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The Safety and Efficacy of the Anterior Approach Total Hip Arthroplasty as per Body Mass Index Peer-reviewed author version

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- 1 The safety and efficacy of the anterior approach total hip arthroplasty as per
- 2 body mass index

3 Abstract

Background: Obesity is associated with component malpositioning and increased revision risk
after total hip arthroplasty (THA). With anterior approaches (AA) becoming increasingly
popular, the goal of this study was to assess whether clinical outcome post-AA-THA is affected
by body mass index (BMI).

8

9 Methods: This multi-center, multi-surgeon, consecutive case-series used a prospective 10 database of 1,784 AA-THAs (1,597 patients) through bikini (n=1,172) or standard (n=612) 11 incisions. Mean age was 63 years (range, 20 to 94) and there were 57.5% women, who had a 12 mean follow-up of 2.7 years (range, 2.0 to 4.1 years). Patients were classified into the following BMI-groups: normal (BMI <25.0; n=572); overweight (BMI: 25.0 to 29.9; n=739); obese 13 14 (BMI: 30.0 to 34.9; n=330); and severely-obese (BMI \geq 35.0; n=143)]. Outcomes evaluated included hip reconstruction (inclination/anteversion and leg-length), complications and 15 16 revision rates), as well as patient-reported outcomes including Oxford Hip Scores (OHS).

17

18 Results: Mean post-operative leg-length difference was 2.0 mm (range, -17.5 to 39.0) with a 19 mean cup inclination of 34.8° (range, 14.0 to 58.0°), and anteversion of 20.3° (range, 8.0 to 20 38.6°). Radiographic measurements were similar between BMI-groups (p=0.1 to 0.7). 21 Complication and revision rates were 2.5 and 1.7%, respectively. The most common 22 complications were fracture (0.7%), periprosthetic joint infection (PJI) (0.5%), and dislocation 23 (0.5%). There was no difference in dislocation (p=0.885) or fracture rates (p=0.588) between 24 BMI-groups. There was a higher rate of wound complications (1.8%; p=0.053) and PJIs 25 (2.1%; p=0.029) among obese and severely obese patients. Wound complications were less 26 common among obese patients with the 'bikini' incision (odds ratio 2.7). Pre-operative

- OHS was worse among the severely obese (p<0.001), which showed similar improvements
 (Change in OHS; p=0.144).
- 29

30	Conclusion: Anterior approach THA is a credible option for obese patients, with low
31	dislocation or fracture risk, and excellent ability to reconstruct the hip, leading to comparable
32	functional improvements among BMI-groups. Obese patients have a higher risk of PJIs.
33	Bikini incision for AA-THA can help minimize the risk of wound-complications. How do
34	you know this???data above→data clarified and highlighted in red
35	
36	Key words:
37	Total Hip Arthroplasty, Anterior Approach, Outcome, Complications, Body Mass Index,
38	Obesity

39 Introduction

40 Obesity is a growing challenge facing the Western healthcare systems, including arthroplasty 41 surgeons. It is estimated that, by the 2030, 20% of the world's adult population will be obese, 42 and this proportion is predicted to continuously increase[1, 2]. Obesity is associated with 43 vounger age at the time of primary total hip arthroplasty (THA)[2, 3]. Although obese patients 44 can expect clinical improvement following THA with a similar survival rate[4], they are at an 45 elevated risk for complications such as infection and dislocation[5, 6]. In most studies on the 46 results of THA among patients who have obesity, an antero-lateral[7-9] or posterior approach[7, 47 10] have been used.

48

49 The anterior approach (AA) is becoming increasingly popular for a primary THA, with 50 presumed advantages such as enhanced recovery and low dislocation rates[11, 12]. However, 51 there is literature reporting increased complication risk[13, 14]. AA is associated with technical 52 difficulties, both on the femoral and on the acetabular side[15], as soft tissues might impede 53 access, increasing risk of component malpositioning, contributing to instability, early loosening 54 or periprosthetic fractures [16]. In addition, obesity has been described as a risk factor for wound 55 complications in AA, due to immune dysfunction and the proximity of the adjacent waist 56 crease, exacerbated in obese patients[17-20].

57

This study aimed to assess the impact of BMI on the clinical outcome (component position, complication- and revision rate, and patient-reported outcome) and to identify factors associated with outcome for patients who have higher BMIs. We hypothesized that the AA can be utilized safely regardless of BMI, leading to good outcomes, equivalent to those seen in nonobese patients.

63 Methods

64 Study design

This is a retrospective, consecutive case series of prospectively recorded data of patients who underwent primary THA through AA in one of two high-volume, tertiary referral institutions (Center 1: The Ottawa Hospital, Ottawa, Canada; and Center 2: Ziekenhuis Oost-Limburg, Genk, Belgium). All six participating surgeons had a minimum of 3 years' experience with, and predominantly use AA for primary THA[21]. The study was approved by the ethical committee and all participants signed an informed consent.

71

72 Study population

Between January 1st, 2018 and June 1st, 2020, 901 total hip arthroplasties were performed in 73 74 832 patients in Center 1 by 4 surgeons, and 1,461 hip arthroplasties in 1,267 patients in Center 2 by 2 surgeons. The inclusion process has been outlined in a flowchart (See Figure 1). 75 76 Exclusion criteria were age less than 18 years old (n=2), patients deceased during the follow-77 up from causes unrelated to THA (n=19), THA through lateral (n=3) or posterior approach 78 (n=133), secondary osteoarthritis to childhood diseases (n=22), femoral neck fracture (n=29), 79 osteonecrosis (n=38), post-traumatic arthritis (n=11), conversion of an intramedullary nail 80 (n=10) or hip fusion (n=1) to THA, rheumatoid arthritis (n=2), metastasis (n=1), absent BMI 81 data (n=179), and follow-up less than 2 years (n=128). This left 1,784 procedures (1,597 82 patients) for inclusion (726 THA in 674 patients from Center 1; and 1,058 THA in 923 patients 83 from Center 2).

84

85 Patients were classified into sub-groups based on their BMI at the time of surgery. The groups

86 were: BMI <25.0 (not overweight); BMI 25.0 to 29.9 (overweight); BMI 30.0 to 34.9 (obesity);

and BMI \geq 35.0 (severe obesity)[22].

Among all included AA THA, 572 had a normal weight (32.1%), 739 were overweight (41.4%), 88 330 had obesity (18.5%), and 143 severe obesity (8.0%). There were 1,025 men (43.4%) and 89 1,337 women (56.6%), who had a mean BMI of 27.6 kg/m² (range, 15.8 to 50.8 kg/m²). The 90 91 mean age of the cohort was 63 years (range, 20 to 94). Patients who had severe obesity were 92 much younger (61 years, range 28 to 86) in comparison to non-overweight (64 years, range, 21 93 to 94; p=0.005), and overweight (62 years, range 25 to 91 years; p=0.009) patients. The mean 94 follow-up was 2.7 years (range, 2.0 to 4.1 years), with no difference among the obesity groups 95 (p=0.134) (See Table 1).

96

97 Surgery and implant characteristics were prospectively collected in the database. All THAs 98 were performed through an AA with the patient in supine position on a standard operating 99 table[23] (n=1,388) or using a positioning table[24] (n=396), through a 'bikini' incision 100 (n=1,172) or a longitudinal incision (n=612). Three surgeons used the 'bikini' incision, these 101 surgeons also performed a capsular repair, while the others perform a capsulectomy. A fourth 102 surgeon uses the 'bikini' incision for patients who had a BMI \geq 35 kg/m². The Pinnacle[®] 103 acetabular cup (DePuy-Synthes, Warsaw, Indiana, United States) was used in 934 cases 104 (52.4%), the G7 acetabular cup (Zimmer-Biomet, Warsaw, Indiana, United States) in 725 cases (40.6%), and the Trilogy[®] cup (Zimmer-Biomet) in 123 cases (6.9%). A total of 1,712 (96.0%) 105 106 stems were uncemented and 72 stems (4.0%) were cemented, in cases of high fracture risk due 107 to osteopenia (Dorr C femur). The decision to use a cemented stem was made during pre-108 operative templating or intra-operatively, based on the surgeons' judgement. The most 109 commonly used stems were Corail[®] (DePuy-Synthes) (n=932), Microplasty[®] (Zimmer-Biomet) (n=656), Avenir[®] (Zimmer-Biomet) (n=104), and Taperlock[®] (Zimmer-Biomet) (n=44). An 110 111 intraoperative radiograph prior to implantation of final implants was used systematically in 112 most cases in Center 1 (3/4 surgeons); no intra-operative fluoroscopy was used in Center 2 (2 surgeons). Patients allowed weight-bearing as tolerated post-operatively without any
anterior/posterior hip precautions (n=1,670) (5 surgeons), or protected weight bearing during
the first 2 post-operative weeks (n=114) (1 surgeon), as per surgeons' preference.

116

117 Radiographic analyses

Standing antero-posterior (AP) pelvic radiographs were analyzed and a calibration marker was used to correct for magnification error. The longitudinal rotation of the pelvis was verified as correct when the tip of the coccyx was in line with pubic symphysis[25, 26]. If the coccyx deviated \geq 1 centimeter from the symphyseal line the X-ray was considered unacceptable for measurement purposes.

123

A power analysis was performed to determine the minimum number of subjects requiring radiographic reconstruction measurements. A sample size was calculated in SPSS v27 (IBM, **Chicago, Illinois, United States)** with the intention to detect a difference in cup anteversion of 10°, using an anteversion of $15^{\circ}\pm10^{\circ}$ as a reference[27]. A minimum of 16 patients per group was necessary to achieve sufficient power ($1-\beta=0.80$, $\alpha=0.05$).

129

130 Two arthroplasty fellowship-trained orthopedic surgeons performed the following 131 measurements: (1) leg length discrepancy (LLD) – defined as the difference of the leg length 132 between the ipsi- and contra-lateral hip, measured by the distance between the inter-teardrop 133 line and the inferior margin of the lesser trochanter[28], (2) cup inclination – defined as the 134 angle between the long axis of the cup and a transverse line connecting the bottom edge of the 135 acetabular teardrops[29] and (3) acetabular cup anteversion – defined as the inverse sine of the 136 division between the distance of the short and long axis of the elliptical projection of the rim of 137 the acetabular component[30]. Intraclass correlation coefficient was calculated with a two-way

mixed model. A value >0.75 was considered to have excellent reliability (0-1: no – absolute
agreement)[31] (See Supplementary Table).

140

141 *Outcome measurements*

142 Clinical, surgical, and hospitalization notes were screened for adverse events. The Clavien-143 Dindo classification was used to grade complications[32]. Grade 1 complications needed no 144 treatment, these included transient nerve dysesthesia, conservatively treated post-operative 145 hematoma, or greater trochanteric fractures. Grade 2 complications required pharmacologic 146 treatment including superficial wound infections necessitating antibiotics. Grade 3 147 complications resulted in reoperation, and these included dislocations requiring closed 148 reduction or revision, patients who had psoas tendinopathy requiring surgical release, 149 superficial wound infections requiring debridement, peri-prosthetic joint infections needing 150 revision, periprosthetic fractures requiring open reduction and internal fixation or revision, 151 aseptic loosening or severe metallosis requiring revision and severe leg length discrepancies 152 requiring revision. Grade 4 complications were potentially life-threatening complications or 153 resulted in permanent disability, and grade 5 complications resulted in death.

154

Patient-reported outcome measures (PROMs) were obtained at 4 weeks pre-operatively, and at a minimum of 12 months post-operatively. Those included Oxford Hip Score (OHS)[33]. EuroQOL Five Dimensions Questionnaire (EQ5D)[34], Patient-Reported Outcome Measurement Information System (PROMIS)[35] in one Center, and Hip disability and Osteoarthritis Outcome Score (HOOS)[36] and 36-item Short Form Survey (SF-36)[37] in the second Center. Length of follow-up was determined from the date of surgery to the last clinical review.

163

164 Data Analyses

165 Statistical analysis was performed using SPSS v27 (IBM). Normal distribution of data was 166 tested with Kolmogorov-Smirnov tests and Q-Q plots. Mann Whitney U tests or Kruskal-Wallis 167 tests were used to compare continuous variables between different groups, for non-normally 168 distributed data, and independent samples *t*-tests or ANOVA tests were used for normally 169 distributed data. Paired samples t-tests were used to compare pre- and post-operative values 170 and Chi-Square tests to compare categorical variables. Survival was calculated with failure 171 defined as any re-operation in which any component was changed. Survival data was obtained 172 by Kaplan-Meier analysis[38]. A p-value of <0.05 was considered significant.

173 **Results**

174 *Radiographic measurements*

Mean post-operative leg-length difference was 2.0 millimeters (range, -17.5 to 39.0) with a mean cup inclination of 34.8° (range, 14.0 to 58.0°), and anteversion of 20.3° (range, 8.0 to 38.6°). There was no significant difference in any of the radiographic parameters measured (cup anteversion, inclination, and leg length difference) between different obesity groups (See Table 2), with only a slight tendency towards increased cup inclination in patients with higher BMI, however, this difference was not significant (See Figure 2).

181

182 *Complications and reoperations*

183 There was no difference in incidence of intra-operative adverse events (calcar fracture or greater
184 trochanteric fracture) (0.7%) among the different groups (p=0.612).

185 The overall rate for Clavien-Dindo grade 3 complications within this cohort was 2.5% 186 (45/1,784). Thirty THA were revised (1.7%); the majority of these were peri-prosthetic 187 fractures (12/1,784; 0.7%), followed by peri-prosthetic joint infection (PJI) (9/1,784; 0.5%), 188 and instability (8/1,784; 0.5%) (See Table 3). There was no difference in survival rate between 189 the different obesity groups (p=0.095) (See Figure 3). Patients who had obesity had the highest 190 incidence of wound problems (6/324; 1.8%) in comparison to overweight (4/735; 0.5%; 191 p=0.053) and not-overweight (1/571; 0.2%; p=0.012) patients. Similarly, patients who had 192 severe obesity (BMI \geq 35 kg/m²) had a significantly higher risk to develop PJI (3/143; 2.1%) in 193 comparison to overweight (3/739; 0.4%; p=0.024) and not-overweight (3/572; 0.5%; p=0.065) 194 patients. The incidence of wound complications was lower among patients who had a horizontal 195 'bikini' incision (odds ratio 2.7; 95% Confidence Interval 0.9-8.5; p=0.039). 196 There were 50 THA (2.8%) patients who had a mean BMI >40 and a mean age of 63 years

197 (range, 34 to 84). There were 54% women, who had a mean BMI of 42.8 (range, 40.0 to 50.8);

Their mean follow-up 2.7 years (range, 2.0 to 3.6)]. Of these, one THA was revised (2.0%)
because of a PJI, which was not significantly different in comparison to other obesity groups
(p=0.102). No other intra- or post-operative complications were present in this group.

201

202 Patient-reported outcome measures

203 Patients who had a higher BMI had lower preoperative PROM scores (OHS, HOOS, and SF-204 36) in comparison to patients who had a lower BMI (See Table 4 and Figure 4). Patients who 205 had severe obesity (mean OHS 15.4, range 1.0 to 36.0) had lower pre-operative OHS scores 206 than not-overweight (mean OHS 21.2, range 4.0 to 44.0; p<0.001), overweight (mean OHS 207 19.9, range 1.0 to 45.0; p=0.002) and obesity patients (mean OHS 18.7, range 1.0 to 42.0; 208 p=0.031). Patients who had severe obesity had a higher change in OHS, HOOS and SF-36 209 scores than the other groups, although the only significant for change in HOOS quality of life 210 (p=0.006) (See Table 4 and Figure 4). PROM scores at latest follow-up were lower in groups 211 of patients who had a higher BMI for EQ5D and OHS, but not anymore for HOOS and SF-36 212 (See Table 4 and Figure 4). Post hoc analyses revealed that patients who had severe obesity 213 (mean OHS 42.0, range 23.0 to 48.0) had lower post-operative OHS scores than not-overweight 214 (mean OHS 43.9, range 11.0 to 48.0; p<0.001) and overweight (mean OHS 43.9, range, 11.0 to 215 48.0; p=0.001) patients, but similar post-operative OHS scores than obese patients (mean OHS 216 42.1, range 14.0 to 48.0; p=0.603).

217 **Discussion**

218 This large, multi-center, multi-surgeon, consecutive case series showed that AA-THA is safe 219 and effective in obese patients, even among those who have a BMI \geq 35 kg/m². Reconstruction 220 with AA allowed for reliable component orientation and hip reconstruction even in obese 221 patients, in contrast to other approaches [39, 40]. At a follow-up of 2.7 years (range, 2.0 to 4.1), 222 overall complication and revision rates were 2.5 and 1.7%, respectively. The low dislocation 223 (0.5%) and periprosthetic fracture risk (0.7%) was not higher in obese patients. However, 224 patients who had severe obesity had a higher risk to develop PJI (2.1%). Patients who had a 225 higher BMI had lower preoperative PROM scores, but sustained a similar improvement in 226 PROMs, further illustrating the efficacy of AA-THA. The risk of infection in obese patients 227 remains a challenge, regardless of approach, even among experienced surgeons, and special 228 attention should be paid to adjunct measure, including post-operative wound management, to 229 minimize this.

230

231 The AA has been shown in some studies to lead to superior reconstruction and component 232 orientation accuracy[41, 42]. This accuracy does not seem to be adversely affected by BMI. 233 Although BMI did not have effect on cup position, nor orientation with AA-THA, there was a 234 tendency towards an increased inclination and anteversion in patients who have obesity. It is 235 plausible that during cup positioning, anterior soft tissues push the handle towards increased 236 anteversion and inclination. We would therefore recommend the use of an offset handle during 237 cup placement to help avoid cup malpositioning. One other study assessed the influence of 238 obesity on acetabular cup positioning in AA-THA and also found no significant difference in 239 cup anteversion/inclination[18], while studies of antero-lateral or posterior THA showed that 240 high BMI is a risk factor of cup malpositioning[39, 40]. A significantly increased inclination 241 and decreased anteversion among obese patients[43-45] led to the suggestion of using

navigation to improve cup orientation when conducting antero-lateral or posterior approach THA in obese patients[46-48]. A large depth of fat can influence the angle of the acetabular component inserter, and pelvic positioning in lateral decubitus is more difficult in obese patients, risking intraoperative pelvic motion[40]. All patients in our study underwent an AA in the supine position, which likely contributes to a more reproducible position of the pelvis during surgery. Leg length restoration was not affected by obesity in our study, while BMI was found to affect leg-length restoration in posterior approach THA[49].

249

250 Different studies found a higher complication rate after primary THA in patients who have 251 obesity, including instability, periprosthetic fracture, and infection[2, 8, 9, 50, 51]. The overall 252 dislocation rate was very low in this cohort (0.5%), and was similar among the different BMI-253 groups. AA appears to be protective against instability, even among obese patients. For other 254 approaches, a dislocation risk up to 3 to 7% has been described in severely obese patients[8, 9, 255 50]. This is likely the consequence of improved cup positioning and preservation of the muscle 256 envelope with AA. Femoral exposure is one of the technical difficulties associated with AA-257 THA[15]. Soft tissues in patients with obesity might impede the access to the femoral canal, 258 risking femoral stem malpositioning and femoral fractures. Although we found a relatively 259 higher periprosthetic fracture rate among patients with severe obesity (1.4%), this was not 260 significantly different than in other groups (0.5 to 0.7%). We found no perioperative calcar 261 fractures among patients with obesity, the overall risk was 0.6%. Although no significant 262 differences in periprosthetic fracture risk were found in this study, it should be acknowledged 263 that femoral exposure can be more difficult in obese patients. All surgeons included in this 264 study are very experienced with AA and femoral exposure in AA is an important aspect of the 265 learning curve[52].

267 Patients who have severe obesity have a higher risk of PJI (2.1%) in comparison to an overall 268 risk within this cohort (0.5%), and patients who have obesity have a higher risk of wound 269 complications (1.8%) compared to an overall risk (0.6%). Patients who have obesity have been 270 shown to be at higher risk for wound complications and infection, due to the increased fat tissue 271 envelope and deeper surgical exploration, adjacency of waist crease with overlying abdominal 272 and higher prevalence of co-morbidities such as diabetes mellitus or pannus, 273 immunodeficiency[17-20]. Delayed wound healing compromises the natural skin barrier 274 allowing for bacterial migration in the wound leading to PJI[53]. The wound complication and 275 infection rate was similar or lower in comparison to other studies on the outcome of AA-THA 276 in patients who have obesity. Purcell et al reported a 2.5% incidence of PJI and 2.0% of 277 superficial wound dehiscence among patients who had severe obesity[19]. Antoniadis et al 278 reported a 4.6% incidence of infection requiring reoperation[18]. Jahng et al reported 11.5% 279 wound complications of which 1.9% required a reoperation [54]. Studies on primary THA 280 through antero-lateral approach found a rate of 11% superficial wound problems and 4% deep 281 infection among severely obese patients[50]. Similar to our findings, some studies suggested a 282 horizontal 'bikini' incision to be beneficial for wound healing[53, 55]. The bikini incision is 283 oriented along Langer's line, allowing for tension free healing during the early-post-operative 284 period[55]. To minimize the risk of wound-complications, possibly contributing to PJI, the 285 bikini incision is recommended. Although incision length was not measured as part of this 286 study, it is plausible that some vertical incisions reached the skin groin crease, which could be 287 associated with an increased risk of slower wound healing[53] due to increased bacterial skin 288 flora[56]. However, the use of the bikini incision is associated with other pitfalls (e.g., not 289 extensile) and should thus be utilized with caution, especially during the learning curve of the 290 AA.

292 The difference between pre- and postoperative PROM scores was not different between BMI-293 groups. While patients who had obesity had lower pre-operative PROM scores, they can expect 294 similar clinical improvement after THA. Most studies that include PROM scores have found 295 good functional outcomes among obese patients [2, 18, 57]. Registry data has shown that 296 increased BMI is associated with significantly smaller improvements in post-operative outcome 297 scores, although these studies did not include AA-THA[58, 59]. Due to the increased 298 complication risk, the American Association of Hip and Knee Surgeons workgroup released a 299 statement recommending to delay arthroplasty in patients who have a BMI>40 kg/m² [60]. 300 Recently, the Cleveland arthroplasty group stated that operative eligibility based on BMI alone 301 could potentially restrict access for patients who would benefit from primary THA and can expect improvement in pain, function and overall quality of life[61], which is supported by our 302 303 data.

304

305 This study has some limitations. It is a retrospective study of prospectively recorded data, and 306 there was a lack of complete pre- and post-operative PROM scores, which were available in 307 only 60 and 70% of patients, respectively. This might have caused bias in interpreting these 308 results. Also, all patients underwent THA through AA, and there was no control group to 309 compare risk of complications between different approaches. In addition, all authors have a 310 large experience with AA and therefore these results might not be representative to surgeons in 311 an early stage of the learning curve. The mean follow-up was only 2.7 years (range, 2.0 to 4.1 312 years); longer follow-up would be necessary to evaluate the longer-term survival among obese 313 patients treated with AA-THA.

314

315 Conclusion

316 The AA is a safe and effective approach for obese patients undergoing THA. It allows for 317 excellent and reproducible cup orientation and hip reconstruction, even among severely obese 318 patients, without the need for navigation. The risk of dislocation and periprosthetic fractures 319 was low, even among patients who had obesity. Patients who have obesity are at higher risk to 320 develop wound complications and PJI following AA-THA. A horizontal 'bikini' incision can 321 help to avoid wound complications. Patients who have higher BMI had lower preoperative 322 PROM scores in comparison to patients who had lower BMI, but similar improvement can be 323 expected post-operatively.

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