ORIGINAL ARTICLE
Hip Pelvis 33(3): 140-146, 2021
https://doi.org/10.5371/hp.2021.33.3.140

Print ISSN 2287-3260
Online ISSN 2287-3279
Hip & Pelvis

How Does Iron Deficiency Anemia Impact Outcomes following Revision Total Hip Arthroplasty?

Mohamed M. Sylla, BS*,†, Lauren Gruffi, BS*,†, Eric S. Roth, MD†, Francis E. Rosato, MD†, Che Hang Jason Wong, MD†, Afshin E. Razi, MD†

State University of New York (SUNY) Downstate College of Medicine, Brooklyn, NY, USA, Department of Orthopaedic Surgery, Maimonides Medical Center, Brooklyn, NY, USA†*

Purpose: Studies have shown the prevalence of iron deficiency anemia (IDA) increasing worldwide, and currently the literature is limited on the impact of IDA on outcomes following revision total hip arthroplasty (RTHA). Therefore, the purpose of this study was to determine whether IDA patients undergoing RTHA have longer: 1) in-hospital lengths of stay (LOS); 2) medical complications; and 3) costs of care.

Materials and Methods: A retrospective query of a nationwide administrative claims database was performed. Using Boolean command operations, the study group consisted of all patients in the database undergoing RTHA with IDA; whereas, patients without IDA served as controls. To reduce the effects of confounding, study group patients were matched to controls in a 1:5 ratio by age, sex, and medical comorbidities yielding 92,948 patients with (n=15,508) and without (n=77,440) IDA undergoing revision THA. A *P*-value less than 0.001 was considered statistically significant.

Results: IDA patients were found to have significantly longer in-hospital LOS (5 days vs. 4 days, *P*<0.0001). Additionally, the study showed IDA patients were found to higher incidence and odds of (73.84% vs. 11.77%, OR 5.04, *P*<0.0001) 90-day medical complications. IDA patients also incurred high 90-day episode of care costs ($25,597.51 vs. $20,085.70, *P*<0.0001).

Conclusion: After adjusting for age, sex, and medical comorbidities this study of over 92,000 patients demonstrated IDA is associated with longer in-hospital LOS, complications, and costs of care. Future studies should compare the duration and severity of IDA on outcomes.

Key Words: Total hip replacement, Joint revision, Iron deficiency anemia, Complications, Costs

Submitted: April 9, 2021 1st revision: May 10, 2021
Final acceptance: May 31, 2021
Address reprint request to
Mohamed M. Sylla, BS
(https://orcid.org/0000-0001-6538-3100)
State University of New York (SUNY) Downstate College of Medicine, 430 Clarkson Drive, Brooklyn, NY 11219, USA
TEL: +1-646-634-7047
E-mail: Mohamed.Sylla@Downstate.edu

INTRODUCTION

Iron deficiency anemia (IDA) is a common health condition with increasing prevalence worldwide[1,2]. The diagnostic criteria for IDA includes a myriad of laboratory values to be considered for the diagnosis, namely a low hemoglobin (<7.7 mmol/L in men and 7.4 mmol/L in women], a low serum iron (<7.1 μg/L), a low serum ferritin – the storage form of iron (<30 ng/L), a low transferrin saturation (<15%), and a high total iron-binding capacity (>13.1 μmol/L)[3]. This observation is even more pertinent in the U.S. where the prevalence of anemia has nearly doubled

(4.0% to 7.1%). Risk factors for IDA include age and comorbidities like diabetes and congestive heart failure[4]. The IDA status of patients is important to consider in invasive procedures such as orthopedic surgeries where it associated with extended recovery time, a longer length of stay, increased readmission rates, and higher costs of care[1,5].

Current literature supports IDA as an independent risk factor in orthopedic procedures, but there is a lack of research investigating the impact of IDA on revision total hip arthroplasty (RTHA). Nesslage et al.[6] found IDA is associated with greater risks of revision following primary total hip arthroplasty (THA). In a recent retrospective cohort study, Sim et al.[7] found preoperative anemia is associated with poorer physical function and health-related quality of life after hip fracture surgery. Furthermore, in a prospective observational cohort study, Halm et al.[5] demonstrated that higher preoperative hemoglobin was associated with shorter length of stay and lower odds of death and readmission within 60 days of discharge following hip fracture surgery. The aforementioned studies suggest IDA is an important risk factor to consider in THA and hip fracture surgery due to its significant impact on patient outcomes. However, the relationship between IDA and outcome following RTHA has not been assessed, and with an increasing prevalence of IDA and need for RTHA, further evaluation of this link is warranted. As such, the purpose of this study is to determine whether IDA patients undergoing RTHA have increased: 1) in-hospital lengths of stay (LOS); 2) medical complications; and 3) costs of care.

MATERIALS AND METHODS

1. Database

A retrospective query of a nationwide administrative claims database was performed from January 1, 2005 to March 31, 2014 using the 100% Parts A and Parts B Medicare Standard Analytical Files (SAF) from the PearlDiver platform[8]. The for-fee database houses the records of over 150 million patients and allows investigators information such as complications, diagnoses, discharge disposition, economic data, and other research variables. Information is queried through the use of International Classification of Disease, Ninth Revision (ICD-9) and Current Procedural Terminology (CPT) codes. The data is subsequently downloaded as a comma separated value (.csv) spreadsheet for further data analyses. As the spreadsheet is devoid of patient information, the current investigation was deemed exempt through our Institutional Review Board (IRB) approvals process.

2. Study Population

The database was initially queried for all patients who underwent RTHA using the ICD-9 procedural codes 81.53 and 84.57. IDA patients were identified using ICD-9 diagnosis code 280.0 (IDA secondary to blood loss – chronic), 280.1 (IDA secondary to inadequate dietary iron intake), 280.8 (other specified IDAs), and 280.9 (IDA, unspecified). Using Boolean command operations ("AND", "OR", "NOT"), the resulting study group consisted of all patients in the database that underwent RTHA with IDA. However, we only included patients who had IDA within 90 days prior to the index procedure, whereas patients without IDA served as controls. To reduce confounding effects, study group patients were matched to controls at a 1:5 ratio by age, sex, and the following medical comorbidities: coronary artery disease (CAD), chronic obstructive pulmonary disease (COPD), diabetes mellitus, hyperlipidemia, hypertension, obesity (defined as body mass index greater than 30 kg/m^2), and tobacco use. This method of matching was utilized based on previously published investigations[8-12]. The search resulted in a total of 92,948 patients with (n=15,508) and without (n=77,440) IDA undergoing revision THA. Matching was successful as there was no statistical differences between the aforementioned matching parameters for the two cohorts (Table 1).

3. Primary Endpoints

Endpoints of the study were to compare in-hospital LOS, 90-day medical complications, in addition to day of surgery and total global 90-day episode of care costs. Ninety-day complications analyzed included: acute renal failure, cerebrovascular accidents (CVAs), deep vein thromboses (DVTs), ileus, myocardial infarction, pneumonia, pulmonary emboli, respiratory failure, surgical site infections (SSIs), and urinary tract infections (UTIs). Healthcare costs were compared using reimbursement data as this is a more accurate representation of what providers are paid from the insurance companies and has been used as a metric in previously published studies utilizing the same database[13].

4. Data Analyses

Statistical analyses were performed using the open programming language known as R (Foundation for Computational

Hip Pelvis 33(3): 140-146, 2021

Statistics, Vienna, Austria). Baseline demographic profiles between the two cohorts were compared using Pearson's chi-square analyses or Fisher's exact test when appropriate. Continuous variables such as in-hospital LOS and costs of care of the two cohorts were analyzed using Welch's *t*-tests. To determine the association of IDA with medical complications, a univariate logistic regression analyses was performed to calculate the odds ratios (OR), 95% confidence intervals (95% CI), and respective *P*-values. For those complications which were found to be of statistical significance based on univariate analyses, a multivariate logistic regression analyses was performed to determine the association of IDA on complications adjusting for age, sex, geographic region, and Elixhauser comorbidity index (ECI). Due to the number of comparisons which were performed within this study, a Bonferroni-correction was made to reduce the probability of a type I error, which is commonly associated with large administrative datasets. As such, a *P*-value less than 0.001 was considered statistically significant.

RESULTS

1. In-hospital Length of Stay

IDA patients were found to have significantly longer in-hospital LOS compared to matched controls (4.82 days vs. 3.61 days, $P<0.0001$). The data demonstrated an increase for in-hospital LOS through the study interval for IDA patients for a mean in-hospital LOS from 3.92 days in 2010 to 5.31 days by the end of the first quarter of 2014. Female patients had longer in-hospital LOS compared to their male counterparts (5.11 days vs. 3.67 days).

2. Medical Complications and Costs of Care

Univariate logistic regression analyses demonstrated RTHA patients who have IDA had significantly higher frequency and odds of developing medical complications (73.84% vs. 11.77%, OR 19.48, 95% CI 18.69-20.20, $P<0.0001$) (Table 2). Specifically, IDA patients were found to have higher frequency and odds of acute renal failure (11.40% vs. 1.15%, OR 11.09, 95% CI 10.21-12.04, $P<0.0001$), pneumoniae (9.23% vs. 1.04%, OR 9.67, 95% CI 8.85-10.56, $P<0.0001$), episodes of ileus (1.76% vs. 0.19%, OR 9.61,

Table 1. Demographic Profile of Iron Deficiency Anemia Patients and Matched-controls Undergoing Revision Total Hip Arthroplasty

Demographic	Iron deficiency anemia (n=15,508)	Control (n=77,440)	*P*-value*
Age (yr)			0.99
≤64	2,734 (17.6)	13,681 (17.7)	
65-69	3,673 (23.7)	18,333 (23.7)	
70-74	3,004 (19.4)	14,991 (19.4)	
75-79	2,662 (17.2)	13,299 (17.2)	
80-84	1,991 (12.8)	9,933 (12.8)	
≥85	1,444 (9.3)	7,203 (9.3)	
Sex			0.99
Female	8,521 (54.9)	42,557 (55.0)	
Male	6,987 (45.1)	34,883 (45.0)	
Comorbidity			
CAD	5,211 (33.6)	26,003 (33.6)	0.96
COPD	228 (1.5)	1,080 (1.4)	0.92
Diabetes mellitus	4,250 (27.4)	21,187 (27.4)	0.91
Hyperlipidemia	9,226 (59.5)	46,092 (59.5)	0.95
Hypertension	12,743 (82.2)	63,642 (82.2)	0.98
Obesity	1,366 (8.8)	6,786 (8.8)	0.86
Tobacco	2,720 (17.5)	13,532 (17.5)	0.85

Values are presented as number (%).
CAD: coronary artery disease, COPD: chronic obstructive pulmonary disease.
* Assessed by Pearson's chi-square analyses.

95% CI 7.85-11.77, *P*<0.0001), respiratory failures (7.56% vs. 0.94%, OR 8.60, 95% CI 7.82-9.45, *P*<0.0001), myocardial infarctions (2.34% vs. 0.32%, OR 7.58, 95% CI 6.44-8.92, *P*<0.0001), UTIs (20.13% vs. 3.51%, OR 6.92, 95% CI 6.55-7.31, *P*<0.0001), CVAs (4.54% vs. 0.72%, OR 6.54, 95% CI 5.84-7.31, *P*<0.0001), pulmonary emboli (1.43% vs. 0.29%, OR 5.05, 95% CI 4.19-6.08, *P*<0.0001), DVTs (4.36% vs. 0.97%, OR 4.64, 95% CI 4.17-5.15, *P*<0.0001), venous thromboemboli (4.81% vs. 1.11%, OR 4.50, 95% CI 4.07-4.97, *P*<0.0001), and SSIs (6.28% vs. 1.53%, OR 4.30, 95% CI 3.94-4.69, *P*<0.0001) (Table 2).

Adjusting for age, sex, geographic region, and ECI the multivariate logistic regression analyses demonstrated IDA patients had a higher incidence and odds of developing medical complications within the episode of care time interval (73.84% vs. 11.77%, OR 5.04, 95% CI 4.82-5.27, *P*<0.0001) (Table 2). Comparing 90-day medical complications amongst IDA patients and matched controls undergoing RTHA, IDA patients had a higher risk of developing acute renal failure (11.40% vs. 1.15%, OR 5.61, 95% CI 5.13-6.14, *P*<0.0001), ileus episodes (1.76% vs. 0.19%, OR 5.46, 95% CI 4.39-6.80, *P*<0.0001), pneumoniae (9.23% vs. 1.04%, OR 5.26, 95% CI 4.78-5.79, *P*< 0.0001), UTIs (20.13% vs. 3.51%, OR 4.75, 95% CI 4.48-5.04, *P*<0.0001), respiratory failures (7.56% vs. 0.94%, OR 4.50, 95% CI 4.06-4.98, *P*<0.0001) myocardial infarctions (2.34% vs. 0.32%, OR 3.93, 95% CI 3.29-4.70, *P*<0.0001), CVAs (4.54% vs. 0.72%, OR 3.77, 95% CI 3.34-4.26, *P*<0.0001), DVTs (4.36% vs. 0.97%, OR 3.32, 95% CI 2.96-3.71, *P*<0.0001), SSIs (6.28% vs. 1.53%, OR 3.21, 95% CI 2.92-3.52, *P*<0.0001), venous thromboemboli (4.81% vs. 1.11%, OR 3.19, 95% CI 2.86-3.55, *P*< 0.0001), and pulmonary emboli (1.43% vs. 0.29%, OR 3.03, 95% CI 2.47-3.72, *P*<0.0001).

When assessing healthcare expenditures, the data showed a higher cost of care for IDA patients both on the day of the surgery ($19,331.94 vs. $17,229.08, *P*<0.0001) and during 90-day complications ($25,597.51 vs. $20,085.70, *P*<0.0001) following the index procedure.

DISCUSSION

Anemia prevalence in the US has increased from 4.0% to 7.1%, nearly doubling from 2003-2004 to 2011-2012[14]. While it is suggested that IDA is generally linked to worse surgical outcomes, research on its impact on RTHA is still lacking[1,4,5]. As such, a nationwide administrative claims database was used to research the association of IDA with outcomes following RTHA. After adjusting for age, sex, and medical comorbidities the current study of over 92,000 patients demonstrated that IDA is associated with a significant increase in-hospital LOS, increased incidence and odds of 90-day medical complications, and increased cost of care both on the day of the surgery and during 90 days postoperative. This study is important as it provides information that can help elucidate possible postoperative com-

Table 2. Frequency of 90-day Medical Complications between Iron Deficiency Anemia Patients and Comparison Cohort

Medical complication	Univariate analyses		Multivariate analyses	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value*
Acute renal failure	11.09 (10.21-12.04)	<0.0001	5.61 (5.13-6.14)	<0.0001
Pneumoniae	9.67 (8.85-10.56)	<0.0001	5.26 (4.78-5.79)	<0.0001
Ileus episodes	9.61 (7.85-11.77)	<0.0001	5.46 (4.39-6.80)	<0.0001
Respiratory failure	8.60 (7.82-9.45)	<0.0001	4.50 (4.06-4.98)	<0.0001
Myocardial infarctions	7.58 (6.44-8.92)	<0.0001	3.93 (3.29-4.70)	<0.0001
Urinary tract infections	6.92 (6.55-7.31)	<0.0001	4.75 (4.48-5.04)	<0.0001
Cerebrovascular accidents	6.54 (5.84-7.31)	<0.0001	3.77 (3.34-4.26)	<0.0001
Pulmonary emboli	5.05 (4.19-6.08)	<0.0001	3.03 (2.47-3.72)	<0.0001
Deep vein thromboses	4.64 (4.17-5.15)	<0.0001	3.32 (2.96-3.71)	<0.0001
Venous thromboemboli	4.50 (4.07-4.97)	<0.0001	3.19 (2.86-3.55)	<0.0001
Surgical site infections	4.30 (3.94-4.69)	<0.0001	3.21 (2.92-3.52)	<0.0001
Total complications	19.48 (18.69-20.20)	<0.0001	5.04 (4.82-5.27)	<0.0001
	Iron deficiency anemia cohort		Control	
In-hospital LOS (day)	4.82		3.61	<0.0001

OR: odds ratios, CI: confidence interval, LOS: lengths of stay.
* Adjusted for age, sex, geographic region, and the Elixhauser comorbidity index.

plications in IDA patients.

While the study is well-powered, it is not without limitations. Some of these limitations are inherent to retrospective studies, where the accuracy of the data cannot be fully ascertained. Patients and complications were identified using the ICD-9 codes, which is not exempted from misdiagnoses and errors[15]. The accuracy of our data is therefore highly dependent on the accuracy of the ICD-9 codes. Although we have matched for age, sex, and medical comorbidities, measurement of outcome still is subject to errors that cannot be accounted for such as worse outcome due to human error or malpractice. Furthermore, IDA cannot be completely identified as an independent variable because low iron levels diagnosed as IDA could be one symptom of a larger, underlying, undiscovered medical condition. For instance, IDA could potentially be an indicator of other underlying medical conditions such as chronic kidney disease, as such, these complications can naturally occur in this patient population. Given this possibility, it is questionable whether the results of this study can be summarized exclusively to patients who have IDA. Therefore, our study is limited to the impact of IDA on RTHA outcome based on ICD-9 IDA diagnosis and our given data, not necessarily IDA itself. Due to limitations of the PearlDiver platform, we were unable to ascertain laboratory markers to further ensure that patients truly had IDA, and to determine the association of IDA with outcomes in patients undergoing the revision procedure. However, this can serve as the basis for future prospective studies as our study provides statistically significant information where the literature is insufficient. This study is a foundation, i suggesting directions for future studies that can further explore the identified relationship between IDA and RTHA outcomes. Further studies are needed to quantify the impact of IDA severity and duration on outcome following RTHA.

There is limited research on the subject of IDA and its impact following RTHA. Nonetheless, our assessment of the link between IDA and outcome following RTHA is echoed by similar studies[5,16-20]. In a retrospective analysis of 146 elective RTHA patients, Mahadevan et al.[16] found that LOS was significantly increased in patients who received transfusions. Transfusion requirements were greater in patients who had lower preoperative hemoglobin concentration, thus anemic patients. Mahadevan et al.[16] also found that LOS was linked to an increase in age with patients that were 80 and older having a LOS of 22 days. That is nearly doubled the LOS of patients that were below 60 years old. Notably, given the low sample size, there is some question as to the power of the study.

Our findings have identified that IDA is associated with higher incidence and odds of medical complications. In a prospective study, Dunne et al.[17] reported an increased incidence of pneumonia from 2.6% to 5.0% with an increasing degree of anemia. Furthermore, low preoperative hematocrit, low postoperative hematocrit, and increased blood transfusion rates were associated with increased mortality ($P<0.01$), increased postoperative pneumonia ($P<0.05$ or $P=0.05$), and increased hospital length of stay ($P<0.05$)[17]. Similarly, in a retrospective cohort study of 7,759 consecutive noncardiac surgical patients, Beattie et al.[18] found that preoperative anemia was associated with a nearly 5-fold increase in the odds of postoperative mortality. After adjusting for major confounders using logistic regression, anemia was still associated with increased mortality (OR 2.36, 95% CI 1.57-3.41). Additionally, Wu et al.[20] found an OR of 1.6 (95% CI 1.1-2.2) increase in 30-day postoperative mortality associated with a decrease in hematocrit value. Further analysis showed an increased 30-day cardiac morbidity linked to a hematocrit level of 39%. Musallam et al.[21] went further and categorized the study group depending on anemia severity. Results show that increased anemia severity is linked to higher morbidity, as shown by an OR of 1.31 (95% CI 1.26-1.36) in mildly anemic patients and 1.56 (95% CI 1.47-1.66) in moderately-to-severely anemic patients[21]. Richards et al.[22] analyzed the impact of preoperative anemia and blood transfusion on postoperative outcomes in gynecological surgery, which monitored outcomes similar to the current study. After adjusting for cofounders, Richards et al.[22] found that preoperative anemia was independently and significantly associated with increased odds of 30-day mortality (OR 2.40, 95% CI 1.06-5.44) and composite morbidity (OR 1.80, 95% CI 1.45-2.24). The study group had a significantly higher odds of all tested morbidities (respiratory, central nervous system, renal, wound, sepsis, and venous thrombosis).

IDA increases the incidence and odds of medical complications in RTHA patients which can lead to higher cost of care. Feng et al.[19] studied hospital costs associated with anemia in elective colorectal surgery. In this study, they found that anemia was associated with an adjusted 14% relative increase in costs. The total hospitalization cost attributable to anemia was 3,027 CAD (95% CI 2,670-3,388). As such, minimizing healthcare expenditures within this population is of critical importance, and can be achieved with adequate preoperative optimization. Studies have shown that treatment for IDA can be executed either with oral or intravenous

supplementation, as both have been shown to restore hemoglobin concentrations, reduce the incidence of postoperative transfusion requirements, and have increased quality of life in patients[23-25]. The time period between the primary diagnosis of the condition and the surgical intervention is the main determinant on whether patients should receive oral or intravenous iron[26,27]. Those patients who have longer than 6 weeks until their surgery can be optimized with oral supplementation with either 40 to 60 mg of elemental iron daily, or 80 to 100 mg, every other day. Hemoglobin values should be assessed 4 weeks after initial administration of oral iron. For those patients who are still anemic, they should be changed to intravenous iron supplementation[27,28]. Studies have found intravenous formulation to be safe[29,30]. In a study of 10,390 patients who received intravenous iron treatment, there was no increased risk of adverse events with a relative risk of 1.04 (95% CI 0.93-1.17)[29].

Some studies in the literature yielded opposite findings about the relationship between IDA and RTHA outcomes. Waters et al.[31] studied the prevalence of iron deficiency in a total joint surgery population, where no association was found between simple iron deficiency and any perioperative complications. However only ferritin was considered as a marker for iron deficiency. Furthermore, only one hundred patients were studied, which puts to question the power of the study. Similarly, Vuille-Lessard et al.[32] and So-Osman et al.[33] found no association between postoperative anemia and poor outcome when compared to a patient without blood loss. These studies examined postoperative anemia, caused mostly by blood loss from surgery, rather than preoperative anemia.

CONCLUSION

The current study found IDA to be associated with longer in-hospital LOS, as well as higher rates of complications and costs. Adjusting for baseline covariates, the association of adverse events in IDA patients persisted. Future prospective studies should evaluate the severity of IDA with laboratory markers for primary and revision total joint arthroplasty procedures. Prior optimization can potentially help to mitigate many of these adverse events and potentially reduce the high costs associated with this comorbidity. The current study can be utilized by healthcare professionals and orthopaedic surgeons to adequately educate these patients of the complications which may occur following their revision procedure.

CONFLICT OF INTEREST

The authors declare that there is no potential conflict of interest relevant to this article.

REFERENCES

1. Mathew KK, Vakharia RM, Salem HS, et al. *Is iron deficiency anemia a risk factor for poorer outcomes in primary total knee arthroplasty? J Arthroplasty. 2020;35:1252-6.*
2. Shander A, Knight K, Thurer R, Adamson J, Spence R. *Prevalence and outcomes of anemia in surgery: a systematic review of the literature. Am J Med. 2004;116 Suppl 7A: 58S-69S.*
3. Johnson-Wimbley TD, Graham DY. *Diagnosis and management of iron deficiency anemia in the 21st century. Therap Adv Gastroenterol. 2011;4:177-84.*
4. Badarudeen S, Shu AC, Ong KL, Baykal D, Lau E, Malkani AL. *Complications after revision total hip arthroplasty in the medicare population. J Arthroplasty. 2017;32:1954-8.*
5. Halm EA, Wang JJ, Boockvar K, et al. *The effect of perioperative anemia on clinical and functional outcomes in patients with hip fracture. J Orthop Trauma. 2004;18:369-74.*
6. Nesslage R, Radtke K, Hohloch L, Floerkemeier T, Windhagen H, Lewinski GV. *[Influence of comorbidities on revision rate within the first year after primary total hip arthroplasty]. Z Orthop Unfall. 2017;155:194-200. German.*
7. Sim YE, Sim SD, Seng C, Howe TS, Koh SB, Abdullah HR. *Preoperative anemia, functional outcomes, and quality of life after hip fracture surgery. J Am Geriatr Soc. 2018;66: 1524-31.*
8. Vakharia AM, Cohen-Levy WB, Vakharia RM, Sodhi N, Mont MA, Roche MW. *Perioperative complications in patients with rheumatoid arthritis following primary total knee arthroplasty: an analysis of 102,898 patients. J Knee Surg. 2019;32: 1075-80.*
9. Cancienne JM, Diduch DR, Werner BC. *High altitude is an independent risk factor for postoperative symptomatic venous thromboembolism after knee arthroscopy: a matched case-control study of medicare patients. Arthroscopy. 2017; 33:422-7.*
10. Quinlan ND, Chen DQ, Werner BC, Barnes CL, Browne JA. *Patients with multiple sclerosis are at increased risk for postoperative complications following total hip and knee arthroplasty. J Arthroplasty. 2019;34:1606-10.*
11. Wang CA, Palmer JR, Madden MO, Cohen-Levy W, Vakharia RM, Roche MW. *Perioperative complications in patients with sleep apnea following primary total shoulder arthroplasty: an analysis of 33,366 patients. J Orthop. 2019; 16:382-5.*
12. Vakharia RM, Sabeh KG, Sodhi N, Naziri Q, Mont MA, Roche MW. *Implant-related complications among patients with opioid use disorder following primary total hip arthroplasty: a matched-control analysis of 42,097 medicare patients. J Arthroplasty. 2020;35:178-81.*
13. Martin CT, D'Oro A, Buser Z, et al. *Trends and costs of anterior cervical discectomy and fusion: a comparison of inpatient and outpatient procedures. Iowa Orthop J. 2018;38:*

Hip Pelvis 33(3): 140-146, 2021

167-76.
14. Le CH. *The prevalence of anemia and moderate-severe anemia in the US population (NHANES 2003-2012). PLoS One. 2016;11:e0166635.*
15. Vakharia RM, Sodhi N, Anis HK, Ehiorobo JO, Mont MA, Roche MW. *Patients who have cannabis use disorder have higher rates of venous thromboemboli, readmission rates, and costs following primary total knee arthroplasty. J Arthroplasty. 2020;35:997-1002.*
16. Mahadevan D, Challand C, Keenan J. *Revision total hip replacement: predictors of blood loss, transfusion requirements, and length of hospitalisation. J Orthop Traumatol. 2010;11:159-65.*
17. Dunne JR, Malone D, Tracy JK, Gannon C, Napolitano LM. *Perioperative anemia: an independent risk factor for infection, mortality, and resource utilization in surgery. J Surg Res. 2002;102:237-44.*
18. Beattie WS, Karkouti K, Wijeysundera DN, Tait G. *Risk associated with preoperative anemia in noncardiac surgery: a single-center cohort study. Anesthesiology. 2009;110:574-81.*
19. Feng S, Greenberg J, Moloo H, Thavorn K, McIsaac DI. *Hospital cost associated with anemia in elective colorectal surgery: a historical cohort study. Can J Anaesth. 2019; 66:877-85.*
20. Wu WC, Schifftner TL, Henderson WG, et al. *Preoperative hematocrit levels and postoperative outcomes in older patients undergoing noncardiac surgery. JAMA. 2007;297:2481-8.*
21. Musallam KM, Tamim HM, Richards T, et al. *Preoperative anaemia and postoperative outcomes in non-cardiac surgery: a retrospective cohort study. Lancet. 2011;378:1396-407.*
22. Richards T, Musallam KM, Nassif J, et al. *Impact of preoperative anaemia and blood transfusion on postoperative outcomes in gynaecological surgery. PLoS One. 2015;10: e0130861.*
23. Gurusamy KS, Nagendran M, Broadhurst JF, Anker SD, Richards T. *Iron therapy in anaemic adults without chronic kidney disease. Cochrane Database Syst Rev. 2014;(12): CD010640.*
24. Froessler B, Palm P, Weber I, Hodyl NA, Singh R, Murphy EM. *The important role for intravenous iron in perioperative patient blood management in major abdominal surgery: a randomized controlled trial. Ann Surg. 2016;264:41-6.*
25. Clevenger B, Gurusamy K, Klein AA, Murphy GJ, Anker SD, Richards T. *Systematic review and meta-analysis of iron therapy in anaemic adults without chronic kidney disease: updated and abridged Cochrane review. Eur J Heart Fail. 2016;18:774-85.*
26. Gómez-Ramírez S, Bisbe E, Shander A, Spahn DR, Muñoz M. *Management of perioperative iron deficiency anemia. Acta Haematol. 2019;142:21-9.*
27. Muñoz M, Acheson AG, Auerbach M, et al. *International consensus statement on the peri-operative management of anaemia and iron deficiency. Anaesthesia. 2017;72:233-47.*
28. Desai N, Schofield N, Richards T. *Perioperative patient blood management to improve outcomes. Anesth Analg. 2018; 127:1211-20.*
29. Avni T, Bieber A, Grossman A, Green H, Leibovici L, Gafter-Gvili A. *The safety of intravenous iron preparations: systematic review and meta-analysis. Mayo Clin Proc. 2015; 90:12-23.*
30. Auerbach M, Adamson J, Bircher A, et al. *On the safety of intravenous iron, evidence trumps conjecture. Haematologica. 2015;100:e214-5.*
31. Waters JH, Johnson P, Yazer MH. *Prevalence of iron deficiency in a total joint surgery population. Hematology. 2018;23:537-41.*
32. Vuille-Lessard E, Boudreault D, Girard F, Ruel M, Chagnon M, Hardy JF. *Postoperative anemia does not impede functional outcome and quality of life early after hip and knee arthroplasties. Transfusion. 2012;52:261-70.*
33. So-Osman C, Nelissen R, Brand R, Brand A, Stiggelbout AM. *Postoperative anemia after joint replacement surgery is not related to quality of life during the first two weeks postoperatively. Transfusion. 2011;51:71-81.*