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ORIGINAL ARTICLE • HIP - ARTHROPLASTY

# Does oversizing an uncemented cup increase post-operative pain in primary total hip arthroplasty?

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## Abstract

**Introduction** It has been suggested that one of the factors related to persistent post-operative pain following total hip arthroplasty (THA) is to over sizing of the acetabular component. In order to investigate this potential issue, we retrospectively analysed a series of consecutive uncemented THA. We assessed the incidence of persistent post-operative pain and the size difference between the implanted acetabular component and the native femoral head.

**Methods** A total of 265 consecutive THAs were retrospectively identified. Standardised pre-operative radiographs were analysed using validated techniques to determine the native femoral head diameter. Post-operative standardised radiographs were reviewed and the acetabular orientation determined. Patients were sent postal questionnaires regarding their outcome and level of pain.

**Results** Questionnaires were returned by 169 patients (189 hips, 71% response rate). A total of 17 were excluded due to inadequate radiographs., leaving 172 THA in the study group. The mean native femoral head (NFH) size was 47 mm. The most common implanted acetabular component size was 52 mm. The mean difference in cup to NFH diameter (delta) was 5.7 mm (range −6.1 to 15.4 mm; 95% CI 5.3–6.2 mm). A delta of > 6 mm was found to be significant for predicting persistent post-operative pain (RR = 1.81; 95% CI 1.1–3.1; $P = 0.027$).

**Conclusion** Our study confirms that a delta of > 6 mm is associated with an increased risk of persistent post-operative pain following THA. We recommend pre-operative templating in all uncemented THA to ensure the planned acetabular component is no more than 6 mm larger than the NFH diameter.

**Keywords** Hip · Pain · Oversize · Arthroplasty · Uncemented · Ceramic

## Introduction

Total hip arthroplasty is a reliable procedure for alleviating pain associated with end-stage osteoarthritis and improving patient function. Despite this, there remains a proportion of patients with persistent post-operative pain. In a systematic review of published prospective studies reporting on post-operative pain, Beswick et al. found a wide range in reported persistent post-operative pain following THA (7–23%), with the most robust studies reporting a rate of 9–13% [1]. Several "generators" of persistent post-operative pain after THA have been reported [4], including poor implant positioning, bearing surfaces, greater trochanteric pain syndrome, anterior iliopsoas impingement, fracture, heterotrophic ossification, infection and implant size and type.

A study published in 2014 concluded that a significant cause of persistent post-operative pain following THA was due to oversizing of the implanted acetabular component by 6 mm or more compared to the native femoral head size [6]. To our knowledge, this has been the first time that a cut-off for size difference between the implanted acetabular component and native femoral head diameter has been explored and reported. We find the NFH diameter to be a simple and reproducible landmark to measure using pre-operative templating software. The aim of our paper was to investigate the relationship between persistent post-operative pain and size difference between implanted acetabular component and native femoral head diameter. In particular, we were interested to know if this cut-off of 6 mm for predicting

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persistent post-operative pain was reproducible and could be used as a clinical guide during pre-operative templating. We therefore performed a retrospective analysis of consecutive uncemented THAs performed at our institution.

## Method

### Patient group

We identified 265 consecutive uncemented THAs (Corail stem, Pinnacle cup, Biolox Delta head/liner. DePuy, Warsaw, Indiana) performed at our institution by six surgeons between September 2007 and August 2010. All THAs were performed before our institution adopted an enhanced recovery programme, and were performed through the posterior approach in the lateral decubitus position. Patients were excluded if their procedure was performed for acute/chronic trauma, infection, malignancy, previous surgery with metalwork in situ or a revision arthroplasty.

### Data collection

Demographic, surgical and implant specific data along with post-operative outcome/complications were gathered from medical records, electronic patient records, theatre logs and locally collected National Joint Registry records. Standardised, calibrated pre-operative radiographs were analysed using templating software (TraumaCad, Brainlab, Germany) to establish the native femoral head (NFH) diameter. The circle tool was utilised to measure the bony outline of the femoral head, and all radiographs were calibrated to account for any magnification using a sizing ball. The cartilage was not taken into account. Post-operative standardised, calibrated radiographs were reviewed and the acetabular orientation calculated using validated radiological software (Wearwithall, Wrightington, UK) [3]. Acetabular cup size was recorded from the operative notes. Implanted femoral heads were 28 mm or 36 mm.

At a median follow-up of 39 months (range 23–58 months), all patients were sent a simple outcome questionnaire with six questions relating to dislocation, feelings of instability, sounds, sensations, pain or limitations to their daily life from their operated hip.

### Statistical analyses

Basic demographic data were summarised and presented using simple descriptive statistics where appropriate, and after assessing for normality for continuous data (Shapiro–Wilk test).

Intra-rater reliability was also assessed. A single rater repeated the native femoral head measurements on the same calibrated radiographs, for 20 randomly chosen patients out of the patient cohort, at approximately 6 months from the first measurements being made.

Cronbach's alpha coefficient for intra-rater reliability was assessed, as well as a two-way random effects single measures intra-class correlation coefficient (ICC (2,1)).

Patients were grouped according to whether or not they reported post-operative pain on the returned questionnaire. A simple receiver operating characteristic (ROC) analysis was performed to determine what cut-off value of delta gave the highest sensitivity and specificity for reported post-operative pain. Potential predictor variables for post-operative pain were explored for associations. Continuous variables (age at procedure, BMI, NFH diameter, delta, version and inclination) were assessed for normality (Shapiro–Wilk test) and variance (Brown–Forsythe test), and appropriate comparisons of mean/median difference between groups were performed (Student *T* test or Wilcoxon–Mann–Whitney test). Categorical variables (sex, ASA, implanted head size and delta > 6 mm) were summarised as $2 \times 2$ tables, and a Chi-square test for difference in proportions was performed for each, along with calculation of relative risk ratios. The relationship between patient-reported post-operative pain locality and delta > 6 mm was analysed using $2 \times 2$ tables and a Chi-square test for difference in proportions, along with calculation of relative risk ratios. Patients were grouped into "anterior pain" if they reported symptoms in the groin or thigh areas, or "posterior pain" if they reported symptoms in the buttock area.

In order to ensure that the non-responders to the questionnaire did not represent an outlying group in respect of potential predictors of pain were compared these variables between responders and non-responders.

Statistical analyses were performed using Analyse-it Standard Edition v 4.65. Statistical significance was set to $P < 0.05$.

## Results

Of the consecutive series of 265 primary THAs, 16 were excluded as they could not have the pre-operative NFH diameter determined on their available pre-operative radiographs due to destruction of the femoral head or electronic radiographs were not available. A further 3 met our exclusion criteria (acute trauma, chronic trauma, previous infection). Of the remaining 246 THAs, 172 questionnaires were returned, giving a 70% response rate.

### Demographics

There were 100 females and 72 males. The mean age at surgery was 53 years (range 23–76 years). Eighty-seven were

left-sided, and 85 were right-sided procedures. The mean follow-up, taken at time of questionnaire completion, was 40 months (range 23–58 months). The mean NFH diameter was 47.2 mm (range 37.2–58.1 mm; 95% CI 46.6–47.8 mm). The mean delta for the whole cohort was 5.7 mm (range −6.1 to 15.4 mm; 95% CI 5.3–6.2 mm). Gender differences are summarised in Table 1. The Cronbach's alpha coefficient was 0.997, and ICC was 0.993 (95% CI 0.982–0.997, $P < 0.0001$). Both measures indicate excellent intra-rater reliability in the measurement of native femoral head size on calibrated radiographs using TraumaCad.

Females were found to have significantly smaller NFH diameters and were more likely to be oversized (i.e. greater delta). The relative risk of being oversized by > 6 mm for females compared to males was 1.92 (95% CI 1.3–2.9, $P = 0.0005$).

## Predictor variables

In our cohort, 42 (24%) patients reported post-operative pain. Table 2 summarises the comparisons between potential predictor variables for reported post-operative pain.

Compared to those without post-operative pain, patients reporting persisting post-operative pain at follow-up were found to have a tendency to a smaller NFH diameter (46 mm vs. 47 mm; difference = −1.3 mm, 95% CI −2.8 to 0.1, $P = 0.07$), and a larger delta (median 6.6 mm vs. 5.5 mm; difference = 1.1 mm, 95% CI 0.1–2.1, $P = 0.041$).

The ROC analysis determined that a cut-off of delta greater than 6 mm gave the highest sensitivity and specificity for post-operative pain. The relative risk of post-operative pain in patients with a delta greater than 6 mm was 1.81 (95% CI 1.1–3.1, $P = 0.027$). Interestingly, despite females being more likely to be oversized, they did not have a statistically significant greater relative risk of persistent post-operative pain compared to males (RR = 1.61; 95% CI 0.92–2.88; $P = 0.099$).

## Pain locality

Persistent post-operative pain (40 out of 172) was localised as follows on the returned patient questionnaires: "anterior pain" (groin or thigh) = 36; "posterior pain" (buttock) = 4. Table 3 summarises the relative risks of reported pain by locality, according to delta > 6 mm. The relative risks of reported generalised pain (RR = 1.81; 95% CI 1.07–3.1) and anterior pain (RR = 1.78; 95% CI 1–3.19) in patients with a delta > 6 mm were found to be statistically significant, but not in posterior pain.

## Complications

Of the 172 patients reviewed, reported complications were low. There were two dislocations (neither revised), 1 deep infection (successful debridement and retention of implants (DAIR) procedure) and no ceramic fractures. At latest follow-up (mean 40 months; range 23–58 months), no implants had been revised.

## Questionnaire non-responders

Out of the 246 THAs (after exclusions), 76 (30%) did not respond to the questionnaires we sent out for this study. Four patients had died (mean = 2.5 years post-op; range = 2 months–6 years), 1 patient was revised for instability (2 years post-op), and 10 patients were lost to follow-up. Table 4 summarises the comparisons of available demographic and measured variables, confirming that the only significant difference between responders and non-responders was from age at the time of surgery and NFH diameter. Non-responders were 5 years younger (95% CI 2–7.9 years, $P = 0.001$) than responders and had a 0.6 mm smaller NFD diameter (95% CI −1.7 to 0.6, $P = 0.34$).

**Table 1** Summary comparisons for gender differences in NFH diameter and delta

| | Female | Male | Difference (95% CI) | *P* value |
|---|---|---|---|---|
| NFH diameter (mm) | 45 (37 to 58)* | 51 (43 to 58)* | −5.6 (−6.5 to −4.7) | **< 0.0001**[a] |
| Cup-NFH diameter (delta in mm) | 6.7 (−6.1 to 15.4)* | 4.9 (−1.8 to 11.5)* | 1.8 (0.9 to 2.7) | **< 0.0001**[a] |
| delta > 6 mm | | | | |
| Yes | 56 | 21 | RR (female vs. male) | **0.0005**[b] |
| No | 44 | 51 | 1.92 (1.3 to 2.9) | |

Bold values indicate $P < 0.05$

*Median (range)

[a]Wilcoxon–Mann–Whitney test for median difference

[b]Chi-square test)

**Table 2** Summary comparisons for potential predictor variables of post-operative pain

| | Post-op Pain | No Pain | Difference (95% CI) | *P* value |
|---|---|---|---|---|
| Age (years) | 53.8 (22.6 to 64.6)* | 53.9 (26.6 to 75.7)* | −0.5 (−3.4 to 2.3) | 0.679[a] |
| BMI (kg/m$^2$) | 29.2 (19.5 to 43)‡ | 27.6 (18 to 50)‡ | 2 (0 to 4) | 0.057[b] |
| NFH diameter (mm) | 46 (41 to 58)* | 47 (37 to 58)* | −1.3 (−2.8 to 0.1) | 0.07[a] |
| delta (mm) | 6.6 (−6.1 to 11.9)* | 5.5 (−1.8 to 15.4)* | 1.1 (0.1 to 2.1) | **0.041[a]** |
| Acetabular anteversion (deg) | 16.1 (0.2 to 30.6)‡ | 18.5(3.9 to 34.9)‡ | −2.3 (−5 to 0.3) | 0.077[b] |
| Acetabular inclination (deg) | 40.4 (26.6 to 54)‡ | 41.5 (23.1 to 65.3)‡ | −1.1 (−3.9 to 1.72) | 0.441[b] |
| Gender | | | | |
| Male | 13 | 59 | RR (female vs. male) | 0.099[c] |
| Female | 29 | 71 | 1.61 (0.92 to 2.88) | |
| ASA | | | | |
| 1 | 12 | 56 | | 0.247[c] |
| 2 | 26 | 64 | | |
| 3 | 4 | 10 | | |
| Head diameter | | | | |
| 28 mm | 9 | 29 | RR (28 vs. 36) | 0.91[c] |
| 36 mm | 33 | 101 | 0.96 (0.5 to 1.75) | |
| delta > 6 mm | | | | |
| Yes | 25 | 52 | RR (yes vs. no) | **0.027[c]** |
| No | 17 | 78 | 1.81 (1.1 to 3.1) | |

Bold values indicate $P < 0.05$

‡Mean (range)

*Median (range)

[a]Wilcoxon–Mann–Whitney test for median difference

[b]Student *T* test for mean difference

[c]Chi-square test)

**Table 3** Summary comparisons for post-operative pain locality by cup-NFH > 6 mm

| | > 6 mm | < 6 mm | Relative risk ratio (95% CI) | *P* value |
|---|---|---|---|---|
| Pain | | | | |
| Yes | 25 | 17 | 1.81 (1.07 to 3.1) | **0.027[a]** |
| No | 52 | 78 | | |
| Anterior pain | | | | |
| Yes | 21 | 15 | 1.78 (1 to 3.19) | **0.049[a]** |
| No | 52 | 78 | | |
| Posterior pain | | | | |
| Yes | 3 | 1 | 4.31(0.63 to 29.65) | 0.161[a] |
| No | 52 | 78 | | |

Bold values indicate $P < 0.05$

[a]Chi-square test

## Discussion

In this retrospective series, we have shown that an acetabular cup-NFH diameter (delta) of > 6 mm is significantly associated with persistent post-operative pain (RR = 1.81 (95% CI 1.1–3.1, $P = 0.027$). We determined a cut-off value for delta of 6 mm, which is concordant with the findings of Odri et al., who looked at metal on poly, ceramic on poly and CoC bearings. We found that females were nearly twice as likely to be oversized by > 6 mm (RR = 1.92; 95% CI 1.3–2.9; $P = 0.0005$) [6]. However, gender alone was not a predictor of post-operative pain. Both generalised post-operative pain and "anterior pain" (groin or thigh) were found to be associated with a delta > 6 mm. This association was not found with "posterior pain" (buttock).

Beverland et al. support the use of pre-operative templating and intra-operative calipers to measure the NFH diameter, with the aim of implanting a cup no more than 4 mm larger than this [2]. Anecdotally they state that using their reaming technique, the implanted cup is rarely more than 6 mm greater than the NFH diameter, further supporting the findings of our study and Odri et al. [6]. It should be noted that intra-operative measurement of the head will likely give a larger value for head diameter compared to measuring pre-operative radiographs due to the residual cartilage thickness.

Our study does have some limitations. Our patient questionnaire response rate was 70%, which is acceptable, yet might unintentionally introduce selection bias [5]. We have attempted to check that the non-responders to our

**Table 4** Summary comparisons between responders and non-responders to questionnaires

| | Responders | Non-responders | Difference (95% CI) | *P* value |
|---|---|---|---|---|
| Age (years) | 54 (22.6 to 75.7)* | 49.3 (15.2 to 73.7)* | 5 (2 to 7.9) | **0.001**[a] |
| NFH diameter (mm) | 47 (27 to 58)[‡] | 48 (39 to 60)[‡] | −0.6 (−1.7 to 0.6) | 0.034[b] |
| delta (mm) | 5.7 (−6.1 to 15.4)[‡] | 5.5 (−4.6 to 12.6)[‡] | 0.3 (−0.6 to 1.1) | 0.565[b] |
| Gender | | | | |
| Male | 72 | 41 | | 0.078[c] |
| Female | 100 | 35 | | |
| ASA | | | | |
| 1 | 68 | 33 | | 0.333[c] |
| 2 | 90 | 34 | | |
| 3 | 14 | 8 | | |
| 4 | 0 | 1 | | |
| delta > 6 mm | | | | |
| Yes | 77 | 33 | | 0.98[c] |
| No | 95 | 41 | | |

Bold value indicates $P < 0.05$

[‡]Mean (range)

*Median (range)

[a]Wilcoxon–Mann–Whitney test for median difference

[b]Student *T* test for mean difference

[c]Chi-square test

questionnaires did not represent a significantly outlying group compared to the responders (demographics, NFH size, delta, delta > 6 mm). Apart from age (non-responders being younger), there were no significant differences between these groups for the variables available for analysis. We have also not determined if pre-operative pain severity was related to reported post-operative pain, or the severity of reported post-operative pain. Furthermore, we have not attempted to correlate patient-reported persistent post-operative pain with objective localising clinical findings (such as greater trochanteric tenderness or a positive psoas provocation test) or radiological findings (such as anterior cup uncoverage on CT, abductor tendinitis, psoas tendinitis). There may be some error in determining the NFH diameter from calibrated pre-operative radiographs, rather than using measuring calipers, as the previously published study [6]. The difference between these two methods (apart from calibration of radiographs) will come down to how much articular cartilage remains on the femoral head and this may lead to an overestimation of the delta using radiographic measurements. However, we would not expect to find significant remaining articular cartilage in patients undergoing THA for end-stage osteoarthritis. We find the NFH diameter to be a simple and reproducible landmark to measure using pre-operative templating software. It is independent of the articular cartilage and saves time intra-operatively by not having to undertake the extra step of measuring the femoral head. In only 6% of the 265 THA studied, the NFH diameter could not be established on the pre-operative radiographs.

There may be a few reasons why a surgeon may potentially oversize an acetabular cup. One explanation may be due to reaming technique and over-reaming in an attempt to achieve sufficient press-fit implant stability. We feel that this is an avoidable situation if a good reaming technique is adhered to. The majority of implanted femoral heads in our series were 36 mm (134; 79%). The Pinnacle (DePuy) system allows the use of a 36-mm femoral head with cup sizes 52 mm and larger. It may be more likely that oversizing occurred to allow implantation of a larger cup to accommodate a larger head size for stability reasons, though we found no increased risk of persistent post-operative pain with the use of 36 mm heads. More recently, it has become our surgical technique to ensure bone coverage of the anterior acetabular rim, in order to protect the psoas tendon from irritation. This technique may protect the patient from some pain generators, even if the socket is oversized.

Further work is need in the analysis of persistent post-operative pain following THA, the potential predicting factors, correlation with clinical and radiological findings (CT, MRI) and most importantly, how we as surgeons can strive to minimise this and improve the functional outcomes of our patients.

## Conclusion

Based on our presented findings, we propose that pre-operative templating and measurement of femoral head diameter should be undertaken for all THAs using good

quality, accurately calibrated radiographs. To minimise the risks of persistent post-operative pain, the final acetabular cup should be no more than 6 mm larger than the NFH diameter as determined on pre-operative templating radiographs. Careful attention to acetabular cup sizing in females should be made, given the increased risks of oversizing.

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## Compliance with ethical standards

**Conflict of interest** One author reports he is Medical Director of the National Joint Registry of England and Wales (NJR), Chairman of the NJR Editorial Board and Past President of the International Society of Arthroplasty Registers (ISAR). The senior author reports grants and personal fees from DePuy Synthes, personal fees from Springer, outside the submitted work; he is Associate Editor of Hip International and a Research Committee Member for British Orthopaedic Association.

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