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Obesity and Total Joint Arthroplasty
A Literature Based Review

A Workgroup of the American Association of Hip and Knee Surgeons (AAHKS) Evidence Based Committee*

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ABSTRACT

The prevalence of obesity in the population is unlikely to decline, and is likely to contribute to the increasing demand for hip or knee arthroplasty. Conflicting data exist on the risk and benefits of total joint arthroplasty in obese patients. The purpose of this manuscript is to define and identify areas of concern for obese patients undergoing total joint arthroplasty. A workgroup of total joint arthroplasty surgeons from the American Association of Hip and Knee Surgeons (AAHKS) was tasked with identifying key questions regarding obesity and total joint arthroplasty. The workgroup evaluated the available literature and sought to create a review regarding obesity and total joint arthroplasty to complement and guide the surgeon-patient discussion in addition to identifying areas of future research.

Obesity has reached epidemic proportions with over 502 million people classified as obese worldwide [1]. In the United States, the age adjusted prevalence of obesity is 32% for men and 36% for women and is now a major health care concern [2]. Flegal et al demonstrated an alarming increase in the prevalence of obesity between 1999 and 2008, with the combined obesity and overweight prevalence of 68.0% [2]. Care for obese is costly to the health care system and may account for as much as 21% of all U.S. medical costs [3].

Both biomechanical and physiological mechanisms are compromised by obesity leading to the development of osteoarthritis [4]. Higher BMI results in elevated articular cartilage loading forces which may eventually cause tissue damage. In addition, adipose tissue releases adipokine, a protein that results in excess cartilage inflammation and degradation [5]. Thus obesity significantly contributes to a higher rate of osteoarthritis and ultimately total joint arthroplasty utilization. The risk of developing knee osteoarthritis is nearly four fold for obese men and five fold for obese women [6]. Individuals with a Body Mass Index (BMI) greater than 40 are 8.5 times more likely to need THA compared to matched non-obese individuals [7]. In 1990, Fehring et al [8] noted that 31% of their total joint arthroplasty patients were obese. In 2005, this proportion had increased to 52.1%. This compared to an overall population prevalence of obesity in the same year of 24%.

The notion that obese patients are at an increased risk for complications following total joint arthroplasty has been pointed out in the literature, but must be examined in context. Obesity risk assessment is compounded by the fact that obesity is rarely an isolated diagnosis, and tends to cluster with other co-morbidities that may independently lead to increased risk such as diabetes mellitus, coronary artery disease, hyperlipidemia, hypertension, and sleep apnea [9]. The majority of the current literature reports an increase in perioperative complications associated with total joint arthroplasty for obese patients. The benefits that total joint arthroplasty affords the obese, namely decreased pain and increased function, must then be balanced against the reported increased risk of perioperative morbidity. That risk/benefit needs to include the assessment of the possibility of timely weight loss as a reliable part of conservative care.

It has been predicted that by the year 2030 the demand for primary hip arthroplasty will exceed 500,000 cases and the demand for primary knee arthroplasty will be nearly 3.5 million cases [10]. Given the prevalence of obesity, a significant percentage of these cases will be in patients outside the normal BMI range. The prevalence of obesity is not likely to decline, and is likely that it will contribute to the increasing demand for hip or knee arthroplasty.

With these issues in mind, the purpose of this manuscript is to define and identify areas of concern for obese patients undergoing

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total joint arthroplasty. A workgroup of total joint arthroplasty surgeons from the American Association of Hip and Knee Surgeons was tasked with identifying key questions regarding obesity and total joint arthroplasty. This is not a literature replete with prospective, randomized studies, nor do the cohort studies available lend themselves to formal meta-analysis. The workgroup evaluated the available literature and sought to create a review regarding obesity and total joint arthroplasty to complement and guide the surgeon-patient discussion in addition to identifying areas of future research.

Methods

A workgroup of twelve surgeons was convened to identify issues related to total joint arthroplasty in obese patients. Each physician is an active member of the American Association of Hip and Knee Surgeons (AAHKS) including members of the Evidence Based Medicine (EBM) committee.

Four key areas of concern regarding obesity and total joint arthroplasty were developed. Each question was assigned to three members of the group. Each subgroup then evaluated the current literature with regards to the proposed questions and formulated a general consensus on the particular topic. Each topic was then circulated among the entire group for changes and/or additions to reach a final consensus among the group and formulate a single manuscript.

The four core areas that were addressed by the workgroup included:

1. A. What is the current definition and classification of obesity, and B. What impact does obesity have on the development of osteoarthritis and need for total joint arthroplasty?
2. Are perioperative medical and surgical complications increased following total joint arthroplasty in obese patients?
3. What are patient related outcomes following total joint arthroplasty in obese patients?
4. Can a threshold be determined for obese patients (BMI or other metrics) beyond which complications for obese patients are unacceptable and should preclude the utilization of total joint arthroplasty?

Findings of the Workgroup

1. A. What is the current definition and classification of obesity?

Body mass index (BMI) is commonly used to determine the classification of adults into the categories of underweight, normal, and overweight. BMI is calculated according to height and weight of the individual utilizing the formula:

$$\begin{aligned}\text{BMI} &= \text{weight(kg)}/\text{height}^2\left(m^2\right) \text{ or BMI}\\ &= \left[\text{weight(pounds)}/\text{height}^2\left(\text{inches}^2\right)\right]x703\end{aligned}$$

Several criticisms of using BMI as a measure of obesity include the fact that it does not distinguish between weight associated with muscle versus weight associated with adipose tissue. In addition, it does not take into account the distribution of adiposity, nor does it allow for differences across populations and genders. It is, however, widely accepted as a measure of obesity due to the ease of data collection for large cohorts.

The World Health Organization (WHO) published on the global epidemic of obesity in 2000 [9]. The WHO classification of obesity is noted in Table 1. Class III obesity has been further categorized into the terms "Morbidly-Obese" and "Super-Obese" in the bariatric surgery literature [11]. Morbid obesity is defined as a BMI of 40.00–49.99 kg/m^2 and super obesity is defined as a BMI of ≥50.00 kg/m^2.

Table 1
World Health Organization Classification of Obesity [9].

Classification	BMI (kg/m^2)	Risk of Comorbidities
Underweight	<18.50	Low (but risk of other clinical problems increased)
Normal range	18.50–24.99	Average
Overweight:	≥25.00	
Preobese	25.00–29.99	Increased
Obese class I	30.00–34.99	Moderate
Obese class II	35.00–39.99	Severe
Obese class III	≥40.00	Very severe

1 B. What is the impact that obesity has on the development of osteoarthritis and need for total joint arthroplasty?

The question of whether obesity is related to the development of osteoarthritis (OA) is complicated by the confounding fact that BMI is a reflection of overall weight rather than fat distribution. It may be weight alone, rather than fat composition that predisposes an individual to OA [12]. The variability of study designs in obesity/OA literature makes meta-analysis difficult. The methods of studies examining the correlation between obesity and OA have varied in their definitions of obesity as well as selecting cohorts for comparison (i.e. some studies compare the highest and lowest quintiles while others use groups based on BMI). The measured endpoints also differ between studies, with some reporting radiographic findings and some reporting arthroplasty as the endpoint. Obesity (BMI ≥30) has been strongly associated with the development of knee OA but not hip OA in several studies [13–15]. Some have reported a significant link between obesity and the development of osteoarthritis in both hip and knee OA, although the strength of association was stronger in knees as compared to hips [16,17].

Despite differences in definitions and study designs, some clear patterns have emerged from the published literature. The link between obesity and the risk of knee osteoarthritis was classically demonstrated by the Framingham Study group [18]. This study, published in 1988, predated the WHO obesity classification. The study design assessed the relative risk of OA among the heaviest quintile of weight with the lightest 3 quintiles, as measured at a baseline examination. The cohort was followed for 18 biennial examinations and knee radiographs were obtained at the 18th examination. The age-adjusted relative risk of men in the heaviest quintile was 1.51 (95% Confidence Interval (CI), 1.14–1.98). The age-adjusted relative risk of women in the heaviest quintile was stronger, 2.07 (95% CI 1.67–2.55).

A population based case–control study demonstrated that relative to a BMI of 20–24.9 kg/m^2, the risk of knee OA was 0.1% (95% CI 0–0.5) for a BMI <20 kg/m^2, increasing to 13.6 (95% CI 5.1–36.2) for a BMI of ≥36 kg/m^2 [19]. Similar data from longitudinal population studies exist in studies from Norway [13] and Sweden [16].

Given the higher incidence of OA in the obese, it is not unexpected that a correlation between obesity and the need for hip or knee arthroplasty exists as well [17,19–21]. The relative risk of women with a BMI ≥30 kg/m^2 requiring arthroplasty compared to women <22.5 kg/m^2 is greater for knee (10.51 (95% CI 9.52–11.62)) than for hip (2.47 (95% CI 2.25–2.71)) [20]. A study of male construction workers noted that BMI is a predictor of OA, even within a normal BMI range [21]. The relative risk of hip arthroplasty was more than double for patients with a BMI of 20–24 kg/m^2 as compared to patients with a BMI of 17–19 kg/m^2. An increase of BMI of 5 kg/m^2 nearly doubled the risk of knee arthroplasty. The age at which arthroplasty is performed may also be affected by BMI. Patients with a BMI ≥35 kg/m^2 may require arthroplasty 7 years earlier, on average, as compared to patients with a BMI ≤25 kg/m^2 [22].

2. Are perioperative medical/surgical complications increased following total joint arthroplasty in the obese patient?

Wound Healing/Infection

Wound healing complications and infection, particularly deep infection, are among the most concerning complications for surgeons and patients alike. A deep infection may ultimately lead to resection or removal of the prosthesis, joint fusion, or amputation, and almost always requires reoperation. There is a clear increase in wound healing complications and deep infection in reports examining joint replacement surgery in the obese. In a single-center analysis of 7181 primary hip and knee arthroplasties for osteoarthritis, Jamsen and colleagues [23] demonstrated that the infection rate increased from 0.37% in patients with a normal body mass index to 4.66% in the morbidly obese group. Furthermore, Malinzak et al showed that in both hip and knee patients a BMI greater than 50 increased the odds ratio of infection to 21.3 [24].

In a study of 60 patients with an average BMI of 39.9, Nunez and co-workers [25] demonstrated almost twice the risk (11.6% vs. 6.6%) of in hospital wound problems as well as three times the rate of deep infections after total knee arthroplasty compared to controls (5.0% vs. 1.6%). Ersozlu et al confirmed that superficial infections were more common in morbidly obese and obese patients undergoing TKA [26].

In regard to total hip arthroplasty Lubbeke and colleagues have shown a dramatic risk of deep infection for obese women with BMI greater than 30 [27]. This group of patients had a 16.1 rate ratio for deep infection compared with non-obese women undergoing THA. Bozic et al further demonstrated that obesity is an independent predictor of periprosthetic infection in a large cohort of Medicare patients undergoing THA [28]. Namba et al reviewed 1071 THA surgeries and demonstrated that obesity was associated with a higher infection rate [29].

Respiratory Complications

There is no question that there is an association between obesity and obstructive sleep apnea (OSA) [5,30]. Sixty to 90% of OSA patients are obese, with indices of obesity such as BMI strongly and directly related to the severity of the OSA [31]. Obstructive sleep apnea is associated with general risks to a patient's health including cardiac disease, hypertension, and the risk of sudden death after surgery due to oversedation. In a study by Gupta et al [32], the authors noted that total joint surgery patients with OSA had a 39% risk of complications compared to 18% in the patients without OSA. Serious complications occurred in 24% of the patients with OSA compared with only 9% in the patients without OSA. In addition to sleep apnea, there might be higher risk in the obese patient for developing thrombosis and potentially a pulmonary embolism.

Thromboembolic Disease

Thromboembolic disease has been a major concern for orthopaedic patients for decades, and prevalence has been shown to increase with patient immobilization and surgical trauma [33]. Obese total joint patients often are slower to mobilize and usually require more invasive surgical exposure. Altintas et al demonstrated in their analysis that the most common risk factors for venous thromboembolism (VTE) in orthopaedic patients are obesity and prolonged immobilization [34]. Furthermore, obesity, history of deep vein thrombosis (DVT), delayed post-operative ambulation, and female sex were considered risk factors for VTE as determined by White et al [35]. Multiple reports identify obese patients as being at elevated risk for thromboembolic disease (TED) in the post-operative period [36–38]. The recent AAOS network meta-analysis regarding VTE, however, did not identify any risk factor other than previous thrombotic event as raising the risk higher than the already higher risk that undergoing joint arthroplasty already entails.

Complications Specific to Total Joint Arthroplasty

Revision Surgery

Chee and colleagues [39] compared 55 consecutive total hip arthroplasties (THA) performed on 53 morbidly obese patients with osteoarthritis with a matched group of 55 total hip arthroplasties in 53 non-obese patients, and followed them prospectively for five years. Survival at five years using revision surgery as an endpoint, was 90.9% for the morbidly obese and 100% for the non-obese patients. This was due to a higher rate of complications (22% vs. 5%, $P = 0.012$) in the morbidly obese group, which included dislocation and both superficial and deep infection.

Spicer et al, evaluated the clinical and radiographic outcome of total knee arthroplasty (TKA) in 326 TKAs with BMI >30 and compared them to a matched group of 425 TKAs with BMI <30 [40]. There was no appreciable difference in the ten year survivorship and functional improvement appeared to be independent of BMI, but a subgroup of patients with BMI greater than 40 had a 5 fold increase in the rate of focal osteolysis on radiographs. Morbidly obese patients were found to be at higher risk of revision. Bordini et al, studied a population of subjects treated with cemented total knee arthroplasty between 2000 and 2005 [41]. A total of 9735 knee prostheses were implanted in 8892 patients; 18.9% of the patients were normal weight (BMI <25), 48.2% were overweight (25>Body Mass Index≤30), 31.1% were obese (30>BMI≤40), and 1.8% were morbidly obese (BMI >40). Mean and range of follow-up were respectively 3.1 and 1.5–6 years. While revision rates and complications were not statistically different among the groups, all showed higher trends in the morbidly obese groups. Foran et al demonstrated a statistically significant difference in survival, revision rates and complications in 78 TKA done in obese and morbidly obese patients when they were age matched to a group of nonobese patients [42]. In addition, they were able to demonstrate that these rates increased in the morbidly obese group (BMI >40) compared to nonobese.

Component Malposition

As technology has advanced and surgical technique has been enhanced, larger patients still pose significant surgical dilemmas for exposure and component positioning. Investigators at the Harris Laboratory [43] used postoperative radiographs on 2061 consecutive patients who received a THA or hip resurfacing from 2004 to 2008 to determine factors that correlated with malpositioned acetabular components. There was an increased risk of malpositioning for minimally invasive surgical approach, low volume surgeons, and obese patients. Jarvenpaa et al stratified patients as obese (BMI >30) and nonobese (BMI <30) for 100 patients undergoing total knee arthroplasty [44]. They found a statistically significant difference in post operative complications in the obese group compared to non-obese group. Technical errors were noted in 17 of the obese patients compared to 5 in the non-obese group ($P<0.007$). Ritter et al demonstrated that excessive varus or valgus alignment was detrimental to TKA survival, and that failures due to malalignment were increased with abnormal BMI [45].

Prosthesis Loosening

Clinical and radiographic success of total joint arthroplasty is also not as robust in obese patients. Aseptic acetabular failure has been shown to be related to obesity [46], and a pooled analysis demonstrated that aseptic loosening was increased in obese patients undergoing primary THA [47].

Amin et al, compared a group of 41 morbidly obese patients (BMI >40) to a matched cohort of 41 non-obese patients (BMI <30) undergoing total knee arthroplasty [48]. At less than four years after

operation, the morbidly obese had a higher incidence of radiolucent lines on post-operative radiographs (29% and 7%, respectively, $P=0.02$), a higher rate of complications (32% and 0%, respectively, $P=0.001$) including superficial and deep infections, and inferior survivorship using revision and pain as end-points (72.3% and 97.6%, respectively, $P=0.02$). Other authors have also noted a trend for obesity to influence the rate of aseptic loosening [49] and long term survival [42]. Ritter et al demonstrated that TKA survival was related to obesity, with greater obesity associated with increased failure and loosening [45].

THA Dislocation

Of the potential complications associated with THA, obese patients have higher dislocation rates. Lubbeke et al studied the gender differences in outcomes of obesity following total hip arthroplasty [27]. Of the 2,186 patients that underwent primary THA, 23.6% were in obese patients. Obese was defined as BMI >30 and was not stratified beyond this. The incidence rate of dislocation was 2.3× higher in the obese than non-obese and obese women were at the highest risk (rate ratio 3.0). Grant et al evaluated 255 males in a VA population undergoing primary THA and demonstrated an increased risk of dislocation in the morbidly obese group (BMI >40) compared to the obese and non-obese group (BMI >30) [50]. A pooled analysis demonstrated that dislocation was increased in obese patients undergoing primary THA [47]. Lastly, Davis et al recently showed a 4.42 times higher dislocation rate in THA patients with a BMI of greater than 35, compared with those with a BMI of less than 25 [51].

Cost and Length of Stay

Although not typically thought of as a complication, cost and length of stay (LOS) have to be considered in an era of relative health care fiscal contraction. These measures are sometimes a surrogate for "quality". In our current health care environment "zero-tolerance" is being invoked as policy for post-operative complications and surrogates for quality are derived from insensitive but easily retrieved parameters. An analysis of LOS, cost, and readmission rates is salient when considering surgery in the obese population.

Obesity has been implicated in increased length of stay for both hip and knee arthroplasty [52]. The relationship of body weight to increased length of stay and increased charges for hospital services for obese patients undergoing elective surgery has been well documented [52]. This is particularly an issue for the so-called "super-obese," those patients with a BMI greater than 45 [53]. In this grouping of patients with a BMI greater than 45, in house complications were 8.44 times more likely than non-obese patients, and the risk of in-hospital complications, complications within 1 year, readmission, and length of stay all increased measurably for each 5 unit increase in BMI. This relationship of increased cost and length of stay has also been demonstrated for total knee patients in the rehabilitation setting with a BMI greater than 30 [54].

Association of Obesity and Outcomes Following Total Hip and Knee Arthroplasty

The goal of Total Joint Arthroplasty (TJA) is to improve the physical function and quality of life in individuals with symptomatic osteoarthritis while minimizing the adverse effects and treatment risks to patients. Understanding the effect that factors such as obesity can have on the functional outcomes of surgery provides better probability of positive prognostic performance and reducing costs of clinical care [55].

Total Knee Arthroplasty

Many investigations have been conducted to develop a better insight into the adverse effects of obesity on both short-term and long-term outcomes of TKA [4,49,56–58]. This understanding provides surgeons and health care providers with more optimal post-operative rehabilitation guidelines and may help with lowering overall cost. In addition, patients are provided more realistic expectations about the outcomes of surgery which prepares them to overcome difficulties during post-op recovery [57].

Although previous studies have reported conflicting results regarding the association of obesity and the outcome of TKA, the reduction of excess BMI has been consistently recommended, especially in morbidly obese individuals [59]. Some studies indicate that obese individuals experience lower quality of life and performance after TKA [48,59–61] and significantly higher risk of post-op infections [29,56,62–64]. Stickles et al investigated the effect of obesity on 1011 primary TKA patients and concluded that the performance of the obese individuals quantified by Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and the Short Form-36 (SF-36) was significantly lower. Additionally, the 1-year follow up indicated that higher BMI negatively affected the ascending and descending capabilities in these individuals [61]. Smith et al used Hospital for Special Surgery (HSS) questionnaires to investigate the effects of obesity and concluded that TKA outcome was altered as depicted by lower HSS scores in obese individuals [65]. In a more recent study, HSS scores were used to assess the performance of 535 patients who underwent TKA. Results indicated significantly lower HSS scores in obese individuals compared to the peer-matched non-obese patients [66]. In 2012 Colllins et al reported on 445 consecutive primary TKAs prospectively followed up to nine years. Clinical outcomes of non-obese (BMI <30) were compared to obese (BMI >30) patients. Significant improvements in outcome were seen and sustained in all groups nine years after TKA. However, lower function scores were seen at all follow-up periods prior to nine years in the highly obese subset group with BMI >35. No significant difference was found in revision or implant survival between obese and non-obese patients nine years after TKA [67].

There are, however, other investigations reporting contradictory findings with no significant differences observed between obese and non-obese individuals in regard to the outcome of TKA [42,49,68,69]. In addition Singh et al indicated that no significant association was detected between the perceived pain outcomes and patients BMI in a 2-year and 5-year primary TKA follow-up [57]. In an even more recent study, the British National Joint Registry assessed patient-reported outcome measures relating to TKA in 13,673 patients who fulfilled criteria for analysis. Preoperative and postoperative assessments using the Oxford Knee Score and general health EuroQol 5D questionnaires were carried out. The improvements in patient-reported outcome measures experienced by patients were similar, irrespective of BMI, although wound complications were significantly higher ($P<0.001$) at a rate of 17% in patients with BMI between 40 and 60 [70].

Despite contradictory findings, the aforementioned studies indicate the beneficial effects of TKA on the improvement of performance and quality of life. Investigations on the satisfaction level after TKA indicated no significant differences between obese and non-obese individuals [26,68,71,72]. Therefore TKA may be considered as the primary treatment for severe knee osteoarthritis in obese patients [58]. Expectations are for a steady, but slower improvement in the severe obese compared to non-obese patients post operatively [73]. There does appear to be a functional "glass ceiling" in obese patients, based on their co-morbid state rather than their joint arthroplasty [40,42].

Total Hip Arthroplasty

Increase in BMI has shown significant increase in the rate of THA utilization. Individuals with Class III obesity are 8.5 times more likely to need THA compared to matched non-obese individuals [7]. Stickles et al investigated the quality of life and performance of 592 patients

who underwent primary THA and concluded that WOMAC and SF-36 scores were significantly lower in obese individuals (WOMAC of 48.4 for nonobese vs. WOMAC of 39.9 for obese). They observed, however, no significant effect of obesity on the surgery satisfaction and pre to post-op physical and mental status changes, and concluded that higher BMI was not significantly associated with worse outcomes of THA in obese patients [61].

Additionally, Michalka et al have not reported significant differences in the short term outcome of THA in 191 patients (57 obese patients). They only reported that obese individuals had poorer performance in the 6 minute walk test (6MWT). It was argued that the 6MWT could not be conducted prior to the operation due to severe pain in the patients. Therefore no comparison could be made between the two groups with regards to overall improvement in this test. McCalden et al have also investigated 3290 THAs and reported similar outcome suggesting that obese patients enjoyed similar improvements in performance assessed by WOMAC, Harris hip score, and Short-form 12 in a 2-year follow-up study [74].

4. Can a threshold be determined for obese patients (BMI or other metrics) beyond which complications for obese patients are unacceptable and should preclude the utilization of total joint arthroplasty?

The current literature on obesity and its impact on total joint arthroplasty was reviewed. A short synopsis of relevant published articles on obesity and total joint arthroplasty is included in the appendix. Below is a summation of those articles. Given the body of work already presented, an attempt was made to determine if a threshold of Body Mass Index could be established, above which complications associated with total joint arthroplasty are unacceptably high.

There are several issues with the current literature that must be taken into consideration when trying to answer this question. Many of the current studies contain only small numbers of patients, particularly when evaluating patients with higher BMI and comparing them to a larger cohort of nonobese patients. Therefore, many studies are underpowered to be able to show a true difference in outcomes, complications or revision rates. The majority of studies do not stratify patients based on BMI. Most studies classify obesity as a dichotomous variable of obese (BMI >30) and nonobese (BMI ≤30).

In addition, and perhaps most importantly, the majority of studies do not further sub classify patients with associated comorbidities. It is well established that obese patients have an increased prevalence of associated conditions, such as diabetes, hypertension, cardiac disease, obstructive sleep apnea and malnutrition. Many of these comorbidities have been shown to be independent risk factors for the development of periprosthetic joint infection and perioperative complications.

Several recent studies published in 2012 have looked at threshold for BMI and associated complications following total joint arthroplasty and bear mentioning here. Schwarzkopf et al [53] evaluated the outcomes of "super-obese" patients undergoing total joint arthroplasty. This retrospective study determined that Super-obese patients had an odds ratio (OR) of 8.44 for developing inhospital complications. Most importantly, each incremental 5-U increase in BMI above 45 was associated with an increased risk of inhospital (OR, 1.69) and outpatient complications (OR, 2.71), and readmission (OR, 2.0). Length of stay was increased by 13.8% for each 5-U increase in BMI above 45. In addition, Kamath et al [75] determined that BMI >35 was an independent risk factor for unplanned admission to the intensive care unit following elective total hip arthroplasty.

Jamsen et al [23], determined in a multivariate analysis, morbid obesity (BMI >40) was an independent risk factor for the development deep periprosthetic infection. In addition, diabetes nearly doubled the risk for development of deep periprosthetic infection, and this effect was highest in the morbidly obese, diabetic group. Namba, et al [76], evaluated risk factors associated with surgical site infection in 30,491 total hip arthroplasties performed between 2001 and 2009. In a multivariate analysis, Body mass index >35 was associated with a 2.37× increased risk for development of surgical site infection.

Critical Findings

- Despite improvements in patient related outcome measures, all obese patients (BMI >30) undergoing total joint arthroplasty are at increased risk for perioperative complications and this needs to be discussed with every patients prior to considering total joint arthroplasty.
- For total knee arthroplasty, based on the current literature, it appears that the morbidly obese patients, defined as a BMI ≥40, are the threshold for which the majority of perioperative complications, including infection and revision rates appear to increase considerably. This needs to be discussed with every patient prior to surgery and strong consideration should be given to reducing weight (BMI <40) and minimizing associated comorbidities.
- The data for total hip arthroplasty appear to be less clear. There are fewer studies that report on obesity and total hip arthroplasty, and there is much less consensus on a threshold above which complications increase. It would seem reasonable to extrapolate data from the total knee arthroplasty group, and recommend that patients with a BMI >40 be counseled regarding weight loss prior to surgery, but a strong recommendation cannot be made.

Further studies are needed to subclassify obese patients to truly determine if a threshold exists. These studies must also take into consideration associated co-morbidities, with a critical question of: Does alteration of these associated comorbidities (diabetes, hypertension, hypercholesterolemia), in spite of obesity, improve outcomes and lower perioperative morbidity?

Conclusions of the Work Group

- Obesity as classified by World Health Organization, defined as BMI >30, has limitations regarding adipose tissue distribution, but remains the most useful and widely used classification system.
- There is clear evidence to suggest that obesity is associated with the development osteoarthritis in the knee, but evidence in the hip is less clear.
- Due to the association of obesity with the development of osteoarthritis, the obese population will be at greater risk for total joint arthroplasty and comprise an ever increasing segment of total joint arthroplasty population.
- Obesity has a strong association with other comorbid conditions that place these patients at increasing risk for perioperative complications following total joint arthroplasty. In addition to obesity alone, it is important that these modifiable comorbid conditions be managed appropriately prior to surgical intervention.
- The degree of functional improvement following total joint arthroplasty in the obese population remains controversial. It appears that obese patients have similar satisfaction rates as the nonobese population following total joint arthroplasty. As BMI increases (>40), however, the functional improvement becomes less and/or occurs more gradually and must be tempered with the associated increased complication profile.
- All obese patients (BMI >30) appear to be at risk for increasing perioperative complications following total joint arthroplasty. This becomes especially relevant as the number of associated comorbidities increases and their control less well regulated.

- The morbidly obese (BMI >40) and the super obese (BMI >50) have complication profiles that may outweigh the functional benefits of total joint arthroplasty. These patients should be counseled regarding these risks prior to any surgical intervention. It is our consensus opinion that consideration should be given to delaying total joint arthroplasty in a patient with a BMI >40, especially when associated with other comorbid conditions, such as poorly controlled diabetes or malnutrition.

This recommendation is tempered by the realization that there will be patients for whom all available means of weight loss have failed; there will also be patients for whom surgery is unavoidable due to truly crippling arthritis, fracture, and/or certain tumors. There should be full disclosure to such patients of the added risk and possibly diminished long term outcomes if surgery is considered.

Further Level I and Level II research is needed to adequately evaluate the impact that obesity has on total joint arthroplasty. In addition, it is important to determine if safe weight loss prior to total joint arthroplasty alters the outcomes of obese patients. It is the intention of this committee to continue to monitor the literature and periodically revisit and update the information provided.

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Appendix B. Appendix of Referenced Studies for Question #4: Obesity and Total Joint Arthroplasty:

In 1993, Jiganti et al compared perioperative outcomes between obese and non-obese patients undergoing total joint arthroplasty [77]. Obesity was defined as >20% above ideal weight for height based on life insurance tables from 1983. Body Mass Index was not calculated and the non-obese group had more preoperative co-morbidities. The authors found no associated increase in perioperative complications for the obese patients.

Malinzak et al, demonstrated that obesity, diabetes and younger age were all risk factors for the development of deep periprosthetic infection following total joint arthroplasty [24]. Patients with BMI greater than 40 had a 3.2 times odds of infection and patients with BMI >50, a 18.3 times odds of infection compared to patients with BMI <40.

Namba et al demonstrated a 6.7× higher risk of infection for obese patients (BMI >30) undergoing primary TKA and 4.2× higher infection risk for obese patients undergoing primary THA compared to a nonobese cohort [29]. In addition, the obese patient population was found to have a higher rate of diabetes and hypertension.

Obesity and Total Knee Arthroplasty

A literature review by Samson et al, evaluated total knee arthroplasty in patients with morbid obesity (BMI >40) [78]. Eight comparative studies were reviewed and while there were overall improvements in outcome measures following total knee arthroplasty, the morbidly obese groups, all studies reported a greater prevalence of complication (10–30%), including a significantly higher prevalence of deep periprosthetic infection(3–9×) and wound complications.

Spicer et al, evaluated the clinical and radiographic outcome of total knee arthroplasty in 326 TKAs with BMI >30 and compared them to a matched group of 425 TKAs with BMI <30 [40]. There was no appreciable difference in the ten year survivorship and functional improvement appeared to be independent of BMI, a subgroup of patients with BMI >40 had 5× the rate of focal osteolysis on radiographs however.

Nunez evaluated quality of life outcomes in a stratified group of severely obese (BMI >35) and morbidly obese (>40) compared to a group of patients with BMI <35 undergoing total knee arthroplasty [26]. There were no differences in the health related quality of life outcomes between all groups. The study group (obese) however had more severe post-operative complications compared to the control group. These results were not stratified by BMI however.

Dewan et al evaluated 169 TKA stratified by BMI into 3 groups (<30 (85 patients), 30–39 (94 patients), >40 (41 patients) [60]. Success, complications and revisions were similar across all groups. The patients with BMI >40 however were 5.4× more likely to have patellofemoral radiolucencies, have quadriceps and hamstring weakness and have patellofemoral problems.

Bordini et al, studied a population of subjects treated with cemented total knee arthroplasty between 2000 and 2005 [41]. A total of 9735 knee prostheses were implanted in 8892 patients; 18.9% of the patients were normal weight (BMI <25), 48.2% were overweight (25>Body Mass Index≤30), 31.1% were obese (30>BMI≤40), and 1.8% were morbidly obese (BMI >40). Mean and range of follow-up were respectively 3.1 and 1.5–6 years. Implant failure was defined as the exchange of at least one component for whatever reason. While revision rates and complications were not statistically different among the groups, all showed higher trends in the morbidly obese groups. In addition, the small number of patient in the morbidly obese group (172) compared to the rest, should caution one's interpretation of these data.

Jarvenpaa et al stratified patients as obese (BMI >30) and nonobese (BMI <30) for 100 patients undergoing total knee arthroplasty [44]. They found a statistically significant difference in post operative complications in the obese group compared to nonobese group. In addition, technical errors were noted in 17 of the obese patients compared to 5 in the non-obese group ($P<0.007$).

Patel et al, evaluated 527 patients that underwent primary total knee arthroplasty [79]. Patients were stratified by BMI (<25, 25–29, 30–34, >35). BMI ranged from 16 to 50, with an average of 29. The authors concluded that BMI did not show any correlation with post op complications, however the data clearly shows a trend towards an increase in complication as the patients BMI increased.

Foran et al demonstrated a statistically significant difference in survival, revision rates and complications in 78 TKA done in obese and morbidly obese patients when they were age matched to a group of nonobese patients [42]. In addition, they were able to demonstrate that these rates increased in the morbidly obese group (BMI >40) compared to nonobese.

Amin et al, compared a group of 41 morbidly obese patients (BMI >40) to a matched cohort of 41 nonobese patients (BMI <30) undergoing total knee arthroplasty [48]. At less than four years after operation, the results were worse in the morbidly obese group compared with the non-obese, as demonstrated by inferior Knee

Society Scores (mean knee score 85.7 and 90.5 respectively, $P=0.08$; mean function score 75.6 and 83.4, $P=0.01$), a higher incidence of radiolucent lines on post-operative radiographs (29% and 7%, respectively, $P=0.02$), a higher rate of complications (32% and 0%, respectively, $P=0.001$) including superficial and deep infections and inferior survivorship using revision and pain as end-points (72.3% and 97.6%, respectively, $P=0.02$).

Although Krushell et al state, that based on their results of 39 TKA in morbidly obese group (BMI >40), that total knee arthroplasty should continue to be offered as a treatment option, their study demonstrates a significantly higher rate of wound complications in the morbidly obese cohort [80]. In addition, overall patient's satisfaction scores were lower and radiographic review showed a trend toward higher incidence of radiolucent lines in the morbidly obese group.

Obesity and Total Hip Arthroplasty

Grant et al evaluated 255 males in a VA population undergoing primary THA and demonstrated an increased risk of dislocation and infection in the morbidly obese group (BMI >40) compared to the obese and nonobese group (BMI >30) [50].

Michalka et al stratified patients undergoing primary THA by BMI into nonobese (BMI <30), Obese (BMI 30–34) and morbidly obese (BMI >35) [81]. In 191 THAs, the authors were unable to identify any significant increase in complications in the obese or morbidly obese group. In addition all outcome measures and quality of life measure were equivalent. It should be noted however that there were only 21 patients in the morbidly obese group, question whether there was enough power in the study to determine a true difference.

Lubbeke et al studied the gender differences in outcomes of obesity following total hip arthroplasty [27]. Of the 2,186 patients that underwent primary THA, 23.6% were in obese patients. Obese was defined as BMI >30 and was not stratified beyond this. The obese group was younger and had a higher ASA scores. The incidence rate for infection was 4.7× higher in the obese group compared to non-obese, and was 16.1× higher in obese women. The incidence rate of dislocation was 2.3× higher in the obese than non-obese and obese women were at the highest risk (rate ratio 3.0).

Ibrahim et al found no statistically significant difference in complications, outcomes, or revision surgery in primary total hip arthroplasty when comparing 179 THAs in patients with BMI average of 22.5 to an obese group of 164 THAs with an average BMI of 33.3 [82]. It should be noted that there were no patients with a BMI >40 in the study.

McLaughlin et al stated that based on their analysis of THA in both obese and nonobese patients, THA should not be with held in the obese patient based solely on BMI [83]. They found no statistical difference in outcomes or revision rates comparing 109 nonobese patients to 100 obese patients. An interesting finding in this study was the high failure rate of the acetabular component at an average of 14 year follow up in both the obese (57%) on nonobese group (66%). Also of note, only 6 patients had BMI >35.

A recent meta-analysis evaluated outcomes and complications in 15 studies of primary THA in obese patients [47]. A pooled analysis demonstrated that dislocation, infection, aseptic loosening and venous thromboembolism were all increased in obese patients undergoing primary THA. Obese patients (BMI >30) were not further stratified.

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