




The Association Between BMI and Mortality in Surgical Patients

Idit Dotan¹ · Tzipora Shochat² · Ilan Shimon^{1,3} · Amit Akirov^{1,3} 

Accepted: 10 January 2021 / Published online: 22 January 2021
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Abstract

Background While obesity is commonly associated with increased morbidity and mortality, in patients with chronic diseases, it has have been associated with a better prognosis, a phenomenon known as the 'obesity paradox'.

Objective We investigated the relationship between mortality, length of hospital stay (LOHS), and body mass index (BMI) in patients hospitalized to general surgical wards.

Methods We extracted data of patients admitted to the hospital between January 2011 and December 2017. BMI was classified according to the following categories: underweight (< 18.5), normal weight (18.5–24.9), overweight (25–29.9), obesity (30–34.9) and severe obesity (\geq 35). Main outcomes were mortality at 30-day mortality and at the end-of-follow-up mortality), as well as LOHS.

Results A total of 27,639 patients (mean age 55 ± 20 years; 48% males; 19% had diabetes) were included in the study. Median LOHS was longer in patients with diabetes vs. those without diabetes (4.0 vs 3.0 days, respectively), with longest LOHS among underweight patients. A 30-day mortality was 2% of those without (371/22,297) and 3% of those with diabetes (173/5,342). In patients with diabetes, 30-day mortality risk showed a step-wise decrease with increased BMI: 10% for underweight, 6% for normal weight, 3% for overweight, 2% for obese and only 1% for severely obese patients. In patients without diabetes, 30-day mortality was found to be 6% for underweight, 3% for normal weight and 1% across the overweight and obese categories. Mortality rate at the end-of-follow-up was 9% of patients without diabetes and 18% of those with diabetes (adjusted OR = 1.3, 95% CI, 1.2–1.5). In patients with diabetes, mortality risk showed an inverse association with respect to BMI: 52% for underweight, 29% for normal weight, 17% for overweight, 14% for obesity and 7% for severely obese patients, with similar trend in patients without diabetes.

Conclusions The results support the 'obesity paradox' in the general surgical patients as those with and without diabetes admitted to surgical wards, BMI had an inverse association with short- and long-term mortality.

This research did not receive any specific grant.

✉ Amit Akirov
amit.akirov@gmail.com

¹ Rabin Medical Center, Institute of Endocrinology, Beilinson Hospital, , 49100 Petach Tikva, Israel

² Rabin Medical Center, Statistical Consulting Unit, Beilinson Hospital, Petach Tikva, Israel

³ Sackler School of Medicine, Tel Aviv University, Tel Aviv, Israel

Introduction

Obesity is increasing in prevalence during the last few decades and is now considered to be a global epidemic [1–4]. Obesity was shown to be associated with several comorbidities [5] and excess mortality from cardiovascular disease (CVD) [6–9] and cancer [6, 10]. Specifically, mortality rates are increasing in parallel to growing BMI [11]. Moreover, obese and severely obese individuals suffer from increased risk for major cardiac, pulmonary, renal

and neurological perioperative complications, as well as surgical site infection, wound dehiscence, need for reoperation, and hospital readmission [12–20]. Accordingly, in the surgical critically ill population, mortality is increased in severely obese patients [21].

In contrast with obesity, underweight is not associated with an increased risk for death from CVD or cancer [6]. Nevertheless, this group of people is also at increased risk for mortality [22, 23], specifically non-cancer and non-CVD mortality [6]. It is still unclear whether underweight pose risk for the patients in the perioperative period. Underweight patients undergoing several types of elective surgery, had perioperative morbidity and mortality that was similar to normal-weight patients [24]. On the other hand, underweight patients undergoing cardiac surgery, orthopedic procedures, intra-abdominal surgery for cancer or lobectomy for lung cancer seem to be at risk of short-term mortality [19, 25–31].

Length of hospital stay (LOHS) of overweight and obese individuals undergoing general surgery is increased with each BMI category [32]. However, in the surgical critically ill population, LOHS is only increased in severely obese patients [21]. LOHS of underweight patients is longer as well [28, 32].

Diabetes was shown to be related to perioperative morbidity and mortality after elective surgery in general [24] and after cardiac surgery in particular [33]. Among patients undergoing non-cardiac surgery, diabetes was associated increased LOHS, ICU admission, major complications (respiratory, kidney, heart or liver failure, CNS complications) and increased 6-month mortality rates [34].

The goal of the current study was to explore the relationship between BMI with LOHS, mortality at 30 days and at the end-of-follow-up in a cohort of patients hospitalized to general surgery wards, according to diabetes status.

Methods

The study was conducted at a large 1,300-bed university-affiliated tertiary medical center. Admissions to the four general surgery wards were done mainly through the emergency department. All patient social and medical data, as well as laboratory tests and imaging were recorded in electronic medical charts. Deaths were entered into the hospital's mortality database, which was regularly updated according to the population registry of the Ministry of the Interior. This nationwide registry includes updated data on all the citizens of Israel, including the death date and enabled us to capture all fatalities.

For this historical prospective, observational study, information was collected from the electronic records of all

subjects hospitalized for any cause to the hospital's general surgery wards between January 1, 2011, and December 31, 2017. All patients were followed up until death or until April 1, 2018. Self-reported data regarding major comorbidities, smoking and alcohol use, were extracted from the medical charts as well.

In most cases, data on weight and height was based on direct measurement on admission and when on-site measurement was not possible, self-reported height and weight were used. BMI was calculated by dividing weight (in kilograms) by height (in meters squared). Patients with missing data on height or weight were excluded from the study. The study participants were classified into the following groups according to their BMI: underweight ($< 18.5 \text{ kg/m}^2$), normal weight ($18.5 \text{ to } < 25.0 \text{ kg/m}^2$), overweight ($25 \text{ to } < 30 \text{ kg/m}^2$), obese ($30 \text{ to } < 35 \text{ kg/m}^2$) and severely obese ($> 35 \text{ kg/m}^2$).

Diagnosis of diabetes was based on data extracted from the medical records regarding a known history of diabetes prior to the admission, or based on the medication list for each patient, as the use of diabetes medications such as oral hypoglycemic agent, glucagon-like peptide 1 (GLP-1) agonist, or insulin, at time of admission.

In subjects with more than one hospital admission, we only included the first admission for analysis.

The study end-points included LOHS, all-cause mortality at 30-day after hospitalization and at the end of follow-up, according to BMI category.

The study was approved by the institutional review board.

Statistical analysis

The statistical analysis for this paper was generated using SAS Software, Version 9.4.

Continuous variables were presented by mean \pm SD and categorical variables were presented by (N, %). T test was used to compare continuous variables between DM groups and Fisher's exact test was used for all categorical values, except for surgery and admission year where we used Chi-square to compare the value of categorical variables between these groups. Analysis of variance (ANOVA) was used to compare the value of continuous variables between BMI groups and the Chi-square test was used to compare the value of categorical variables between these groups. As LOHS was skewed, a common normalizing transformation of $1/\text{LOHS}$ was used and this variable was analyzed using ANOVA in a generalized linear model. A 30-day mortality was assessed by logistic regression. Overall survival was assessed by Kaplan–Meier survival analysis, with the log-rank test. Overall survival, adjusted for covariates, was assessed by the Cox proportional hazards model. In overall survival model there was a

significant interaction between BMI categories and diabetes status and the comparison between the different BMI categories were computed from the model with this interaction. In the adjustment model two interactions between the covariates and diabetes were also included. Adjustment was made for age, gender, ischemic heart disease, congestive heart failure, hypertension, cerebrovascular disease, malignancy, chronic renal failure, smoking, as well as surgery type and year of hospitalization. LOHS was added to model and the $1/\text{LOHS}$ transformation was used to stabilize this variable. Two-sided p values less than 0.05 were considered statistically significant. In order to check proportional hazard assumption, we added an interaction term between log (follow-up time) and BMI to the Cox proportional hazard model (if the interaction is significant, proportional hazard is not warranted). The interaction term was not statistically significant ($p = 0.74$). Additionally, a model with the interaction between BMI and diabetes and mortality risks for BMI categories were computed at diabetes = 1 and at diabetes = 0.

To account for missing data on smoking and alcohol, missing data categories were created for both.

Results

Of a total of 42,188 admissions to the 4 general surgery wards between January 2011 and December 2017, we excluded 12,198 repeat admissions and 2,351 patients with missing data on height or weight to calculate BMI. Thus, the study cohort included 27,639 unique patients; of these 48% (12,840 patients) were male. Mean age (\pm SD) for the population was 55 ± 20 years. In total, 19% (5,342 patients) had diabetes.

As shown in Table 1, patients with diabetes were older than those without diabetes (65 ± 12 years vs. 53 ± 20 years). Unsurprisingly, congestive heart failure, chronic renal failure, ischemic heart disease, hypertension and cerebrovascular disease were more common among subjects with diabetes than those without diabetes.

In those with diabetes, mean BMI was 28.3 ± 7.0 , compared to a mean BMI of 25.7 ± 5.9 kg/m² in subjects without diabetes. Most patients, regardless of their diabetes status, had BMI < 30 kg/m² (60% for diabetic patients and 78% for non-diabetic patients). Normal weight was the most frequent BMI category (41%) in the group of patients without diabetes, while in those with diabetes, overweight (33%) was the most common classification. BMI < 18.5 kg/m² category was significantly more common among those without diabetes (4% vs. 1%), while BMI > 35 kg/m² was twice as common in those with diabetes, compared to those without diabetes (19% vs. 9%). (Table 2).

The most common reasons for admissions to the surgical wards included hernia repair, including inguinal, umbilical or ventral hernia (16%), gallbladder or bile duct disease (12.6%), malignant disease (9.6%), appendiceal disease (7.1%), abdominal pain (5%), gastrointestinal bleeding (3.8%) and bowel obstruction (2.8%). The most common surgical interventions included hernia repair (22.2%), breast surgery (9.9%), appendectomy (9.7%), cholecystectomy (7.8%), partial, total or sleeve gastrectomy (6.2%), hemicolecotomy (2.6%), and rectal surgery (2.1%).

Length of hospital stay

Median LOHS was longer in patients with diabetes (4.0 days; interquartile range [IQR]: 3.0–6.0 days), compared to those without diabetes (3.0 days; IQR: 2.0–7.0 days). As LOHS was skewed, a common normalizing transformation of $1/\text{LOHS}$ was used and the mean was 0.29 (95% CI, 0.28–0.29) for patients with diabetes and 0.36 (95% CI, 0.35–0.36) ($p < 0.001$) for patients without diabetes, supporting the association between LOHS and BMI category.

The Longest LOHS was evident among underweight patients, whether they had diabetes (10.4 ± 13.6 days) or not (6.2 ± 8.2). The LOHS of those BMI in the normal range was longer among those with diabetes (6.4 ± 8.2 days), compared to those without diabetes (4.5 ± 5.6 days). Among all patients, regardless of the diabetes status, the LOHS was similar for overweight, obese and severely obese patients (4.3 days for non-diabetic patients and 5.6 days for diabetic patients, Table 3).

Mortality

30-day mortality

Overall 30-day mortality was 2% (544/27,930), including 2% of patients without diabetes (371/22,297 patients) and 3% of those with diabetes (173/5,342 patients).

In the total study cohort, underweight patients had the highest mortality risk (6%), followed by subjects with BMI in the normal range (3%). Mortality was similar in patients who were overweight, obese or severely obese (1%).

Among subjects with diabetes, BMI has an inverse association with 30-day mortality risk. The 30-day mortality risk decreased in parallel to increasing BMI. It was 10% for underweight patients, 6% for normal-weight patients, 3% for overweight patients, 2% for obese patients and 1% for the severely obese patients. Similarly, BMI < 18.5 kg/m² was also associated with the maximal mortality risk in those without diabetes (6%), followed by patients with BMI in the normal range (2%), but there was no statistically significant difference in mortality risks for

Table 1 Baseline characteristics. Baseline characteristics and comorbidities of patients with and without diabetes. * $p < 0.05$

	Patients without diabetes ($n = 22,297$)	Patients with diabetes ($n = 5,342$)
Patient characteristics		
Age, mean (years)	53 ± 20	65 ± 12
Men, n (%)	10,662 (48%)	2,558 (48%)
Smoking (%)	3,510 (24%) Missing = 7,731	542 (17%) Missing = 2,171
Alcohol (%)	452 (3%) Missing = 7,828	45 (1%) Missing = 2,200
BMI, mean ± SD	25.7 ± 5.9	28.3 ± 7.0
Comorbidities, n (%)		
Malignancy	1,717 (8%)	532 (10%)
Hypertension	3,624 (16%)	2,781 (52%)*
Ischemic heart disease	920 (4%)	864 (16%)*
Congestive heart failure	269 (1%)	260 (5%)*
Cerebrovascular disease	313 (1%)	262 (5%)*
Chronic renal failure	228 (1%)	202 (4%)*
BMI		
Underweight (< 18.5)	805 (4%)	73 (1%)
Normal (18.5–24.99)	9,111 (41%)	1,364 (26%)
Overweight (25–29.99)	7,338 (33%)	1,768 (33%)
Obesity (30–34.99)	3,141 (14%)	1,108 (21%)
Severe obesity (> 35)	1,902 (9%)	1,029 (19%)

patients who were overweight, obese and severely obese (1%).

Diagnosis of diabetes was associated with a 2-times greater 30-day mortality risk (OR = 2.0, 95% CI, 1.7–2.4). Adjustment for age, gender, ischemic heart disease, congestive heart failure, hypertension, cerebrovascular disease, malignancy, chronic renal failure, smoking and alcohol attenuated that risk, though it was still significantly higher with diabetes (aOR = 1.3, 95% CI, 1.1–1.6). The association remained significant following further adjustment for surgery type and admission year (aOR = 1.2, 95% CI, 1.0–1.5).

For each of the BMI categories in our study, mortality risk was higher for patients with diabetes, compared to patients without diabetes, except for severe obesity category. Mortality risk associated with severe obesity was similar for patients suffering from diabetes and those without (1%).

Mortality at the end of follow-up

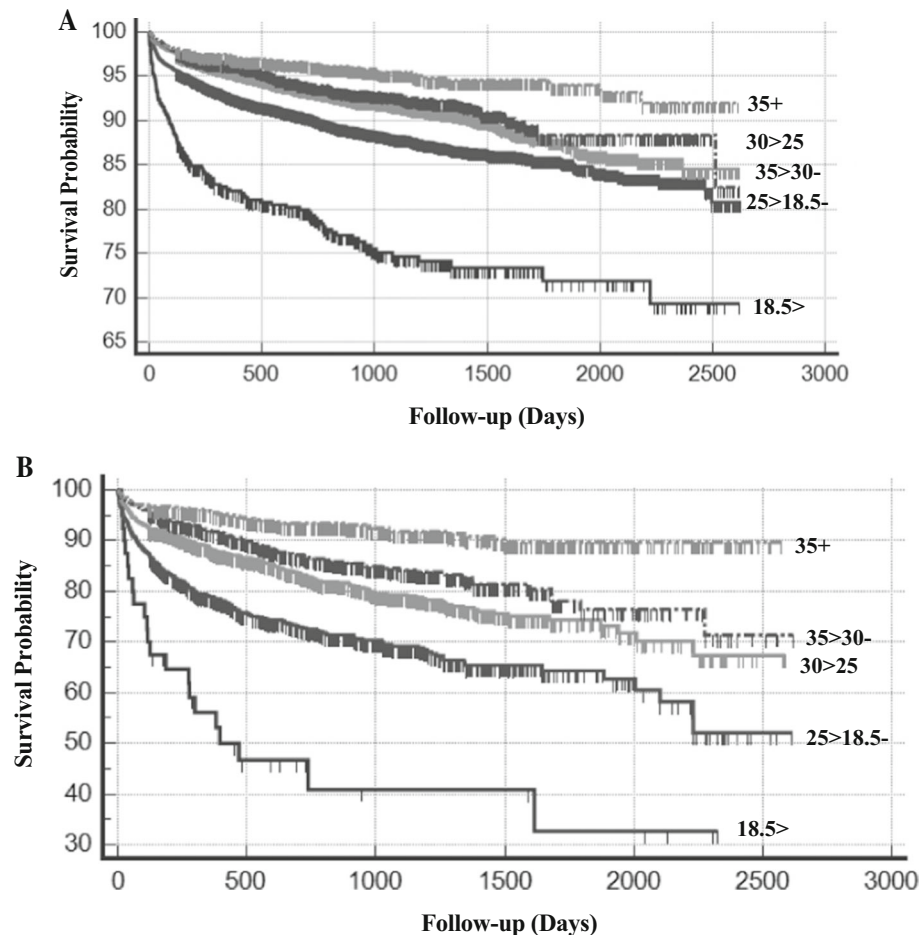
The median follow-up time for all patients was 2.4 years (IQR: 1.2–3.7 years); the median follow-up time for patients with diabetes was 2.1 years (IQR: 1.0–3.5 years) and for those without diabetes it was 2.4 years (IQR: 1.2–4.1 years). At the end of follow-up, mortality rate was 11% (2,921/27,639), including 18% of subjects with

diabetes (949/5,342 patients) and 9% of those without diabetes (1,972/22,297 patients). Kaplan–Meier curves revealed that all patients, including those with diabetes and those without diabetes, survived better when BMI was above 25 kg/m², compared to subjects with normal BMI and the prognosis was worse for those with BMI lower than 18.5 kg/m². (Fig. 1).

In overall survival model, there was a significant interaction between BMI categories and diabetes status ($p = 0.005$) and the comparisons between the different BMI categories were computed from the model with this interaction. In patients with diabetes, an inverse association between mortality and BMI at the end of follow-up was shown. Mortality risk was highest for patients who were underweight (52%) and thereafter there was a decrease in mortality risk with increasing BMI category, from 29% for patients with normal BMI, 17% for overweight, 14% for obese patients and lowest mortality risk was evident for severely obese patients (7%).

Similar findings were evident in those without diabetes with maximal mortality risk for underweight patients (22%), followed by 11% mortality risk for those with normal BMI, 7% for overweight, 6% for obese and 4% for severely obese patients without diabetes. Assessing mortality risk by diabetes status revealed that in every BMI category separately, the risk was greater in those with diabetes, compared to subjects without diabetes (Table 3).

Fig. 1 Kaplan–Meier analysis of patients following discharge. Patient survival analyzed as time until death according to BMI category; observations were censored at the end of follow-up ($p < .05$). **a** Patients with diabetes and **b** patients without diabetes



In subjects with diabetes and in those without diabetes, the adjusted hazard ratios (aHR) for mortality at the end of follow-up, compared to normal BMI, indicated the risk was three times greater for underweight patients, while for overweight, obese and severely obese patients, the mortality risk was 30–60% lower, compared to normal BMI (Table 3, Model 2). Adjustment for LOHS had no statistically significant impact on mortality risk (Table 3, model 3). Further adjustment for surgery type and admission year had no statistically significant impact on the findings (Table 3, Model 4).

In all participants, regardless of their diabetes status, (diabetic as well as non-diabetic), the adjusted HR for mortality at the end of follow-up was significantly higher for underweight patients in comparison with all other BMI categories. In patients with diabetes, severe obesity was found to be protective compared to all other BMI categories, except obesity. Among those without diabetes, severe obesity was also associated with decreased mortality risk, compared with underweight or normal weight, but there was no statistically significant difference compared to those with overweight or obesity (Table 3).

To account for missing data on smoking and alcohol, missing data categories were created for both. In patients without diabetes, mortality risk was not statistically significantly different for smokers vs. non-smokers, but was lower for those with missing data on smoking habits vs. non-smokers (HR, 0.59; 95% CI, 0.4–0.8). Furthermore, compared with patients who did not consume alcohol, mortality risk was not statistically significantly different for those who consumed alcohol, but the risk was increased for those with missing data on alcohol consumption (HR 1.6; 95% CI, 1.2–2.2). On the other hand, in patients with diabetes there was no statistically significant difference in mortality risk for each of the 3 categories of smoking or alcohol consumption.

A separate model with the interaction between BMI and diabetes included both patients with diabetes and those without diabetes. In patients without diabetes, the aHRs for mortality at the end of follow-up, compared to normal BMI, were 2.3 (2.0–2.7) for underweight patients, 0.6 (0.6, 0.7) for overweight patients, 0.6 (0.5, 0.7) for obese patients and 0.5 (0.4, 0.6) for severely obese patients. In patients with diabetes, the aHRs for mortality at the end of

Table 2 Baseline characteristics and comorbidities according to BMI category

	Patients without diabetes					Patients with diabetes				
	Underweight	Normal	Overweight	Obesity	Severe obesity	Underweight	Normal	Overweight	Obesity	Severe obesity
Patients, n (%)	805 (4%)	9,111 (41%)	7,338 (33%)	3,141 (14%)	1,902 (9%)	73 (1%)	1,364 (26%)	1,768 (33%)	1,108 (21%)	1,029 (19%)
Age, mean (years)	48 ± 23*	51 ± 22	56 ± 19*	55 ± 17*	49 ± 16	67 ± 18	70 ± 15	68 ± 13	65 ± 13*	56 ± 14*
Men, n (%)	523 (65%)*	4,380 (48%)	3,047 (42%)	1,516 (48%)	1,196 (63%)*	34 (47%)*	592 (44%)	731 (41%)*	553 (50%)*	648 (63%)*
Malignancy	69 (9%)	720 (8%)	566 (8%)	251 (8%)	111 (6%)	15 (21%)*	176 (13%)	163 (9%)*	107 (10%)*	71 (7%)*
Hypertension	89 (11%)	1,193 (13%)	1,304 (18%)*	647 (21%)*	391 (21%)*	36 (49%)	643 (47%)	961 (54%)*	586 (53%)*	555 (54%)*
Ischemic heart disease	36 (5%)	355 (4%)	332 (5%)	139 (4%)	58 (3%)	12 (16%)	256 (19%)	319 (18%)	177 (16%)	100 (10%)*
Congestive heart failure	11 (1%)	118 (1%)	69 (1%)	46 (2%)	25 (1%)	5 (7%)	80 (6%)	92 (5%)	43 (4%)	40 (4%)
Chronic renal failure	13 (2%)	106 (1%)	71 (1%)	29 (1%)	9 (1%)	4 (6%)	64 (5%)	70 (4%)	39 (4%)	25 (2%)*
Cerebrovascular disease	13 (2%)	133 (2%)	99 (1%)	50 (2%)	18 (1%)	6 (8%)	102 (8%)	96 (5%)	43 (4%)*	15 (2%)*

**p* < 0.05 compared to normal BMI.

follow-up, compared to normal BMI, were 2.3 (1.7–3.3) for underweight patients, 0.6 (0.5, 0.7) for overweight patients, 0.6 (0.5, 0.7) for obese patients and 0.4 (0.3, 0.5) for severely obese patients.

Age categories

Patients were divided to age groups according to registered age on their first admission: young-less than 40 years of age, middle-aged—between 40 and 65 years of age and elderly—65 years of age and above. Of patients without diabetes, 6,722 were young, 8,475 were middle-aged and 7,100 were elderly. The group of subjects with diabetes included 372 young, 1,905 middle-aged and 3,065 elderly patients.

Patients without diabetes

Mortality risk at the end of follow-up was 1% (60/6,722 patients for young patients, 5% (462/8,475 patients) for middle-aged and 20% (1,405/7,100 patients) for elderly patients.

For young patients (< 40 years) there was no statistically significant difference in risk for mortality at the end of follow-up between patients in different BMI categories.

Among middle-aged patients, underweight was associated with a significantly increased mortality risk, compared to all other BMI categories (aHR = 4.6, 95% CI = 3.1–6.7, compared to normal weight). Severe obesity was again found to be protective, compared to underweight (aHR = 0.07, 95% CI = 0.04–0.1), or normal weight (aHR = 0.3, 95% CI = 0.2–0.5).

This pattern was similar in elderly patients, as underweight was associated with an increased mortality risk compared to all other BMI categories (aHR = 2.6, 95% CI = 2.0–3.3, compared to normal weight). Severe obesity was again found to be protective, compared to underweight (aHR = 0.2, 95% CI = 0.1–0.3), or normal weight (aHR = 0.6, 95% CI = 0.4–0.8).

Patients with diabetes

We did not analyze mortality cases of young patients, due to the small number of deceased patients < 40 years of age with diabetes.

Risk for mortality at the end of follow-up was 9% for middle-aged (176/1,905 patients) and 25% (770/3,065 patients) for elderly patients.

Among middle-aged patients, underweight was associated with a significant increased mortality risk, compared to all other BMI categories (aHR = 2.8, 95% CI = 1.0–8.2, compared to normal weight). Severe obesity was again found to be protective, compared to all other

Table 3 Length of stay end-of-follow-up mortality according to BMI category

	Patients without diabetes						Patients with diabetes													
	Underweight		Normal		Overweight		Obesity		Severe Obesity		Underweight		Normal		Overweight		Obesity		Severe Obesity	
	n (%)	mean ± SD	n (%)	mean ± SD	n (%)	mean ± SD	n (%)	mean ± SD	n (%)	mean ± SD	n (%)	mean ± SD	n (%)	mean ± SD	n (%)	mean ± SD	n (%)	mean ± SD	n (%)	mean ± SD
Patients, n (%)	805 (4%)	9,111 (41%)	7,338 (33%)	3,141 (14%)	1,902 (9%)	73 (1%)	1,364 (26%)	1,768 (33%)	1,108 (21%)	1,029 (19%)										
Length of stay, days, mean ± SD (median; minimum, maximum)	6.2 ± 8.2* (3; 1, 101)	4.5 ± 5.6 (3; 1, 193)	4.3 ± 5.2 (3; 1, 192)	4.3 ± 4.7 (3; 1, 83)	4.2 ± 3.9 (3; 1, 62)	10.4 ± 13.6* (5; 2, 66)	6.5 ± 8.2 (4; 1, 119)	5.6 ± 6.8* (4; 1, 124)	5.6 ± 7.6* (4; 1, 84)	5.6 ± 9.7* (4; 1, 193)										
End-of-follow-up mortality	175 (22%)	983 (11%)	545 (7%)	197 (6%)	72 (4%)	38 (52%)	393 (29%)	294 (17%)	153 (14%)	71 (7%)										
Mortality at end of follow-up (Hazard ratio)	Model 1 [#]	2.3 (1.9, 2.8)*	–	0.7 (0.6, 0.8)*	0.6 (0.5, 0.7)*	0.4 (0.3, 0.5)*	2.4 (1.5, 3.7)*	–	0.6 (0.5, 0.7)*	0.5 (0.4, 0.6)*	0.2 (0.2, 0.3)*	Model 2 [†]	2.7 (2.2, 3.4)*	–	0.7 (0.6, 0.7)*	0.6 (0.5, 0.7)*	0.6 (0.5, 0.8)*	0.4 (0.3, 0.6)*	0.6 (0.5, 0.8)*	0.4 (0.3, 0.6)*
	Model 3 [‡]	2.5 (2.0, 3.1)*	–	0.6 (0.6, 0.7)*	0.6 (0.5, 0.7)*	0.6 (0.4, 0.8)*	2.3 (1.5, 3.6)*	–	0.7 (0.6, 0.9)*	0.6 (0.5, 0.8)*	0.4 (0.3, 0.6)*	Model 4 [§]	2.3 (1.9, 2.8)*	–	0.7 (0.6, 0.7)*	0.6 (0.5, 0.7)*	0.6 (0.5, 0.8)*	0.5 (0.3, 0.7)*	0.6 (0.5, 0.8)*	0.5 (0.3, 0.7)*

*p < 0.05 compared to normal BMI.

[#]Model 1: Unadjusted model.

[†]Model 2: Comparison to normal BMI following adjustment for age, gender, smoking, alcohol, hypertension, malignancy, ischemic heart disease, congestive heart failure, cerebrovascular disease and chronic renal failure.

[‡]Model 3: Model 2 + adjustment for length of hospital stay.

[§]Model 4: Model 3 + adjustment for surgery type and admission year.

BMI categories, including underweight (aHR = 0.1, 95% CI = 0.04–0.4), normal weight (aHR = 0.3, 95% CI = 0.2–0.7), overweight (aHR = 0.50, 95% CI = 0.3–0.9), or obesity (aHR = 0.5, 95% CI = 0.3–1.0).

This pattern was similar in elderly patients, as underweight was found to be associated with an increased mortality risk when compared to other BMI categories (aHR = 2.8, 95% CI = 1.7–4.6, compared to normal weight). Severe obesity was found to be protective, compared to underweight (aHR = 0.1, 95% CI = 0.07–0.2), normal weight (aHR = 0.4, 95% CI = 0.2–0.5), or overweight (aHR = 1.7, 95% CI = 1.1–2.7), but not compared to obesity.

Discussion

Obesity poses an increased risk of mortality in the general population [6–10], with higher mortality paralleling higher BMI [11]. It is to be expected then, that similar pattern will characterize the surgical population. However, the ‘obesity paradox’ has been described for overweight and obese individuals admitted to the ICU or undergoing vascular surgery [35–37], showing a reverse J-shaped relationship, in which the underweight and severely obese individuals tend to have worse outcome [37]. We found that BMI increase has a step-wise protection from death after surgical procedures, both short and long-term, in patients with and without diabetes.

We, too, found that short-term mortality in our cohort was maximal for underweight patients. Being underweight was previously associated with an increased risk for mortality in certain post-surgical conditions [35]2936, but not in others [38]24,26. Underweight patients might suffer from a chronic condition that renders them with lower overall reserve and hence prone to post-operative complications and death.

There is ambiguity in the literature regarding the association between increased BMI and short-term mortality after surgery. In line with our results, a meta-analysis including more than 400,000 patients undergoing cardiac surgery, found that overweight and obese patients have lower short-term mortality rates in comparison to normal weight individuals [25]. The same was shown in patients with surgical peritonitis [39], after hip surgery [29], post-vascular surgery [36] and among patients in the surgical ICU [35]. However, overweight and obesity were also shown to increase short-term mortality after multiple types of elective surgery [24] and surgical intervention for gastric, colorectal and pancreatic cancer [40–42]. We found a lower short-term mortality as BMI increases and the difference was more pronounced in patients with diabetes. We speculate that this finding can be explained by improved

perioperative care, but a thorough literature search did not yield any objective evidence on the subject. Since obese patients are prone to complications and mortality, the medical staff takes extra-care in this critical period and this may have an important effect on complication and survival.

Unlike the debate in the literature regarding underweight, overweight and obese patients, there is a general consensus that severe obesity increase LOHS, short-term mortality and morbidity after surgical procedures [20, 35, 36, 43–45]. We found that severely obese patients had the best short- and long-term mortality rates and LOHS that was similar to overweight and obese patients. Perhaps the reason for this improved outcome lies in better general care of all CV risk factors in these patients, with vigilant attention and preventive measures of surgical complication.

The association between long-term mortality and BMI is less reported. Our data show that in subjects with diabetes (and a similar trend was seen in those without diabetes), a higher BMI is associated with lower mortality risk. It is not surprising that cancer patients undergoing surgery will have better long-term prognosis if they are not underweight [19, 28, 30, 31, 46, 47]. In this condition, low weight may represent catabolism due to extensive disease and lower reserve. Nevertheless, in our cohort only 8.1% of the patients (2249 patients) had history of malignancy, hence, this cannot explain our results. In line with our results, other reports found increased long term death in underweight patient after surgery [48] [27] [39]. Additionally, another study from the general surgery ward, found that long term mortality is increased in underweight patients and decreased in overweight and obese patients, but no difference was demonstrated across the different obesity categories [46]. Long term mortality is affected by many parameters. First, it is related to the baseline illness that brought the patient to require surgery. Second, it is related to the success of the surgical procedure and the ability of the patient to recuperate after the operation. But most importantly, it is affected from an innate condition of the patient. Could obesity and even morbid obesity change the baseline condition of the patients in a way that actually extends life? Could there be another hormone or mediator that we are yet to reveal?

We found that hospital LOHS in patients with or without diabetes was longer in underweight patients in comparison to normal weight patients. In addition, for patients with diabetes, overweight, obese and severely obese patients had shorter LOHS in comparison to normal weight individuals. These results are in agreement with others who found longer LOHS for underweight patients [28, 32, 44] or shorter LOHS for overweight/obese patients, but are contradictive to others who found increased LOHS for overweight/obese [32, 45, 49].

Finally, we found that diabetes was a risk factor for extended hospital stay, as well as short- and long-term mortality after surgery. This is in line with others, who found that diabetes was shown to be related to increased LOHS, ICU admission, perioperative morbidity and mortality after several types of surgery [24] 33, 34]. Diabetes causes micro- and macrovascular complications and despite improved hospital care, these patients have several underlying conditions that may affect their LOHS and short-term mortality. As for the long term, the increased mortality in patients with diabetes might not even be related to the surgical procedure per se.

We acknowledge several study limitations, including the retrospective design, potential unmeasured confounders, along with limitations associated with the use of self-report data or information from the medical records. Furthermore, the analysis is based on all-cause mortality and the specific cause of death is not available. Additional limitation of the study is the lack of data on weight changes during time of follow-up, medication taken, glycemic control, functional status and overall fitness. In addition, the patients reviewed here were admitted to the surgical wards with a variety of medical conditions, which might affect our results. Our analysis only focused on the first admission and not the time-varying effect of multiple admissions for some patients, as well as other time-varying variables including BMI, length of stay. Due to the large amount of missing data for smoking and alcohol status, we also completed a separate analysis for patients with and without available data on these habits. Our results showed that mortality risk was identical for those with and without available data on smoking and alcohol. Another limitation was the potential misclassification bias caused by using BMI as a measure of obesity. Additionally, reverse causation is an important factor, as for example, underweight can be caused by a number of chronic conditions that may put the patient at increased risk for mortality and complications. However, our patients underwent several types of surgical interventions, implying that not all of them had serious operations due to severe baseline condition, only 8.1% of our patients (2249 patients) had cancer (at any stage) and 1.53% (430 patients) had chronic renal failure.

Our study also has several strengths. First, the large number of patients and the multiple types of surgical procedures, validates our results. Second, the length of the follow-up adds important information regarding the long-term effects of obesity and severe obesity on surgical outcomes. Third, since there are a few surgical wards and several surgeons in our hospital, the results cannot be attributed to one distinct mode of action of a certain ward, but can be generalized. Moreover, we adjusted our results for key comorbidities. In addition, the fact that our data was collected in a single-center limits the risk for heterogeneity.

In summary, this study suggests a protective effect of severe obesity in patients admitted to general surgery wards, regardless of their diabetes status. Short- and long-term mortality risks were greatest in underweight patients (diabetic or non-diabetic). Unsurprisingly, for each BMI category, mortality at the end of follow-up was higher for diabetic patients versus non-diabetic patients. Our results indicate that surgical procedures are not only safe in the obese and severely obese population, but the short and long term outcome tends to be improved in comparison to normal weight individuals.

Funding No funding was received for this study.

Compliance with ethical standards

Conflict of interest The authors have no conflicts of interest to disclose.

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