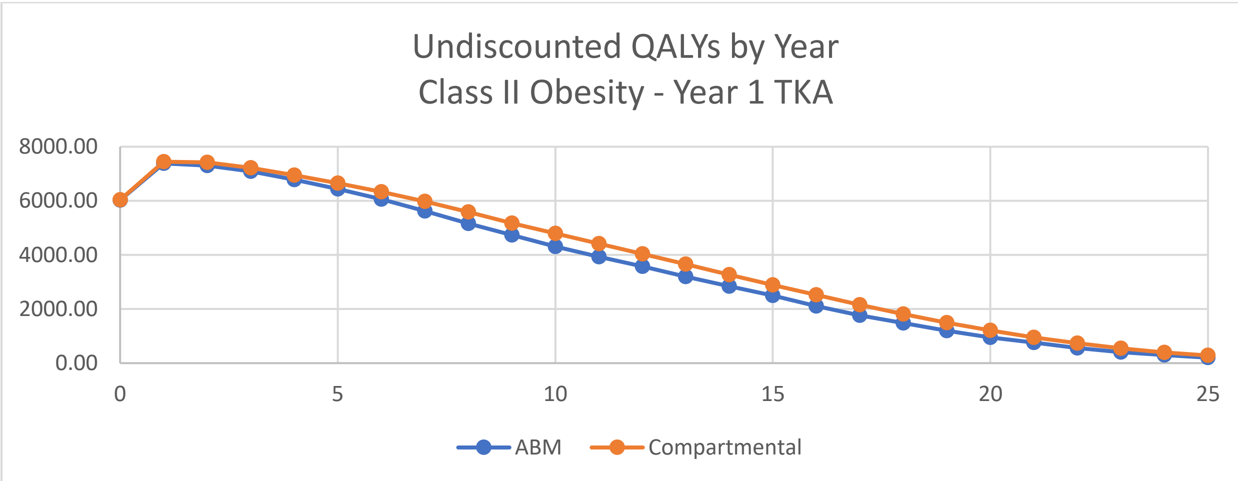


Figure E-7 Undiscounted Costs by Year: Class III Obesity– Year 1 TKA

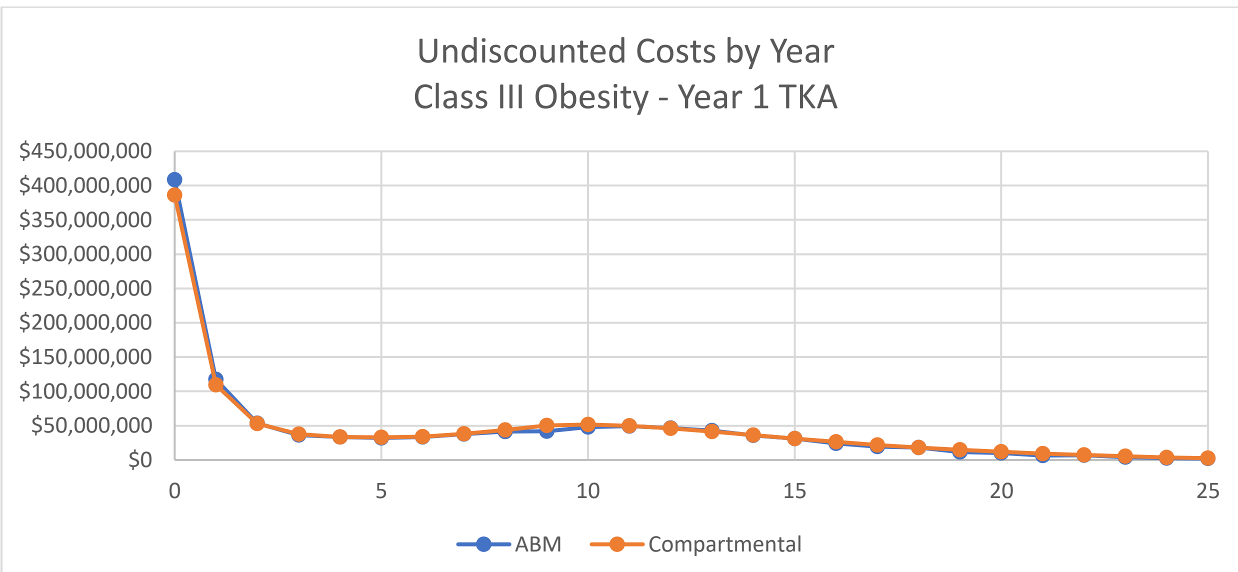


Figure E-8 Undiscounted QALYs by Year: Class III Obesity– Year 1 TKA

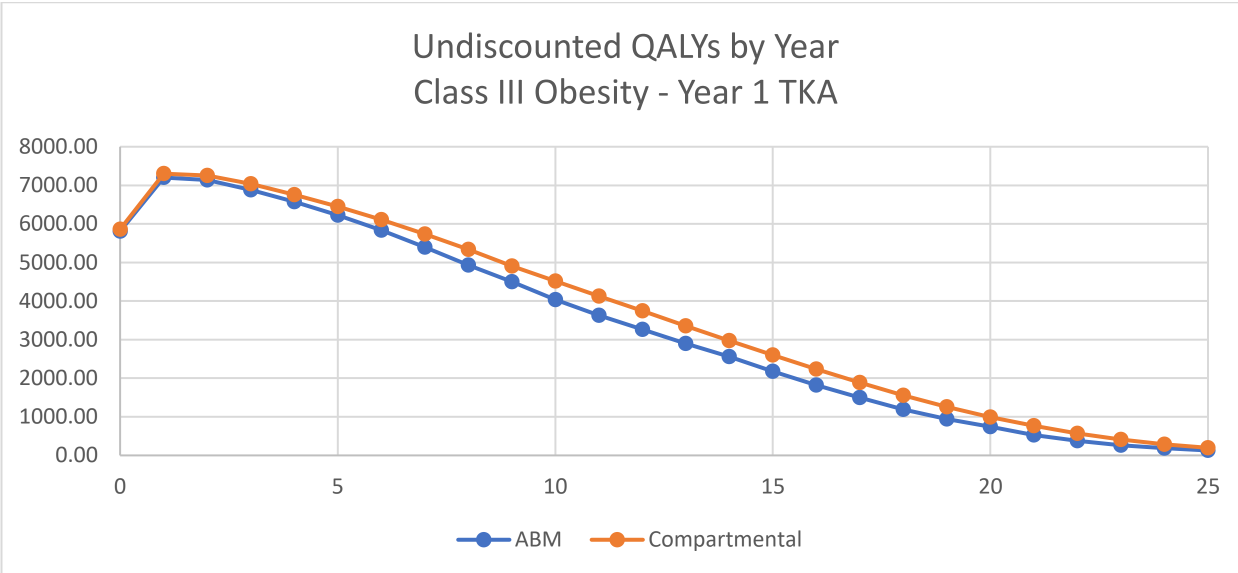


Figure E-9 Undiscounted Costs by Year: Nonobese – No TKA

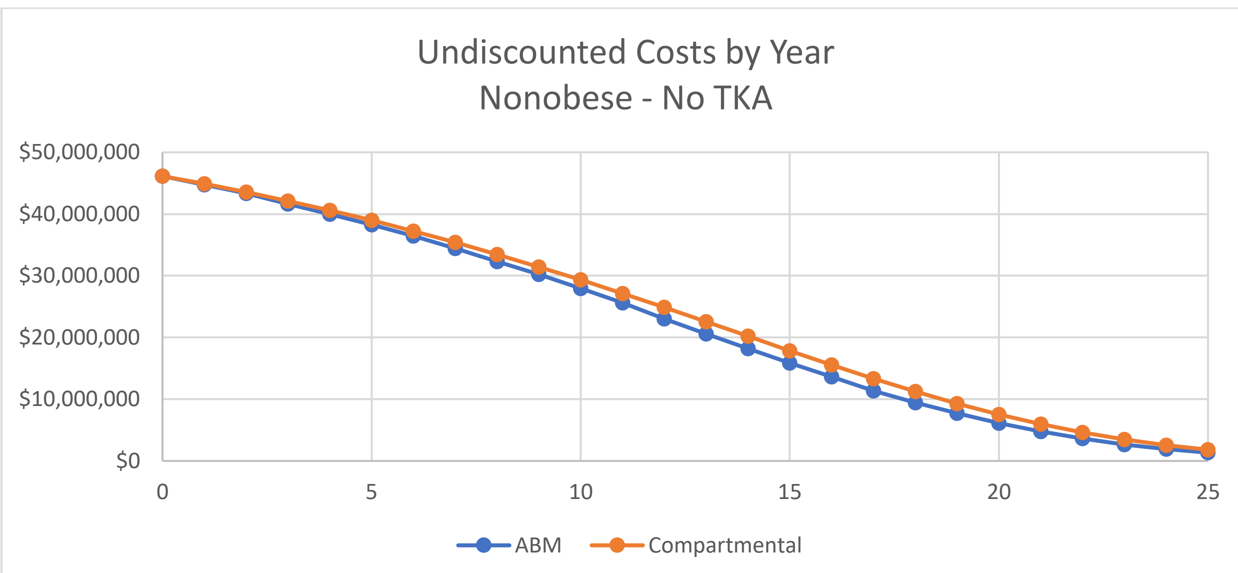


Figure E-10 Undiscounted QALYs by Year: Nonobese- No TKA

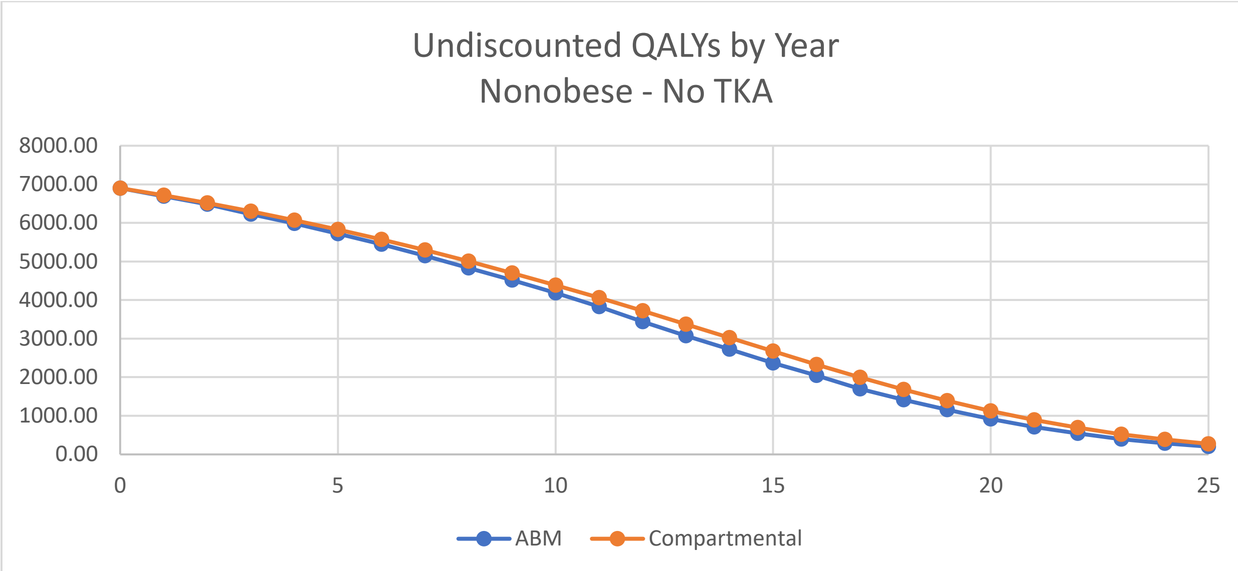


Figure E-11 Undiscounted Costs by Year: Class I Obesity– No TKA

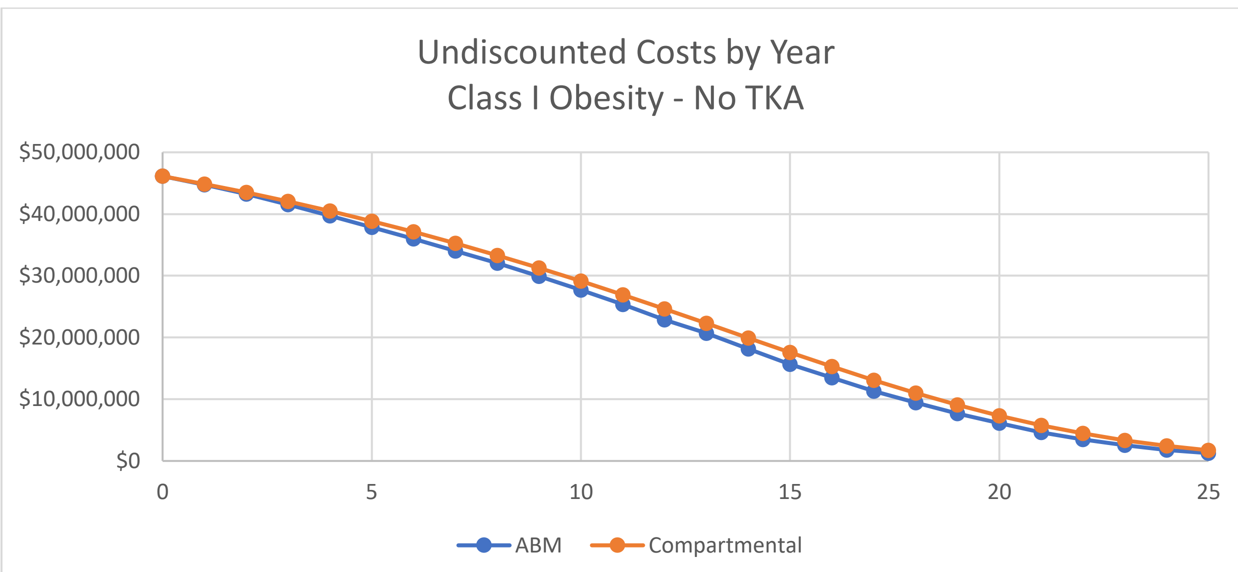


Figure E-12 Undiscounted QALYs by Year: Class I Obesity– No TKA

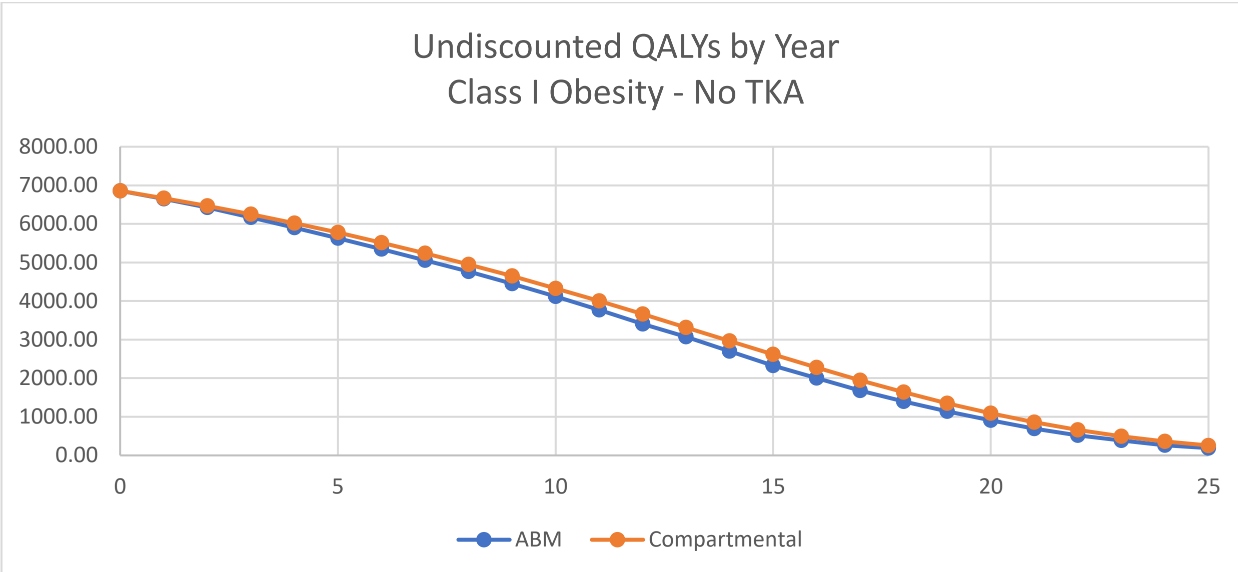


Figure E-13 Undiscounted Costs by Year: Class II Obesity– No TKA

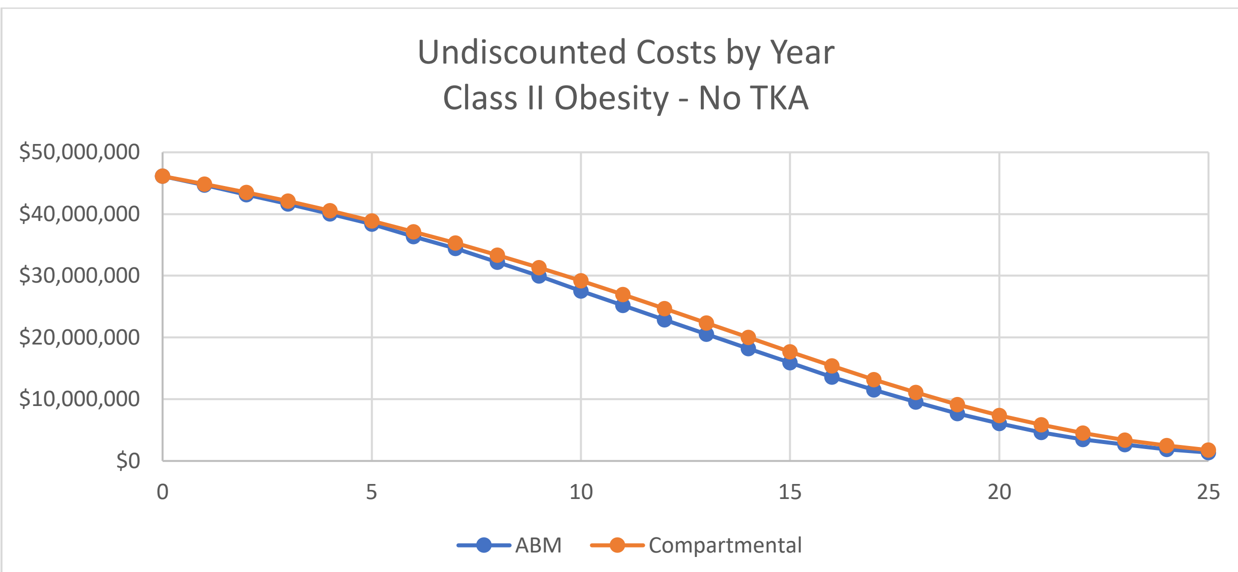


Figure E-14 Undiscounted QALYs by Year: Class II Obesity– No TKA

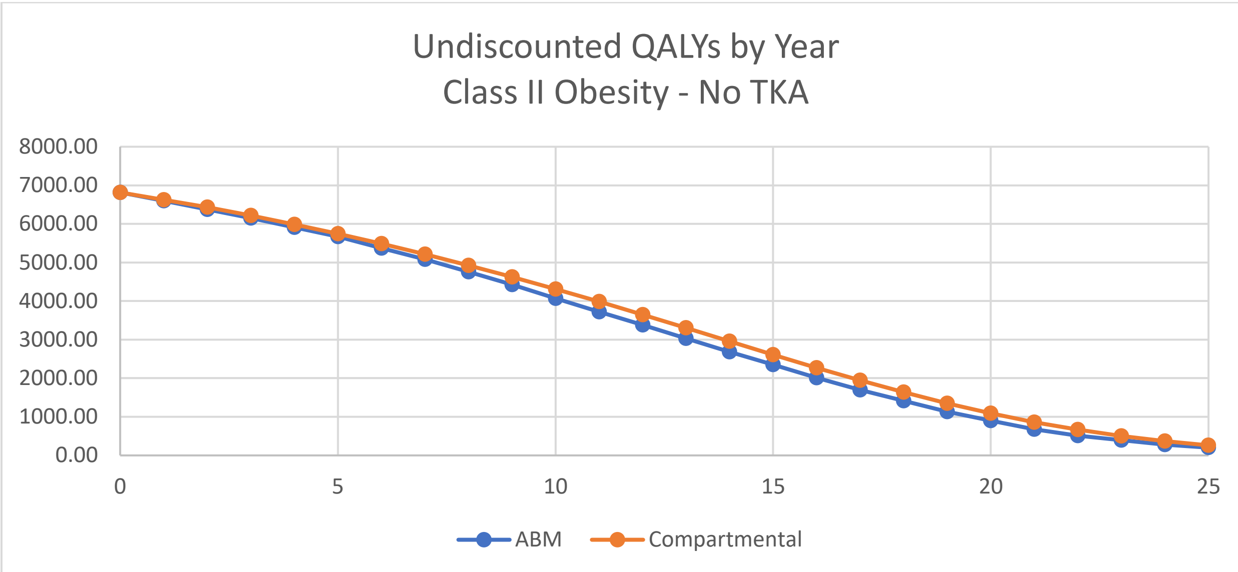


Figure E-15 Undiscounted Costs by Year: Class III Obesity– No TKA

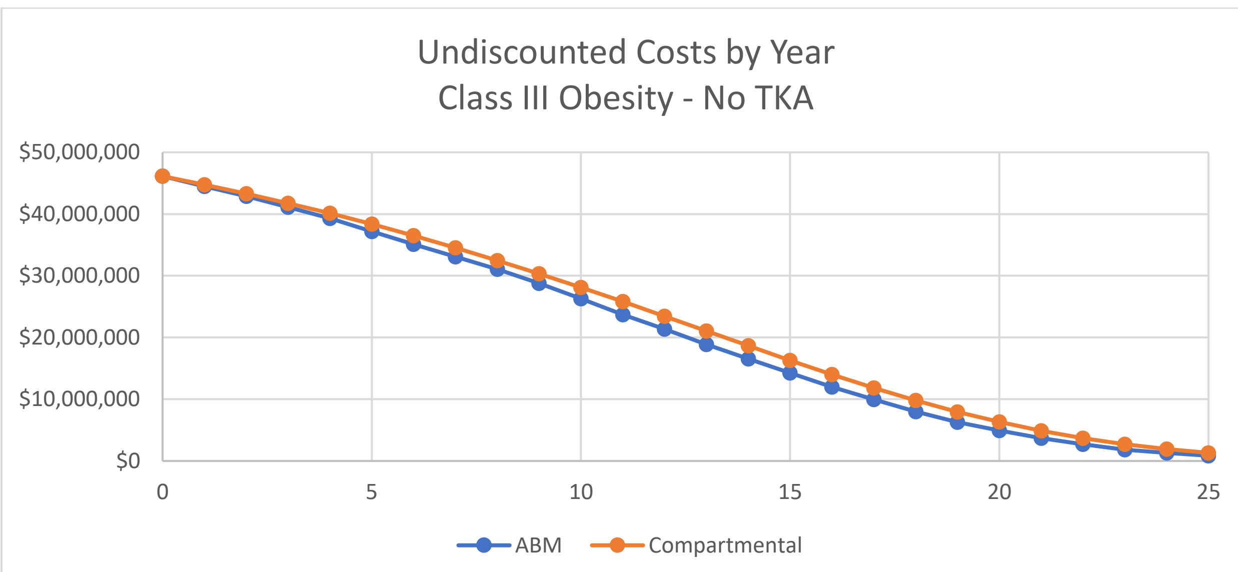
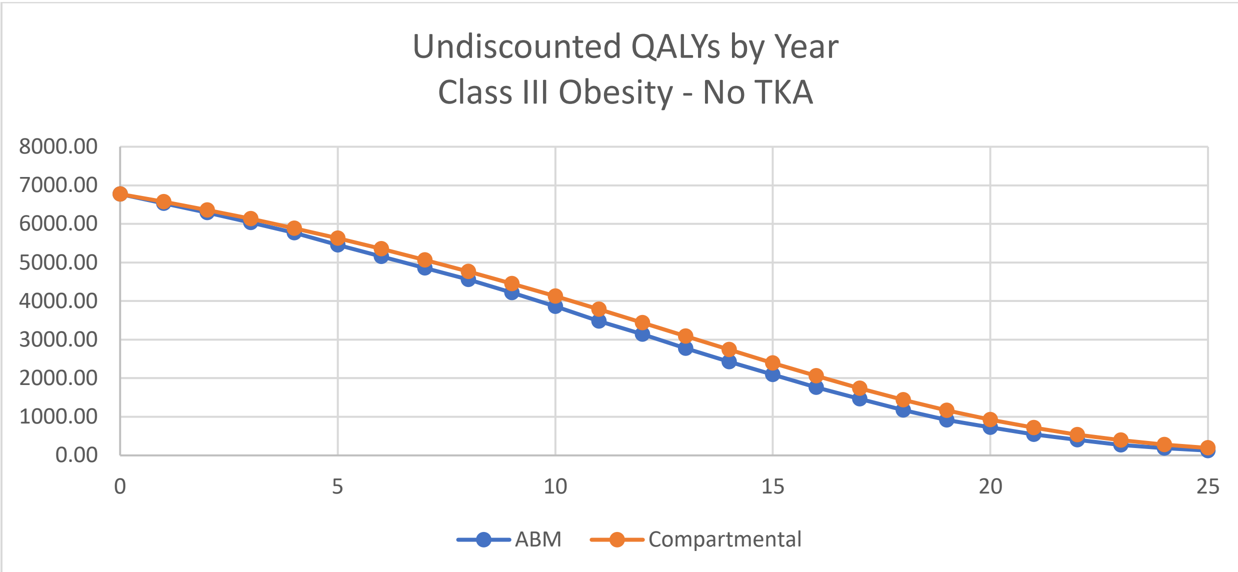


Figure E-16 Undiscounted QALYs by Year: Class III Obesity– No TKA



APPENDIX F:

Calibration Results

Calibration relied on three criteria all centered on the HCUP data as available. The first and second rely on objective fit criteria. The tables below show the parameter sets tried and the results of those criteria. The first is the number of time points where the regressed model line was inside the HCUP Confidence Interval (Table F-1). The second is the count of whether the confidence intervals overlapped (Table F-2). The joint age and gender groups only have 3 years of data points and the rest are 15 years. The final column shows the percent of the 108 data points that fit the criteria. Figure F-13 shows the uptake rates over time for each group using the final parameter set. While not used in the calibration, Table F-3 shows the MSE for each parameter set with the chosen parameters having the lowest total MSE. In all three tables the yellow row or parameter scenario 10 is the final calibration set.

The third criteria involved a visual inspection of the trend against the HCUP data. This served as a final check of the parameter set's suitability. The graphs below show the 12 demographics categories available with the HCUP and final parameter set along with their confidence intervals (Figures F-1 - 12).

Overall, there is a good fit across all the data point types and time. The HCUP confidence intervals have widely varying widths and the smallest were the least likely to contain the model trendline. The joint estimates are also less likely to contain the trendline as they are only 3 years and have artificial confidence intervals which cause a sharp v shape. A visual inspection shows that even the worst group (Males 45-64) on the objective measures tracks nearly as well as the overall population estimate. (Figure F-6)

Table F-1 Calibration Regression Lines Inside HCUP Confidence Intervals

Scenario	Parameter Set							95 % Confidence Intervals Overlap 2000-2014 Relative to HCUP Discharges													
				All Ages	Both Genders																
	Base	*Trend*	*Trend 45-64*	*Female*	*RR-U45*	*RR 65-84*	*RR-O85*	*Female 45-64*	*Female 65-84*	*Female 85+*	*Male 45-64*	*Male 65-84*	*Male 85+*	*45-64*	*65-84*	*85+*	*Female*	*Male*	*Overall*	*Sum*	*% Inside*
1	0.04	0.06	0.11	0.8	1	0.8	0.1	-	3	3	-	-	-	7	-	2	5	6	-	26	24%
2	0.038	0.07	0.11	0.8	1	1	0.2	3	3	-	1	-	-	10	3	-	15	5	11	51	47%
3	0.038	0.08	0.11	0.8	1	1	0.15	1	3	-	-	1	-	11	9	1	7	7	4	44	41%
4	0.04	0.075	0.11	0.75	1	1	0.1	-	3	-	-	2	-	-	6	3	15	3	11	43	40%
5	0.043	0.07	0.11	0.75	1	1.1	0.075	-	3	3	-	1	-	7	8	3	10	6	15	56	52%
6	0.035	0.1	0.115	0.75	1	1.1	0.075	1	3	1	-	3	-	11	10	2	7	1	7	46	43%
7	0.035	0.1	0.115	0.7	1	1.1	0.07	-	2	-	-	3	-	6	7	-	4	-	4	26	24%
8	0.035	0.09	0.115	0.65	1	1.1	0.075	-	3	2	-	3	-	6	15	2	6	-	9	46	43%
9	0.035	0.1	0.115	0.75	1	1.1	0.075	1	2	1	-	3	-	12	2	3	5	-	4	33	31%
10	0.03	0.09	0.115	0.75	0.09	1.1	0.07	1	3	3	-	3	-	11	15	4	9	15	13	77	71%
11	0.028	0.09	0.11	0.775	1	1.1	0.068	3	3	2	1	3	-	1	5	5	7	15	8	53	49%

Table F-2 Calibration Regression HCUP Confidence Intervals Overlapping

Scenario	Parameter Set							95 % Confidence Intervals Overlap													
			All Ages	Both Genders				2000-2014 Relative to HCUP Discharges													
	Base	Trend	Trend 45-64	Female	RR-U45	RR 65-84	RR-O85	Female 45-64	Female 65-84	Female 85+	Male 45-64	Male 65-84	Male 85+	45-64	65-84	85+	Female	Male	Overall	Sum	% Inside
1	0.04	0.06	0.11	0.8	1	0.8	0.1	3	3	3	3	-	-	15	1	15	10	12	15	80	74%
2	0.0375	0.07	0.11	0.8	1	1	0.2	3	3	-	3	2	3	15	6	3	15	13	15	81	75%
3	0.0375	0.08	0.11	0.8	1	1	0.15	3	3	-	3	3	-	15	15	6	15	15	15	93	86%
4	0.04	0.075	0.11	0.75	1	1	0.1	3	3	3	-	3	3	15	9	15	15	7	15	91	84%
5	0.0425	0.07	0.11	0.75	1	1.1	0.075	-	3	3	3	3	3	15	15	15	15	15	15	105	97%
6	0.035	0.1	0.115	0.75	1	1.1	0.075	3	3	3	3	3	3	15	15	15	15	15	15	108	100%
7	0.035	0.1	0.115	0.7	1	1.1	0.07	1	3	3	3	3	3	15	15	15	11	15	11	98	91%
8	0.035	0.09	0.115	0.65	1	1.1	0.075	3	3	3	3	3	3	15	15	15	10	2	15	90	83%
9	0.035	0.1	0.115	0.75	1	1.1	0.075	3	3	3	3	3	-	15	5	9	8	1	6	59	55%
10	0.03	0.09	0.115	0.75	0.09	1.1	0.07	3	3	3	-	3	3	15	15	15	15	15	15	105	97%
11	0.0275	0.09	0.11	0.775	1	1.1	0.0675	3	3	3	3	3	-	7	15	15	10	15	15	92	85%

Table F-3 Calibration Regression MSE Results

Scenario	Parameter Set							MSE Values						
	All Ages				Both Genders			2000-2014 Relative to HCUP Discharges						
	Base	*Trend*	*Trend 45-64*	*Female*	*RR-U45*	*RR 65-84*	*RR-O85*	*45-64*	*65-84*	*85+*	*Female*	*Male*	*Overall*	*Sum*
1	0.04	0.06	0.11	0.8	1	0.8	0.1	522,288,882	3,796,724,268	48,003,427	4,040,719,515	119,378,128	3,844,822,294	12,371,936,515
2	0.0375	0.07	0.11	0.8	1	1	0.2	662,525,205	3,262,034,730	418,424,697	464,011,311	1,903,422,157	2,669,276,185	9,379,694,285
3	0.0375	0.08	0.11	0.8	1	1	0.15	1,806,257,014	1,830,235,215	161,256,551	3,137,629,548	1,361,079,198	7,023,130,428	15,319,587,954
4	0.04	0.075	0.11	0.75	1	1	0.1	2,056,403,039	650,563,316	76,297,184	1,555,776,371	3,291,977,163	5,139,666,066	12,770,683,140
5	0.0425	0.07	0.11	0.75	1	1.1	0.075	835,878,665	2,544,982,767	72,384,715	1,439,015,371	2,181,562,550	3,998,548,855	11,072,372,924
6	0.035	0.1	0.115	0.75	1	1.1	0.075	1,156,957,886	2,440,685,768	57,950,981	599,214,879	2,801,726,293	5,018,133,848	12,074,669,655
7	0.035	0.1	0.115	0.7	1	1.1	0.07	622,981,397	2,895,801,901	56,914,056	2,674,035,918	2,458,428,060	4,993,389,640	13,701,550,971
8	0.035	0.09	0.115	0.65	1	1.1	0.075	1,005,030,686	1,223,933,035	44,993,747	2,921,740,299	2,053,197,798	1,850,564,782	9,099,460,348
9	0.035	0.1	0.115	0.75	1	1.1	0.075	320,404,048	964,015,243	21,102,441	308,861,482	1,304,324,412	1,926,947,723	4,845,655,349
10	0.03	0.09	0.115	0.75	0.09	1.1	0.07	386,907,711	225,096,557	22,387,369	939,857,063	272,045,885	524,693,414	2,370,988,000
11	0.0275	0.09	0.11	0.775	1	1.1	0.0675	710,304,954	1,443,860,739	32,785,672	2,309,097,994	115,502,993	2,954,289,365	7,565,841,718

Figure F-1 Final Calibration Against HCUP - Overall

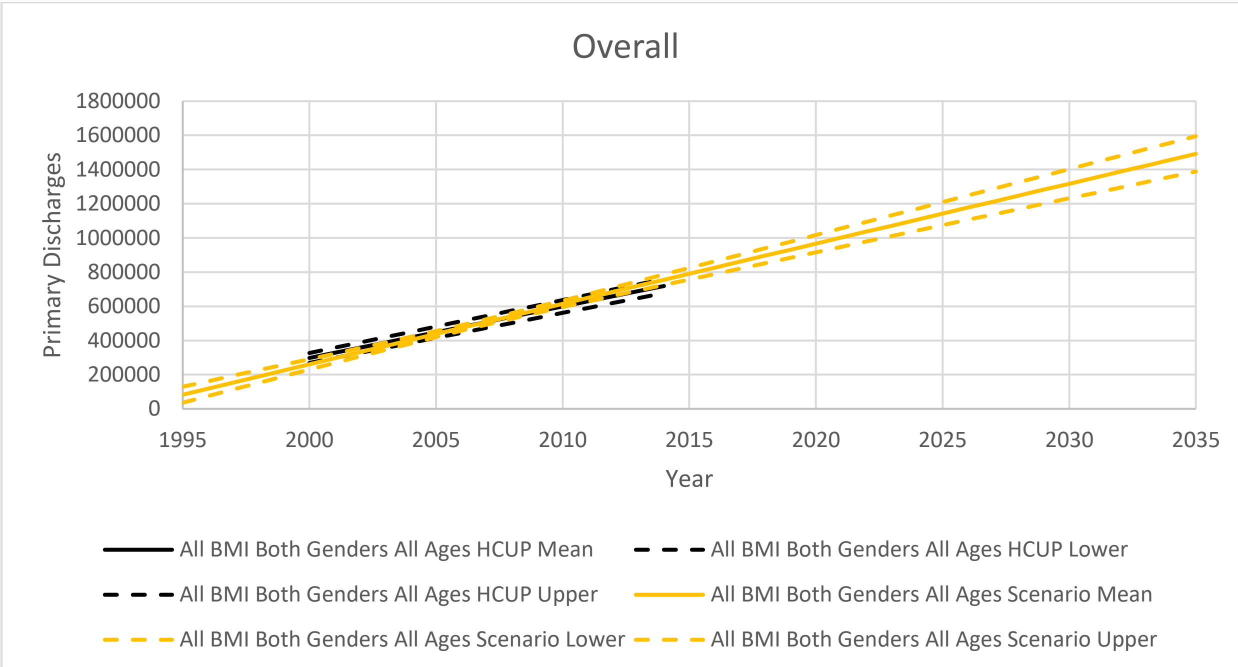


Figure F-2 Final Calibration Against HCUP – Females- All Ages

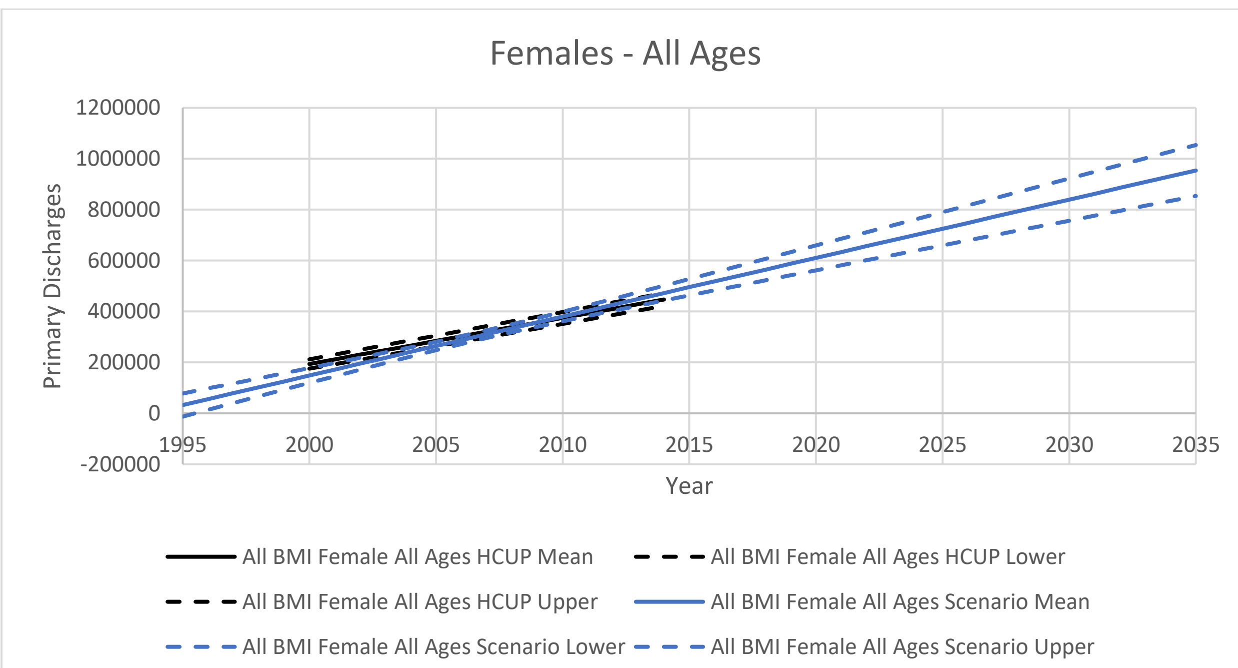


Figure F-3 Final Calibration Against HCUP – Males- All Ages

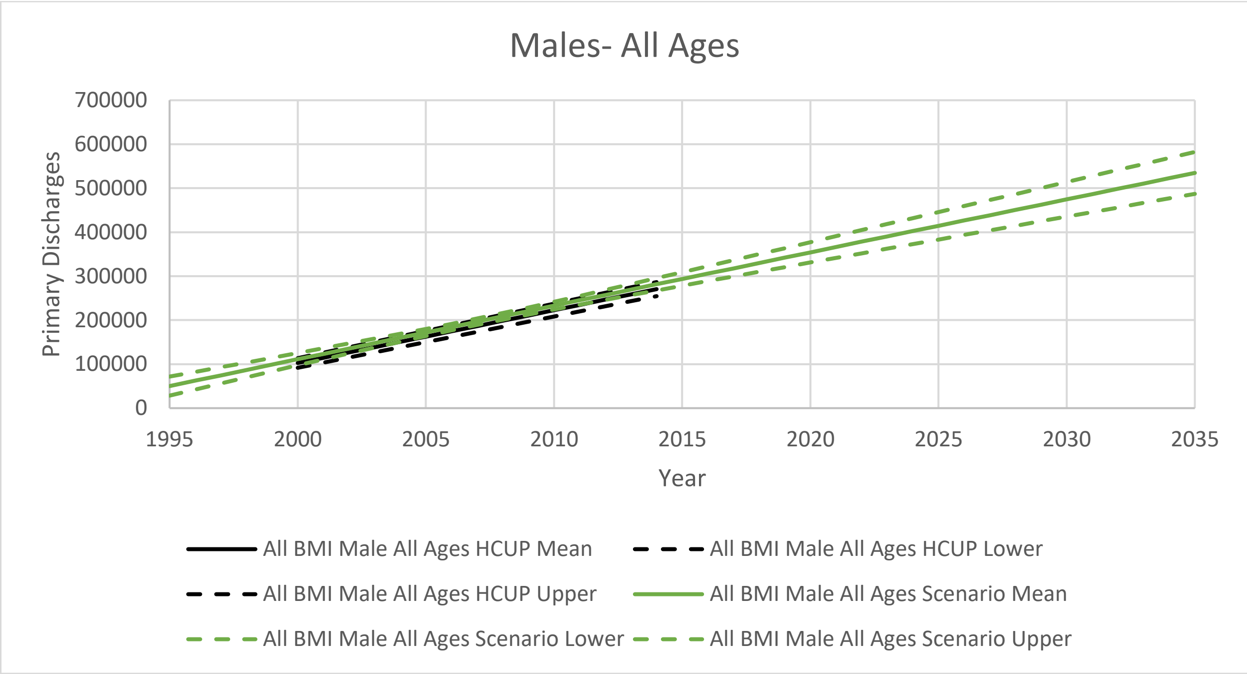


Figure F-4 Final Calibration Against HCUP – Both Genders- 45-64 Year Olds

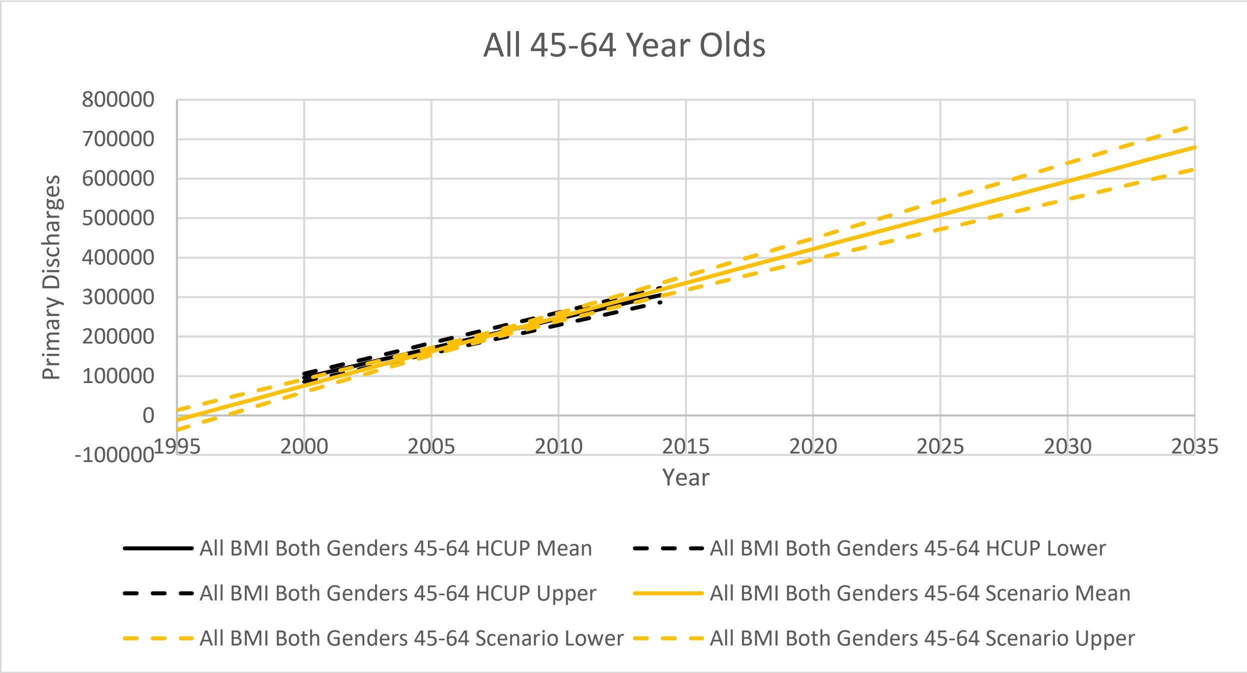


Figure F-5 Final Calibration Against HCUP – Female- 45-64 Year Olds

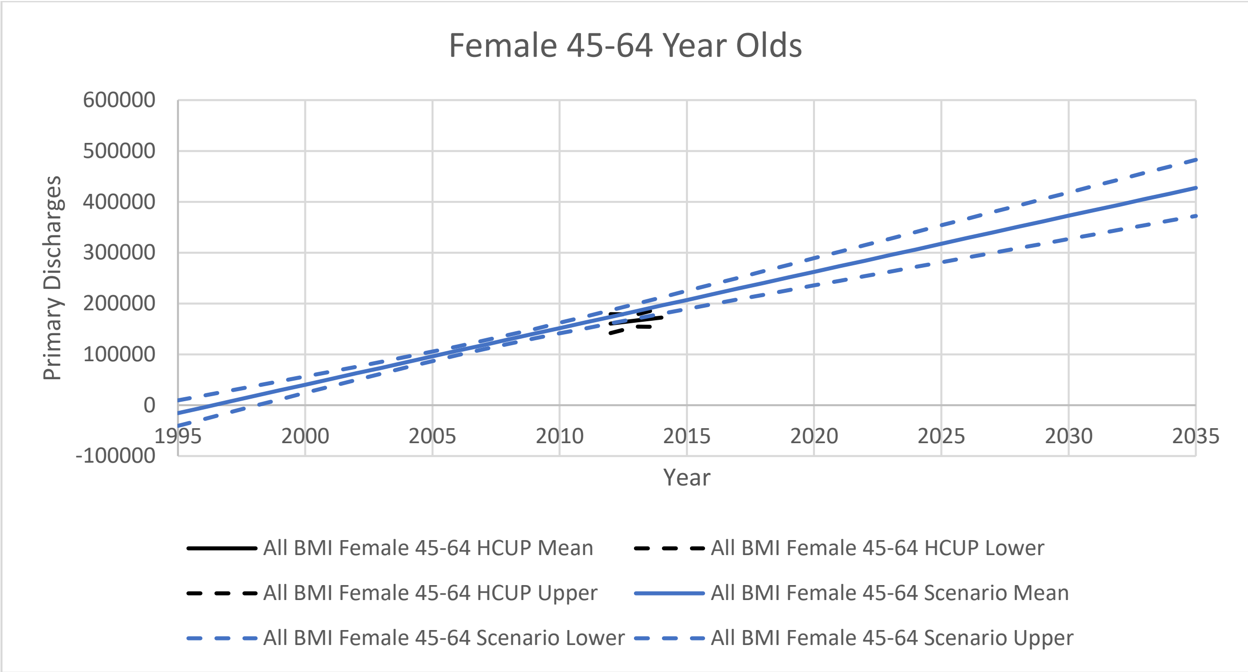


Figure F-6 Final Calibration Against HCUP – Males- 45-64 Year Olds

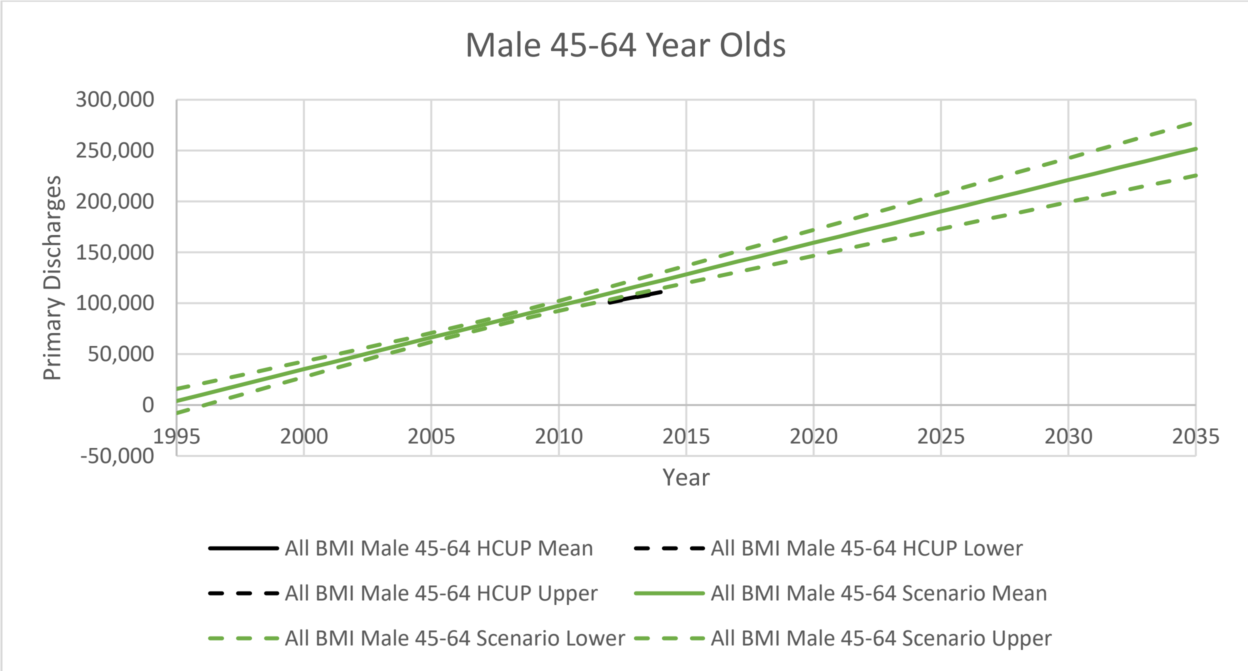


Figure F-7 Final Calibration Against HCUP – Both Genders- 65-84 Year Olds

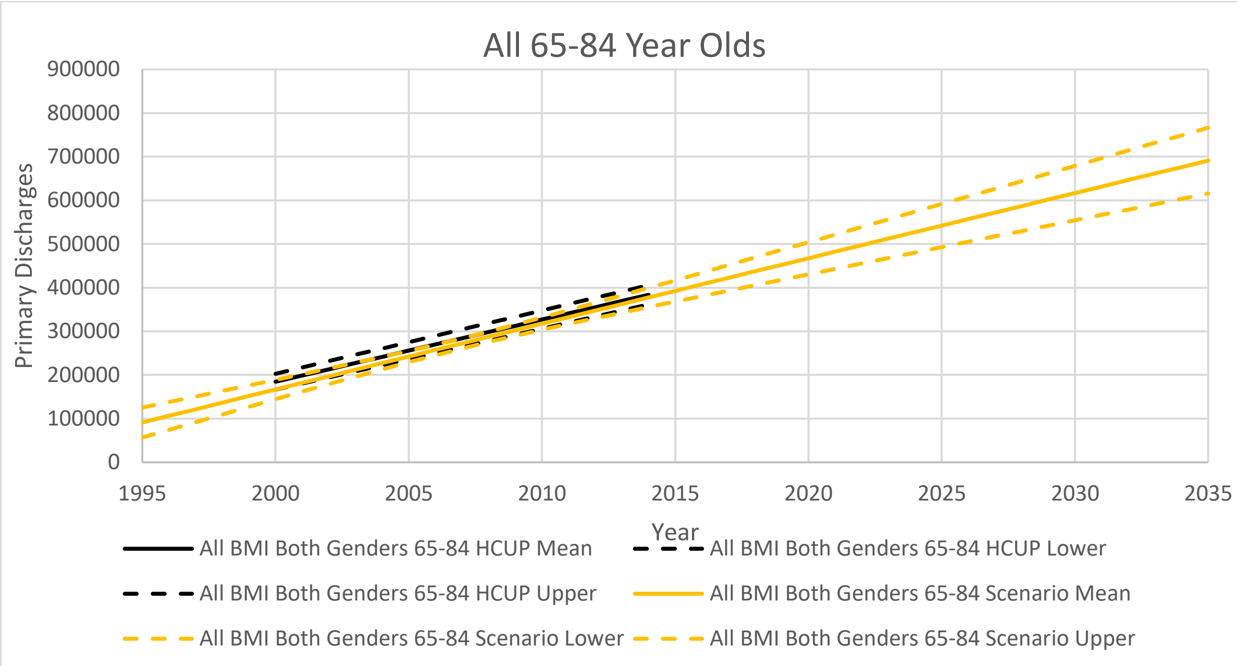


Figure F-8 Final Calibration Against HCUP – Females- 65-84 Year Olds

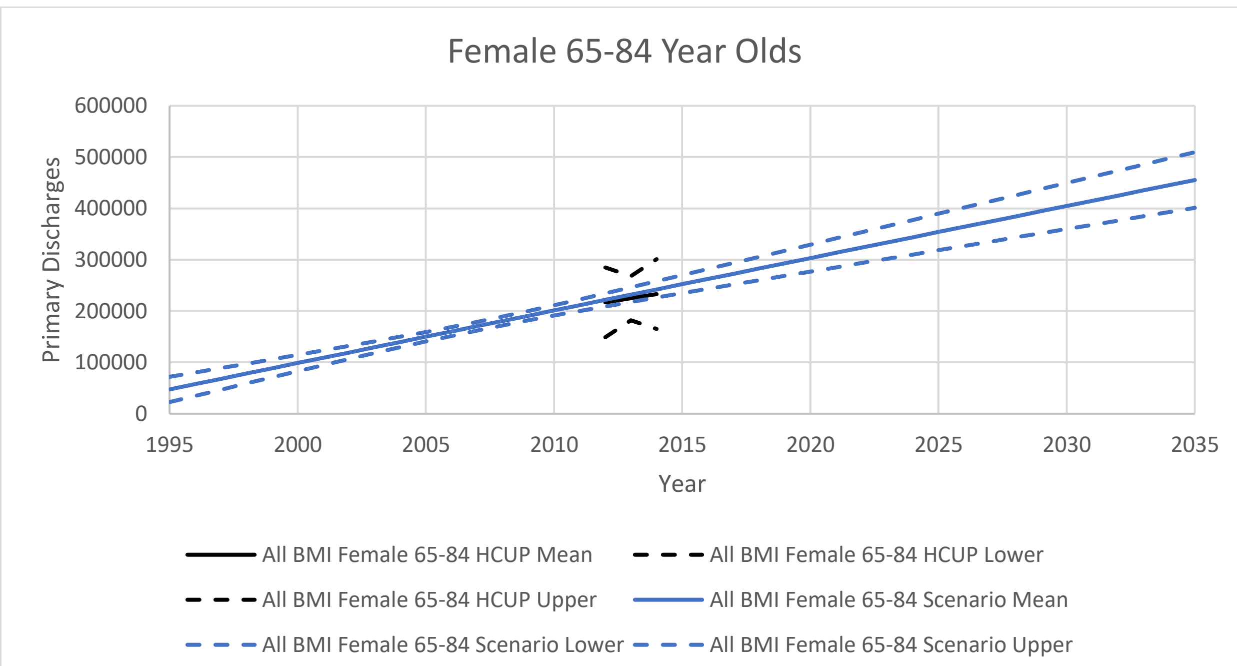


Figure F-9 Final Calibration Against HCUP – Males- 65-84 Year Olds

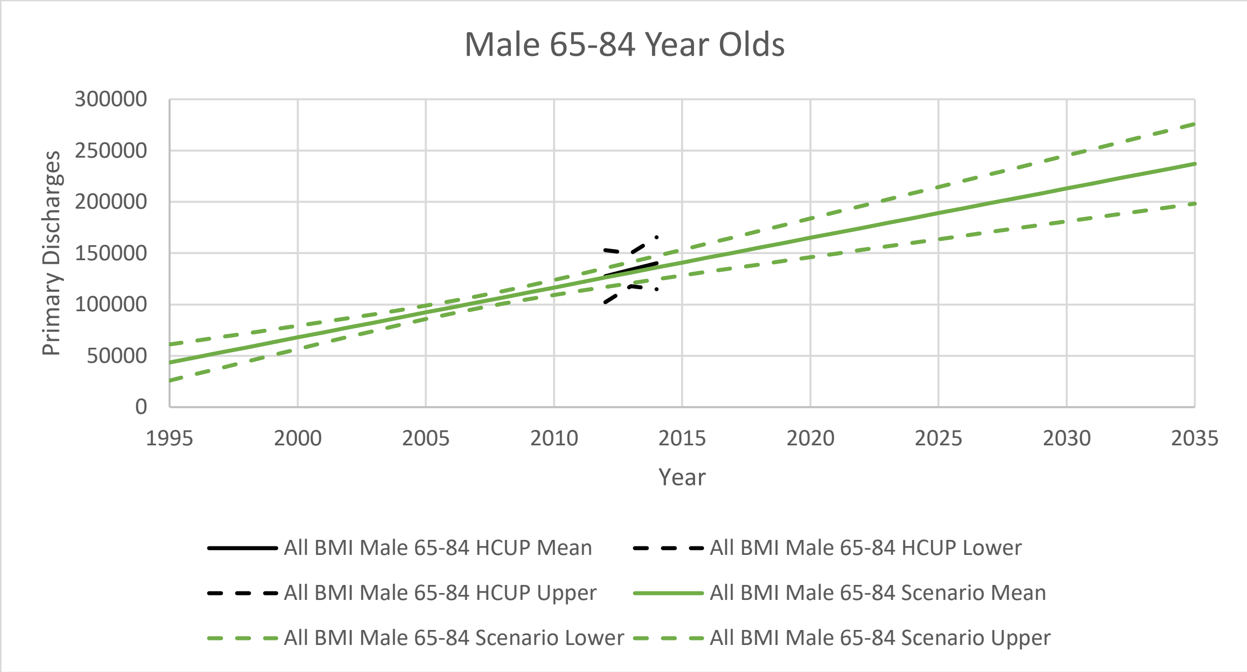


Figure F-10 Final Calibration Against HCUP – Both Genders- 85 Years and Older

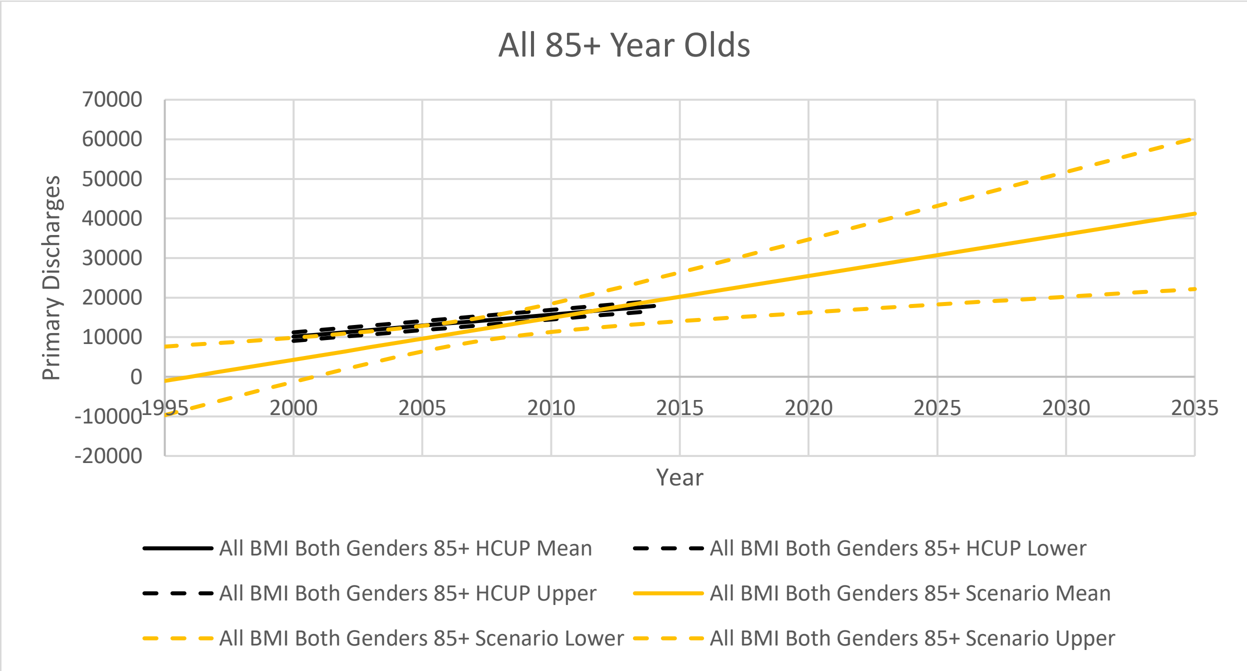


Figure F-11 Final Calibration Against HCUP – Females- 85 Years and Older

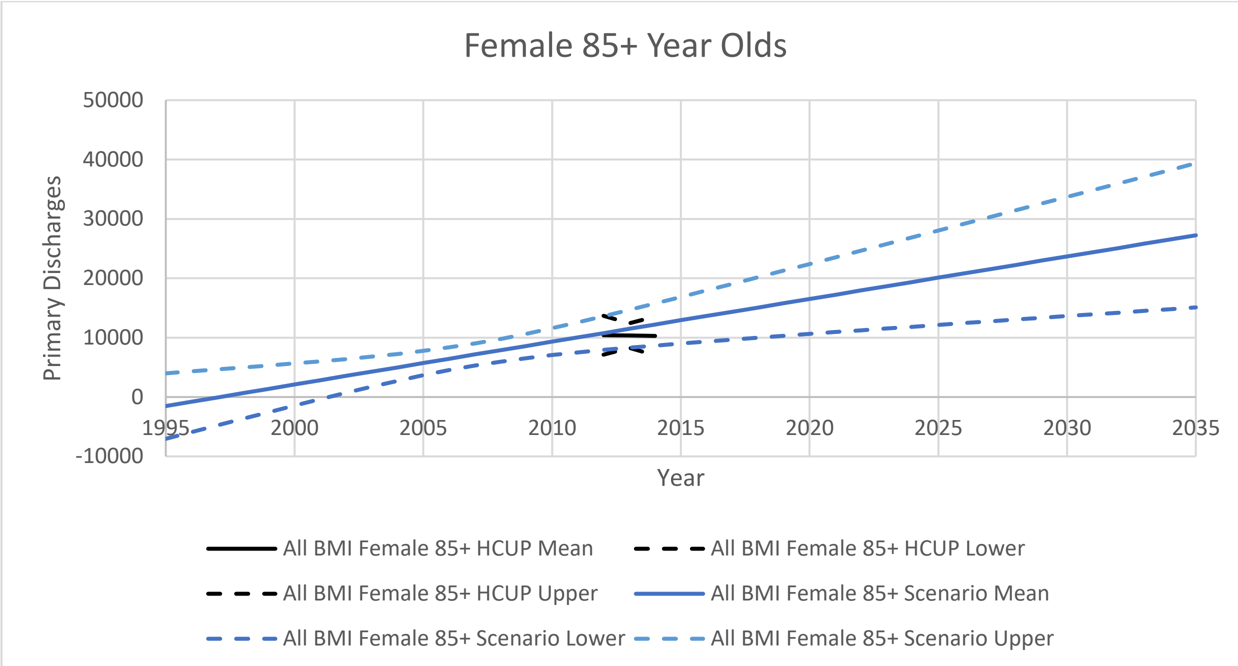


Figure F-12 Final Calibration Against HCUP – Males- 85 Years and Older

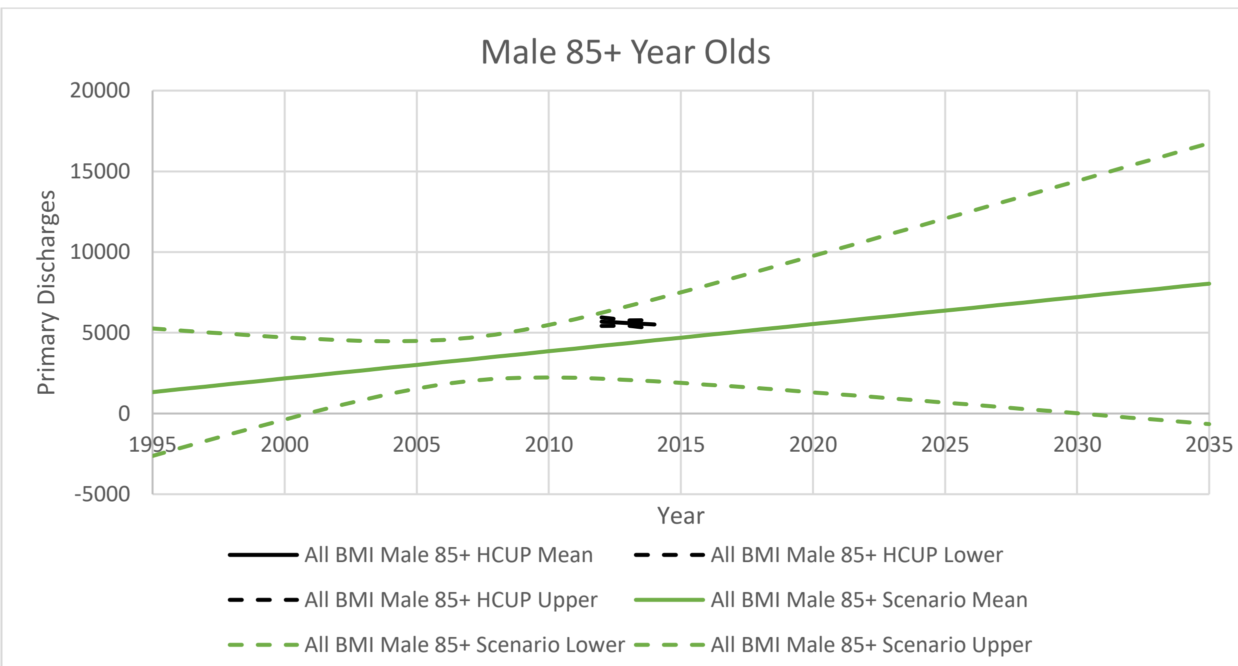
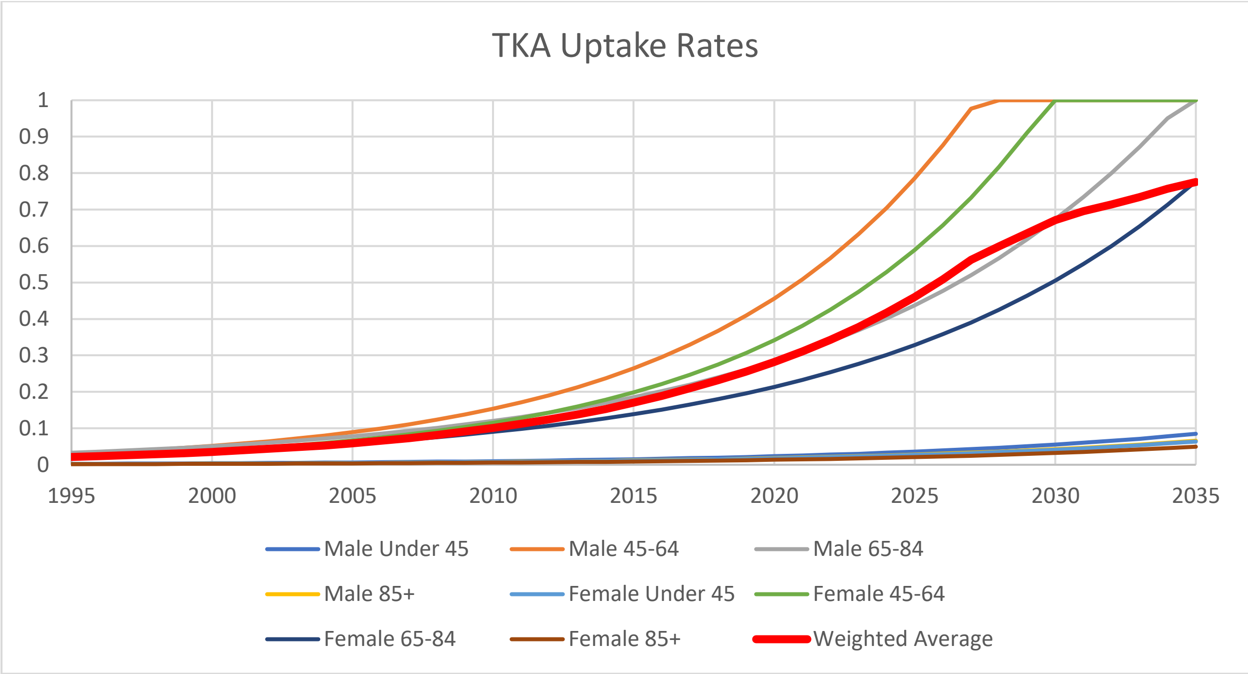


Figure F-13 TKA Uptake Rates by Group Using Final Calibration Values



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