Published in final edited form as:

J Am Geriatr Soc. 2009 March ; 57(3): 419–426. doi:10.1111/j.1532-5415.2008.02141.x.

Body Mass Index and Risk of Adverse Cardiac Events in Elderly Hip Fracture Patients: A Population-Based Study

John A. Batsis, MD^{*}, Jeanne M. Huddleston, MD^{†,‡}, L. Joseph Melton III, MD, MPH^{§,‡,||}, Paul M. Huddleston, MD, MSc[§], Francisco Lopez-Jimenez, MD, MSc[¶], Dirk R. Larson, MS[‡], Rachel E. Gullerud, BS[‡], and M. Molly McMahon, MD^{||}

^{*}Section of General Internal Medicine, Dartmouth-Hitchcock Medical Center, College of Medicine, Mayo Clinic, Rochester, MN 55905

[†]Division of Hospital Internal Medicine, College of Medicine, Mayo Clinic, Rochester, MN 55905

^{||}Division of Endocrinology, Diabetes, Metabolism and Nutrition, College of Medicine, Mayo Clinic, Rochester, MN 55905

[¶]Division of Cardiovascular Diseases, Department of Medicine, College of Medicine, Mayo Clinic, Rochester, MN 55905

[‡]Department of Health Sciences Research, College of Medicine, Mayo Clinic, Rochester, MN 55905

[§]Department of Orthopedic Surgery, College of Medicine, Mayo Clinic, Rochester, MN 55905

Abstract

Objectives—Obesity is protective for the development of hip fractures yet a risk factor for cardiac disease. Whether obesity impacts cardiac complications following hip fracture repair is unknown.

Design—A population-based, historical study using the Rochester Epidemiology Project

Corresponding Author: John A. Batsis, MD, Section of General Internal Medicine, Dartmouth-Hitchcock Medical Center, 1 Medical Center Drive, Lebanon, NH 03756, (603) 650-6943, Fax: (603) 653-6110.

^{*}Work was performed while at Mayo Clinic Rochester

Author for Reprints, Alternate Corresponding Author: Jeanne M. Huddleston, MD, Division of Hospital Internal Medicine, Mayo Clinic, 200 First Street SW, Rochester, MN 55905, (507) 255-7815, Huddleston.jeanne@mayo.edu

Conflict of Interest: The editor in chief has reviewed the conflict of interest checklist provided by the authors and has determined that the authors have no financial or any other kind of personal conflicts with this paper.

AUTHOR CONTRIBUTIONS:

John A. Batsis: conception and design, acquisition of data, analysis and interpretation of data, drafting the article and revisions, final approval of submitted manuscript

Jeanne M. Huddleston: conception and design, analysis and interpretation of data, critical revision of manuscript for important intellectual content, final approval of submitted manuscript

L. Joseph Melton III: conception and design, analysis and interpretation of data, critical revision of manuscript for important intellectual content, final approval of submitted manuscript

Paul M. Huddleston: conception and design, analysis and interpretation of data, critical revision of manuscript for important intellectual content, final approval of submitted manuscript

Francisco Lopez-Jimenez: analysis and interpretation of data, critical revision of manuscript for important intellectual content, final approval of submitted manuscript

Dirk R. Larson: analysis and interpretation of data, critical revision of manuscript for important intellectual content, final approval of submitted manuscript

Rachel E. Gullerud: analysis and interpretation of data, critical revision of manuscript for important intellectual content, final approval of submitted manuscript

M. Molly McMahon: conception and design, analysis and interpretation of data, critical revision of manuscript for important intellectual content, final approval of submitted manuscript

Setting—Olmsted County, Minnesota

Participants—All urgent hip fracture repairs between 1988–2002.

Measurements—Body mass index (BMI) was categorized as underweight ($<18.5\text{kg/m}^2$), normal ($18.5\text{--}24.9\text{kg/m}^2$), overweight ($25.0\text{--}29.9\text{kg/m}^2$) and obese ($\geq 30\text{kg/m}^2$). Post-operative cardiac complications were defined as myocardial infarction, angina, congestive heart failure, or new-onset arrhythmias within one-year of surgery. Incidence rates were estimated for each outcome and overall cardiac complications were assessed using Cox proportional hazard models, adjusted for age, sex, year of surgery, use of beta-blockers and the Revised Cardiac Risk Index.

Results—There were 184 (15.6%) underweight, 640 (54.2%) normal, 251 (21.3%) overweight, and 105 (8.9%) obese hip fracture repairs (mean age, 84.2 ± 7.5 years; 80% female). Baseline American Society of Anesthesia status was similar among all groups (ASA I/II vs. III–V, $p=0.14$). Underweight patients had a significantly higher risk of developing myocardial infarction (odds ratio [OR] 1.44; 95% CI 1.0–2.1; $p=0.05$) and arrhythmias (OR 1.59; 95% CI: 1.0–2.4; $p=0.04$) than normal BMI patients. Multivariate analysis demonstrated underweight patients had a higher risk of developing an adverse cardiac event of any type (OR 1.56; 95% CI: 1.22–1.98; $p<0.001$). Overweight and obese hip fracture patients had no excess risk of any cardiac complication.

Conclusion—The obesity paradox and low functional reserve in underweight patients may influence the development of post-operative cardiac events in this elderly hip fracture population.

Keywords

obesity; hip fractures; cardiovascular disease; elderly; post-operative

INTRODUCTION

Age-related health concerns have become important public health issues. Along with the greater number of patients aged >65 years (1) who are living longer (2), the number of overweight and obese patients is rising with a 3-fold increase in prevalence in the past four decades alone (3). Obesity is associated with a number of medical co-morbidities and has been established as an independent risk factor for cardiovascular disease (4). However, little attention has been given to the obese elder, largely due to a paucity of studies that include older patients. This is important with respect to managing the growing number of hip fractures (5), a devastating potential complication of osteoporosis (6). We have previously demonstrated a 3.6 times higher rate of adverse cardiac events (CE) following hip fracture repair as compared to a lower-risk elective hip arthroplasty population (7). Although there is a well-known inverse correlation between obesity and osteoporotic fractures (8), the effect on risk of CE to overweight hip fracture patients is unknown. Literature regarding the impact of obesity on post-operative CE has focused on cardiac surgery patients (9–11). Data detailing the orthopedic population has been limited to elective spine and hip arthroplasty populations (12–14), patients who are likely healthier than those undergoing urgent hip fracture repair. To the best of our knowledge, no data exist regarding the impact of body mass index (BMI) on cardiac outcomes post-operatively following fracture repair. We sought to determine the incidence of BMI on one-year post-operative CE following hip fracture.

METHODS

We conducted a population-based, historical cohort study of all Olmsted County, Minnesota residents undergoing surgery for hip fracture repair from January 1st, 1988, through December 31st, 2002. Patients were identified using the data resources of the Rochester Epidemiology Project, a medical record linkage system funded continually by the Federal

government since 1966 (15). Disease-related epidemiology studies are possible in this setting because Olmsted County residents have their medical histories indexed, allowing for complete case ascertainment, and their complete (inpatient and outpatient) records in the community are available for review. This county is geographically isolated, with medical care provided primarily by the Mayo Clinic and the Olmsted Medical Center, in addition to a few individual private providers. Approximately 95% of all hip fracture surgeries are performed and managed at Mayo's affiliated St. Mary's Hospital.

Following approval by both the Mayo Clinic and Olmsted Medical Center Institutional Review Boards, Olmsted County residents with a hip fracture were identified using ICD-9 diagnosis codes (820–829). We included all hip fracture repairs of both sexes who underwent an indexed surgical repair for hip fracture (n=1,310). Exclusion criteria consisted of repairs of patients: <65 years of age (n=2); with a pathological fracture (n=20); with multiple injuries or fractures (n=19); operated on >72 hours after injury (n=5); sustaining an in-hospital fracture during a hospitalization (n=3); not undergoing hip fracture repair (n=56); and patients with missing information (n=10). All patients included in this study provided an authorization to use their medical records for research, as per institutional protocols (16).

After identification of the patient cohort, data were abstracted from Mayo Clinic and Olmsted Medical Center medical records, and other individual providers when applicable, by trained nurse abstractors using standardized data collection forms and entered into a database with the assistance of a data entry specialist. Regarding quality assurance, nurse abstractors were deemed certified after abstracting 15 records, and intra/inter-abstractor agreement was based on 10 records re-abstracted monthly. There was no masking of abstractors to the study hypothesis. Minnesota and Federal death registries were used to elicit patient death and primary cause of death as indicated on the patient's death certificate.

Body mass index was classified by World Health Organization (WHO) criteria: underweight (BMI <18.5); normal (BMI 18.5–24.9); overweight (BMI 25.0–29.9); and obese (BMI ≥30.0) (17). Each patient's admission height and weight were recorded; if these were unavailable, the nearest height and weight prior to fracture repair with two months of surgery were obtained.

Potential CE outcomes were evaluated, including myocardial infarction (MI), congestive heart failure (CHF), arrhythmias, angina, and death due to cardiac cause within one year of the date of surgery, consistent with current and previous risk stratifications that measure outcomes to one year (18–22). Our overall outcome variable consisted of the sum of all of these events. Acute MI was defined as patients with an elevated total creatinine kinase and MB-fraction; diagnostic electrocardiographic changes including ST-elevation and Q-wave changes; and elevated troponin levels. CHF was defined per Framingham major and minor criteria (23). A diagnosis required either two major or one major and two minor criteria. Arrhythmias were defined as patients having evidence on electrocardiogram or telemetry of a new ventricular or atrial rhythm disturbance that had not been previously documented in the medical record. Angina was defined as a symptom documented in the medical record, or patients with a diagnosis of acute coronary syndrome with negative cardiac biomarkers. A cardiac death was defined broadly as a primary cause of death from ICD-9 codes 375–449 (Diseases of the Circulatory System), as documented on the patient's death certificate.

Lee's Revised Cardiac Risk Index (RCRI) (19) was determined by the number of comorbidities from among the following criteria: ischemic heart disease, compensated or chronic CHF, diabetes mellitus on insulin, a history of cerebrovascular disease, or a creatinine of > 2mg/dL. In this scheme, patients were deemed to have ischemic heart disease if they had a history of MI, any history of angina or cardiac chest pain, unstable angina prior

to admission, a positive ischemic threshold on dobutamine stress echocardiogram, fixed defects on nuclear stress imaging, or angiographic evidence of coronary artery disease. Congestive heart failure was defined as a history of CHF symptoms as defined by the Framingham criteria, an ejection fraction <40% on echocardiogram or ventriculogram. In addition, we considered patients with a creatinine <2mg/dL but on hemodialysis to have fulfilled the chronic renal insufficiency criterion of this index.

Statistical Analysis

Continuous data are presented as means±standard deviation and categorical data as numbers and percents. Kruskal-Wallis tests were performed for continuous variables to test for differences across BMI groups and Fisher's Exact or Cochran-Mantel-Haenszel tests were used for discrete variables. When a significant global test was observed, multiple comparison analyses were performed to identify specific differences between BMI groups. The primary outcome was the incidence of the overall cardiac composite outcome defined as the first of any of the following cardiovascular events during the first twelve months following urgent hip fracture repair: MI, CHF, new arrhythmias, angina or death due to cardiac cause. Separate estimates were also made for each individual cardiac component. Incidence rates were calculated for the overall cohort and for sex, calendar year and BMI subsets. As the proportion of deaths due to non-cardiac causes was large, the outcomes were analyzed using survivorship methods, and deaths due to non-cardiac causes were censored. One-year survival rates were estimated using the method of Kaplan and Meier(24,25). The impact of BMI on the rate of post-operative CE was evaluated using Cox Proportional hazards regression(26). Body mass index was evaluated univariately, as a categorical variable (according to the WHO criteria), as a continuous variable, and dichotomized as BMI 18.5–24.9kg/m² (normal) vs. all other BMIs. For the multivariable model, our outcome variable was the overall composite CE outcomes defined above. *A priori*, we adjusted for age, gender, year of surgery, the use of beta-blockers, and the number of components of Lee's RCRI. We also performed a stepwise regression analysis to confirm our *a priori* findings. As a secondary analysis, we assessed the time-to-CE during the one-year period, using the method of Kaplan and Meier to estimate time-specific rates. All statistical tests were two-sided and p-values less than 0.05 were considered significant. All analyses were performed using SAS for UNIX (version 9.1.3, SAS Institute, Cary, NC).

RESULTS

We identified 1,195 total hip fracture repairs between 1988 and 2002 who met our inclusion and exclusion criteria. However, BMI was missing in 15 repairs and these were excluded. For patients with more than one hip fracture during the study period (7 patients), only their first fracture episode was included in the analyses. Altogether 184 repairs (15.6%) were in the underweight group, 640 (54.2%) in the normal BMI group, 251 (21.3%) in the overweight group, and 105 repairs (8.9%) in the obese group. Other baseline characteristics are displayed in Table 1. Underweight patients were less likely than overweight patients to be admitted from home, but no differences were appreciated between groups for functional status in the multiple analysis. Underweight patients were less likely to have hypertension or diabetes than either normal, overweight, or obese patients, and less likely to have chronic renal insufficiency or be on insulin or beta-blockers than overweight or obese patients. Obese patients were more likely to have diabetes and congestive heart failure and to be on insulin than overweight or normal patients. They were also more likely to have chronic renal insufficiency, but less likely to have dementia than normal BMI patients.

There were 191 MIs, 231 episodes of CHF, 135 new arrhythmias, 30 episodes of angina, and 75 overall cardiac deaths in our cohort. Figures 1A–E demonstrate the incidence of each of the one-year CE outcomes, and Figure 2 represents cardiac-specific survival. Most

myocardial infarctions occurred within one week of hip fracture repair, particularly in the underweight group, where all events occurred by this time point. Likewise, over half of all arrhythmias documented at one-year had occurred by one week in all BMI groups. Patients with CHF were more likely to have their events following hospital discharge in all BMI groups. Finally, the majority of patients were more likely to experience angina within six months of surgery in all BMI categories.

Obese and overweight patients were less likely to be discharged to a nursing home than normal BMI patients (79 vs 85.5%; $p=0.03$ and 79.3 vs. 85.5%; $p=0.01$), respectively. There was a higher proportion of in-hospital deaths in the underweight group (9.3%), than the normal BMI (4.4%), overweight (3.6%), or obese (2.9%) groups ($p<0.001$). Median length of stay did not differ among groups ($p=0.09$). There were 75 cardiac related deaths at one year from a total of 282 deaths (27.0%). There were no differences in cardiac deaths between normal BMI patients and the other BMI categories.

The univariate analysis for each individual CE outcome is shown in Table 2. Underweight patients had a significantly higher risk of developing MI and arrhythmias than the normal BMI group; there were no significant differences between normal and overweight or obese patients. There were no significant differences among BMI groups with regard to CHF, angina or cardiac death. When dichotomizing BMI as $<25\text{kg/m}^2$ vs. $\geq 25\text{kg/m}^2$, there were no significant differences in any of the individual cardiac outcomes. In addition, comparing a normal BMI ($18.5\text{--}24.9\text{kg/m}^2$) to all other patients, the overall risk of any CE was lower in normal BMI patients than in the extremes of BMI. Examining BMI as a continuous variable did not reveal any appreciable differences in outcomes.

Table 3 demonstrates the univariate and multivariable analysis for the overall composite number of adverse cardiac events. Underweight patients appeared to have a higher risk of developing CE than the referent normal BMI group, while overweight and obese patients were at similar risk to the normal BMI group. A stepwise regression analysis also confirmed the directionality and significance of these *a priori* variables. In a subsequent analysis, we demonstrated that there was no calendar year effect of BMI in this population, ensuring that patients behaved similarly across time (data not shown).

DISCUSSION

In the orthopedic literature, the association of BMI with post-operative outcomes has been limited as most of the research has described elective surgical populations. Studies of elective spine and knee arthroplasty populations demonstrated that an elevated BMI was associated with a higher number of short-term surgical complications, but neither study specifically assessed cardiac complications (13,14). Conversely, Perka *et al* did not observe differences in peri-operative morbidity and mortality in obese patients undergoing revision hip arthroplasties (12). To our knowledge, this may be the first study to examine the impact of BMI on post-operative adverse cardiac events following urgent hip fracture repair. To our surprise, the results suggest that underweight patients are at higher risk of developing CE following hip fracture repair than normal, overweight, or obese patients.

Traditionally, overweight patients are at higher risk of developing coronary heart disease, congestive heart failure and arrhythmias(4). Our results suggest otherwise and provide evidence for the “obesity paradox,” i.e., that obese patients with chronic diseases may actually fare better than those without them in certain settings (27,28). The course following hip fracture repair could be defined as a chronic disease state where fat and muscle mass are lost and unintentional rapid weight loss may also occur. The rapidity of weight loss, as demonstrated in other patient populations, including hip fracture patients, can lead to

increased morbidity and mortality. However, because we recorded pre-operative BMI to measure adiposity pre-operatively, and did not ascertain it post-operatively, we were unable to assess the degree of sarcopenia and unable to gauge the extent to which muscle mass is replaced by fat mass.

Low bone mineral density has been associated with high atherosclerotic burden and cardiovascular events, particularly among elderly females (29–32), and our predominantly female elderly cohort adds credence to these results. The pathogenesis between cardiovascular disease and osteoporosis is complex and ill-defined, but epidemiological studies have demonstrated possible associations(33). Serum lipids may be the common denominator(33), as they are actively involved in atherosclerotic processes but also have effects on osteoclastic cells. Systemic inflammation has also been demonstrated to lead to increased cardiovascular disease and mortality in frail geriatric patients (34,35). This could account for the increased incidence of MI in our underweight group, the group with the highest prevalence of documented osteoporosis.

Reduced functional capacity following hip fracture repair in our patient population could also contribute to the increased morbidity reflected in our results. In stratifying patients according to BMI, underweight patients will have a more reduced caloric and functional reserve than corresponding obese patients, thereby rendering them more vulnerable to a physiologic insult or stressor such as a hip fracture, which may then precipitate complications. Furthermore, although studies have shown reduced cardiac survival among patients that are overweight and obese(36), obese patients that survive into the geriatric age-group might, in fact, have a survival advantage. However, this is speculative and further research is needed to better understand the biological nature of this phenomenon.

Although the definitions outlined by the WHO for underweight and obesity are commonly used, age-related reductions in lean mass(37,38) may underestimate adiposity in the elderly population. A poor correlation between BMI and % body fat exists within the >65 year age group when compared to the <65 age group(39), and hence, we may have underestimated the true impact of adiposity on patient outcomes. Yet the ease of using BMI, an anthropometric measurement often documented in patients' medical records, makes this current study feasible. The inherent challenges of BMI measurements in the hospital setting, particularly with the extent of lean mass lost and volume status changes post-operatively, may lead to recording bias. Furthermore, there may be some measurement bias as admission heights and weights may differ depending on nurse measurements or bed calibration. We can speculate that patients may have indeed a higher proportion of fat mass, which may not have been measured accurately by BMI. Whether BMI should actually be utilized in this patient population is debated.

The inherent limitations observed in historical studies may be offset by the population-based nature of our study. The Rochester Epidemiology Project facilitates complete ascertainment of patient data and follow-up while minimizing referral biases observed in single-institution studies. Ascertainment of cases and of cardiovascular outcomes is particularly high using the Rochester Epidemiology Project, and the external validity of results of such studies has also been demonstrated(15). The evolving definitions and improved diagnostic capabilities of post-operative cardiac events may have led to under-representation in the number of events captured. However, by using standardized definitions in the data collection phase and adjusting for surgical year, we minimized diagnostic suspicion bias and ensured adequate internal validity of our variables and outcomes.

The implications of these results are not insignificant as they highlight that underweight patients may be at higher pre-operative risk from a cardiac standpoint than might be

presumed clinically. In addition, whether there are factors that have yet to be ascertained to explain this increased incidence of CE is unknown. We specifically adjusted for variables used in pre-operative risk scores and may have overlooked other baseline factors that could impact CE post-operatively. In addition inpatient variables may impact this relationship, including post-operative delirium, infections, post-operative anemia and blood transfusion, which deserve further attention. However, in this particular study, the measurement of such variables would occur during the same time frame as our primary outcome, CE, introducing marked complexity in our time-dependent analysis and requiring the sample to be markedly limited as many CE occur within one week of surgery. We believe there is likely an interplay between the surgical intervention itself, its postoperative rehabilitation course, and this population's high incidence of underlying co-morbidities which may place patients at higher risk from the cardiac perspective (40,41). Attention towards these elders in the post-operative setting cannot be overemphasized, particularly in the context of our study. Our results suggest the need for enhanced pre-operative screening and management.

A low body mass index is associated with a higher risk of one-year post-operative cardiac events in a population-based cohort of elderly hip fracture patients. Further research is needed to better characterize the influence of body composition and adiposity on cardiovascular events in this population. In the interim, aggressive monitoring and evaluation of underweight patients in this population is needed to reduce the incidence of post-operative cardiac events.

Acknowledgments

The authors would like to thank Donna K. Lawson, LPN, Kathy Wolfert, and Cherie Dolliver, for their assistance in data collection and management. Dr. Huddleston is supported by Grant Number 1 KL2 RR024151-01 from the National Center for Research Resources (NCRR), a component of the National Institutes of Health (NIH), and NIH Roadmap for Medical Research. Its contents are solely the responsibility of the authors and do not necessarily represent the official view of NCRR or NIH. Information on NCRR is available at <http://www.ncrr.nih.gov/> <<http://www.ncrr.nih.gov/>>. The research was made possible by the American Heart Association – National Scientist Development Award (Grant #03-30103N-04).

Jeanne M. Huddleston is a recipient of the AHAP grant.

ABBREVIATIONS

BMI	Body Mass Index
CE	Cardiac Events
CHF	Congestive Heart Failure
MI	Myocardial infarction
RCRI	Revised Cardiac Risk Index

REFERENCES

1. Spillman BC, Lubitz J. The effect of longevity on spending for acute and long-term care. *N Engl J Med*. 2000 May 11;342:1409–1415. [PubMed: 10805827]
2. Lubitz J, Cai L, Kramarow E, et al. Health, life expectancy, and health care spending among the elderly. *N Engl J Med*. 2003; 349:1048–1055. [PubMed: 12968089]
3. Flegal KM, Carroll MD, Kuczmarski RJ, et al. Overweight and obesity in the United States: prevalence and trends, 1960–1994. *Int J Obes Relat Metab Disord*. 1998; 22:39–47. [PubMed: 9481598]
4. Eckel RH. Obesity and heart disease: A statement for healthcare professionals from the Nutrition Committee, American Heart Association. *Circulation*. 1997; 96:3248–3250. [PubMed: 9386201]

5. Burge R, Dawson-Hughes B, Solomon DH, et al. Incidence and economic burden of osteoporosis-related fractures in the United States, 2005–2025. *J Bone Miner Res.* 2007; 22:465–475. [PubMed: 17144789]
6. Melton LJ 3rd. Adverse outcomes of osteoporotic fractures in the general population. *J Bone Miner Res.* 2003; 18:1139–1141. [PubMed: 12817771]
7. Huddleston JM, Huddleston PM, Larson D, et al. Incidence of Cardiac Complications Following Hip Surgery: A Population Based Study. *J Hosp Med.* 2007; 2 Suppl 2:S17.
8. De Laet C, Kanis JA, Oden A, et al. Body mass index as a predictor of fracture risk: a meta-analysis. *Osteoporos Int.* 2005; 16:1330–1338. [PubMed: 15928804]
9. Wigfield CH, Lindsey JD, Munoz A, et al. Is extreme obesity a risk factor for cardiac surgery? An analysis of patients with a BMI > or = 40. *Eur J Cardiothorac Surg.* 2006; 29:434–440. [PubMed: 16504529]
10. Yap CH, Zimmet A, Mohajeri M, et al. Effect of obesity on early morbidity and mortality following cardiac surgery. *Heart Lung Circ.* 2007; 16:31–36. [PubMed: 17161973]
11. Shubair MM, Prabhakaran P, Pavlova V, et al. The relationship of body mass index to outcomes after percutaneous coronary intervention. *J Interv Cardiol.* 2006; 19:388–395. [PubMed: 17020562]
12. Perka C, Labs K, Muschik M, et al. The influence of obesity on perioperative morbidity and mortality in revision total hip arthroplasty. *Arch Orthop Trauma Surg.* 2000; 120:267–271. [PubMed: 10853893]
13. Patel N, Bagan B, Vadera S, et al. Obesity and spine surgery: Relation to perioperative complications. *J Neurosurg Spine.* 2007; 6:291–297. [PubMed: 17436915]
14. Miric A, Lim M, Kahn B, et al. Perioperative morbidity following total knee arthroplasty among obese patients. *J Knee Surg.* 2002; 15:77–83. [PubMed: 12013077]
15. Melton L. History of the Rochester Epidemiology Project. *Mayo Clin Proceedings.* 1996; 71:266–274.
16. Melton LJ 3rd. The threat to medical-records research. *N Engl J Med.* 1997; 337:1466–1470. [PubMed: 9380105]
17. Quetelet, L. *Antropometrie ou Mesure des Differences Facultes de l'Homme.* Brussels: Musquardt; 1871.
18. Goldman L, Caldera DL, Nussbaum SR, et al. Multifactorial index of cardiac risk in noncardiac surgical procedures. *N Engl J Med.* 1977; 297:845–850. [PubMed: 904659]
19. Lee TH, Marcantonio ER, Mangione CM, et al. Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiac surgery. *Circulation.* 1999; 100:1043–1049. [PubMed: 10477528]
20. Detsky AS, Abrams HB, Forbath N, et al. Cardiac assessment for patients undergoing noncardiac surgery. A multifactorial clinical risk index. *Arch Intern Med.* 1986; 146:2131–2134. [PubMed: 3778043]
21. Auerbach AD, Goldman L. beta-Blockers and reduction of cardiac events in noncardiac surgery: Scientific review. *JAMA.* 2002; 287:1435–1444. [PubMed: 11903031]
22. Fleisher LA, Beckman JA, Brown KA, et al. ACC/AHA 2007 guidelines on perioperative cardiovascular evaluation and care for noncardiac surgery: A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 2002 Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac Surgery): developed in collaboration with the American Society of Echocardiography, American Society of Nuclear Cardiology, Heart Rhythm Society, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, and Society for Vascular Surgery. *Circulation.* 2007; 116:e418–e499. [PubMed: 17901357]
23. McKee PA, Castelli WP, McNamara PM, et al. The natural history of congestive heart failure: The Framingham study. *N Engl J Med.* 1971; 285:1441–1446. [PubMed: 5122894]
24. Kaplan E, Meier P. Nonparametric Estimation from Incomplete Observations. *J Am Statistical Assoc.* 1958; 53:457–481.
25. Peto R, Peto J. Asymptotically efficient rank invariant procedures (with discussion). *J Royal Statistical Soc Series A.* 1972; 135:185–207.

26. Cox D. Regression Models and life-tables (with discussion). *J Royal Statistical Soc Series B*. 1972; 34:187–220.
27. Curtis JP, Selter JG, Wang Y, et al. The obesity paradox: Body mass index and outcomes in patients with heart failure. *Arch Intern Med*. 2005; 165:55–61. [PubMed: 15642875]
28. Romero-Corral A, Montori VM, Somers VK, et al. Association of bodyweight with total mortality and with cardiovascular events in coronary artery disease: A systematic review of cohort studies. *Lancet*. 2006; 368:666–678. [PubMed: 16920472]
29. Tanko LB, Christiansen C, Cox DA, et al. Relationship between osteoporosis and cardiovascular disease in postmenopausal women. *J Bone Miner Res*. 2005; 20:1912–1920. [PubMed: 16234963]
30. Browner WS, Seeley DG, Vogt TM, et al. Non-trauma mortality in elderly women with low bone mineral density. Study of Osteoporotic Fractures Research Group. *Lancet*. 1991; 338:355–358. [PubMed: 1677708]
31. Samelson EJ, Kiel DP, Broe KE, et al. Metacarpal cortical area and risk of coronary heart disease: The Framingham Study. *Am J Epidemiol*. 2004; 159:589–595. [PubMed: 15003963]
32. von der Recke P, Hansen MA, Hassager C. The association between low bone mass at the menopause and cardiovascular mortality. *Am J Med*. 1999; 106:273–278. [PubMed: 10190374]
33. Bagger YZ, Rasmussen HB, Alexandersen P, et al. Links between cardiovascular disease and osteoporosis in postmenopausal women: Serum lipids or atherosclerosis per se? *Osteoporos Int*. 2007; 18:505–512. [PubMed: 17109061]
34. Arnold AM, Psaty BM, Kuller LH, et al. Incidence of cardiovascular disease in older Americans: the cardiovascular health study. *J Am Geriatr Soc*. 2005; 53:211–218. [PubMed: 15673343]
35. Walston J, McBurnie MA, Newman A, et al. Frailty and activation of the inflammation and coagulation systems with and without clinical comorbidities: Results from the Cardiovascular Health Study. *Arch Intern Med*. 2002; 162:2333–2341. [PubMed: 12418947]
36. Flegal KM, Graubard BI, Williamson DF, et al. Excess deaths associated with underweight, overweight, and obesity. *JAMA*. 2005; 293:1861–1867. [PubMed: 15840860]
37. 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; 143:228–239. [PubMed: 8561156]
38. Smalley KJ, Knerr AN, Kendrick ZV, et al. Reassessment of body mass indices. *Am J Clin Nutr*. 1990; 52:405–408. [PubMed: 2393001]
39. Romero-Corral A, Somers VK, Sierra-Johnson J, et al. Accuracy of body mass index in diagnosing obesity in the adult general population. *Int J Obes (Lond)*. 2008; 32:959–966. Epub 2008 Feb 19. [PubMed: 18283284]
40. Poor G, Atkinson EJ, O'Fallon WM, et al. Determinants of reduced survival following hip fractures in men. *Clin Orthop Relat Res*. 1995; 319:260–265. [PubMed: 7554638]
41. Kenzora JE, McCarthy RE, Lowell JD, et al. Hip fracture mortality. Relation to age, treatment, preoperative illness, time of surgery, and complications. *Clin Orthop Relat Res*. 1984; 186:45–56. [PubMed: 6723159]

1B

Incidence of Congestive Heart Failure Following Hip Fracture Repair by Body Mass Index

1D

Incidence of Angina Following Hip Fracture Repair by Body Mass Index

1E

Incidence of Any Cardiac Event Following Hip Fracture Repair by Body Mass Index

Figure 1A-E. Cumulative incidence of myocardial infarction, congestive heart failure, arrhythmias, and angina, up to one year post-operatively in 1,180 Olmsted County residents undergoing urgent hip fracture repair, 1988–2002.

Cardiac Death Following Urgent Hip Fracture Repair

Figure 2.
Cardiac-specific survival up to one year post-operatively in 1,180 Olmsted County residents undergoing urgent hip fracture repair, 1988–2002.

Baseline Characteristics of 1,180 Olmsted County Residents Undergoing Urgent Hip Fracture Repair, 1988–2002, by Body Mass Index Classification

TABLE 1

Variable	Underweight ($< 18.5\text{kg/m}^2$) n=184	Normal ($18.5\text{--}24.9\text{kg/m}^2$) n=640	Overweight ($25\text{--}29.9\text{kg/m}^2$) n=251	Obese ($\geq 30\text{kg/m}^2$) n=105	P-value [‡]
Age (years)	84.8±8.0	85.0±7.2	83.1±7.3	80.7±7.4	<0.001
Female Sex	171 (92.9)	525 (82)	177 (70.5)	76 (72.4)	<0.001
Pre-Admission Residence					
ALC/SNF	79 (42.9)	250 (39.1)	83 (33.1)	36 (34.3)	0.024
Home	105 (57.1)	390 (60.9)	168 (66.9)	69 (65.7)	
Functional Status [*]					
Dependent	25 (13.6)	80 (12.5)	24 (9.6)	7 (6.7)	0.044
Walking Independently	159 (86.4)	560 (87.5)	226 (90.4)	97 (93.3)	
History of:					
Hypertension	84 (45.7)	374 (58.4)	159 (63.3)	70 (66.7)	<0.001
Diabetes	9 (4.9)	71 (11.1)	30 (12)	30 (28.6)	<0.001
Cerebrovascular Disease	40 (21.7)	175 (27.3)	77 (30.7)	33 (31.4)	0.028
Myocardial Infarction	44 (23.9)	140 (21.9)	61 (24.3)	36 (34.3)	0.106
Congestive Heart Failure	48 (26.1)	150 (23.4)	76 (30.3)	44 (41.9)	0.003
Atrial Fibrillation/Flutter	49 (26.6)	119 (18.4)	57 (22.7)	26 (24.8)	0.985
Chronic Renal Insufficiency	11 (6)	64 (10)	34 (13.5)	20 (19)	<0.001
Dementia	63 (34.2)	233 (36.4)	74 (29.5)	26 (24.8)	0.031
COPD	41 (22.3)	100 (15.6)	32 (12.7)	17 (16.2)	0.032
Osteoporosis	77 (41.8)	253 (39.5)	73 (29.1)	31 (29.5)	<0.001
Cancer	61 (33.2)	169 (26.4)	75 (29.9)	32 (30.5)	0.88
Cardiac Related Hospitalization within 90 days of Hip Fracture	5 (2.7)	9 (1.4)	8 (3.2)	4 (3.8)	0.14
Major Surgery within 90 days	3 (1.6)	10 (1.6)	8 (3.2)	3 (2.9)	0.366
ASA Class [‡]					
I or II	19 (10.4)	93 (14.5)	46 (18.3)	12 (11.4)	0.144

Variable	Underweight ($< 18.5 \text{ kg/m}^2$) n=184	Normal ($18.5\text{--}24.9 \text{ kg/m}^2$) n=640	Overweight ($25\text{--}29.9 \text{ kg/m}^2$) n=251	Obese ($\geq 30 \text{ kg/m}^2$) n=105	P-value [‡]
III, IV or V	164 (89.6)	547 (85.5)	205 (81.7)	93 (88.6)	
Admission Medications					
Insulin	2 (1.1)	18 (2.8)	11 (4.4)	17 (16.2)	<0.001
Aspirin	50 (27.2)	197 (30.8)	82 (32.7)	37 (35.2)	0.126
Beta-blockers	18 (9.8)	90 (14.1)	50 (19.9)	25 (23.8)	<0.001
Revised Cardiac Risk Index (median # of components)	0.9 (1.0)	0.9 (1.0)	1.1 (1.1)	1.4 (1.2)	<0.001
Discharge Destination [#]	1 (0–4)	1 (0–4)	1 (0–4)	1 (0–5)	
Home	20 (10.9)	65 (10.2)	43 (17.1)	19 (18.1)	
ALC/Nursing Home	146 (79.8)	547 (85.5)	199 (79.3)	83 (79)	<0.001
In-hospital death	17 (9.3)	28 (4.4)	9 (3.6)	3 (2.9)	

Continuous variables are represented as mean $\pm$ standard deviations. Discrete variables are represented as number (%)

* there were two (2) patients with missing data

[†] there was one (1) patient with missing data

[‡] P-values are Kruskal-Wallis tests for continuous variables and either Fisher Exact or Cochran-Mantel-Haenszel values for discrete variables.

Abbreviations: ALC – Assisted Living Center; ASA – American Society of Anesthesia; COPD – Chronic Obstructive Pulmonary Disease; SNF – Skilled Nursing Facility

Univariate Analysis for Specific Cardiac Outcomes among 1,180 Olmsted County Residents Undergoing Urgent Hip Fracture Repair, 1988–2002

Table 2

	Composite Outcome [§] n=441 ^{//}	Myocardial Infarction n=191 ^{//}	Congestive Heart Failure n=231 ^{//}	Arrhythmia n=135 ^{//}	Angina n=30 ^{//}	Cardiac Death n=75 ^{//}
Underweight	1.48 (1.2–1.9) *	1.44 (1.0–2.1) *	1.33 (0.9–1.9)	1.59 (1.0–2.4) *	0.47 (0.1–1.6)	1.14 (0.8–2.6)
Normal	Referent	Referent	Referent	Referent	Referent	Referent
Overweight	1.06 (0.8–1.3)	1.19 (0.8–1.7)	1.27 (0.9–1.7)	1.03 (0.7–1.6)	0.44 (0.2–1.3)	1.00 (0.6–1.8)
Obese	1.16 (0.8–1.6)	1.21 (0.7–2.0)	1.18 (0.8–1.8)	1.08 (0.6–2.0)	0 (0–0) *	0.59 (0.2–1.7)
BMI ≥25kg/m² †	0.99 (0.8–1.2) *	1.09 (0.8–1.5)	1.17 (0.9–1.5)	0.93 (0.6–1.3)	0.35 (0.1–1.0) *	0.81 (0.5–1.4)
BMI Not Normal ‡	1.22 (1.0–1.5) *	1.28 (1.0–1.7)	1.05 (0.7–1.6)	1.22 (0.9–1.7)	0.36 (0.2–0.8) *	1.05 (0.7–1.7)

All values are Hazard Ratios (95% Confidence Intervals)

* P<0.05

† Compared to those with BMI <25kg/m²

‡ Comparing to those with a normal BMI of 18.5–24.9kg/m²

§ Composite outcome consists of the first occurrence myocardial infarctions, congestive heart failure, arrhythmias, angina or cardiac deaths within one year of surgical intervention

// The number of observed events of this type

Abbreviations: BMI – Body mass index

Table 3
Multivariable Analysis for Overall Adverse Cardiac Events in 1,180 Hip Fracture Repairs in Olmsted County

Underweight < 18.5kg/m ² §n=184	Normal 18.5–24.9kg/m ² §n=640	Overweight 25–29.9kg/m ² §n=251	Obese ≥30kg/m ² §n=105	Age [‡]	Male Sex [‡]	Revised Cardiac Risk Index [‡]	Beta-Blocker [‡]	Surgical Year [‡]
1.48 (1.17–1.87) [*]	Referent	1.15 (0.91–1.46)	1.36 (0.98–1.88)	1.04 (1.03–1.05) [*]	---	---	---	---
1.51 (1.20–1.91) [*]	Referent	1.04 (0.82–1.31)	1.14 (0.83–1.58)	---	1.24 (0.99–1.55)	---	---	---
1.52 (1.20–1.93) [*]	Referent	1.01 (0.80–1.26)	0.97 (0.70–1.35)	---	---	1.43 (1.32–1.55) [*]	---	---
1.49 (1.17–1.88) [*]	Referent	1.05 (0.83–1.33)	1.14 (0.82–1.58)	---	---	---	1.15 (0.91–1.46)	---
1.50 (1.18–1.89) [*]	Referent	1.06 (0.84–1.35)	1.14 (0.83–1.58)	---	---	---	---	1.02 (1.00–1.04)
†1.56 (1.22–1.98) [*]	Referent	1.07 (0.85–1.35)	1.12 (0.81–1.56)	1.04 (1.03–1.05) [*]	1.23 (0.99–1.54)	1.39 (1.28–1.51) [*]	0.97 (0.75–1.24)	1.01 (0.99–1.03)

Each row represents a separate multivariable analysis. All values listed as Hazard Ratios (95% Confidence Intervals)

^{*} P<0.05

[‡] Final Multivariable model after adjusting for age, sex, Lee's Revised Cardiac Risk Index, use of beta-blockers, and year of surgery.

[‡] Hazard Ratio for variable, after adjusting for body mass index category

[§] The number of observed events of this type