Title
Body mass index as a correlate of postoperative complications and resource utilization

Journal
The American Journal of Medicine, 102(3)

ISSN
0002-9343

Authors
Thomas, Eric J
Goldman, Lee
Mangione, Carol M
et al.

Publication Date
1997-03-01

DOI
10.1016/s0002-9343(96)00451-2

Peer reviewed

Body Mass Index as a Correlate of Postoperative Complications and Resource Utilization

Eric J. Thomas, MD, MPH, *Boston, Massachusetts,* Lee Goldman, MD, *San Francisco, California,* Carol M. Mangione, MD, MSPH *Los Angeles, California,* Edward R. Marcantonio, MD, SM, *Boston, Massachusetts,* E. Francis Cook, ScD, *Boston, Massachusetts,* Lynn Ludwig, RN, MSN, *Boston, Massachusetts,* David Sugarbaker, MD, *Boston, Massachusetts,* Robert Poss, MD, *Boston, Massachusetts,* Magruder Donaldson, MD, *Boston, Massachusetts,* Thomas H. Lee, MD, MSc, *Boston, Massachusetts*

PURPOSE: To describe the relationship of body mass index (BMI) with postoperative complications and resource utilization.

PATIENTS AND METHODS: Two thousand nine hundred and sixty-four patients 50 years or older undergoing elective noncardiac surgery with an expected length of stay ≥2 days were enrolled in a prospective cohort study to measure major cardiac complications, noncardiac complications, length of stay, and costs. The setting was an urban teaching hospital. A preoperative history, physical, electrocardiogram (ECG), and chart review were performed by study personnel. Postoperative complications were detected by ECGs, creatine kinase and creatine kinase MB levels, and daily chart review. Total costs were obtained from the hospital's computerized database.

RESULTS: Complication rates were not different among BMI groups (underweight <20, normal 20 to 29, overweight 30 to 34, most overweight >34), but patients with BMI 30 to 34 and >34 who underwent abdominal or gynecologic procedures had significantly higher wound infection rates (11% each) than normal weight patients (4.7%) or the underweight (0%). After adjusting for age, race, gender, smoking history, comorbid diseases, procedure type, and insurance status, there were nonsignificant trends toward increased resource utilization by the most overweight patients (BMI >34). These patients stayed 0.8 days longer (*P* = 0.13) and had total costs that were $843 higher (*P* = 0.17) than patients of normal weight (BMI 20 to 29). The underweight patients stayed 0.9 days longer (*P* = 0.23) and had total costs that were $3,150 higher (*P* = 0.04) than patients of normal weight. Quadratic models to test for a U-shaped relationship found no correlation between BMI and length of stay, but did find that BMI was significantly correlated with total costs (*P* = 0.04). This relationship persisted when patients who had complications were excluded from the analysis.

CONCLUSIONS: Overall, BMI was not significantly correlated with postoperative complications or length of stay. However, overweight patients who underwent abdominal or gynecologic procedures had higher wound infection rates, and patients with the highest and lowest BMIs had significantly higher adjusted total costs. *Am J Med.* 1997;103: 277–283. © 1997 by Excerpta Medica, Inc.

From the Division of General Internal Medicine (EJT, ERM, EFC, THL), the Section for Clinical Epidemiology (ERM, EFC, LL, THL), and the Cardiovascular Division (THL), Department of Medicine, and the Departments of Surgery (DS, MD) and of Orthopedic Surgery (RP), Brigham and Women's Hospital and Harvard Medical School, Boston, Massachusetts; the Department of Medicine, (LG) University of California at San Francisco, San Francisco, California; and the Division of General Internal Medicine and Health Services Research, (CMM) Department of Medicine, University of California at Los Angeles School of Medicine, Los Angeles, California.

Supported in part by Grant 1R01-HS06573 from the Agency for Health Care Policy and Research, Rockville, Maryland. Dr. Thomas was supported in part by National Service Research Award 2 T32 PE 1100106.

Requests for reprints should be addressed to Thomas H. Lee, MD, Suite 1150 Prudential Tower, Partners Community HealthCare Inc., 800 Boylston Street, Boston, Massachusetts 02199.

Manuscript submitted March 21, 1996 and accepted in revised form November 18, 1996.

Being overweight, which affects more than one quarter of the US adult population, increases the risk for coronary artery disease, hypertension, diabetes, and other medical diseases.[1,2] However, whether being overweight increases the risk for postoperative complications in the 25 million patients[3] undergoing noncardiac surgery each year is less clear.[4] Some data suggest that overweight patients have a higher rate of postoperative complications and that preoperative weight loss may be beneficial,[4,5] but other data do not support this conclusion.[6,7] In contrast, research on malnourished underweight patients has shown that they have higher risks for postoperative complications and that nutritional support may improve outcomes for the severely malnourished.[8,9]

Length of stay and costs are indirect markers for postoperative complications and an important outcome for physicians and institutions trying to improve their efficiency. Nevertheless, there are almost

0002-9343/97/$17.00
PII S0002-9343(96)00451-2

no data on the effect of body weight on postoperative resource use. One small study from our institution suggested that extremely over and underweight patients had increased postoperative resource use after total hip and knee replacement surgery.[10]

To test the hypothesis that body weight, as measured by body mass index (BMI, weight in kilograms divided by height in meters squared) is correlated with postoperative complications and resource utilization, we analyzed detailed prospective clinical data from a large cohort of patients undergoing major elective noncardiac surgery.

METHODS

Subjects

All patients 50 years or older undergoing elective noncardiac surgery with an expected length of stay ≥2 days were eligible for the study. These criteria were used to enroll a population with a relatively high risk of postoperative complications. Patients who had more than one major elective procedure during their admission were excluded from this analysis. Of 180 surgeons contacted, 178 (99%) gave permission to the investigators to approach their patients for participation in the study. During the study period (November 1, 1990 to September 10, 1993), 80% of the patients eligible for enrollment were approached. On days of high surgical volume, study personnel were unable to approach all eligible patients. Because eligible patients were selected from the hospital's surgical schedule (which listed only name, medical record number, age, surgeon, and procedure), study personnel could not have selectively enrolled patients based on their comorbid illnesses or BMI.

Of 3,139 patients who were approached, 391 declined to participate in the full study protocol, which included collection of health status data not used in this report. However, sufficient clinical data were available from the medical record for 216 of these patients to allow their inclusion in this analysis. The 175 patients who were excluded had statistically significant differences, but not clinically significant differences in BMI (24.4 ±5.0 versus 26.2 ± 5.0, P = 0.0001). They had similar ages (67.6 ± 9 versus 66.9 ± 10 for those included in the analysis, P = 0.3), but nonconsenters were more likely to be male (57% [n = 100] versus 47% [n = 1400], P = 0.001), nonwhite (28% [n = 49] versus 6% [n = 192], P = 0.001), and they were more likely to have more than one comorbid illness (72% [n = 126] versus 65% [n = 1935], P = 0.004). These 175 nonconsenters had longer lengths of stay (10.8 ± 11 days versus 8.0 ± 8 days, P <0.0001), but a trend toward fewer noncardiac complications (8.0% versus 12.9%, P = 0.06) The study protocol was approved by the institutional review board, and informed consent was obtained prior to enrollment.

Data Collection

A history, physical examination, electrocardiogram (ECG), and chart review were performed by study personnel preoperatively. Data recorded included the cardiac history, medical comorbidities, medications, smoking history, physical examination findings, and ECG results.

Height and weight were obtained by patient self report or by measurement on hospital scales. In other studies, the correlation between self reported and measured height and weight was greater than 0.95.[11,12] BMI was used as the measure of body weight, and based on published recommendations was categorized as follows: less than 20, 20 to 29, 30 to 34, and greater than 34.[13]

Data to determine the presence of comorbid diseases were obtained from preoperative interviews, chart review, and ECGs. The comorbid diseases were defined as follows: coronary artery disease—history of myocardial infarction or angina, or Q waves on the preoperative ECG; congestive heart failure—history of congestive heart failure or cardiac pulmonary edema, or a third heart sound on physical examination; hypertension—history of hypertension; diabetes—history of diabetes and taking a oral hypoglycemic or insulin; cerebrovascular accident—history of stroke; peripheral vascular disease—history of peripheral vascular disease; pulmonary disease—history of chronic obstructive pulmonary disease or asthma; chronic renal insufficiency—history of chronic renal insufficiency; renal failure requiring dialysis; chronic liver disease—history of chronic liver disease; arthritis—history of osteoarthritis or rheumatoid arthritis; and cancer—history of solid tumor, lymphoma, or leukemia.

Intraoperative data were obtained from the anesthesia flow sheets and surgeons' notes. The followup protocol included measuring creatine kinase (CK) and CK-MB levels in the recovery room, on the night of surgery, and on the first 2 postoperative days if the patient remained hospitalized; and an ECG in the recovery room and on postoperative days 3 and 5. Charts were reviewed daily by study personnel for the occurrence of complications.

Classification of Outcomes

The presence or absence of cardiac complications was determined by a reviewer who was blinded to preoperative clinical data. This reviewer used postoperative clinical data including copies of relevant ECGs and other records. "Major cardiac complications" were defined as the occurrence of any of the following in the hospital during or after the surgery: (1) cardiac death; (2) acute myocardial infarction; (3) pulmonary edema; (4) ventricular fibrillation; or (5) complete heart block. Criteria for perioperative myocardial infarction included: (1) new Q wave of greater than or equal to 0.04 seconds long; (2) CK-MB levels greater than 5% of an elevated total CK with a typical rise and fall in CK-MB levels; or (3) CK-MB levels greater than 3% of an elevated total CK in the setting of ECG changes consistent with ischemia. Pulmonary edema was classified as present if the radiologist used this term in the official chest x-ray reading and there was a consistent physical examination. Major noncardiac complications included: (1) pulmonary embolism documented by autopsy, angiography or a high probability ventilation-perfusion scan; (2) respiratory failure requiring intubation for ≥2 days or reintubation; (3) noncardiac pulmonary edema; (4) lobar pneumonia confirmed by chest x-ray and requiring antibiotic therapy; (5) acute renal failure requiring dialysis; or (6) cerebrovascular accident with new neurologic deficits.

Other complications were detected by daily chart review and defined as follows: Wound infection: wound erythema or purulent discharge noted in the chart requiring treatment with antibiotics or surgical drainage; urinary tract infection: the presence of a positive urine culture; decubitus ulcer: the presence of skin breakdown noted in the chart by physicians or nurses; and deep venous thrombosis: the presence of thrombosis documented by doppler ultrasonography or venogram.

Postoperative length of stay was calculated from the collected data, and cost estimates were calculated using charge-to-cost ratios for specific cost centers from the hospital's computerized data base. Total costs were measured beginning on the day of surgery.

Statistical Analysis

Statistical analyses were performed using SAS software (SAS Institute Inc, Cary, North Carolina). Frequency distributions were determined for all variables and categorized by BMI. Significant differences in the distribution of variables (including postoperative complications) by BMI were said to exist if the two-tailed P value was <0.05 as determined by chi-square test for association or Fisher's exact test for categorical variables, or the Kruskal Wallis test for non-normal multicategory continuous variables.

To determine its relationship with total costs, BMI was entered as a quadratic function in multiple linear regression models. A quadratic function was chosen for BMI because of the suspected U-shaped relationship of this variable with total cost. The model also included the potential confounders age (entered as a continuous variable), race, gender, insurance status, smoking history (current, past, never), comorbid diseases, and procedures.

To adjust for the effect of procedure on total costs, each type of procedure was represented by an indicator variable in the multivariate model: back and neck surgeries; orthopedic procedures including joint replacements, joint fusions, amputations, and other orthopedic surgery; abdominal aortic aneurysm repair; other vascular procedures; abdominal procedures, including biliary, intestinal, gastric, splenic, pancreatic, and exploratory surgery; urologic procedures, including cystectomy, nephrectomy, prostatectomy, and transurethral prostatectomy; gynecologic procedures, including vaginal and abdominal hysterectomy, rectocele repair, and cystocele repair; thoracic procedures including esophagectomy, pneumonectomy, lobectomy, thorascopic wedge resection, and other thoracic procedures; and "other" procedures including mastectomy, lumpectomy, thyroidectomy, parathyroidectomy, skin grafts, hernia repair, craniotomy, and other general surgery.

The relationship between length of stay and BMI was also analyzed with BMI as a quadratic function. The model also included the potential confounders age (entered as a continuous variable), race, gender, insurance status, smoking history (current, past, never), and comorbid diseases. To adjust for the effect of procedure on length of stay, the 1991 national average length of stay[14] for the diagnosis related group (DRG) without complications associated with the patient's primary procedure was subtracted from that patient's actual length of stay to calculate a patient-specific outcome variable called "deviation from mean DRG length of stay."

The significance of the conditional relationship of BMI (expressed as a quadratic function) to either of these outcomes was tested using a partial F-test.

Two other linear regression models were used to test for a relationship between BMI and length of stay and total costs. Each of these models had the same independent variables described above, but instead of entering BMI as a quadratic function, it was grouped into the four categories described above. Two comparisons were made in each model using a least-squares means procedure: First, we compared total costs and length of stay for the average patient in the BMI 20 to 29 category (normal weight) and the BMI >34 category (most overweight); second, we made the same comparison for the average patient in the BMI 20 to 29 category and the BMI <20 category (underweight). Because total costs and length of stay were not normally distributed, they were con-

TABLE I

Patient Characteristics By Body Mass Index

Variable	Body Mass Index <20	20–29	30–34	>34	P Value*
Number of Subjects	234 (8%)	2202 (74%)	368 (12%)	160 (6%)	
Mean age ± SD	68 ± 10	67 ± 9	66 ± 8	64 ± 8	0.0001
Sex					
Female	164 (70%)	1087 (49%)	186 (51%)	109 (68%)	<0.0001
Race					
Caucasian	220 (94%)	2073 (94%)	336 (91%)	143 (89%)	0.03
Insurance					
Private	172 (74%)	1706 (77%)	263 (71%)	103 (64%)	<0.0001
HMO	41 (17%)	327 (15%)	71 (19%)	32 (20%)	0.06
Medicare only	15 (6%)	111 (5%)	23 (6%)	18 (11%)	0.009
Other	6 (3%)	58 (3%)	11 (3%)	7 (4%)	0.6
Comorbid Diseases					
Degenerative joint disease	57 (24%)	538 (24%)	81 (22%)	46 (29%)	0.4
Hypertension	77 (33%)	919 (42%)	191 (52%)	97 (61%)	<0.0001
Cancer	42 (18%)	363 (16%)	56 (15%)	25 (16%)	0.8
Coronary artery disease	58 (25%)	648 (29%)	109 (30%)	46 (29%)	0.5
Peripheral vascular disease	11 (5%)	88 (4%)	11 (3%)	6 (4%)	0.73
Diabetes	12 (5%)	186 (8%)	45 (12%)	33 (21%)	<0.0001
Emphysema/Asthma	39 (17%)	287 (13%)	47 (13%)	23 (14%)	0.4
Congestive Heart Failure	23 (10%)	143 (6%)	19 (5%)	9 (6%)	0.14
Stroke	10 (4%)	114 (5%)	18 (5%)	7 (4%)	0.9
Liver Disease	5 (2%)	16 (1%)	3 (1%)	0 (0%)	0.08
Renal failure	0	6 (<1%)	0	1 (<1%)	0.5
Smoking History					
Never	77 (33%)	770 (35%)	144 (39%)	60 (37%)	
Past	90 (38%)	1093 (50%)	172 (47%)	79 (49%)	
Current	67 (29%)	339 (15%)	52 (14%)	21 (13%)	<0.0001
Procedures					
Orthopedic	50 (21%)	632 (29%)	161 (44%)	67 (42%)	<0.0001
Abdominal	34 (14%)	249 (11%)	40 (11%)	19 (12%)	0.5
Thoracic	43 (18%)	293 (13%)	37 (10%)	8 (5%)	<0.0001
Urologic	8 (3%)	221 (10%)	31 (8%)	13 (8%)	0.009
Gynecologic	16 (7%)	110 (5%)	12 (3%)	16 (10%)	0.008
Vascular	41 (17%)	321 (15%)	32 (9%)	13 (8%)	0.001
Back and Neck	7 (3%)	109 (5%)	17 (5%)	9 (6%)	0.6
Abdominal Aneurysm Repair	13 (6%)	112 (5%)	12 (3%)	5 (3%)	0.3
Other	16 (9%)	120 (7%)	21 (7%)	7 (6%)	0.7

*Chi-square test for association or Kruskall Wallis test.

verted to a log scale for parametric statistical analyses.

RESULTS

Patient Population

The group was predominantly elderly (mean +SD age 67+9 years), white (94%), and privately insured (76% indemnity, 16% HMO). Common comorbid diseases included hypertension (43%), coronary artery disease (29%), degenerative joint disease (24%), and malignancy (16%). When categorized by BMI, the most overweight (BMI >34) were younger, and more likely to be female and nonwhite; they were less likely to have private insurance or to smoke, and they were more likely to have hypertension and diabetes.

The most common procedures were orthopedic operations (38%). Of these 910 orthopedic procedures, 340 were total hip replacements, and 402 were total knee replacements. When categorized by BMI, the most overweight were more likely to have orthopedic and gynecologic procedures and less likely to have thoracic or vascular procedures. (**Table I**).

Postoperative Complications

The complication rates were low in the cohort as a whole and in all categories of BMI (**Table II**). There were no statistically significant differences in complication rates among the body mass groups. Compared with normal weight patients (BMI 20 to 29), the most overweight patients (BMI >34) had statistically nonsignificant trends toward increased un-

TABLE II

Complications By Body Mass Index

Complication	All Subjects	Body Mass Index <20	20–39	30–34	>34	Relative Risk for BMI >34 Compared to BMI 20–29 (95% CI)
	N = 2964	234	2202	368	160	
Cardiac	64 (2%)	6 (3%)	46 (2%)	6 (2%)	6 (4%)	1.8 (0.8, 4.1)
Wound Infection	77 (3%)	5 (2%)	53 (2%)	13 (3%)	6 (4%)	1.6 (0.7, 3.7)
Pneumonia	20 (1%)	1 (<1%)	17 (1%)	2 (<1%)	0	
Urinary Tract Infection	52 (2%)	3 (1%)	42 (2%)	6 (2%)	1 (1%)	0.3 (0.4, 2.4)
Decubitus Ulcer	15 (<1%)	2 (1%)	9 (<1%)	2 (1%)	2 (1%)	3.1 (0.7, 14.4)
Deep Venous Thrombosis	26 (1%)	1 (<1%)	19 (1%)	4 (1%)	2 (1%)	1.4 (0.3, 6.2)
Pulmonary Embolism	5 (<1%)	0	3 (<1%)	2 (<1%)	0	
Stroke	14 (<1%)	0	14 (1%)	0	0	
Renal Failure	7 (<1%)	0	6 (<1%)	0	1 (<1%)	2.3 (0.3, 19.0)
Respiratory Failure	33 (1%)	2 (1%)	23 (1%)	5 (1%)	3 (2%)	1.8 (0.5, 5.9)
Noncardiac Pulmonary edema	0	1	0	0	0	
Death	16 (<1%)	2 (<1%)	12 (<1%)	1 (<1%)	1 (<1%)	1.1 (0.1, 8.8)
Total*	267 (14%)	18 (8%)	197 (9%)	35 (9%)	17 (11%)	1.2 (0.7, 1.9)

*The sums of the columns do not equal the totals because some patients had more than one complication.

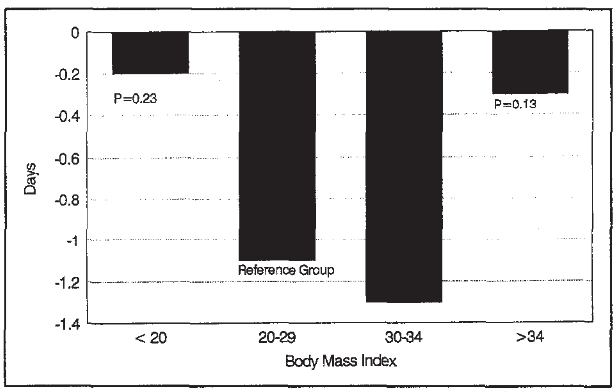

Figure 1. Deviation from average diagnosis related group length of stay (adjusting for age, race, gender, comorbid diseasses, insurance, and smoking history). The *Pe* value is for the comparison of body mass index 20 to 29 to >34 and 20 to 29 to <20.

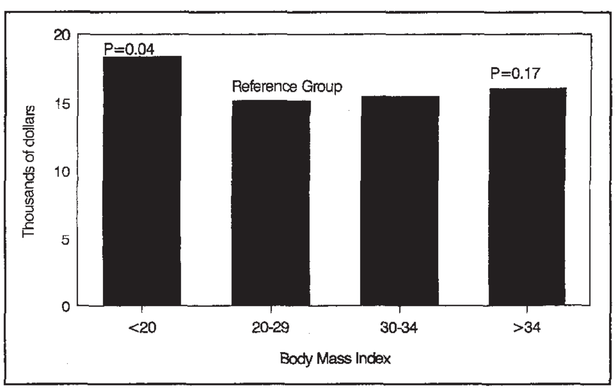

Figure 2. Total costs (adjusted for procedure, age, race, gender, comorbid diseases, insurance, and smoking history). The *P* value is for the comparison of body mass index 20 to 29 to >34 and 20 to 29 to <20.

adjusted relative risks for 7 of the 11 complications: major cardiac complications, death, wound infections, decubitus ulcers, deep venous thromboses, renal failure, and respiratory failure. Patients with BMI 30 to 34 and >34 who underwent abdominal or gynecologic procedures had wound infection rates of 11% each. These rates were significantly higher than normal weight patients (4.7%) or the underweight (0%).

Postoperative Resource Utilization

The unadjusted mean length of stay (±SD) for the entire patient population was 8.0 ± 8 days. In models adjusting for age, race, gender, comorbidity, smoking history, and insurance status, patients of normal weight stayed 1.1 days less than the national average for the DRG associated with their procedure, and patients with BMI >34 (the most overweight) stayed 0.3 days less than the national average for the DRG for this procedure. Therefore, the most overweight stayed 0.8 days longer than patients of normal weight (P=0.13) (Figure 1). Patients with BMI <20 (underweight) stayed 0.2 days less than the national average for their DRG compared to normal weight patients who stayed 1.1 days less. Therefore, the underweight patients stayed 0.9 days longer than normal weight patients (P = 0.23) (Figure 1). A model with BMI as a quadratic function found no significant relationship between BMI and length of stay (P = 0.58).

After adjusting for procedure, age, race, gender, comorbidity, smoking history, and insurance status, patients with a BMI >34 had total costs that were $843 higher than patients with a BMI of 20 to 29 (P = 0.17), and patients with a BMI <20 had total costs that were $3,151 dollars higher ($P$ = 0.04) (Figure 2). A model with BMI as a quadratic function found a significant relationship between BMI and total costs (P = 0.04). This relationship remained significant after excluding all patients who had a complication ($P = 0.01$).

Discussion

Our study of patients undergoing major elective noncardiac surgery found no difference in complication rates among the four BMI groups. After adjusting for age, race, gender, smoking history, comorbid diseases, procedure, and insurance status, the most overweight patients (BMI >34) and the underweight patients (BMI <20) had statistically insignificant increases in postoperative lengths of stay. Total costs were higher only for the underweight patients. When BMI was entered as a quadratic function to test if the relationship between BMI and length of stay and total costs was U-shaped, BMI was significantly related only to total costs, with underweight and overweight patients having higher costs.

The most overweight group (BMI >34) had a mean BMI of 40.5 ± 5 for women, and 38.1 ± 3 for men. To attain these BMIs, an average height woman (5'4", 1.6 meters) would weigh 238 pounds (107 kilograms, 82% above ideal body weight), and an average height man (5'9", 1.7 meters) would weigh 244 pounds (110 kilograms, 61% above ideal body weight). The mean BMI for the underweight group (BMI <20) was 18.2 ±1.7 for women and 18.5 ± 1.5 for men. To attain these BMIs, an average height woman would weigh 103 pounds (46 kilograms, 21% below ideal body weight) and an average height man would weigh 119 pounds (54 kilograms, 21% below ideal body weight).

Previous studies of overweight patients undergoing noncardiac surgery have reported higher mortality rates,[15] wound infection rates,[16-18] respiratory complications,[19-23] and thromboembolic complications,[24-30] but most of these studies were limited by small sample sizes, and failure to adjust for the type of procedure or comorbid diseases. Two more recent articles on the topic[4,5] also suggest that overweight patients have an increased risk of postoperative complications. These papers even recommend weight loss prior to surgery but neither cite evidence to support this view. In fact, one of these papers also concludes that surgery should not be denied based on weight alone.[5] Other studies and literature reviews suggest that the overweight patient is not at higher risk,[6,7] and our study lends support to this conclusion.

Many of the studies suggesting higher complication rates were of overweight patients undergoing abdominal or gynecologic procedures. Overall, we found no significant increases in complication rates for the most overweight group (BMI >34) when compared to normal weight patients. The 87 overweight patients (BMI >30) who had abdominal or gynecologic procedures had no pneumonias or pulmonary emboli. Furthermore, there was only 1 deep venous thrombosis in the 30 to 34 group. However, patients with BMI 30 to 34 and >34 undergoing abdominal or gynecologic procedures had wound infection rates of 11% each. These rates were significantly higher than normal weight patients (4.7%) or the underweight (0%).

Although overall complication rates and lengths of stay for the most overweight group were not higher than the rates for normal weight patients, we did find a significant U-shaped relationship between BMI and total costs. This relationship persisted after excluding all patients who had complications suggesting that other factors may be causing the increased costs. For example, it is possible that the number of complications is not significantly greater in underweight or the most overweight patients, but the most over and underweight patients had increased total costs because more resources were expended on these groups to prevent complications. The increased prevalence of certain comorbid diseases in the over- and underweight patients could also have increased costs, even though we attempted to adjust for comorbidity in our analysis.

Low complication rates were also found in a study of 3,174 overweight patients who had surgery (mostly vertical banded gastroplasty or roux gastric bypass) as a treatment for obesity: 0.35% had deep venous thrombosis, 4.5% had respiratory complications, 1.6% had wound infection, 0.03% had pulmonary embolism, and 0.41% had cardiac complications.[6] Although the patients in that study were relatively young and healthy, and none of our patients underwent those specific procedures, it indirectly supports our finding that overweight patients can be operated on with low overall risk.

Research on malnourished underweight patients suggests that they are at higher risk for postoperative complications.[8,9] Our underweight patients had nonsignificant trends towards higher rates of cardiac complications and decubitus ulcers. The overall complication rate for these patients may have been lower than expected because they were not necessarily malnourished.

Although this is one of the largest cohorts of elective noncardiac surgery patients to be described, the power of our analyses was limited by small sample sizes for the most overweight and the underweight groups and our low complication rates. When comparing the normal weight to the most overweight patients, we had 80% power to detect a $4,100 increase in total costs, a 1.6 day increase in length of stay, and a 1.8 relative risk for all complications between the most overweight and normal weight patients. Furthermore, this was a study of relatively healthy patients undergoing a variety of elective procedures.

Our results may not be generalizable to patients with more comorbid diseases, patients having nonelective or ambulatory surgeries, or to some specific surgical procedures. Although we adjusted for the effect of procedure on length of stay and total costs in multivariate models, it is possible that a different mix of procedures undergone by patients of differing BMIs may have confounded the relationship between BMI, length of stay, and total costs. Also, we did not adjust for severity of the underlying illnesses for which the procedures were performed.

While not affecting the validity of our conclusions for this cohort, our observation that nonconsenters had more comorbid illnesses and longer lengths of stay reinforces the importance of limiting the generalizability of this study to patients with similar characteristics. Generalizability is also limited by the possibility that surgeons and anesthesiologists selected relatively healthy overweight patients to have elective surgery.

The findings in this report nevertheless have implications for physicians, patients, and policy makers. Even if there is more resource use and an increased risk for complications in the overweight or underweight, the absolute differences are small, lower than what many physicians might expect, and probably confined to patients with a BMI >34 and <20. These data suggest that being overweight or underweight itself is not a reason to deny elective noncardiac surgery. It is known that the malnourished underweight patient is at risk for poor outcomes, but more research is necessary to determine which, if any, subpopulations of overweight patients are at a substantially higher risk for postoperative complications.

REFERENCES

1. Williamson DF. Descriptive epidemiology of body weight change in US adults. *Ann Intern Med.* 1993;119(suppl):646S–649S.
2. Pi-Sunyer FX. Medical hazards of obesity. *Ann Intern Med.* 1993;119(suppl):655S–660S.
3. National Center for Health Statistics: Vital Statistics of the United States. 1980. Vol. II-Mortality, Part A. DHHS Publication No. (PHS) 85-1101. Hyatsville, MD: NCHS, U.S. Public Health Service, 1985.
4. Pasulka PS, Bistrian BR, Benotti PN. The risks of surgery in obese patients. *Ann Intern Med.* 1986;104:540–546.
5. Harris WH, Sledge CB. Total hip and total knee replacement. *NEJM.* 1990;323:801–807.
6. Mason EE, Renquist KE, Jiang D. Perioperative risks and safety of surgery for severe obesity. *Am J Clin Nutr.* 1992;55:573S–576S.
7. Jaginti JJ, Goldstein WM, Williams CS. A comparison of the perioperative morbidity in total joint arthroplasty in the obese and nonobese patient. *Clin Orthop.* 1993;289:175–179.
8. Dempsey DT, Mullen JL, Buzby GP. The link between nutritional status and clinical outcome: Can nutritional intervention modify it? *Am J Clin Nutr.* 1988;47(suppl 2):352S–356S.
9. The Veterans Affairs Total Parenteral Nutrition Cooperative Study Group. Perioperative total parenteral nutrition in surgical patients. *NEJM.* 1991;325:525–532.
10. Epstein AM, Read JL, Hoefer M. The relation of body weight to length of stay and charges for hospital services for patients undergoing elective surgery: A study of two procedures. *Am J Public Health.* 1987;77:993–997.
11. Stunkard AJ, Albaum JM. The accuracy of self-reported weights. *Am J Clin Nutr.* 1981;34:1593–1599.
12. Willet WC, Browne ML, Bain C, et al. Relative weight and risk of breast cancer aming premenopausal women. *Am J Epidemiol.* 1985;122:731–740.
13. Bray GA. Pathophysiology of obesity. *Am J Clin Nutr.* 1992;55(suppl 1):488S–494S.
14. Federal Register 1992;57:39879–39893.
15. Prem KA, Mensheha NM, McKelvey JL. Operative treatment of adenocarcinoma of the endometrium in obese women. *Am J Obstet Gynecol.* 1965;92:16–22.
16. Postlethwait RW, Johnson WD. Complications following surgery for duodenal ulcer in obese patients. *Arch Surg.* 1972;105:438–440.
17. Pemberton LB, Manax WG. Relationship of obesity to postoperative complications after cholecystectomy. *Am J Surg.* 1971;121:87–90.
18. Pitkin RM. Abdominal hysterectomy in obese women. *Surg Gynecol Obstet.* 1976;142:532–536.
19. Latimer RG, Dickman M, Day WC, et al. Ventilatory patterns and pulmonary complications after upper abdominal surgery determined by preoperative and postoperative computerized spirometry and blood gas analysis. *Am J Surg.* 1971;122:622–632.
20. Gould AB Jr. Effect of obesity on respiratory complications following general anesthesia. *Anesth Analg.* 1962;41:448–452.
21. Thoren L. Post-operative pulmonary complications: Observations on their prevention by means of physiotherapy. *Acta Chir Scand.* 1954;107:193–205.
22. Hansen G, Drablos PA, Steinert R. Pulmonary complications, ventilation and blood gases after upper abdominal surgery. *Acta Anesthesiol Scand.* 1977;21:211–215.
23. Garibaldi RA, Britt MR, Coleman ML, et al. Risk factors for postoperative pneumonia. *Am J Med.* 1981;70:677–680.
24. Snell AM. The relation of obesity to fatal post-operative pulmonary embolism. *Arch Surg.* 1927;15:237–244.
25. Coon WW, Coller FK. Some epidemiologic considerations of thromboembolism. *Surg Gynecol Obstet.* 1959;109:487–501.
26. Breneman JC. Postoperative thromboembolic disease: computer analysis leading to statistical prediction. *JAMA.* 1965;193:106–110.
27. Clayton JK, Anderson JR, McNicol GP. Preoperative prediction of postoperative deep vein thrombosis. *BMJ.* 1976;2:910–912.
28. Rakoczi I, Chamone D, Collen D, Verstraete M. Prediction of postoperative leg-vein thrombosis in gynaecologic patients. *Lancet.* 1978;1:509–510.
29. Kakkar W. The current status of low dose heparin in the prophylaxis of thrombophlebitis and pulmonary embolism. *World J Surg.* 1978;3:3–18.
30. Kakkar W, Howe CT, Nicolaides AN, et al. Deep vein thrombosis of the leg: Is there a "high-risk" group? *Am J Surg.* 1970;120:527–530.