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ORIGINAL PAPER

Does the body mass index influence the long-term survival of unicompartmental knee prostheses? A retrospective multi-centre study

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Abstract

Purpose The effect of being obese on the long-term survival of total joint arthroplasty is persistently discussed. Considering only studies with large cohort of patients and meta-analysis, a high body mass index has been correlated with a higher incidence of complication but not univocally with a lower survival rate. In this study, we analyzed, retrospectively, the data of patients that received unicompartmental knee prostheses in order to examine if obesity has an effect on clinical outcomes.

Methods A retrospective multi-centre study was carried out on 4964 unicompartmental knee replacements between July 2000 and December 2016, the patients involved were 3976, with 988 bilateral cases. The patients were categorized into three groups: non-obese with a body mass index (BMI) < 30 kg/m^2, obese with BMI ranged between 30 and 39 kg/m^2, and morbidly obese (BMI ≥ 40 kg/m^2). The outcome was measured using the Cox proportional hazards model with end point UKA revision for any reasons. Results were stratified for sex, age, weight, and bi-laterality.

Results The morbidly obese group was significantly younger and required a significantly longer operating time. No statistical significant differences were observed considering the BMI groups in terms of type of insert, type of tibial component, prosthetic condyle, and prosthesis fixation ($p > 0.05$; chi-square test).

Conclusions Obese and morbidly obese patients have as much to gain from total knee replacement as non-obese patients.

Keywords UKA · Outcomes · Body mass index · Body weight · Obesity · Morbidly obese · Normal

Introduction

A total knee arthroplasty (TKA) is a surgical procedure in which the original knee is replaced with a metallic femoral component, a plastic tibial, and patellar components, all fixed to the bone with the aim to re-establish the joint function and alleviate pain [1]. TKA is indicated when the knee joint is severely damaged by osteoarthritis, rheumatoid arthritis, and other diseases. However, it may happen that only one compartment can be damaged; in this case, the current trend towards less invasive operation for the patient using the unicompartmental knee prostheses. The unicompartmental knee arthroplasty (UKA) represents a new and alternative approach to the TKA for those patients with a localized tibio-femoral non-inflammatory disease (localized osteoarthritis) [2]. UKA consists in the replacement of only the medial or lateral compartment and it is a minimal invasive surgical operation [3]. The surgery of UKA could not only solve the arthropathy in the medial or lateral compartment but also preserve the cruciate ligament and bone [3]. Although the use of unicompartmental knee prosthesis in the treatment of end-stage osteoarthritis is controversial, Wang et al. [4] observed that mortality and major complications were lower after UKA than after TKA. UKA systems have been shown to perform comparably to total knee replacements [5].

However, whether or not you use a total or unicompartmental knee prostheses, these implants are often destined to fail not only for wear, dislocations, aseptic loosening, etc. but also for damage due to the patient's obesity. Obesity is known as the major contributing risk factor for knee osteoarthritis [6]. Clinical evidence of obesity can be dated as far back as Greco-Roman times [7]; little scientific progress was made towards under-standing the condition until the twentieth century. The incidence of obesity

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has increased in recent decades and it has been widely reported in scientific journals and more widely in the media as an epidemic problem, which affects worldwide patients [8, 9]. According to the directions of the Lancet commission, obesity is "an emergent problem of underlying complex adaptive systems, such as food systems, urban systems, and economic systems, that are fundamentally designed to improve people's lives" [10]. Several studies have assessed the role of obesity on the timing of arthroplasty [11]. In the 2011, Losina and colleagues [12] estimated the impact of obesity on various associated medical conditions. Their analysis demonstrated that reducing obesity to the levels of ten years earlier could prevent 111,206 knee replacements.

In the half of the late 1800, Adolphe Quetelet, a Belgian astronomer, mathematician, statistician, and sociologist, during its studies on anthropometric data of human growth, concluded that the "weight of a person grows with the square of its height" [13, 14]. Currently, the modern term "body mass index" (BMI) is commonly used to classify underweight, overweight, and obesity in adults. It is defined as the weight in kilograms divided by the square of the height in meters (kg/m^2) [7, 15, 16]. The International Classification [7, 17] defines normal people (non-obese) those with BMI between 18 e 24.9 kg/m^2, obesity with BMI ≥ 30 kg/m^2, and morbid obesity with BMI ≥ 40 kg/ m^2. Even if the links between overweight and obesity and a range of other serious diseases (diabetes, heart disease, cancer, etc.) are clearly understood, more recently epidemiological studies have shown a strong association between increased BMI and the risk of developing osteoarthritis in hip and knee joint at an earlier age [18–20]. It is believed that obese UKA patients tend to have poorer outcome and possible early failure; Woo et al. [6] found that obesity did not guarantee a poorer early outcome for UKA patients, even if obese patients had a poorer preoperative knee score. Conversely, Kerkhoffs et al. [21] found that obesity had a negative influence on outcome after total knee arthroplasty. With this in mind, our study is aimed with the hypothesis that weight affects the long-term rate of survival of UKAs. In particular:

- At evaluating if the obesity could influence the survival rate/outcome of UKP considered in a multi-centre
- At addressing if the obesity influences the laterality of the previous UKA
- At investigating whether the results differed between obese women and men and their relative age

Table 2 Average BMI for gender and for age

		Non-obese		Obese		Morbidly obese	
Females	Age [years]	*N.*	[%]	*N.*	[%]	*N.*	[%]
	< 60	338	15.6	263	23.0	30	48.4
	60–69	804	37.0	482	42.1	22	35.5
	≥ 70	1029	47.4	399	34.9	10	16.1
Males	< 60	216	20.0	112	22.8	6	37.5
	60–69	442	41.0	241	49.0	9	56.2
	≥ 70	421	39.0	139	28.2	1	6.2

Methods

Study design

We retrospectively analyzed data of 4964 patients, who underwent a UKA for primary arthritis between July 2000 and December 2016. Patients were divided into three groups: non-obese with a BMI < 30 kg/m^2, obese with BMI ranged between 30 and 39 kg/m^2, and morbidly obese (BMI ≥ 40 kg/m^2). More details about the characteristics of the patients are given in Table 1.

Table 1 Demographics for patients considered in this study

	Non-obese	Obese	Morbidly obese
Mean age in years (range)	67.8 (24–90)	65.7 (28–89)	61.2 (47–79)
Patients bi-laterality (%)	17.5	24.5	21.8
Male (%)	33.2	30.1	20.5
Indication for UKA			
Primary arthritis (%)	82.8	87.9	87.2
Deformity (%)	7.1	5.8	3.85
Necrosis of the condyle (%)	6.3	3.5	5.1
Other (%)	3.8	2.8	3.85
Age at UKA (%)			
< 60	17.0	22.9	46.2
60–69	38.3	44.2	39.7
≥ 70	44.6	32.9	14.1

Table 3 Laterality of the condyle of the UKA considered

	Non-obese	Obese	Morbidly obese
Prosthesis fixation			
Cemented (%)	93.9	91.3	89.7
Prosthetic condyle			
Lateral (%)	21.8	28.7	26.6
Type of tibial component			
All poly (%)	26.2	26.0	26.9
Metal back (%)	73.8	74.0	73.1
Type of insert			
Mobile (%)	18.3	15.0	19.2

The same population was then divided in two other groups based on the sex and then taken into account of the age of the population and dividing the population for the laterality of the condyle of UKA and considering the fixation of the condyle (Tables 2 and 3).

Data sources

We used available sources deriving from the regional Register of the Orthopaedic Prosthetic Implants (RIPO) [22–24]. RIPO collect all surgery and it is the arthroplasty registry of Emilia-Romagna (region located in northen-Italy), involving more than 4,450,000 inhabitants. It actively collects primary and revision hip, knee, and shoulder arthroplasty procedures since January 2000. The database includes the clinical conditions of patients, the features of surgical procedures, and the type (batch and code) and fixation of implants, similar to the most important national registries. It involves 68 orthopaedic units in Emilia-Romagna. To avoid the bias due to the lack of follow-up data, the analyses were limited to patients living in Emilia-Romagna region. In fact, procedures on residing patients are systematically captured by the registry, as every hospital admission is always billed back to the Emilia-Romagna region itself, even if the patient is treated outside the region; thus, the data are sure. Moreover, were excluded from these analyses all patients which data to calculate BMI were missing. The protocol was not submitted for ethical approval due to its retrospective and analytical nature.

Statistical analysis

For the three cohorts considered, subject demographics were presented as a percentage of the total cohort. Patient ages were compared using a *t* test, while gender, indication for surgery, and type of UKA were compared using chi-square analysis. Differences between BMI categories were considered statistically significant if the *p* values were less than 0.05.

Survivorship analysis was performed using the Kaplan-Meier analysis considering revision of any component as the endpoint and survival times of unrevised UKAs taken as the last date of observation (December 31, 2016 or date of death). Revision for any cause was the outcomes measured. The identification of the cause of failure was up to the surgeon who performed the revision. All data came from the registry. The log-rank test was used to compare survivorship between the BMI categories. The Cox multiple regression models for analyzing survival data were considered. The proportionality hazards risk (HR) assumption was tested by the Schoenfeld residual method; age, gender, bi-laterality, and BMI category used for adjustment fulfilled the proportional hazard assumption for the all period. The Wald test was used to calculate the *p* values for data obtained from the Cox multiple regression analyses.

Statistical analyses were performed using SPSS 14.0 for Windows, version 14.0.1 (SPSS Inc., Chicago, IL) and JMP, version 12.0.1 (SAS Institute Inc., Cary, NC, 1989–2007).

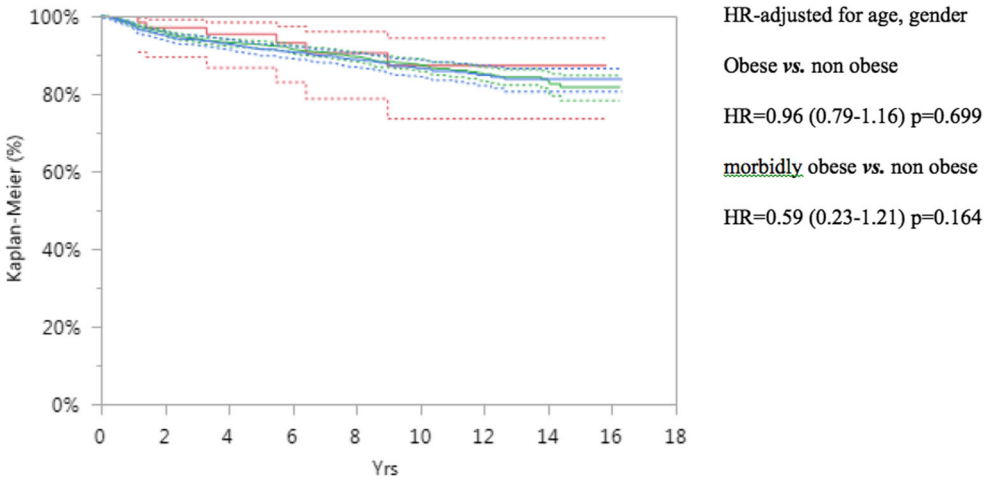

Fig. 1 Kaplan-Meier survival curves. Survivorship estimates for the BMI category are shown with their associated 95% confidence intervals: morbidly obese is represented by the red line, obese by the blue line, and non-obese by the green line. Hazard ratio (HR) is also given in the picture

Table 4 Survivorship estimates and numbers at risk for the BMI category

% survival (confidence interval 95%)				
	3 years	5 years	7 years	10 years
Non-obese	94.3 (93.3–95.1)	92.6 (91.6–93.6)	90.7 (89.5–91.8)	87.4 (85.8–88.8)
Numbers at risk	2361	1928	1453	759
Obese	93.9 (92.5–95.0)	91.4 (89.8–92.8)	89.8 (88.0–91.3)	86.7 (84.4–88.7)
Numbers at risk	1186	955	737	381
Morbidly obese	97.2 (89.6–99.3)	95.5 (87.0–98.6)	90.7 (79.0–96.2)	87.5 (73.8–94.6)
Numbers at risk	58	45	34	18

Results

We accessed and used 4964 unicompartmental knee replacements population-based data sources, aged between 24 and 90 years. In BMI groups was observed a difference in age, the obese group had a mean age at surgery higher than non-obese ($p = 0.001$, t test). The obese patients were more frequently female and with a bilateral UKA ($p < 0.05$; chi-square test). The mean weight was 73.5 kg (ranged between 40 and 135 kg) and 84.4 (ranged between 54 and 140 kg) for the female and male, respectively ($p < 0.05$; t test).

No statistical significant differences were observed considering the BMI groups in terms of type of insert, type of tibial component, prosthetic condyle, and prosthesis fixation ($p > 0.05$; chi-square test). The final follow-up was 6.5 (range 0.0–16.3); no statistical significant differences were observed through the three BMI groups ($p > 0.05$; t test).

Kaplan-Meier survival curves of the categorization of the patients considered in this study (non-obese, obese, and morbidly obese) are shown in Fig. 1.

The survival details with number at risk are given in Table 4. Revision for any cause was set as the endpoint. The causes for revision are detailed in Table 5.

The difference between the survival curves was also found with no significant statistical difference at 87.4% survival at ten years for non-obese vs. 86.7% obese vs. 87.5 for morbidly obese ($p = 0.37$, Wilcoxon test). Outcome not significantly affected by BMI or Body weight and with increasing age of the patient decreases the risk of revision surgery. Concerning age at surgery, the patients of the group less than 60 years had a higher risk of failure of 1.7 (1.4–2.0) than patients of the group more than 60 years compared to the others variables when equal.

Table 5 Reason for revision for the BMI categories

Reason for revision	Non-obese Rate	Obese Rate	Morbidly obese Rate
Total aseptic loosening	121/3250	55/1636	2/78
Pain without loosening	53/3250	41/1636	1/78
Tibial aseptic loosening	35/3250	27/1636	1/78
Septic loosening	17/3250	12/1636	–
Femoral aseptic loosening	16/3250	1/1636	–
Insert wear	12/3250	1/1636	–
Breakage of prosthesis	7/3250	3/1636	–
Dislocation	4/3250	5/1636	1/78

Discussion and conclusions

The increasing of obesity represents an important worldwide public health issue. Obesity has reached epidemic proportions globally, with more than 1.9 billion adults were overweight in 2014 according to World Health Organization and at least 600 million of them are clinically obese [4]. Economic consequences of obesity are not well understood. This has led to considerable interest in the economic consequences of obesity and assessment of its costs may be useful in providing recommendations for policy and decision makers [25–27].

The number of patients presenting for UKA who are obese is increasing and there have been concerns that these patients have an increased risk of complications and a reduced benefit of surgery in terms of function and pain relief. This study wanted to address whether weight affects the long-term rate of survival of UKRs. We examined the relationship between BMI, sex, age, and laterality based on a retrospective cohort of 4964 patients aged between 20 and 90 years over a follow-up of 16 years. The results demonstrated that when BMI was chosen as a parameter of differentiation, the 16-year survival analysis of the different groups (obese vs. non-obese vs. morbidly obese) was not statistically different. Concerning age at surgery, the patients of the group less than 60 years had a higher risk of failure of 1.7 (1.4–2.0) than patients of the group more than 60 years compared to the other variables when equal.

The effect of obesity may be gender-specific; Lübbeke et al. [28], on a total of 817 patients that received a total hip prosthesis, after a five year clinical follow-up, found that the obese women had an increased rate of complication from

infection and dislocation, whereas obesity appeared to have no effect in men. Wilson and co-workers [29] analyzing 839 primary TKA found that that obese TKA patients are at increased odds of superficial and deep SSI compared to other BMI cohorts. Interestingly, male obese patients demonstrated a higher rate of deep infection compared to their female counterparts. Conversely, Cavaignac and collaborators [30] on a retrospective study of 212 UKAs at a mean follow-up of 12 years confirms that weight does not influence the long-term rate of survival of UKR. They applied a multimodal regression analysis and found that weight plays a part in reducing the risk of revision with a relative risk of 0.387, although this did not reach statistical significance ($p = 0.662$). Plate and co-workers [31] suggest that BMI does not influence clinical outcomes and readmission rates of robotic-assisted UKA at mid-term. Zengerink et al. [32] reviewed retrospectively 147 medial UKA and found, after two years of follow-up, that the survival of these prostheses is not influenced by obesity. In agreement, Murray et al. [33] in a prospective study analyzed 2438 medial Oxford UKAs and found that increasing BMI was not associated with an increasing failure rate.

To the best of the author's knowledge, this is the first study analyzing sex differences and laterality as related to outcomes in obese UKA patients on a high number of patients. However, this study has a number of limitations. First, we analyzed all UKA prostheses without to take into account of the size and/or the prosthetic design. The second limit of this study is the complete absence of a clinical evaluation of the patients i.e. evaluation of their level of activity.

Our study revealed that obesity does not influence the survival outcome of UKA. From Table 3, it is possible to emphasize that the obese patients received a lateral UKA more than the non-obese patients. From Table 5, it is possible to emphasize that wear of the insert was found not influent between non-obese and obese patients. BMI did not increase in infection, dislocation, and subsequent revision surgery for septic loosening. Vice versa, it was found that the non-obese patients showed a high percentage, with respect to the obese patients, of increase in infection and dislocation (Table 5). In conclusion, we found that the BMI does not increase the risk of UKA failure or revision. However, it was stressed that we do not know the level activity of the patients and so we cannot say if the obese patient walked or not nor performed other living activities. Further studies are necessary in order to acquire details about level activity and also to compare the unicompartmental knee prostheses with the total knee prostheses in order to reduce the risk of developing osteoarthritis. At the state of the art, interventions and policies worldwide have not been able to stop the rise in BMI in most countries [34]. Surely, patients should be encouraged to reduce their weight prior of UKA intervention. Obviously, it seems unacceptable to deny patients the benefit of unicompartmental knee treatment solely on the basis of their BMI and perceived diminished clinical benefit. Our study emphasizes that young obese patients can receive a unicompartmental knee prosthesis without running more risks.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The protocol was not submitted for ethical approval due to its retrospective and analytical nature.

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