Original Article

Low Albumin Is a Risk Factor for Complications after Revision Total Knee Arthroplasty

Atul F. Kamath, MD[1] Charles L. Nelson, MD[1] Nabil Elkassabany, MD[2] Zhenggang Guo, MD[3] Jiabin Liu, MD, PhD[2]

[1] Department of Orthopaedic Surgery, University of Pennsylvania, Philadelphia, Pennsylvania
[2] Department of Anesthesiology and Critical Care, University of Pennsylvania, Philadelphia, Pennsylvania
[3] Department of Anesthesia, First Affiliated Hospital of General Hospital of PLA, Beijing, China

Address for correspondence Atul F. Kamath, MD, Department of Orthopaedic Surgery, University of Pennsylvania, 800 Spruce St, 8th Floor Preston, Philadelphia, PA 19107 (e-mail: akamath@post.harvard.edu).

J Knee Surg

Abstract

Low serum albumin has been shown in the primary joint arthroplasty setting to increase the rate of perioperative complications. Our present work examined a large national inpatient administrative dataset to study the relationship between serum albumin level and key outcome measures after revision total knee arthroplasty (RTKA). Our hypothesis was that lower serum albumin would be an independent risk factor for poor outcomes after RTKA. We analyzed the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database from 2006 to 2014, specifically evaluating patients undergoing RTKA. Patients were grouped as having hypoalbuminemia (serum albumin < 3.5 mg/dL) or normal albumin (serum albumin ≥ 3.5). We analyzed data on 22 complications as reported in the NSQIP database and developed composite complication variables (any infections, cardiac/pulmonary complications, and any major complications). For each complication, multivariable logistic regression analysis was used to evaluate its association. The cohort included 4,551 patients undergoing RTKA. Patients in the low serum albumin group were statistically more likely to develop deep surgical site infection, organ space surgical site infection, pneumonia, urinary traction infection, and sepsis. The hypoalbuminemic group was more likely to require unplanned intubation, blood transfusion intraoperatively or postoperatively, remain on a ventilator $>$ 48 hours, and develop acute renal failure. There was also a higher risk of mortality and coma. Across the three composite complication variables, any complication (with or without transfusion), any major complication, and any infection (systemic, wound) were more prevalent among the patients with low serum albumin. This study confirms the relationship between suboptimal nutritional status and complications following RTKA. Hypoalbuminemia may be used as a potential preoperative predictor of outcomes. Understanding the effects of malnutrition on perioperative complications informs the choice of appropriate candidates for surgical intervention, timing of surgery, resource allocation, and risk counseling preoperatively.

Keywords

- revision total knee arthroplasty
- complications
- malnutrition
- serum albumin

received
April 6, 2016
accepted
May 9, 2016

DOI http://dx.doi.org/10.1055/s-0036-1584575.
ISSN 1538-8506.

The success of revision total knee arthroplasty (RTKA) depends on several allied factors, including mode of arthroplasty failure,[1] surgical technique and technical preparation, and patient-related issues. The burden of failed joint arthroplasty is significant.[2,3] Patient-related factors include soft tissue and bony deficits, neuromuscular status, socioeconomic factors such as support network and smoking status, and the number and severity of medical comorbidities.[4]

Perioperative optimization of the host remains a critical component of successful outcomes after primary and revision arthroplasty.[5,6] However, unlike most cases of elective primary TKA for which there is normally no clinical urgency to proceed with surgical intervention, in some cases in the setting of periprosthetic infection, periprosthetic or bearing fracture, or marked osteolysis with concern of an impending fracture, RTKA may be associated with clinical urgency and less opportunity for preoperative optimization. Malnutrition represents an increasingly important risk factor for poor outcomes after general and cardiac surgery[7–13] as well as orthopedic surgery,[14–21] including joint arthroplasty.[22–27] This has been demonstrated previously in work by our group[28,29] in the primary arthroplasty setting. The role of adequate nutrition and metabolic reserves in the revision arthroplasty setting, with more complex surgery and challenged hosts, may prove especially important. Malnutrition may have detrimental effects not only on surgical healing, but also on the risk of early and late infection.[30]

Understanding the effects of malnutrition on perioperative complications and postoperative outcomes has important consequences. These include choosing appropriate candidates for surgical intervention, timing of surgery around host optimization, resource allocation, and counseling patients on the risks of surgery. Our present work examined a large national inpatient administrative dataset to study the relationship between serum albumin level and key outcome measures. The study included only RTKA patients to more closely define the risks in this revision knee subset. Our hypothesis was that lower serum albumin would be an independent risk factor for poor outcomes after RTKA.

Methods

We retrospectively analyzed 4,551 patients from the American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) database from 2006 to 2014. The ACS-NSQIP, a national, prospective, multicenter, validated, risk-adjusted surgical registry, aims to measure and improve surgical outcomes.[31] Our analysis of this observational dataset study was exempt by the institutional review board protocol. The cohort included patients with the principal procedure Current Procedural Terminology (CPT) code for revision total knee arthroplasty: 27486, 27487, and 27488. There were a total of 10,003 retrieved NSQIP entries, with 4,981 entries with available albumin values. The study exclusion criteria were American Society of Anesthesiologists (ASA) Class 4 (252 entries) and Class 5 (2 entry), "Emergency" admission status (110 entries), and bilateral surgery (66 entries). The final study cohort included 4,551 patients. Patients were divided into two subgroups: those with preoperative serum albumin $\geq$ 3.5 g/dL (normal albumin group) and those patients with a serum albumin $<$ 3.5 g/dL (low albumin/ hypoalbuminemic group).

In addition to mortality, we analyzed data on 21 complications reported in the NSQIP database: superficial wound infection, deep incisional wound infection, organ space surgical site infection, surgical wound disruption, pneumonia, unplanned intubation, pulmonary embolism, on ventilator $>$ 48 hours, progressive renal insufficiency, acute renal failure, urinary tract infection, stroke/cerebrovascular accident (CVA), coma $>$ 24 hours, peripheral nerve injury, cardiac arrest requiring cardiopulmonary resuscitation (CPR), myocardial infarction, bleeding transfusion, prosthesis failure, deep vein thrombosis, sepsis, and septic shock. This analysis is by the similar methodology as presented in prior work.[28,29]

Six composite complication variables were developed to represent risk of any infections (including superficial wound infection, deep incisional wound infection, organ space surgical site infection, surgical wound disruption, pneumonia, urinary tract infection, sepsis, and septic shock); cardiac/pulmonary complications (including unplanned intubation, pulmonary embolism, on ventilator $>$ 48 hours, cardiac arrest requiring CPR, and myocardial infarction); and any major complications (including unplanned intubation, pulmonary embolism, on ventilator $>$ 48 hours, progressive renal insufficiency, acute renal failure, stroke/CVA, coma $>$ 24 hours, cardiac arrest requiring CPR, myocardial infarction, sepsis, and septic shock).

Patient demographic information was analyzed (►**Table 1**). The mean age was statistically higher in the hypoalbuminemic group. The hospital length of stay was statistically longer in the hypoalbuminemic group. The groups were otherwise similar for gender and race.

Table 1 Patient demographic information summary by different groups (N = 4,551)

	Albumin ≥ 3.5	**Albumin < 3.5**	***p*-Value**
Total subjects (N)	3,838	713	
Age (y)	65.1 ± 10.8	68.1 ± 11.8	<0.001
Gender			
Male	1,570 (40.9)	309 (43.4)	0.048
Female	2,265 (59.1)	403 (56.6)	
Race			
White	2,954 (77.0)	547 (76.8)	0.873
Black	414 (10.8)	74 (10.4)	
Hispanic	197 (5.1)	35 (4.9)	
Others	99 (2.6)	16 (2.2)	
LOS (d)	3.6 ± 3.0	7.1 ± 7.5	<0.001

Abbreviation: LOS, length of stay.
Note: Data are presented as mean ± SD or N (%).

There were several statistically significant differences in the prevalence of preexisting comorbidities among study groups (►**Table 2**). The group with low albumin had a higher prevalence of nearly all comorbidity variables, including ASA class, Charlson comorbidity index (CCI) score, functional health status prior to surgery, congestive heart failure within 30 days of surgery, coronary artery disease, peripheral vascular disease, hypertension requiring medication, dyspnea, end-stage liver disease, diabetes mellitus, central nervous system disease, disseminated cancer/chemotherapy/radiotherapy, and bleeding disorders. Moreover, nearly 6% of patients in the low albumin group had undergone an operation within 30 days of the revision procedure (also statistically significant when compared with the rate in group with normal albumin).

Statistical Analysis

All data analyses were executed in STATA 12.1 statistical software (StataCorp LP, College Station, TX). Continuous variables were analyzed via Student *t*-test, and categorical variables were analyzed with Fisher exact test and chi-square test. For each complication, multivariate logistic regression analysis was used to evaluate association with hypoalbuminemia, while compensating for potential confounding by

Table 2 Prevalence of comorbidities among patients in the different groups ($N = 4{,}551$)

	Albumin $\geq$ 3.5	Albumin $<$ 3.5	*p*-Value
	N (%)	*N* (%)	
Total subjects (*N*)	3,838	713	
ASA			
1	32 (0.834)	4 (0.562)	<0.001
2	1,552 (40.47)	134 (18.82)	
3	2,246 (58.57)	575 (80.76)	
Charlson comorbidity index			
0	2,825 (73.66)	444 (62.36)	<0.001
1	197 (5.137)	53 (7.444)	
2	738 (19.24)	175 (24.58)	
≥3	78 (2.034)	41 (5.758)	
Functional health status prior to surgery			
Partially dependent	137 (3.572)	96 (13.48)	<0.001
Dependent	1 (0.026)	11 (1.545)	
CHF in 30 d before surgery	13 (0.339)	15 (2.107)	<0.001
Coronary artery disease	100 (2.608)	36 (5.056)	0.0379
Peripheral vascular disease	3 (0.078)	6 (0.843)	0.0004
Hypertension requiring medication	2,585 (67.41)	517 (72.61)	0.0066
Dyspnea			
Moderate exertion	291 (7.588)	67 (9.41)	<0.001
At rest	7 (0.183)	4 (0.562)	
History of severe COPD	210 (5.476)	45 (6.32)	0.3707
End-stage liver disease	0 (0)	2 (0.281)	0.001
Renal failure	9 (0.235)	5 (0.702)	0.0388
Diabetes mellitus with oral agents or insulin			
Oral/noninsulin	545 (14.21)	91 (12.78)	<0.001
Insulin	243 (6.336)	105 (14.75)	
Central nervous system disease	51 (1.33)	21 (2.949)	0.0398
Spinal cord injury	6 (0.157)	3 (0.421)	0.3082
Disseminated cancer, chemotherapy/radiotherapy	11 (0.287)	10 (1.405)	0.0001
Bleeding disorders	161 (4.198)	89 (12.5)	<0.001
Prior operation within 30 d	16 (0.417)	29 (4.073)	<0.001

Abbreviations: ASA, American Society of Anesthesiologists; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease.

preexisting comorbidities and other patient factors. The independent variables included patient age, sex, race, ASA classification, year of surgery, and CCI score. Adjusted odds ratio, 95% confidence intervals, and *p*-values were reported. Each regression model was evaluated with the C statistic for model adequacy.

Results

Low Serum Albumin and Postoperative Complications

Patients in the low serum albumin group were statistically more likely to develop deep surgical site infection, organ space surgical site infection, pneumonia, urinary traction infection, and sepsis (►**Table 3**). The hypoalbuminemic group was more likely to require unplanned intubation, remain on a ventilator >48 hours, and develop acute renal failure; there was a higher risk of mortality and coma. Patients in the low serum albumin group were also more likely to require blood transfusion either intraoperatively or postoperatively.

Across the three composite complication variables, any complication (with or without transfusion), any major complication, and any infection (systemic, wound) were more prevalent among the patients with low serum albumin (►**Table 3**).

Discussion

Understanding the effects of malnutrition on perioperative complications and postoperative outcomes has important consequences. Our present work examined a large national

Table 3 Incidences of perioperative complications by different TKA groups ($N = 4{,}551$)

Complication	Albumin ≥ 3.5 g/dL	Albumin < 3.5 g/dL	*p*-Value	Multivariable regression		
	N (%)	*N* (%)		Odds ratio	95% CI	*p*-Value
Superficial incisional SSI	27 (0.70)	6 (0.84)	0.69	1.35	0.54–3.36	0.519
Deep incisional SSI	31 (0.81)	12 (1.69)	0.0265	2.30	1.15–4.60	0.019
Organ space SSI	48 (1.25)	29 (4.07)	<0.001	3.79	2.31–6.21	<0.001
Wound disruption	14 (0.37)	5 (0.70)	0.2007	1.46	0.51–4.16	0.480
Pneumonia	20 (0.52)	13 (1.83)	0.0002	2.84	1.37–5.88	0.005
Unplanned intubation	10 (0.26)	8 (1.12)	0.0008	4.11	1.44–11.74	0.008
Pulmonary embolism	16 (0.42)	3 (0.42)	0.9882	0.67	0.15–3.01	0.604
On ventilator > 48 h	7 (0.18)	4 (0.56)	0.0587	2.97	0.68–12.99	0.147
Progressive renal insufficiency	11 (0.29)	5 (0.70)	0.0859	2.03	0.67–6.12	0.208
Acute renal failure	3 (0.08)	7 (0.98)	<0.001	7.89	1.90–32.71	0.004
Urinary tract infection	29 (0.76)	21 (2.95)	<0.001	3.01	1.66–5.45	<0.001
Stroke/CVA	5 (0.13)	2 (0.28)	0.3473	1.83	0.34–9.84	0.483
Coma > 24 h	0 (0)	0 (0)				
Peripheral nerve injury	2 (0.05)	0 (0)	0.5355	1.00		
Cardiac Arrest Requiring CPR	2 (0.05)	4 (0.56)	0.0006	5.28	0.90–30.98	0.065
Myocardial infarction	6 (0.16)	2 (0.28)	0.4674	1.87	0.35–9.84	0.461
Transfusions/intra-op/post-op	582 (15.18)	224 (31.46)	<0.001	2.34	1.93–2.83	<0.001
Graft/prosthesis/flap failure	1 (0.03)	0 (0)	0.6614	1.00		
DVT requiring therapy	42 (1.10)	14 (1.97)	0.0532	1.69	0.86–3.31	0.125
Sepsis	41 (1.07)	43 (6.04)	<0.001	5.30	3.31–8.50	<0.001
Septic shock	7 (0.18)	5 (0.70)	0.0131	3.73	1.11–12.55	0.034
Mortality	5 (0.13)	13 (1.83)	<0.001	9.81	3.38–28.49	<0.001
Any complication	1,740 (45.37)	427 (59.97)	<0.001	2.74	2.21–3.39	<0.001
Any complication w/o transfusion	1,316 (34.32)	295 (41.43)	0.0003	2.40	1.86–3.08	<0.001
Major complication	1,203 (31.37)	236 (33.15)	0.3548	2.18	1.50–3.17	<0.001
Systemic infection	188 (4.90)	115 (16.15)	<0.001	3.53	2.72–4.59	<0.001
Wound infection	115 (3.00)	49 (6.88)	<0.001	2.57	1.79–3.69	<0.001
Cardiac pulmonary complication	31 (0.81)	16 (2.25)	0.0005	2.49	1.28–4.85	0.007

Abbreviations: CPR, cardiopulmonary resuscitation; CVA, cerebrovascular accident; DVT, deep vein thrombosis; SSI, surgical site infection.

inpatient administrative dataset to study the relationship between serum albumin level and key outcome measures related to RTKA. Our hypothesis that lower serum albumin would be an independent risk factor for poor outcomes after RTKA was confirmed.

Our group has demonstrated that low serum albumin may be associated with increased incidence of perioperative complications after primary TKA.[29] Other retrospective[6] and prospective[24] studies of TKA has demonstrated a link between malnutrition and risk of postoperative infection. A retrospective review of 17,960 patients undergoing total hip arthroplasty and TKA correlated low serum albumin with risk of periprosthetic joint infection.[23] One prospective study of primary and revision joint arthroplasty procedures found no link between poor nutrition and prosthetic joint infection.[26]

The potential link between malnutrition and poor postoperative outcomes has been understudied when specifically looking at RTKA. With respect to revision joint arthroplasty, Yi et al conducted a single-center, retrospective analysis of revision hip and knee arthroplasty procedures.[30] Including complications within 90 days of surgery, the authors found that a relationship exists between low albumin and septic failure in revision total joint arthroplasty. A follow-up study[32] by the same group queried the NSQIP database and identified 4,517 patients who had undergone either a revision hip or revision knee procedure. There were 2,045 RTKA procedures for aseptic indications and 273 RTKA procedures for septic indications. The authors found that patients undergoing revision for a septic indication had over a threefold higher rate of hypoalbuminemia (<3.5 g/dL) than patients undergoing revision for an aseptic indication ($p < 0.001$). Of the 3,802 patients who underwent revision TKA for an aseptic indication, patients with hypoalbuminemia had a twofold higher rate of early periprosthetic joint infection (within 30 days of surgery) after the revision than patients with normal serum albumin levels ($p < 0.005$). Our present study sought to separate out the two major types of surgeries (revision knee and revision hip procedures) to reduce heterogeneity among patient and surgical procedural populations. In contrast, our study included 4,551 RTKA procedures over a 9-year period. With a larger sample size, our work did confirm the same finding that hypoalbuminemia adversely affects complications related to aseptic and septic causes.

From this present study, it must be emphasized that with more complex surgery, the influence of low serum albumin appears greater. Moreover, there exist a higher number of patients who have had prior surgery within 30 days, and the importance of host optimization is important in this patient subset. Albumin levels suggestive of malnutrition are common among RTKA patients. Laboratory values associated with malnutrition may be affected by several conditions, including stress, trauma, major surgery, and acute and chronic comorbidities (e.g., diabetes).[8,33] These may all effect a state of relative immunocompetance.[34] This may be compounded by a diet that is lacking essential nutrients or that is insufficient in calories.[35] The role of obesity and accordant malnutrition state[36,37] is a related field requiring further elucidation, especially with respect to complications after joint replacement.[28,29]

Our study has several limitations. First, the study is a retrospective analysis of the NSQIP prospective data collection. The observational study design challenges our ability to determine the causality and direction of the relationship between hypoalbuminemia and certain complications such as infection. There also remain inherent limitations of any database, including recording and coding errors. Second, the influence of individual hospital and surgeon quality, case-mix complexity, and experience on the outcomes after RTKA is unknown, given the NSQIP confidentiality parameters. Third, the reader must be aware that the NSQIP records complications out to 30 days postoperatively, which limits our ability to determine the effect of low albumin on complications that would occur later.

Another limitation is that serum albumin levels were not available for all patients in the NSQIP database (albumin is not a required factor); patients without albumin data were considered as missing data in the analysis. Albumin values were present in 49.8% of all RTKA patients (4,981 of 10,003 entries). The presence or absence of obtained serum albumin data is more likely related to specific institutional protocols related to preoperative testing rather than specific provider suspicion of preoperative malnutrition. It is also likely that more providers collect albumin data routinely now than in the past; this is supported by our analysis where when we looked at data from 2006 to 2012, 49.1% had albumin data, data from 2013 subjects contained 48.4% albumin data, and data from 2014 patients included 50.4% albumin data. Given the systematic findings with respect to missing albumin data, we believe this is a random sampling limitation, rather than a bias related to sampling error. The proportion of available albumin data should have a limited effect on our conclusions and may actually underestimate the association between low serum albumin and an increase in perioperative complications that was demonstrated in this study. The percentage of patients with low serum albumin in our study (16.1%) is similar to that observed in other arthroplasty studies. Therefore, we believe this represents a random sampling rather than sampling error.

Strengths of this study include the use of a large, national, validated, prospectively collected dataset incorporating multiple practice settings (community, academic) in a contemporary cohort (up to 2013) of patients undergoing RTKA. The large cohort allows the ability to control for multiple covariates and more rare events. In future study, it is important to further explore, elucidate, and establish potential links between malnutrition and adverse outcomes after revision total joint arthroplasty. This may be best done through a multicenter, prospective study format, with standardized protocols for malnutrition screening and subsequent correction. This prospective study should analyze whether correcting malnutrition preoperatively reduces the risk of complications after RTKA. Orthopedic surgical management should be informed by comanagement pre- and postoperatively and involved experts in nutrition, endocrinology, metabolic disease, internal medicine, gastroenterology, bariatric and weight management, psychology, rheumatology, and those treating chronic inflammatory disorders.

Malnutrition needs further definition in orthopedic populations. While serum albumin may be critiqued as a marker of nutritional status, low albumin has been used in the surgical and orthopedic literature as a surrogate for inadequate nutritional status.[14,38–40] The availability of a standardized measure of albumin in large administrative datasets such as the NSQIP demonstrates an association between multiple major perioperative complications and low serum albumin. Future study in large patient cohorts with other parameters, such as total lymphocyte count, transferrin, and anthropometric measurements, may offer additional insights. The cutoff for low serum albumin (i.e., 3.5 g/dL) set in 1996[41,42] may also need to be reexamined with respect to the risks of perioperative complications in the revision setting. A more stringent threshold may need to be considered when evaluating patients for RTKA in comparison to primary joint arthroplasty. There may also be an age-dependent association that may need to be examined further.[43,44]

In summary, understanding the effects of malnutrition on perioperative complications and postoperative outcomes has important consequences. These include choosing appropriate candidates for surgical intervention, timing of surgery around host optimization, resource allocation, and counseling patients on the risks of surgery. The role of adequate nutrition and metabolic reserves in the revision arthroplasty setting, with more complex surgery and challenged hosts, may prove especially important. Our study suggests that hypoalbuminemia, a widely used marker for malnutrition, is independently associated with an increased risk of aseptic and septic complications after RTKA. The identification and correction of malnutrition before surgery may influence patient-related risk of complications after RTKA, and additional work is required to determine whether hypoalbuminemia is a modifiable risk factor with respect to reducing perioperative complications after RTKA. However, it is important to understand that not all cases of RTKA are elective, and in some circumstances, particularly in the setting of periprosthetic or bearing fracture, periprosthetic infection or impending fracture from massive osteolysis urgent revision may be indicated preventing patient optimization. In the constraints of accountable care models, in which the ability to accurately identify high-risk patients is of paramount importance for healthcare providers, there should be a role for delaying elective surgery to correct malnutrition and to optimize the patient prior to joint arthroplasty. In the absence of emergent surgery, the treating physician should take even greater care to attempt to correct malnutrition in the revision setting.

References

1 Mulhall KJ, Ghomrawi HM, Scully S, Callaghan JJ, Saleh KJ. Current etiologies and modes of failure in total knee arthroplasty revision. Clin Orthop Relat Res 2006;446(446):45–50

2 Kamath AF, Ong KL, Lau E, et al. Quantifying the burden of revision total joint arthroplasty for periprosthetic infection. J Arthroplasty 2015;30(9):1492–1497

3 Bozic KJ, Kurtz SM, Lau E, et al. The epidemiology of revision total knee arthroplasty in the United States. Clin Orthop Relat Res 2010; 468(1):45–51

4 Everhart JS, Altneu E, Calhoun JH. Medical comorbidities are independent preoperative risk factors for surgical infection after total joint arthroplasty. Clin Orthop Relat Res 2013;471(10): 3112–3119

5 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): 775–782

6 Peersman G, Laskin R, Davis J, Peterson M. Infection in total knee replacement: a retrospective review of 6489 total knee replacements. Clin Orthop Relat Res 2001;(392):15–23

7 Hennessey DB, Burke JP, Ni-Dhonochu T, Shields C, Winter DC, Mealy K. Preoperative hypoalbuminemia is an independent risk factor for the development of surgical site infection following gastrointestinal surgery: a multi-institutional study. Ann Surg 2010;252(2):325–329

8 Nakamura K, Moriyama Y, Kariyazono H, et al. Influence of preoperative nutritional state on inflammatory response after surgery. Nutrition 1999;15(11–12):834–841

9 Hill GL, Blackett RL, Pickford I, et al. Malnutrition in surgical patients. An unrecognised problem. Lancet 1977;1(8013):689–692

10 Bistrian BR, Blackburn GL, Hallowell E, Heddle R. Protein status of general surgical patients. JAMA 1974;230(6):858–860

11 Mullen JL, Gertner MH, Buzby GP, Goodhart GL, Rosato EF. Implications of malnutrition in the surgical patient. Arch Surg 1979; 114(2):121–125

12 Ho JW, Wu AH, Lee MW, et al. Malnutrition risk predicts surgical outcomes in patients undergoing gastrointestinal operations: results of a prospective study. Clin Nutr 2015;34(4):679–684

13 Yu PJ, Cassiere HA, Dellis SL, Manetta F, Kohn N, Hartman AR. Impact of preoperative prealbumin on outcomes after cardiac surgery. JPEN J Parenter Enteral Nutr 2015;39(7):870–874

14 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

15 Jensen JE, Jensen TG, Smith TK, Johnston DA, Dudrick SJ. Nutrition in orthopaedic surgery. J Bone Joint Surg Am 1982;64(9):1263–1272

16 Pratt WB, Veitch JM, McRoberts RL. Nutritional status of orthopedic patients with surgical complications. Clin Orthop Relat Res 1981;(155):81–84

17 Deren ME, Huleatt J, Winkler MF, Rubin LE, Salzler J, Behrens SB. Assessment and treatment of malnutrition in orthopaedic surgery. JBJS Reviews 2014;2(9):e1

18 Adogwa O, Martin JR, Huang K, et al. Preoperative serum albumin level as a predictor of postoperative complication after spine fusion. Spine 2014;39(18):1513–1519

19 Patterson BM, Cornell CN, Carbone B, Levine B, Chapman D. Protein depletion and metabolic stress in elderly patients who have a fracture of the hip. J Bone Joint Surg Am 1992;74(2):251–260

20 Koval KJ, Maurer SG, Su ET, Aharonoff GB, Zuckerman JD. The effects of nutritional status on outcome after hip fracture. J Orthop Trauma 1999;13(3):164–169

21 Dickhaut SC, DeLee JC, Page CP. Nutritional status: importance in predicting wound-healing after amputation. J Bone Joint Surg Am 1984;66(1):71–75

22 Jaberi FM, Parvizi J, Haytmanek CT, Joshi A, Purtill J. Procrastination of wound drainage and malnutrition affect the outcome of joint arthroplasty. Clin Orthop Relat Res 2008;466(6):1368–1371

23 Mraovic B, Suh D, Jacovides C, Parvizi J. Perioperative hyperglycemia and postoperative infection after lower limb arthroplasty. J Diabetes Sci Technol 2011;5(2):412–418

24 Font-Vizcarra L, Lozano L, Ríos J, Forga MT, Soriano A. Preoperative nutritional status and post-operative infection in total knee replacements: a prospective study of 213 patients. Int J Artif Organs 2011;34(9):876–881

25 Greene KA, Wilde AH, Stulberg BN. Preoperative nutritional status of total joint patients. Relationship to postoperative wound complications. J Arthroplasty 1991;6(4):321–325

26 Huang R, Greenky M, Kerr GJ, Austin MS, Parvizi J. The effect of malnutrition on patients undergoing elective joint arthroplasty. J Arthroplasty 2013;28(8, Suppl):21–24

27 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

28 Walls JD, Abraham D, Nelson CL, Kamath AF, Elkassabany NM, Liu J. Hypoalbuminemia more than morbid obesity is an independent predictor of complications after total hip arthroplasty. J Arthroplasty 2015;30(12):2290–2295

29 Nelson CL, Elkassabany NM, Kamath AF, Liu J. Low albumin levels, more than morbid obesity, are associated with complications after TKA. Clin Orthop Relat Res 2015;473(10):3163–3172

30 Yi PH, Frank RM, Vann E, Sonn KA, Moric M, Della Valle CJ. Is potential malnutrition associated with septic failure and acute infection after revision total joint arthroplasty? Clin Orthop Relat Res 2015;473(1):175–182

31 American College of Surgeons National Surgical Quality Improvement Program. User guide for the participant use data file. Available online at: http://www.acsnsqip.org. Accessed December 1, 2015

32 Bohl DD, Shen MR, Kayupov E, Cvetanovich GL, Della Valle CJ. Is hypoalbuminemia associated with septic failure and acute infection after revision total joint arthroplasty? A study of 4517 patients from the National Surgical Quality Improvement Program. J Arthroplasty 2016;31(5):963–967

33 White JV, Guenter P, Jensen G, Malone A, Schofield M; Academy of Nutrition and Dietetics Malnutrition Work Group; A.S.P.E.N. Malnutrition Task Force; A.S.P.E.N. Board of Directors. 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

34 WorldHealthOrganization. WHO, nutrition experts take action on malnutrition. Available at: http://www.who.int/nutrition/pressnote_action_on_malnutrition/en/. Accessed April 1, 2016

35 Fuhrman MP. The albumin-nutrition connection: separating myth from fact. Nutrition 2002;18(2):199–200

36 Kaidar-Person O, Person B, Szomstein S, Rosenthal RJ. Nutritional deficiencies in morbidly obese patients: a new form of malnutrition? Part A: vitamins. Obes Surg 2008;18(7):870–876

37 Kaidar-Person O, Person B, Szomstein S, Rosenthal RJ. Nutritional deficiencies in morbidly obese patients: a new form of malnutrition? Part B: minerals. Obes Surg 2008;18(8):1028–1034

38 Vanek VW. The use of serumalbumin as a prognostic or nutritional marker and the pros and cons of IV albumin therapy. Nutr Clin Pract 1998;13(3):110–122

39 Seres DS. Surrogate nutrition markers, malnutrition, and adequacy of nutrition support. Nutr Clin Pract 2005;20(3):308–313

40 Kudsk KA, Tolley EA, DeWitt RC, et al. Preoperative albumin and surgical site identify surgical risk for major postoperative complications. JPEN J Parenter Enteral Nutr 2003;27(1):1–9

41 Shenkin A, Cederblad G, Elia M, Isaksson B. International Federation of Clinical Chemistry. Laboratory assessment of protein-energy status. Clin Chim Acta 1996;253(1–2):S5–S59

42 Dati F, Schumann G, Thomas L, et al; International Federation of Clinical Chemistry. Community Bureau of Reference of the Commission of the European Communities. College of American Pathologists. Consensus of a group of professional societies and diagnostic companies on guidelines for interim reference ranges for 14 proteins in serum based on the standardization against the IFCC/BCR/CAP Reference Material (CRM 470). Eur J Clin Chem Clin Biochem 1996;34(6):517–520

43 Hickson M. Malnutrition and ageing. Postgrad Med J 2006;82(963):2–8

44 Lesourd B, Mazari L. Nutrition and immunity in the elderly. Proc Nutr Soc 1999;58(3):685–695