Obesity
The Modifiable Risk Factor in Total Joint Arthroplasty

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KEYWORDS

• Arthroplasty • Total hip arthroplasty • Total knee arthroplasty • Obesity • Risk factors

KEY POINTS

- Obesity is associated with increased complication rates in arthroplasty patients.
- Obese patients are at higher risk for infection and dislocation, and have poorer implant survivorship and functional scores postoperatively.
- To some degree, obesity is a modifiable risk factor and nutritional or bariatric surgery evaluation should be considered.
- Obese patients must be counseled to set realistic expectations after arthroplasty.

INTRODUCTION

Obesity is a significant and growing challenge facing the entire health care system. It has reached epidemic status in the United States. Obesity poses several challenges and raises unique issues for the arthroplasty surgeon.[1] Of the US population, 37% is classified as obese and rates are climbing.[2,3] Overall, medical costs in the United States due to obesity exceed $275 billion and account for more than 20% of all US health care expenditure.[4]

For adults, the World Health Organization defines a normal body mass index (BMI) as 19.5 to 24.9 kg/m^2 and overweight as 25 to 29.9 kg/m^2. A BMI greater than 30 kg/m^2 is defined as obese, greater than 40 kg/m^2 as morbidly obese, and greater than 50 kg/m^2 as superobese.[5] The terminology of class 1 obesity (BMI 30.0–34.9 kg/m^2), class II obesity (35.0–39.9 kg/m^2), and class III obesity (40.0 kg/m^2 and up) can also be used.[5]

The purpose of this discussion is to characterize how the modifiable risk factor of obesity interacts with total joint arthroplasty (TJA). This article examines the role obesity plays in early progression of osteoarthritis (OA) and need for TJA; discusses perioperative optimization, the role of bariatric surgery, and the rate of complications in obese patients; and assesses the outcomes of arthroplasty in obese patients.

INCIDENCE AND TIMING OF ARTHROPLASTY

It stands to reason that obese patients are at higher risk of developing OA.[6,7] OA is multifactorial in origin and obesity is among the principal modifiable risk factors.[4] The intuitive biomechanical explanation is clear: increased joint reactive forces from higher body weight cause subsequent wear and articular cartilage breakdown.[6] Obesity may also act via local and systemic biomechanical changes to activate inflammatory pathways that affect progression of cartilage damage and perception of pain.[3,6] Although OA has been labeled as noninflammatory, there

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is evidence that it has an inflammatory component. Obesity is characterized by secretion of proinflammatory cytokines causing a low-grade, chronic inflammatory state that may contribute to progression of OA.[6]

Several studies have assessed the role of obesity on the timing of arthroplasty. A biomechanical model by Recnik and colleagues[7] assessed a cohort of 431 consecutive hip arthroplasty subjects. They used radiographic parameters to model peak contact hip stresses and joint reactive forces. They found that increased body weight tracked directly with increased hip contact stresses in their model. Additionally, higher body weight was significantly correlated with earlier age at total hip arthroplasty (THA).[7]

A large cohort study by Bourne and colleagues[8] of 54,406 subjects from the Canadian Joint Registry analyzed the association between obesity and the subsequent need for hip or knee arthroplasty. Compared with a control group of subjects with BMIs 25 kg/m^2 or less,[2] they found that increasing BMI was progressively correlated to higher risk of arthroplasty. At BMI 25 to 29.9 kg/m^2, risk was 3.2-fold higher for TKA and 1.92-fold higher for THA. At BMI 30 to 34.9 kg/m^2, relative risk progressed to 8.53 for total knee arthroplasty (TKA), and 3.42 for THA. At BMI 35 to 39.9, risk was 18.73 for TKA, and 5.24 for THA. Finally, for those subjects with BMI greater than 40 kg/m^2, risk was 32.73-fold higher for TKA, and 8.56-fold higher for THA. The data support the conclusion that obesity is a significant risk factor for severe OA progressing to need for arthroplasty, likely disproportionately affecting progression of knee OA more than hip OA.

In a 2011 study in *Annals of Internal Medicine*, Losina and colleagues[9] estimated the impact of obesity on various associated medical conditions. Their analysis attempted to quantify an overall loss of per-person quality-adjusted life years due to knee arthritis in obese subjects. Subjects lost 3.5 quality-adjusted life years due to knee OA from obesity, with a total of 86 million quality-adjusted life years lost in the United States due to obesity and/or knee OA. Their model demonstrated that reducing obesity to the levels of 10 years earlier could avert 111,206 knee replacements.[9]

PREOPERATIVE CONSIDERATIONS

Obesity is associated with multiple medical comorbidities that can negatively affect both the results of arthroplasty and the associated medical and anesthetic risks.[10] Diabetes, obstructive sleep apnea, and cardiopulmonary disease are all clearly associated with obesity and significantly increase risk of overall complications.[10]

Diabetes is a major complicating factor for arthroplasty. A recent study, analyzing a large cohort of morbidly obese (BMI >40 kg/m^2) subjects who underwent TKA, looked at diabetes and insulin dependence as an independent risk factor, with a cohort stratified into nondiabetics, type II diabetics who required no insulin, and type II diabetics who used insulin.[11] All subjects had complication rates far greater than the norm in nonobese subjects (74%–85% 10-year reoperation rate and 5%–9% infection rates). The nondiabetic and diabetic morbidly obese subjects had similarly high complication rates; however, the insulin-dependent diabetics had even higher complication rates, with significantly increased rates of reoperation (75% 10-year reoperation rate) and prosthetic joint infection (PJI; 9% 10-year infection rate). Overall, implant survivorship rates at 10 years (84% for insulin-dependent diabetics) were also significantly decreased.

Obstructive sleep apnea and restrictive lung disease pose multiple challenges in the perioperative period. Obesity causes a restrictive lung disease picture, which makes ventilating these patients much more difficult, with significantly decreased airway compliance.[1] Obstructive sleep apnea, of which obesity is a major risk factor, increases the risk of dangerous apneic episodes, leading to hypoxia, especially due to the use of general anesthetic agents and opiates in the perioperative period.[1] The risk screening questionnaire for obstructive sleep apnea, the STOP-BANG score, allows for a quick screening for this condition. STOP-BANG is an acronym for the screening questions: *S*noring, often feeling Tired, Observed apnea, high blood Pressure, BMI greater than 35 kg/m^2, Age greater than 50, Neck circumference greater than 16 inches, and male Gender.[1] For this reason, many anesthesiologists advocate for increased use of neuraxial anesthesia and regional blocks in these high-risk patients to help make anesthesia safer.[10]

PREOPERATIVE WEIGHT LOSS AND THE ROLE OF BARIATRIC SURGERY

It is common practice to encourage weight loss in obese patients before arthroplasty.

Guidelines vary but many centers have practices to refer all morbidly obese patients to a weight loss clinic before considering THA or TKA. Strong recommendations should be made

for improved diet and decreased obesity. Referral to an appropriate specialist should be made to help achieve these goals.[6]

If medical weight loss fails, bariatric surgery should also be considered. Watts and colleagues[12] performed a matched cohort study and compared the outcomes of obese THA subjects who underwent bariatric surgery preoperatively to those who did not. Mean BMIs improved from 49.7 to 35.3 in the bariatric group. Subjects in the preoperative bariatric surgery cohort were significantly less likely to require short-term reoperation (hazard ratio [HR] 3.2) or longer term revision (HR 5.4) compared with subjects who did not have bariatric surgery before the THA surgery.[12]

However, this conclusion is controversial. A meta-analysis of subjects who underwent bariatric surgery before arthroplasty, with a total of 657 bariatric surgery subjects compared with 22,691 obese control subjects, found no statistically significant differences in superficial infection, deep infection, venous thromboembolism (VTE), or revision surgery.[13]

Contrary to popular perception, a large percentage of obese patients are also malnourished.[14] In a recent review of obese patients scheduled to undergo bariatric surgery, 15% were hypoalbuminemic, 93% had vitamin D deficiencies, and 36% had iron deficiencies.[14] Hypoalbumenia, specifically, has been given particular attention because it has been associated with increased risk of postoperative complications.[1] Given the prevalence of nutritional deficiencies in these patients, even if not undergoing bariatric surgery, a nutritional evaluation is recommended to help correct these deficiencies preoperatively.

COMPLICATIONS

Infection

Obesity and increased BMI has consistently been shown to be associated with both increased early and late infection. This association has been consistently and reliably demonstrated with both THA and TKA.[15,16]

In a landmark study on the topic, Dowsey and colleagues[17] prospectively followed 1214 consecutive TKA subjects for 1 year to compare infection rates between obese and nonobese subjects. The overall infection rate was 1.5% and obese subjects were at much higher risk, with an odds ratio (OR) for a deep PJI of 8.96.

This same association has been demonstrated in multiple large registry studies.[18,19] In a retrospective cohort study of 56,216 TKA patients over an 8-year period in the Kaiser-Permanente system, it was shown that BMI greater than 35 kg/m^2 carried a hazard risk ratio of 1.47 for deep infection.[19] Similarly, a report from the New Zealand Joint Registry of 64,566 primary TKA surgeries over a 13-year period, demonstrated that the OR for revision for infection was 3.35 in patients with a BMI greater than 40 kg/m^2 when compared with those with a BMI less than 35 kg/m^2.[18]

Similar trends have been shown in THA.[18,20] A large single-specialty center retrospective review of 3672 consecutive primary THA cases demonstrated that BMI greater than 40 kg/m^2 was a significant risk factor for deep PJI, with an OR of 4.13.[20] However, a recent systematic review of complication rates in THA demonstrates that, although the association between THA and infection is clear, the magnitude is likely lower than that for TKA.[4]

Importantly, not only is obesity associated with increased risk of periprosthetic infection but an obese patient with an infected TKA is also more likely to fail a 2-stage reimplantation procedure.[21] In a 2-to-1 matched cohort study of morbidly obese subjects undergoing revision TKA, Watts and colleagues[21] demonstrated that reinfection risk following 2-stage reimplantation was 22% in the morbidly obese group versus 4% in the nonobese group (P<.01).

Total Hip Arthroplasty Dislocation Rate

Other than infection, dislocation is among the principal early complications in THA. In a series of 1617 subjects in the United Kingdom, BMI was highly correlated with increased incidence of instability. For every 10-point increase in BMI, the risk of dislocation increased by 113.9%.[22]

Elkins and colleagues[23] performed a sophisticated biomechanical analysis, developing a finite element model of a THA construct in an obese patient. In their model, they were able to adjust BMI, creating soft tissue thigh impingement. They mechanistically demonstrated that at BMI greater than 40 kg/m^2 increased soft tissue at the thigh, placed a laterally directed force on the prosthesis, and made dislocation more likely. This risk was slightly mitigated by lower cup abduction angles and higher offset necks; however, increases in head size were not protective. Huffman and colleagues[24] have similarly demonstrated, in a motion capture study, that obese subjects have significantly higher hip abduction angles and abduction movements during the sit-to stand motion. Peak hip abduction angles were 50% greater in the obese group, and the hip was much more abducted throughout the entire sit-to-stand cycle.[24]

Survivorship and Need for Revision

It stands to reason that a higher BMI patient would put higher mechanical strain on an implanted prosthesis that would lead to increased wear, shorter survivorship, and increased need for revision due to aseptic failure. Two recent large-meta analysis studies have assessed this reasoning in both TKA and THA.[25–27]

A recent large meta-analysis pooled 20 studies, for an overall group of 15,276 TKA subjects.[25] The overall revision rate in the cohort was significantly higher for obese subjects, OR 1.30.[25] However, when assessing for revisions specifically for aseptic loosening, no statistically significant difference was found. A study with 14-year follow-up assessing the results of overall implant survivorship in obese versus nonobese subjects found that implant survival was at 97% in the nonobese subject cohort, but only 93% in the obese subject cohort.[27] Abdel and colleagues[26] found a significantly higher failure rate due to aseptic tibial loosening in obese subjects with BMI greater than 35 kg/m^2 undergoing TKA, with a 15-year-risk of 2.7%. They recommended considering additional fixation, with possible stemmed primary implants in obese subjects undergoing TKA. A recent prospective cohort study by Mulhall and colleagues[28] of 291 consecutive revision TKA subjects similarly found that the majority of their revision cohort was obese and that BMI was significant risk factor for worse survivorship of primary TKA components and increased risk of progression to early revision.

With regard to THA, a similar association is found in the literature.[29,30] In a cohort of revision THA subjects at a single center, the relative risk for early revision (within 5 years) due to aseptic failure was found to be 4.7 (BMI >30). In subjects with a BMI greater than 30, aseptic failure was the cause of 56% of early revisions, significantly higher than nonobese subjects (12%).[29] In a superobese cohort with BMI greater than 50 kg/m^2, Issa and colleagues[31] found overall poor implant survivorship. They matched these subjects to a nonobese group, with a 6-year follow-up. Implant survivorship was only 89.6% in the superobese group, compared with 97.8% in the nonobese group. Meta-analysis data of 5137 THA subjects also supports this trend, with higher revision rates for aseptic loosening in subjects with a BMI greater than 30 kg/m^2 (OR 0.6 favoring less revision in nonobese subjects).[30]

Venous Thromboembolism

VTE, including deep vein thrombosis (DVT) and pulmonary embolism (PE), are common and potentially severe complications after TJA, and several studies have specifically examined the rates of VTE in obese subjects.[32,33] Friedman and colleagues[32] analyzed the Regulation of Coagulation in Orthopedic Surgery Clinical Trial data of 12,355 THA and TKA subjects and found that although morbidly obese subjects (BMI >40 kg/m^2) were at overall higher rates of adverse events, they had no significant increase in asymptomatic DVT, symptomatic DVT, or PE postoperatively.

Similarly, D'Apuzzo and colleagues[33] examined the Healthcare Cost and Utilization Project Nationwide Inpatient Sample database with 1,777,609 primary TKA cases, of which 98,410 were morbidly obese. They found no significant difference in DVT rates, with a rate of 0.44% among the morbidly obese cohort compared with a rate of 0.38% in the nonobese cohort, with an OR of 0.8 (0.7–1.0). They also found no significant difference in PE rates at 0.45% in the obese cohort as compared with 0.39% in the nonobese cohort, OR 0.8 (0.7–1.0).[33]

OUTCOMES

Because the goal of any arthroplasty operation is to reduce pain and improve function, it must also be assessed if total hip and knee arthroplasty in obese patients has similar subjective functional outcomes in this higher risk cohort. A systematic review of TKA outcomes in obesity found that Knee Society Scores were significantly better in nonobese subjects, by 3.23 points on average.[25] A meta-analysis of THA subjects showed a similar effect with postoperative Harris Hip Scores, with a mean difference of 4.54 points higher in the nonobese group.[30]

Naziri and colleagues[34] specifically looked at TKA in a cohort of superobese subjects, with BMI greater than 50 kg/m^2, which was matched to a control group of nonobese subjects. At a mean follow-up of 5 years, these subjects had lower Knee Society scores at 82 compared with 90, and achieved poorer knee flexion at 109° compared with 121°. Similar trends were shown in the same groups' cohort of THA subjects with BMI greater than 50 kg/m^2. Superobese subjects at mean 6-year follow-up had significantly lower postoperative Harris Hip Scores (82 compared with 91), Short Form Health Survey (SF)-36 scores, and University of California, Los Angeles (UCLA) activity scale scores.[31]

Although nonobese patients generally rate higher postoperative functional scores than their obese counterparts, the mean difference between preoperative and postoperative scores is

often similar in these patients.[35] Chee and colleagues[35] matched obese subjects with a nonobese control cohort and found that, although postoperative Harris Hip Scores at 5 years were significantly better in the nonobese cohort (91.8 vs 85.5, $P<.05$), the mean change in score from preoperative to postoperative was similar between the groups (52.0 vs 48.1, $P = .8$). Essentially, although nonobese patients have better absolute functional scores, the relative improvement in scores from surgery may be similar between obese and nonobese patients.

SUMMARY

Overall, obesity is an extremely prevalent complicating factor that poses several challenges for the arthroplasty surgeon. Obese patients are at much higher risk for infection after THA or TKA and dislocation after THA. They also have poorer implant survivorship and lower absolute functional scores postoperatively. However, obese patients also have more severe and earlier progression of OA, and can benefit significantly from TJA.

The ethics of this issue must also be considered. Many surgeons and centers do not recommend limiting access to TJA in obese patients; however, it is common practice to refer for nutritional evaluation, medical weight loss, or bariatric evaluation preoperatively. Patients must be counseled on the increased complication risk and need to have realistic expectations of their excepted outcome postoperatively. Delaying surgery to optimize the patient and improve the chances for a good outcome is often the right thing to do for the patient, the physician, the hospital, and the payer. As obesity rates continue to grow, this is an issue that will only become more important and commonplace for the arthroplasty surgeon.

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REFERENCES

1. Mihalko WM, Bergin PF, Kelly FB. Obesity, orthopaedics, and outcomes. J Am Acad Orthop Surg 2014;22(11):683–90.
2. Ogden CL, Carroll MD, Fryar CD, et al. Prevalence of obesity among adults and youth: United States, 2011-2014. NCHS Data Brief 2015;(219):1–8.
3. Heymsfield SB, Wadden TA. Mechanisms, pathophysiology, and management of obesity. N Engl J Med 2017;376(3):254–66.
4. Haynes J, Nam D, Barrack RL. Obesity in total hip arthroplasty: does it make a difference? Bone Joint J 2017;99-B(1 Supple A):31–6.
5. World Health Organization. Obesity: preventing and managing the global epidemic. WHO Technical Report Series; 2000. p. 894.
6. Koonce RC, Bravman JT. Obesity and osteoarthritis: more than just wear and tear. J Am Acad Orthop Surg 2013;21(3):161–9.
7. Recnik G, Kralj-Iglič V, Iglič A, et al. The role of obesity, biomechanical constitution of the pelvis and contact joint stress in progression of hip osteoarthritis. Osteoarthr Cartil 2009;17(7):879–82.
8. Bourne R, Mukhi S, Zhu N, et al. Role of obesity on the risk for total hip or knee arthroplasty. Clin Orthop Relat Res 2007;465:185–8.
9. Losina E, Walensky RP, Reichmann WM, et al. Impact of obesity and knee osteoarthritis on morbidity and mortality in older Americans. Ann Intern Med 2011;154(4):217–26.
10. Martin JR, Jennings JM, Dennis DA. Morbid obesity and total knee arthroplasty: a growing problem. J Am Acad Orthop Surg 2017;25(3):188–94.

11. Watts CD, Houdek MT, Wagner ER, et al. Insulin dependence increases the risk of failure after total knee arthroplasty in morbidly obese patients. J Arthroplasty 2016;31(1):256–9.
12. Watts CD, Martin JR, Houdek MT, et al. Prior bariatric surgery may decrease the rate of reoperation and revision following total hip arthroplasty. Bone Joint J 2016;98-B(9):1180–4.
13. Smith TO, Aboelmagd T, Hing CB, et al. Does bariatric surgery prior to total hip or knee arthroplasty reduce post-operative complications and improve clinical outcomes for obese patients? Systematic review and meta-analysis. Bone Joint J 2016;98-B(9):1160–6.
14. Peterson LA, Cheskin LJ, Furtado M, et al. Malnutrition in bariatric surgery candidates: multiple micronutrient deficiencies prior to surgery. Obes Surg 2016;26(4):833–8.
15. Gage MJ, Schwarzkopf R, Abrouk M, et al. Impact of metabolic syndrome on perioperative complication rates after total joint arthroplasty surgery. J Arthroplasty 2014;29(9):1842–5.
16. Schwarzkopf R, Thompson SL, Adwar SJ, et al. Postoperative complication rates in the "super-obese" hip and knee arthroplasty population. J Arthroplasty 2012;27(3):397–401.
17. Dowsey MM, Choong PFM. Obese diabetic patients are at substantial risk for deep infection after primary TKA. Clin Orthop Relat Res 2009;467(6):1577–81.
18. Tayton ER, Frampton C, Hooper GJ, et al. The impact of patient and surgical factors on the rate of infection after primary total knee arthroplasty: an analysis of 64 566 joints from the New Zealand Joint Registry. Bone Joint J 2016;98-B(3):334–40.
19. Namba RS, Inacio MCS, Paxton EW. Risk factors associated with deep surgical site infections after primary total knee arthroplasty: an analysis of 56,216 knees. J Bone Joint Surg Am 2013;95(9):775–82.
20. Maoz G, Phillips M, Bosco J, et al. The Otto Aufranc Award: modifiable versus nonmodifiable risk factors for infection after hip arthroplasty. Clin Orthop Relat Res 2014;473(2):1–7.
21. Watts CD, Wagner ER, Houdek MT, et al. Morbid obesity: a significant risk factor for failure of two-stage revision total knee arthroplasty for infection. J Bone Joint Surg Am 2014;96(18):e154.
22. Davis AM, Wood AM, Keenan ACM, et al. Does body mass index affect clinical outcome post-operatively and at five years after primary unilateral total hip replacement performed for osteoarthritis? A multivariate analysis of prospective data. J Bone Joint Surg Br 2011;93(9):1178–82.
23. Elkins JM, Daniel M, Pedersen DR, et al. Morbid obesity may increase dislocation in total hip patients: a biomechanical analysis. Clin Orthop Relat Res 2013;471(3):971–80.
24. Huffman KD, Sanford BA, Zucker-Levin AR, et al. Increased hip abduction in high body mass index subjects during sit-to-stand. Gait Posture 2015;41(2):640–5.
25. Kerkhoffs GMMJ, Servien E, Dunn W, et al. The influence of obesity on the complication rate and outcome of total knee arthroplasty. J Bone Joint Surg Am 2012;94(20):1839–44.
26. Abdel MP, Bonadurer GF, Jennings MT, et al. Increased aseptic tibial failures in patients with a BMI $\geq$35 and well-aligned total knee arthroplasties. J Arthroplasty 2015;30(12):2181–4.
27. Vazquez-Vela Johnson G, Worland RL, Keenan J, et al. Patient demographics as a predictor of the ten-year survival rate in primary total knee replacement. J Bone Joint Surg Br 2003;85(1):52–6.
28. Mulhall KJ, Ghomrawi HM, Mihalko W, et al. Adverse effects of increased body mass index and weight on survivorship of total knee arthroplasty and subsequent outcomes of revision TKA. J Knee Surg 2007;20(3):199–204.
29. Electricwala AJ, Narkbunnam R, Huddleston JI, et al. Obesity is associated with early total hip revision for aseptic loosening. J Arthroplasty 2016;31(9 Suppl):217–20.
30. Haverkamp D, Klinkenbijl MN, Somford MP, et al. Obesity in total hip arthroplasty–does it really matter? A meta-analysis. Acta Orthop 2011;82(4):417–22.
31. Issa K, Harwin SF, Malkani AL, et al. Bariatric Orthopaedics: total hip arthroplasty in super-obese patients (those with a BMI of $\geq$50 kg/m2). J Bone Joint Surg Am 2016;98(3):180–5.
32. Friedman RJ, Hess S, Berkowitz SD, et al. Complication rates after hip or knee arthroplasty in morbidly obese patients. Clin Orthop Relat Res 2013;471(10):3358–66.
33. D'Apuzzo MR, Novicoff WM, Browne JA. The John Insall Award: morbid obesity independently impacts complications, mortality, and resource use after TKA. Clin Orthop Relat Res 2015;473(1):57–63.
34. Naziri Q, Issa K, Malkani AL, et al. Bariatric orthopaedics: total knee arthroplasty in super-obese patients (BMI > 50 kg/m2). Survivorship and complications. Clin Orthop Relat Res 2013;471(11):3523–30.
35. Chee YH, Teoh KH, Sabnis BM, et al. Total hip replacement in morbidly obese patients with osteoarthritis: results of a prospectively matched study. J Bone Joint Surg Br 2010;92(8):1066–71.