Title
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Journal
JAMA Network Open, 8(8)

ISSN
2574-3805

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Publication Date
2025-08-01

DOI
10.1001/jamanetworkopen.2025.28875

Peer reviewed

Body Mass Index and Post-surgical Outcomes in Older Adults

Running Head: Body Mass Index and Post-surgical Outcomes

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Funding and Conflicts of Interest: This work is supported by UCLA RCMAR/CHIME NIA Grant (5P30AG021684-PI Mangione) and UCLA CTSI NCATS Grant (UL1TR001881-PI Dubinett) for Dr. Canales-RCMAR/CHIME Scientist. Dr. Canales was also awarded a National Academy of Medicine, Diagnostic Excellence Award, supported through the John A. Hartford Foundation. Dr. Sarkisian was supported by National Institutes of Health/National Institute on Aging (NIH/NIA) Midcareer Award in Patient-Oriented Aging Research (1K24AG047899), NIH/NIA Resource Centers for Minority Aging Research IV/Center for Health Improvement of Minority Elderly (5P30AG021684 (PI Mangione) and NIH/NCATS UCLA Clinical and Translational Science Institute (CTSI) (UL1TR001881 PI Dubinett). No authors have conflicts of interest related to the research, Dr. Cannesson is co-owner of Sironis.

KEY POINTS:

Question: In older adults (≥65 years) presenting for surgery is higher body mass index associated with lower 30-day all-cause mortality?

Findings: In this observational cohort study, patients categorized as being overweight had the lowest 30-day all-cause mortality rate compared to patients categorized as having a normal body mass index.

Meaning: Traditional BMI risk categories may need to be re-calibrated for the population ≥65 years old undergoing surgery.

ABSTRACT

Importance: High body mass index (BMI) has been associated with increased postoperative complications including mortality in the general population, leading many perioperative providers to recommend pre-operative lifestyle modifications aimed at achieving normal body weight. However, aging introduces physiological changes associated with frailty such as altered body composition, fat redistribution, stature reduction due to height loss, all which may modify the relationship between BMI and surgical outcomes in older adults.

Objective: To determine if a higher BMI in older adults who are undergoing major elective surgery is protective against all-cause mortality.

Design: We conducted an observational cohort study of older adults presenting for surgery from 2019-2022.

Setting: Large academic Center in Southern California

Participants: Adults 65 years or older presenting to a pre-operative clinic prior to planned major elective surgery.

Exposure: Body mass index

Main Outcomes and Measures: Post-operative outcomes included all-cause 30-day and 1-year mortality, post-operative delirium, discharge disposition, and complications classified using the Clavien-Dindo system.

Results: The study included 414 older adults undergoing major elective surgery with a mean age was 75.9 $\pm$ 7.2 (95% CI 75.2 – 76.6), and 54.8% (95% CI 50.2% – 60.4%) of the cohort were female. The prevalence of frailty was 24.2% (95% CI 20.3% - 28.5%) and 37% (95% CI 32.6% - 41.8%) of the cohort was pre-frail. The overall 30-day all-cause mortality rate was 11% (95% CI 8.5% - 14.5%). Patients categorized as overweight (BMI 25–29.9 kg/m^2) had the lowest 30-day all-cause mortality rate, with a significant risk reduction compared to patients with a normal BMI (18.5–24.9 kg/m^2) [1/128 (0.8%) vs. 25/133 (18.8%)] (OR 0.03 (95% CI 0.01 – 0.26, p=0.001). This association remained significant in the multivariable logistic regression model after adjusting for potential confounders (OR 0.14 (95% CI 0.06 – 0.34, p<0.001). Patients categorized as underweight (BMI <18.5 kg/m^2) had the highest 30-day all-cause mortality rate [15/20 (75%, 95% CI 55% - 90%)].

Conclusions and Relevance: In this observational cohort study of older adults undergoing major elective surgery, being overweight was associated with lower odds of 30-day all-cause mortality. These findings suggest that traditional weight loss recommendations based on achieving normal BMI may need to be re-evaluated for this population.

Introduction

More than half of Americans are classified as overweight or obese based on their body mass index (BMI), with a growing number of adults aged 65 years and older falling into the overweight and obese categories.[1] Higher BMI is strongly associated with an increased risk of chronic conditions such as cardiovascular disease, type 2 diabetes, obstructive sleep apnea, and certain cancers, as well as decreased life expectancy in the general population.[2-5] BMI, calculated using a person's height and weight, classifies individuals into categories such as underweight (<18.5 kg/m²), normal weight (18.5–24.9 kg/m²), overweight (25–29.9 kg/m²), obese (30–34.9 kg/m²), and morbidly obese (≥35 kg/m²).[6] Population-based studies in younger and middle-aged adults often demonstrate a J-shaped relationship between BMI and outcomes, with the lowest risk of all-cause mortality observed among those with normal BMI and increased mortality at the extremes of BMI categories.[7-9]

However, body composition and its implications for health outcomes vary substantially by age, gender, and race.[10,11] Aging is associated with functional decline, multimorbidity, and frailty, which independently contribute to poorer post-operative outcomes.[10,12] Emerging evidence suggests that in community dwelling older adults, a higher BMI may be protective against all-cause mortality.[7,9] This protection has been hypothesized to stem from increased physiological reserve, better nutritional status, or greater metabolic adaptability, which may provide resilience against age-related health declines and acute stressors.

In the perioperative setting across patients of all ages, high BMI has been linked to increased postoperative complications, including blood loss, infection, and thromboembolic events.[13,14] Additionally, higher BMI has been linked to greater postoperative mortality in certain populations.[15] As a result, many perioperative providers recommend pre-operative lifestyle modifications, including weight loss, with the intention of optimizing surgical outcomes and reduce obesity-related health risks.[3,16,17]

Despite these efforts, the relationship between BMI and perioperative outcomes remains unclear in older adults. Given that older adults experience unique age-related physiological changes which may modify the impact of BMI on health outcomes, [10,12] it raises questions about the appropriateness of current recommendations for overweight older adults to lose weight before surgery[17]. We hypothesized that higher BMI in older adults undergoing major elective surgery is protective against all-cause mortality. To test whether higher BMI provides a survival advantage for older adults undergoing major elective surgery, we conducted a longitudinal observational cohort study of older adults undergoing major elective surgery, at a large urban academic center.

Methods

After institutional review board approval, waiver of consent, and in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines,[18] we conducted an observational cohort study of older adults presenting to our pre-operative clinic at a large academic center in southern California. The process for pre-operative evaluation at UCLA Health has been described in detail elsewhere.[19] Briefly, the pre-operative clinic evaluates over 36,000 patients annually. Those deemed appropriate for a telephone pre-operative interview are assessed in that manner, with the remaining approximately 1,200 patients are evaluated in the clinic annually. All adults 65 years of age or older who present for an in-person assessment in the pre-operative clinic undergo routine standardized geriatric and frailty assessments.

Study Population

In this study we included all adults 65 years of age or older who were assessed by the pre-operative clinic for non-cardiac, non-transplant, elective surgery and expected to require postoperative hospitalization of at least one night over a three-year period (February 2019-January 2022). Patients scheduled for intracranial neurosurgery were excluded as well. Those patients who presented to the pre-operative clinic multiple times for medical optimization or for multiple surgeries were only included during their last assessment prior to surgery. The last visit was chosen, as weight may vary from the first to last visit. Therefore, the cohort was comprised of only unique patient visits.

Demographic and Frailty Assessments

In addition to measuring height and weight, to account for potential moderating or confounding factors, we collected demographic and clinical data. This included age, gender, height, weight, nutrition and weight loss screening results, American Society of Anesthesiologists (ASA) status, type of surgery, and co-morbidities such as hypertension and diabetes. All data including height, weight, and comorbidities were recorded by the pre-operative clinic nursing team during the pre-operative clinic encounters. Patients were categorized based on BMI into groups [underweight (BMI<18.5 kg/m^2); normal weight (BMI=18.5-24.9 kg/m^2); overweight (BMI= 25-29.9 kg/m^2); obese (BMI=30-39 kg/m^2) and morbidly obese (BMI>40 kg/m^2)]. Given that cancer is associated with un-intentional weight loss and overall outcomes (including mortality), we also specifically noted if a patient had an active cancer diagnosis at the time of the pre-operative visit. Frailty was assessed using the 5-item modified frailty index(mFI-5) prospectively by a trained nurse at the time of the patient's pre-operative clinic[20]. The modified frailty scale uses health deficit accumulation and includes comorbid factors of 1) congestive heart failure (within 30 days of surgery), 2) diabetes mellitus, 3) chronic obstructive pulmonary disease or pneumonia; 4) dependent functional health status (total or partial) at time of surgery; 5) hypertension requiring medication.

Post-Surgical Outcomes Data

The primary outcomes were 30-day and 1-year, postoperative all-cause mortality. Our secondary outcome was the incidence of complications. We (CC and MA) performed a chart review of each patient's electronic medical record to obtain postsurgical complications, non-home discharge disposition, and all-cause 30-day and 1-year postoperative mortality. The mFI-5 was calculated based on the sum of categories and assigned into Frail= mFI-5 ≥ 2; Pre-Frail= mFI-5 =1; or Not Frail mFI-5 =0. Complications were categorized as re-operation, readmission within 30 days, in hospital cardiac events (i.e. arrhythmia, myocardial infarction), in hospital pulmonary events (i.e. reintubation, in hospital pneumonia), and other in hospital complications including surgical site infection, deep vein thrombosis (DVTs) and strokes. We also calculated the Clavien-Dindo Complication (CDC) classification, as it offers a standardized method for comparing severity of complications across diverse surgical populations at 30 days postoperatively.[21] Delirium was identified in the first five days after surgery both by assessment with the Confusion Assessment Method (CAM) and chart review using published criteria.[22] Hospitalized patients 65 years of age or older at our institution undergo delirium screening using CAM or CAM-ICU (intensive care unit) twice per day by nursing staff as standard patient care (every 12 hour shift). CAM scores are entered into the electronic medical record. We elected *a priori* to also include delirium by chart review, as it has been shown to complement CAM, given that delirium is a state of altered consciousness that waxes and wanes throughout the day.[23] CAM assessments can miss acute episodes of delirium.

Statistical Analysis

The primary independent variable of interest was BMI. Patient characteristics and study variables were summarized by BMI groups using mean ± SD or frequency (percentage) unless otherwise noted and compared between groups using the one-way ANOVA or chi-square test. The primary outcomes were 30-day and 1-year all-cause mortality. Secondary outcomes included the incidence of complications, and specifically severe complications (CDC grade III or higher) defined as any complication leading to invasive intervention, re-operation, unplanned ICU admission, single- or multi-organ failure, or death within 30 days of surgery[21] To identify an optimal BMI cut-off associated with mortality, we applied Youden's Index, a commonly used metric in diagnostic testing. Youden's index is calculated as (sensitivity + specificity – 1) and identifies the point on the receiving operating characteristic (ROC) curve that maximizes the combined sensitivity and specificity of a given cut-off. However, since we hypothesized having low or high BMI were associated with mortality, we conducted all further analyses using standard BMI categories for consistency and interpretability. To evaluate the association between BMI categories and mortality, multivariable logistic regression models were used to calculate adjusted odds ratios (ORs) with 95% confidence intervals (CIs). Normal BMI (18.5–24.9 kg/m^2) was used as the reference group based on prior population studies indicating the lowest all-cause mortality in this category. Adjustments were made for key potential confounders, including age, sex, ASA status, and frailty, to account for their potential influence on the outcomes. All tests were 2-tailed, and a p value of <0.05 was considered statistically significant. All statistical analyses were performed using IBM SPSS V29 (Armonk, NY) or R V4.1.0 (Vienna, AU, www.r-project.org).

Power Analysis

A power analysis was conducted to assess the minimal detectable odds ratios (ORs) for each BMI category (<18.5, normal, 25–29.9, 30–39, and >40) in relation to the two outcomes (30-day and 1-year mortality). The sample sizes varied by BMI group, ranging from 20 patients in the <18.5 group to 133 in the normal BMI group. For 30-day mortality, the minimal detectable ORs were 2.16, 0.34, 0.31, and 0.004, respectively. For 1-year mortality, the minimal detectable ORs were 3.72, 0.43, 0.40, and 0.07, respectively. These estimates were derived using the observed sample sizes and mortality rates and reflect the smallest effect sizes that could be detected with 80% power at a significance level of 0.05. Given these values, the study is adequately powered to detect clinically meaningful differences in outcomes across BMI groups.

Results

Over a three-year period, we enrolled 414 consecutive older adults with a mean age was 75.9-year-old (+/- 7.20) (95% CI 75.2 – 76.6) and women represented 54.8% (50.2% - 60.4%) (n =227) (Figure 1). Baseline characteristics (Table 1) showed no statistical differences in demographics, ASA status, and surgical type between the BMI groups. Twenty-four percent (n=100) of patients were frail (95% CI 20.3% - 28.5%) while 37% (n= 153) were pre-frail (95% CI 32.6% - 41.8%) (Table 2).

Primary Outcome

Overall, 11% (95% CI 8.5% - 14.5%) of patients experienced mortality at 30 days, and 17% (95% CI 13.7% - 21.3%) at 1 year. Univariable logistic regression showed that underweight patients had a significantly higher odds of 30-day mortality compared to normal weight patients [OR:12.9 (95% CI: 4.31-38.99)] $p<0.001$. In contrast, overweight and obese patients demonstrated a significantly lower 30-day mortality risk compared to normal weight patients, [OR: 0.03 (95%CI: 0.01-0.26)] $p=0.001$ for overweight patients, and [0.04 (95% CI: 0.01-0.30)] $p=0.018$ for obese patients. Similarly, underweight patients had a significantly higher risk of 1-year mortality compared to normal weight patients [OR:10 (95% CI: 3.14-31.84)] $p<0.001$, while overweight and obese patients showed lower risk [OR: 0.14 (95%CI: 0.06-0.34)] p=0.001 for overweight patients, and [0.12 (95% CI: 0.05-0.32)] p=0.018 for obese patients. The multivariable models yielded similar findings (Table 3). Using Youden's Index, a BMI cut-off of 22.5 kg/m2 was identified. As a sensitivity and hypothesis generating sub-analysis, we further subdivided the normal weight category to (18.5-22.5 kg/m2, 22.5-25 kg/m2) (Figure 2 and eTable 1 in the Supplement).

Secondary Outcomes

Both extremes of BMI categories, underweight and morbidly obese, were associated with higher risk of postoperative complications (Table 3, eTable 2 and 3 in the Supplement). In unadjusted analyses, underweight patients experienced postoperative delirium in 50% (95% CI 35% - 65%) of cases, and morbidly obese patients experienced postoperative delirium in 21% (95% CI 8.3% - 33.3%) of cases [combined 'extremes' rate of 34.1% (95% CI 22.7% - 45.5%)], compared to normal weight, overweight, and obese patients who experienced postoperative delirium in 12.7% (95% CI 9.7% - 15.9%) p<0.001. When comparing types of complications, morbidly obese patients were at greatest risk of pulmonary complications (33%, 95% CI 20.8% - 45.8%) and were more likely to have other complications including deep vein thrombosis and strokes (21%, 95% CI 8.3% - 33.3%). Overweight patients had the fewest number of postoperative complications, with just 16% (95% CI 10.2% - 22.7%) experiencing any complication. When comparing by frailty status, frail patients were at highest risk of complication with 20% (95% CI 14.0% - 26.0%) of frail patients experiences severe CDC complications (grade III or higher).

Discussion

Our study findings challenge the traditional belief that attaining a "normal" BMI (18.5–24.9 kg/m^2) is ideal prior to major elective surgery for older adults. Instead, our findings suggest that older adults, particularly frail individuals, may benefit from being in the overweight category. Specifically, patients with a BMI of 25.0–29.9 kg/m^2 had higher odds of survival at 30 days and 1 year following surgery compared to those with normal body weight. This BMI range was also associated with fewer overall postoperative complications, and these patients were more likely to be discharged home.

Previous studies of community-dwelling middle-aged and older adults have found that being overweight or having low-grade obesity is associated with lower overall mortality in frail individuals, while this benefit was less apparent in non-frail individuals.[9] Population studies across various age groups, accounting for underlying disease, indicate that all-cause mortality is lowest within the "normal" BMI range of 18.5–24.9 kg/m^2. However, for older adults, particularly septuagenarians and octogenarians, the BMI associated with the lowest mortality tends to be higher.[7-9] Major surgery represents a significant physiological stressor for older adults, particularly for those who are frail and have limited reserves to withstand such stress.[12,24-26] Our findings suggest that all older adults, regardless of frailty status, may benefit from slightly higher BMIs, likely due to the increased demands of surgical recovery. One possible causal mechanism for this observation is that a higher BMI may provide additional energy reserves that are critical for recovery following the acute insult of surgery.[27] Alternatively, we cannot rule out the potential impact of unmeasured confounding: it is also possible that having a higher BMI is simply a marker of better overall health; many patients in the “normal” BMI category may have had occult underlying illness that was not captured by our models and put them at a higher risk of mortality. It is also possible that older adults should be categorized into different BMI zones to better capture the risk profile of older adults undergoing surgery.

A significant proportion of patients in the "normal" BMI range experienced adverse postoperative events, including all-cause mortality and other complications. To investigate this further as a hypothesis generating sub-analysis, we performed a sensitivity and hypothesis generating analysis by subdividing the "normal" BMI category into two subgroups: 18.5–22.5 kg/m² and 22.5–25 kg/m², based on a Youden's Index cut-off of BMI 22.5 kg/m². Nearly all mortality and complication events occurred in the lower subcategory (18.5–22.5 kg/m²), reinforcing the concept of protective role of a slightly higher BMI in older adults undergoing major surgery.

It is important to note, however, that the benefits of being overweight or having low-grade obesity do not extend to individuals with the highest BMIs; those with high-grade obesity experience significantly higher rates of postoperative complications, excluding all-cause mortality. Specifically, patients with BMIs >40 kg/m² had the highest complication rate, with 79% experiencing at least one complication. Pulmonary complications were most prevalent in this group, with 33% requiring reintubation, an upgrade in care, or developing pneumonia during their hospitalization. Additionally, these patients were more likely to develop deep vein thromboses (DVTs) or experience concerns for a stroke. Conversely, underweight patients (BMI <18.5 kg/m²) had the highest risk of all-cause mortality, likely reflecting diminished physiological reserves and increased vulnerability to the acute stress of surgery.

An obesity paradox has previously been describes, and refers to the counterintuitive observation that, in certain populations and clinical conditions, individuals with overweight or mild obesity (typically defined as BMI 25–35 kg/m²) sometimes have better survival outcomes than those with a "normal" body mass index (BMI 18.5–24.9 kg/m²)[28]. Possible explanations for this include and increased nutritional and metabolic reserves with more adipose and muscle mass may help withstand catabolic stress, such as during illness, surgery, or hospitalization[28,29]. Another explanation may be lead-time bias where some patients with lower BMI may have undiagnosed chronic illnesses causing weight loss before diagnosis[29]. However, the obesity paradox does not imply that obesity is protective overall, rather, it highlights the complexity of how weight, fat distribution, and muscle mass interact with specific disease processes and outcomes[30].

Limitations

This study has several limitations. First, the single-center, observational design limits the generalizability of the findings and leaves room for potential confounding variables that were not accounted for in the analysis, such as the example of occult illness mentioned above. One of the most significant limitations is that BMI does not differentiate between adipose tissue distribution, such as visceral or abdominal fat, which is strongly associated with metabolic syndrome and related complications. Moreover, BMI does not account for variations in body composition, such as differences in muscle mass and fat distribution, which can differ substantially across genders, races, and ethnicities. Indeed, previous studies have shown that BMI alone may be an inadequate measure of health or surgical risk in diverse populations.[31] BMI was never intended to serve as a single marker of postoperative risk. Additionally, the m-FI 5 is determined as a composite of comorbidity and does not evaluate other items of frailty including nutritional status. This may account for the seemingly improved outcomes in “pre-frail” older adults. Further, the sample sizes in the underweight and morbidly obese BMI categories are small, and the resulting confidence intervals are wide, the lower bounds of these intervals remain far from 1, suggesting potentially meaningful associations despite limited precision.

Further research is needed to replicate these findings in larger, multicenter studies, and ultimately clinical trials to determine when if ever weight loss should be recommended pre-operatively for older adults. Future investigations should also explore how BMI interacts with other critical factors, including nutritional status, muscle mass, and frailty, to refine pre-operative optimization strategies. Tailoring these strategies to the unique needs of older adults, might improve surgical outcomes and reduce complications in this growing population.

Conclusion

Older adults that are overweight and or have low grade obesity who undergo major elective surgery have higher odds of 30-day and 1-year mortality compared to those with a normal BMI. These challenge traditional pre-operative guidelines emphasizing trying to achieve "normal weight" prior to surgery for older adults.

ACKNOWLEDGMENTS

Everyone who contributed significantly to the work is listed as an author.

Author Contributions: CC was involved in the concept, design, data collection, data analysis, results interpretation, and writing of the manuscript. CC had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis

MA was involved in the concept, design, data collection and writing and editing of the manuscript

DE was involved in the design, data analysis, data interpretation writing, and editing of the manuscript

TG was involved in the design, data analysis, data interpretation and writing of the manuscript

MR was involved in the data interpretation, writing, and editing of the manuscript

VD was involved in the design, data collection and editing of the manuscript

RW was involved in the design, data interpretation and editing of the manuscript

MC was involved in the design, data interpretation, writing, and editing of the manuscript

CS was involved in the design, data interpretation, writing, and editing of the manuscript

Conflict of Interest Statement:

There are no conflicts of interest related to the research. This work is supported by UCLA RCMAR/CHIME NIA Grant #P30-AG021684 and UCLA CTSI NCATS Grant #UL1TR001881 for Dr. Canales-RCMAR/CHIME Scientist. Dr. Canales was also awarded a National Academy of Medicine, Diagnostic Excellence Award, supported through the John A. Hartford Foundation. Dr. Sarkisian was supported by National Institutes of Health/National Institute on Aging (NIH/NIA) Midcareer Award in Patient-Oriented Aging Research (1K24AG047899), NIH/NIA Resource Centers for Minority Aging Research IV/Center for Health Improvement of Minority Elderly (5P30AG021684 (PI Mangione) and NIH/NCATS UCLA Clinical and Translational Science Institute (CTSI) (UL1TR001881 PI Dubinett). Dr. Cannesson is owner of Sironis.

Sponsor's Role: All funding for Dr. Canales and Sarkisian provided time to participate in research activities. No sponsor had influence in the design and conduct of the study; collection,

management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

REFERENCES

1.McKee AM, Morley JE. Obesity in the Elderly. In: Feingold KR, Anawalt B, Blackman MR et al., eds. Endotext South Dartmouth (MA), 2000.
2.Bhardwaj PV, Rastegar V, Meka R et al. The Association Between Body Mass Index, Frailty and Long-Term Clinical Outcomes in Hospitalized Older Adults. Am J Med Sci 2021;362:268-75.
3.Fruh SM. Obesity: Risk factors, complications, and strategies for sustainable long-term weight management. J Am Assoc Nurse Pract 2017;29:S3-S14.
4.Visaria A, Setoguchi S. Body mass index and all-cause mortality in a 21st century U.S. population: A National Health Interview Survey analysis. PLoS One 2023;18:e0287218.
5.Samper-Ternent R, Al Snih S. Obesity in Older Adults: Epidemiology and Implications for Disability and Disease. Rev Clin Gerontol 2012;22:10-34.
6.Dhurandhar NV. What is obesity? : Obesity Musings. Int J Obes (Lond) 2022;46:1081-2.
7.Bhaskaran K, Dos-Santos-Silva I, Leon DA et al. Association of BMI with overall and cause-specific mortality: a population-based cohort study of 3.6 million adults in the UK. Lancet Diabetes Endocrinol 2018;6:944-53.
8.Global BMIMC, Di Angelantonio E, Bhupathiraju Sh N et al. Body-mass index and all-cause mortality: individual-participant-data meta-analysis of 239 prospective studies in four continents. Lancet 2016;388:776-86.
9.Jayanama K, Theou O, Godin J et al. Relationship of body mass index with frailty and all-cause mortality among middle-aged and older adults. BMC Med 2022;20:404.
10.Gallagher D, Visser M, Sepulveda D et al. How useful is body mass index for comparison of body fatness across age, sex, and ethnic groups? Am J Epidemiol 1996;143:228-39.
11.Kyrou I, Tsigos C. Obesity in the elderly diabetic patient: is weight loss beneficial? No. Diabetes Care 2009;32 Suppl 2:S403-9.
12.Vacas S, Canales C, Deiner SG, Cole DJ. Perioperative Brain Health in the Older Adult: A Patient Safety Imperative. Anesth Analg 2022;135:316-28.
13.Madsen HJ, Gillette RA, Colborn KL et al. The association between obesity and postoperative outcomes in a broad surgical population: A 7-year American College of Surgeons National Surgical Quality Improvement analysis. Surgery 2023;173:1213-9.
14.Lang LH, Parekh K, Tsui BYK, Maze M. Perioperative management of the obese surgical patient. Br Med Bull 2017;124:135-55.
15.Kassahun WT, Mehdorn M, Babel J. The impact of obesity on surgical outcomes in patients undergoing emergency laparotomy for high-risk abdominal emergencies. BMC Surg 2022;22:15.
16.Tsigos C, Hainer V, Basdevant A et al. Management of obesity in adults: European clinical practice guidelines. Obes Facts 2008;1:106-16.
17.Griffin SB, Palmer MA, Strodl E et al. Impact of a dietitian-led very low calorie diet clinic on perioperative risk for patients with obesity awaiting elective, non-bariatric surgery: A retrospective cohort study. Surgery 2024;175:463-70.
18.von Elm E, Altman DG, Egger M et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Lancet 2007;370:1453-7.

19.Kamdar NV, Huverserian A, Jalilian L et al. Development, Implementation, and Evaluation of a Telemedicine Preoperative Evaluation Initiative at a Major Academic Medical Center. Anesth Analg 2020;131:1647-56.
20.Weaver DJ, Malik AT, Jain N et al. The Modified 5-Item Frailty Index: A Concise and Useful Tool for Assessing the Impact of Frailty on Postoperative Morbidity Following Elective Posterior Lumbar Fusions. World Neurosurg 2019;124:e626-e32.
21.Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg 2004;240:205-13.
22.Kuhn E, Du X, McGrath K et al. Validation of a consensus method for identifying delirium from hospital records. PLoS One 2014;9:e111823.
23.Culley DJ, Flaherty D, Fahey MC et al. Poor Performance on a Preoperative Cognitive Screening Test Predicts Postoperative Complications in Older Orthopedic Surgical Patients. Anesthesiology 2017;127:765-74.
24.Fried LP, Tangen CM, Walston J et al. Frailty in older adults: evidence for a phenotype. J Gerontol A Biol Sci Med Sci 2001;56:M146-56.
25.Mitnitski AB, Mogilner AJ, Rockwood K. Accumulation of deficits as a proxy measure of aging. ScientificWorldJournal 2001;1:323-36.
26.Norris CM, Close JCT. Prehabilitation for the Frailty Syndrome: Improving Outcomes for Our Most Vulnerable Patients. Anesth Analg 2020;130:1524-33.
27.Casas-Vara A, Santolaria F, Fernandez-Bereciartua A et al. The obesity paradox in elderly patients with heart failure: analysis of nutritional status. Nutrition 2012;28:616-22.
28.Naderi N, Kleine CE, Park C et al. Obesity Paradox in Advanced Kidney Disease: From Bedside to the Bench. Prog Cardiovasc Dis 2018;61:168-81.
29.Banack HR, Kaufman JS. The obesity paradox: understanding the effect of obesity on mortality among individuals with cardiovascular disease. Prev Med 2014;62:96-102.
30.Drame M, Godaert L. The Obesity Paradox and Mortality in Older Adults: A Systematic Review. Nutrients 2023;15.
31.Gutin I. In BMI We Trust: Reframing the Body Mass Index as a Measure of Health. Soc Theory Health 2018;16:256-71.

Legend:

Figure 1: Study Flow Diagram. Depicts study population, inclusion, exclusion, surgical cases cancelled, and final study population.

Figure 2: All-Cause Mortality at 30-Days and 1-Year. Panel A) depicts 30-day and 1 year mortality based on standard BMI Categories. Panel B) depicts 30-day and 1 year mortality based on adjusted BMI Categories from Youden's Index cut-off at BMI of 22.5 kg/m^2. Panel C) depicts 30-day mortality by frailty status based on standard BMI categories. Panel D) depicts 1-year mortality by frailty status based on standard BMI categories.

BMI = body mass index

mFI = Modified frailty Index

ASA = American Society of Anesthesiology

Table 1. Baseline Characteristics by body mass index

		Body Mass Index Categories (Kg/m2)					
	Total (n=414)	< 18.5 (n=20)	18.5-24.9 (n=133)	25-29.9 (n=128)	30-39 (n=109)	40> (n=24)	P-Value
Age, mean years (SD)	75.9 (7.2)	74.2 (7.9)	75.9 (7.2)	76.3 (7.0)	76.4 (7.4)	73.1 (6.0)	0.23
Women, n (%)	227 (54.8%)	14 (70.0%)	71 (53.4%)	63 (49.2%)	64 (58.7%)	15 (62.5%)	0.31
***ASA Status**, n (%)*							0.19^
2	93 (22.5%)	1 (5.0%)	35 (26.3%)	28 (21.9%)	24 (22.0%)	5 (20.8%)	
3	285 (68.8%)	19 (95.0%)	84 (63.2%)	89 (69.5%)	78 (71.6%)	15 (62.5%)	
4	36 (8.7%)	0	14 (10.5%)	11 (8.6%)	7 (6.4%)	4 (16.7%)	
Race/Ethnicity*, *n (%)*							0.42^
Asian	34 (8.2%)	1 (5%)	16 (12%)	10 (7.8%)	7 (6.4%)	0	
Black/African American	27 (6.5%)	1 (5%)	12 (9%)	7 (5.5%)	5 (4.6%	2 (8.3%)	
Hispanic	40 (9.7%)	1 (5%)	10 (7.5%)	12 (9.4%)	13 (11.9%)	4 (16.4%)	
White	300 (72.5%)	16 (80%)	93 (69.9%)	91 (71.1%)	82 (75.2%)	18 (75%)	
Other/Not disclosed	13 (3.1%)	1 (5%)	2 (1.5%)	8 (6.3%)	2 (1.8%)	0	
***Surgical Type**, n (%)*							0.70^
H&N/ENT	83 (20.0%)	6 (30.0%)	26 (19.5%)	27 (21.1%)	18 (16.5%)	6 (25.0%)	
Major Abdominal/Colorectal	69 (16.7%)	4 (20.0%)	25 (18.8%)	20 (15.6%)	19 (17.4%)	1 (4.2%)	
Other	38 (9.2%)	2 (10.0%)	14 (10.5%)	7 (5.5%)	13 (11.9%)	2 (8.3%)	
Spine/Orthopedic	133 (32.1%)	4 (20.0%)	36 (27.1%)	47 (36.7%)	37 (33.9%)	9 (37.5%)	
Uro/Gyn	91 (22.0%)	4 (20.0%)	32 (24.1%)	27 (21.1%)	22 (20.2%)	6 (25.0%)	
***Cancer**, n (%)*	179 (43.2%)	9 (45.0%)	57 (42.9%)	51 (39.8%)	53 (48.6%)	9 (37.5%)	0.69

***Frail Status**, n (%)*							0.11^
Frail	100 (24.2%)	4 (20.0%)	31 (23.3%)	31 (24.2%)	23 (21.1%)	11 (45.8%)	
Pre-frail	153 (37.0%)	9 (45.0%)	41 (30.8%)	56 (43.8%)	40 (36.7%)	7 (29.2%)	
Not Frail	161 (38.9%)	7 (35.0%)	61 (45.9%)	41 (32.0%)	46 (42.2%)	6 (25.0%)	
***Recommended Weight Loss**, n (%)*	107 (25.8%)	0	8 (6.0%)	21 (16.4%)	54 (49.5%)	24 (100.0%)	<0.001^
***Unintentional Weight Loss**, n (%)*	44 (10.6%)	9 (45.0%)	19 (14.3%)	12 (9.4%)	4 (3.7%)	0	<0.001^

SD= standard deviation; ASA= American Society of Anesthesia; H&N= Head and Neck; ENT= Otolaryngology. ^ Fisher's exact test. * race/ethnicity was self-reported; other/not disclosed was its own category without detailed sub-categories.

Table 2. Logistic Regression Models

	30-Day Mortality Outcome				**1-Year Mortality Outcome**			
	Univariable Models		**Multivariable Model**		**Univariable Models**		**Multivariable Model**	
	OR (95% CI)	**p-value**	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**
BMI Category		<0.001		<0.001		<0.001		<0.001
<18.5 vs 18.5-24.9	12.96 (4.31 - 39.00)	<0.001	21.81 (6.24 - 76.21)	<0.001	10.00 (3.14 - 31.85)	<0.001	12.40 (3.70 - 41.61)	<0.001
25-29.9 vs 18.5-24.9	0.03 (0.01 - 0.26)	0.001	0.03 (0.00 - 0.23)	0.001	0.14 (0.06 - 0.34)	<0.001	0.13 (0.06 - 0.32)	<0.001
30-39 vs 18.5-24.9	0.04 (0.01 - 0.30)	0.002	0.03 (0.00 - 0.24)	0.001	0.12 (0.05 - 0.32)	<0.001	0.10 (0.04 - 0.28)	<0.001
>40 vs 18.5-24.9	1.14 (0.39 - 3.34)	0.815	0.82 (0.24 - 2.79)	0.753	0.83 (0.31 - 2.26)	0.720	0.62 (0.21 - 1.83)	0.386
Frailty		0.002		0.002		0.002		0.002

Pre-frail vs not frail	0.63 (0.28 - 1.44)	0.277	0.43 (0.15 - 1.26)	0.125	0.73 (0.38 - 1.39)	0.334	0.66 (0.30 - 1.44)	0.298
Frail vs not frail	2.41 (1.19 - 4.88)	0.015	3.19 (1.24 - 8.20)	0.016	2.22 (1.21 - 4.08)	0.010	2.69 (1.27 - 5.72)	0.010
Age			1.05 (1.00 - 1.11)	0.072			1.03 (0.98 - 1.07)	0.217
Female			1.64 (0.74 - 3.60)	0.220			1.53 (0.83 - 2.83)	0.174
ASA			1.72 (0.85 - 3.48)	0.134			1.30 (0.75 - 2.26)	0.346

Table 3. Complications by Body Mass Index and Frailty

	Body Mass Index Categories (Kg/m2)						Frailty Status			
	< 18.5 (n=20)	18.5-24.9 (n=133)	25-29.9 (n=128)	30-39 (n=109)	40> (n=24)	p-value	Not Frail (n=161)	Pre-Frail (n=153)	Frail (n=100)	p-value
30 Day Mortality	15 (75.0%)	25 (18.8%)	1 (0.8%)	1 (0.9%)	5 (20.8%)	<0.001^	16 (9.9%)	10 (6.5%)	21 (21.0%)	0.001
1-year Mortality	16 (80.0%)	38 (28.6%)	7 (5.5%)	5 (4.6%)	6 (25.0%)	<0.001^	25 (15.5%)	18 (11.8%)	29 (29.0%)	0.001
Delirium	10 (50.0%)	19 (14.3%)	14 (10.9%)	14 (12.8%)	5 (20.8%)	0.001^	18 (11.2%)	22 (14.4%)	22 (22.0%)	0.057
Discharge other than	10 (50.0%)	21	9 (7.0%)	16	7	<0.001	18 (11.2%)	23	22	0.061

Home		(15.8%)		(14.7%)	(29.2%)	^		(15.0%)	(22.0%)	
Clavien-Dindo Classification						<0.001 ^				<0.001 ^
3	0	1 (0.8%)	0	1 (0.9%)	1 (4.2%)		2 (1.2%)	1 (0.7%)	0	
4	0	3 (2.3%)	0	0	2 (8.3%)		2 (1.2%)	0	3 (3.0%)	
5	11 (55.0%)	20 (15.0%)	1 (0.8%)	1 (0.9%)	4 (16.7%)		12 (7.5%)	8 (5.2%)	17 (17.0%)	

^ Fisher's exact test