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2019 Chitranjan S. Ranawat Award: Elective joint arthroplasty outcomes improve in malnourished patients with nutritional intervention

A PROSPECTIVE POPULATION ANALYSIS DEMONSTRATES A MODIFIABLE RISK FACTOR

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Aims

To date, no study has demonstrated an improvement in postoperative outcomes following elective joint arthroplasty with a focus on nutritional intervention for patients with preoperative hypoalbuminaemia. In this prospective study, we evaluated differences in the hospital length of stay (LOS), rate of re-admission, and total patient charges for a malnourished patient study population who received a specific nutrition protocol before surgery.

Patients and Methods

An analytical report was extracted from the electronic medical record (EMR; Epic, Verona, Wisconsin) of a five-hospital network joint arthroplasty patient data set between 2014 and 2017. A total of 4733 patients underwent joint arthroplasty and had preoperative measurement of albumin levels: 2220 at four hospitals and 2513 at the study hospital. Albumin ≤ 3.4 g/l, designated as malnutrition, was found in 543 patients (11.5%). A nutritional intervention programme focusing on a high-protein, anti-inflammatory diet was initiated in January 2017 at one study hospital. Hospital LOS, re-admission rate, and 90-day charges were compared for differential change between patients in study and control hospitals for all elective hip and knee arthroplasty patients, and for malnourished patients over time as the nutrition intervention was implemented.

Results

Malnourished patients with nutritional intervention at the study hospital had shorter hospital LOS beginning in 2017 than malnourished patients at control hospitals during the same period ($p = 0.04$). Similarly, this cohort had significantly lower primary hospitalization charges, charges associated with hospital re-admissions, and 90-day total charges ($p < 0.001$). Inclusion of covariant potential confounders (age, anaemia, diabetes, and obesity) did not alter the conclusions of the primary statistical analysis.

Conclusion

Joint arthroplasty outcomes were positively affected in study patients with low albumin when a high-protein, anti-inflammatory diet was encouraged. Elective surgery was neither cancelled nor delayed with a malnutrition designation. While the entire network population experienced improved postoperative outcomes, malnourished control patients did not experience this improvement. This study demonstrated that education on malnutrition can benefit patients.

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Approximately 25% of orthopaedic surgery patients are at risk for malnutrition, defined as a state of altered body composition and function resulting from a lack of nutritional uptake or intake.[1] Malnutrition in elective joint arthroplasty patients has been associated with increased risk of prosthetic joint infections, hospital re-admission, and cost of care.[2-7] Malnutrition is one of several medical conditions denoted as a modifiable risk factor (MRF), which is defined as a condition that presents the opportunity to be altered positively prior to surgery. Initial reports on MRFs were

Table I. Description of the cohorts

Variable	Control hospitals, n (%)	Study hospital, n (%)
Patients	2220	2513
2014 to 2016		
Nourished	1356 (*89.7*)	1497 (*88.4*)
Malnourished	155 (*10.3*)	196 (*11.6*)
2017		
Nourished	625 (*88.2*)	712 (*86.8*)
Malnourished	84 (*11.8*)	108 (*13.2*)

Table II. Description of the anti-inflammatory, high-protein diet given to all malnourished study patients

Anti-inflammatory diet
Limit/omit red meat, sugar, saturated fats, and simple carbohydrates
Increase fish, nuts, seeds, fruits, vegetables, and whole grains
Increase protein to 100 g per day unless medically contraindicated
Liquid protein supplements only when goals not met through food

focused on the individual effect of a risk factor on surgical outcomes and complications.[2,8-12] More recent studies have incorporated financial analysis as an outcome allowing reporting on the relative impact of MRFs, which demonstrates that malnutrition increases the cost of care more than other MRFs.[7]

Examination of MRFs has demonstrated their association with poor surgical outcomes and led to the hope that alterations in patient status prior to surgery might lead to improved outcomes in joint arthroplasty. To date, few studies have demonstrated significant improvement in outcomes following preoperative patient optimization. No study has reported specific nutritional intervention that significantly improved elective joint arthroplasty outcomes. In this prospective study, we evaluate differences in the hospital length of stay (LOS), rate of re-admission, and total patient charges in the first 90 postoperative days for a malnourished patient study population who received a specific nutrition protocol before surgery.

Patients and Methods

In anticipation of alternative payment models for lower limb joint arthroplasty, administrators of a network of five adult hospitals tasked a leadership council of orthopaedic surgeons to define parameters for cost containment with knowledge of current practice patterns, local incidence, and impact of defined risk factors. The initial focus identified by the council was the impact of six MRFs on joint arthroplasty care and cost. The network informatics team was requested to compile outcomes using Clarity software (Poinciana, Florida) to explore the electronic medical record (EMR; Epic, Verona, Wisconsin) data for all hip and knee arthroplasties across the five-adult hospital network. This analytical report allows unrestricted real-time analysis of the entire EMR held in a relational database management system. Database tables are updated by an extract, transform, load (ETL) process in which EMR data are extracted daily, transformed to fit relational databases, and then loaded into database tables. Since 2015, this ETL process has provided concurrent actionable data in real time on patient care. Institutional review board approval was obtained for analysis and dissemination of these EMR data to data analysts.

The focus of the data analysis for this report was the interaction of malnutrition on postoperative outcomes. Hypoalbuminaemia (serum albumin ≤ 3.4 g/l) was used as a surrogate for malnutrition.[2,4-7,9,13] For this study, serum albumin > 3.4 g/l was defined as nourished, while ≤ 3.4 g/l was defined as malnourished. Other previously defined MRFs were also included as potential confounders and modelled in the statistical analysis as covariates: anaemia (haemoglobin < 100 g/l), obesity (body mass index ≥ 50.0 kg/m^2), and uncontrolled diabetes (random serum glucose > 180 mg/dl (10 mmol/l) or an A1C > 8.0%).

Cohorts defined. EMR data were extracted for all 8930 patients undergoing elective primary knee and hip arthroplasties between 2014 and 2017 across a five-hospital network. The study population included 4733 patients who had serum albumin levels obtained prior to surgery (2220 patients at the control hospitals and 2513 patients at the study hospital) with 543 identified as malnourished (Table I). In January 2017, the study hospital prospectively introduced a nutritional intervention programme. Four cohorts (nourished patients at the study and control hospitals, and malnourished patients at the study and control hospitals) were analyzed for differential changes in outcome measures over time between 2014 to 2016 and 2017 as the nutritional intervention was implemented (Table I).

Nutritional intervention. The focus of the nutritional intervention programme is a diet that encourages high-protein, anti-inflammatory foods. Beginning in January 2017, a three-point programme was started at the study hospital. First, at the mandatory preoperative joint arthroplasty education class, all patients were informed of the benefits of an anti-inflammatory, high-protein diet. Handouts were provided with sample menus and recommended foods. Verbal and visual nutrition education was also provided during the class to improve patient compliance. Patients were instructed to start this diet immediately and to follow it for at least one month after surgery. The goals of the diet were to limit known inflammatory foods such as red meat, processed meats, sugar, saturated fats, and simple carbohydrates, as well as salt intake.[14] Increasing intake of anti-inflammatory foods such as fish, nuts, seeds, fruits, vegetables, and whole grains was recommended (Table II).[14] In addition, increasing protein intake to 100 g/day was suggested unless the patient had a medical contraindication such as renal disease. If patients believed they could not meet the protein intake goal with food, protein supplements were suggested.

Second, all patients had a serum albumin level measured as part of their preoperative blood investigations. Patients with low albumin (albumin ≤ 3.4 g/l) were documented as malnourished, contacted by telephone, informed of their laboratory value and increased risk of perioperative complication, and reminded of the benefits of the anti-inflammatory diet. A low albumin level did not delay the scheduled surgery or require further laboratory testing. Third, all malnourished patients were seen by the inpatient dietitian during their hospital stay. The dietitian reinforced the importance of the anti-inflammatory, high-protein diet and answered patient questions or concerns. Specific diet recommendations were also included in patient instructions at time of discharge from the hospital.

Outcomes and statistics. Data analysis looked at the association between malnutrition and multiple dependent variables:

Table III. Results of cohort comparison over time

Dependent variable	Year	Control hospitals (n = 2220 patients)				Study hospital (n = 2513 patients)				Primary analysis: differential change	Secondary analysis: inclusion of covariates
		Nourished	p-value	Malnourished	p-value	Nourished	p-value	Malnourished	p-value	p-value	p-value
Mean length of stay, days (SD; range)	2014 to 2016	3.1 (1.5; 1 to 22)	< 0.001*	3.7 (2.2; 1 to 16)	0.53†	3.0 (1.0; 1 to 14)	0.07	3.5 (1.5; 1 to 14)	0.24	0.04*	0.007*
	2017	2.7 (1.2; 1 to 15)		3.9 (2.8; 1 to 21)		2.8 (1.1; 1 to 20)		3.2 (1.4; 1 to 11)			
Mean total of all charges, $ (SD)	2014 to 2016	43 031 (28 717)	< 0.001*	50 371 (30 265)	< 0.001*†	37 415 (25 946)	< 0.001*	43 937 (44 164)	< 0.001*	< 0.001*	< 0.001*
	2017	41 559 (15 023)		53 049 (34 957)		33 714 (10 605)		36 493 (10 494)			
Mean joint charges, $ (SD)	2014 to 2016	37 849 (9605)	< 0.001*†	42 818 (13 687)	< 0.001*†	32 538 (7140)	< 0.001*	35 679 (11 059)	< 0.001*	< 0.001*	< 0.001*
	2017	38 593 (8413)		45 751 (25 258)		32 100 (5270)		34 599 (6871)			
Re-admission number of patients (%)	2014 to 2016	104 (*7.7*)	0.45	14 (*9*)	0.14†	107 (*7.2*)	0.06	17 (*8.7*)	0.5	0.32	0.98
	2017	42 (*6.7*)		13 (*15.5*)		36 (*5.1*)		7 (*6.5*)			
Re-admission charges, $ (SD)	2014 to 2016	3390 (17 870)	< 0.001*	3687 (13 554)	< 0.001*†	2867 (14 397)	< 0.001*	5618 (37 105)	< 0.001*	< 0.001*	< 0.001*
	2017	2782 (11 560)		6909 (22 170)		1506 (7694)		1709 (6915)			

*Statistically significant

†Increase in the observed outcome between the 2014 to 2016 cohort and the 2017 cohort

hospital LOS, hospital re-admission, and charges incurred by the patient for services. Charges were determined by applying a standard 'Chargemaster', a consistent list of charges for any service or product offered across the hospital network. Charges represent an estimate of services and costs for labour, facility use and improvement, current and projected technology, and the provision of underinsured care. While not a direct measure of cost, charges provide a relative measure of utilization of services. Charges were determined for primary hospitalization, total 90-day charges for care, and charges associated with any hospital re-admission.

Dependent variables (outcomes) were compared across the three independent variables: control *versus* study hospital, malnutrition (malnourished *vs* nourished), and time when nutritional intervention was implemented (2014 to 2016 *vs* 2017) through a generalized linear model with log link and conditional distribution as Poisson (for LOS and cost variables) or as binomial (for the occurrence of re-admission). The focus of the analysis was the three-way interaction of the independent variables. Least squares means were used to provide additional p-values within each of the four cohorts. We also performed an ancillary analysis that was precisely analogous to the analysis previously described but with the inclusion of covariates. Significance was determined with a p-value < 0.05.

Results that evaluate three research questions are reported: 1) assessment of change between 2014 to 2016 and 2017 within each of the four cohorts; 2) the principal analysis tested for differential change between 2014 to 2016 and 2017 for the nourished compared with the malnourished for patients in the control hospitals compared with the study hospital; and 3) the principal analysis with age and MRFs (anaemia, uncontrolled diabetes, and obesity) included as covariates to control for potential confounders.

Results

The change in LOS between 2014 to 2016 and 2017 for the nourished as compared with the malnourished patients was significantly different for those who received nutritional intervention education at the study hospital compared with those who had surgery at the control hospitals (p = 0.04; Table III). No significance was reached in decreased LOS for either the malnourished cohort (p = 0.24) or the nourished cohort (p = 0.07) at the study hospital. Nourished patients at the control hospitals had significantly lower hospital LOS over time (p < 0.001) (Table III).

Hospital re-admission rate within 90 days of surgery did not significantly vary at the study hospital over time for either the nourished cohort (p = 0.06) or the malnourished cohort (p = 0.50), nor at the control hospitals over time for either the nourished (p = 0.45) or the malnourished (p = 0.14). No significant change was noted in re-admission rate for the patient cohorts between the study hospital and the control hospitals (Table III).

Charges associated with initial hospitalization, individual re-admissions, and total 90 days of care decreased significantly for the malnourished cohort at the study hospital (p < 0.001) and for the nourished cohorts at both the study and control hospitals between 2014 to 2016 and 2017 (p < 0.001). However, a significant increase in all charges occurred for the malnourished cohort over time at the control hospitals (p < 0.001; Table III).

When age, anaemia, uncontrolled diabetes, and obesity were included in the differential change model as covariates, the group interaction was still significantly decreased for the

malnutrition study cohort, for LOS ($p = 0.007$) and all three analyses of charges ($p < 0.001$).

Discussion

Malnutrition has been associated with increased risk of prosthetic joint infection, hospital LOS, hospital re-admission, and total cost of care following elective knee and hip arthroplasties.[2-7,9,13,15-17] The majority of these studies define malnutrition as a serum albumin < 3.5 g/l. Surgical outcomes studies often refer to hypoalbuminaemia as malnutrition, despite the fact that protein/calorie malnutrition is only one condition leading to hypoalbuminaemia. Albumin is primarily synthesized in the liver and functions as a plasma transport protein with a half-life of 21 days. Hypoalbuminaemia results from alterations in the synthesis, distribution, or degradation of albumin. In addition to protein/calorie malnutrition, nephrotic syndrome, cirrhosis, heart failure, and chronic inflammatory conditions lead to hypoalbuminaemia.[18] However, independent of other malnutrition markers, hypoalbuminaemia has been repetitively demonstrated as an important marker for predicting poor surgical outcomes.[2-6,9,15-17]

In a study of more than 20 000 total hip arthroplasty patients, hypoalbuminaemia was found to be a stronger predictor of negative surgical outcomes than obesity including respiratory complications, need for transfusion, extended hospital stay, wound complications, and return to the operating theatre for all causes.[19] In a recent study by the authors, hypoalbuminaemia was found to be the third most common MRF for elective joint arthroplasty behind only the incidence of smoking and prescription narcotic use.[7] Due to this high prevalence and the significantly increased cost of care associated with negative surgical outcomes, hypoalbuminaemia was determined to be the greatest source of increased utilization of care across the elective hip and knee arthroplasty population.[7] Despite evidence of significant surgical morbidity and cost of care, no study to date has prospectively demonstrated improving surgical outcomes through an organized approach to improving nutrition.

Few prospective data have been published to demonstrate improved outcomes if elective surgery is postponed until MRFs are optimized. Preoperative reduction in opioid use before joint arthroplasty has demonstrated improved clinical outcomes that are comparable with patients not taking opioids.[20,21] Similarly, Springer[11] has demonstrated that smoking cessation four to six weeks before joint arthroplasty decreases postoperative complications. With regard to nutrition, a single study reports better outcomes with an improved protein diet following hip fractures.[22]

In the current prospective study, a specific nutritional intervention led to improved surgical outcomes. There was significant differential change in hospital LOS for the study hospital patients who received the nutritional intervention. Similarly, hospital charges for the primary hospitalization, re-admissions, and 90 days of care were significantly reduced in the cohort of malnourished patients who received nutritional instruction. Combined, these outcomes represent an important reduction in the utilization of services throughout the 90 days of care after surgery. This patient education programme focused on the benefits of a high-protein, anti-inflammatory diet and was simple to implement on top of an established perioperative patient education programme. A previous report on the ability to involve patients in their own care similarly demonstrated the positive impact on nutritional status through patient education.[23] No current consensus in the literature describes how long patients need to optimize their nutrition prior to surgery or if further laboratory markers would be beneficial to determine when a malnourished patient should proceed to elective surgery.[3,9,19] In the current study, scheduled surgical procedures were not delayed and further laboratory testing was not required prior to proceeding with surgery. The authors acknowledge that this may not be best practice for individual patients. However, due to the timeline and ease of implementation across several surgical practices, with varied levels of acceptance of delaying surgical intervention, this approach was deemed the most practical course across a hospital network population. With the benefits of nutrition instruction demonstrated in this study, the programme has now been implemented across the entire hospital network, including for other elective surgical specialties.

The ability of the EMR-generated analytical report to view concurrently surgical outcomes as a new variable was prospectively introduced as a powerful tool in improving patient care and is an inherent strength of this study. The rigorous statistical analysis employed in this study was able to look for differential change across time as this new nutrition intervention was prospectively initiated at the study hospital. Certainly, all hospitals were involved in multiple efforts to improve patient care under a national bundled payment programme. These common efforts were standardized across all hospitals by an orthopaedic clinical leadership council and were statistically controlled using control hospitals data across time for both nourished and malnourished patients. In addition, potential confounding effects of alternative covariates (MRFs) were statistically examined and found not to alter the primary statistical analysis (Table III).

This study may be limited by a sample bias of total joint arthroplasty patients because, of the 8930 patients in the original sample, only 4733 (53%) of those patients had a recorded preoperative albumin value extracted for the statistical analysis. However, all consecutive patients with a preoperative albumin value who had elective total joint arthroplasty between 2014 and 2017 at any of the five adult hospitals in the network were included in this study.

Another weakness in this study is the relatively few surgery-specific outcomes that could be followed. The use of a large local multi-hospital population allows specific patient data to be extracted from a single large EMR, obviating concerns about data extraction techniques seen with reviews of Centers for Medicare & Medicaid Services (CMS) administrative claims data and national surgical registries.[13,24] However, our study population was not large enough to view negative clinical outcomes that, fortunately, are relatively uncommon following elective joint arthroplasty surgery: wound complications, additional surgery, prosthetic joint infection, and mortality. Similarly, incidence of hospital re-admission, the most frequent negative clinical outcome we track, was too low to demonstrate a statistically significant improvement in our malnourished study population due to a nationally top decile re-admission rate during the 90 days following surgery.

An additional concern of this study is the use of hospital charges as an outcome measure. Charges reported in this study

do not directly correlate with cost incurred or payment received by the hospital and do not allow conclusions to be drawn on ability to directly reduce costs. However, charges are applied in a consistent manner across this hospital network and give a reproducible measure of relative care required by each patient.[7] Additionally, the reported charges are only for services provided through this hospital network. Out-of-network hospital charges, emergency department visits, and post-acute care at outside skilled nursing or rehabilitation hospitals would not be captured in this data query. However, medical comorbidities would not be expected to decrease utilization of outside hospital and post-acute care facilities, but rather, likely to increase further costs associated with malnutrition in this study.

In conclusion, in the current study, a specific prospective nutritional intervention led to improved surgical outcomes in patients with low albumin before elective total joint arthroplasty without delay or cancellation of surgery. Hospital LOS and charges associated with elective total joint surgery were significantly reduced, demonstrating significant decrease in the requirement for services for the cohort of malnourished patients who received nutritional advice. Malnutrition is truly a modifiable medical risk factor.

Take home message

- Malnourished patients experienced inferior outcomes following primary joint arthroplasty.
- Instruction on an anti-inflammatory, high-protein diet led to improved outcomes in malnourished patients.
- This improvement was demonstrated across our patient population without delaying or cancelling surgery.

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