Review Article

HSS Journal®: The Musculoskeletal Journal of Hospital for Special Surgery
2022, Vol. 18(3) 418–427

DOI: 10.1177/15563316211030923
journals.sagepub.com/home/hss
SAGE

Preoperative Patient Optimization in Total Joint Arthroplasty—The Paradigm Shift from Preoperative Clearance: A Narrative Review

Aoife MacMahon, MD[1], Sandesh S. Rao, MD[1], Yash P. Chaudhry, DO[1], Syed A. Hasan, DO[1], Jeremy A. Epstein, MD[2], Vishal Hegde, MD[1], Daniel J. Valaik, MD[1], Julius K. Oni, MD[1], Robert S. Sterling, MD[1], and Harpal S. Khanuja, MD[1,3]

Abstract

Background: Total joint arthroplasty (TJA) is one of the most common procedures performed in the United States. Outcomes of this elective procedure may be improved via preoperative optimization of modifiable risk factors. *Purposes:* We sought to summarize the literature on the clinical implications of preoperative risk factors in TJA and to develop recommendations regarding preoperative optimization of these risk factors. *Methods:* We searched PubMed in August 2019 with an update in September 2020 for English-language, peer-reviewed publications assessing the influence on outcomes in total hip and knee replacement of 7 preoperative risk factors—obesity, malnutrition, hypoalbuminemia, diabetes, anemia, smoking, and opioid use—and recommendations to mitigate them. *Results:* Sixty-nine studies were identified, including 3 randomized controlled trials, 8 prospective cohort studies, 42 retrospective studies, 6 systematic reviews, 3 narrative reviews, and 7 consensus guidelines. These studies described worse outcomes associated with these 7 risk factors, including increased rates of in-hospital complications, transfusions, periprosthetic joint infections, revisions, and deaths. Recommendations for strategies to screen and address these risk factors are provided. *Conclusions:* Risk factors can be optimized, with evidence suggesting the following thresholds prior to surgery: a body mass index <40 kg/m^2, serum albumin ≥ 3.5 g/dL, hemoglobin A1C $\leq 7.5\%$, hemoglobin >12.0 g/dL in women and >13.0 g/dL in men, and smoking cessation and $\geq 50\%$ decrease in opioid use by 4 weeks prior to surgery. Surgery should be delayed until these risk factors are adequately optimized.

Keywords
total joint arthroplasty, risk factors, complications, outcomes, patient optimization

Introduction

Total hip arthroplasty (THA) and total knee arthroplasty (TKA) are commonly performed procedures that are projected to increase substantially in the coming decades [74]. Preoperative medical evaluation conventionally determines how "safe" it is for a patient to undergo a procedure. With the advent of value-based care and bundled payments [1], there is increasing emphasis on mitigating risk factors for adverse outcomes [17]. Because total joint arthroplasty (TJA), which for this review includes THA and TKA, is primarily an elective intervention, there is ample opportunity to optimize modifiable patient risk factors preoperatively. This is important in ensuring safety, reducing complications, and maximizing long-term outcomes [3,33].

Previous studies have identified modifiable risk factors in TJA that increase the risk of complications; these include deep and superficial infections, pulmonary emboli, and

[1]Department of Orthopedic Surgery, Johns Hopkins University School of Medicine, Baltimore, MD, USA
[2]Department of Medicine, Johns Hopkins University School of Medicine, Baltimore, MD, USA
[3]Department of Orthopaedic Surgery, Johns Hopkins Bayview Medical Center, Baltimore, MD, USA

Corresponding Author:
Harpal S. Khanuja, MD, Department of Orthopaedic Surgery, Johns Hopkins Bayview Medical Center, 4940 Eastern Ave., Baltimore, MD 21224-2780, USA.
Email: khanuja@jhmi.edu

myocardial infarction [7,8]. Modifiable risk factors have also been associated with increased readmissions, length of stay, costs, and revisions [52,68,79]. Pruzansky et al [62] found that 80% of patients undergoing any TJA and 93% of patients undergoing revision TJA for periprosthetic joint infection had at least 1 modifiable risk factor, with the most common being morbid obesity (46%), anemia (29%), malnutrition (26%), and diabetes (20%). Periprosthetic joint infection (PJI) is a particularly devastating complication that has been associated with a 5-year mortality rate of 21% in THA and 22% in TKA [51,59], emphasizing the importance of optimizing modifiable risk factors whenever possible.

Preoperative risk factor optimization is a multidisciplinary effort that requires input from medical and surgical providers involved in the evaluation of TJA candidates. Effective management of risk factors requires an understanding of the clinical implications as well as knowledge of evidence-based criteria for optimization. Effective preoperative optimization has been shown to enhance perioperative outcomes in TJA [9,41,48] and may improve long-term results. We aim to provide a review of the clinical implications of obesity, malnutrition, hypoalbuminemia, diabetes, anemia, smoking, and opioid use [52,68,79] in TJA and evidence-based recommendations for their optimization.

Methods

Search Strategies and Criteria

For this narrative review, we selected 7 risk factors for investigation: obesity, malnutrition, hypoalbuminemia, diabetes, anemia, smoking, and opioid use. We chose these risk factors based on expert opinions of primary care physicians and orthopedic surgeons as well as prior studies that showed them to be modifiable and to adversely affect TJA outcomes. A search was performed of PubMed/MEDLINE databases in August 2019 with an update in September 2020 for English-language systematic reviews, meta-analyses, randomized controlled trials, and observational studies performed in the last 20 years (January 2000 to September 2020). The following search terms were used: "total joint arthroplasty" or "total knee arthroplasty" or "total hip arthroplasty" AND "obesity" or "malnutrition" or "hypoalbuminemia" or "diabetes" or "anemia" or "smoking" or "opioid use." The clinical practice guidelines of the American Academy of Orthopedic Surgeons, the American Association of Hip and Knee Surgeons (AAHKS), and the American College of Rheumatology (ACR) were also examined. References of select publications were also reviewed for relevant literature. The final selection of studies was agreed upon following discussion among authors; ultimately, preference was given to clinical practice guidelines, systematic reviews, randomized controlled trials, and large database studies. Recent studies and those with large sample sizes were also prioritized, given the rapidly changing protocols being implemented in TJA.

Results

Recommendations for screening and optimization of preoperative risk factors based on clinical practice guidelines and our review are summarized in Table 1.

Obesity

Rates of obesity, a body mass index (BMI) of $\geq$ 30 kg/m^2, and morbid obesity, a BMI of $\geq$ 40 kg/m^2, have been reported to be 40.3% and 7.4% in THA, respectively [76], with corresponding rates of 47.8% and 15.8% in TKA, respectively [75]. Studies using the American College of Surgeons National Quality Improvement Program (NSQIP), Medicare, and Veterans Health Administration databases have found that morbidly obese patients undergoing TKA have up to 2- to 6-fold increased risk of readmission, reoperation, superficial and periprosthetic joint infection, wound dehiscence, urinary tract infection, reintubation, renal insufficiency, in-hospital mortality, discharge to a facility, and higher total hospital costs [19,25,55,84].

In addition, obesity is associated with many comorbidities, including diabetes, hypertension, coronary heart disease, stroke, respiratory dysfunction, and some cancers [2]. An AAHKS workgroup review in 2013 concluded that for all TJA patients with BMI $\geq$30 kg/m^2, comorbidities must be closely regulated and optimized [87]. They also recommended that all patients with BMI $\geq$40 kg/m^2 must be counseled on the increased risks of surgery and their significant complication profiles, and providers should consider delaying the procedure, especially for patients with other associated conditions, such as poorly controlled diabetes or malnutrition [87]. Moreover, many institutions have established a BMI cutoff of 40 kg/m^2 for elective TJA [70].

Weight loss prior to TJA has been inconsistently shown to improve outcomes in certain patient populations. In a single-center study of 14 784 obese TJA patients, Inacio et al [38] found that preoperative weight loss of up to 5% had no effect on surgical site infection and readmissions. However, a single-center study of 203 morbidly obese patients by Keeney et al [43] found that those who lost at least 20 pounds before TKA (but not those who lost 5 or 10 pounds) had a shorter length of stay and lower odds of discharge to a rehabilitation facility than those who did not lose weight, even though most of the patients remained obese or morbidly obese. This suggests that, particularly in morbidly obese patients, greater preoperative weight loss may facilitate earlier and safer mobilization and that patients who are motivated to lose at least 20 pounds preoperatively

Table 1. Evidence-based recommendations and practices at our institution for detection and optimization of preoperative risk factors prior to total joint arthroplasty.

Risk factor	Recommendations
Obesity	• Identify and optimize concomitant comorbidities, eg, malnutrition, diabetes, hypertension • Delay surgery for BMI ≥40 kg/m^2 until BMI is reduced below this threshold
Malnutrition and hypoalbuminemia	• Perform thorough clinical assessment of nutritional status • Obtain preoperative serum albumin, transferrin, and TLC in patients with particular comorbidities[a] • For albumin <3.5 g/dL, transferrin <200 mg/dL, or TLC <1500 cells/mm^3, delay surgery and refer for nutritional counseling
Diabetes	• Screen patients preoperatively for diabetes according to guidelines from the American Diabetes Association [4] • Delay surgery until HbA1c <7.5%
Anemia	• Obtain hemoglobin level 4 weeks preoperatively • Work-up and treat newly diagnosed or chronic anemia • Delay surgery until Hgb levels >12.0 g/dL in women and >13.0 g/dL in men
Smoking	• Ensure smoking cessation by 4 weeks preoperatively with negative cotinine test
Opioid use	• Use multimodal pain management to minimize opioid prescribing, eg, with NSAIDs and acetaminophen • Wean off opioids by at least 50% 4 weeks prior to surgery

BMI body mass index, *TLC* total lymphocyte count, *Hgb* hemoglobin, *NSAIDs* nonsteroidal anti-inflammatory drugs.
[a]See text for listing of specific comorbidities.

may be well suited to an earlier and safer discharge. However, a meta-analysis of morbidly obese patients undergoing TJA that included 9 studies with 38 728 patients found that although bariatric surgery prior to TJA was associated with reduced short-term medical complications, length of stay, and operative time, it did not reduce risks of short-term surgical complications, including superficial wound infection, venous thromboembolism, dislocation, PJI, periprosthetic fracture, or revision [49]; these results suggest that surgical intervention for weight loss is less effective. Another study found that after 111 morbidly obese patients underwent a nutritional counseling program prior to TJA, 102 (92%) achieved weight loss at a mean of 17 pounds and a decrease of BMI by 2.7 points, with 71 (64%) participating patients receiving TJA by reducing their BMI below 40 kg/m^2. Outcomes for the patients who did not undergo TJA were not described, although they had increased treatment time with the dietician (198 vs 129 days) [50]. These findings emphasize the importance and feasibility of weight loss in morbidly obese patients, as this may significantly improve outcomes after TJA. At our institution, we discuss the implications of morbid obesity with patients and delay surgery for those with BMI ≥40 kg/m^2 until BMI is reduced below this threshold.

Malnutrition and Hypoalbuminemia

Albumin is an acute-phase protein that is more likely to reflect the magnitude of inflammatory response rather than malnutrition, as it has not been shown to change consistently with weight loss, calorie restriction, or nitrogen balance [86]. However, many studies have used serum albumin as a surrogate marker for malnutrition, and hypoalbuminemia has demonstrated significant associations with adverse outcomes in TJA [18,31]. Other laboratory values proposed as markers of malnutrition include total lymphocyte count (TLC; <1500 cells/mm^3) and transferrin level (<200 mg/dL) [18]. Depending on the laboratory values assessed, the reported incidence of malnutrition in primary TJA patients has ranged from 3.7% to 56% [31].

Multiple studies have highlighted the association between hypoalbuminemia and increased risk of complications in TJA. In studies using the NSQIP database, hypoalbuminemia has been found to be an independent predictor of postoperative mortality, surgical site infections, respiratory events, cardiac events, bleeding with need for transfusion, sepsis, PJI, readmission, reoperation, and increased length of stay in TJA patients [5,11,22]. A study of 819 TJA cases by Rao et al found that congestive heart failure, chronic kidney disease, pancreatic insufficiency, gastroesophageal reflux disease, osteoporosis, and dementia were associated with abnormal preoperative albumin; Parkinson disease was associated with abnormal transferrin; and dementia, BMI, and cancer history were associated with abnormal TLC, suggesting that these laboratory tests may be most warranted in patients with these comorbidities [65]. We only obtain preoperative serum albumin, transferrin, and TLC in TJA patients with these comorbidities.

A high prevalence of malnutrition among obese TJA patients has also been reported. Huang et al found that among TJA patients, 42% of malnourished patients—defined as having serum albumin ≤ 3.5 g/dL or transferrin < 200 g/dL—were obese. They also found that preoperative hypoalbuminemia and low transferrin were independent predictors of overall complications, hematoma and seroma formation, infection, and renal and neurovascular complications [36]. Analyses of the NSQIP database have also found that the prevalence of preoperative hypoalbuminemia in TJA increases significantly with increasing obesity, and that hypoalbuminemia is a stronger predictor of complications, readmissions, and reoperations than obesity [23,24,75].

While serum markers are frequently used as indicators of nutritional status, a thorough history and clinical assessment is paramount. Questionnaires can also be used to assess malnutrition preoperatively. One study found that interview-based screening tools performed preoperatively in hospitalized TJA patients, including the Nutritional Risk Screening (NRS 2002), Mini Nutritional Assessment (MNA), and Short-Form Mini Nutritional Assessment (SF-MNA), were able to predict risks of prolonged hospitalization, delayed mobilization, quality of life, and adverse events postoperatively [37]. In particular, the MNA has been shown to have a significant association with serum albumin and increased length of stay [67].

Several studies have found that nutritional interventions may improve outcomes in TJA. In a study of 4733 TJA patients, Schroer et al [69] found that patients with preoperative hypoalbuminemia who underwent a nutritional intervention program focusing on a high-protein, anti-inflammatory diet had shorter lengths of stay, primary hospitalization charges, readmission charges, and 90-day total charges than hypoalbumenic patients who did not undergo this program, although the researchers did not specify whether this intervention resulted in weight loss or an increase in serum albumin. In a double-blind, placebo-controlled, randomized controlled trial of 60 patients undergoing primary TKA, patients who received preoperative supplementation with essential amino acids had increased rectus femoris area, quadriceps muscle diameter, and serum albumin level, and decreased time to recovery of activities of daily living compared to controls [83]. Although further research is required to evaluate the efficacy of interventions to treat malnutrition and hypoalbuminemia in patients prior to TJA, these are risk factors that should be thoroughly assessed preoperatively.

Diabetes

The prevalence of diabetes among patients undergoing TJA has been estimated to be about 20%, with 33.6% to 40.9% newly diagnosed upon preoperative screening [14,71]. Diabetes has been shown to have significant associations with complications and worse outcomes after TJA. One single-center series of 7181 primary TJA cases found that a preoperative diagnosis of diabetes more than doubled the independent risk of PJI [39]. A study by Marchant et al [53] that used the National Inpatient Sample (NIS) found that compared to TJA patients with controlled diabetes, those with uncontrolled diabetes, as determined by ICD-9 codes, had increased odds of stroke, urinary tract infection, ileus, hemorrhage, transfusion, wound infection, death, and increased length of stay. Using a statewide database, Duensing et al [21] found that Type 1 diabetes was associated with a greater risk of PJI than Type 2 diabetes, with both types having an increased risk compared to non-diabetic patients. Moreover, a study of TKA patients in the NSQIP database found that compared to those with non-insulin-dependent diabetes, those with insulin-dependent diabetes had a greater risk of adverse perioperative outcomes relative to non-diabetic patients [85].

Although optimal preoperative hemoglobin A1c (HbA1c) or glucose thresholds have not been determined, poor blood glucose control in diabetics, whether acute or chronic, is associated with worse outcomes in TJA. In a study of 13 272 primary TJA patients from a Veterans Affairs database, Chrastil et al [16] found an increased risk of mortality with HbA1c ≥ 7%, and a single-center study of 1702 primary TJA patients found that patients with a preoperative HbA1c > 6.7% had an independently increased risk of wound complications [80]. A retrospective study of 6088 diabetic TJA patients from the Veterans Health Administration found that the risk of complications increases linearly with HbA1c, rather than surging at a threshold of 7% [34]. A multicenter retrospective study of 1645 diabetic TJA patients found that a HbA1c threshold of 7.7% was optimal for predicting risk of PJI [81]. Maradit Kremers et al [64] studied 16,085 primary TJA patients and found that preoperative glucose >180 mg/dL was associated with increased risk of overall revisions and revisions for aseptic loosening in diabetic patients. Serum fructosamine, which measures the level of glycated serum proteins, primarily albumin, reflects glucose levels over a shorter time frame than HbA1c at 14 to 21 days and has been suggested as a better marker of glycemic control than HbA1c. A study that assessed preoperative HbA1c and serum fructosamine levels in 829 TJA patients found that those with fructosamine levels ≥292 µmol/mL, which corresponds to a HbA1c ≥ 7%, had increased risks of deep infection, readmission, and reoperation, whereas those with HbA1c levels ≥7% did not demonstrate increased risks for any of these outcomes [72]. These findings highlight the importance of maintaining preoperative blood glucose control in diabetic patients. We have established a HbA1c threshold of ≤7.5% to proceed with surgery, which balances access with risk [26].

Recommendations have also been made to routinely screen TJA patients for type 2 diabetes preoperatively, given the prevalence of the disease and the high proportion of patients who are previously undiagnosed [71]. We screen patients preoperatively for diabetes according to guidelines from the American Diabetes Association [2].

Anemia

Preoperative anemia, defined as hemoglobin <12 g/dL in women and <13 g/dL in men, has been reported in up to 14.8% of TKA and 22.9% of THA patients [56] and has been attributed to iron deficiency in about 40% of TJA patients [40]. Large database studies have shown that preoperative anemia in TJA is associated with significantly increased transfusions, reoperations, complications (wound, pulmonary, cardiac, and renal), sepsis, urinary tract infections, deaths, and prolonged hospital stay [30,56]. Moreover, rates of preoperative anemia and thus transfusion rates in TJA patients aged ≥80 years are almost double that of younger patients [56]. Preoperative hemoglobin and transfusion thresholds are the strongest predictors of blood transfusion [42], with one study showing that blood transfusions were only required for primary TJA patients with preoperative hemoglobin ≤13.0 g/dL [29]. This is a relevant consideration during TJA, as transfusions have also been independently associated with increased complications, infections, costs, and lengths of stay [44,66].

The Network for Advancement of Transfusion Alternatives (NATA) guidelines strongly recommend that hemoglobin values be obtained for elective orthopedic patients 28 days preoperatively [27]. Preoperative screening for anemia in TJA has been shown to decrease transfusions, readmissions, length of stay, and costs [63], and surgery should be delayed until anemia has been treated to mitigate the increased risk of adverse events [45,58]. A complete workup of anemia should be performed, with the etiology dictating treatment. For patients with chronic anemia, workup and evaluation is still warranted to minimize postoperative risks. Maximizing preoperative hemoglobin levels may help to decrease the risk of postoperative anemia and transfusions and thus enhance recovery. At our institution, we obtain hemoglobin levels 4 weeks preoperatively and delay surgery until hemoglobin is >12.0 g/dL in women and >13.0 g/dL in men. Patients with hemoglobin levels below these thresholds are referred to their primary care providers for further workup and appropriate management.

Smoking

Up to 11% of TJA patients are smokers preoperatively [20,54]. A meta-analysis of 14 studies including 227 289 TJA procedures found that current and former smokers had increased risks of wound complications and PJI compared to non-smokers, and that current smokers had a greater risk of PJI than former smokers [6]. Another study of 117 024 TJA patients found that smokers had increased risk of lower respiratory tract infection and myocardial infarction, opioid use, and mortality 1 year postoperatively [54]. Smoking also increased the risk of implant revision in a single-center study of 7926 TJA patients [73].

Smoking cessation has been shown to reduce the postoperative risks associated with tobacco use in TJA and to be cost effective [12]. A randomized controlled trial of 120 TJA patients by Møller et al [57] investigated a smoking intervention carried out 6 to 8 weeks preoperatively, which involved counseling and nicotine replacement therapy (NRT). It found that 86% of smokers who received the intervention reduced or stopped smoking preoperatively compared to 6.7% in the control group. The intervention group also had reduced complication rates compared to smokers who did not undergo the intervention, with the greatest effects seen for wound and cardiovascular complications and reoperations. A systematic review and meta-analysis of 13 randomized controlled trials with 2020 participants found that intensive preoperative smoking cessation interventions that began 4 to 8 weeks preoperatively, including weekly counseling and NRT, were more likely to have an impact on complications and long-term smoking cessation than short-term interventions [82]. Moreover, cotinine testing has been found to increase self-reported quit rates prior to TJA and to identify the 15% of patients who falsely report abstinence [35]. However, the optimal duration of smoking cessation prior to surgery remains unclear [61]. At our institution, patients are required to abstain from smoking for 4 weeks prior to and after TJA, confirmed with a documented preoperative negative serum cotinine test.

Opioid Use

Preoperative opioid use has been reported in almost a quarter of TJA patients [28]. A study by Blevins et al of TJA patients in an administrative claims database found that preoperative opioid use was associated with increased length of stay, nonhome discharge, 30-day unplanned readmission, surgical site infections, revisions, medical spending, and lower rate of postoperative opioid cessation [10]. Another study using multiple state inpatient databases found that patients with opioid use disorder undergoing TJA had greater risk for in-hospital mortality, 90-day readmissions, and pulmonary and infectious complications [15]. Additional large database studies have found that patients with opioid use disorder have increased risks of PJI and thromboembolic complications [77,78]. Moreover, a systematic review and meta-analysis including 7356 TJA patients found that preoperative opioid use was associated with worse postoperative patient-rated outcome scores compared to those with no preoperative opioid use [28].

Reduction in preoperative opioid use has been associated with improved outcomes in TJA patients. In a retrospective study, 41 TJA patients who used opioids preoperatively and who successfully weaned their opioid use by 50% before surgery were found to have improvements in clinical outcomes that were comparable to TJA patients who did not use opioids preoperatively; their outcomes were also superior to those of patients who did not wean opioid use before surgery [60]. A study of 461 patients with hip or knee arthritis, of whom 23% had received a preoperative opioid prescription, found that the most common prescribers of preoperative opioids were primary care physicians (59.5%), followed by pain medicine specialists (11.3%), and orthopedic surgeons (11.3%) [13]. This emphasizes the importance for all providers to be cognizant of adverse outcomes associated with preoperative opioid use in TJA patients and to make a concerted effort to reduce opioid prescribing. Although many providers may increase opioid prescribing in TJA patients preoperatively as a means of pain control, the literature shows that this may be detrimental to outcomes.

The AAHKS clinical practice guidelines for opioids in TJA found with moderate strength of evidence that preoperative opioid use is associated with inferior patient-reported outcomes, increased opioid consumption after surgery, increased risk for chronic opioid use, and increased risk of complications after TJA. They also made the limited recommendation that reduction of opioid use prior to TJA may lead to improved patient-reported outcomes after TJA compared to patients who do not reduce opioid consumption prior to surgery [32]. The ACR clinical practice guidelines for the management of hand, hip, and knee arthritis conditionally recommended tramadol for the management of knee, hip, or hand osteoarthritis, such as when patients may have contraindications to nonsteroidal anti-inflammatory drug (NSAID), find other therapies ineffective, or have no available surgical options, and conditionally recommended against non-tramadol opioids in patients with knee, hip, or hand osteoarthritis [46]. In our practice, given the adverse outcomes associated with preoperative opioid use, we require all patients to wean off all opioids by at least 50% at least 4 weeks prior to TJA.

Non-opioid pharmacologic interventions have been shown to be effective for pain control in knee and hip osteoarthritis. One randomized controlled trial evaluated 240 patients from Veterans Affair primary clinics with chronic back pain or pain from hip or knee osteoarthritis despite prior analgesic use [47]. Patients were randomized to opioid or non-opioid medication therapy. The non-opioid intervention started with acetaminophen or an NSAID, with medication adjustments based on patient response. At 12 months, patients in the non-opioid group had greater improvement in pain intensity and fewer adverse medication-related symptoms compared to the opioid group. It is important for providers to consider these non-opioid interventions in treating hip and knee osteoarthritis, and to educate patients regarding their efficacy.

Discussion

Our purpose was to review the current evidence on the clinical implications of obesity, malnutrition, hypoalbuminemia, diabetes, anemia, smoking, and opioid use [52,68,79] in TJA and to propose evidence-based recommendations for the optimization of these risk factors. We found that they were associated with worse outcomes, including increased rates of in-hospital complications, transfusions, periprosthetic joint infections, revisions, and mortality. These risk factors can be optimized, with evidence suggesting the following thresholds prior to surgery: BMI $<$40 kg/m^2, serum albumin $\geq$3.5 g/dL, HbA1C $\leq$7.5%, hemoglobin $>$12.0 g/dL in women and $>$13.0 g/dL in men, and smoking cessation and $\geq$50% decrease in opioid use by 4 weeks prior to surgery. Surgery should be delayed until these risk factors are adequately optimized.

There were several limitations to this review. First, many included studies were retrospective studies of large national databases, which are subject to errors in data entry and variability that could not be accounted for; these errors may include surgical protocols, patient populations, and surgeons. However, the large numbers of patients in these retrospective studies allowed for robust findings and wide generalizability of results. Second, many of the randomized controlled trials included small numbers of subjects, so findings should be interpreted with caution. Third, due to the heterogeneous nature of included studies, we were unable to perform a meta-analysis of the clinical implications of the risk factors assessed or of effects of interventions. Fourth, we did not contact researchers to determine whether they had unpublished negative data, so it is possible that our review reflected a positive study bias in the literature. However, there were also several strengths to this review. We described the current evidence on 7 modifiable risk factors that have been shown to have adverse effects on outcomes in TJA, as well as on interventions to mitigate them preoperatively. We also assessed clinical practice guidelines, which were compared with findings in the literature to provide updated evidence-based recommendations on optimization of risk factors prior to TJA.

There are also ethical considerations to consider when delaying surgery to optimize modifiable risk factors. It may be argued that it is unethical to delay TJA to optimize modifiable risk factors in a patient who is suffering from severe, intractable pain due to end-stage arthritis. However, given the disproportionate risk of complications and adverse outcomes associated with morbid obesity, malnutrition, hypoalbuminemia, diabetes, anemia, smoking, and opioid use in TJA, one could also argue that it would be unethical to proceed with surgery without addressing these risk factors. In the presence of these modifiable risk factors, considering the significant ramifications to the patient and society of a complication such as PJI, the risks of surgery would outweigh the benefits. As the duty of a physician is to first do no harm, preoperatively optimizing risk factors that have been shown to significantly increase the risk of catastrophic complications is important to maximize safety and outcomes in TJA. Given the high percentage of TJA patients who have these modifiable risk factors preoperatively, delaying surgery until these risk factors are optimized has broad implications. It is important for future studies to evaluate how such changes affect hospital workflows and protocols as well as patient outcomes.

Optimizing modifiable risk factors in TJA to evidence-based targets is crucial in order to minimize complications and improve outcomes. In an era of value-based care, management of modifiable risk factors is more important than ever. Both medical and surgical providers have an important role in identifying and addressing these risk factors. Further research is required to determine the efficacy of preoperative optimization protocols in decreasing costs and improving clinical outcomes in TJA. Specifically, randomized controlled trials of interventions to optimize modifiable risk factors with larger numbers of patients are needed, as well as evaluations of the efficacy of different types of interventions, particularly in regard to preoperative weight loss, management of hypoalbuminemia, and opioid and smoking cessation. Moreover, large scale studies assessing the effects of implementing the aforementioned thresholds on outcomes in TJA will be crucial to determine their efficacy. Such findings will provide valuable additions to the current evidence and recommendations regarding preoperative optimization of modifiable risk factors in TJA.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Julius K. Oni, MD, reports relationships with Zimmer, Smith and Nephew, and Omega, outside the submitted work. The other authors declare no potential conflicts of interest.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Human/Animal Rights

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2013.

Informed Consent

Informed consent was not sought for this review article.

Required Author Forms

Disclosure forms provided by the authors are available with the online version of this article as supplemental material.

References

1. Agarwal R, Liao JM, Gupta A, Navathe AS. The impact of bundled payment on health care spending, utilization, and quality: a systematic review. *Health Affairs*. 2020;39(1):50–57. https://doi.org/10.1377/hlthaff.2019.00784.
2. American Diabetes Association. Standards of medical care in diabetes—2020 abridged for primary care providers. *Clin Diabetes*. 2020;38(1):10–38. https://doi.org/10.2337/cd20-as01.
3. Apovian CM. Obesity: definition, comorbidities, causes, and burden. *Am J Manag Care*. 2016;22(suppl 7):s176–s185.
4. Aronson S, Martin G, Gulur P, et al. Preoperative optimization: a continued call to action. *Anesth Analg*. 2020;130(4):808–810. https://doi.org/10.1213/ANE.0000000000004492.
5. Bala A, Ivanov DV, Huddleston JI, Goodman SB, Maloney WJ, Amanatullah DF. The cost of malnutrition in total joint arthroplasty. *J Arthroplasty*. 2020;35(4):926–932. https://doi.org/10.1016/j.arth.2019.11.018.
6. Bedard NA, DeMik DE, Owens JM, Glass NA, DeBerg J, Callaghan JJ. Tobacco use and risk of wound complications and periprosthetic joint infection: a systematic review and meta-analysis of primary total joint arthroplasty procedures. *J Arthroplasty*. 2019;34(2):385–396. https://doi.org/10.1016/j.arth.2018.09.089.
7. Belmont PJ, Goodman GP, Hamilton W, et al. Morbidity and mortality in the thirty-day period following total hip arthroplasty: risk factors and incidence. *J Arthroplasty*. 2014;29(10):2025–2030. https://doi.org/10.1016/j.arth.2014.05.015.
8. Belmont PJ, Goodman GP, Waterman BR, Bader JO, Schoenfeld AJ. Thirty-day postoperative complications and mortality following total knee arthroplasty: incidence and risk factors among a national sample of 15,321 patients. *J Bone Joint Surg Am*. 2014;96(1):20–26. https://doi.org/10.2106/JBJS.M.00018.
9. Bernstein DN, Liu TC, Winegar AL, et al. Evaluation of a preoperative optimization protocol for primary hip and knee arthroplasty patients. *J Arthroplasty*. 2018;33(12):3642–3648. https://doi.org/10.1016/j.arth.2018.08.018.
10. Blevins Peratikos M, Weeks HL, Pisansky AJB, Yong RJ, Stringer EA. Effect of preoperative opioid use on adverse outcomes, medical spending, and persistent opioid use following elective total joint arthroplasty in the united states: a large retrospective cohort study of administrative claims data. *Pain Med*. 2020;21(3):521–531. https://doi.org/10.1093/pm/pnz083.
11. Bohl DD, Shen MR, Kayupov E, Della Valle CJ. Hypoalbuminemia independently predicts surgical site infection, pneumonia, length of stay, and readmission after total joint arthroplasty. *J Arthroplasty*. 2016;31(1):15–21. https://doi.org/10.1016/j.arth.2015.08.028.
12. Boylan MR, Bosco JA, Slover JD. Cost-effectiveness of preoperative smoking cessation interventions in total joint arthroplasty. *J Arthroplasty*. 2019;34(2):215–220. https://doi.org/10.1016/j.arth.2018.09.084.

13. Calkins TE, Hannon CP, Nam D, et al. Who is prescribing opioids preoperatively? a survey of new patients presenting to tertiary care adult reconstruction clinics. *J Am Acad Orthop Surg*. 2020;28(7):301–307. https://doi.org/10.5435/JAAOS-D-19-00602.
14. Capozzi JD, Lepkowsky ER, Callari MM, et al. The prevalence of diabetes mellitus and routine hemoglobin a1c screening in elective total joint arthroplasty patients. *J Arthroplasty*. 2017;32(1):304–308. https://doi.org/10.1016/j.arth.2016.06.025.
15. Chen SA, White RS, Tangel V, et al. Preexisting opioid use disorder and outcomes after lower extremity arthroplasty: a multistate analysis, 2007–2014. *Pain Med*. 2020;21(12):3624–3634. https://doi.org/10.1093/pm/pnaa059.
16. Chrastil J, Anderson MB, Stevens V, et al. Is hemoglobin a1c or perioperative hyperglycemia predictive of periprosthetic joint infection or death following primary total joint arthroplasty? *J Arthroplasty*. 2015;30(7):1197–1202. https://doi.org/10.1016/j.arth.2015.01.040.
17. Courtney PM, Markel DC. Arthroplasty registries: improving clinical and economic outcomes. *J Knee Surg*. 2017;30(1):7–11. https://doi.org/10.1055/s-0036-1593615.
18. Cross MB, Yi PH, Thomas CF, Garcia J, Della Valle CJ. Evaluation of malnutrition in orthopaedic surgery. *J Am Acad Orthop Surg*. 2014;22(3):193–199. https://doi.org/10.5435/JAAOS-22-03-193.
19. 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. https://doi.org/10.1007/s11999-014-3668-9.
20. Duchman KR, Gao Y, Pugely AJ, Martin CT, Noiseux NO, Callaghan JJ. The effect of smoking on short-term complications following total hip and knee arthroplasty. *J Bone Joint Surg Am*. 2015;97(13):1049–1058. https://doi.org/10.2106/JBJS.N.01016.
21. Duensing I, Anderson MB, Meeks HD, Curtin K, Gililland JM. Patients with type-1 diabetes are at greater risk of periprosthetic joint infection: a population-based, retrospective, cohort study. *J Bone Joint Surg Am*. 2019;101(20):1860–1867. https://doi.org/10.2106/JBJS.19.00080.
22. Fryhofer GW, Sloan M, Sheth NP. Hypoalbuminemia remains an independent predictor of complications following total joint arthroplasty. *J Orthop*. 2019;16(6):552–558. https://doi.org/10.1016/j.jor.2019.04.019.
23. Fu MC, D'Ambrosia C, McLawhorn AS, Schairer WW, Padgett DE, Cross MB. Malnutrition increases with obesity and is a stronger independent risk factor for postoperative complications: a propensity-adjusted analysis of total hip arthroplasty patients. *J Arthroplasty*. 2016;31(11):2415–2421. https://doi.org/10.1016/j.arth.2016.04.032.
24. Fu MC, McLawhorn AS, Padgett DE, Cross MB. Hypoalbuminemia is a better predictor than obesity of complications after total knee arthroplasty: a propensity score-adjusted observational analysis. *HSS J*. 2017;13(1):66–74. https://doi.org/10.1007/s11420-016-9518-4.
25. George J, Piuzzi NS, Ng M, Sodhi N, Khlopas AA, Mont MA. association between body mass index and thirty-day complications after total knee arthroplasty. *J Arthroplasty*. 2018;33(3):865–871. https://doi.org/10.1016/j.arth.2017.09.038.
26. Giori NJ, Ellerbe LS, Bowe T, Gupta S, Harris AHS. Many diabetic total joint arthroplasty candidates are unable to achieve a preoperative hemoglobin A1c goal of 7% or less. *J Bone Joint Surg Am*. 2014;96(6):500–504. https://doi.org/10.2106/JBJS.L.01631.
27. Goodnough LT, Maniatis A, Earnshaw P, et al. Detection, evaluation, and management of preoperative anaemia in the elective orthopaedic surgical patient: NATA guidelines. *Br J Anaesth*. 2011;106(1):13–22. https://doi.org/10.1093/bja/aeq361.
28. Goplen CM, Verbeek W, Kang SH, et al. Preoperative opioid use is associated with worse patient outcomes after Total joint arthroplasty: a systematic review and meta-analysis. *BMC Musculoskelet Disord*. 2019;20(1):234. https://doi.org/10.1186/s12891-019-2619-8.
29. Greco NJ, Manocchio AG, Lombardi AV, et al. Should postoperative haemoglobin and potassium levels be checked routinely following blood-conserving primary total joint arthroplasty? *Bone Joint J*. 2019;101-B(1, suppl A):25–31. https://doi.org/10.1302/0301-620X.101B1.BJJ-2018-0554.R1.
30. Gu A, Malahias MA, Selemon NA, et al. Increased severity of anaemia is associated with 30-day complications following total joint replacement. *Bone Joint J*. 2020;102-B(4):485–494. https://doi.org/10.1302/0301-620X.102B4.BJJ-2018-0991.R3.
31. Gu A, Malahias MA, Strigelli V, et al. Preoperative malnutrition negatively correlates with postoperative wound complications and infection after total joint arthroplasty: a systematic review and meta-analysis. *J Arthroplasty*. 2019;34(5):1013–1024. https://doi.org/10.1016/j.arth.2019.01.005.
32. Hannon CP, Fillingham YA, Nam D, et al. *American Association of Hip and Knee Surgeons (AAKHS) Clinical Practice Guideline: Opioids in Total Joint Arthroplasty*. Rosemont, IL: American Association of Hip and Knee Surgeons; 2020.
33. Hansen TB, Bredtoft HK, Larsen K. Preoperative physical optimization in fast-track hip and knee arthroplasty. *Dan Med J*. 2012;59(2):A4381.
34. Harris AHS, Bowe TR, Gupta S, Ellerbe LS, Giori NJ. Hemoglobin A1C as a marker for surgical risk in diabetic patients undergoing total joint arthroplasty. *J Arthroplasty*. 2013;28(suppl 8):25–29. https://doi.org/10.1016/j.arth.2013.03.033.
35. Hart A, Rainer WG, Taunton MJ, et al. Cotinine testing improves smoking cessation before total joint arthroplasty. *J Arthroplasty*. 2019;34(suppl 7):S148–S151. https://doi.org/10.1016/j.arth.2018.11.039.
36. Huang R, Greenky M, Kerr GJ, Austin MS, Parvizi J. The effect of malnutrition on patients undergoing elective joint arthroplasty. *J Arthroplasty*. 2013;28(suppl 8):21–24. https://doi.org/10.1016/j.arth.2013.05.038.
37. Ihle C, Weiß C, Blumenstock G, et al. Interview based malnutrition assessment can predict adverse events within 6 months after primary and revision arthroplasty: a prospective observational study of 351 patients. *BMC Musculoskelet Disord*. 2018;19(1):83. https://doi.org/10.1186/s12891-018-2004-z.

38. Inacio MCS, Kritz-Silverstein D, Raman R, et al. The impact of pre-operative weight loss on incidence of surgical site infection and readmission rates after total joint arthroplasty. *J Arthroplasty*. 2014;29(3):458–464.e1. https://doi.org/10.1016/j.arth.2013.07.030.
39. Jämsen E, Nevalainen P, Eskelinen A, et al. Obesity, diabetes, and preoperative hyperglycemia as predictors of periprosthetic joint infection: a single-center analysis of 7181 primary hip and knee replacements for osteoarthritis. *J Bone Joint Surg Am*. 2012;94(14):e101. https://doi.org/10.2106/JBJS.J.01935.
40. Jans Ø, Nielsen CS, Khan N, et al. Iron deficiency and preoperative anaemia in patients scheduled for elective hip- and knee arthroplasty: an observational study. *Vox Sang*. 2018;113(3):260–267. https://doi.org/10.1111/vox.12630.
41. Johns WL, Layon D, Golladay G, et al. Preoperative risk factor screening protocols in total joint arthroplasty: a systematic review. *J Arthroplasty*. 2020;35(11):3353–3363. https://doi.org/10.1016/j.arth.2020.05.074.
42. Kasivisvanathan R, Ramesh V, Rao Baikady R, Nadaraja S. Preoperative anaemia is associated with increased allogeneic pack red cell transfusion in revision hip and knee joint arthroplasty: a retrospective analysis of 5387 patients over a 10-year period at a single high volume centre. *Transfus Med*. 2016;26(4):271–277. https://doi.org/10.1111/tme.12322.
43. Keeney BJ, Austin DC, Jevsevar DS. Preoperative weight loss for morbidly obese patients undergoing total knee arthroplasty: determining the necessary amount. *J Bone Joint Surg Am*. 2019;101(16):1440–1450. https://doi.org/10.2106/JBJS.18.01136.
44. Klasan A, Dworschak P, Heyse TJ, et al. Transfusions increase complications and infections after hip and knee arthroplasty: an analysis of 2760 cases. *Technol Health Care*. 2018;26(5):825–832. https://doi.org/10.3233/THC-181324.
45. Klein AA, Arnold P, Bingham RM, et al. AAGBI guidelines: the use of blood components and their alternatives 2016. *Anaesthesia*. 2016;71(7):829–842. https://doi.org/10.1111/anae.13489.
46. Kolasinski SL, Neogi T, Hochberg MC, et al. 2019 American College of Rheumatology/Arthritis Foundation guideline for the management of osteoarthritis of the hand, hip, and knee. *Arthritis Rheumatol*. 2020;72(2):220–233. https://doi.org/10.1002/art.41142.
47. Krebs EE, Gravely A, Nugent S, et al. Effect of opioid vs nonopioid medications on pain-related function in patients with chronic back pain or hip or knee osteoarthritis pain: the SPACE randomized clinical trial. *JAMA*. 2018;319(9):872–882. https://doi.org/10.1001/jama.2018.0899.
48. Layon DR, Johns WL, Morrell AT, et al. Does adherence to preoperative surgical selection criteria reduce the rate of prosthetic joint infection in primary and revision total knee arthroplasties? *Arthroplast Today*. 2020;6(3):410–413. https://doi.org/10.1016/j.artd.2020.04.019.
49. Li S, Luo X, Sun H, Wang K, Zhang K, Sun X. Does prior bariatric surgery improve outcomes following total joint arthroplasty in the morbidly obese? a meta-analysis. *J Arthroplasty*. 2019;34(3):577–585. https://doi.org/10.1016/j.arth.2018.11.018.
50. Lingamfelter M, Orozco FR, Beck CN, et al. Nutritional counseling program for morbidly obese patients enables weight optimization for safe total joint arthroplasty. *Orthopedics*. 2020;43(4):e316–e322. https://doi.org/10.3928/01477447-20200521-08.
51. Lum ZC, Natsuhara KM, Shelton TJ, et al. Mortality during total knee periprosthetic joint infection. *J Arthroplasty*. 2018;33(12):3783–3788. https://doi.org/10.1016/j.arth.2018.08.021.
52. 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*. 2015;473(2):453–459. https://doi.org/10.1007/s11999-014-3780-x.
53. Marchant MH, Viens NA, Cook C, Vail TP, Bolognesi MP. The impact of glycemic control and diabetes mellitus on perioperative outcomes after total joint arthroplasty. *J Bone Joint Surg Am*. 2009;91(7):1621–1629. https://doi.org/10.2106/JBJS.H.00116.
54. Matharu GS, Mouchti S, Twigg S, et al. The effect of smoking on outcomes following primary total hip and knee arthroplasty: a population-based cohort study of 117,024 patients. *Acta Orthop*. 2019;90(6):559–567. https://doi.org/10.1080/17453674.2019.1649510.
55. Meller MM, Toossi N, Gonzalez MH, Son M-S, Lau EC, Johanson N. Surgical risks and costs of care are greater in patients who are super obese and undergoing THA. *Clin Orthop Relat Res*. 2016;474(11):2472–2481. https://doi.org/10.1007/s11999-016-5039-1.
56. Meybohm P, Kohlhof H, Wirtz DC, et al. Preoperative anaemia in primary hip and knee arthroplasty. *Z Orthop Unfall*. 2020;158(2):194–200. https://doi.org/10.1055/a-0974-4115.
57. Møller AM, Villebro N, Pedersen T, Tønnesen H. Effect of preoperative smoking intervention on postoperative complications: a randomised clinical trial. *The Lancet*. 2002;359(9301):114–117. https://doi.org/10.1016/S0140-6736(02)07369-5.
58. Muñoz M, Acheson AG, Auerbach M, et al. International consensus statement on the peri-operative management of anaemia and iron deficiency. *Anaesthesia*. 2017;72(2):233–247. https://doi.org/10.1111/anae.13773.
59. Natsuhara KM, Shelton TJ, Meehan JP, Lum ZC. Mortality during total hip periprosthetic joint infection. *J Arthroplasty*. 2019;34(suppl 7):S337–S342. https://doi.org/10.1016/j.arth.2018.12.024.
60. Nguyen L-CL, Sing DC, Bozic KJ. Preoperative reduction of opioid use before total joint arthroplasty. *J Arthroplasty*. 2016;31(9):282–287. https://doi.org/10.1016/j.arth.2016.01.068.
61. Papas PV, Gold CA, Scuderi GR. The effects of smoking on postoperative complications after total joint arthroplasty. *Tech Orthop*. 2019;34(3):183–186. https://doi.org/10.1097/BTO.0000000000000388.
62. Pruzansky JS, Bronson MJ, Grelsamer RP, Strauss E, Moucha CS. Prevalence of modifiable surgical site infection risk factors in hip and knee joint arthroplasty patients at an urban academic hospital. *J Arthroplasty*. 2014;29(2):272–276. https://doi.org/10.1016/j.arth.2013.06.019.

63. Pujol-Nicolas A, Morrison R, Casson C, et al. Preoperative screening and intervention for mild anemia with low iron stores in elective hip and knee arthroplasty. *Transfusion*. 2017;57(12):3049–3057. https://doi.org/10.1111/trf.14372.
64. Maradit Kremers H, Schleck CD, Lewallen EA. Diabetes mellitus and hyperglycemia and the risk of aseptic loosening in total joint arthroplasty. *J Arthroplasty*. 2017;32(9S):S251–S253.
65. Rao SS, Chaudhry YP, Solano MA, et al. Routine preoperative nutritional screening in all primary total joint arthroplasty patients has little utility. *J Arthroplasty*. 2020;35(12): 3505–3511. https://doi.org/10.1016/j.arth.2020.06.073.
66. Saleh A, Small T, Chandran Pillai ALP, et al. Allogenic blood transfusion following total hip arthroplasty: results from the nationwide inpatient sample, 2000 to 2009. *J Bone Joint Surg Am*. 2014;96(18):e155. https://doi.org/10.2106/JBJS.M.00825.
67. Sayeed Z, Anoushiravani AA, Simha S, et al. Markers for malnutrition and BMI status in total joint arthroplasty and pharmaconutrient therapy. *JBJS Rev*. 2019;7(5):e3. https://doi.org/10.2106/JBJS.RVW.18.00056.
68. Schroer WC, Diesfeld PJ, LeMarr AR, Morton DJ, Reedy ME. Modifiable risk factors in primary joint arthroplasty increase 90-day cost of care. *J Arthroplasty*. 2018;33(9):2740–2744. https://doi.org/10.1016/j.arth.2018.04.018.
69. Schroer WC, LeMarr AR, Mills K, et al. 2019 Chitranjan S. Ranawat Award: elective joint arthroplasty outcomes improve in malnourished patients with nutritional intervention. *Bone Joint J*. 2019;101-B(7, suppl C):17–21. https://doi.org/10.1302/0301-620X.101B7.BJJ-2018-1510.R1.
70. Shohat N, Fleischman A, Tarabichi M, Tan TL, Parvizi J. Weighing in on body mass index and infection after total joint arthroplasty: is there evidence for a body mass index threshold? *Clin Orthop Relat Res*. 2018;476(10):1964–1969. https://doi.org/10.1007/s11999.0000000000000141.
71. Shohat N, Goswami K, Tarabichi M, et al. All patients should be screened for diabetes before total joint arthroplasty. *J Arthroplasty*. 2018;33(7):2057–2061. https://doi.org/10.1016/j.arth.2018.02.047.
72. Shohat N, Tarabichi M, Tischler EH, Jabbour S, Parvizi J. Serum fructosamine: a simple and inexpensive test for assessing preoperative glycemic control. *J Bone Joint Surg Am*. 2017;99(22):1900–1907. https://doi.org/10.2106/JBJS.17.00075.
73. Singh JA, Schleck C, Harmsen WS, et al. Current tobacco use is associated with higher rates of implant revision and deep infection after total hip or knee arthroplasty: a prospective cohort study. *BMC Med*. 2015;13:283. https://doi.org/10.1186/s12916-015-0523-0.
74. Sloan M, Premkumar A, Sheth NP. Projected volume of primary total joint arthroplasty in the US, 2014 to 2030. *J Bone Joint Surg Am*. 2018;100(17):1455–1460. https://doi.org/10.2106/JBJS.17.01617.
75. Sloan M, Sheth NP, Nelson CL. Obesity and hypoalbuminaemia are independent risk factors for readmission and reoperation following primary total knee arthroplasty. *Bone Joint J*. 2020;102-B(6, suppl A):31–35. https://doi.org/10.1302/0301-620X.102B6.BJJ-2019-1509.R1.
76. Smith EL, Shahien AA, Chung M, et al. The obesity paradox: body mass index complication rates vary by gender and age among primary total hip arthroplasty patients. *J Arthroplasty*. 2020;35(9):2658–2665. https://doi.org/10.1016/j.arth.2020.04.094.
77. Sodhi N, Anis HK, Acuña AJ, et al. Opioid use disorder is associated with an increased risk of infection after total joint arthroplasty: a large database study. *Clin Orthop Relat Res*. 2020;478:1752–1759. https://doi.org/10.1097/CORR.0000000000001390.;
78. Sodhi N, Anis HK, Acuña AJ, et al. The effects of opioid use on thromboembolic complications, readmission rates, and 90-day episode of care costs after total hip arthroplasty. *J Arthroplasty*. 2020;35(suppl 6):S237–S240. https://doi.org/10.1016/j.arth.2020.02.014.
79. Sodhi N, Anis HK, Vakharia RM, et al. What are risk factors for infection after primary or revision total joint arthroplasty in patients older than 80 years? *Clin Orthop Relat Res*. 2020;478(8):1741–1751. https://doi.org/10.1097/CORR.0000000000001389.
80. Stryker LS, Abdel MP, Morrey ME, et al. Elevated postoperative blood glucose and preoperative hemoglobin A1C are associated with increased wound complications following total joint arthroplasty. *J Bone Joint Surg Am*. 2013;95(9): 808–814, S1–S2. https://doi.org/10.2106/JBJS.L.00494.
81. Tarabichi M, Shohat N, Kheir MM, et al. Determining the threshold for hba1c as a predictor for adverse outcomes after total joint arthroplasty: a multicenter, retrospective study. *J Arthroplasty*. 2017;32(9):S263–S267.e1. https://doi.org/10.1016/j.arth.2017.04.065.
82. Thomsen T, Villebro N, Møller AM. Interventions for preoperative smoking cessation. *Cochrane Database Syst Rev*. 2014;2014(3):CD002294. https://doi.org/10.1002/14651858.CD002294.pub4.
83. Ueyama H, Kanemoto N, Minoda Y, Taniguchi Y, Nakamura H. 2020 Chitranjan S. Ranawat Award: perioperative essential amino acid supplementation suppresses rectus femoris muscle atrophy and accelerates early functional recovery following total knee arthroplasty. *Bone Joint J*. 2020;102–B(6, suppl A):10–18. https://doi.org/10.1302/0301-620X.102B6.BJJ-2019-1370.R1.
84. Ward DT, Metz LN, Horst PK, Kim HT, Kuo AC. Complications of morbid obesity in total joint arthroplasty: risk stratification based on BMI. *J Arthroplasty*. 2015;30(suppl 9): 42–46. https://doi.org/10.1016/j.arth.2015.03.045.
85. Webb ML, Golinvaux NS, Ibe IK, et al. Comparison of perioperative adverse event rates after total knee arthroplasty in patients with diabetes: insulin dependence makes a difference. *J Arthroplasty*. 2017;32(10):2947–2951. https://doi.org/10.1016/j.arth.2017.04.032.
86. White JV, Guenter P, Jensen G, Malone A, Schofield M. Consensus statement of the Academy of Nutrition and Dietetics/American Society for Parenteral and Enteral Nutrition: characteristics recommended for the identification and documentation of adult malnutrition (undernutrition). *J Acad Nutr Diet*. 2012;112(5):730–738. https://doi.org/10.1016/j.jand.2012.03.012.
87. Workgroup of the American Association of Hip and Knee Surgeons Evidence Based Committee. Obesity and total joint arthroplasty: a literature based review. *J Arthroplasty*. 2013;28(5):714–721. https://doi.org/10.1016/j.arth.2013.02.011.