International Orthopaedics (SICOT) (2001) 25:246–249
DOI 10.1007/s002640100255

ORIGINAL PAPER

D.D.M. Spicer · D.L. Pomeroy · W.E. Badenhausen Jr L.A. Schaper · J.I. Curry · K.E. Suthers M.W. Smith

Body mass index as a predictor of outcome in total knee replacement

Accepted: 6 March 2001 / Published online: 27 June 2001

Abstract The clinical and radiographic outcomes of 326 total knee replacements (TKR) in 285 osteoarthritic patients with body mass index (BMI) greater than 30 kg/m^2 were compared with the results of a matched group of 425 TKR in 371 patients with BMI less than 30 kg/m^2. At an average follow-up of 75.9 (48–144) months the Knee Society score (KSS) in the obese patients had increased by 41.9 points, and the joint score by 43.7. In the non-obese group the KSS rose by 40.2 points and the joint score by 42.6 points. Although patients with BMI greater than 40 kg/m^2 achieved a lower final KSS the 'absolute improvement' appeared to be independent of BMI. Of the obese patient group 4.9% underwent a revision of their TKR, compared with 3.1% of the non-obese group. Although linear osteolysis (radiolucency) rates were comparable, focal osteolysis rates were 5 times those of control subjects when the BMI exceeded 40 kg/m^2. Ten-year survivorship figures were similar for both obese and non-obese patients.

Résumé Les résultats cliniques et radiographiques de 326 prothèses totales du genou (PTG) chez 285 patients arthrosiques avec un Index de Masse corporelle (BMI) >30 kg/m2 ont été comparés avec les résultats d'un groupe apparié de 425 PTG chez 371 patients avec une BMI <30 kg/m2. À un suivi moyen de 75.9 (48 –144) mois le score de la "Knee Society" (KSS) chez les malades obèses avait augmenté de 41.9 points, et le score articulaire de 43.7. Dans le groupe non – obèse le KSS a augmenté de 40.2 points et le score articulaire de 42.6 points. Bien que les patients avec une BMI> 40 kg/m2 aient atteint un score définitif inférieur, l'amélioration a paru indépendante de la BMI. 4.9% de patients obèses avaient une révision de leur PTG, comparée avec 3.1% du groupe non – obèse. Bien que le taux d'ostéolyse linéaire (liseré) était comparable, l'ostéolyse focale était 5 fois plus importante quand la BMI a dépassé 40 kg/m2. Les chiffres de survie après 10 ans étaient semblables pour les patients obèses et non – obèses.

D.D.M. Spicer (✉)
Orthopaedic Department, St Mary's Hospital,
Praed St, London W2 1NY, UK
e-mail: DDMSpicer@AOL.COM
Tel.: +44-207-7366592

D.L. Pomeroy · W.E. Badenhausen · J.L.A. Schaper · J.I. Curry
K.E. Suthers · M.W. Smith
The Louisville Institute for Joint Replacement &
The Arthroplasty Foundation, 234 E Gray St,
#332, Louisville, Kentucky, USA

D.D.M. Spicer
1 Alderville Road, Parsons Green, Fulham,
London SW6 3RL, UK

Introduction

Morbidity and mortality associated with obesity has been well documented in many branches of medicine. There have been several recent studies in the orthopaedic literature examining the link between joint replacement, obesity and operative morbidity. However, the findings of theses studies are at best, inconclusive [11, 17, 18] with no consensus regarding the effect of obesity on postoperative function and implant survival [3, 9, 12, 16, 17, 18, 20]. Differing activity levels of the subjects may be a significant contributory factor [8].

The aim of the present study was to assess the effect of body mass index (BMI) [2] as a predictor of outcome and survival in total knee replacement (TKR).

Materials and methods

Body mass index (BMI) is defined as body weight (in kg) divided by the square of the height (in metres) (i.e., BMI=kg/m^2) [2]. BMI correlates well with the amount of body fat. Measurements over 30 kg/m^2 correlate with 'moderate obesity'; over 40 kg/m^2 with 'severe' (morbid) obesity; whereas scores less than 30 kg/m^2 are classed as non-obese.

The outcome for all patients with a BMI greater than 30 kg/m^2, undergoing primary TKR (408 patients in total), between January 1986 and December 1996, was assessed and compared with a control group of 371 non-obese patients, matched for age, sex, preoperative diagnosis and deformity, who were undergoing the same

procedure within the same time frame. Patients whose body mass changed over the study period were eliminated. One hundred and twenty-three obese patients were lost to follow-up, leaving 285 patients (326 TKR) in the obese group (group A), and 371 patients (425 TKR) in the non-obese, control group (group B). Group A was subcategorized (A1=BMI 30–34.9 kg/m^2 [177 TKR]: A2=BMI 35–39.9 kg/m^2 [90 TKR]: A3=BMI greater than 40 kg/m^2 [59 TKR]).

Outcome for group A was assessed at an average follow-up of 75.9 (48–144) months and 73.7 (48–144) months for group B. PFC (Johnson & Johnson, Raynham, Mass., USA), posterior cruciate retaining TKR with patellofemoral resurfacing were used in each case. All patients had a preoperative diagnosis of either osteoarthritis or post-traumatic arthritis. Sixty-two percent of group A and 58.5% of group B were female. Average ages were: A1: 66.6 (35–83) years, A2: 64.5 (36–82) years, A3: 62.7 (41–78) years, B: 69.7 (35–83) years.

The method of implant fixation utilized in each group is recorded in Table 2. Pre- and postoperative Knee Society, joint and function scores [6], and the presence, absence or progression of periprosthetic radiolucencies were recorded for each group. The Knee Society's radiographic scoring system was used to determine component alignment, positioning and the zonal distribution of radiolucencies when present. Polyethylene wear was assessed by measurement of polyethylene thickness on weight-bearing films.

Statistical analysis to compare preoperative and latest follow-up joint-, function- and Knee Society scores was performed by using the Wilcoxon Rank sum and the Kruskal-Wallis tests.

Revision rates and osteolysis rates between the various groups were compared using Fisher's exact probability test.

Results

The pre- and postoperative Knee Society (KSS), joint and function scores for each of the groups are shown in Table 1.

Preoperative KSS among obese patients were lower than their non-obese counterparts (resulting from correspondingly lower function scores in the obese groups A2 and A3 (group A1 P=0.19: A2 P=0.002: A3 P=0.003). However, preoperative joint scores were comparable). At the most recent follow-up, no statistical difference was noted in either the KSS or function scores of groups A1, A2 or A3 compared to control subjects. Similarly, there was no statistical difference in the 'absolute improvement' in scores.

Sixteen revisions (4.9%) were performed in group A and 13 revisions (3.1%) in control group B. This difference was not statistically significant (P=0.25).

Six of 425 TKR in group B were revised for osteolysis and an additional 5 unrevised knees (1.2%) exhibited radiographic evidence of focal osteolysis at most recent follow-up. This contrasted with a revision rate for osteolysis of 5 of 326 TKR in the obese group, and radiographically identifiable lytic lesions in 13 of the remaining TKR (3.9%). This radiographic rate was statistically higher than that found in the non-obese group (P=0.016).

The incidence of focal osteolysis became greater as the BMI increased, with four unrevised TKR patients with a BMI greater than 40 kg/m^2 (6.8%) having at least one focal lesion at latest follow-up (Table 3).

Three TKR in group B and four in group A were revised for wear-related problems affecting the tibial polyethylene insert. Although not noted in the obese patients, an additional 1.2% of group B had radiographic evidence of tibial component wear as judged by polyethylene thickness on standard weight-bearing radiographs (statistically insignificant). Three knees were revised for problems related to polyethylene wear in porous-coated metal-backed patellae – two in group A and one in group B. Two TKR in the obese patient group were revised for late, hematogenous infections, at 81 and 109 months (*Staphylococcus epidermidis* was isolated in both cases).

Linear periprosthetic radiolucencies were infrequently seen, all less than 2 mm and never progressive (Table 2).

By using revision of any component as an endpoint, survivorship analysis at an average follow-up of 6 years, showed statistically similar survival rates for both groups (group A 98.1%, group B 99.9%). This similarity was maintained until the tenth year (group A 97.2%, group B 95.5%) postoperatively.

Table 1 Mean pre- and postoperative joint-, function- and Knee Society scores for each patient group (including improvement)

Preoperative	Patient groups			
Group	A1	A2	A3	B
Knee Society score	31.1	33.0	32.8	39.3
Function score	26.5	21.7	20.3	30.1
Joint score	45.3	43.8	44.8	47.9
Postoperative				
Knee Society score	77.2	77.9	72.9	79.5
Function score	64.9	65.8	59.8	67.9
Joint score	88.9	89.4	85.5	90.5
Mean 'absolute' improvement				
Knee Society score	41.1	44.9	40.1	40.2
Function score	38.4	44.1	39.5	37.8
Joint score	43.6	45.6	40.7	42.6

Group A, obese group; subcategorised (A1=BMI 30–34.9 kg/m^2: A2=BMI 35–39.9 kg/m^2: A3=BMI greater than 40 kg/m^2). Group B non-obese, control group

Table 2 The incidence of periprosthetic radiolucencies in relation to BMI and the method of component fixation

Group	A1	A2	A3	B
Cemented femur	1/86	0/35	1/25	6/230
Non-cemented femur	0/91	2/55	0/34	5/195
Cemented tibia	5/101	1/54	2/33	11/267
"Hybrid" cemented tibia	0/61	5/31	0/23	11/139
Non-cemented tibia	0/15	1/5	0/3	4/19

Group A, obese group; subcategorised (A1=BMI 30–34.9 kg/m^2: A2=BMI 35–39.9 kg/m^2: A3=BMI greater than 40 kg/m^2).Group B non-obese, control group

Discussion

Several reports have reviewed the link between obesity and outcome following joint replacement. Following to-

tal hip replacement some studies have reported a positive correlation with regard to risk for perioperative complications [19], whereas others have reported no [1, 11, 17] or even negative correlations [7, 15]. Similarly, studies documenting the effect on both postoperative function scores and implant longevity also differ in their conclusions [4, 17, 21].

Increased body weight would, intuitively, be expected to lead to a poorer outcome after joint replacement as a result of the greater biomechanical forces generated. However, differentiation between weight and obesity is important, as one is an absolute measure and the other a relative one. Whereas body weight may be predictive of increased failure, BMI may not [14]. This differentiation has not always been clearly made in the literature [21].

Although weight (or obesity) has often been advocated as an adverse factor in the success of total knee arthroplasties, few reports have addressed this issue specifically [3, 9, 12, 13, 16, 18, 20]. Those that have, differ in their conclusions regarding the effect on the outcome. It is known that high BMI increases stress at the cement-bone interface thereby potentially leading to mechanical loosening [10]. Retrieval analyses of TKR components have demonstrated a significant positive correlation between wear damage seen on the components and patient weight [5]. Ranawat and Boachie-Adjei found that the incidence of radiolucencies at the tibial – bone cement interface was positively correlated with patient weight [13]. Although the association between obesity and the incidence of radiolucent lines has been noted in several studies [3, 16] this has not been an invariable finding in all studies [9].

Stern and Insall, in a study of 257 cemented TKR found no correlation with obesity and loosening rates; however, they did note that 30% of the moderately and severely obese patients had patellofemoral symptoms (in comparison to 14% in the other groups [18]). Griffin et al. later confirmed this finding of pooled patellar scores in a 10-year report published in 1998 [3]. Although minor non-progressive radiolucent lines were seen more commonly, overall, 10-year Hospital for Special Surgery scores and KSS for patients who were obese (average BMI 35 (30.4–51.8) kg/m^2) were comparable with scores for patients who were non-obese (average BMI 25.4 (19–29.5) kg/m^2). Additionally, revision rate differences were unremarkable. In 1992, Smith et al. [16] found that the presence and severity of radiolucencies, and isokinetic joint strength were found to have a statistically significant correlation with patient weight in their evaluation of 109 TKR patients. The Hospital for Special Surgery score was found to have a negative correlation with weight for patients weighing less than 80 kg, and it was found to have negative correlations with the percentage by which patients were heavier than their ideal weights. However, they noted that sex appeared to be a much more influential factor.

A medium term study of 50 uncemented TKR in obese patients (BMI>40 kg/m^2) compared with 50 matched, non-obese control subjects also reached the conclusion that there was no significant difference in clinical results at an average 7-year follow-up. Radiographic results were comparable in both groups [9].

In contrast, Pritchett et al., defining obesity as over 180% of ideal body weight came to different conclusions. In a group of matched TKR they found that at a mean follow-up of 33 months, results in the morbidly obese group were poorer than those for the control knees. No comment was made regarding radiological outcome in this report [12].

A study reported by Winiarsky et al. in 1998 found that, at an average of 5 years postoperatively, there was a significant difference between morbidly obese patients (mean BMI>44 kg/m^2) and a control group with regard to the knee and functional scores. No significant difference between the groups was detected with regard to radiographic scores [20]. That poorer KS scores are associated with obesity is substantiated by the findings in the present study – but appear to relate to the fact that preoperative scores in these groups are lower. This is most notable when the BMI exceeds 40 kg/m^2.

In contrast to Griffin's study [3], at an average follow-up of just over 6 years, revision rates in obese patients exceeded those in patients with a normal BMI – but this rate failed to reach statistical significance. Survivorship analysis revealed that survivorship rates were statistically similar at 6.2 years and that this similarity was maintained up to the tenth year.

Although there was no significant difference in the incidence of non-progressive radiolucencies, osteolysis rates were higher in patients with higher BMIs (Table 3). However, the absolute numbers were small. Further follow-up is necessary to ascertain whether these osteolytic lesions progress.

A suggested reason for the disparity between previously reported results may lie in the fact that in many studies, one of the main non-matched variables is activity level. McClung et al. recently evaluated the relationship between BMI and activity level in hip and knee arthroplasty patients [8]. They showed that a higher BMI was associated with lower activity level. This might be expected to produce a reduction in the amount of polyethylene wear, as wear is a manifestation of use, not time. The lack of correlation between results and activity level is a recognized shortcoming in the paper.

The present study, reporting the clinical and radiological outcome of obese osteoarthritic patients undergoing

Table 3 Number of cases with revision and cases with radiographic polyethylene wear and radiographic focal osteolysis

Group	A1	A2	A3	B
Revision	7	6	3	13
Radiographic polyethylene wear	0	0	0	5
Radiographic osteolysis	5	4	4	5

Group A, obese group; subcategorised (A1=BMI 30–34.9 kg/m^2: A2=BMI 35–39.9 kg/m^2: A3=BMI greater than 40 kg/m^2).Group B non-obese, control group

posterior cruciate retaining TKR, shows that revision and survivorship rates over the first decade are comparable to non-obese controls.

References

1. Anderson L, Kammerer WS, Greer RB III (1979) Risk factor assessment in 101 total hip arthroplasties: A medical perspective. Clin Orthop 141:50–54
2. Bray GA (1987) Overweight is risking fate. Definition, classification, prevalence, and risks. Ann NY Acad Sci 9:14–29
3. Griffin FM, Scuderi GR, Insall JN, Colizza W (1998) Total knee arthroplasty in patients who were obese with 10 years follow-up. Clin Orthop 356:28–33
4. Hierton C, Blomgren G, Lindgren U (1983) Factors leading to rearthroplasty in a material with radiographically loose total hip prostheses. Acta Orthop Scand 54:562–565
5. Hood RW, Wright TM, Burstein AH (1983) Retrieval analysis of total knee prostheses: A method and its application to forty-eight total condylar prostheses. J Biomed Mater Res 17:829–836
6. Insall JN, Dorr LD, Scott RD, Scott WN (1989) Rationale of the knee society clinical rating system. Clin Orthop 248:13–14
7. Jiganti JJ, Goldstein WM, Williams CS (1993) A comparison of the perioperative morbidity in total joint arthroplasty in the obese and nonobese patient. Clin Orthop 289:175–179
8. McClung, Zahiri CA, Higa JK, Amstutz HC, Schmalzried TP (2000) Relationship between body mass index and activity in hip and knee arthroplasty patients. J Orthop Res 18:35–39
9. Mont MA, Mathur SK, Krackow KA, Loewy JW, Hungerford DS (1996) Cementless total knee arthroplasty in obese patients. A comparison with a matched control group. J Arthroplasty 11:153–156
10. Morrison JB (1970) The mechanics of the knee joint in relation to normal walking. J Biomech 3:51–61
11. Perka C, Labs K, Muschik M, Buttgereit F (2000) The influence of obesity on perioperative morbidity and mortality in revision total hip arthroplasty. Arch Orthop Trauma Surg 120: 267–271
12. Pritchett JW, Bortel DT (1991) Knee replacement in morbidly obese women. Surg Gynecol Obstet 173:119–122
13. Ranawat CS, Boachie-Adjei O (1988) Survivorship analysis and results of total condylar knee arthroplasty. Clin Orthop 226:6–13
14. Schurman DJ, Bloch DA, Segal MR, Tanner CM (1989) Conventional cemented total hip arthroplasty: assessment of clinical factors associated with revision for mechanical failure. Clin Orthop 240:173–180
15. Sikorski BE, Hampson WG, Staddon GE (1981) The natural history and aetiology of deep vein thrombosis after total hip replacement. J Bone Joint Surg [Br] 63:171–177
16. Smith BE, Askew MJ, Gradisar IA, Gradisar JS, Lew MM (1992) The effects of patient weight on the functional outcome of total knee arthroplasty. Clin Orthop 276:237–244
17. Søballe K, Christensen G, Luxhøj T (1987) Hip replacement in obese patients. Acta Orthop Scand 58:223–225
18. Stern SH, Insall JN (1990) Total knee arthroplasty in obese patients. J Bone Joint Surg [Am] 72:1400–1404
19. Surin VV, Sundholm K (1983) Survival of patients and prostheses after total hip arthroplasty. Clin Orthop 177:148–153
20. Winiarsky R, Barth P, Lotke P (1998) Total knee arthroplasty in morbidly obese patients. J Bone Joint Surg [Am] 80:1770–1774
21. Young N, Cheah D, Waddell J, Wright J (1998) Patients characteristics that affect outcome of total hip arthroplasty: a review. Can J Surg 41:188–195