



Original article

Perioperative nutrition assessment in musculoskeletal trauma patients: Dietitian evaluation is superior to serum chemistries or modified screening questionnaire for risk stratification



Nathan R. Hendrickson^{*}, Natalie Glass, Jocelyn Compton, Brandon G. Wilkinson, J. Lawrence Marsh, Michael C. Willey

Department of Orthopedics and Rehabilitation, University of Iowa Hospitals and Clinics, Iowa City, IA, United States

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SUMMARY

Introduction: Malnutrition is a potentially modifiable risk factor associated with increased hospital charges, major wound complication, and fracture non-union after orthopaedic surgery. The goal of this study was to examine the relationship between three nutrition screening tools and postoperative complications in patients undergoing acute fracture fixation.

Methods: Patients aged 18 or older undergoing acute operative fracture fixation at a Level I academic trauma center were screened upon admission using a malnutrition screening questionnaire (MSQ), and classified as low-, moderate- or high risk. Patients at moderate-to-high risk were assessed for clinical malnutrition by dietitian. Serum albumin, transferrin, total lymphocyte count, and 25(OH) Vitamin D were measured preoperatively. Primary outcome measures included twelve-month postoperative surgical and medical complications obtained by retrospective chart review.

Results: Of 373 patients, 17% were moderate-to-high risk of malnutrition by MSQ. Clinical malnutrition was diagnosed by dietitian in 4.3% of patients assessed. Nearly half of all subjects had deficiency in one or more serum biomarkers. Cost of biomarker assays was \$624 per patient. Medical or surgical complications occurred in 19% of patients. Dietitian diagnosed malnutrition (clinical malnutrition) was the strongest predictor of complication (OR 3.49, $p = 0.017$). Hypoalbuminemia was also associated with increased complication risk (OR 1.79, $p = 0.045$). MSQ score was not correlated with postoperative complication.

Conclusions: Among the examined malnutrition screening tools, clinical malnutrition had the strongest association with postoperative complication. Hypoalbuminemia was associated with increased odds of complication, however there was a large false positive rate with all tested serum chemistries and high associated hospital charges compared to dietitian assessment. MSQ was a poor predictor of malnutrition and clinical outcome. Dietetic assessment is advised for orthopaedic trauma patients.

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1. Introduction

Malnutrition is part of the clinical spectrum of frailty; the declining health condition that places individuals at increased risk for adverse health outcomes. Though often reported, malnutrition lacks consistent diagnostic criteria in the literature. Prior studies have used dietitian assessment, screening questionnaires, and

serum chemistries to determine nutritional status. This inconsistent definition of malnutrition has led to significant variation in reported malnutrition rates, as well as difficulty assessing any consistent association with postoperative outcomes. Patients sustaining musculoskeletal trauma are at risk for complication due to prolonged immobilization, as well as inadequate fluid and energy intake in the postoperative period [1]. Research evaluating nutrition screening tools in musculoskeletal trauma patients is largely limited to elderly patients presenting with hip fracture. Further investigation is needed to determine the prognostic accuracy of malnutrition screening tools in the musculoskeletal trauma population including.

^{*} Corresponding author. Department of Orthopedics and Rehabilitation, University of Iowa Hospitals and Clinics, 200 Hawkins Drive, Iowa City, IA 52242, USA.

E-mail address: nathan-hendrickson@uiowa.edu (N.R. Hendrickson).

The Joint Commission standards mandate nutritional and functional assessment within 24 hours of hospital admission when the patient's condition warrants it, however this standard allows for organizations to independently define which patients should undergo assessment as well as who may perform this evaluation [2]. Evaluation by a dietitian is considered the gold standard for the diagnosis of malnutrition, but is not commonly reported in the orthopaedic literature as a risk stratification tool. Surrogate measures including screening questionnaires and serum chemistries are widely reported for malnutrition screening, but their diagnostic and prognostic accuracy has not been rigorously assessed in patients with acute trauma [3]. Serum albumin, transferrin, vitamin D, and total lymphocyte count are commonly investigated as biomarkers of nutritional status [3–6]. Orthopaedic trauma patients have been shown to have higher rates of nutritional deficiency compared to other orthopaedic specialties [3,7–9]. Deficiencies in these serum biomarkers are common in patients with established non-union after fracture [10].

Despite multiple reported screening modalities for malnutrition, there is a lack of information about the association between these screening tools and postoperative outcomes in orthopaedic trauma patients. The purpose of our study was to evaluate a malnutrition screening program using multiple screening tools for orthopaedic trauma patients, determine the positive screening rates for these screening tools, and assess the relationship between these screening tools and complications after operative fracture fixation. Our goal was to determine which tools most accurately predicted postoperative complications in patients with acute orthopaedic trauma.

2. Methods

Patients aged 18 or older with acute orthopaedic injuries treated operatively at a level-1 trauma center between August 1, 2014 and July 31, 2015 were enrolled prospectively. Institutional Review Board approval was granted for malnutrition screening and recording outcomes in this patient population. Beginning in August 2014, we implemented an admission nutrition screening program in accordance with Joint Commission standards [2]. Upon admission, patients were administered a malnutrition screening questionnaire by nursing staff. The malnutrition screening tool is a modification of a validated malnutrition screening questionnaire (MSQ) developed to identify hospitalized adult patients at risk for malnutrition [11,12]. The MSQ consisted of six questions categorizing patients into low risk (<4 points), moderate risk (4–6 points), and high risk of malnutrition (≥ 7 points) (Fig. 1). Additionally, patients who met the MSQ criteria for moderate or high risk for malnutrition were referred for dietitian assessment for malnutrition. Malnutrition was diagnosed by the dietitian using the American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.) criteria [13].

Serum markers of nutritional status were obtained at the time of admission and included preoperative albumin (g/dL), transferrin (mg/dL), total lymphocyte count (cells/mm³), and 25(OH) Vitamin D (ng/mL). For consistency, these lab studies were protocolled into a single trauma order set ordered at the time of admission to the hospital. Albumin deficiency was defined as < 3.5 g/dL. Serum transferrin deficiency was defined as < 200 mg/dL. Total lymphocyte count deficiency was defined as < 1500 cells/mm² [3]. 25(OH)-vitamin D deficiency was defined as < 20 ng/mL.

Patient age, BMI, gender, medical comorbidities including Charlson Comorbidity Index, smoking status, injury, and details of the procedure performed were recorded. Injury severity score was calculated retrospectively, using the abbreviated injury scale 2005 update [14]. Post-operative clinical notes were retrospectively reviewed to identify medical and surgical complications occurring in the 12 months following surgery. Patients who were discharged

Question	Score
Are you currently receiving, or have you recently been on tube feeds or total parenteral nutrition?	4
Have you been eating poorly because of a decreased appetite?	4
What is your usual weight?	
Have you lost weight without trying within the last 6 months ?	4
Do you have a chronic non-healing wound?	4
Are you status post surgery and 77 years of age or older?	4
Have you recently had chewing or swallowing difficulty?	4
Have you had recent vomiting or diarrhea?	
No	0
Yes in past 3 days	2
Yes for past 4-6 days	4
Yes for greater than 7 days	7

Fig. 1. The malnutrition screening questionnaire was administered by a nurse or nursing assistant upon admission. A score of <4 was considered low risk; 4–6 points was moderate risk; ≥ 7 points was considered high risk. Patients at moderate and high risk were referred for evaluation by Food and Nutrition Services for the presence of malnutrition and need for supplementation.

from follow-up or failed to return for routine postoperative clinic visits for any reason other than death were excluded from the study. Medical complications included myocardial infarction, pulmonary embolus, deep vein thrombosis, pneumonia, stroke, congestive heart failure exacerbation, decubitus ulcer, acute kidney injury, and death. Surgical site infections were classified according to the CDC classification for surgical site infections [15]. Other complications included delayed union, non-union, hardware failure, unplanned hardware removal, and neuropathy. Minor wound complication included pin site infection, minor wound dehiscence, incisional cellulitis, and wound drainage not requiring surgical intervention. Socioeconomic factors including poverty and homelessness were not assessed in the current study.

2.1. Statistical analysis

The association between preoperative serum markers of nutritional status and subsequent postoperative complications were evaluated using logistic regression. The sensitivity, specificity, positive predictive value, and negative predictive values for predicting postoperative complications were calculated for the malnutrition screening questionnaire and dietitian assessment. Student t-tests were used to evaluate the difference between patients with and without malnutrition, as well as between patients discharged or lost to follow-up and patients included in the analyses.

Continuous variables were assessed for normality using Shapiro–Wilk test and through evaluation of histograms. Normally distributed continuous variables were compared using Student t-tests for continuous data. Categorical data was assessed using χ^2 or Fisher's exact test for categorical variables as appropriate. Data not meeting the assumption of normal distribution was compared using the Wilcoxon rank-sum test.

3. Results

Five hundred and three total patients met inclusion criteria. One hundred and thirty patients were either lost to follow up or discharged prior to 1 year, and therefore excluded—leaving 373 eligible patients (74%). Of these, the malnutrition screening questionnaire (MSQ) was recorded for 312 patients (84% completion). BMI was slightly lower in patients lost to follow up (median, IQR = 26.0, 7.6) compared with those included in the analyses (median, IQR = 28.3, 9, $p = 0.0071$). The two groups were otherwise similar for all demographic variables available. The mean age of patients was 56 years (range 18–99 years, interquartile range 29). There were 387 operatively treated orthopedic injuries in the study cohort (Table 1), 30 of which were open fractures. There were 44 patients (11.8%) with ISS ≥ 19 . The rates of diabetes mellitus and current tobacco use were 12 and 31 percent, respectively.

3.1. Screening results

Table 2 displays results from nutrition screening. Fifty-three of the 312 patients (17.0%) were identified as moderate or high risk for malnutrition; 36 of these patients went on to receive dietitian assessment. An additional 104 patients had dietetic evaluation as part of their admission to the ICU, for a total of 140 patients undergoing formal dietetics evaluation. Of these, 16 patients were diagnosed with malnutrition by dietitian.

Serum biomarker results are reported in Table 2. Hypoalbuminemia was present in 40.1% of screened patients, hypotransferrinemia was present in 43.4% of screened patients, lymphopenia was present in 53.6% of those screened, and vitamin D deficiency was identified in 49.4% of patients screened.

3.2. Clinical outcomes

At minimum 1-year follow-up, 88 complications occurred in 72 of 373 patients. Surgical complications are presented in Table 3. Medical complications were as follows: 7 thromboembolic events, 5 deaths, 5 transient neuropraxia, 1 congestive heart failure exacerbation, 1 NSTEMI, 1 episode of gastritis.

Clinical malnutrition as diagnosed by the dietitian was the strongest predictor of combined surgical and medical complication, with an odds ratio of 3.49 (95% CI 1.26–9.72, $p = 0.017$) (Table 4). Hypoalbuminemia was also associated with significantly increased odds of postoperative complication (OR 1.79, 95% CI 1.01–3.14, $p = 0.045$), but to a lesser degree than clinical malnutrition. Transferrin, total lymphocyte count, and vitamin D deficiencies were not associated with complication (Table 4). ISS was not significantly associated with complication: among patients with ISS

≥ 19 , 10 developed a complication (22.7%), while 62 patients with ISS < 19 developed complication (18.8%) ($p = 0.54$). Median ISS in the group developing complications was 9, IQR = 9, versus median ISS of 9, IQR = 5, in the group without complications. Tobacco use and diabetes mellitus were not predictive of complications in our cohort (Table 4).

The mean length of stay was 6.7 days for the entire group. Length of stay was longer for patients with clinical malnutrition (median = 6, mean \pm SD = 9.0 \pm 10.2 days) compared to those without (median = 4, mean \pm SD = 6.2 \pm 6.7 days) but this did not reach statistical significance ($p = 0.098$). Length of stay was also significantly correlated with ISS ($r = 0.52$, $p < 0.0001$), but was not significantly related to albumin, transferrin, total lymphocyte count, or vitamin D status. Hospital charges related to obtaining the studied nutritional laboratory measures were \$624 per patient and \$120 for dietitian assessment.

4. Discussion

Malnutrition is a condition of frailty related to inadequate nutrition intake and physiologic reserve, and is a potentially modifiable risk factor for wound complications, infection, and poor surgical outcomes among patients. Malnutrition is more common among orthopaedic trauma patients compared to patients undergoing elective orthopaedic procedures. Despite the Joint Commission mandate requiring nutrition screening at the time of hospital admission, there is no consensus regarding how to best screen patients, demonstrating a need for objective assessment of screening tools. Inconsistency between previously reported laboratory measures and clinical assessments complicates comparison between studies. Although previous studies have demonstrated significant relationships between biochemical markers of malnutrition and increased complications after elective orthopaedic surgery, relatively little is known regarding the prognostic value of these markers in acute orthopedic trauma patients.

In the current study, nursing-administered nutrition screening was a poor predictor of complications. Dietetic assessment of clinical malnutrition was the strongest predictor of postoperative complication risk. We observed discordance between rates of positive malnutrition screenings, with abnormal serum chemistries being ten-fold more common than diagnosis of clinical malnutrition. Clinical malnutrition proved superior in predicting postoperative complication compared to commonly used serum biomarkers.

It is important to note the low sensitivity of clinical nutrition assessment for predicting postoperative complications in the current study, (21% sensitivity), although it was highly specific (87% specificity). The relatively small portion of patients undergoing dietitian assessment is a weakness of this study, as it is possible patients with malnutrition were missed in this study design. However, the current study design follows clinical practice guidelines set forth by Academy of Nutrition and Dietetics, A.S.P.E.N, and E.S.P.E.N, which recommend using preliminary screening tools to identify patients at risk for malnutrition and referral for detailed dietetic assessment [13,17].

The current heterogeneous cohort of patients included young patients with high energy and open injuries who are less likely to be malnourished. However high-risk patients (ICU admission and positive nursing screening questionnaire) were more likely to be evaluated by a dietitian, which is a source of potential bias in this assessment. These patients often have greater medical comorbidity and severity of injury leading to increased risk of complication, making the dietitian screening appear as a more useful tool, but dietitian screening based on ICU admission and positive nutrition

Table 1
Distribution of orthopedic injuries treated by anatomic region.

Region	Count
Clavicle, scapula, shoulder	10
Humerus	20
Olecranon, coronoid, radial head	27
Forearm	14
Pelvic ring and acetabulum	26
Native hip dislocation	1
Proximal femur	59
Femoral diaphysis and distal femur	53
Knee, patella	9
Tibial plateau and diaphysis	60
Rotational ankle and plafond	81
Foot	27
Total	387

Table 2
The rates of positive nutrition screening tests in orthopaedic trauma patients.

Value	N	Number deficient	Median (interquartile range)	Percent with positive screening
Malnutrition screening questionnaire	312	53	n/a	17.0
Dietitian assessment	140	16	n/a	11.4
Albumin (<3.5 mg/dl)	319	128	3.6 (0.8)	40.1
Transferrin <200 ng/ml)	304	132	206.5 (75)	43.4
Total lymphocyte count (<1500 cells/mm ³)	211	113	1400 (890)	53.6
25(OH) Vitamin D (<20 ng/ml)	320	158	20 (15)	49.4

Table 3
Medical and surgical complications.

	Total	Dietitian assessment		
		Not assessed	Adequate nutrition	Malnourished
Superficial surgical site infection/Complication	12 (3.2%)	9	3	0
Deep surgical site infection	23 (6.1%)	16	6	1
Delayed union/Nonunion	6/12 (1.6%/3.2%)	5/6	1/4	0/2
Avascular necrosis	2 (0.5%)	1	1	
Hardware removal/Failure	8/7 (2.1/1.9%)	5/4	2/1	1/1
Medical complication	19 (5.1%)	9	8	2

Complications observed following operative fixation of orthopedic injuries grouped by dietitian assessment of nutrition status. Wound complications were classified according to the CDC classification of surgical site complications. Patients undergoing hardware removal were grouped into those with hardware failure necessitating revision surgery (failure) and those with removal for pain, prominent hardware, or other reason not related to hardware failure.

Table 4
Associations between preoperative predictors and subsequent medical and surgical complication (OR, 95% CI).

	Percent of patients experiencing complication		Odds Ratio	95% CI	P value
	Risk factor absent	Risk factor present			
Malnutrition screening questionnaire					
Screen ≥ 4	19.3%	24.5%	1.36	0.68–2.73	0.39
Screen ≥ 7	20.7%	11.8%	0.51	0.11–2.30	0.38
Albumin	15.2%	24.2%	1.79	1.01–3.14	0.045
Total lymphocyte count	23.5%	23%	0.98	0.51–1.85	0.94
Transferrin	18.6%	20.5%	1.13	0.64–1.99	0.69
Vitamin D 25(OH)	22.2%	17.1%	0.72	0.41–1.26	0.25
Diabetes mellitus	19.3%	18.2%	1.07	0.48–2.42	0.86
Smoking	17.8%	22.8%	0.73	0.43–1.26	0.26
Malnutrition by dietitian assessment	18.2%	43.8%	3.49	1.26–9.72	0.017

Observed complication rate stratified by presence and absence of preoperative risk factors. Risk factors with odds ratios meeting statistical significance ($P < 0.05$) are noted with bold text.

screening would be an easily implemented protocol for hospitals that manage high energy trauma patients.

Despite recommendations of the major nutritional societies, serum albumin is frequently used as a surrogate marker of malnutrition in the literature and hypoalbuminemia has been correlated with increased risk of wound healing complications and mortality in patients undergoing elective arthroplasty, spine surgery and after traumatic injuries [4,18–23]. Serum concentration of visceral proteins, such as albumin, are not included in the Academy of Nutrition and Dietetics or American Society for Parenteral and Enteral Nutrition (A.S.P.E.N) guidelines [13]. Furthermore, the European Society for Parenteral and Enteral Nutrition advise against using serum protein concentrations as indicators of patient nutritional status [16]. Although hypoalbuminemia in this investigation was associated with complications in the first year after injury (OR 1.79, 95% CI 1.01–3.14, $p = 0.045$), other lab markers including transferrin, total lymphocyte count, and vitamin D were not associated with complications. Alterations in these serologies may be due to the acute phase reaction after trauma, which leads to redistribution from plasma into the interstitial fluid space due to increased capillary permeability, as well as the dilutional effect of administration of resuscitative fluids [24]. Compared to previous reports of geriatric hip fracture patients, the current cohort may have had increased fluid or blood product resuscitation resulting in dilutional changes to serum biomarkers, as well as increased injury

severity resulting in greater acute phase decrease to serum albumin and lymphocyte count, although we did not assess these potential confounders post-hoc. This heterogeneity in trauma patients makes the use of biomarkers as a screening test for malnutrition less effective. Furthermore, hospital charges associated with collecting the four serum chemistries used in this study were higher than charges for dietitian consultation, suggesting dietitian consultation may be a more cost-effective assessment of nutritional status compared to serum chemistries.

Our 40% rate of albumin deficiency is within the wide range of rates previously reported among orthopedic trauma patients. Kieffer et al. reported 43.6% hypoalbuminemia among geriatric femoral neck fracture patients; they also observed increased 1-year mortality among patients with hypoalbuminemia [23]. Koval et al. reported preoperative albumin less than 3.5 g/dL was present in 18% of hip fracture patients and was associated with increased length of hospital stay, poorer recovery, and increased mortality during hospitalization [3]. Patterson et al. reported a 58% rate of protein depletion and observed a significant correlation with poor outcomes postoperatively in elderly patients with hip fracture [20]. Our cohort varied from these previous studies because we included all fracture patients over 18 years of age.

The prevalence of vitamin D deficiency in the current cohort (49%) was similar to previous reports in the literature [7,8,25]. The current study did not, however, identify significant relationship

between hypovitaminosis D and increased complication risk. Vitamin D deficiency is associated with parathyroid hormone-related bone loss and is present more commonly in orthopaedic trauma patients than other orthopaedic specialties, and is therefore frequently supplemented during fracture healing when indicated [8,25]. Childs et al. recently reported a theoretical cost savings with vitamin D and calcium supplementation, based upon an assumed 5% reduction in non-union rate. There is no definitive evidence demonstrating improved fracture healing with vitamin D supplementation, however clinical trials are underway to evaluate the efficacy of vitamin D screening and supplementation fracture patients.

Our cohort had a lower rate of lymphopenia than previous reports of hip fracture patients, which is likely due to differences in patient cohorts [1,3,6,26–30]. In comparison to previous studies of hip fracture patients aged greater than 65 years, the current cohort of patients includes younger patients with increased injury severity that may confound comparisons with previous reports. Total and relative lymphocyte counts are known to decrease with aging, which may partially explain the increased prevalence of lymphopenia in previous studies of elderly hip fracture patients.

Limitations of preoperative malnutrition assessment tools have led to investigation of improved objective markers to identify patients at greater risk of complications due to frailty. Sarcopenia, which is decreased muscle mass and functional ability, has been evaluated as an objective marker for frailty and increased complications in geriatric patients [31]. Sarcopenia can be objectively assessed by multiple imaging modalities, including DeXA, CT, MRI, and ultrasound, and is associated with poor clinical outcomes following hospitalization for hip fractures, acetabulum fractures, and solid organ tumor resection in elderly patients [31,32]. Unlike elective orthopaedic procedures, which can be postponed to medically optimize patients, acute orthopaedic trauma surgeries are often time-sensitive. There is a lack of prospective studies evaluating malnutrition or sarcopenia screening as well as postoperative supplementation as a method to improve clinical outcomes in orthopaedic trauma patients. Prospective studies evaluating preoperative screening and perioperative nutritional interventions are needed to improve clinical outcomes in trauma patients. Although, the current study does not answer these questions, it does provide direction as to which tools are superior in predicting malnutrition-associated complications. We have since undertaken prospective clinical research to address these questions.

5. Conclusions

In summary, poor clinical outcomes associated with malnutrition are well documented, but current malnutrition screening tools lack diagnostic accuracy. In our population of individuals that underwent operative fixation of acute musculoskeletal trauma, clinical diagnosis of malnutrition by a dietitian most accurately predicted morbidity. Hypoalbuminemia also conferred increased odds of complication, however, due to the cost and poor prognostic accuracy of predicting postoperative complication, we recommend against routinely obtaining serum chemistries for nutrition screening in patients that suffer acute musculoskeletal trauma and are capable of nutrition assessment. Additional prospective studies are needed to identify accurate and objective screening tools to stratify risk of postoperative complications and to evaluate the efficacy of targeted interventions for improving clinical outcomes in this patient population.

Conflict of interest statement

None.

Authors' contributions

NRH and MCW contributed to conception and design of the research; all authors contributed to acquisition, analysis, or interpretation of the research; NRH drafted the manuscript; All authors critically revised the manuscript.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.clnesp.2018.11.012>.

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