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ORIGINAL ARTICLE • HIP - ARTHROPLASTY

Patient-dependent risk factors for self-perceived leg length discrepancy after total hip arthroplasty

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Abstract

Purpose Patients with equal objective leg length discrepancy (LLD) may have different subjective perceptions of this condition. Our aim was to analyze the effects of gender, age, operated side, surgical approach, body height, body mass index (BMI) and LLD measurements on self-perceived LLD after total hip arthroplasty (THA).

Materials and methods Observational cohort study with minimum 5-year follow-up included 159 patients with unilateral primary THA at a single institution, who reported subjective feeling of equal or unequal leg lengths after THA. Gender, age, body height, BMI, surgical approach, preoperative and postoperative absolute/relative/pelvic radiographic LLD measurements were included in direct comparison between groups and multivariate analyses with self-perceived LLD as the outcome variable.

Results Out of 159 participants, 39% subjectively perceived postoperative LLD, while others reported equal leg lengths. The two groups postoperatively differed in the median relative LLD (10 mm vs. 5 mm; $p=0.01$) and WOMAC (230 mm vs. 110 mm; $p<0.01$), but not in the pelvic radiographic LLD. After adjustment for gender, age, operated side and surgical approach, postoperative relative LLD (odds ratio 1.38 for each 5 mm increment; 95% CI 1.01–1.74) and combination of BMI < 26 kg/m^2 and body height < 1.75 m (odds ratio 2.49; 95% CI 1.14–5.41) were independent risk factors for self-perceived LLD.

Conclusions Clinical relative LLD measurements are better predictors of self-perceived postoperative LLD than pelvic radiographic measurements. Patients with smaller body dimensions will more likely report subjective leg length inequality at a given objective LLD, regardless of gender or age.

Keywords Hip · Arthroplasty · Self-perceived outcome · Leg length discrepancy

Introduction

Achieving equal leg lengths at primary total hip arthroplasty (THA) still remains a surgical challenge in current orthopedic surgery [1, 2]. Excessive leg length discrepancy (LLD) magnitudes over 1.5 cm can cause lower back pain, gait disorders and general dissatisfaction [3]. However, subjective perception of LLD magnitudes below 1.5 cm and consequential THA outcome is less clear. While some authors report even small differences in leg length after THA have a negative influence on limping and pain [4], other recent studies showed no significant correlation between radiographic LLD assessment [5, 6] and patient-reported satisfaction [7]. One of the reasons for conflicting reports on LLD in patients undergoing THA is the use of different LLD measurement methods in clinical practice and published studies, most commonly clinical absolute/relative tape measurements and radiographic measurements based on pelvic radiographs [1, 8, 9]. Gradual increase in LLD (e.g., idiopathic LLD progressing with growth in adolescence) is less likely to be noted by the patients in comparison with sudden leg lengthening at THA, but the confounding factor of age has not been confirmed in this regard [10].

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Likewise, the physiological and psychological influence of gender and body dimensions on subjective LLD perception has not been determined yet [10, 11]. The question therefore remains, why patients with the same objective LLD measurements after THA may have considerably different subjective perception of this condition.

The aim of our study was to analyze the impact of patient-dependent characteristics (gender, age, operated side, surgical approach, body height, body mass index) and objective LLD measurements on self-perceived LLD after primary total hip arthroplasty. We tested the hypothesis that subjective feeling of postoperative leg length inequality is more likely reported by women, older participants, patients with shorter body height, subjects with lower body mass index (BMI) and patients with larger amplitudes of clinically measured absolute/relative LLD or radiographically measured LLD.

Materials and methods

Patients

Observational cohort study of prospectively collected data was conducted on consecutive 218 patients with unilateral idiopathic hip osteoarthritis, who had primary total hip arthroplasty performed by three experienced orthopedic surgeons at the same hospital department in the period between January 1, 2004, and December 31, 2012, with postoperative WOMAC scores available in the medical records and at least 5 years of documented clinical follow-up. The patients were operated either by the anterolateral or by the posterior surgical approach. The criteria for choosing the specific THA model were based on patient's age and the corresponding intramedullary canal-flare-index shape; in patients older than 75 years or stove-pipe shape of the proximal femur, we regularly used the cemented endoprosthesis Link-SP II®, while patients younger than 75 years with normal or champagne-flute intramedullary canal were implanted the cementless implants, based on the time period of implantation: In the 2004–2008 period, the default cementless hip endoprosthesis used by the operating surgeons was Endo-Plus-Zweymüller® and in 2009–2011 Wright-ProfemurZ® and in 2012 Implantcast-EcoFit®. Medical documentation and pelvic radiographs of patients were collected from the archives in order to obtain the data on preoperative diagnosis, patient's age at the time of surgery, body weight, body height, BMI, objective leg length discrepancy measurements as described below, possible intraoperative complications and subsequent revision operations in the course of follow-up. In the process of data acquisition, 17 patients had to be excluded from the initial study cohort due to the lack of proper radiographs to perform radiographic measurements, eight patients did not have clinical LLD measurements available, and two patients were excluded due to intraoperative complications (periprosthetic fracture and massive bleeding). The remaining 191 patients were sent a custom-made questionnaire on the quality of life at least 2 years after the index operation that also included the following question: "Are your legs equally long after THA? YES/NO." Out of 191 questionnaires sent, 159 patients (83%) responded and were eventually included in the study analysis. The mean time interval between the total hip arthroplasty and the postoperative questionnaire response was 4.9 ± 1.8 years.

The study protocol was reviewed and approved by the National Medical Ethics Committee of the Republic of Slovenia on August 19, 2014, case No.# 97/08/14. All participants signed an informed consent form for participation in the study.

Leg length discrepancy measurements

Leg length discrepancy (LLD) was measured in each patient preoperatively and postoperatively with three different measurement methods (absolute, relative and radiographic), and the operating surgeons were excluded from the measurement process to ensure objectivity. Absolute and relative clinical tape measurements were performed by two independent examiners who measured LLD as the difference in lengths from anterior spina to inner malleolus on both sides (absolute) or the difference in lengths from umbilicus to each inner malleolus (relative) and recorded the mean of their measured values [9, 12]. Radiographic LLD measurements were performed by another two investigators as the difference in vertical distance of lesser trochanters from the interteardrop line [9, 12] on pelvic radiographs, taken in the standardized supine position at the same radiographic department (Fig. 1). Clinical tape measurements were performed with the nearest reading of 5 mm, and radiographic measurements were performed with the nearest reading of 1 mm.

Evaluation of preoperative and postoperative clinical status

Preoperative and postoperative clinical assessments were performed with the officially validated version of Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC score) in the Slovenian language, WOMAC 3.1-VAS [13]. Standardized WOMAC questionnaire consists of 24 questions divided into three separate categories (pain, stiffness and physical function) concerning patient's condition before and after THA; each question is evaluated on the VAS scale from 0 to 100 mm. The final WOMAC score is the sum of all 24 questions, expressed in millimeters from 0 to 2400 (0 mm = no problems, 2400 mm = intolerable

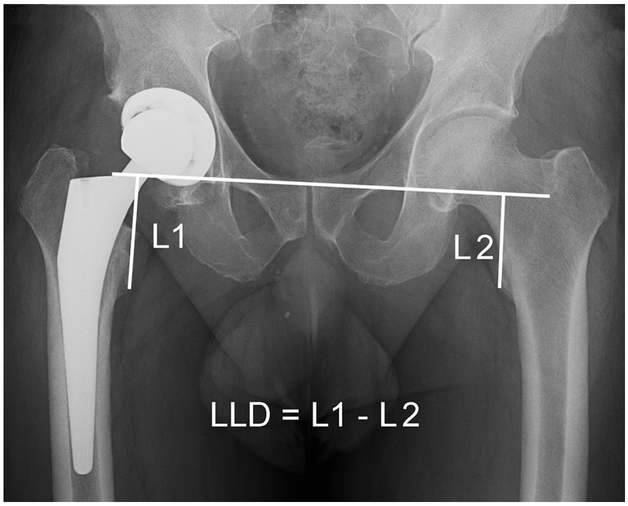

Fig. 1 Illustrative postoperative anterior–posterior pelvic radiograph after total hip arthroplasty with an implanted endoprosthesis Implantcast-EcoFit®. Radiographic leg length discrepancy is measured from such a radiograph by drawing a horizontal reference line between both radiographically visible "teardrops" and then measuring the difference in vertical distance between this line and both lesser trochanters

problems), whereby higher WOMAC score indicates worse pain, stiffness and functional limitations [13]. Preoperative WOMAC score was recorded for 55 out of 159 included subjects. Postoperative WOMAC score was available for all included participants (this was one of the inclusion criteria), and the score was reported by the patients at least 1 year after the index operation.

Statistical methods

Statistical data analysis was performed with Office Excel 2016 (Microsoft Corp, Redmond, WA), IBM SPSS Statistics 23.0 for Windows (IBM Corp, Armonk, NY) and GPower 3.1.9.3 (Heinrich-Heine-University, Germany). In statistical computations, LLD magnitudes were used as absolute positive values of the difference between the longer and the shorter leg. p values for differences between the group of patients with reported equal leg lengths and the group with self-perceived LLD were computed with the two-tailed nonparametric Mann–Whitney U test for continuous numeric variables and Fisher's exact test for categorical variables. Statistical significance was set at $p < 0.05$. Measurement reliability between different investigators was evaluated with the intraclass correlation coefficients. The impact of patient-dependent factors on the risk of self-perceived postoperative LLD after THA was evaluated with separate binary logistic regression models for each type of LLD measurements (absolute/relative/radiographic) and five confounding variables (gender, age, operated side, surgical approach and categorical variable of body dimensions BMI < 26 kg/m^2 and body height < 1.75 m). The binary output variable of self-perceived postoperative LLD was defined according to the patients' response to the question in the custom-made questionnaire: "Do you feel that after total hip arthroplasty your legs are equally long? YES/NO."

An a priori power analysis was performed to determine the minimal required sample sizes for statistical tests, whereby the effect sizes were computed from the threshold for clinically detectable LLD (= 5 mm) and from the LLD data in THA population of the previous methodological study [9]. For comparison of means with the two-tailed nonparametric Mann–Whitney U test with effect size 0.5 at $\alpha = 0.05$ and power $(1-\beta) = 0.80$, the required minimum total sample size was 134 subjects. The minimum sample size for logistic regression models with odds ratio = 2.0, $\alpha = 0.05$ and power $(1-\beta) = 0.80$ was 82 subjects.

Results

Out of total 159 study participants, 62 (39%) patients subjectively perceived postoperative LLD after THA and the remaining 97 reported equal leg lengths. The two participant groups were further compared with regard to gender, operated side, surgical approach, age, weight/height/mass index, pre/postoperative leg length measurements, pre/postoperative WOMAC scores and revision operations in the postoperative follow-up period of at least 5 years (Table 1). The intraclass correlation coefficient of measurement reliability between different investigators was 0.82 for clinical measurements and 0.89 for radiographic measurements. Preoperatively, there was no significant difference between the two groups in age, gender, body dimensions or LLD measurements. After THA, the group with subjectively perceived LLD had significantly higher postoperative relative LLD (median 10 mm vs. 5 mm; $p = 0.01$) and considerably higher percentage of patients with smaller body dimensions BMI < 26 kg/m^2 and body height < 1.75 m (42% vs. 26%; $p = 0.04$), while there was no difference in gender distribution, mean age, operated side proportions, surgical approach, mean body weight/height/mass index or postoperative radiographic LLD. The group with reported equal leg lengths had worse preoperative and better postoperative WOMAC scores in comparison with patients with self-perceived LLD, but clinical complication rates after minimum 5 years of follow-up were equal (Table 1). None of the included patients in this study had any modular implant femoral neck fracture in the course of follow-up.

After adjustment for gender, age, operated side and surgical approach with multivariate logistic regression models, clinically measured postoperative relative LLD (odds ratio 1.38 for each 5 mm increment; 95% CI 1.01–1.74)

Table 1 Demographic characteristics, preoperative measurements and postoperative outcomes for patients with self-perceived equal leg lengths versus self-perceived leg length discrepancy after total hip arthroplasty

	Self-perceived equal leg lengths after THA ($n=97$ patients)	Self-perceived leg length discrepancy after THA ($n=62$ patients)	p value
Demographic characteristics			
Gender	56 female/41 male	36 female/26 male	0.99
Operated side	58 right/39 left	34 right/28 left	0.62
Surgical approach	60 anterolateral/37 posterior	44 anterolateral/18 posterior	0.31
Age at operation (years)	63 ± 12	62 ± 12	0.58
Body weight (kg)	79 ± 14	75 ± 13	0.25
Body height (m)	1.7 ± 0.1	1.7 ± 0.1	0.71
Body mass index—BMI (kg/m^2)	28 ± 4	26 ± 4	0.11
BMI < 26 kg/m^2 and height < 1.75 m	25 yes/72 no	26 yes/36 no	0.04*
Preoperative measurements			
Operated leg shorter	67 yes/30 no	42 yes/20 no	0.86
Preoperative absolute LLD (mm)	5 (Q_1 0/Q_3 10)	10 (Q_1 5/Q_3 10)	0.06
Preoperative relative LLD (mm)	10 (Q_1 5/Q_3 15)	10 (Q_1 5/Q_3 15)	0.95
Preoperative radiographic LLD (mm)	5 (Q_1 2/Q_3 8)	6 (Q_1 3/Q_3 10)	0.11
Preoperative WOMAC (mm)	2160 (Q_1 1770/Q_3 2280)	1850 (Q_1 1510/Q_3 2050)	0.04*
Postoperative outcomes			
Operated leg shorter	13 yes/84 no	15 yes/47 no	0.09
Postoperative absolute LLD (mm)	5 (Q_1 0/Q_3 10)	5 (Q_1 0/Q_3 10)	0.35
Postoperative relative LLD (mm)	5 (Q_1 0/Q_3 10)	10 (Q_1 5/Q_3 20)	0.01*
Postoperative radiographic LLD (mm)	5 (Q_1 3/Q_3 10)	5 (Q_1 2/Q_3 10)	0.45
Postoperative WOMAC (mm)	110 (Q_1 50/Q_3 290)	230 (Q_1 100/Q_3 660)	< 0.01*
Revisions with retained components	1 luxation, 1 infection, 2 hematomas	1 hematoma	0.65
Revisions with removed components (in the follow-up period over 5 years)	1 infection, 1 aseptic loosening	2 aseptic loosenings	0.64

Results are shown as subject counts, mean ± standard deviation or median with quartiles Q_1/Q_3. p values ≤ 0.05 are marked with an asterisk (*)

and smaller body dimensions with BMI < 26 kg/m^2 and body height < 1.75 m (odds ratio 2.49; 95% CI 1.14–5.41) were the only independent risk factors for self-perceived postoperative LLD after THA (Table 2). A increment of 5 mm in clinically measured relative LLD therefore increased the risk of self-reported LLD by 38%, while the constellation of BMI < 26 kg/m^2 and body height < 1.75 m increased this risk by almost 2.5-fold. In the multivariate analyses, postoperative absolute and radiographic LLD measurements had no significant predictive value for subjectively perceived LLD after THA.

Table 2 Binary logistic regression model with postoperative relative LLD measurement and covariables (gender, age, operated side, surgical approach, categorical variable of body dimensions BMI < 26 kg/m^2 and body height < 1.75 m) for the dependent variable of subjectively perceived LLD after total hip arthroplasty ($N=159$)

	B	SE	Exp(B)	95% confidence interval		p value
Gender (female)	−0.44	0.39	0.64	0.30	1.39	0.26
Age (years)	−0.01	0.02	0.99	0.96	1.02	0.66
Operated side (right)	−0.08	0.35	0.92	0.47	1.82	0.81
Surgical approach (anterolateral)	0.38	0.38	1.47	0.70	3.08	0.31
BMI < 26 kg/m^2 and body height < 1.75 m (–)	0.91	0.40	2.49	1.14	5.41	0.02*
Postoperative relative LLD (5 mm increments)	0.32	0.12	1.38	1.10	1.74	< 0.01*

Model summary Nagelkerke $R^2=0.13$; $p=0.02$. p values < 0.05 are marked with an asterisk (*)

B regression line coefficient, *SE* standard error, *Exp(B)* odds ratio

Discussion

Equal objective leg length discrepancy may cause different subjective perceptions in different patients, and the impact of gender, age, operated side, surgical approach, body height, body mass index and objective LLD measurements on self-perceived LLD after total hip arthroplasty has not been determined yet. In the presented study, we asked whether subjective feeling of postoperative leg length inequality is more likely reported by women, older participants, patients with shorter body height, subjects with lower BMI, patients with clinically measured absolute/relative LLD or radiographically measured LLD. Multivariate analyses showed clinical relative LLD measurements and combined body dimensions of BMI < 26 kg/m^2 and body height < 1.75 m were the only independent risk factors for subjectively perceived LLD after THA.

The main limitations of the presented paper include measurement errors of LLD measurements, lack of functional LLD testing with wooden blocks in the upright position and the uncontrolled confounding factor of concomitant spinal disease that could influence subjective LLD perception [14]. Clinical methods (absolute or relative) tape measurements were performed with the nearest reading of 5 mm [9], and measurement errors of radiographic methods were in the range of 1–3 mm [12]. Previous analyses have shown that such measurement methods have sufficient reliability and accuracy [15, 16]. Another limitation of our study is the uncontrolled confounding variable of concomitant spinal disease that could influence self-reported THA outcomes, particularly in patients with preoperative imbalanced sagittal alignment or deformity [17, 18], since there was no direct diagnostics performed to determine the prevalence of spinal disease in our study subjects. However, the impact of this confounding variable may have been very small, as the patients with larger body dimensions who could be expected to have more spinal problems (higher age, body height and BMI) [19] were actually less sensitive about the LLD issue. The number of cases in the presented series did not allow for statistical data stratification according to the endoprosthesis type. Nevertheless, previous studies have indicated the implant-specific increased risk of postoperative LLD in patients with high canal flare index who were implanted single-wedge femoral stems with cementless metaphyseal fixation [20]. Likewise, the impact of modular femoral necks on the ability to better restore leg length has also been assessed in a comparison with a single-surgeon–patient series with either Profemur Z or Zweymüller endoprosthesis; Profemur Z femoral stems on average had larger shear force magnitudes in the femoral neck than nonmodular Zweymüller, but there was no significant difference in postoperative LLD or clinical WOMAC score [21]. Type of endoprosthesis could therefore be considered one of potential confounding factors in patients with particular shapes of the proximal femur.

Less favorable WOMAC scores in the group of patients with self-perceived LLD (Table 1) confirm previous findings that THA patients who perceived a postoperative difference in their limb lengths reported worse clinical outcomes [10, 14]. It has been found the impact of LLD on the overall clinical satisfaction was detectable, but not considerable [9]. These studies already pointed out the relationship between LLD perception and patient dissatisfaction is complex and likely to be patient specific. In addition to physical patient-dependent factors analyzed in our study (age, gender, body dimensions), psychological factors might also play an important role in coping with postoperative THA outcome generally and LLD in particular (e.g., required levels of physical activity, personality traits) [24]. Identifying modifiable risk factors, rescheduling surgery until their optimization and informing the patient thoroughly about expected postoperative physical changes (including leg length) could thus contribute to better chances of successful THA outcome [14, 22].

Recent scientific reports have already pointed out that pelvic radiographic LLD [1] and absolute (i.e., true anatomical) LLD [23] do not correlate with patients' subjective perception of leg lengths, while other variables like the distance from the middle of the tibial plafond to ground, sagittal knee alignment and pelvic obliquity have more significant impact [23], resulting in strong association between the relative (i.e., apparent) LLD and patient perceived leg length inequality [24]. Gait analysis has indicated the impact of LLD on the human pelvis and spine is less pronounced under dynamic conditions when compared to static conditions [25], and patients with chronical real LLD develop more effective compensation strategies during gait in comparison with subjects with acute simulated LLD [26]. Findings of our study concur with these conclusions and bring them to a new quantitative level: Each additional 5 mm of clinically measured relative LLD increases risk of self-reported LLD by 38% and body dimensions also play an important role in subjective perceptions of this condition. Some modern navigational methods to equalize leg lengths at THA were validated only by pelvic radiographs [2], and the question therefore arises whether radiographic millimeter-exact leg equalization at the hip level really brings any benefit to the patient if at the same instance possible 0.5–1.0 cm length discrepancies are being ignored at other leg levels [1]. Leg length discrepancy in patients undergoing THA should therefore always be considered a potentially multifactorial problem (not merely a hip problem) that can only be evaluated with clinical/radiographic measurements of entire legs and sometimes with gait analysis [25, 26] and subsequent planning of auxiliary soft-tissue procedures [27].

Outcomes of the presented study emphasize the impact of smaller body height and lower BMI on increased risk of self-perceived postoperative LLD after THA. Previous studies on THA and obesity mainly focused on increased risk of catastrophic postoperative complications (e.g., higher infection and dislocation risks, modular implant femoral neck fracture) [11, 28, 29], but the issue of LLD has not been thoroughly studied in this regard. The impact of body dimensions on subjective LLD perception is not necessarily a merely physical phenomenon and could perhaps be explained by psychological factors, i.e., patients with smaller body height and lower BMI could be more sensitive and observant about perioperative changes of their body scheme. Patient education prior to THA should, of course, focus on reducing body weight of obese patients [11, 22], but in patients with normal BMI values, it is likewise important to conduct psychological preparation [30] for expected changes in leg lengths due to contracture release and the inevitable amount of elongation.

In conclusion, this is the first published study to show the impact of body dimensions of subjectively reported LLD after THA. Clinical relative LLD measurements are better predictors of self-perceived postoperative LLD than pelvic radiographic measurements, whereby the risk of self-reported LLD is increased by 38% for each additional 5 mm. Patients with smaller body height and lower body mass index will more likely report subjective leg length inequality at a given objective LLD, regardless of gender or age.

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Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest with respect to this study.

Ethical approval The study protocol was reviewed and approved by the National Medical Ethics Committee of the Republic of Slovenia on August 19, 2014, case No.# 97/08/14.

Human and animal rights All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study who provided prospectively collected data.

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