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ORIGINAL CONTRIBUTIONS

# Effects of Post-operative Nutritional Disorders Following Bariatric Surgery on Health Care Cost and Use

**Jaewhan Kim**[1] · **Norman Waitzman**[2] · **Steven Simper**[3] · **Rodrick McKinlay**[3] · **Daniel Cottam**[4] · **Amit Surve**[4] · **Nathan Richards**[5] · **Ted Adams**[6]

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## Abstract

**Purpose** Risk of nutritional disorders (NDs) in bariatric surgical patients has led to guideline recommendations for pre- and post-operative nutrient deficiency screening. The aim of this study was to identify baseline factors associated with incident NDs and, in addition, to explore possible differences in health care spending and use between patients with and without incident NDs following bariatric surgery.

**Materials and Methods** Using data linked with a state-wide bariatric surgical registry and a state-wide claims database, subjects who underwent bariatric surgery between July 1, 2013, and December 31, 2015, were identified. Incident NDs and health care cost and use outcomes following 1 year from surgery were extracted from the claims data. Logistic regression was used to identify baseline factors associated with incident NDs. Zero-inflated negative binomial regression and generalized linear regression were used to estimate health care cost and use outcomes.

**Results** A total of 3535 patients who underwent bariatric surgery were identified. Of these patients, those without continuous health insurance enrollment ($n$=1880), having prevalent (pre-surgery) NDs ($n$=461), and missing baseline BMI ($n$=41) were excluded. Of patients analyzed ($n$=1153), about 30% had incident NDs, with a mean (SD) age and BMI at surgery of 46 (12) years and 48 (9.2) kg/m$^2$, respectively. Patients with one incident ND had higher total health care spending (coefficient=$41118, $p$-value<0.01) and ED visits (IRR=1.86, $p$-value<0.01).

**Conclusion** Those without pre-operative NDs may have a higher chance of having NDs post-operatively. Taking multivitamins and continues monitoring are necessary to prevent any negative outcomes related to post-operative NDs.

**Keywords** Bariatric surgery · Nutritional disorders · Health care use and cost

✉ Jaewhan Kim
jaewhan.kim@utah.edu

Norman Waitzman
waitzman@economics.utah.edu

Steven Simper
ssimper@rmapinc.com

Rodrick McKinlay
mckinlay.rod@gmail.com

Daniel Cottam
drdanielcottam@yahoo.com

Amit Surve
dramitksurve@gmail.com

Nathan Richards
nathan.richards@imail.org

Ted Adams
ted.adams@utah.edu

1 Department of Physical Therapy, University of Utah, 520 Wakara Way, Salt Lake City, UT 84108, USA

2 Department of Economics, University of Utah, 260 Central Campus Dr. #4100, Salt Lake City, UT 84112, USA

3 Rocky Mountain Associated Physicians, 1160 E 3900 S, Suite 4100, Salt Lake City, UT 84124, USA

4 Bariatric Medicine Institute, 1046 E 100 S, Salt Lake City, UT 84102, USA

5 Intermountain Health Care, 5300 South State Street, Murray, UT 84107, USA

6 Division of Epidemiology, University of Utah, 295 Chipeta Way, Salt Lake City, UT 84108, USA

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## Introduction

Bariatric surgery has been associated with significant and sustained weight loss and remission of comorbidities such as diabetes, hypertension, and sleep apnea [1–3]. Despite potential favorable clinical outcomes following bariatric surgery, adverse effects of surgery such as increased malnutrition rates have also been reported [4, 5].

Specific to the nutritional disorders, commonly reported deficient micronutrients both pre- and post-surgery have included vitamin B1, folate, vitamin B12, calcium, iron, and vitamin D [6, 7]. Pre-operative vitamin D deficiency has been reported in the range of 13 to 90% among patients who have undergone bariatric surgery [8]. Some studies have reported post-operative vitamin D deficiency [9], while other studies have reported no significant change in vitamin D level or an improvement in vitamin D deficiency after bariatric surgery [10–12]. Similarly, multiple studies have shown vitamins A, B1, calcium, and folate deficiencies not to be significantly changed before and after surgery [13–16], while other studies have reported high incidence of vitamin A, B1, and iron deficiencies following bariatric surgery [12, 16, 17]. In response to the potential for nutritional deficiencies among bariatric surgical candidates, a bariatric surgery guidelines report (2016, American Society for Metabolic and Bariatric Surgery Nutrition) has recommended pre-operative and post-operative screening of nutrient deficiencies [6].

Risk factors that have been shown to be associated with nutritional deficiencies and disorders following bariatric surgery are surgery type, gender, race, and weight regain [11, 18, 19]. Differences in nutritional deficiencies between RYGB and SG have been somewhat inconclusive, with multiple studies reporting a higher risk of nutritional disorders (NDs) among post-Roux-en-Y gastric bypass (RYGB) patients compared to sleeve gastrectomy (SG) patients [12, 18–20], and one study reporting no differences between procedures [4]. Finally, greater than 50% of patients who underwent RYGB were reported to have had ≥2 post-operative ND [11]. However, factors associated post-bariatric surgical incidence of NDs and the effects these NDs have upon health care use and cost are not well known.

This primary aims of the study examined what baseline factors were associated with incident NDs following bariatric surgery, and whether NDs, including number of diagnosed NDs, following bariatric surgery were associated with increase in health care use. The NDs included deficiency of nutrient elements and malnutrition. Using a state-wide claims database, this study captured all clinical visits regardless of where patients visited before and after their bariatric surgery within a state.

## Methods

### Data and Study Population

The University of Utah Institutional Review Board (IRB) approved this study. The Utah Bariatric Surgery Registry (UBSR) was used to identify patients who underwent open and laparoscopic bariatric surgery in Utah (USA) between July 1, 2013, and December 31, 2015. Using International Classification of Disease (ICD)-9 procedure codes and Current Procedural Terminology (CPT) codes in the UBSR, identification of bariatric surgical procedures included Roux-en-Y gastric bypass (RYGB), adjustable gastric band (AGB), sleeve gastrectomy (SG), and duodenal switch (DS). Age of patients at the time of surgery was limited to 18 to 64 years [21]. Patients with revisional bariatric surgical codes or with less than 30 kg/m$^2$ body mass index (BMI) at surgery were excluded in the study [22].

Identified patients were linked to the Utah All Payers Claims Database (APCD) that contains about 80% of the Utah population covered by private insurance and Medicare Advantage. [23, 24] For this study, only patients covered by private insurance between January 1, 2013, and December 31, 2016, were included in the analyses. Based on the APCD eligibility data, only surgical patients who had 6-month continuous enrollment before surgery and 12-month continuous enrollment after surgery were included for calculation of study outcomes. The UBSR- and APCD-identified patients were also linked to the Utah Population Database (UPDB) to acquire Rural-Urban Commuting Area Codes (RUCA) for the purpose of identifying rural/urban residence at the time of bariatric surgery. [21, 25]

### Study Endpoints

Nutritional disorders in this study included identification of deficiencies in iron, vitamin A, vitamin B1 (thiamine/pyridoxine), vitamin B12, vitamin D, and calcium, other vitamin deficiencies (folate deficiency anaemia, nutritional anaemia, anaemia, riboflavin deficiency, deficiency of other specified B group vitamins, vitamin B deficiency, dietary zinc deficiency, and deficiency of other nutrient elements), and malnutrition. Patient-related nutritional disorders were identified using International Classification of Disease, Ninth Revision and Tenth Revision (ICD-9/10) diagnosis codes. [26, 27]

Specific cost-related study endpoints included annual health care use and total health care cost after bariatric surgery (1-year post-surgery). Number of all-cause inpatient admissions and number of all-cause emergency department (ED) visits at 1-year post-surgery were also compared between patients with and without a post-surgical nutritional disorder diagnosis. ED visits were identified by CPT (99281~99285), place of service (code: 23), and revenue codes (450, 459, 981).

Inpatient admissions were identified by CPT (99221~99223, 99231~99236, 99238~99239), place of service (code: 21 and 51), and revenue codes (100~169) [21]. CPT codes provide information about medical services and procedures that are provided to patients. Place of service contains information about where medical services are provided. This code is used to identify specific medical claims. Furthermore, revenue codes give information about where the medical procedure was provided. This code is specific for facility claims such as emergency rooms and hospitals.

Total annual health care costs, medical costs, and medication costs were also identified for comparative analyses. Total annual health care costs were defined as the sum of medical costs, (reimbursed, co-pay, co-insurance, prepaid, and deductible amounts) and total medication costs. Because healthcare resources use after the first 3 months following surgery can be dramatic, we compared healthcare use and cost with and without the first 3 months after surgery.

Inflation adjustment using the Personal Consumption Expenditure Health was applied to health care spending to adjust for variation in health care costs across years due to inflation [21, 28, 29]. Costs were expressed in 2016 dollars because this was the last year of the APCD data used in this study [21].

### Covariates

Pre-operative covariates included BMI (kg/m$^2$) at surgery, age (years) at surgery, gender (female/male), and race/ethnicity (non-Hispanic White, Hispanic, and others). Procedure types (RYGB, AGB, SG, and DS) were controlled for in all regression-related analyses. Comorbid conditions were identified from the UBSR (i.e., pre-surgical history and physical examination patient reports) and the APCD. The comorbid conditions included type 2 diabetes (T2D), hypertension, dyslipidemia, sleep apnea, rheumatoid arthritis/osteoarthritis, low back pain, liver disease, chronic pain, any mental health disorders, and asthma/chronic obstructive pulmonary disease (COPD), and were identified by ICD-9/10 diagnosis codes based on 6-month pre-surgery claims data in the APCD. Pre-operative mental disorders that were identified by ICD-9/10 diagnosis codes from both the UBSR and APCD included depression, anxiety disorders, substance abuse–related mental disorders, bipolar disorders, depressive disorders, personality disorders, schizophrenia, and psychotic disorders [21]. Associated ICD-9/10 codes to identify the comorbid conditions were obtained from Centers for Medicare and Medicaid Services Chronic Conditions Data Warehouse website and from Agency for Healthcare Research and Quality (AHRQ) Chronic Condition Indictor (CCI) [30, 31].

Baseline numbers of ED and hospital visits along with healthcare cost in the 6 months before surgery were calculated from the APCD and they were controlled in all regressions. Rural vs. urban place of residence at the time of surgery was identified based on RUCA codes (1~3.99 as urban and 4~10.99 as rural) [21, 25]. Extracting APCD pre-operative diagnosis codes 6 months before surgery, the combined comorbid index scores (Charlson Index and Elixhauser Index) were used to calculate the baseline (i.e., up to 6 months pre-surgery) comorbidity index score [32] and this index was controlled in all regressions.

### Statistical Analysis

Summary statistics such as mean, standard deviation (SD), and percentage were used to summarize characteristics of the patients. Baseline characteristics and outcomes between the two groups (i.e., nutritional disorder vs. no nutritional disorder) were compared with *t*-test and chi-square tests. Logistic regression was used to identify factors associated with incident nutritional disorders, and results were reported as odds ratios. Health care utilization outcomes, such as number of annual inpatient admissions and number of annual ED visits, were analyzed using zero-inflated negative binomial regressions (ZNBR). Count outcomes with high-to-the-right skewness and multiple subjects presenting with zero ED visits or zero inpatient admissions made ZNBR the best statistical option. Over-dispersion was modeled with mean dispersion and the results were shown as incidence rate ratios (IRR).

Generalized linear models (GLM) were used for health care cost analysis outcomes. Because health care spending was highly skewed to the right, due to a small number of patients with extremely high spending, GLM was adopted. To identify the most appropriate link function and distributional form, the Pregibon link test and the modified Part test were used. [33–35] Based on these tests, generalized linear models (GLM) which identify link function and Gaussian distribution were used for the analyses involving health care spending outcomes. Results were shown in dollars instead of coefficients. The Wald test was performed to compare the coefficients and IRR of those with 1 ND and ≥2 NDs after the regressions. A *p*-value less than 0.05 was considered statistically significant.

## Results

A total of 3535 patients who underwent bariatric surgery between 2013 and 2015 were identified from the UBSR, of which 1880 patients were eliminated from analyses due to their lack of continuous enrollment (6 months before and 12 months after) in health insurance. Of the remaining 1655 patients, 461 and 41 were excluded in the analysis because of pre-operative ND diagnoses and missing BMI, respectively.

Of the 1153 patients included in the final analyses, 29.66% ($n$=342) had a ND within 1 year following the surgery, and specific NDs included 12% iron, 10% thiamine, 16% vitamin D, and 10% malnutrition. Seventeen percent (*n*=196) of patients were identified to have ≥2 incident NDs (Table 1).

Mean (SD) age and BMI of those with ND at surgery were 46 (12) years and 48 (9.2) kg/m2, respectively. Of patients with ND, 75% were female, 82% were non-Hispanic white, 59% had RYGB, 29% had SG, 5% had AGB, and 12% had DS (Table 2).

One year following bariatric surgery, patients with incident NDs had higher total health care spending and use when compared to patients without incident NDs (Table 3).

### Factors Associated with Incident Nutritional Disorders

Gender, type of surgery, comorbid conditions, and comorbidity index score were statistically significant factors associated with incident NDs. Female sex was more likely to have nutritional disorders (OR=1.42, *p*-value=0.03). Those who underwent AGB (OR=0.46, *p*-value=0.01) and SG (OR=0.67, *p*-value=0.02) had lower odds than those who underwent RYGB. Patients with hypertension (OR=2.09, *p*-value<0.01), chronic pain (OR=2.04, p-value=0.01), and mental disorders (OR=1.48, *p*-value=0.01) had higher odds for incident NDs than those without these comorbid conditions. Increase in the comorbidity index score was associated with higher odds in incident NDs (OR=1.15, *p*-value=0.03) (Table 4).

### Nutritional Disorders Associated with Health Care Use and Cost

Using the binary ND independent variable (any ND; yes or no), patients identified with any ND had higher total health care spending (coefficient=$41118, *p*-value<0.01) and medical cost (coefficient=$38165, *p*-value<0.01), compared to patients without incident NDs. Medication cost (coefficient=$2704, *p*-value=0.54) was not significantly different between the two groups. Patients with any incident ND had higher ED visits (IRR=1.86, *p*-value<0.01) and higher inpatient admissions (IRR=2.03, p-value=0.00) that those without incident NDs. Analyses of data without the first 3-month health care spending and use resulted in similar findings as those with the first 3-month data (results not reported) (Table 5).

Patients with ≥2 incident NDs had the highest total health care spending (coefficient=$44548, *p*-value<0.01), medical spending (coefficient=$42644, *p*-value<0.01), ED visit (IRR=2.13, *p*-value<0.01), and inpatient admissions (IRR=2.07, *p*-value<0.01). Although patients with ≥2 incident NDs had higher health care spending and use compared to those with no ND, outcome differences with the ≥2 incident NDs and only 1 incident ND groups were not statistically significant: total health care spending, *p*-value=0.57; medical spending, *p*-value=0.47; medication spending, *p*-value=0.41; ED visit, *p*-value=0.26; and inpatient admission, *p*-value=0.53 (Table 6).

**Table 1** Subjects (*n*=1153) with nutritional disorders 1 year following bariatric surgery

| Nutritional disorder | % |
|---|---|
| Any nutritional disorder | 29.66 |
| Iron deficiency | 11.71 |
| Vitamin A deficiency | 1.91 |
| Thiamine and/or Pyridoxine deficiency | 10.49 |
| Vitamin B12 deficiency | 8.15 |
| Vitamin D and/or Calcium deficiency | 15.87 |
| Other vitamin deficiency | 16.13 |
| Malnutrition | 10.41 |
| Number of nutritional disorders | |
| 0 | 70.34 |
| 1 | 12.66 |
| ≥2 | 17.00 |

## Discussion

This study examined associations between incident NDs and healthcare use and costs of those who underwent bariatric surgery. About 30% of patients 1 year following bariatric surgery had diagnosed NDs. Vitamin deficiencies such as folate and vitamin B, vitamin D, and calcium deficiencies are the most common NDs, followed by iron deficiency. Johnson et al. reported that rates of post-operative vitamin D and vitamin B12 deficiencies are 5.2% and 0.9% for SG patients, while 11.5% and 1.2% for RYGB patients [12]. Arias et al. (2019) reported that those with vitamin D, calcium, and iron deficiencies 1 year following surgery are 50%, 3%, and 3%, respectively [16]. In our study, about 16% of patients had vitamin D and calcium deficiency within a year following surgery higher than reported results from Johnson et al. (2009) and Aria et al. (2020). The differences in the results could be two differences: (1) the previous studies measured and tested nutritional deficiencies; (2) included those who had pre-operative NDs.

Females experiencing hypertension, chronic pain, and mental disorder have higher odds of having incident NDs, while those with AGB and SG had lower odds of having NDs than those with RYGB. Our result is consistent with findings from Gehrer et al. and Lange et al. about if the restrictive procedures such as AGB and SG as compared to the malabsorptive procedures such as RYGB had a lower probability of having NDs [18, 19]. However, other baseline factors that could be associated with post-surgical NDs are not well known. We found that patients with comorbid conditions such

**Table 2** Baseline characteristics of surgical patients with and without nutritional disorders 1 year following bariatric surgery

| | Those with nutritional disorders | | Those without nutritional disorders | | |
|---|---|---|---|---|---|
| | *N*=342 | | *N*=811 | | |
| Variable | Mean/% | SD | Mean/% | SD | *p*-value |
| Age at surgery | 46.43 | 11.99 | 44.64 | 12.90 | 0.03 |
| BMI at surgery | 47.69 | 9.20 | 46.88 | 8.57 | 0.15 |
| Female, % | 74.85 | | 70.16 | | 0.11 |
| Race/ethnicity, % | | | | | 0.49 |
| Non-Hispanic White | 82.46 | | 79.53 | | |
| Hispanic | 14.04 | | 15.91 | | |
| Non-Hispanic others | 3.51 | | 3.51 | | |
| Urban, % | 87.43 | | 87.18 | | 0.91 |
| Surgical procedure, % | | | | | |
| Roux-en-Y | 59.36 | | 51.17 | | <0.01 |
| Band | 4.97 | | 7.52 | | |
| Sleeve | 28.71 | | 30.95 | | |
| Duodenal switch | 12.28 | | 10.36 | | |
| Comorbid conditions, % | | | | | |
| Diabetes | 40.35 | | 27.87 | | <0.01 |
| Hypertension | 59.36 | | 35.64 | | <0.01 |
| Dyslipidemia | 46.20 | | 29.47 | | <0.01 |
| Asthma/COPD | 16.96 | | 13.19 | | 0.10 |
| Chronic pain | 12.57 | | 5.18 | | <0.01 |
| Any mental disorder | 63.74 | | 44.88 | | <0.01 |
| Comorbidity index score | 0.54 | 1.40 | 0.31 | 1.12 | <0.01 |
| Number of ED visits | 0.18 | 0.54 | 0.11 | 0.46 | 0.02 |
| Number of admissions | 0.31 | 1.27 | 0.12 | 0.68 | <0.01 |
| Total healthcare cost* ($) | 11493.30 | 22671.13 | 5817.38 | 17562.22 | <0.01 |
| Surgery year, % | | | | | <0.01 |
| 2013 | 26.61 | | 18.00 | | |
| 2014 | 43.27 | | 40.57 | | |
| 2015 | 30.12 | | 41.43 | | |

*COPD* chronic obstructive pulmonary disease

*Sum of medical and medication costs

**Table 3** Health care use and cost outcomes one year following surgery

| | Those with nutritional disorders | | Those without nutritional disorders | | |
|---|---|---|---|---|---|
| Outcome | Mean (SD) | Median | Mean (SD) | Median | *p*-value |
| Total healthcare cost ($) | 48871 (115573) | 27166 | 18366 (29384) | 7985 | <0.01 |
| Medical cost ($) | 43869 (114647) | 22904 | 14454 (25260) | 3273 | <0.01 |
| Medication cost ($) | 5002 (13434) | 1148 | 3912 (16138) | 589 | 0.24 |
| Healthcare use | | | | | |
| All-cause ED visit | 0.94 (1.99) | 0 | 0.40 (1.55) | 0 | <0.01 |
| All-cause inpatient admission | 1.99 (4.41) | 1 | 0.73 (1.65) | 0 | <0.01 |

**Table 4** Baseline factors associated with incident nutritional disorders

| Covariate | OR | *p*-value | 95% CI | |
|---|---|---|---|---|
| Female | 1.42 | 0.03 | 1.03 | 1.94 |
| BMI at surgery | 1.01 | 0.34 | 0.99 | 1.02 |
| Age at surgery | 1.00 | 0.99 | 0.99 | 1.01 |
| Race/ETHNICITY | | | | |
| Non-Hispanic White | Reference | | | |
| Hispanic | 0.88 | 0.52 | 0.59 | 1.30 |
| Non-Hispanic others | 0.76 | 0.46 | 0.37 | 1.57 |
| Urban | 0.92 | 0.69 | 0.61 | 1.38 |
| Type of surgery | | | | |
| RYGB | Reference | | | |
| AGB | 0.46 | 0.01 | 0.25 | 0.84 |
| SG | 0.67 | 0.02 | 0.48 | 0.93 |
| DS | 0.92 | 0.73 | 0.58 | 1.46 |
| DM | 1.11 | 0.51 | 0.81 | 1.51 |
| Hypertension | 2.09 | <0.01 | 1.49 | 2.93 |
| Dyslipidemia | 1.27 | 0.16 | 0.91 | 1.76 |
| Asthma/COPD | 0.74 | 0.16 | 0.49 | 1.13 |
| Chronic pain | 2.04 | 0.01 | 1.24 | 3.34 |
| Mental disorder | 1.48 | 0.01 | 1.09 | 2.00 |
| Comorbidity index score | 1.15 | 0.03 | 1.01 | 1.30 |
| Total cost (6 months pre) | 1.00 | 0.04 | 1.00 | 1.00 |
| Surgical year | | | | |
| 2013 | Reference | | | |
| 2014 | 0.63 | 0.01 | 0.44 | 0.90 |
| 2015 | 0.42 | <0.01 | 0.29 | 0.62 |

as chronic pain and mental disorder have a higher probability of having NDs.

It was not well known about whether NDs are associated with more health care use. In this study, we found out that NDs are positively associated with health care use and costs. Those with NDs spent \$41118 more than those without NDs, and this was mainly due to the difference in medical cost (i.e., medication costs were similar between the two groups). In addition, we see increasing trends in healthcare cost and use as patients have more incident NDs. Patients with one ND spend \$36919 more and patients with ≥2 NDs spend \$44548 more than those with no NDs. All-cause ED visits of those with one ND and ≥2 NDs are 1.64 times and 2.13 times higher than those with no ND.

Considering the results in this study, NDs are not trivial in that are associated with high healthcare cost and use. NDs should be considered as critical comorbid conditions and their effects to health outcomes. Because it was known to be common for patients with bariatric surgery to have NDs, it is recommended for regular and continuous monitoring in NDs over time.

Strengths of this study included access to linked data between two state-wide databases, used to identify surgical patients and NDs. While some studies use electronic medical records (EMR) or claim data alone to identify and extract surgical patient data, post-surgery clinical data of study patients who visit out-of-network clinics or hospitals are not attainable. Lost to follow-up is a common problem using such EMR or claims data. We were able to capture bariatric surgical patient data, including all diagnoses, that were correctly captured over time regardless which hospitals/clinics patients visited.

Despite the strengths of the study, there were limitations of this investigation. First, nutritional deficiencies or disorders were identified based on ICD-9/10 diagnosis codes instead of measured clinical values. Second, although a study reported that weight regain was a factor associated with an incident ND, we did not control this covariate in the regressions. However, in our study, weight regain could be minimal because our study examined NDs 1 year following surgery because changes in BMI after surgery could affect incidents in NDs. Third, some of the patients could take prescribed or over-the-counter vitamins or supplements once they had nutritional disorder diagnoses. However, this study did not consider this factor in the analysis. Fourth, those who were not continuously enrolled in insurance were dropped in our analysis that could affect our results. Finally, socioeconomic status such as income and years of education that could affect health care use and spending was not available in the current data and

**Table 5** Regression results on health care spending and use of those with nutritional disorders 1 year following surgery

| Outcome 1 year following surgery | Coefficient (\$)/IRR | *p*-value | 95% CI | |
|---|---|---|---|---|
| Total cost | 41118.00 | <0.01 | 34375.70 | 49182.70 |
| Medical cost | 38165.00 | <0.01 | 30285.80 | 48094.20 |
| Medication cost | 2703.71 | 0.54 | 2160.26 | 3383.86 |
| ED visit* | 1.86 | <0.01 | 1.39 | 2.47 |
| Inpatient admission* | 2.03 | <0.01 | 1.67 | 2.47 |

Other controlled covariates such as age at surgery, BMI at surgery, gender, and surgery type were not shown in the table

*ED visit and inpatient admission were reported in IRR

*The reference group in each regression was those without nutritional disorders 1 year following surgery

**Table 6** Regression results on health care spending and use by number of nutritional disorders 1 year following bariatric surgery

| Outcome 1 year following surgery | Coefficient ($)/IRR | *p*-value | 95% CI | |
|---|---|---|---|---|
| Total cost | | | | |
| No disorder | Reference | | | |
| 1 disorder | 36919.20 | <0.01 | 28145.40 | 48428.10 |
| ≥2 disorders | 44547.50 | <0.01 | 35137.10 | 56478.30 |
| Medical cost | | | | |
| No disorder | Reference | | | |
| 1 disorder | 32875.90 | <0.01 | 23254.90 | 46477.30 |
| ≥2 disorders | 42643.50 | <0.01 | 31453.60 | 57814.30 |
| Medication cost | | | | |
| No disorder | Reference | | | |
| 1 disorder | 3483.65 | 0.32 | 2464.11 | 4925.04 |
| ≥2 disorders | 2224.99 | 0.98 | 1657.26 | 2987.20 |
| ED visit* | | | | |
| No disorder | Reference | | | |
| 1 disorder | 1.64 | 0.01 | 1.15 | 2.34 |
| ≥2 disorders | 2.13 | <0.01 | 1.46 | 3.12 |
| Inpatient admission* | | | | |
| No disorder | Reference | | | |
| 1 disorder | 1.87 | <0.01 | 1.43 | 2.43 |
| ≥2 disorders | 2.07 | <0.01 | 1.63 | 2.61 |

*The reference group in all regressions was those who had no nutritional disorder

Other controlled covariates were not shown in the table

*ED visit and inpatient admission were reported in IRR

was not controlled in the analysis. Fifth, this study included subjects who were covered by private insurance because subjects covered by Medicaid and Medicare were not included in this study, the subjects in this study may be inherently a higher socio-economic status cohort. Therefore, our results may not be generalizable to Medicaid and Medicare population. Lastly, post-operative complications and NDs were intertwined factors that could contribute to higher healthcare costs. However, post-operative complications were not considered in this study.

## Conclusion

Those without pre-operative NDs may have a higher chance of having NDs post-operatively. Taking multivitamins and continues monitoring are necessary to prevent any negative outcomes related to post-operative NDs. Long-term follow-up studies to examine any changes in NDs status and their negative effects will be important.

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## Declarations

**Ethical Approval Statement** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study, formal consent was not required.

**Informed Consent Statement** This does not apply.

**Conflict of Interest** Dr. Cottom reports personal fees and others from Medtronic and GI Windows, outside the submitted work. The other authors declare that they have no conflicts of interest.

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