

Nutritional Insufficiency as a Predictor for Adverse Outcomes in Adult Spinal Deformity Surgery

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Abstract

Study Design: Retrospective analysis of prospectively collected data.

Objectives: The effect of malnutrition on outcomes after general surgery has been well reported in the literature. However, there is a paucity of data on the effect of malnutrition on postoperative complications during adult deformity surgery. The study attempts to explore and quantify the association between hypoalbuminemia and postoperative complications.

Methods: A retrospective cohort analysis was performed on the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database from 2010 to 2014. Patients (≥ 18 years of age) from the NSQIP database undergoing adult deformity surgery were separated into cohorts based serum albumin (< 3.5 or > 3.5 g/dL). Chi-square and multivariate logistic regression models were used to identify independent risk factors.

Results: A total of 2236 patients met the inclusion criteria for the study, of which 2044 (91.4%) patients were nutritionally sufficient while 192 (8.6%) patients were nutritionally insufficient. Multivariate logistic regressions revealed nutritional insufficiency as a risk factors for mortality (odds ratio [OR] = 15.67, 95% confidence interval [CI] = 6.01-40.84, $P < .0001$), length of stay ≥ 5 days (OR = 2.22, 95% CI = 1.61-3.06, $P < .0001$), any complications (OR = 1.82, 95% CI = 1.31-2.51, $P < .0001$), pulmonary complications (OR = 2.29, 95% CI = 1.29-4.06, $P = .005$), renal complications (OR = 2.71, 95% CI = 1.05-7.00, $P = .039$), and intra-/postoperative red blood cell transfusion (OR = 1.52, 95% CI = 1.08-2.12, $P = .015$).

Conclusions: This study demonstrates that preoperative hypoalbuminemia is a significant and independent risk factor for postoperative complications, 30-day mortality, and increased length of hospital in patients undergoing adult deformity surgery. Nutritional status is a modifiable risk factor that can potentially improve surgical outcomes after adult deformity surgery.

Keywords

nutrient, insufficiency, adult spinal deformity, fusion, complications, ACS, NSQIP, hypoalbuminemia, malnutrition, mortality

Introduction

With the aging population, there is a growing prevalence of adult spinal deformity. However, elderly patients undergoing deformity surgery are more likely to have preoperative morbidities that can negatively affect the outcomes of the operation. This can lead to increased postoperative complications and place a larger financial burden on the health care system. Thus, a greater understanding of patient-related factors that influence postoperative complications is needed to improve surgical outcome.

In particular, preoperative nutritional status of patients has been widely recognized to affect surgical outcome.¹ The

relationship between nutritional deficiency and poor outcomes has been investigated in the general surgical literature, surrounding severe catabolic states such as polytrauma, burns,

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sepsis, and malignancy. Malnutrition has been shown to cause postoperative complications, such as infection, poor wound healing, delayed postoperative recovery, and mortality. In the literature, studies have reported malnourishment in 20% to 50% of hospitalized patients.²⁻⁶ Preoperative malnutrition has also been shown to have relatively high prevalence in both developed and developing countries.^{2,7} Furthermore, elderly patients are more likely to be malnourished as they have a naturally reduced caloric intake.⁸ While prior published evidence has supported the relationship between malnutrition and poor wound healing and outcomes in the general surgical and orthopedic literature, the investigation of this relationship in adult spinal deformity is not well established. In the context of spinal surgery, up to 25% of patients undergoing lumbar spine surgery have been shown to have poor nutrition prior to undergoing surgery. When stratified by age, it was found that 42% of patients aged >60 years were malnourished prior to surgery.⁹

Serum albumin concentration has been established as a clinical marker of nutritional status.¹⁰ One marker of malnutrition is serum hypoalbuminemia, which is defined as a serum albumin concentration <3.5 g/dL. Studies have suggested that preoperative hypoalbuminemia can independently increase the risk of postoperative complication. This has been shown in a variety of surgical procedures, including gastrointestinal, cardiovascular, gynecological, rectal, and orthopedic hip procedures.¹¹⁻¹⁷ However, no studies to date have investigated the link between preoperative nutrient insufficiency and postoperative outcomes following adult spinal deformity surgery. This association is especially pertinent as the rising life expectancy will likely increase spinal deformity surgeries on elderly patients who are more susceptible to malnourishment.^{18,19}

We used the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database to determine the relationship between nutritional status and 30-day outcomes of adult spinal deformity surgery. Preoperative serum albumin levels were used as the marker of overall nutritional status.

Methods

Data Source

This was a retrospective study of prospectively collected data in the 2010 to 2014 ACS-NSQIP database. ACS-NSQIP data is collected by dedicated clinical abstractors at each institution on more than 150 demographic, preoperative, intraoperative, and 30-day postoperative variables.²⁰⁻²⁴ Over 500 hospitals that vary in size, socioeconomic location, and academic affiliation contributed data to the 2010 to 2014 ACS-NSQIP database.²⁰ The success of quality improvement initiatives based on ACS-NSQIP data has been validated in the Veteran's Administration and private sector^{22,25} and described in detail previously.²⁶⁻²⁹

Inclusion and Exclusion Criteria

The ACS-NSQIP database from 2010 to 2014 was used in this study. Adult patients (≥ 18 years) undergoing spinal fusion for

deformity were identified based on Current Procedural Terminology (CPT) codes 22800, 22802, 22804, 22808, 22810, 22812, 22818, 22819. CPT codes 22843, 22844, 22846, or 22847 were also included to capture long, multilevel fusion constructs. Patients with CPT codes 22842 and 22845 were included if they had an International Classification of Diseases, Ninth Edition, diagnosis for spinal deformity (including 737.1, 737.2, 737.3, 737.4, 737.8, 737.9). Cases with missing preoperative data; emergency cases; patients with a wound class of 2, 3, or 4; an open wound on their body; current sepsis; current pneumonia; prior surgeries within 30 days; cases requiring cardiopulmonary resuscitation prior to surgery; any patients undergoing a nonelective procedure; or cases with diagnoses of cervical spine, trauma, or injury to spine, or neoplasm of spine were excluded in order to reduce the risk of confounding variables.

Variable Definition

Patient demographic variables included sex, age (≥ 50 , 51-60, 61-70, 71-80, and ≥ 80 years), and race (white, black, Hispanic, and other). Other race included American Indian or Alaska Native, Asian, Native Hawaiian or Pacific Islander, or unknown/not reported. Preoperative variables included obesity (≥ 30 kg/m²), diabetes (non-insulin-dependent diabetes mellitus or insulin-dependent diabetes mellitus), current smoking (within 1 year of surgery), dyspnea (≤ 30 days prior to surgery), functional status prior to surgery (independent or partially/ totally dependent ≤ 30 days prior to surgery), pulmonary comorbidity (ventilator dependent ≤ 48 hours prior to surgery or history of chronic obstructive pulmonary disease ≤ 30 days prior to surgery), cardiac comorbidity (use of hypertensive medication or history of chronic heart failure ≤ 30 days prior to surgery), renal comorbidity (acute renal failure ≤ 24 hours prior to surgery or dialysis treatment ≤ 2 weeks prior to surgery), steroid use for chronic condition (≤ 30 days prior to surgery), $\geq 10\%$ loss of body weight (in the last 6 months), bleeding disorder (chronic, active condition), preoperative transfusion of ≥ 1 unit of whole/packed red blood cells (RBCs; ≤ 72 hours prior to surgery), and American Society of Anesthesiology (ASA) physical status classification (≥ 3).

Intraoperative variables included operation year (2010-2014), fusion length (long fusion is ≥ 4 levels during an anterior approach and ≥ 7 levels during a posterior approach), surgical approach (anterior, posterior, or combined), pelvic fixation, osteotomy, operative time (≥ 4 hours), and total relative value units. Thirty-day postoperative outcome variables include mortality, any postoperative complication, length of stay (≥ 5 days), wound complication (superficial or deep surgical site infection, organ space infection, or wound dehiscence), pulmonary complication (pneumonia, unplanned reintubation, or duration of ventilator-assisted respiration ≥ 48 hours), venous thromboembolism (pulmonary embolism or deep vein thrombosis), renal complication (progressive renal insufficiency or acute renal failure), urinary tract infection, cardiac complication (cardiac arrest requiring cardiopulmonary

resuscitation or myocardial infarction), intra-/postoperative transfusion, sepsis, reoperation (related to initial procedure), and unplanned readmission (related to initial procedure). ACS-NSQIP provides further information on variable characteristics.²⁴ Patients were divided into cohorts depending on whether they were nutritionally sufficient (n = 2044) or not nutritionally sufficient (n = 192).

Statistical Analysis

Patients were divided into cohorts based on whether they were nutritionally sufficient or not. A bivariate analysis was performed on patient demographic, preoperative, intraoperative, and postoperative characteristics using Pearson's χ^2 test. Fischer's exact test was used where appropriate. Multivariate logistic regression models were employed, adjusting for patient demographic, preoperative, and intraoperative variables, to identify the influence of nutritional status on each of the investigated 30-day postoperative complications. The extent of the fusion was inputted into the regression model along with hypoalbuminemia in order to assess whether fusion length or hypoalbuminemia had the statistically significant correlation with postoperative outcomes. Regression models utilized a stepwise entry and removal criteria, set to a significance level of .05. SAS Studio Version 3.4 (SAS Institute Inc, Cary, NC) was used for all statistical analysis.

Results

Patient Demographics

A total of 2236 patients met the inclusion criteria for the study, of which 2044 (91.4%) patients were nutritionally sufficient while 192 (8.6%) patients were nutritionally insufficient (see Table 1). The number of males and females in both nutritionally sufficient and insufficient groups were comparable. The number of patients who were aged 51 to 60 years and 61 to 70 years was higher in the nutritionally sufficient group when compared with the nutritionally insufficient group. The nutritionally insufficient group had a higher proportion of patients in the ≤ 50 , 71 to 80 and > 80 years age groups. There were no significant differences in the proportion of white, black, Hispanic, and other races between the 2 groups. In the nutritionally sufficient group, the majority of the patients were white, followed by other races, black, and then Hispanic. In the nutritionally insufficient group, the majority of the patients were white, followed by black, Hispanic, and other races. Compared with those that were nutritionally insufficient, nutritionally sufficient patients were more likely to be obese (45.3% vs 27.1%). Between the 2 groups there was no significant difference with regard to the proportion of patients that were smokers, had diabetes, dyspnea, a partially or totally dependent functional status, and an independent functional status.

Surgical Variables

A greater proportion of patients in the nutritionally insufficient group received long fusion when compared with that of the

nutritionally sufficient group (75.5% vs 60.7%). As a result, a greater proportion of patients in the nutritionally sufficient group received short fusion (39.3% vs 24.5%). The surgical approach chosen was predominately a posterior approach (56.4%) for the nutritionally sufficient group, followed by an anterior (40.8%) and then combined approach (2.8%). The most common surgical approach for the patients in the nutritionally insufficient group was also via a posterior route (66.1%), followed by an anterior approach (30.7%) and combined approach (3.1%). There were no significant differences between the groups with regard to fusion to pelvis and osteotomy.

Comorbidities and Preoperative Variables

The nutritionally insufficient group, when compared with the nutritionally sufficient group, had higher rates of preoperative transfusion (1.0% vs 0.1%), recent weight loss (2.6% vs 0.0%), and ASA ≥ 3 (73.4% vs 55.6%). There were no significant differences between the nutritionally sufficient and insufficient groups with regard to pulmonary comorbidity, cardiac comorbidity, renal comorbidity, steroid usage, and bleeding disorder.

Postoperative Outcomes

The nutritionally insufficient group, when compared with the nutritionally sufficient group, had higher rates of mortality (4.7% vs 0.3%), length of stay ≥ 5 days (47.9% vs 27.4%), any complication (45.3% vs 31.4%), pulmonary complication (8.9% vs 2.5%), renal complication (2.1% vs 0.6%), cardiac complication (2.1% vs 0.6%), intra-/postoperative RBC transfusion (38.5% vs 28.1%), and reoperation (7.8% vs 4.2%). There was no significant difference between nutritionally sufficient and nutritionally insufficient group with regard to wound complication, venous thromboembolism, urinary tract infection, sepsis, or unplanned readmission (see Tables 2 and 3).

Multivariate Analysis

Multivariate logistic regressions revealed nutritional insufficiency as an independent risk factor for mortality (odds ratio [OR] = 15.67, 95% confidence interval [CI] = 6.01-40.84, $P < .0001$), length of stay ≥ 5 days (OR = 2.22, 95% CI = 1.61-3.06, $P < .0001$), all complications (OR = 1.82, 95% CI = 1.31-2.51, $P < .0001$), pulmonary complications (OR = 2.29, 95% CI = 1.29-4.06, $P = .005$), renal complications (OR = 2.71, 95% CI = 1.05-7.00, $P = .039$), and intra-/postoperative RBC transfusion (OR = 1.52, 95% CI = 1.08-2.12, $P = .015$).

Discussion

With the rising life expectancy, more elderly patients are being selected for adult spinal deformity surgery. In this older population, there is an increased prevalence of malnourishment.⁸ Poor preoperative nutrition has been suggested to detrimentally affect the outcomes of a variety of surgical procedures. Our

Table 1. Patient Demographic, Preoperative, and Intraoperative Characteristics Between Nutritionally Insufficient and Nutritionally Sufficient Groups (N = 2236).^a

Category	Nutritionally Sufficient	% Nutritionally Sufficient	Nutritionally Insufficient	% Nutritionally Insufficient	P Value
Sex					.552
Female	1179	57.7%	115	59.9%	
Male	865	42.3%	77	40.1%	
Race					.219
White	1646	80.5%	162	84.4%	
Other	160	7.8%	8	4.2%	
Hispanic	83	4.1%	10	5.2%	
Black	155	7.6%	12	6.3%	
Age (years)					.023
≤50	417	20.4%	45	23.4%	
51-60	546	26.7%	38	19.8%	
61-70	630	30.8%	58	30.2%	
71-80	382	18.7%	37	19.3%	
>80	69	3.4%	14	7.3%	
Obese	925	45.3%	52	27.1%	<.001
Diabetes	334	16.3%	41	21.4%	.075
Smoke	455	22.3%	50	26.0%	.231
Dyspnea	136	6.7%	11	5.7%	.621
Functional status					.271
Partially/totally dependent	101	4.9%	13	6.8%	
Independent	1943	95.1%	179	93.2%	
Fusion length					<.001
Long	1241	60.7%	145	75.5%	
Short	803	39.3%	47	24.5%	
Surgical approach					.024
Posterior	1152	56.4%	127	66.1%	
Anterior	834	40.8%	59	30.7%	
Combined	58	2.8%	6	3.1%	
Fusion to pelvis	161	7.9%	19	9.9%	.326
Osteotomy	281	13.7%	26	13.5%	.937
Pulmonary comorbidity	121	5.9%	15	7.8%	.294
Cardiac comorbidity	1193	58.4%	111	57.8%	.882
Renal comorbidity	11	0.5%	2	1.0%	.380
Steroid use	121	5.9%	9	4.7%	.485
Weight loss	0	0.0%	5	2.6%	<.001
Bleeding disorder	33	1.6%	3	1.6%	.956
Preoperative transfusion	2	0.1%	2	1.0%	.003
ASA ≥3	1137	55.6%	141	73.4%	<.001

Abbreviation: ASA, American Society of Anesthesiology.

^aBold values indicate $P < .05$.

study found that nutrient insufficiency in adult spinal deformity surgery patients was significantly and independently associated with an increased 30-day mortality, length of hospital stay, and postoperative complications. This data suggests that optimizing patient nutrient status prior to surgery may help reduce postoperative complications and improve surgical outcomes for adult spinal deformity surgery. Baseline serum albumin may be an important prognostic tool for assessing malnutrition and, thus, risk of postoperative complications and outcomes.

The effect of malnourishment on postoperative outcomes have been explored in the general surgical literature, but the evidence is not well established in the realm of spinal surgery and specifically adult spinal deformity surgery. In a retrospective analysis of 114 patients undergoing elective lumbar decompression and fusion, Klein et al⁹ determined that 24 out

of 26 complications (92.3%) in their study were in the malnourished cohort. Similarly, in 44 patients with cerebral palsy and spastic quadriplegia undergoing spinal arthrodesis for scoliosis, Jevsevar and Karlin reported an increased risk of infection and longer hospital stay in malnourished patients, which was defined as preoperative serum albumin level <35 g/L and total blood-lymphocyte count of less than 1.5 g/L.³⁰ Adogwa et al analyzed 136 patients retrospectively, comprising 35.7% malnourished versus 11.7% non-malnourished patients. Following propensity-score matching, the authors found that preoperative hypoalbuminemia was a significant predictor of increased postoperative complications in patients undergoing surgery for degenerative spinal diseases or deformity.¹ However, given the smaller sample size and lack of adequate statistical power, the authors were unable to stratify this

Table 2. Thirty-Day Postoperative Outcomes Between Nutritionally Insufficient and Nutritionally Sufficient Groups (N = 2236).^a

Category	Nutritionally Sufficient	% Nutritionally Sufficient	Nutritionally Insufficient	% Nutritionally Insufficient	P Value
Mortality	7	0.3%	9	4.7%	<.001
Length of stay ≥ 5 days	561	27.4%	92	47.9%	<.001
Any complication	641	31.4%	87	45.3%	<.001
Wound complication	48	2.3%	5	2.6%	.824
Pulmonary complication	51	2.5%	17	8.9%	<.001
Venous thromboembolism	43	2.1%	2	1.0%	.316
Renal complication	13	0.6%	4	2.1%	.027
Urinary tract infection	44	2.2%	6	3.1%	.384
Cardiac complication	13	0.6%	4	2.1%	.027
Intra-/postoperative RBC transfusion	575	28.1%	74	38.5%	.002
Sepsis	39	1.9%	3	1.6%	.736
Reoperation (related to initial procedure)	85	4.2%	15	7.8%	.019
Unplanned readmission (related to initial procedure)	136	6.7%	16	8.3%	.377

Abbreviation: RBC, red blood cell.

^aBold values indicate $P < .05$.

Table 3. Nutritional Insufficiency as a Risk Factor for 30-Day Postoperative Outcomes (N = 2421).

Outcome	Odds Ratio	Lower Confidence Limit	Upper Confidence Limit	P Value	C Statistic
Mortality	15.67	6.01	40.84	<.0001	0.760
Length of stay ≥ 5 days ^a	2.22	1.61	3.06	<.0001	0.809
Any complications	1.82	1.31	2.51	<.0001	0.834
Pulmonary complications	2.29	1.29	4.06	.005	0.758
Renal complications	2.71	1.05	7.00	.039	0.743
Intra-/postoperative RBC transfusion	1.52	1.08	2.12	.015	0.847

Abbreviation: RBC, red blood cell.

^aN = 2417.

relationship according to the specific type of complication. There is also evidence to suggest that malnutrition offers prognostic value in posterior lumbar fusion surgery. Bohl et al³¹ analyzed 4310 patients from the NSQIP database and demonstrated that malnutrition independently predicted infections, wound dehiscence, urinary tract infections, alongside increased length of stay and readmission.

The overall conclusions of these prior studies are broadly consistent with the current findings in the present study with regard to adult spinal deformity surgery.

There are several proposed mechanisms for malnutrition that may translate into poor outcomes following surgery. In elderly patients, malnutrition can result from a natural reduction in food consumption and caloric intake.^{8,32} Insufficient food intake can result in a negative caloric balance, which has detrimental impact on a patient's reserve to withstand nutrition and surgical stress during the procedure. This hypothesis is supported by published studies that have shown that recent weight loss associated with malnutrition independently increases the risk of postoperative complications.³³ While some studies have failed to find an association between recent weight loss and postoperative complications, these studies had a low number of patients with complications and thus may not be adequately powered to study this relationship.^{34,35} In surgical gastric cancer patients, there was also no association between recent

weight loss and mortality, although our study found an independent association between malnutrition and increased mortality.³⁵ In converse, obese patients undergoing spine surgery have been demonstrated to be at greater risk of postoperative complications, a relationship that may be mediated by higher likelihood of malnutrition in obese patients. This was the case in the study by Adogwa et al,¹ who noted higher body mass index in patients with malnutrition. Collectively, this evidence suggest that malnutrition may be a complex multifactorial state associated with increased surgical morbidity via mechanisms including both weight loss or poor nutritional intake.

Other factors found to be possible contributors to preoperative malnutrition include social and environmental stressors, such as financial need or psychological distress, which also can cause malnutrition.¹ Intense physical activity can also result in malnourishment if an appropriately higher caloric diet is not consumed. Our current study also found that malnutrition was independently associated with a longer length of hospital stay. Patients with longer hospital stays may be more vulnerable to further detrimental effects as studies have shown that these patients have an elevated risk of postoperative complications.^{34,36} Prolonged length of stay may be secondary to increased postoperative complications such as urinary tract infections and wound dehiscence as was the case for Bohl et al's³¹ analysis of posterior lumbar fusions. In our study, there

was also an independent association between malnutrition and increased intra-/postoperative RBC transfusions. Malnutrition has been associated with anemia, particularly in the elderly population.^{37,38} Thus, the nutritionally insufficient patients in our study may have also been anemic, thus requiring blood transfusions. Ultimately, as malnutrition detrimentally affects the outcomes of surgery via a multitude of mechanisms, surgeons must place a greater preoperative emphasis on ensuring that patients undergoing deformity surgery understand the importance of nutritional status on operative success.

In our current study, preoperative serum albumin levels <3.5 g/dL was used as the measure of malnutrition. This marker has been established and extensively used as a clinical indicator of overall nutritional status and systemic disease.¹⁰ However, patients with chronic kidney diseases who have proteinuria or are overhydrated will have lower serum albumin, which is not indicative of nutrition levels.³⁹⁻⁴¹ Other biomarkers for malnutrition have been used including hemoglobin levels, total lymphocyte count, and cholesterol.⁴² However, these markers have not been tested as extensively and have low consistency and reliability with regard to its association with surgical outcomes.^{42,43} Alternatively, nutrition status has been evaluated using questionnaires like the Mini Nutritional Assessment–Short Form.⁴³ However, questionnaires are susceptible to innate limitations such as recall error and misreporting. This could explain the poor association between surgical outcomes and nutrition status when assessed using a survey. There is potential in the future for metabolic profiles or “food metabolomes” to be used as a more sensitive biomarker of nutrition status.⁴⁴ Until then, serum albumin levels are currently the most practical and economic measure of nutrition status in patients undergoing surgery.

Given the association between malnutrition and outcomes following surgery for adult spinal deformity, these findings suggest a possible role for nutritional supplementation in optimizing patients preoperatively. Dietary advice can be used as an initial method to ameliorate malnourishment.³² Improving the taste and variety of food or adding energy-rich sauces are some other methods of increasing caloric intake.³² For patients that have difficulty consuming enough food to achieve adequate nutrient levels, oral nutrient supplements can be used.⁴⁵ Some patients may be unable to reach adequate nutrient levels due to chronic gastrointestinal diseases, cancer, or depression. For these patients, treatment or management of their chronic disease would be necessary to ameliorate their chronic malnourishment.¹

It is important to acknowledge the limitations of the current study. First, the data was obtained from a multicenter database, introducing heterogeneity among the selected patients. There may be variations between institutions with regard to albumin measurement methods, surgeon experience, and surgical technique used to treat adult spinal deformity, and because the NSQIP database classifies cases based on CPT codes, there is likely to be some variance in the types of spinal deformity procedures among the different institutions involved. As our study was retrospective, there remains an inevitable level of

bias that results from inconsistent reporting. While many baseline patient demographic variables were factored into the multivariable-adjusted model, other factors like patient dietary practices and lifestyle differences were not reported and, thus, not accounted for. Malnutrition is also a systemic and heterogeneous process, and thus, using only serum albumin as an indicator of overall nutrition can be limiting. NSQIP data obtains outcomes that are limited to 30 days and may not reflect long-term outcomes, which may display different patterns associated with hypoalbuminemia.

In conclusion, this study demonstrates that preoperative hypoalbuminemia is a significant and independent risk factor for postoperative complications, 30-day mortality, and increased length of hospital in patients undergoing adult spinal deformity surgery. Thus, by improving a patient’s nutrient status prior to surgery, surgical outcomes can potentially be improved. We suggest that patients should be screened for their nutrition status prior to surgery as it can be used in the assessment of operative risk.

Authors’ Note

This study was qualified as exempt by the Mount Sinai Hospital Institutional Review Board.

Declaration of Conflicting Interests

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