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Effect of Body Mass Index (BMI) on 30-Day and 1-Year Mortality after Endovascular Abdominal Aortic Aneurysm Repair

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Abstract

Objective: Obesity contributes to chronic diseases including diabetes, hypertension, and heart failure, disease states that negatively affect life expectancy. While there is evidence that patients with moderate obesity have improved 30-day outcomes after vascular procedures, we hypothesize that conditions associated with abnormal nutritional status, as indicated by body mass index (BMI), will affect mid-term survival.

Methods: The Vascular Quality Initiative (VQI) data base was accessed for all patients undergoing elective endovascular repair of abdominal aortic aneurysms (EVAR) in the calendar years of 2015 and 2016. Body mass index (BMI) was calculated and patients were stratified using the NIH obesity classification. Patient demographics, prehospital characteristics, operative variables, 30-day outcomes and one-year survival were recorded. "Normal" BMI served as the reference group. Primary outcomes were 30-day mortality, 1-year mortality, and 1-year mortality in 30-day survivors.

Results: A total of 10,726 patients met inclusion criteria. There was a stepwise increase incidence of diseases associated with obesity as BMI increased (hypertension, diabetes, congestive heart failure). In the underweight cohort, women comprised a larger percentage (43.6%) than in the other BMI groups (14.2% - 26.4%). Likewise, aneurysms were noted to be larger in the underweight BMI group. Percutaneous EVAR was lowest in the underweight group (48.4%) and was higher in all obese classes (55.6-60.4%) compared to the normal BMI group (55.4%). Mortality at 30 days was highest in the underweight group (OR 2.68, $p \leq 0.05$) and lowest in the Obese II group (OR 0.60, p=NS). One-year mortality was highest in the underweight cohort (OR 2.29, $p<0.001$) and lowest in Obese I, II, and III (OR 0.46, $p \leq 0.01$) for Obese I and II and ≤0.05 for Obese III). When adjusting for perioperative variables, operative variables and postoperative complications, 1-year mortality remained highest in the underweight group (OR 1.92, $p<0.01$) and lowest in the Obese I group (OR .57, $p<0.001$).

Conclusion: Underweight patients have the highest risk for mortality following EVAR. Interestingly, the group found to have the lowest risk for 1-year mortality was those patients who were moderately obese (class I). It is assumed that underweight patients have associated conditions that contribute to the low BMI. The reason for improved survival in the moderately obese patient (class I) is unclear but may be related to improved nutritional status and/or a better overall physiologic condition.

Keywords: Obesity; Body Mass Index (BMI); Abdominal Aortic Aneurysm

List of abbreviations: BMI: Body Mass Index; VQI: Vascular Quality Initiative; NSQIP: National Surgical Quality Initiative Program; EVAR: Endovascular Aneurysm Repair; NIH: National Institute of Health; ANOVA: Analysis of Variance; COPD: Chronic Obstructive Pulmonary Disease; AAA: Abdominal Aortic Aneurysm

Introduction

The incidence of obesity is rising in industrialized countries throughout the world, with the result that obesity is now considered to be an epidemic [1]. Obesity is associated with development of chronic medical conditions such as diabetes, hypertension, and coronary disease; conditions that put a patient at risk for increased mortality [2-4]. These chronic diseases associated with obesity are well-known cardiovascular risk factors for patients undergoing vascular surgery. Therefore, it is important to understand what effect body mass index (BMI) has on surgical outcomes: both peri-operative and longer-term outcomes. In a prior report that evaluated 30-day outcomes in patients undergoing vascular surgical procedures, Davenport et al, found that the lowest mortality occurred, not in patients with normal BMI, but in patients with mild obesity [5]. He also demonstrated that those who were either underweight (BMI<18.5) or morbidly obese (BMI>40) had the highest mortality when compared to patients with a normal BMI. This study was done using the National Surgical Quality Improvement Program (NSQIP) data set and included patients who underwent a variety of vascular procedures including lower extremity revascularization, abdominal aortic aneurysm repair, cerebrovascular intervention, mesenteric/renal revascularization, vascular access procedures and other vascular procedures.

An obvious limitation when using NSQIP data is that data is recorded for thirty days after surgery and thus the results only reflect peri-operative outcomes. Additionally, as noted, the cited study included a wide variety of vascular procedures. Since obesity is associated with chronic diseases that are associated with increased risk for long-term mortality, we hypothesized that mid-term outcome after vascular surgery would be adversely affected in obese patients. To test this hypothesis, we utilized the Vascular Quality Initiative (VQI) national data set to obtain outcomes at one year after surgery in patients undergoing elective endovascular aneurysm repair (EVAR).

Methods

The Society for Vascular Surgery VQI began in 2011. Currently 612 centers with more than 3,200 physicians participate from both academic and community practices in the United States and Canada. Detailed patient and procedural information are prospectively collected. Follow-up information is collected on these patients for up to one year after their procedure. Twelve vascular surgery categories, one of which is endovascular abdominal aortic aneurysm repair (EVAR), are included in the VQI data set. Data is de-identified and the current study was felt to be exempt by the University of Kentucky Institutional Review Board. Therefore, informed consent was not required.

Initially, data for patients undergoing elective endovascular abdominal aortic aneurysm (EVAR) repair were obtained between January 2012 and 2016. Because of significant VQI changes in definitions regarding endovascular terminology that occurred in 2014, we chose to limit our evaluation to patients undergoing EVAR in the calendar years of 2015 and 2016. Patients were excluded if BMI could not be calculated. Patients who underwent emergent or urgent AAA repair were also excluded. Patient factors including age, gender, race, pre-hospitalization functional status, comorbid medical conditions, and operative details were recorded. Primary outcomes were 30-day mortality, 1-year mortality, and 1-year mortality in patients who survived 30-days. Patients were stratified by NIH classification of obesity: Underweight (BMI ≤ 18.5 kg/m^2), Normal (BMI 18.5 - 24.9 kg/m^2), Overweight (BMI 25.0 - 29.9 kg/m^2), Obese I (30.0 - 34.9 kg/m^2), Obese II (BMI 35.0 - 39.9 kg/m^2) and Obese III/Morbid obesity (BMI ≥ 40.0 kg/m^2).

Bivariate relationships with pre- and intra-operative risk factors were assessed using chi-square and ANOVA tests. Multivariable regression analyses assessed the relationship with 30-day and 1-year mortality after adjusting for significant independent risk factors from the bivariate analyses. Normal BMI served as the reference group. Significance was set at $p < 0.05$. Statistical calculations were performed using SPSS® version 24 (IBM® Corp., Armonk, NY).

Results

Patient Characteristics

A total of 10,726 patients were identified who met inclusion criteria (Table 1). A larger percentage (43.6%) of patients in the underweight cohort was women as compared to the other BMI groups (14.2% - 26.4%). As BMI increased, a stepwise and significant increase in the incidence of comorbid conditions associated with obesity was observed including diabetes mellitus (12.8% underweight, 33.2% morbid obesity), hypertension (76.8% underweight, 90.4% class II obesity), and congestive heart failure (8.4% underweight, 15.5% class II obesity). Patients in the underweight category had the highest incidence of "currently smoking" (58.0%), COPD (54.0%), were more likely to have an abnormal ejection fraction (26.5%), had the lowest preoperative hemoglobin (12.8 ± 2.0 gm), and had the lowest incidence of being treated with aspirin (58.0%) or statins (55.2%) preoperatively.

BMI class	Underweight	Normal	Overweight	Obese I	Obese II	Obese III	All patients	p-value1
BMI, Kg/m^2	<18.5	18.5-24.9	25-29.9	30-34.9	35-39.9	>40		
No. Patients	250	2,974	4,160	2,255	738	349	10,726	
Proportion of Total	2.3%	27.7%	38.8%	21.0%	6.9%	3.3%	100.0%	
Demographics								
Mean Age, y (SD)	75.1 (8.2)	75.5 (8.3)	73.5 (8.5)	71.7 (8.2)	69.5 (7.9)	68.4 (8.0)	73.3 (8.5)	< .001
Female Gender	43.6%	22.3%	14.2%	16.0%	19.8%	26.4%	18.3%	< .001
Race								< .001
White	87.6%	88.2%	90.5%	92.2%	90.1%	89.7%	90.1%	

Black/African American	8.4%	5.3%	4.8%	4.3%	6.1%	7.4%	5.1%	
Other	4.0%	6.5%	4.7%	3.5%	3.8%	2.9%	4.8%	
Family hx AAA	5.3%	6.8%	8.4%	9.5%	10.2%	7.6%	8.2%	.001
Transfer from hospital or rehab unit	5.6%	2.9%	1.6%	1.8%	1.5%	2.3%	2.1%	< .001
Nursing Home Resident	4.0%	1.5%	0.9%	0.8%	0.7%	1.7%	1.1%	< .001
Full Functional Status vs. Assisted Care	62.0%	66.2%	73.7%	74.1%	72.0%	66.8%	71.1%	< .001
Comorbidities								
Smoking Status								< .001
Never	8.4%	14.3%	14.0%	11.0%	8.9%	11.2%	12.9%	
Prior	33.6%	48.7%	58.3%	62.3%	63.1%	60.9%	56.3%	
Current	58.0%	37.0%	27.8%	26.7%	27.9%	27.9%	30.8%	
HTN	76.8%	79.3%	82.3%	86.6%	90.4%	88.8%	83.0%	< .001
Any Diabetes	12.8%	13.4%	19.7%	26.6%	33.0%	33.2%	20.6%	< .001
Diet	3.6%	3.3%	4.9%	5.0%	5.0%	5.7%	4.5%	
Non-insulin	6.8%	7.7%	11.9%	16.3%	19.9%	21.5%	12.4%	
Insulin	2.4%	2.4%	2.9%	5.3%	8.1%	6.0%	3.7%	
Prior CAD								.036
Asympt, Hx MI	21.2%	22.4%	23.0%	24.1%	26.2%	22.6%	23.2%	
Stable Angina	3.6%	5.2%	5.7%	5.9%	6.5%	5.4%	5.6%	
Unstable Angina or MI < 6 Mos.	1.6%	0.9%	0.9%	0.9%	2.2%	1.4%	1.0%	
Prior CHF								.027
Asymp, Hx CHF	6.0%	7.6%	6.6%	7.9%	8.4%	8.3%	7.3%	
Mild	1.6%	2.6%	2.7%	3.1%	3.9%	3.7%	2.9%	
Moderate/Severe	0.8%	1.6%	1.3%	2.3%	2.2%	2.3%	1.7%	
Prior CABG								.003
>= 5 y ago	2.4%	4.1%	5.2%	5.8%	5.7%	6.3%	5.0%	
< 5 y ago	10.0%	13.1%	13.2%	15.0%	13.1%	10.0%	13.4%	
Prior PCI								< .001
>= 5 y ago	6.4%	9.1%	9.7%	8.7%	10.0%	11.5%	9.3%	
< 5 y ago	9.6%	11.2%	13.3%	14.5%	16.9%	10.3%	13.0%	
Preop EF (n=6002)								.074
< 30%	5.3%	4.4%	3.4%	3.5%	3.0%	2.4%	3.7%	
30 - 50%	21.2%	19.7%	18.6%	17.7%	20.1%	21.1%	19.0%	
> 50%	73.5%	75.9%	77.9%	78.8%	76.9%	76.6%	77.3%	
COPD								< .001
Yes, Untreated	18.0%	10.3%	8.5%	8.1%	6.0%	7.7%	9.0%	
Medically Treated	32.0%	19.9%	17.5%	19.4%	22.0%	23.2%	19.4%	
Home oxygen	4.0%	5.8%	3.4%	4.7%	6.1%	9.7%	4.7%	
Dialysis/ Functional Transplant	0.8%	2.0%	1.1%	1.2%	0.5%	0.6%	1.3%	.005
Preop Hgb Mean (SD)	12.8 (2.0)	13.1 (2.0)	13.7 (1.8)	13.9 (1.8)	13.9 (1.7)	13.7 (1.8)	13.6 (1.9)	< .001
Preop. Medication								
ASA	58.0%	62.8%	66.9%	68.0%	66.0%	61.9%	65.6%	< .001
Statin	55.2%	66.2%	73.1%	74.8%	74.0%	69.6%	71.1%	< .001
Beta-blocker	43.2%	45.7%	51.1%	56.8%	61.8%	62.8%	51.7%	< .001
Anticoagulant	9.2%	10.6%	11.8%	12.8%	16.4%	17.2%	12.1%	.001
ACE	36.8%	40.8%	46.6%	51.4%	58.4%	56.7%	46.9%	< .001

[1]ANOVA for continuous variables, chi-square or Fisher's exact test of proportions across groups. Risk factors that did not vary with BMI group included: Preop. Creatinine > 1.2 (25.8%), P2Y use (14.6%), Anticoagulant use (12.4%), Hx Stroke (10.1%), Preop Dysrhythmia (19.0%), and Genetic history (0.7%)

Table 1: Patient characteristics

Aneurysm and Operative Characteristics

Patients in the underweight group, despite having the highest incidence of women, tended to have larger aneurysms with the highest incidence of aneurysms >6.0 cm (25.2%) and the lowest incidence of aneurysms smaller than 5.0 cm (18.4%) (Table 2). Patients in the obese class II appeared to have the smallest aneurysms with an incidence of aneurysm <5.0 cm of 25.9% and an incidence of aneurysms >6.0 cm of 18.9%. Percutaneous endovascular repair was done in fewer of the underweight cohort (48.4%) compared to the highest incidence seen in the obese I group (60.4%); but all obese cohorts had a higher incidence of percutaneous repair (55.6% - 60.4%) than the normal BMI group (55.4%). The choice of endograft differed among groups, specifically a higher use of an aorto-uni graft being utilized in the underweight group (10.0%) compared to the other BMI groups (4.3% - 6.7%). The incidence of blood transfusion was highest in the underweight group (18.6%) and lowest in the obese I group (5.9%). There were relatively minimal differences in intraoperative complications among groups with the normal BMI group having the highest incidence (29.8%). Injury to an iliac artery was rare, but more frequent in the underweight (2.4%) and normal (2.0%) BMI groups.

BMI class	Underweight	Normal	Overweight	Obese I	Obese II	Obese III	All Patients	p-value[1]
BMI, kg/m^2	8 - 18.49	18.5 - 24.9	25 - 29.9	30 - 34.9	35 - 39.9	40 +		
No. Patients	250	2,974	4,160	2,255	738	349	10,726	
Access								.001
Percutaneous Femoral	48.4%	55.4%	58.2%	60.4%	57.6%	55.6%	57.6%	
Open Femoral	48.8%	42.4%	40.3%	38.2%	40.9%	43.6%	40.8%	
None, Iliac, unknown	2.8%	2.2%	1.4%	1.4%	1.5%	0.9%	1.6%	
Aortic Device								.002
Bifurcated infra-renal	63.2%	68.3%	69.4%	71.1%	69.6%	70.8%	69.3%	
Bifurcated Supra-renal	12.8%	14.2%	15.7%	14.1%	16.0%	14.3%	14.9%	
Aorto-uni-iliac	10.0%	6.7%	4.8%	4.6%	5.7%	4.3%	5.4%	
Bilateral aorto-iliac limbs	7.6%	7.4%	6.8%	7.6%	6.5%	7.2%	7.1%	
Aorto-aortic	3.2%	1.2%	1.3%	1.0%	0.8%	1.1%	1.2%	
Other/Unknown	3.2%	2.2%	2.0%	1.7%	1.4%	2.3%	2.0%	
Mean Duration of operation, min. (SD)	131 (74)	131 (70)	124 (63)	127 (68)	134 (66)	142 (74)	128 (67)	< .001
Blood Transfusion Periop.	18.6%	12.0%	6.6%	5.9%	7.0%	10.0%	8.3%	< .001
Any Intraop Complication	27.6%	29.8%	28.2%	26.4%	25.9%	23.2%	27.9%	.020
Leak at Completion	18.0%	23.1%	22.5%	20.8%	20.3%	20.3%	22.0%	.131
Iliac Injury	2.4%	2.0%	1.0%	0.4%	0.9%	0.9%	1.2%	< .001
Preop. Max AAA Diam,								.045
<= 50.00	18.4%	23.4%	24.5%	25.9%	22.2%	20.6%	24.1%	
50.01 - 55.00	32.4%	31.8%	32.9%	33.4%	34.1%	32.1%	32.7%	
55.01 - 60.00	20.8%	21.4%	20.8%	20.4%	20.2%	22.6%	20.9%	
60.01+	25.2%	21.5%	20.0%	18.9%	22.2%	23.8%	20.6%	
Unknown	3.2%	2.0%	1.9%	1.4%	1.2%	0.9%	1.7%	
Any Iliac Adjunct Procedure	20.0%	14.7%	12.8%	10.9%	11.0%	12.0%	12.9%	< .001

[1]Factors not associated with BMI included: Iliac aneurysm (26.4%) or location (common 23%, internal or both 3.4%); Aortic neck length (26.0) or diameter (23.8), any proximal aortic extensions (19.0%)

Table 2: Aneurysm and Intraoperative Variables

Outcomes

Specific postoperative complications did not differ between groups (Table 3). However, when evaluating patients with a composite of complications, the underweight cohort had the highest incidence (10.4%) compared to the other BMI groups (5.5 - 6.6%). 30-day mortality was highest in the underweight category (2.4%) and lowest in the Obese II cohort (0.5%) (Table 4). Even though there was a large difference in 30-day death between the underweight group and the other BMI cohorts, this outcome occurred at such a low rate that the difference approached, but did not achieve, statistical significance (p=0.057). However, 1-year mortality did demonstrate significant differences between BMI groups. Overall one-year morality, adjusting for multiple perioperative variables, operative variables, and postoperative complications was highest in the underweight group (OR 1.98, $p < 0.01$) and lowest in the obese class I cohort (OR 0.68, $p < 0.05$). One-year mortality adjusting for perioperative variables, operative variables and postoperative complications* in patients who survived the initial 30-day postoperative period was similar with the highest mortality seen in the underweight patients (OR 1.92, $p < 0.01$) and lowest in obese class I patients (OR 0.57, $p < 0.001$).

BMI class	Underweight	Normal	Over-weight	Obese I	Obese II	Obese III	All patients	p-value
BMI, Kg/m²	<18.5	18.5-24.9	25-29.9	30-34.9	35-39.9	>40		
Number (%) of Patients	250 (2.3%)	2,974 (27.7%)	4,160 (38.8%)	2,255 (21.0%)	738 (6.9%)	349 (3.3%)	10,726 (100%)	
Any ICU stay	33.2%	33.6%	31.4%	29.2%	31.2%	33.8%	31.7%	0.028
Median LOS (IQR)	2 (1-3)	1 (1-3)	1 (1-2)	1 (1-2)	1 (1-2)	1 (1-2)	1 (1-2)	<0.001
Return to OR	3.6%	1.8%	1.6%	1.4%	1.2%	1.1%	1.6%	0.114
Complications								
Composite (Any of the following)	10.4%	6.3%	5.4%	5.5%	5.4%	6.6%	5.8%	0.026
MI	1.2%	0.4%	0.6%	0.8%	0.4%	0.9%	0.6%	0.467
Dysrhythmia	3.2%	1.9%	1.5%	2.0%	1.1%	1.7%	1.7%	0.175
CHF	0.8%	0.6%	0.6%	0.7%	0.7%	0.6%	0.7%	0.997
Respiratory	1.2%	1.1%	1.2%	1.2%	1.5%	1.4%	1.2%	0.980
Leg embolism	1.6%	0.6%	0.6%	0.5%	0.5%	0.6%	0.6%	0.498
SSI	0.0%	0.1%	0.1%	0.1%	0.4%	0.3%	0.1%	0.220
Stroke	0.0%	0.1%	0.2%	0.0%	0.0%	0.3%	0.1%	0.067
Hematoma	1.6%	1.0%	1.1%	1.0%	1.5%	1.1%	1.1%	0.861
Dialysis	0.0%	0.3%	0.3%	0.4%	0.1%	0.3%	0.3%	0.836
Site occlusion	0.4%	0.2%	0.1%	0.2%	0.1%	0.0%	0.1%	0.693

Table 3: Perioperative Outcomes and complications

BMI class	Under-weight	Normal	Overweight	Obese I	Obese II	Obese III	All	p-value
BMI, Kg/m²	<18.5	18.5-24.9	25-29.9	30-34.9	35-39.9	>40	**patients**	
Number (%) of Patients	250 (2.3%)	2,974 (27.7%)	4,160 (38.8%)	2,255 (21.0%)	738 (6.9%)	349 (3.3%)	10,726 (100%)	
Discharge status								0.001
Home	88.8%	92.8%	95.0%	94.9%	95.3%	91.7%	94.1%	
Healthcare facility	10.4%	6.8%	4.5%	4.6%	4.3%	8.0%	5.5%	
Death	0.8%	0.4%	0.5%	0.6%	0.4%	0.3%	0.5%	
30-day death	2.4%	0.9%	0.6%	0.8%	0.5%	0.6%	0.8%	0.057
Crude odds ratio	2.68*	1.00	0.71	0.88	0.60	0.63		
Adjusted odds ratio	2.47	1.00	0.85	1.15	0.88	0.95		
1-year death	12.8%	6.0%	3.7%	2.9%	2.8%	2.9%	4.3%	<0.001
Crude odds ratio	2.29†	1.00	0.60†	0.46†	0.46†	0.46*		
Adjusted odds ratio[1]	2.24†	1.00	0.68†	0.57†	0.63	0.65		
Adjusted odds ratio[2]	1.98#	1.00	0.81	0.68	0.66	0.56		
1-year death in 30-day survivors	10.7%	5.2%	3.1%	2.1%	2.3%	2.3%	3.5%	<0.001
Crude odds ratio	2.19†	1.00	0.58†	0.40†	0.44†	0.43*		
Adjusted odds ratio[1]	2.15†	1.00	0.66†	0.48†	0.59*	0.60		
Adjusted odds ratio[2]	1.92#	1.00	0.79	0.57†	0.62	0.51		

[1]Adjusted for age and gender
[2]Adjusted for preoperative risk factors by order of entry: hemoglobin, COPD, age, functional status, transfer status, nursing home resident, preop statin use (protective), preop anticoagulant use, and smoking status; then intraoperative risk factors: transfusion of any PRBCs, duration of operation; then occurrence of any of the composite complications (yes/no)
Odds ratio differs from †1.00, p ≤ .001, # p ≤ .01, * p ≤ .05

Table 4: Outcomes

Discussion

The current study demonstrates that there is a higher incidence of peri-operative complications, 30-day mortality and 1-year mortality in patients undergoing EVAR who are underweight. Interestingly, significantly lower one-year mortality was seen in patients with class I obesity (BMI 30.0-34.9) and, while not reaching statistical significance, 30-day mortality was also lowest in the class I obesity cohort. The reason for the worse outcomes in the underweight group of patients intuitively would seem to be that this group of patients has concomitant and underlying medical conditions that are wasting and leave them in a malnourished state. This study does not directly identify such conditions, but as noted these patients had the highest incidence of COPD, current smoking history, abnormal ejection fraction, lowest preoperative hemoglobin and were least likely to be treated with aspirin and statins. We are unable to determine measures of nutritional reserve such as low serum albumin, prealbumin, or sarcopenia. Therefore, we can only hypothesize that the underlying condition that resulted in the underweight BMI had an effect on the patients' nutritional status and physiologic reserve capacity.

What is more difficult to explain is why patients who are moderately obese have the lowest mortality which would seem to disprove our hypothesis that increasing obesity, with its increase in associated chronic diseases, would result in higher mid-term (1-year) mortality. We suspect that as BMI increases, there is an associated increase in physiologic reserve. This may be in the form of nutritional reserve. It could also be that in obese patients, better cardiac function is needed for patients to carry out normal activities such as ambulation. There is conflicting evidence for this in this data set. In support of improved cardiac function, the number of patients with an EF of greater than 50% tended to increase with BMI classification. On the other hand, we also noted that the incidence of congestive heart failure increased as BMI increased.

Others have also found that outcomes are better in patients with moderate obesity, given the label "obesity paradox". Examples include obese patients with heart failure [6,7] and those undergoing coronary artery bypass [8]. Elagizi, *et al.* recently published an overview of obesity and the "obesity paradox" in relation to cardiovascular diseases [9]. They clearly outline that obesity's effect on outcome is complex on multiple levels. There are limitations in categorizing patients by BMI in that BMI does not discriminate between fat mass, fat-free mass, or lean mass. The physiologic effects of obesity are conflicting. Increase in obesity causes an increase in total blood volume, increased preload and decreased systemic vascular resistance resulting in increased cardiac output. While these are beneficial, obesity can also lead to left ventricular hypertrophy and diastolic dysfunction. Adipose tissue also serves as an endocrine organ. Adipokines have myocardial protective effects [10,11]. However, the adipose tissue can also produce pro-inflammatory cytokines that in animal models have resulted in diastolic dysfunction [9,12,13]. Elagizi, *et al.* conclude that BMI is a good marker for excess body weight, but emphasize that rather than an improved prognosis seen in obese I patients, attention should be directed to the poor prognosis seen in the underweight patients, specifically those with low muscle mass and poor cardiorespiratory fitness. Our study is in line with these conclusions, demonstrating that the underweight have the highest risk for mortality.

A recent study by Locham *et al.* also used Vascular Quality Initiative data to evaluate the effect of obesity on outcome in patients undergoing abdominal aortic aneurysm repair [14]. Their conclusions were that obesity increases risk with open aneurysm repair, but not with endovascular repair. There are a number of notable differences between the current report and Locham's study. In Locham's study, the authors evaluated patients undergoing both open AAA repair and EVAR between 2003 and 2017 whereas we chose to evaluate only endovascular repair and limited our study to two years (2015 and 2016). Locham classified patients as obese (BMI < 30 kg/m^2) and non-obese (BMI < 30 kg/m^2) while in the current study, we stratified patients by the six NIH classifications for obesity. The primary outcome for Locham's study was in-hospital mortality, while the current study also evaluated 1-year mortality. The current study does not dispute the results reported by Locham *et al.* but suggests that a factor responsible for higher mortality is actually the underweight status of the patient. This cohort of underweight patients is small in number and its effects would be diluted by the normal and overweight groups (as combined by Locham). The better outcomes in the Obese I group are countered by somewhat worse outcomes in the morbidly obese groups. Therefore, we feel that in order to accurately assess the effect of obesity on outcome; patients need to be stratified using the NIH classification. It is also possible that the increased technical difficulty of open AAA repair in obese patients (BMI>30) contributed to the worse outcomes seen in Locham's study.

In the current report, we attempted to reduce confounding factors. As such, we limited our study to patients who underwent elective EVAR, eliminating those who had open repair or underwent urgent or emergent repair. This was done with the expectation that the physiologic responses to surgery would be minimized. Thus, our finding that there is an association between BMI and mortality suggests that the results are a true reflection of BMI status. Additionally, if the effect of BMI on outcome is secondary to the patient's inherent physiologic reserve, we would hypothesize that if/when a similar analysis is done for open AAA repair, the physiologic stress of surgery may amplify any protective effects (moderate obesity) or negative effects (underweight) that BMI has on physiologic reserve.

Preoperative variables included hemoglobin, COPD, age, functional status, transfer status, nursing home resident, preoperative statin use (protective), preoperative anticoagulant use, smoking status. Intraoperative variables included transfusion of any PRBC, duration of operation. Postoperative complication was presence or absence of a complication.

One other observation bears comment. The underweight group had a significantly higher incidence of women (43.6%) compared to the other BMI groups (14.2-26.4%). Additionally, the underweight group had the lowest prevalence of small aneurysms (<5 cm). In men, it is recommended that patients with aneurysms <5.0 cm be followed with imaging, while those with aneurysms >5.4 be considered for elective repair, but in women elective repair is recommended for aneurysms measuring between 5 and 5.4 cm [15]. These findings raise the questions whether there was bias for repair in this group due to the relatively larger aneurysm size in women.

A fundamental question however remains: how to use the information from this study. Certainly, the results can be used when discussing expected outcomes with patients prior to operation. However, we feel that the importance of this study is that it highlights that we incompletely understand how to measure "physiologic reserve". BMI may be a crude measure of a patient's reserve, but it is interesting that the best outcomes appear to be in those patients who are somewhat overweight (Obese class 1) as opposed to "normal" BMI patients. More work is needed in this area, such as correlating prealbumin and albumin serum levels with BMI and metabolic function studies following surgical intervention. BMI is a crude indicator of nutritional status and it has been suggested that seemingly inconsistent associations of mortality with BMI reflect that inability of BMI to discriminate between lean and fat mass [16,17]. Nevertheless, it is easy to calculate and use BMI and our results indicate that BMI is a risk factor to be taken into consideration when counseling patient that will undergo elective EVAR.

There are limitations to the current study. The study utilizes a large retrospective database with the potential for inaccurate data entry. However, VQI does an annual check and hospitals with significant missing data are required to complete the missing information. There were relatively few patients in the extremes of BMI (underweight and obese III) compared to the other BMI groups which could affect the results. As noted, BMI is an imprecise measurement of body fat and does not assess variations for race, gender and age. Additionally, BMI does not identify body fat mass, lean mass, and fat-free mass, nor it is taken into account cardiopulmonary fitness. However, it is safe to assume that at the extremes (underweight and morbid obesity); BMI is a reasonable estimate for patients who are significantly underweight or obese. While an elevated BMI may be misleading in those individuals with increased muscle mass (weight lifters, athletes), in this older patient population, it is unlikely that there are many, if any, who will fall into this category. There may also be confounding factors that were not included in the multivariate analysis. We also excluded open repairs and urgent and emergent AAA repairs in an attempt to provide minimize the confounding factors as discussed above.

Conclusion

In conclusion, we have shown that in patients undergoing elective EVAR, one-year mortality is lowest in patients with moderate (class I) obesity and highest in the underweight patients. The higher mortality in underweight patients is most likely secondary to underlying disease processes that, in turn, result in the low weight status. It is not clear why patients with moderate obesity have the lowest mortality, but may be secondary to better physiologic reserve and/or nutritional status.

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