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BASIC RESEARCH

Surgical Risks and Costs of Care are Greater in Patients Who Are Super Obese and Undergoing THA

Menachem M. Meller MD, PhD, Nader Toossi MD, Mark H. Gonzalez MD, PhD, Min-Sun Son PhD, Edmund C. Lau MS, Norman Johanson MD

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Abstract

Background Patients with morbid obesity, defined as a BMI greater than 40 kg/m^2, and super obesity, defined as a BMI greater than 50 kg/m^2, increasingly present for total hip replacement. There is disagreement in the literature whether these individuals have greater surgical risks and costs for the episode of care, and the magnitude of those risks and costs. There also is no established threshold for obesity as defined by BMI in identifying increased complications, risks, and costs of care. Until recently, analysis of higher BMI data was limited to small cohorts from hospital-based data banks, based on BMI or height and weight only, often as part of a multivariate analysis. On October 1, 2010 the Centers for Medicare & Medicaid Services added a fifth digit to the BMI data, V85.xx, in the Medicare data bank, which allowed data mining of cases of patients with higher BMI. To our knowledge, our study is the first large retrospective Medicare data mining study, which allows us to examine BMI levels greater than 40 and 50 kg/m^2 to delineate risks, complications, and costs for these patients.

Questions/purposes We sought to quantify (1) the surgical risk, and (2) the costs associated with complications after THA in patients who were morbidly obesity (BMI $\geq$ 40 kg/m^2) or super obese (BMI $\geq$ 50 kg/m^2).

Methods This is a retrospective study of patients, using Medicare hospital claims data, who underwent THA. The ICD-9 Clinical Modification (CM) diagnosis code V85.4x was used to identify patients with morbid obesity and with super obesity from October 1, 2010 through December 31, 2014. Patients without any BMI-related diagnosis codes were used as the control group. Twelve complications occurring during the 90 days after THA were analyzed using multivariate Cox models adjusting for patient demographic, comorbidities, and institutional factors. In addition, hospital charges and payments were compared from primary surgery through the subsequent 90 days.

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Each author certifies that his or her institution approved or waived approval for the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.
This study was performed via electronic collaboration at the authors' institutions.

M. M. Meller (✉)
Department of Orthopaedic Surgery,
Mercy Philadelphia Hospital, 501 South 54th Street,
Philadelphia, PA 19143, USA
e-mail: mmmeller@verizon.net

N. Toossi, N. Johanson
Department of Orthopaedic Surgery,
Drexel University College of Medicine,
Philadelphia, PA, USA

M. H. Gonzalez
Department of Orthopedic Surgery, University of Illinois
College of Medicine, Chicago, IL, USA

M.-S. Son
Exponent Inc, Philadelphia, PA, USA

E. C. Lau
Exponent Inc, Menlo Park, CA, USA

Results Patients with morbid obesity had increased postoperative complications including prosthetic joint infection (hazard ratio [HR], 3.71; 95% CI, 3.2–4.31; $p < 0.001$), revision (HR, 1.91; 95% CI, 1.69–2.16; $p < 0.001$), and wound dehiscence (HR, 3.91; 95% CI, 3.14–4.86; $p < 0.001$). In addition, patients with morbid obesity had increased risk of deep vein thrombosis (HR, 1.43; 95% CI, 1.14–1.79; $p < 0.002$), pulmonary embolism (HR, 1.57; 95% CI, 1.25–1.99; $p < 0.001$), implant failure (HR, 1.48; 95% CI, 1.3–1.68; $p < 0.001$), acute renal failure (HR, 1.68; 95% CI, 1.56–1.80; $p < 0.001$), and all-cause readmission (HR, 1.48; 95% CI, 1.40–1.56; $p < 0.001$). However, death (HR, 0.94 95% CI, 0.73–1.19 $p < 0.592$), acute myocardial infarction (HR, 0.94; 95% CI, 0.74–1.2 $p < 0.631$), and dislocation (HR 1.07; 95% CI, 0.85–1.34; $p < 0.585$) were not different between patients in the control and morbidly obese groups. Super obese patients had an increased risk of infection (HR, 6.48; 95% CI, 4.54–9.25; $p < 0.001$), wound dehiscence (HR, 9.81; 95% CI, 6.31–15.24; $p < 0.001$), and readmission (HR, 2.16; 95% CI, 1.84–2.54; $p < 0.001$) compared with patients with normal BMI. Controlling for patient and institutional factors, each THA had mean total hospital charges of USD 88,419 among patients who were super obese compared with USD 73,827 for the control group, a difference of USD 14,591. Medicare payment for the patients who were super obese also was higher, but only by USD 3631.

Conclusions Patients who are super obese are at increased risk for serious complications compared with patients with morbid obesity, whose risks are elevated relative to patients whose BMI is less than 40 kg/m^2. Costs of care for patients who were super obese, likewise, were increased. We present BMI outcomes to allow an objective basis for patient counseling, risk stratification, maintaining access to orthopaedic surgical care, and maintaining hospital operating margins.

Level of Evidence Level III, therapeutic study.

Introduction

According to the National Center for Health Statistics, the prevalence of obesity (BMI $\geq$ 30 kg/m^2) and morbid obesity (BMI $\geq$ 40 kg/m^2) in the adult population in the United States is approximately 36% and 6%, respectively [9, 29] . In addition the prevalence of super obesity, defined as a BMI greater than 50 kg/m^2, has increased 120% between 2000 and 2010 in the United States, with 15.5 million adult Americans or 6.6% of the population having an actual BMI greater than 40 kg/m^2 [26, 27] . Because obesity may be an independent risk factor for hip osteoarthritis [5, 22], many patients presenting for elective THA will be obese. According to Bourne et al. [4], the Canadian Joint Replacement Registry showed an 8.56-fold increased risk for a patient with class III obesity (BMI > 40 kg/m^2) to undergo a total hip replacement. There is controversy regarding whether obesity poses additional complications and costs with THA [7, 20, 28]. Some studies have reported that the risk of postoperative complications after joint arthroplasty in patients who are obese is comparable to the risk in patients who are nonobese as long as their BMI is less than 40 kg/m^2 [1, 17]. However, morbid obesity is associated with a higher risk of postoperative complications [6, 21, 24]. In addition, super obesity (BMI $\geq$ 50 kg/m^2) has been reported to pose an even more substantial risk compared with the risk in patients who are less obese (BMI < 50 kg/m^2) [8, 15, 23]. However, few peer-reviewed studies have addressed the surgical dilemma regarding whether to perform THA on patients who are morbidly obese or super obese [2, 6, 16, 23].

Previous studies of complications in patients who are super obese were done in single institutions and focused on surgical complications rather than patient complications or costs involved [2, 23, 25]. However, to our knowledge, a nationwide study has not been performed on risks and costs when stratified by the degree of obesity, as measured by BMI. As methods of payment for health care change from fee-for-service to bundled care or episode-of-care models, the potential added cost of care for complications associated with elective surgery in patients who are morbidly or super obese requires further exploration.

We therefore asked: What are (1) the surgical risks and (2) costs associated with complications after THA in patients who are morbidly obese or super obese?

Patients and Methods

Data Sources

For this retrospective study, the Medicare inpatient claims data were used to identify patients who underwent primary THA between October 1, 2010 and December 31, 2014. The Medicare hospital data were accessed in a limited data set format, which represents the traditional fee-for-service claims submitted by hospitals to the Centers for Medicare & Medicaid Services (CMS) for reimbursement and does not include claims from beneficiaries enrolled in health maintenance organizations and other private health insurance plans. Each beneficiary in these limited data set files is identified by a synthetic but unique number, allowing tracking of the patient for any subsequent complications.

THA was identified using the ICD-9-CM procedure code 81.51 (Table 1). Patients had to be 65 years or older at the time of the arthroplasty and residing in the United States. In addition, each beneficiary must have been

Table 1. ICD-9-CM codes used to identify postoperative complications

Complication	Identification
Death	Medicare enrollment data
Deep vein thrombosis	453.40, 453.41, 453.42, 453.8x, 453.2x, 451.1x, 451.83
Periprosthetic joint infection	996.66
Hip revision	81.53, 00.70, 00.71, 00.72, 00.73
Pulmonary embolism	415.1x
Implant failure	996.4x, 996.77
Wound dehiscence	998.30, 998.31, 998.32
Acute myocardial infarction	410.0x – 410.9x
Acute renal failure	584.x
Pneumonia	480.x – 486.x
Dislocation	996.42
Readmission (all cause)*	Subsequent claim records in 90 days

*Not including subsequent admission for inpatient rehabilitation.

enrolled in Medicare for at least 1 year before admission for THA. This preoperative period was used to capture diagnoses and procedures performed before the THA for establishing the general health status of the patient at time of the surgery. Additionally, patients undergoing THA who received any knee arthroplasties during the study period were removed. This screening was taken to ensure that any complication, if observed, was not associated with any knee procedure performed on patients with hip disorders.

Patients' obesity level can be identified using the ICD-9-CM codes 278.0x or V85.xx (Table 2). The three levels of the 278.0x code correspond to obese unspecified (278.00), overweight (278.02), and morbidly obese (278.01). In a previous validity study, Lau et al. [14] determined that the sensitivity of the 278.xx for capturing obesity status was 67.7% with a positive predictive value of 50%. The more-specific V85.xx code corresponds to specific levels of the BMI. For example, V85.34 indicates someone with a BMI of 34 to 35 kg/m^2, and V85.4 indicates someone with a BMI of 40 kg/m^2 or greater. Lau et al. [14] determined that the sensitivity and positive predictive value of the V85.x code were 100%. On October 1, 2010, the V85.4 code was expanded to include a fifth digit that specifically captures patients with high BMI levels (eg, V85.43 = BMI of 50 to 60 kg/m^2). The nonobese or "normal-weight" comparison group was defined as patients without any BMI-related codes on their list of diagnoses. Diabetes mellitus is strongly associated with obesity [19] and some complications after THA [3]. To control for the confounding effect of diabetes, the analysis was stratified based on the diabetic status of the patient (Table 3). A dose-response behavior was analyzed with increasing levels of BMI from the overweight (BMI of 25 to 29 kg/m^2) to the super obese

Table 2. Patient characteristics

Variable	Normal weight (BMI < 25 kg/m^2)	Morbidly obese (BMI ≥ 40 kg/m^2)	Super obese (BMI ≥ 50 kg/m^2)
Sex			
Male	144,607 (38%)	3194 (32%)	188 (23%)
Female	232,075 (62%)	6713 (68%)	617 (77%)
Age group			
65–69	104,155 (28%)	5082 (51%)	450 (56%)
70–74	96,484 (26%)	2937 (30%)	249 (31%)
75–79	80,706 (21%)	1343 (14%)	79 (10%)
80–84	59,246 (16%)	451 (5%)	21 (3%)
85+	36,091 (10%)	94 (1%)	6 (1%)
Race			
White	352,239 (94%)	8884 (90%)	709 (88%)
Black	15,941 (4%)	831 (8%)	84 (10%)
Other	8502 (2%)	192 (2%)	12 (1%)
Region			
Midwest	97,124 (26%)	3464 (35%)	316 (39%)
Northeast	71,679 (19%)	1989 (20%)	158 (20%)
South	134,348 (36%)	3018 (30%)	247 (31%)
West	73,531 (20%)	1436 (14%)	84 (10%)
Charlson index			
0	215,553 (57%)	3871 (39%)	271 (34%)
1–2	128,592 (34%)	4670 (47%)	427 (53%)
3–4	25,777 (7%)	1131 (11%)	89 (11%)
5+	6760 (2%)	235 (2%)	18 (2%)
Discharge			
Home	199,764 (54%)	4144 (42%)	259 (33%)
Skilled nursing	125,382 (33%)	4104 (41%)	355 (44%)
Rehabilitation facility	39,435 (10%)	1353 (14%)	164 (20%)
Other facility	12,101 (3%)	306 (3%)	27 (3%)
Total	376,682	9907	805
Age (years)	74.7 ± 6.8	70.4 ± 4.8	69.8 ± 4.3
Length of stay (days)	3.3 ± 2.1	3.5 ± 2.4	3.7 ± 2.2
Hospital charge	USD 61,345 ± 36,925	USD 62,213 ± 45,300	USD 63,829 ± 35,844
CMS payment	USD 13,359 ± 6134	USD 13,469 ± 6589	USD 13,571 ± 5832

CMS = Centers for Medicare & Medicaid Services.

(BMI ≥ 50 kg/m^2). The dose-response relationship between obesity and postoperative complications also was investigated with patients grouped in six levels of BMI: 25 to 29 kg/m^2 (V85.2x), 30 to 34 kg/m^2 (V85.30–V85.34), 35 to 39 kg/m^2 (V85.35–V85.39), 40 to 44 kg/m^2 (V85.41), 45 to 49 kg/m^2 (V85.42), and 50 kg/m^2 or greater (V85.43–V85.45) (Fig. 1). Hazard ratios (HR) for each BMI level, relative to the patients with normal weight, were estimated after adjusting for age, sex, race, and other covariates described in the previous analysis. A contrast was constructed to test for a linear dose-response trend in the HR associated with increasing levels of BMI.

Table 3. 90-day complications and corresponding hazard ratios

	Nonstratified model			Stratified by diabetic status					
	Obese			Obese and with diabetes			Obese and without diabetes		
Complication	HR	95% CI	p Value	HR	95% CI	p Value	HR	95% CI	p Value
Acute myocardial infarction	0.94	0.74–1.20	0.631	0.82	0.58–1.17	0.284	0.99	0.70–1.39	0.950
Deep vein thrombosis	1.43	1.14–1.79	0.002	1.26	0.90–1.77	0.174	1.50	1.13–1.97	0.004
Death	0.94	0.73–1.19	0.592	0.90	0.63–1.29	0.575	0.90	0.64–1.25	0.516
Dislocation	1.07	0.85–1.34	0.585	0.99	0.71–1.40	0.963	1.09	0.80–1.50	0.582
Pulmonary embolism	1.57	1.25–1.99	< 0.001	0.99	0.64–1.53	0.970	1.93	1.49–2.50	< 0.001
Implant failure	1.48	1.30–1.68	< 0.001	1.31	1.06–1.62	0.013	1.58	1.34–1.85	< 0.001
Periprosthetic joint infection	3.71	3.20–4.31	< 0.001	2.81	2.23–3.54	< 0.001	4.44	3.67–5.36	< 0.001
Pneumonia	1.11	0.94–1.30	0.214	1.01	0.79–1.29	0.937	1.14	0.92–1.40	0.242
Readmission	1.48	1.40–1.56	< 0.001	1.31	1.20–1.42	< 0.001	1.58	1.47–1.70	< 0.001
Renal failure	1.68	1.56–1.80	< 0.001	1.51	1.37–1.67	< 0.001	1.73	1.57–1.90	< 0.001
Revision	1.91	1.69–2.16	< 0.001	1.65	1.35–2.02	< 0.001	2.07	1.78–2.41	< 0.001
Wound dehiscence	3.91	3.14–4.86	< 0.001	2.85	2.01–4.04	< 0.001	4.75	3.65–6.17	< 0.001

HR = hazard ratio.

The Medicare Limited Data Set hospital data identified 593,486 records of patients who had primary hip arthroplasty between October 1, 2010 through December 31, 2014. After applying the exclusions outlined in Materials and Methods, 432,841 remained, which included 376,682 patients of normal weight, 9907 who were morbidly obese, and 805 who were super obese. A small fraction of the patients (approximately 0.3%) had bilateral procedures, which were analyzed with unilateral THA records, with no special treatment (Table 2). The group of 45,447 patients not included in the numbers above are those with milder degrees of obesity.

They were neither normal-weight nor morbidly or super obese. Some were just listed as overweight.

Complication Outcomes and Other Evaluations

Twelve complications occurring during the 90 days after THA were examined (Fig. 2). These complications were identified from hospital claims records, suggesting that the complication occurred while the patient was still hospitalized after the THA or was the cause of a subsequent readmission. For complications identified on the same records with the THA, the presence-on-admission code (only available from 2011 and onward) also was checked to ensure that the condition was not present before the surgery. Subsequent admission for rehabilitation after THA was not considered a complication and was not counted under all-cause readmission. Examining the risk of these short-term complications minimizes confounding by other subsequent procedures or changes in the health status of the patient during longer times. In addition to clinical outcomes, the total hospital charges and CMS payments were tracked from the time of the primary procedure through any additional rehospitalization during a 90-day period (hospital charges and CMS payments were adjusted to June 2015 level by the Consumer Price Index for medical services).

Postoperative complications and risks were evaluated using multivariate Cox models adjusting for the patient's age, sex, race, resident census region, economic status using state Medicaid buy-in as a proxy, and overall health status as captured by the Charlson Comorbidity Index. Specific morbidity indicators for diabetes, heart failure, pulmonary disease, depression, and acute renal failure were included to capture the effects beyond the overall health status characterized by the Charlson Comorbidity Index. Institutional factors included were hospital ownership (eg, private), bed size, teaching or nonteaching status, and urban or rural location. In addition, two volume measures treated as proxy variables for experience were included, quantifying the approximate annual THAs performed at the facility and performed by the physician for Medicare patients. If a revision was performed during the 90-day period, the search for complications stopped at the time of revision. Except for death, other complications did not have an obvious competing risk relationship. Each complication was evaluated independent of the presence or absence of other complications.

The data and results reported in our study were processed and analyzed using SAS® 9.4 statistical software (SAS® Institute Inc, Cary, NC, USA).

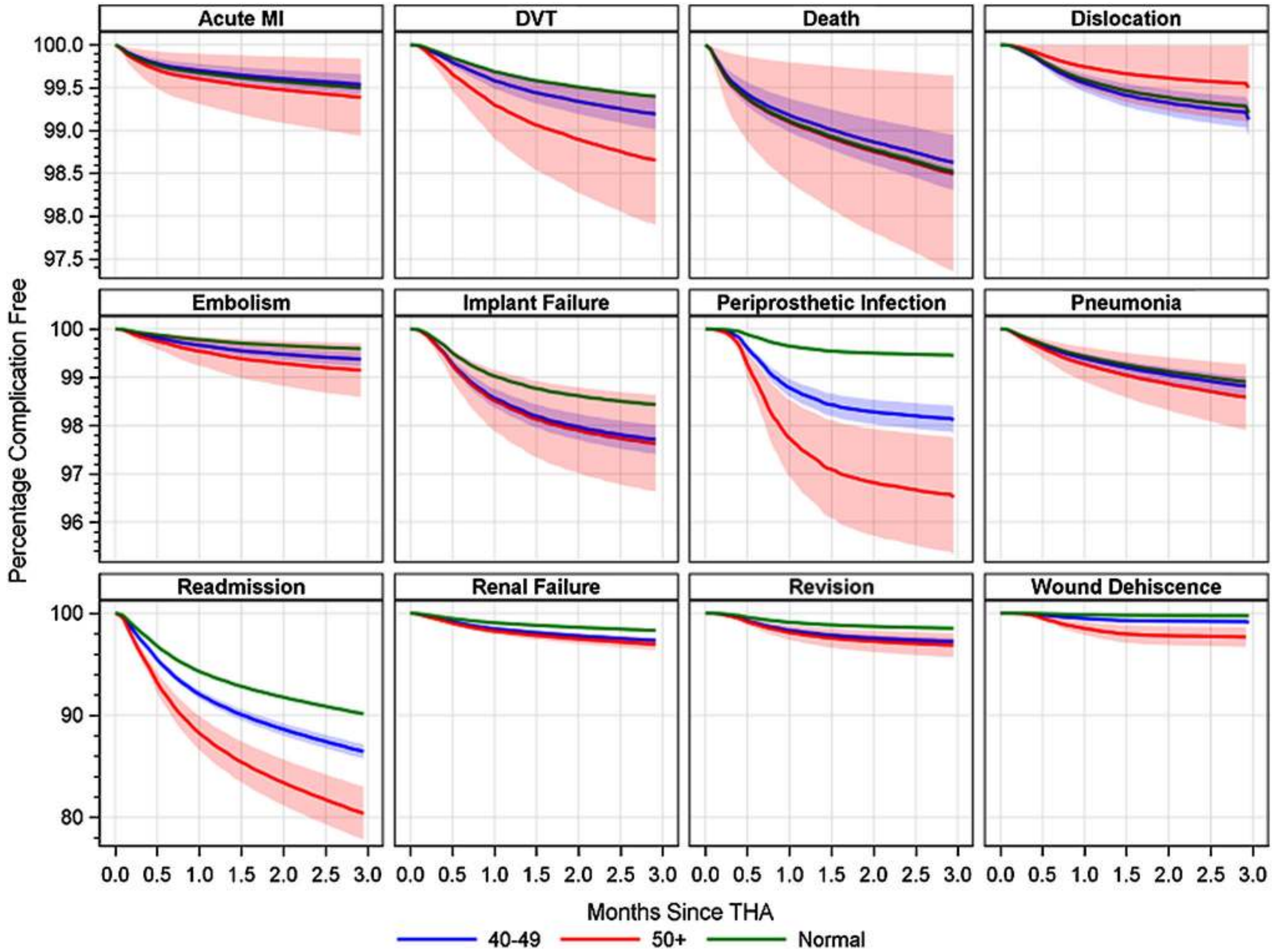

Fig. 1 The trend analysis of hazard ratios for 90-day complications by BMI level (kg/m^2) is presented. MI = myocardial infarction; DVT = deep vein thrombosis.

Results

90-day Complications

Patients with morbid obesity were at increased risk for complications compared with patients with normal weight (Table 3). Complications with an HR greater than 2.0 include periprosthetic joint infection (HR, 3.71; 95% CI, 3.20–4.31; $p < 0.001$), revision (HR, 1.91; 95% CI, 1.69–2.16; $p < 0.001$), and wound dehiscence (HR, 3.91; 95% CI, 3.14–4.86; $p < 0.001$). With the numbers available, there were no differences between patients who were morbidly obese or normal weight for death, acute myocardial infarction, pneumonia, and hip dislocation. When stratified by the presence of diabetes at the time of the THA, the association of obesity and the risk of periprosthetic joint infection and wound dehiscence, independent of diabetes, was more pronounced than for other complications. In patients without diabetes, periprosthetic joint infection and wound dehiscence had HRs of 4.44 (95% CI, 3.67–5.36; $p < 0.001$) and 4.75 (95% CI, 3.65–6.17; $p < 0.001$) respectively.

Among patients who were morbidly obese, 15% (HR, 1.48; 95% CI, 1.40–1.56; $p < 0.001$) returned to hospitals within 90 days for additional treatment compared with 10% among the patients with normal weight (Fig. 1). Periprosthetic joint infection was the complication with the second largest difference (HR, 3.71; 95% CI, 3.20–4.31; $p < 0.001$) between patients who were morbidly obese and those who were normal weight. Other than readmission, acute renal failure (HR, 1.68; 95% CI, 1.56–1.80; $p < 0.001$), hip revision (HR, 1.91; 95% CI, 1.69–2.16; $p < 0.001$), and implant failure (HR, 1.48; 95% CI, 1.30–1.99; $p < 0.001$) were the three most common complications during the 90-day period after THA among patients who were morbidly obese.

The complication risk posed by patients who were super obese was examined by comparing these patients with

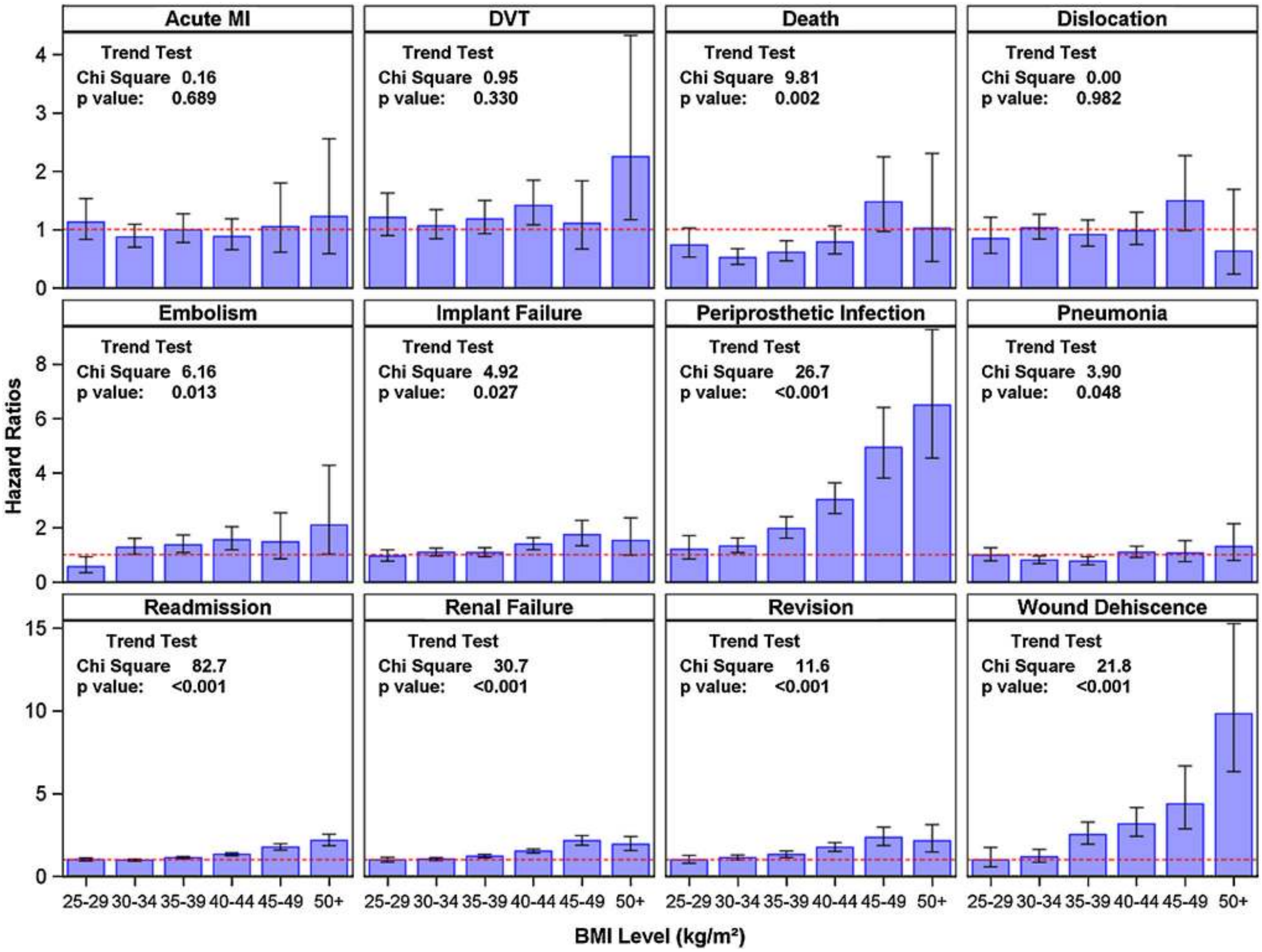

Fig. 2 The complication-free trends 90 days after THA for the patients who were super obese, morbidly obese, or normal weight are shown. The scale on the third row is adjusted to show the full survival decrease for readmission. MI = myocardial infarction; DVT = deep vein thrombosis.

patients who were normal weight, and with patients with a BMI of 40 to 49 kg/m^2 (Table 4). The second comparison (BMI $\geq$ 50 kg/m^2 versus BMI of 40 to 49 kg/m^2) helped identify additional risk beyond obesity at the BMI 40- to 49-kg/m^2 level. There were only 805 patients who were super obese during the period studied, and the HR estimates were not precise compared with those of the less-obese patient groups with substantially more subjects. Several complications in the super obese patients had elevated HRs compared with the complications in patients of normal weight, including periprosthetic joint infection (HR, 6.48; 95% CI, 4.54–9.25; $p < 0.001$), readmission (HR, 2.16; 95% CI, 1.84–2.54; $p < 0.001$), and wound dehiscence (HR, 9.81; 95% CI, 6.31–15.24; $p < 0.001$) (Table 4). These three complications also showed an increase in risk in patients who were super obese compared with patients with a BMI of 40 to 49 kg/m^2 (periprosthetic joint infection: HR, 1.87; 95% CI, 1.28–2.74; $p < 0.001$); (readmission: HR, 1.53; 95% CI, 1.28–1.82; $p < 0.001$); (wound dehiscence: HR, 2.85; 95% CI, 1.77–4.59; $p < 0.001$). Acute renal failure showed a higher HR for patients who were super obese (HR, 1.93; 95% CI, 1.55–2.40; $p < 0.001$) compared with patients with normal weight, but showed little additional risk more than the BMI 40- to 49-kg/m^2 group (HR, 1.17; 95% CI, 0.93–1.47; $p < 0.186$). The readmission rate was 20% among patients who were super obese compared with 15% among those with a BMI 40 to 49 kg/m^2 and only 10% among the patients with normal weight (HR, 2.16; 95% CI, 1.84–2.54; $p < 0.001$) (Table 4). Super obesity did not seem to be associated with an increased risk of dislocation (HR, 0.63; 95% CI, 0.23–1.68; $p < 0.335$).

We found a strong dose response relationship between increasing BMI and an increased likelihood of the patient having a periprosthetic joint infection develop, readmission, renal failure, and wound dehiscence, and a weaker relationship between increasing BMI and the risk of death and postoperative pneumonia. Risks increased

Table 4. Comparison of complications for patients who were super obese with those of normal weight

Complication	BMI ≥ 50 kg/m^2 versus normal weight			BMI ≥ 50 kg/m^2 versus BMI of 40–49 kg/m^2		
	HR	95% CI	p Value	HR	95% CI	p Value
Acute myocardial infarction	1.22	0.58–2.55	0.596	1.33	0.61–2.92	0.473
Deep vein thrombosis	2.25	1.17–4.32	0.016	1.67	0.83–3.37	0.148
Death	1.02	0.45–2.30	0.968	1.10	0.47–2.58	0.823
Dislocation	0.63	0.23–1.68	0.355	0.57	0.21–1.58	0.279
Pulmonary embolism	2.09	1.02–4.28	0.044	1.37	0.64–2.92	0.421
Implant failure	1.52	0.98–2.35	0.059	1.04	0.65–1.65	0.881
Periprosthetic joint infection	6.48	4.54–9.25	< 0.001	1.87	1.28–2.74	< 0.001
Pneumonia	1.30	0.79–2.14	0.304	1.20	0.71–2.03	0.500
Readmission	2.16	1.84–2.54	< 0.001	1.53	1.28–.1.82	< 0.001
Renal failure	1.93	1.55–2.40	< 0.001	1.17	0.93–1.47	0.186
Revision	2.14	1.47–3.12	< 0.001	1.13	0.76–1.70	0.537
Wound dehiscence	9.81	6.31–15.24	< 0.001	2.85	1.77–4.59	< 0.001

HR = hazard ratio.

steadily for periprosthetic joint infections (HR, 3.0; 95% CI, 4.9–6.5; $p < 0.048$), readmission (HR, 1.3; 95% CI, 1.8–2.2; $p < 0.001$), and wound dehiscence (HR, 3.2; 95% CI, 4.4–9.8; $p < 0.001$) corresponding to BMIs of 40,45, and 50+ kg/m^2 respectively. The HRs for death increased for a BMI of 40 to 44 kg/m^2 and 45 to 49 kg/m^2 but then decreased at a BMI of 50+ kg/m^2 (Fig. 2). The HR for renal failure increased for BMIs of 35, 40, and 45 kg/m^2 but then decreased for a BMI of 50+ kg/m^2 (HR, 1.2; 1.5; 2.1; and 1.9; $p < 0.001$). The HR for pneumonia remained at a level of 1.1 ($p < 0.048$) for BMI 40 to 49 kg/m^2 and increased incrementally to 1.3 beyond a BMI of 50+ kg/m^2.

Costs of Care

In general, the costs of care were higher in patients with morbid obesity and super obesity than in the control group (Fig. 3). Controlling for patient and institutional factors, each THA had a median total hospital charge of USD 88,419 (± USD 1313) among patients who were super obese compared with USD 73,827 (± USD 609) for the control group, a difference of USD 14,592. Medicare payment for the patients who were super obese also was higher, but only by USD 3631 (Table 5).

Discussion

Patients with morbid obesity (BMI ≥ 40 kg/m^2) and super obesity BMI ≥ 50 kg/m^2) increasingly present for total hip replacement. There is disagreement regarding whether these individuals have greater surgical risks and costs for the episode of care [2, 4, 6, 10] and the magnitude of those risks and costs. Further, there is no established threshold for obesity as defined by BMI in defining increased complications and risks. We therefore asked what were (1) the surgical risks and (2) costs associated with complications after THA in patients who were morbidly obese and patients who were super obese.

A limitation of our study is the reliance on the hospital records for identification of subsequent complications. The complications we studied are a subset of all complications that occurred after THA that are serious enough to require hospitalization. Some complications such as revisions, acute myocardial infarction, and pulmonary embolism require hospitalization. It is possible that complications occurred and were treated in an outpatient setting, therefore they would not be included in the inpatient data set. Nonetheless, complications requiring hospitalization can be viewed as more serious in terms of their effect on patients' health and the financial implications to care for such patients. Second there were only 805 patients who were super obese included in the database during the time of our study, which reduces precision of hazard risk estimates compared with the less obese or normal weight groups, which included substantially more patients. However, our power analysis indicates that our findings are robust. Finally, hospital charges often bear little resemblance to true costs, and often reflect proprietary or institution-based charge master listings. However, as the patient groups were studied contemporaneously, were covered by a single insurance payer (Medicare), and were treated at a wide range of hospitals, we believe the overall trends in costs are accurate.

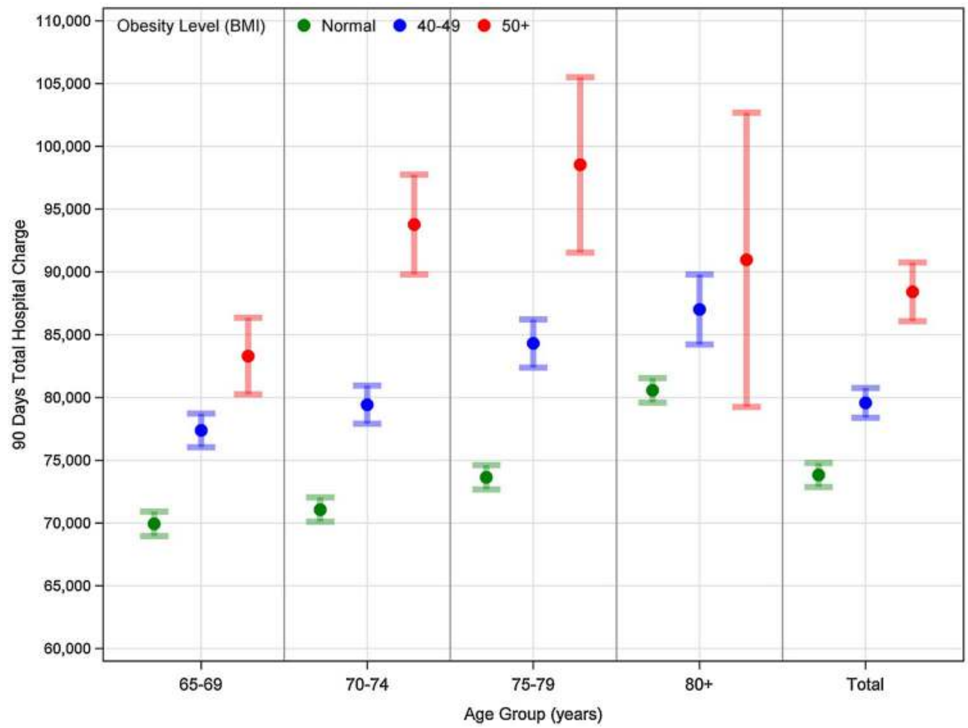

Fig. 3 The total hospital charges for patients with normal BMI, BMI of 40 to 49 kg/m^2, and BMI $\geq$ 50 kg/m^2 by age group (years) from the initial THA through 90 days postoperative are shown as average charges with 95% CI.

Table 5. Total average hospital charges and CMS payment

Variable	BMI level (kg/m^2)			Difference		
	Normal	40–49	50+	40–49 versus normal weight	50+ versus 40–49	50+ versus normal weight
Hospital charges by age group						
65–69	69,938 ± 619	77,372 ± 805	83,297 ± 1678	7434 ± 507	5925 ± 1639	13,359 ± 1570
70–74	71,069 ± 613	79,425 ± 897	93,769 ± 2149	8356 ± 645	14,344 ± 2149	22,700 ± 2045
75–79	73,640 ± 614	84,300 ± 1101	98,527 ± 3685	10,659 ± 918	14,228 ± 3727	24,887 ± 3624
80+	80,574 ± 619	87,012 ± 1537	90,966 ± 6099	6438 ± 1411	3954 ± 6229	10,391 ± 6069
All ages	73,827 ± 609	79,569 ± 725	88,419 ± 1313	5741 ± 361	8850 ± 1207	14,591 ± 1162
CMS payment by age group						
65–69	16,806 ± 101	18,539 ± 158	20,597 ± 397	1733 ± 124	2058 ± 404	3791 ± 387
70–74	17,221 ± 100	19,533 ± 185	22,586 ± 517	2312 ± 157	3053 ± 530	5365 ± 509
75–79	18,060 ± 100	20,555 ± 243	24,199 ± 890	2495 ± 224	3644 ± 911	6139 ± 884
80+	20,006 ± 101	21,374 ± 358	22,455 ± 1495	1367 ± 345	1082 ± 1531	2449 ± 1492
All ages	18,030 ± 99	19,303 ± 132	21,661 ± 302	1273 ± 87	2358 ± 297	3631 ± 286

CMS = Centers for Medicare & Medicaid Services.

We found that most complications were more common in patients with morbid obesity than in patients whose BMI was less than 40 kg/m^2. Surgically significant complications, including readmission, wound dehiscence, and prosthetic joint infection were markedly increased in the presence of super obesity. McCalden et al. [16] studied 3290 patients with the primary diagnosis of osteoarthritis at a minimum followup of 2 years. They concluded that morbid obesity does not affect the postoperative outcome after THA with the possible exception of a marginally increased rate of infection. This conclusion is distinctly different from our findings. We attribute this difference to the degree of obesity and the limited number of patients who were super obese. Some prior studies on obesity did not report super obesity as a separate category [1, 17], and were based on a limited population (41 and 1617 respectively) or defined morbid obesity as a BMI greater than 35 kg/m^2 [5, 18]. Michalka et al. [18] reported on operative time, blood loss, suboptimal implant placement, the surgeons' perception of operative difficulty, and the six- minute walk test. Davis et al. [6] studied dislocation, revision, duration of surgery, and deep and superficial infections. Both groups concluded total hip replacement "should not be withheld" or that "obese patients gain similar benefit". These subjective conclusions were offered despite the documented 4.42 times greater dislocation rate in the group with a BMI of 35 kg/m^2 or greater. Our data do not support a continuous increase in renal failure as previously reported [11–13]. Our data do correspond to that of Hanly et al. [10] who reported a 12.8%, 30-day readmission rate. Finally, to our knowledge there has not been a previous report of a 20% readmission rate for patients with super obesity undergoing a THA at 90 days, based on a large administrative database.

There is a large financial burden that corresponds to a 20% readmission rate and attending to the prosthetic infections, wound dehiscence, and component failures. A root-cause analysis in improving the complications we have identified may help minimize these readmissions.

Morbid obesity and super obesity should be considered along with other potentially modifiable risk factors, and should be optimized before elective arthroplasty. Overreliance on BMI may be simplistic, and we recommend consideration of age, percentage of lean body mass, serum markers of nutrition, and anthropomorphic measurements. Because we believe that it is not feasible or ethical to deny access to arthroplasty for these patients, we propose that institutions and providers providing care for this population should be compensated for the additional resources required. Use of improved coding systems, such as the ICD-10, might allow researchers, providers, and payers better information regarding the risks and costs of surgery in patients who are obese and super obese.

References

1. Amin AK, Clayton RA, Patton JT, Gaston M, Cook RE, Brenkel IJ. Total knee replacement in morbidly obese patients: results of a prospective, matched study. *J Bone Joint Surg Br.* 2006;88:1321–1326.
2. Arsoy D, Woodcock JA, Lewallen DG, Trousdale RT, Outcomes and complications following total hip arthroplasty in the super-obese patient, BMI > 50. J *Arthroplasty.* 2014;29:1899–1905.
3. Bolognesi MP, Marchant MH Jr, Viens NA, Cook C, Pietrobon R, Vail TP. The impact of diabetes on perioperative patient outcomes after total hip and total knee arthroplasty in the United States. *J Arthroplasty.* 2008;23:92–98.
4. Bourne R, Mukhi S, Zhu N, Keresteci M, Marin M. Role of obesity on the risk for total hip or knee arthroplasty. *Clin Orthop Relat Res.* 2007;465:185–188.
5. Cooper C, Inskip H, Croft P, Campbell L, Smith G, McLaren M, Coggon D. Individual risk factors for hip osteoarthritis: obesity, hip injury, and physical activity. *Am J Epidemiol.* 1998;147:516–522.
6. Davis AM, Wood AM, Keenan AC, Brenkel IJ, Ballantyne JA. Does body mass index affect clinical outcome post-operatively and at five years after primary unilateral total hip replacement performed for osteoarthritis? A multivariate analysis of prospective data. *J Bone Joint Surg Br.* 2011;93:1178–1182.
7. Deshmukh RG, Hayes JH, Pinder IM. Does body weight influence outcome after total knee arthroplasty? A 1-year analysis. *J Arthroplasty.* 2002;17:315–319.
8. Everhart JS, Altneu E, Calhoun JH. Medical comorbidities are independent preoperative risk factors for surgical infection after total joint arthroplasty. *Clin Orthop Relat Res.* 2013;471:3112–3119.
9. Flegal KM, Carroll MD, Kit BK, Ogden CL. Prevalence of obesity and trends in the distribution of body mass index among US adults, 1999–2010. *JAMA.* 2012;307:491–497.
10. Hanly RJ, Marvi SK, Whitehouse SL, Crawford RW. Morbid obesity in total hip arthroplasty: redefining outcomes for operative time, length of stay, and readmission. *J Arthroplasty*. 2016 Feb 17. [Epub ahead of print]
11. Jafari SM, Huang R, Joshi A, Parvizi J, Hozack WJ. Renal impairment following total joint arthroplasty: who is at risk? *J Arthroplasty.* 2010;25:49–53.
12. Kelz RR, Reinke CE, Zubizarreta JR, Wang M, Saynisch P, Even-Shoshan O, Reese PP, Fleisher LA, Silber JH. Acute kidney injury, renal function, and the elderly obese surgical patient: a matched case-control study. *Ann Surg.* 2013;258:359–363.
13. Kimmel LA, Wilson S, Janardan JD, Liew SM, Walker RG. Incidence of acute kidney injury following total joint arthroplasty: a retrospective review by RIFLE criteria. *Clin Kidney J.* 2014;7:546–551.
14. Lau EC, Son MS, Mossad D, Toossi N, Johanson NA, Gonzalez MH, Meller MM. The validity of administrative BMI data in total joint arthroplasty. *J Arthroplasty.* 2015;30:1683–1687.
15. Malinzak RA, Ritter MA, Berend ME, Meding JB, Olberding EM, Davis KE. Morbidly obese, diabetic, younger, and unilateral joint arthroplasty patients have elevated total joint arthroplasty infection rates. *J Arthroplasty.* 2009;24:84–88.
16. McCalden RW, Charron KD, MacDonald SJ, Bourne RB, Naudie DD. Does morbid obesity affect the outcome of total hip replacement? An analysis of 3290 THRs. *J Bone Joint Surg Br.* 2011;93:321–325.
17. McElroy MJ, Pivec R, Issa K, Harwin SF, Mont MA. The effects of obesity and morbid obesity on outcomes in TKA. *J Knee Surg.* 2013;26:83–88.
18. Michalka PK, Khan RJ, Scaddan MC, Haebich S, Chirodian N, Wimhurst JA. The influence of obesity on early outcomes in primary hip arthroplasty. *J Arthroplasty.* 2012;27:391–396.
19. Mokdad AH, Ford ES, Bowman BA, Dietz WH, Vinicor F, Bales VS, Marks JS. Prevalence of obesity, diabetes, and obesity-related health risk factors, 2001. *JAMA.* 2003;289:76–79.
20. Moran M, Walmsley P, Gray A, Brenkel IJ. Does body mass index affect the early outcome of primary total hip arthroplasty? *J Arthroplasty.* 2005;20:866–869.
21. Napier RJ, O'Brien S, Bennett D, Doran E, Sykes A, Murray J, Beverland DE. Intra-operative and short term outcome of total knee arthroplasty in morbidly obese patients. *Knee.* 2014;21:784–788.
22. Oliveria SA, Felson DT, Cirillo PA, Reed JI, Walker AM. Body weight, body mass index, and incident symptomatic osteoarthritis of the hand, hip and knee. *Epidemiology.* 1999;10:161–166.
23. Rajgopal R, Martin R, Howard JL, Somerville L, MacDonald SJ, Bourne R. Outcomes and complications of total hip replacement in super-obese patients. *Bone Joint J.* 2013;95:758–763.

24. Sadr Azodi O, Adami J, Lindstrom D, Eriksson KO, Wladis A, Bellocco R. High body mass index is associated with increased risk of implant dislocation following primary total hip replacement: 2,106 patients followed for up to 8 years. *Acta Orthop.* 2008;79:141–147.
25. Schwarzkopf R, Thompson SL, Adwar SJ, Liublinska V, Slover JD. Postoperative complication rates in the 'super-obese' hip and knee arthroplasty population. *J Arthroplasty.* 2012;27:397–401.
26. Sturm R. Increases in morbid obesity in the USA: 2000-2005. *Public Health.* 2007;121:492–496.
27. Sturm R, Hattori A, Morbid obesity rates continue to rise rapidly in the United States. *Int J Obes (Lond).* 2013;37:889–891.
28. Suleiman LI, Ortega G, Ong'uti SK, Gonzalez DO, Tran DD, Onyike A, Turner PL, Fullum TM. Does BMI affect perioperative complications following total knee and hip arthroplasty. *J Surg Res.* 2012;174:7–11
29. Wang Y, Beydoun MA. The obesity epidemic in the United States–gender, age, socioeconomic, racial/ethnic, and geographic characteristics: a systematic review and meta-regression analysis. *Epidemiol Rev.* 2007;29:6–28.