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Clinical Study

Serum albumin levels predict which patients are at increased risk for complications following surgical management of acute osteoporotic vertebral compression fractures

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Abstract

BACKGROUND: Osteoporotic vertebral compression fractures (OVCF) account for a substantial portion of the US healthcare financial burden. With a growing elderly population, the number of fractures contributing to sagittal imbalance is expected to increase. For those patients undergoing surgery, preoperative markers, such as albumin, may help to predict the occurrence of postoperative complications.

PURPOSE: To evaluate the association between preoperative serum albumin levels and the incidence of postoperative complications, mortality, and 30-day readmissions following surgical intervention for OVCF.

STUDY DESIGN: Retrospective study.

PATIENT SAMPLE: Patient data were obtained from the American College of Surgeons National Surgery Quality Improvement Project (ACS-NSIP) database between the years 2007 and 2014.

OUTCOME MEASURES: No outcome measures related to self-reporting, physiology, or functionality were evaluated in this study. Primary outcome measures analyzed included various postoperative complications, patient mortality, and 30-day readmission.

METHODS: A retrospective analysis of the American College of Surgeons National Surgery Quality Improvement Project (ACS-NSQIP) database between 2007 and 2014 was performed, identifying 1,979 patients who met inclusion criteria. Patients were subcategorized into three groups based on preoperative nutritional status as defined by albumin levels. Outcome measures for this study included minor postoperative complication(s), major postoperative complication(s), patient mortality, 30-day readmission due to any cause, 30-day readmission related to OVCF, and total length of hospital stay. Analysis of variance was used to evaluate for associations between continuous variables and preoperative albumin levels. Spearman's rank correlation coefficient, chi-square trend, and Kruskal-Wallis analyses were utilized, as appropriate, for categorical variables. A multivariate logistic regression analysis was then conducted to calculate odds ratios with corresponding p values and 95% confidence intervals.

RESULTS: Functional status showed a statistically significant decline when correlated with preoperative albumin levels. Sepsis, septic shock, pulmonary embolism, reintubation, prolonged

FDA device/drug status: Not applicable.

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This study is exempt from IRB approval as it utilizes data from the deidentified American College of Surgeons National Surgery Quality Improvement Project (ACS-NSQIP) database.

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intubation, and major complications in general are statistically more likely to occur in patients with hypoalbuminemia. Among minor complications evaluated in this study, only surgical site complications failed to demonstrate a statistical correlation with nutritional status. No statistically significant associations were identified between postoperative outcomes and age, sex, or BMI.
CONCLUSIONS: Preoperative albumin levels were statistically correlated to the likelihood of minor complications, major complications, or mortality.

Keywords: Adverse outcomes; Albumin; Mortality; NSQIP; Osteoporosis; Surgical complications; 30-day readmission; Vertebral compression fracture

Introduction

Osteoporosis is a common disease affecting millions of people around the globe. In the United States alone, two million osteoporotic fractures are reported to occur annually, leading to hospitalizations in over 500,000 elderly patients [1], nearly half of whom will require extended care [2]. Osteoporotic fractures place an estimated annual financial burden of $5.1 billion on the United States alone, eclipsing that of myocardial infarction ($4.1 billion), stroke ($3.0 billion), and breast cancer ($0.5 billion) [2]. Of the two million fragility fractures occurring annually, a third are estimated to be osteoporotic vertebral compression fractures (OVCF) [3]. According to Dang et al., 13.8% of patients with an OVCF will endure a subsequent fracture within 3 years [4]. This problem is compounded by the significant association between these fractures and the development of sagittal imbalance [5,6]. With the incidence of OVCFs on the rise [7], information regarding management of affected patients becomes increasingly important.

Treatment of OVCFs can vary. Current options include bracing, medication, percutaneous cement augmentation procedures (such as vertebroplasty or kyphoplasty), and open surgery. While treatment decisions are based on individual clinical factors and influenced by the chronicity of the fracture, recent studies have suggested that cement augmentation and surgical intervention may offer greater pain relief than medical management [8−11]. Before recommending surgery, however, it is imperative to consider how a patient will fare after the procedure.

Malnutrition has been defined as “an acute, subacute, or chronic state of nutrition, in which varying degrees of overnutrition or undernutrition with or without inflammatory activity” that “have led to a change in body composition and diminished function.” [12] Clinicians frequently use prealbumin and albumin as surrogates for nutritional status [13−15]. Hypoalbuminemia, defined as a serum albumin less than 3.5 g/dL, is commonly viewed as a proxy for malnutrition [16]. The ensuing catabolic state has been associated with poorer clinical outcomes and an increased incidence of postoperative complications following a variety of orthopedic surgical procedures, ranging from spinal fusions to hip fractures [17−19]. Klein et al. showed that 42% of spine surgery patients >60 years of age were malnourished before surgery [20]. As the elderly population may be a particularly at-risk group, this study sought to determine whether there is an association between a patient’s nutritional status and the frequency of postoperative complications, mortality, and 30-day readmission rates following surgical treatment for OVCF. We hypothesized that lower albumin levels would be statistically correlated with a higher incidence of complications, mortality, and 30-day readmission.

Methods

A retrospective analysis of the American College of Surgeons National Surgery Quality Improvement Project (ACS-NSQIP) database between 2007 and 2014 was conducted. Since information within this database is de-identified, the study is exempt from institutional review board approval. Using a methodology similar to that of other studies [21−23], patients who sustained an OVCF in the thoracic or lumbar region were identified using Current Procedural Terminology codes and International Classification of Disease (ICD-9 or ICD-10) codes. Patients with ICD-9 codes 733.13, 805.2, and 805.4 were included. In 2014, ACS-NSQIP began to incorporate ICD-10 codes into its database. As a result, patients that had ICD-10 codes M48.56XA, S22.009A, S22.068A, and S22.089A were also included in the study. In addition, to ensure all target patients in the ACS-NSQIP database were captured, patients who had any of the following Current Procedural Terminology codes were included as well: 22510, 22511, 22512, 22513, 22514, or 22515.

Patients lacking preoperative albumin data, those with spinal or central nervous system tumors, and those with an OVCF in the cervical, sacral, or unclassified region of the spine were excluded. Variables to include or exclude in the study were then identified based on available information. If more than 10% of patients were missing data for a given variable, that variable was excluded from the study.

As in prior studies, patients were subcategorized into three groups based on preoperative nutritional status as defined by albumin levels: normal nutritional status (albumin level≥3.5 g/dL), mild malnutrition (albumin level 3.0−3.49 g/dL), and severe malnutrition (albumin level<2.5 g/dL). The following patient characteristics were tabulated: demographics (age, sex, and BMI), functional status before surgery (Table 1), preoperative comorbidities, ASA status (Table 2), postoperative complications, mortality, reoperations, readmissions, and length of hospital stay (Table 3).

Table 1
Patient characteristics

	Albumin>3.5 (N=1,194)	SD or %	Albumin 3.00−3.49 (N=461)	SD or %	Albumin<3.00 (N=324)	SD or %	Total (N=1,979)	SD or %	p Value
Parameter									
Age (y)*	73.23	10.82	75.76	10.68	73.81	10.41	73.92	10.82	.6502
Sex (female)	826	69.2%	294	63.8%	208	64.2%	1328	67.1%	.0527
BMI	26.96	6.22	26.37	5.98	26.45	7.21	26.74	6.45	.2213
Smoking history	157	13.1%	65	14.1%	48	14.8%	270	13.6%	.4267
Steroid use for chronic condition	162	13.6%	68	14.8%	63	19.4%	293	14.8%	.0144
Chronic kidney disease	7	0.6%	10	2.2%	13	4.0%	30	1.5%	<.0001
Mean preoperative albumin	3.99	0.41	3.22	0.14	2.56	0.31	3.58	0.65	<.0001
Functional status before surgery									
Independent	1,049	89.7%	371	81.2%	241	253.7%	1,661	85.3%	<.0001
Partially dependent	119	10.2%	75	16.4%	71	74.7%	265	13.6%	<.0001
Totally dependent	2	0.2%	11	2.4%	9	9.5%	22	1.1%	<.0001
Unknown	24	–	4	–	3	–	31	–	–

Table 2
Patient comorbidities and ASA status

Diagnosis	Albumin>3.5 (N=1,194)	%	Albumin 3.00−3.49 (N=461)	%	Albumin<3.00 (N=324)	%	Total	%	p Value
Comorbidity									
CHF	13	1.1%	22	4.8%	21	6.5%	56	2.8%	<.0001
COPD	160	13.4%	73	15.8%	74	22.8%	307	15.5%	<.0001
Coagulopathy	77	6.4%	55	11.9%	41	12.7%	173	8.7%	<.0001
CVA	8	0.7%	5	1.1%	3	0.9%	16	0.8%	.6113
Diabetes	209	17.5%	93	20.2%	83	25.6%	385	19.5%	.0013
Dialysis	6	0.5%	8	1.7%	12	3.7%	26	1.3%	<.0001
Hypertension	770	64.5%	316	68.5%	231	71.3%	1,317	66.5%	.0131
Ascites	0	0.0%	1	0.2%	2	0.6%	3	0.2%	–
MI<6 mo	0	0.0%	0	0.0%	0	0.0%	0	0.0%	–
Obesity (BMI≥30)	301	25.2%	112	24.3%	84	25.9%	497	25.1%	.9460
Renal failure	1	0.1%	2	0.4%	1	0.3%	4	0.2%	.4058
Smoker (w/in last year)	157	13.1%	65	14.1%	48	14.8%	270	13.6%	.4267
Steroid use for chronic condition	162	13.6%	68	14.8%	63	19.4%	293	14.8%	.0144
Weight loss	25	2.1%	22	4.8%	19	5.9%	66	3.3%	<.0001
ASA status									
ASA class I	8	0.7%	3	0.7%	0	0.0%	11	0.6%	<.0001
ASA class II	296	24.8%	62	13.5%	32	9.9%	390	19.7%	<.0001
ASA class III	785	65.9%	304	66.1%	208	64.2%	1,297	65.6%	<.0001
ASA class IV	102	8.6%	89	19.3%	83	25.6%	274	13.9%	<.0001
ASA class V	1	0.1%	2	0.4%	1	0.3%	4	0.2%	<.0001
None listed	2	–	1	–	0	–	3	–	–

Primary outcome measures for this study include minor postoperative complication(s), major postoperative complication(s), patient mortality, 30-day readmission due to any cause, 30-day readmission related to OVCF, and total length of hospital stay. Using definitions from the study by Chung et al. [23], the following were considered minor postoperative complications: deep vein thrombosis, pneumonia, urinary tract infection, or surgical site complication. Major postoperative complications included acute myocardial infarction, cardiac arrest, sepsis, septic shock, stroke, pulmonary embolism, acute renal failure, coma >24 hours, or reintubation.

Statistical analysis

Analysis of variance was used to evaluate for associations between continuous variables and preoperative albumin levels.

Table 3
Major and minor complication rates

Diagnosis	Albumin>3.5 (N=1,194)	SD or %	Albumin 3.00−3.49 (N=461)	SD or %	Albumin<3.00 (N=324)	SD or %	Total	SD or %	p Value
Mortality	28	2.3%	31	6.7%	32	9.9%	91	4.6%	<.0001
Reoperations	43	3.6%	20	4.3%	20	6.2%	83	4.2%	.0446
Readmissions	148	12.7%	58	13.1%	53	16.4%	259	13.1%	.1063
Readmission related to VCF	91	7.8%	40	9.0%	38	11.7%	169	8.5%	.0273
Mean length of hospital admission	4.25	16.02	7.70	10.37	9.63	9.26	5.93	13.89	<.0001
Major complications									
Acute MI	4	0.3%	2	0.4%	1	0.3%	7	0.4%	.8327
Cardiac arrest	4	0.3%	4	0.9%	2	0.6%	10	0.5%	.4275
Sepsis	14	1.2%	11	2.4%	13	4.0%	38	1.9%	.0010
Septic shock	4	0.3%	6	1.3%	8	2.5%	18	0.9%	.0004
Stroke	5	0.4%	4	0.9%	1	0.3%	10	0.5%	.9653
Pulmonary embolism	5	0.4%	4	0.9%	7	2.2%	16	0.8%	.0047
Acute renal failure	3	0.3%	0	0.0%	2	0.6%	5	0.3%	.6799
Coma>24 h	0	0.0%	1	0.2%	0	0.0%	1	0.1%	.9362
Reintubation	9	0.8%	13	2.8%	9	2.8%	31	1.6%	.0017
Prolonged intubation (>7 d)	5	0.4%	6	1.3%	6	1.9%	17	0.9%	.0104
Overall	36	3.0%	32	6.9%	33	10.2%	101	5.1%	<.0001
Minor complications									
DVT	12	1.0%	11	2.4%	8	2.5%	31	1.6%	.0292
Pneumonia	24	2.0%	24	5.2%	16	4.9%	64	3.2%	.0009
Urinary tract infection	24	2.0%	19	4.1%	20	6.2%	63	3.2%	<.0001
Surgical site complication	19	1.6%	13	2.8%	7	2.2%	39	2.0%	.3214
Overall	74	6.2%	52	11.3%	17	5.2%	143	7.2%	.5387

Spearman's rank correlation coefficient, chi-square trend, and Kruskal-Wallis analyses were utilized, as appropriate, for categorical variables.

A multivariate logistic regression analysis was conducted to calculate odds ratios with corresponding p values and 95% confidence intervals. Outcomes analyzed included minor complications, major complications, mortality, 30-day readmissions for any cause, and 30-day readmissions related specifically to OVCF. To determine which variables to utilize for this analysis, several bivariate analyses were first completed. Those that generated p values less than .05 were included in the multivariate analysis. Any variable for which fewer than five incidences occurred within the patient dataset was excluded.

Results

A total of 1,979 patients met inclusion and exclusion criteria. Of these, 1,194 had normal nutritional status, 461 were mildly malnourished, and 324 were severely malnourished. With the exception of BMI (31 patients with missing data), functional status (31 patients with missing data), and ASA status (3 patients with unknown ASA status), all variables studied had a 100% response rate among the 1,979 patients in the study, yielding a total of 1,914 patients. Table 1 shows that the demographic characteristics across the three subcategories were similar, that is, no statistically significant differences between these groups were evident with regards to age, sex, and BMI. However, as expected, functional status diminished significantly ($p<.0001$) as nutritional status declined; steroid use for chronic conditions and chronic kidney disease were also statistically correlated to preoperative albumin levels.

As Table 2 illustrates, patients with increasingly severe hypoalbuminemia were statistically more likely to have a history of congestive heart failure, chronic obstructive pulmonary disease, coagulopathy, diabetes, dialysis, hypertension, steroid use, weight loss of greater than 10% in the last 6 months, and a poorer ASA status (each with $p<.05$).

Table 3 shows that mortality, readmissions related to OVCF, and hospital stay all had strong correlations with preoperative albumin levels. Sepsis, septic shock, pulmonary embolism, reintubation, prolonged intubation, and major complications in general are statistically more likely to occur in patients with hypoalbuminemia. Among minor complications, all but surgical site complications demonstrated a statistical correlation with nutritional status.

Fig. 1 presents data from the multivariate logistic regression analysis. This analysis isolated the effects of preoperative albumin levels, demographics, functional status, and various comorbidities in order to determine the respective effects of each on postoperative complications, patient mortality, and readmission. Variables with fewer than five incidences, in this case both ascites and renal failure (highlighted in red), were excluded from the multivariate analysis.

Preoperative albumin levels showed a statistically significant association with the development of minor complications, major complications, and mortality. Other factors are

	Minor Complication			Major Complication			Mortality			General Readmissions			VCF-Related Readmissions		
	Odds Ratio	P-Value	95% CI	Odds Ratio	P-Value	95% CI	Odds Ratio	P-Value	95% CI	Odds Ratio	P-Value	95% CI	Odds Ratio	P-Value	95% CI
Albumin Level															
Albumin >= 3.5 (normal nutrition)	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Albumin 3.00-3.49 (mild malnutrition)	1.78	0.004	1.20-2.65	1.94	0.012	1.16-3.27	2.14	0.007	1.23-3.74	0.85	0.347	0.60-1.20	0.96	0.833	0.63-1.44
Albumin < 3.00 (severe malnutrition)	2.18	<0.001	1.44-3.29	2.48	0.001	1.47-4.20	2.96	0.000	1.70-5.15	1.08	0.671	0.75-1.56	1.26	0.283	0.83-1.93
Demographic															
Age	0.98	0.002	0.96-0.99	0.97	0.009	0.95-0.99	1.00	0.768	0.98-1.02	1.02	0.004	1.01-1.03	1.01	0.082	1.00-1.03
Sex (male = 1)	0.90	0.560	0.63-1.29	1.14	0.569	0.73-1.76	1.58	0.050	1.00-2.48	1.41	0.017	1.06-1.87	1.26	0.197	0.89-1.77
Preoperative Functional Status															
Independent	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Partially Dependent	1.58	0.031	1.04-2.42	2.49	<0.001	1.52-4.07	1.70	0.054	0.99-2.91	1.39	0.069	0.97-2.00	1.14	0.554	0.74-1.77
Completely Dependent	2.79	0.048	1.00-7.74	2.95	0.076	0.89-9.73	5.68	0.001	2.04-15.75	0.99	0.991	0.29-3.45	0.41	0.385	0.05-3.10
Comorbidities															
CHF	-	-	-	-	-	-	-	-	-	1.62	0.167	0.82-3.20	-	-	-
COPD	1.36	0.137	0.91-2.04	1.48	0.127	0.89-2.44	1.22	0.480	0.71-2.09	1.57	0.008	1.12-2.20	1.89	0.001	1.28-2.78
Coagulopathy	-	-	-	1.89	0.026	1.08-3.32	-	-	-	-	-	-	1.60	0.058	0.98-2.59
CVA	5.36	0.017	1.35-21.31	4.60	0.046	1.03-20.51	-	-	-	-	-	-	-	-	-
Diabetes	1.36	0.120	0.92-2.00	1.32	0.264	0.81-2.14	-	-	-	-	-	-	-	-	-
Dialysis	1.67	0.352	0.57-4.88	1.93	0.283	0.58-6.38	-	-	-	-	-	-	-	-	-
Hypertension	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ascites		-	-	-	-	-	-	-	-	-	-	-	-	-	-
Obesity	1.26	0.211	0.88-1.82	-	-	-	-	-	-	-	-	-	1.60	0.011	1.11-2.29
Renal Failure	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Smoker	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Steroid Use	-	-	-	1.48	0.133	0.89-2.47	1.81	0.027	1.07-3.05	-	-	-	1.37	0.139	0.90-2.07
Weight Loss	1.40	0.360	0.68-2.89	1.69	0.205	0.77-3.80	1.96	0.106	0.87-4.42	1.70	0.097	0.91-3.19	2.07	0.042	1.03-4.16
ASA Class>2	2.05	0.012	1.17-3.60	1.81	0.125	0.85-3.88	14.65	0.008	2.02-106.43	1.46	0.060	0.98-2.18	1.99	0.016	1.14-3.48

Fig. 1. Multivariate logistic regression analysis for minor complications, major complications, mortality, 30-day readmissions, and 30-day readmissions related to osteoporotic vertebral compression fracture. Variables with statistically significant p values are highlighted in orange.

tabulated as shown with odds ratio, p values, and 95% confidence intervals listed.

Discussion

The Charlson comorbidity index is commonly described in the literature as a metric to assess a patient's general health. Specifically, this metric is a weighted index that attempts to predict the risk of death within 1 year of hospitalization based on particular comorbid conditions [24,25]. While some studies have utilized both the Charlson comorbidity index and preoperative albumin to predict postoperative outcomes [26], others have utilized just albumin to identify strong correlations [27−29]. One study suggested that albumin is able to better predict 30-day mortality upon intensive care unit admission than the Charlson comorbidity index [30]. Due to the ease with which it can be measured through a simple blood draw, preoperative albumin bears strong potential as a practical metric to assess a patient's overall health.

Our data suggest that low preoperative albumin levels can predict the incidence of postoperative complications following surgery for OVCFs. Moreover, the lack of correlation between patient demographics and adverse outcomes depicted in the multivariate analysis implies that postoperative complications are not simply due to older age or gender, but rather are highly associated with nutritional status. Notably, a given patient's chance of experiencing an adverse postoperative outcome is strongly correlated with the degree of his or her hypoalbuminemia. For example, a patient with severe hypoalbuminemia has an odds ratio of 2.18 for minor complications, 2.48 for major complications, and 2.96 for mortality relative to that of healthy patients.

Advanced age by itself does not appear to drastically change the odds of an adverse outcome. Nevertheless, the decreased odds ratios with increasing age for some outcomes may be due to the notion that surgeons are more likely to operate on younger patients rather than older patients. As one study notes, older patients may draw a more conservative approach, and physicians may be more likely to try nonoperative treatment for these patients [31]. Alternatively, this phenomenon might also be explained by the notion that younger patients suffering from an OVCF may be, in general, more frail and therefore more likely to suffer adverse outcomes. Since the prevalence of OVCF increases with age, reaching 40% in women by age 80 [32], one might expect only the most frail patients, who may suffer from other comorbidities such as hypoalbuminemia, to endure an osteoporotic fracture at a young age.

Another noteworthy finding is the role of gender on adverse outcomes. Men who sustained an OVCF in this study had a statistically higher mortality rate than women. Since women on average have a lower bone density than men, at least through the first seven decades of life [33], if a male endures an OVCF, he is likely to be more frail than a woman who develops an OVCF with a similar bone density.

Fig. 1 shows no statistically significant correlation between 30-day readmission rates and preoperative albumin levels. We believe this is due to a limitation of the ACS-NSQIP database since ACS-NSQIP defines a 30-day readmission from the date of surgery and not the date of discharge [34]. Patients with increasingly severe hypoalbuminemia have longer hospital stays, on average, which skews the data. A severely malnourished patient discharged 20 days after surgery only has 10 days to qualify for a 30-day readmission per the ACS-NSQIP database. On the other hand, a patient with normal preoperative albumin levels who is discharged the day after surgery has 29 days to be readmitted in order to qualify as a 30-day readmission. Unfortunately, this inherent error affects our ability to properly assess the relationship between 30-day readmission and preoperative albumin levels.

While the results from this study are promising with respect to their strong statistical significance and applicability to the management of patients suffering from OVCF, there are some limitations. For example, the study utilizes ICD-9 and ICD-10 codes from a large database to identify the appropriate patients without the benefit of actual patient charts. As a result, it is possible that patients may have been improperly included or excluded. Unfortunately, there is no obvious way to correct for this. Another disadvantage of the NSQIP database is its use of the term "null" in the CNS tumor column for several patients. In this study, we assumed that this meant the patient did not have a CNS tumor and therefore should not be excluded. However, the "null" value does not provide the same certitude that "no" provides in marking a patient as CNS tumor-free. Additionally, variables recorded in the ACS-NSQIP database changed from year to year; some variables were added and others removed. While this constraint was carefully tracked and accounted for, it necessitated the exclusion of some variables from our analysis.

Although ACS-NSQIP is a powerful surgical database available to the medical community, for some of the variables included in this study, there was not enough of a sample size to make a statistically significant conclusion. Having an even larger database may have enabled some other statistically significant observations. Furthermore, for purposes of identifying clinically useful data, preoperative albumin was treated as a categorical variable in this study instead of as a continuous variable. This allows physicians to convey mortality and complication rates using odds ratios and is therefore practical. However, from a purely statistical perspective, categorizing a variable reduces its statistical power and increases the standard error (See Figs. 2 and 3 below as an illustration). Fig. 2 depicts the probability of mortality for patients of varying nutritional statuses where preoperative albumin is treated as a categorical variable. Fig. 3, on the other hand, describes a similar relationship but treats preoperative albumin as a continuous variable. Note the size of the error bars and the number of data points.

Based on the findings from this study, clinicians should ideally attempt to optimize patient nutritional status before surgery. Admittedly, however, this may be difficult in some cases, as correcting nutritional status often cannot be done quickly. Furthermore, patients with osteoporotic fractures are frequently in intractable pain and request urgent treatment. One of the other limitations of using a national database is the lack of information relating to the subset of patients that underwent optimization of nutritional status before surgery. In a future study, the outcomes of such a cohort could be compared to patients who did not undergo optimization.

While ACS-NSQIP provides data for postoperative complications that occur within 30 days of surgery, it does not keep track of complications that occur after this time period, which may be of value to study as well. Nonetheless, the data found in this study makes a strong argument in favor of the utilization of preoperative albumin levels to optimize patient care and manage patients with OVCF.

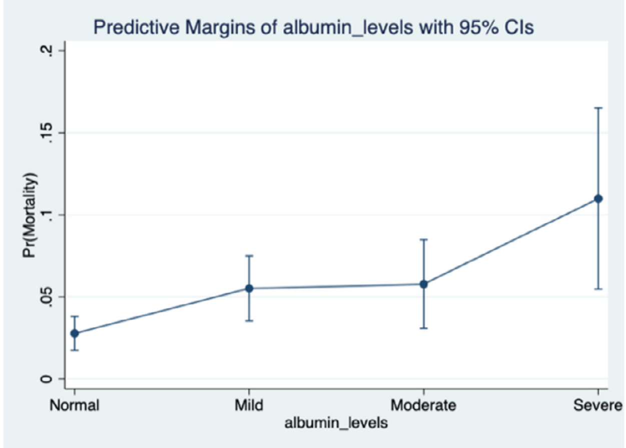

Fig. 2. Probability of mortality vs. nutritional levels with error bars. Albumin is treated as a categorical variable.

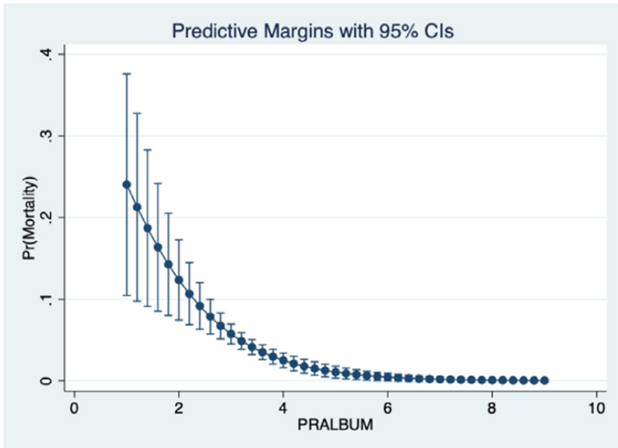

Fig. 3. Probability of mortality vs. nutritional levels with error bars. Albumin is treated as a continuous variable.

Conclusions

Preoperative albumin has the potential to serve as a prognostic indicator of adverse outcomes for patients undergoing surgery for OVCF. We recommend surgeons attempt to optimize patients before surgery in order to avoid a greater likelihood of postoperative complications or mortality. As this study demonstrates, preoperative albumin may serve as a reliable marker for a patient's general well-being and may be considered an indicator of medical frailty. Clinicians can utilize this metric to help convey information to patients regarding the potential for adverse outcomes after surgery for OVCFs.

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References

[1] Wasfie T, Jackson A, Brock C, Galovska S, McCullough JR, Burgess JA. Does a fracture liaison service program minimize recurrent fragility fractures in the elderly with osteoporotic vertebral compression fractures? Am J Surg 2018;217:557–60.

[2] Singer A, Exuzides A, Spangler L, O'Malley C, Colby C, Johnston K, et al. Burden of illness for osteoporotic fractures compared with other serious diseases among postmenopausal women in the United States. Mayo Clin Proc 2015;90:53–62. Epub 2014/12/08.

[3] Lee BG, Choi JH, Kim DY, Choi WR, Lee SG, Kang CN. Risk factors for newly developed osteoporotic vertebral compression fractures following treatment for osteoporotic vertebral compression fractures. Spine J 2018;19:301–5.

[4] Dang DY, Zetumer S, Zhang AL. Recurrent fragility fractures: a cross-sectional analysis. J Am Acad Orthop Surg 2018;27: e85–e91.

[5] Fechtenbaum J, Etcheto A, Kolta S, Feydy A, Roux C, Briot K. Sagittal balance of the spine in patients with osteoporotic vertebral fractures. Osteoporos Int 2016;27:559–67. Epub 2015/08/15.

[6] Zhang YL, Shi LT, Tang PF, Sun ZJ, Wang YH. Correlation analysis of osteoporotic vertebral compression fractures and spinal sagittal imbalance. Orthopade 2017;46:249–55. Epub 2017/01/25.

[7] Li HM, Zhang RJ, Gao H, Jia CY, Zhang JX, Dong FL, et al. New vertebral fractures after osteoporotic vertebral compression fracture between balloon kyphoplasty and nonsurgical treatment PRISMA. Medicine (Baltimore) 2018;97:e12666. Epub 2018/10/07.

[8] Yu WB, Jiang XB, Liang D, Xu WX, Ye LQ, Wang J. Risk factors and score for recollapse of the augmented vertebrae after percutaneous vertebroplasty in osteoporotic vertebral compression fractures. Osteoporos Int 2018;30:423–30.

[9] Shah LM, Jennings JW, Kirsch CFE, Hohenwalter EJ, Beaman FD, Cassidy RC, et al. ACR appropriateness criteria(R) management of vertebral compression fractures. J Am Coll Radiol 2018;15(11s): S347–s64. Epub 2018/11/06.

[10] Yang W, Yang J, Liang M. Percutaneous vertebroplasty does not increase the incidence of new fractures in adjacent and nonadjacent vertebral bodies. Clin Spine Surg 2018;32:E99–E106.

[11] Schupfner R, Stoevelaar HJ, Blattert T, Fagan D, Fransen P, Marcia S, et al. Treatment of osteoporotic vertebral compression fractures: applicability of appropriateness criteria in clinical practice. Pain Physician 2016;19:E113–20. Epub 2016/01/12.

[12] Mueller C, Compher C, Ellen DM. A.S.P.E.N. clinical guidelines: nutrition screening, assessment, and intervention in adults. JPEN J Parenter Enteral Nutr 2011;35:16–24. Epub 2011/01/13.

[13] Yang F, Wei L, Huo X, Ding Y, Zhou X, Liu D. Effects of early postoperative enteral nutrition versus usual care on serum albumin, prealbumin, transferrin, time to first flatus and postoperative hospital stay for patients with colorectal cancer: a systematic review and meta-analysis. Contemp Nurse 2018;54:1–17. Epub 2018/09/05.

[14] Yang J, Zhang Q, Wang X. Role of nutritional support for postoperative recovery of respiratory function in patients with primary lung cancer. Oncol Lett 2018;16:5978–82.

[15] Roche M, Law TY, Kurowicki J, Sodhi N, Rosas S, Elson L, et al. Albumin, prealbumin, and transferrin may be predictive of wound complications following total knee arthroplasty. J Knee Surg 2018;31:946–51. Epub 2018/10/04.

[16] Ryan SP, Politzer C, Green C, Wellman S, Bolognesi M, Seyler T. Albumin versus American Society of Anesthesiologists Score: which is more predictive of complications following total joint arthroplasty? Orthopedics 2018;41:1–9. Epub 2018/10/16.

[17] Adogwa O, Martin JR, Huang K, Verla T, Fatemi P, Thompson P, et al. Preoperative serum albumin level as a predictor of postoperative complication after spine fusion. Spine (Phila Pa 1976) 2014;39:1513–9. Epub 2014/05/31.

[18] Miyanishi K, Jingushi S, Torisu T. Mortality after hip fracture in Japan: the role of nutritional status. J Orthop Surg (Hong Kong) 2010;18:265–70. Epub 2010/12/29.

[19] Lumbers M, New SA, Gibson S, Murphy MC. Nutritional status in elderly female hip fracture patients: comparison with an age-matched home living group attending day centres. Br J Nutr 2001;85:733–40. Epub 2001/06/30.

[20] Klein JD, Hey LA, Yu CS, Klein BB, Coufal FJ, Young EP, et al. Perioperative nutrition and postoperative complications in patients undergoing spinal surgery. Spine (Phila Pa 1976) 1996;21:2676–82. Epub 1996/11/15.

[21] Stone AV, Jinnah A, Wells BJ, Atkinson H, Miller AN, Futrell WM, et al. Nutritional markers may identify patients with greater risk of re-admission after geriatric hip fractures. Int Orthop 2018;42:231–8. Epub 2017/10/11.

[22] Lau E, Ong K, Kurtz S, Schmier J, Edidin A. Mortality following the diagnosis of a vertebral compression fracture in the Medicare population. J Bone Joint Surg Am 2008;90:1479–86. Epub 2008/07/03.

[23] Chung AS, Hustedt JW, Walker R, Jones C, Lowe J, Russell GV. Increasing severity of malnutrition is associated with poorer 30-day outcomes in patients undergoing hip fracture surgery. J Orthop Trauma 2018;32:155–60. Epub 2018/03/21.

[24] Deyo RA, Cherkin DC, Ciol MA. Adapting a clinical comorbidity index for use with ICD-9-CM administrative databases. J Clin Epidemiol 1992;45:613–9. Epub 1992/06/01.

[25] Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis 1987;40:373–83. Epub 1987/01/01.

[26] Piccoli GB, Nielsen L, Gendrot L, Fois A, Cataldo E, Cabiddu G. Prescribing hemodialysis or hemodiafiltration: when one size does not fit all the proposal of a personalized approach based on comorbidity and nutritional status. J Clin Med 2018;7. Epub 2018/10/10.

[27] Sun X, Luo L, Zhao X, Ye P. Controlling nutritional status (CONUT) score as a predictor of all-cause mortality in elderly hypertensive patients: a prospective follow-up study. BMJ Open 2017;7:e015649.

[28] Kwon YE, Kee YK, Yoon CY, Han IM, Han SG, Park KS, et al. Change of nutritional status assessed using subjective global assessment is associated with all-cause mortality in incident dialysis patients. Medicine (Baltimore) 2016;95:e2714.

[29] Kovesdy CP, Shinaberger CS, Kalantar-Zadeh K. Epidemiology of dietary nutrient intake in ESRD. Semin Dial 2010;23:353–8.

[30] Oh TK, Song IA, Lee JH. Clinical usefulness of C-reactive protein to albumin ratio in predicting 30-day mortality in critically ill patients: a retrospective analysis. Sci Rep 2018;8:14977.

[31] Blattert TR, Schnake KJ, Gonschorek O, Gercek E, Hartmann F, Katscher S, et al. Nonsurgical and surgical management of osteoporotic vertebral body fractures: recommendations of the spine section of the German Society for Orthopaedics and Trauma (DGOU). Global Spine J 2018;48:50S–5S.

[32] Old JL, Calvert M. Vertebral compression fractures in the elderly. Am Fam Physician 2004;69:111–6. Epub 2004/01/20.

[33] Singh M, Arora S, Kaur A, Ghildiyal S, Kumar R. Patterns of age- and sex-related variations in bone mineral density of lumbar spine and total femur: a retrospective diagnostic laboratory-based study. J Midlife Health 2018;9:155–61.

[34] Bernatz JT, Tueting JL, Anderson PA. Thirty-day readmission rates in orthopedics: a systematic review and meta-analysis. PLoS One 2015;39:E7.