ONLINE FIRST

The Relationship Between Body Mass Index and 30-Day Mortality Risk, by Principal Surgical Procedure

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Objective: To examine the relationship between body mass index (BMI; calculated as weight in kilograms divided by height in meters squared) and 30-day mortality risk among patients in the participant use data file database of the American College of Surgeons National Surgical Quality Improvement Program. Obesity is a prevalent chronic disease in the United States, and general and vascular surgeons are caring for an increasing population of obese patients.

Design: Multivariable logistic regression analysis was used to assess the statistical significance of the relationship between BMI and mortality, with adjustments for patient-level differences in overall mortality risk and principal operating procedures. Odds ratios with 95% CIs were calculated to measure the relative difference in mortality by BMI quintile, with reference to the middle quintile of the BMI. The overall significance of the BMI and of the other covariates was measured using the Wald χ^2 test statistic. A separate multivariable logistic regression model was developed to assess the significance of the interaction between BMI and primary procedure.

Setting: A total of 183 sites.

Patients: Patients with major surgical procedures reported in the participant use data file database of the American College of Surgeons National Surgical Quality Improvement Program.

Results: The data included 189 533 cases of general and vascular surgical procedures reported in 2005 and 2006 for patients with known overall probabilities of death. Among these, 3245 patients died within 30 days of their surgery (1.7%). Patients with a BMI of less than 23.1 demonstrated a significant increased risk of death, with 40% higher odds compared with patients in the middle range for BMI (26.3 to <29.7). Important differences in the association between BMI and mortality risk occur by type of primary procedure.

Conclusions: Body mass index is a significant predictor of mortality within 30 days of surgery, even after adjusting for the contribution to mortality risk made by type of surgery and for a specific patient's overall expected risk of death.

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OBESITY IS THE MOST PREVALENT chronic disease in the United States.[1] Recent reports suggest that the prevalence of obesity among US adults has increased more than 100% since 1990.[2] Current estimates indicate that 63.6 million adults (31.4%) in the United States are obese[3] and that the prevalence of obesity among Americans is continuing to increase.[4] Increases in obesity-related diseases and obesity-related mortality have accompanied this trend.[5-7] Some studies indicate that obesity is associated with a 20-year decrease in average life expectancy.[8] This analysis examines the relationship between obesity (as measured by body mass index [BMI; calculated as weight in kilograms divided by height in meters squared]) and surgical mortality.

The effect of BMI on perioperative mortality risk has been examined in several prior studies. Many studies indicate that there is no statistically significant association between obesity and perioperative mortality. No difference in mortality was reported for obese patients undergoing general surgery[9] or a urologic, gynecologic, or thoracic surgical procedure.[10] No difference in mortality was reported for obese patients among elective, non–cardiac surgery patients.[11] Obesity also was not associated with increased mortality in patients undergoing coronary artery bypass graft surgery,[12] elective laparoscopic colorectal surgery,[13,14] pancreatic resec-

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tion,[15] pancreaticoduodenectomy,[16] or exploratory laparotomy for adenocarcinoma of the endometrium.[17] A few selected studies[18,19] have also found no difference in mortality between obese and extremely obese patients undergoing a laparoscopic Roux-en-Y gastric bypass procedure, although that has not been the overall experience in the bariatric surgery literature.

Prior studies, however, have found that obese patients undergoing a renal transplant were at significantly higher risk of death at 1 year[20] and at 5 years postoperatively.[21,22] Significantly higher mortality rates were also demonstrated for obese patients after rectal resection.[23]

Patients at the extremes of BMI undergoing a coronary artery bypass graft were found to have a higher risk of death than normal-weight patients.[24-26] Underweight patients have also been reported to have an increased risk of perioperative death following major intra-abdominal cancer surgery[27] and following percutaneous transluminal coronary angioplasty.[28]

Although most studies do not show a difference in mortality between obese and nonobese adult surgical patients, these studies have important limitations, including small numbers of patients, predetermined grouping criteria of levels of BMI, and limited length of follow-up. Few studies have made adjustments for the interaction between BMI and mortality or between BMI and type of surgery.

General and vascular surgeons are treating an increasing population of obese patients for non–weight loss procedures. A better understanding of the relationship between perioperative mortality risk and BMI is needed. Our study takes advantage of the information available about BMI and mortality risk in the large population of patients in the American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) data set with broad coverage of standard general surgical procedures.

METHODS

Our study examines the relationship between BMI and 30-day mortality among patients who underwent a major surgical procedure that was reported in the ACS NSQIP participant use data file for procedures performed in either 2005 or 2006 for patients from 183 sites.[29,30] The ACS NSQIP data are abstracted from the medical records at each site according to a protocol implemented using Web-based software. Participating sites submit cases under varying sampling procedures and case inclusion and exclusion criteria. Hospitals with a high volume of procedures reported the first 40 consecutive cases meeting the inclusion and exclusion criteria for 42, 8-day cycles each year. Hospitals with a low volume of surgical patients submit data for all cases, with a minimum of 900 cases annually. Reported patient data are audited and assessed for accuracy and interrater reliability. The ACS NSQIP data do not include identifying information for individual patients or for participating sites. This research was reviewed and approved as exempt human subject research by the University of Virginia institutional review board.

Baseline differences in mortality risk were measured for each patient in the study population using the ACS NSQIP probability of 30-day mortality risk score. The score is calculated using values for more than 30 demographic characteristics, comorbidities, and preoperative laboratory values measured for each patient. Example characteristics include serum albumin level, blood urea nitrogen level, white blood cell count, American Society of Anesthesia class, presence of disseminated cancer, and patient age in years. The mortality prediction models developed in the ACS NSQIP data have been demonstrated to obtain excellent statistical performance.[31-34]

A patient's BMI was measured using the following nonmetric conversion formula: BMI = [(weight in pounds/(height in inches)^2)] $\times$ 703. Patient BMI values are often grouped into categories for convenient interpretation. Standard thresholds of BMI, obtained from analysis of data collected from large populations of generally healthy adults, classify individuals into the following groups: underweight ($<$18.5), normal (18.5 to $<$25), overweight (25 to $<$30), and obese ($\geq$30).[35] However, these threshold values are not directly relevant to our population of patients who underwent major surgery because the overall distribution of values is different from that of the general population. Instead of these standard thresholds, our study identified the actual quintiles of the distribution of BMI values in the study population.

The principal operative procedure is identified in the ACS NSQIP by *Current Procedural Terminology* codes. The principal operative procedure is defined as the most complex procedure performed by the primary operating team. Categories of principal operating procedures were defined by grouping *Current Procedural Terminology* codes using the Clinical Classifications Software for Services and Procedures, which arranges the codes into 244 clinically coherent, mutually exclusive categories.[36]

Multivariable logistic regression analysis was used to measure the independent effect of BMI quintile on mortality risk, adjusted for the concurrent effects of differences in procedures performed and for differences in baseline mortality risk associated with the ACS NSQIP mortality risk adjustment score. The statistical significance and magnitude of the relative difference in the adjusted odds of mortality were assessed for each BMI quintile, with the middle quintile serving as the reference point for these comparisons. Odds ratios (ORs) with 95% CIs were calculated for each BMI quintile, with reference to the middle quintile of BMI values. Statistically significant effects (at the $P > .05$ level) are represented by CIs that exclude 1.0, which is the ratio obtained when the effects of one group are equal to the effects of the reference group. The overall significance of BMI grouped by quintiles and of the other covariates in the model was measured using the Wald χ^2 test statistic, which is used to test the null hypothesis that there is no significant difference between groups in the mean estimated probability of death.

The independent effect on mortality risk of the type of procedure was similarly assessed, with adjustments for the concurrent effects of differences in BMI quintile and for differences in baseline mortality risk measured using the ACS NSQIP. The statistical significance and magnitude of the relative difference in the adjusted odds of mortality were assessed for each type of procedure performed, referent to the average mortality risk in the study population. Odds ratios with 95% CIs were calculated for each procedure using the Wald χ^2 test statistic.

Multivariable logistic regression analysis was also used to assess the statistical significance of differences in the effect of BMI on mortality by category of principal operating procedure. The original multivariable model was reformulated to include an additional covariate representing the interaction between BMI and each type of principal operating procedure. Assessment of the statistical significance of this interaction covariate provides an empirical test of whether or not there are meaningful differences in the effect of BMI on mortality across different types of principal operating procedures.

The statistical significance of the effect of principal operating procedure was also assessed separately for patients in each quintile of BMI, adjusted for baseline mortality risk using the ACS NSQIP score. Relative differences in the contribution to model

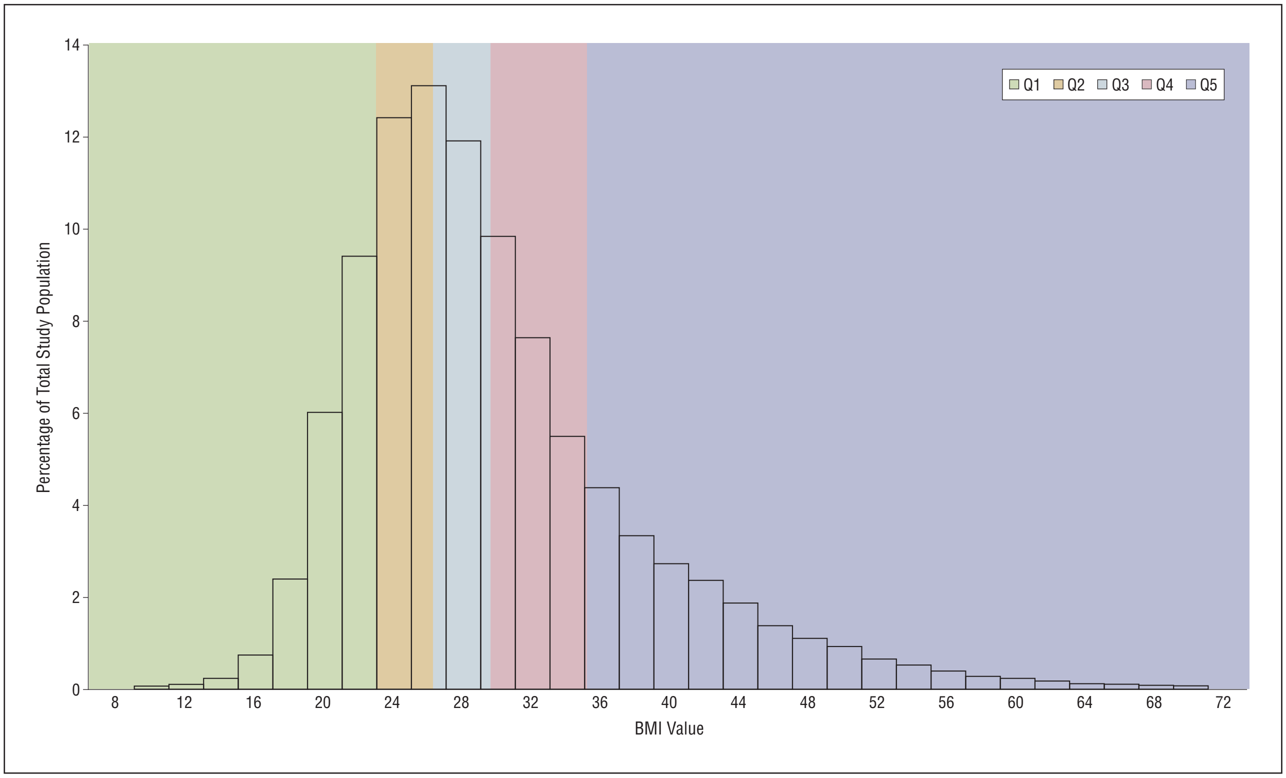

Figure. Distribution of the percentage of the total study population grouped by body mass index (BMI; calculated as weight in kilograms divided by height in meters squared) values within increments of 2 units of BMI. The horizontal axis displays BMI values at the midpoint of each plotted group. The vertical axis plots the percentage of the total study population included by each group. Quintiles of the distribution of BMI values are identified by portions of the distribution separated by dotted lines located at the following thresholds: 23.1, 26.3, 29.7, and 35.3. For example, patients in the first quintile (Q1) of the study population had a BMI of less than 23.1.

Table 1. BMI Quintile Frequencies, Number of Deaths, and Adjusted Odds of Mortality for Patients in the Participant Use Data File Database of the ACS NSQIP

BMI Quintile	Patients, No.	Deaths, No. (%)	AOR (95% CI)[a]	*P* Value[b]
Quintile 1 (<23.1)	38 025	1073 (2.8)	1.40 (1.25-1.58)	<.001
Quintile 2 (23.1 to <26.3)	37 697	680 (1.8)	1.11 (0.98-1.26)	.07
Quintile 3 (26.3 to <29.7)	37 933	562 (1.5)	1 [Reference]	NA
Quintile 4 (29.7 to <35.3)	37 989	539 (1.4)	1.02 (0.89-1.17)	.99
Quintile 5 (≥35.3)	37 889	391 (1.0)	0.91 (0.78-1.06)	.26

Abbreviations: ACS, American College of Surgeons; AOR, adjusted odds ratio; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); NA, not applicable; NSQIP, National Surgical Quality Improvement Program.

[a] Calculated with adjustments for the concurrent effects of differences in baseline mortality risk (ACS NSQIP probability of death) and for type of principal operating procedure.

[b] Determined by use of the Wald χ^2 test statistic.

explanatory power made by principal operating procedure, compared with that made by baseline mortality risk, were made by comparing the relative magnitudes of the Wald χ^2 test statistic obtained across groups of patients in different BMI quintiles.

RESULTS

The ACS NSQIP data file included data for 211 407 cases submitted by 183 sites. Probabilities of mortality were reported for 189 533 cases with general and vascular surgical procedures (reported in 2005 and 2006). There were 3245 patients who died within 30 days of their surgery (1.7%).

Our **Figure** presents a plot of the exact distribution of BMI values measured for the study population, with percentages represented for patients grouped within 2 BMI units. Quintiles of the distribution of BMI values are plotted at the following thresholds: 23.1, 26.3, 29.7, and 35.3. Thus, one-fifth of the study population had a BMI of less than 23.1. The percentage of patients in the study population included at standard BMI thresholds were as follows: 2.6% underweight (BMI ≤ 18.5), 30.4% overweight (25 ≤ BMI < 30), 38.3% obese (BMI ≥ 30), 17.6% grade 1 obesity (30 ≤ BMI < 35), 9.1% grade 2 obesity (35 ≤ BMI < 40), and 11.6% grade 3 obesity (BMI ≥ 40).

Table 1 presents a summary of the frequencies, number of deaths, and the adjusted odds of mortality associated with each BMI quintile, referent to the middle quintile (BMI range, 26.3 to <29.7). The percentages of deaths

Table 2. Principal Operative Procedure Frequencies, Number of Deaths, and Adjusted Odds of Mortality for Patients in the Participant Use Data File Database of the ACS NSQIP

Procedure	Patients, No.	Deaths, No. (%)	AOR (95% CI)[a]	P Value: Procedure[a]	P Value: BMI × Procedure Interaction[b]
Exploratory laparotomy	2352	327 (13.9)	2.17 (1.47-3.21)	<.001	.35
Amputation of lower extremity	2533	206 (8.1)	2.15 (1.46-3.17)	<.001	.59
Small bowel resection	3278	260 (7.9)	1.80 (1.22-2.66)	.003	.28
Aortic resection, replacement or anastomosis	1852	142 (7.7)	2.41 (1.61-3.62)	<.001	.09
Therapeutic procedures on respiratory system	366	23 (6.3)	1.49 (0.78-2.83)	.23	.21
Vascular bypass and shunt, not heart	379	23 (6.1)	2.47 (1.39-4.39)	.002	.97
Colostomy, temporary and permanent	917	53 (5.8)	1.09 (0.66-1.78)	.74	.009
Embolectomy and endarterectomy of lower limbs	1877	107 (5.7)	1.47 (0.96-2.23)	.07	.56
Excision, lysis peritoneal adhesions	1346	66 (4.9)	1.48 (0.94-2.32)	.09	.81
Debridement of wound, infection or burn	410	20 (4.9)	1.68 (0.92-3.05)	.09	.002
Ileostomy and other enterostomy	2399	106 (4.4)	1.56 (1.03-2.36)	.03	.008
Gastrectomy, partial and total	1069	43 (4.0)	1.08 (0.65-1.78)	.77	.99
Procedures on spleen	815	32 (3.9)	0.97 (0.56-1.69)	.93	.91
Lobectomy or pneumonectomy	340	13 (3.8)	1.83 (0.94-3.57)	.08	.76
Colorectal resection	18 199	695 (3.8)	1.00 (0.69-1.44)	.10	.03
Procedures on vessels of head and neck	204	7 (3.4)	1.88 (0.82-4.33)	.14	.66
Procedures on vessels other than head and neck	5443	177 (3.3)	1.10 (0.75-1.63)	.62	.64
Peripheral vascular bypass	4621	130 (2.8)	1.15 (0.77-1.71)	.49	.17
Gastrointestinal therapeutic procedures	5389	137 (2.5)	0.76 (0.50-1.13)	.18	.16
Laparoscopy	1704	34 (2.0)	1 [Reference]		
Incision and drainage, skin and subcutaneous tissue	823	13 (1.6)	0.57 (0.28-1.13)	.11	.48
Lower GI therapeutic procedures	7347	106 (1.4)	0.64 (0.42-0.96)	.03	.32
Therapeutic procedures on muscles and tendons	1701	23 (1.4)	0.66 (0.38-1.14)	.14	.19
Therapeutic procedures on musculoskeletal system	297	4 (1.4)	0.49 (0.15-1.57)	.23	.03
Creation, revision, and removal of arteriovenous fistula or vessel-to-vessel cannula for dialysis	1090	12 (1.1)	0.56 (0.29-1.10)	.09	.48
Skin graft	190	2 (1.1)	0.59 (0.14-2.49)	.47	.41
Endarterectomy, vessel of head and neck	6217	61 (1.0)	0.55 (0.36-0.85)	.007	.002
Upper GI therapeutic procedures	16 363	145 (0.9)	0.42 (0.28-0.62)	<.001	<.001
Excision of skin lesion	629	5 (0.8)	0.39 (0.14-1.06)	.07	.59
Cholecystectomy and common duct exploration	20 161	109 (0.5)	0.27 (0.18-0.41)	<.001	.04
Therapeutic procedures, female organs	216	1 (0.5)	0.17 (0.02-1.48)	.11	.55
Therapeutic procedures on skin and breast	678	3 (0.4)	0.23 (0.07-0.77)	.02	.07
Therapeutic procedures, hemic and lymphatic system	1166	5 (0.4)	0.24 (0.09-0.63)	.004	.13
Other hernia repair	17 574	68 (0.4)	0.24 (0.15-0.36)	<.001	.45
Therapeutic procedures on skin and breast	264	1 (0.4)	0.23 (0.03-1.69)	.15	.15
Hemorrhoid procedures	278	1 (0.4)	0.20 (0.03-1.50)	.12	.10
Appendectomy	11 990	27 (0.2)	0.13 (0.08-0.22)	<.001	.22
Therapeutic endocrine procedures	3655	8 (0.2)	0.14 (0.06-0.30)	<.001	.74
Inguinal and femoral hernia repair	13 954	31 (0.2)	0.13 (0.08-0.21)	<.001	.003
Mastectomy	6624	6 (0.1)	0.05 (0.02-0.13)	<.001	.001
Thyroidectomy, partial or complete	6289	5 (0.1)	0.05 (0.02-0.13)	<.0001	.74
Therapeutic cardiovascular procedures	1387	1 (0.1)	0.05 (0.01-0.33)	.002	.81
Varicose vein stripping, lower limb	1744	1 (0.1)	0.04 (0.01-0.26)	.001	.26
Lumpectomy, quadrantectomy of breast	13 175	6 (0.1)	0.03 (0.01-0.07)	<.001	.53
Partial excision bone	228	0 (0.0)	Undefined	.93	.10

Abbreviations: ACS, American College of Surgeons; AOR, adjusted odds ratio; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); GI, gastrointestinal; NSQIP, National Surgical Quality Improvement Program.
[a] The significance of AORs (95% CI) was calculated using the model without the BMI × procedure interaction.
[b] The significance of the association between procedure and BMI was calculated using the model with the BMI × procedure interaction.

among patients in the first BMI quintile (2.8%) was over twice that of the percentage of deaths among patients in the fifth BMI quintile (1.0%), which included patients with a BMI of 35.3 or greater. Patients in the first BMI quintile had statistically significant higher odds of death (OR, 1.40 [95% CI, 1.25-1.58]) than did patients in the middle BMI quintile, after adjusting for the concurrent influence of differences in mortality risk and type of surgery. Patients in the BMI quintiles 4 and 5 who were in the obese range had lower odds of death than did patients in the middle BMI quintile, although these differences in mortality were not statistically significant at the $P < .05$ level. Each of the reported ORs are adjusted for the concurrent effects of differences in baseline mortality risk (ACS NSQIP probability of death) and for differences in the type of principal operating procedure.

Table 2 presents a summary of frequencies, number of deaths, and adjusted odds of mortality associated

Table 3. Covariate Statistical Significance and Model Performance Measures[a]

Model Parameter	Model Without BMI × Procedure Interaction	*P* Value	Model With BMI × Procedure Interaction	*P* Value
BMI quintile	57.3	<.001	23.5	<.001
Principal operative procedure	1282.3	<.001	171.7	<.001
NSQIP estimated probability of death	4929.9	<.001	4793.7	<.001
BMI × principal procedure interaction	NA		131.7	<.001
Maximum adjusted R^2	0.34		0.34	
C statistic (ROC area)	0.91		0.91	

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); NA, not applicable; NSQIP, National Surgical Quality Improvement Program; ROC, receiver operating characteristic.

[a] Wald χ^2 test statistic values are measures of the relative contribution to the explanatory power of the parameters included in the model. The statistical significance of the parameters was assessed using *P* values obtained for each Wald χ^2 test statistic. The overall statistical performance of the multivariable logistic regression models is measured using the maximum adjusted R^2 and C statistics. The maximum adjusted R^2 is a measure of the total likelihood explained by the model compared with the total likelihood explainable by a perfect model. The C statistic measures the model's capacity to discriminate between survivors and decedents. A value of 1.0 for the C statistic indicates that perfect discrimination was obtained by the model, and a value of 0.5 indicates that no discrimination between survivors and decedents was obtained. The C statistic is equivalent to the area under the ROC curve, which plots the relationship between sensitivity and (1 – specificity) at alternative thresholds of the model-predicted probabilities of mortality for the total study population.

Table 4. Covariate Statistical Significance and Model Performance Measures by BMI Quintile

Model Parameter[a] or Statistical Performance Measure	Quintile 1 (<23.1)	Quintile 2 (23.1 to <26.3)	Quintile 3 (26.3 to <29.7)	Quintile 4 (29.7 to <35.3)	Quintile 5 (≥35.3)
Principal operative procedure	330.4	261.9	262.8	289.7	237.6
NSQIP estimated probability of death	1519.9	1017.8	817.9	814.2	590.3
Maximum adjusted R^2	0.35	0.32	0.34	0.35	0.34
C statistic (ROC area)	0.91	0.91	0.91	0.91	0.91

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); NSQIP, National Surgical Quality Improvement Program; ROC, receiver operating characteristic.

[a] *P* values (all of which were <.001) were determined by use of the Wald χ^2 test statistic.

with type of procedure. Patients who underwent a laparoscopy were selected as the reference population for comparing the relative effect of each of the other procedure types on mortality. These patients had an overall mortality of 2.0%, which was near the average for the total study population. Patients who underwent an exploratory laparotomy had the highest percentage of deaths (13.9%), in comparison with patients in all other categories of principal surgery. The adjusted odds of death for patients who underwent an exploratory laparotomy (OR, 2.17 [95% CI, 1.47-3.21]) were more than twice that of the reference population (patients who underwent an laparoscopy as their principal procedure). Patients who underwent a breast lumpectomy had one of the lowest overall mortality percentages (0.1%). Their odds of death were 97% lower than those of the reference population (OR, 0.03 [95% CI 0.01-0.07]). Each of the reported ORs are adjusted for the concurrent effects of differences in baseline mortality risk (ACS NSQIP probability of death) and for differences in BMI quintile.

A separate multivariable logistic regression model was developed to assess the interaction between BMI and category of principal operative procedure. A statistically significant interaction was identified for several procedures ($P<.05$), indicating that the effect of BMI on mortality was significantly different for patients who underwent these procedures compared with patients who underwent the reference procedure (laparoscopy). Procedures for which the effect of BMI on mortality risk was significantly different included colostomy, wound debridement, ileostomy, colorectal resection, musculoskeletal system procedures, endarterectomy of head and neck vasculature, upper gastrointestinal procedures, cholecystectomy, hernia repair, and mastectomy. The *P* values for the statistical significance of each interaction effect are listed in Table 2.

Table 3 presents results from tests of the overall statistical significance of each parameter's association with mortality risk. Results for 2 multivariable logistic regression model formulations are presented. Both models include BMI quintile, type of principal operative procedure, and the ACS NSQIP estimated probability of death as predictors of death occurring within 30 days of surgery. One model includes an additional predictor for the interaction between BMI and category of primary surgery. Each covariate's overall effect was highly statistically significant ($P<.001$) in both model formulations. The ACS NSQIP estimated probability of death contributed the most to the explanatory power of each model. Both model formulations explained 34% of the total likelihood explainable by a perfect model. Both model formulations also obtained a C statistic of 0.91, which indicates that the models obtained excellent discrimination between survivors and decedents.

Table 4 presents separate tests of the statistical significance of differences in mortality risk by type of procedure, adjusted for baseline mortality risk using the ACS NSQIP score, for subpopulations of patients in each quintile of BMI. Type of principal operating procedure is a statistically significant predictor of mortality risk for patients in each BMI quintile ($P < .001$), even after adjusting for differences in baseline mortality risk. Interestingly, the relative magnitude of the contribution made by principal operating procedure to the estimated probability of death increases with increases in BMI, compared with the effect of baseline mortality risk. The overall statistical performance of the model is uniform across quintiles of BMI, accounting for between 32% and 35% of the total likelihood explainable by a perfect model. A C statistic of 0.91 was obtained by the model in each quintile of BMI.

COMMENT

Mortality risk stratification by BMI for specific procedures can be helpful in preoperative decision making and patient education. For general surgery, the question remains whether or not obese patients are at significantly higher mortality risk for specific procedures. General surgeons are having increased experience with the obese and severely obese not only in the area of weight reduction procedures and surgery on postbariatric surgery patients, but also in the increasingly obese population. Intuitively, one might consider that head and neck procedures such as thyroidectomy might be associated with less of a risk than laparotomy. Hawn et al[37] evaluated the effect of obesity on general surgical procedures. Their study[37] was a retrospective analysis of patients undergoing a cholecystectomy, a unilateral mastectomy, or an abdominal colectomy at a university hospital. They divided their groups into normal-weight, overweight, and obese patients, with the obese patients defined as having a BMI of greater than 30. They evaluated more than 1300 patients and demonstrated that obese patients had a significantly longer operating time than did the other 2 groups of patients. The obese patients did not have a longer length of hospital stay or more complications related to surgery compared with the other 2 groups of patients. The overall complication rate was not affected by any of the 3 different case types. This intriguing study[37] begs the question of why a more detailed evaluation of the broad scope of cases was not performed by general surgeons. In our study, a higher percentage of surgical patients compared with the general population were obese. However, our surgical population does include obese patients undergoing gastric restrictive procedures.

Our findings are similar to the findings in Reeves et al.[25] They studied obesity in patients who underwent coronary artery bypass graft surgery. Their group of patients included 4372 patients and looked at 4 groups of BMI and multiple outcomes, including early death, perioperative myocardial infarctions, renal and neurologic complications, transfusion requirements, duration of ventilation, and duration of intensive care unit and hospital stay. Reeves et al[25] found that underweight patients were more likely to die in the hospital than were patients with normal weight. Overweight patients (with a BMI between 25 and 30), obese patients (BMI between 30 and 35), and severely obese patients (BMI > 35) were not at higher risk for adverse outcomes than normal-weight patients. These 3 groups of patients were less likely than normal-weight patients to require transfusions. Reeves et al[25] concluded that obesity did not affect the risks of perioperative death or other adverse outcomes compared with normal-weight patients.

Our data are unique in that the analysis of such a large number of patients allowed us to analyze individual procedures done by general surgeons to a level of specificity not previously available. Interestingly, but in agreement with other studies, the combined group of patients with the highest BMI values do not show an increased mortality compared with the reference group. Our data agree with the data in Mullen et al.[27] However, analysis of individual types of procedures demonstrates the unique finding that obesity is related to increased mortality. These individual types of procedures include procedures with which the general surgeon should have definite experience: colorectal resection, colostomy formation, cholecystectomy, hernia repair, mastectomy, and wound debridement. With regard to colorectal procedures, our data are not in agreement with the data in the study by Benoist et al[23] in that we do find an effect of obesity on mortality. Benoist et al[23] found no difference in overall mortality but a difference in complication rates. Finally, our data are not in agreement with the findings of Hawn et al[37] in that we did find increased mortality in the ACS NSQIP data for colorectal resections, mastectomy, or cholecystectomy, whereas they did not.

There is increasing evidence and supportive literature that obesity effects the practice of surgery in the United States and worldwide. Reports to date have shown that, at the very least, complication rates and hospital resources have been affected by procedures on obese patients. The ACS NSQIP database allows for the evaluation of a larger number of patients and for the examination of more specific types of procedures, and it shows the previously unreported finding that mortality risk for several standard general surgical procedures is indeed effected by obesity.

These results indicate that BMI is a significant predictor of mortality within 30 days of surgery, even after adjusting for the contribution to mortality risk made by type of surgery and for a specific patient's overall expected risk of death. Patients with a BMI of less than 23.1 demonstrated a significant increased risk of death, with 40% higher odds than the risk of death among patients in the middle range for BMI (26.3 to <29.7). Interestingly, almost 40% of the patients in the study population would be classified as obese using standard thresholds for grouping BMI values. Patients with a BMI of 29.7 or greater had lower odds of death compared with patients in the middle range, but these differences were not statistically significant.

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