Influence of surgical approach on complication risk in primary total hip arthroplasty

Systematic review and meta-analysis

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Background and purpose — Systematic comparisons of anterior approach (A) versus posterior approach (P) in primary total hip arthroplasty (THA) have largely focused on perioperative outcomes. In this systematic review with meta-analysis, we compared complication risk of A versus P in studies of primary THA with at least 1-year mean follow-up.

Patients and methods — We performed a systematic review of prospective and retrospective studies with at least 1-year mean follow-up that reported complications of A and P primary THA. Complications included infection, dislocation, reoperation, thromboembolic event, heterotopic ossification, wound complication, fracture, and nerve injury. Random effects meta-analysis was used for all outcomes. Complication risk was reported as rate ratio (RR) to account for differential follow-up durations; values > 1 indicated higher complication risk with A and values < 1 indicated lower risk with A.

Results — 19 studies were included; 15 single-center comparative studies with 6,620 patients (2,278 A; 4,342 P) and 4 multi-center registries with 157,687 patients (18,735 A; 138,952 P). Median follow-up was 16 (12–64) months) with A and 18 (12–110) months with P. Anterior approach was associated with lower rate of infection (RR = 0.55, p = 0.002), dislocation (RR = 0.65, p = 0.03), and reoperation (RR = 0.84, p < 0.001). No statistically significant differences were observed in rate of thromboembolic event (RR = 0.59, p = 0.5), heterotopic ossification (RR = 0.63, p = 0.1), wound complication (RR = 0.93, p = 0.8), or fracture (RR = 1.0, p = 0.9). There was a higher rate of patient-reported nerve injury with A (RR = 2.3, p = 0.01).

Interpretation — Comparing A with P in primary THA, A was associated with lower risk of reoperation, dislocation, and infection, but higher risk of patient-reported nerve injury.

The durability of total hip arthroplasty (THA) is excellent with 10-year survivorship exceeding 90% (Hailer et al. 2015, Makela et al. 2014). All standard approaches to the hip have been shown to be safe and effective, with certain advantages and disadvantages of each approach (Mjaaland et al. 2017). While the anterior approach (A) has been increasingly used in the United States, little is known about the safety of the A relative to other common surgical approaches. Several groups (Higgins et al. 2015, Meermans et al. 2017, Putananon et al. 2018) have performed systematic reviews comparing the A with the posterior approach (P) in primary THA. However, follow-up durations of the included studies varied widely, with most studies having less than 1-year follow-up. Comparative safety evaluation of these surgical techniques over a longer period is warranted. The purpose of this systematic review with meta-analysis was to compare the complication risk of A versus P in studies with at least 1-year mean follow-up.

Methods

Literature search and data extraction

In accordance with the PRISMA guidelines, we searched MEDLINE and EMBASE for comparative studies of primary THA performed using the A or P. Therapeutic search terms consisting of THA and total hip arthroplasty were combined with the following surgical approach-specific search terms: anterior, direct, posterior, posterolateral, and Smith-Petersen. We also manually searched the Directory of Open Access Journals (DOAJ), Google Scholar, and the reference lists of included papers and relevant systematic reviews. No language or date restrictions were applied to the searches. The final search was conducted on June 30, 2017.

Study eligibility was determined by 2 independent researchers (LM, DF). Disagreements were resolved by discussion. Main inclusion criteria included comparison of A versus P in primary THA, predominant diagnosis of osteoarthritis, mean follow-up duration at least 1 year, and extractable complication data. Titles and abstracts were initially screened to exclude review articles, commentaries, letters, case reports, and obviously irrelevant studies. Full-texts of the remaining articles were retrieved and reviewed. Studies were excluded if patients received revision or bilateral THA. When multiple studies included overlapping series of patients, only the study with the largest sample size was included. Data were independently extracted from eligible peer-reviewed articles by the same 2 researchers. Data discrepancies were resolved by discussion.

Identification

| Records identified through database searching n = 337 | Records identified through other sources n = 3 |

Screening

| Records screened n = 340 | Records excluded n = 226 |

Eligibility

| Full-text articles assessed for eligibility n = 114 | Full-text articles excluded (n = 95):
– mean follow-up < 1 year, 27
– no relevant outcomes reported, 25
– no anterior vs. posterior groups, 20
– review paper, 12
– single arm study, 4
– letter/commentary, 3
– cross-sectional study, 1
– duplicate publication, 1
– revision THA, 1
– bilateral THA, 1 |

Inclusion

| Included articles n = 19 |

PRISMA study flow diagram.

Definitions and outcomes

When data were reported at multiple intervals during follow-up, the final value was extracted for analysis. Complications included infection, dislocation, reoperation (for any reason), thromboembolic event, heterotopic ossification, wound complication, fracture, and nerve injury. To account for differential follow-up durations, complication data were extracted by determining the number of events and then calculating the number of person-years in each group to determine incidence rates. Risk of bias in each study was assessed with the Cochrane Collaboration tool, which included evaluations of sequence generation, allocation concealment, blinding, incomplete outcome data, selective outcome reporting, and other sources of bias (Higgins et al. 2011).

Data analysis

We assumed heterogeneous effects among studies a priori and conservatively applied a random effects model for all outcomes. Denominators were adjusted to include the number of patients or hips, as appropriate. The rate ratio (RR) was the effect size statistic of interest, which indicates the ratio of incidence rates (events per person-year) between A and P. A RR value > 1 indicates higher complication incidence rate with A and a value < 1 indicates lower complication incidence rate with A. For each complication, the RR and 95% confidence interval (CI) were calculated in each study and pooled among all studies. Inconsistency in complication risk among studies was quantified with the I^2 statistic; values of ≤ 25%, 50%, and ≥ 75% represented low, moderate, and high inconsistency, respectively (Higgins et al. 2003). Publication bias was visually assessed with funnel plots (not shown) and quantitatively assessed using Egger's regression test. Post hoc random effects meta-regression using the Knapp–Hartung method (Knapp and Hartung 2003) was performed to assess the possible influence of study design, median surgery year,
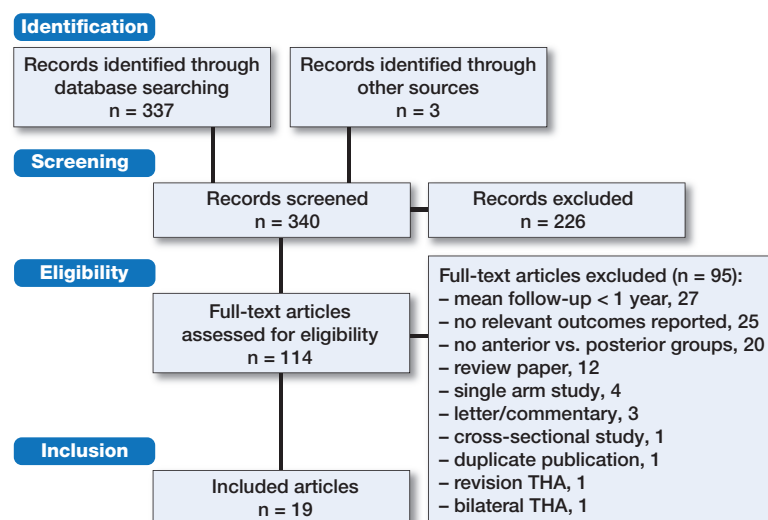
inclusion of learning cases, and follow-up duration on complication risk. P-values were 2-sided with a significance level < 0.05. Analyses were performed using Comprehensive Meta-analysis (version 3.3, Biostat, Englewood, NJ, USA).

Funding and potential conflicts of interest

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Results

Study selection

After screening 340 records for eligibility, 19 studies were included in this review, including 15 single-center comparative studies with 6,620 patients (2,278 A; 4,342 P) and 4 multi-center registries with 157,687 patients (18,735 A; 138,952 P). Primary reasons for study exclusion included mean follow-up less than 1 year (27 studies), complications not reported (25 studies), and no comparison of A with P (20 studies) (Figure).

Study and patient characteristics

This review included 4 randomized controlled trials, 1 prospective nonrandomized study, 10 retrospective studies, and 4 multicenter registries. Surgeries in each group occurred during the same period in 11 studies. In 7 studies, learning curve cases comprised some or all of the A group. Median follow-up duration was 16 months (range: 12–64 months) with A and 18 months (range: 12–110 months) with P. Comparing patients treated with A versus P, baseline patient characteristics were well matched for age (median 63 years per group), female sex (median 60% versus 58%), and BMI (median 28 per group)

Table 1. Study and patient characteristics

Study	Study design [a]	Treatment period	Parallel treatment period	Learning cases included	Mean follow-up, months A	P	Sample size [b] A	P	Mean age, years A	P	Female, % A	P	Mean BMI A	P
Comparative studies:														
Balasubramaniam et al. 2016	RN	2006–2011	No	Yes	12	12	50	42	63	57	50	67	31	30
Barrett et al. 2013	RCT	2010–2011	Yes	No	12	12	43	44	61	63	33	57	31	29
Batailler et al. 2017	RN	2013–2015	Yes	Yes	14	14	201	101	72	74	65	65	26	28
Fransen et al. 2016	RN	2012	Yes	Yes	12	12	45	38	64	63	67	63	25	28
Luo et al. 2016	RCT	2014	Yes	No	14	14	52	52	62	64	67	58	23	24
Malek et al. 2016	RN	2010–2014	Yes	No	18	18	265	183	71	70	56	53	29	29
Newman et al. 2016	RN	–	NR	NR	24	24	235	120	63	59	54	57	29	34
Rathod et al. 2014	RN	2007–2011	No	No	16	30	286	293	62	61	55	57	26	26
Rodriguez et al. 2014	PN	2010	Yes	No	12	12	60	60	60	59	53	57	27	28
Sugano et al. 2009	RN	2005–2007	No	NR	24	24	33	39	56	57	88	92	23	23
Taunton et al. 2014	RCT	2012	Yes	No	12	12	27	27	62	66	56	52	28	29
Tripuraneni et al. 2016	RN	2012–2015	Yes	Yes	14	13	66	66	60	60	61	61	28	28
Tsukada and Wakui 2015	RN	2000–2009	No	NR	64	110	139	177	67	62	90	83	23	24
Watts et al. 2015	RN	2010–2014	NR	NR	12	12	716	3,040	64	62	51	51	29	30
Zhang et al. 2006	RCT	2002–2004	Yes	NR	20	20	60	60	61	63	58	53	–	– [c]
Registries														
Amlie et al. 2014	RN	2008–2010	Yes	No	24	30	421	421	67	66	69	64	–	–
Mjaaland et al. 2017	RN	2008–2013	Yes	Yes	52	52	2,017	5,961	67	65	67	65	–	–
Sheth et al. 2015	RN	2001–2011	No	Yes	36	36	1,851	31,747	65	66	60	58	28	29
Zijlstra et al. 2017	RN	2007–2015	No	Yes	40	40	14,446	100,823	–	–	68	68	–	–

A = anterior approach; P = posterior approach; NR = not reported
[a] Study design: PN = prospective nonrandomized; RCT = randomized controlled trial; RN = retrospective nonrandomized.
[b] Reported as number of patients or hips.
[c] All patients with BMI ≤ 27 kg/m^2.

Table 2. Cochrane risk of bias assessment

Study	A	B	C	D	E	F	G
Comparative studies:							
Balasubramaniam et al. 2016	🔴	🔴	🔴	🔴	🔴	🟢	🟢
Barrett et al. 2013	🟡	🟡	🟡	🟡	🟡	🟢	🟢
Batailler et al. 2017	🔴	🔴	🔴	🔴	🔴	🟢	🟢
Fransen et al. 2016	🔴	🔴	🔴	🔴	🔴	🟡	🟢
Luo et al. 2016	🟡	🟡	🟡	🟡	🟡	🔴	🟡
Malek et al. 2016	🔴	🔴	🔴	🔴	🔴	🟢	🟢
Newman et al. 2016	🔴	🔴	🔴	🔴	🔴	🟢	🔴
Rathod et al. 2014	🔴	🔴	🔴	🔴	🔴	🟡	🟡
Rodriguez et al. 2014	🔴	🔴	🔴	🔴	🔴	🟡	🟢
Sugano et al. 2009	🔴	🔴	🔴	🔴	🔴	🟡	🟡
Taunton et al. 2014	🟢	🟢	🟡	🟡	🟡	🟢	🔴
Tripuraneni et al. 2016	🔴	🔴	🔴	🔴	🔴	🟡	🟡
Tsukada and Wakui 2015	🔴	🔴	🔴	🔴	🔴	🟡	🟡
Watts et al. 2015	🔴	🔴	🔴	🔴	🔴	🟡	🟡
Zhang et al. 2006	🔴	🟡	🟡	🟡	🟡	🔴	🟡
Registries							
Amlie et al. 2014	🔴	🔴	🔴	🔴	🔴	🟡	🟡
Mjaaland et al. 2017	🔴	🔴	🔴	🔴	🔴	🟢	🟡
Sheth et al. 2015	🔴	🔴	🔴	🔴	🔴	🟢	🟡
Zijlstra et al. 2017	🔴	🔴	🔴	🔴	🔴	🟢	🟢

Notes: 🟢 low bias risk; 🟡 uncertain bias risk; 🔴 high bias risk.
A. Random sequence generation
B. Allocation concealment
C. Blinding of participants
D. Blinding of personnel
E. Blinding of outcome assessment
F. Incomplete outcome data
G. Selective outcome reporting

(Table 1). The primary risks of bias were attributable to inclusion of retrospective nonrandomized studies (Table 2).

Complications

The A was associated with lower rates of infection (RR = 0.55, p = 0.002 from 7 studies), dislocation (RR = 0.65, p = 0.03 from 11 studies), and reoperation (RR = 0.84, p < 0.001 from 16 studies). In a subgroup analysis of infection, the rate of superficial (RR = 0.47, p = 0.5) and deep infection (RR = 0.23, p = 0.1) remained low with A, but neither was statistically significant. When explicitly reported, the most common reasons for reoperation were aseptic loosening, dislocation, fracture, and infection in the A group and dislocation, aseptic loosening, infection, and fracture in the P group. No statistically significant differences were observed in the rate of thromboembolic event (RR = 0.59, p = 0.5 from 4 studies), heterotopic ossification (RR = 0.63, p = 0.1 from 4 studies), wound complication (RR = 0.93, p = 0.8 from 5 studies), or fracture (RR = 1.0, p = 0.9 from 10 studies). Most fracture reports were of intraoperative periprosthetic fractures; however, type and time to fracture was not consistently reported. There was a higher rate of patient-reported nerve injury with A vs. P (RR = 2.3, p = 0.01 from 2 studies). Nerve injuries were described as patient-reported sensory deficit (Luo et al. 2016) or patient-reported nerve injury with no distinction between

Table 3. Complication rates with anterior versus posterior approach in primary total hip arthroplasty

Outcome	Studies	Event rate per 100 person-years		Effect size Rate ratio (95% CI) [a]	p-value	Heterogeneity (I^2), %	Publication bias (Egger's p-value)
		A	P				
Infection	7	0.2	0.4	0.55 (0.38–0.80)	0.002	0	0.5
Thromboembolic event	4	0.5	1.1	0.59 (0.14–2.43)	0.5	0	0.2
Heterotopic ossification	4	1.5	2.3	0.63 (0.35–1.13)	0.1	0	0.3
Dislocation	11	0.2	0.2	0.65 (0.44–0.95)	0.03	17	0.5
Reoperation	16	0.6	0.7	0.84 (0.75–0.93)	< 0.001	0	1.0
Wound	5	1.7	1.9	0.93 (0.54–1.63)	0.8	0	0.4
Fracture	10	0.3	0.1	1.02 (0.75–1.38)	0.9	0	0.2
Patient-reported nerve injury	2	3.0	1.3	2.31 (1.22–4.39)	0.01	0	[b]

Notes: A = anterior approach; P = posterior approach.
[a] Rate ratio >1 indicates higher complication incidence rate with anterior approach; rate ratio < 1 indicates lower complication incidence rate with anterior approach.
[b] Inadequate number of studies to calculate value.

Table 4. Subgroup analysis of study design on complication rates with anterior versus posterior approach in primary total hip arthroplasty

Outcome	Comparative studies		Registries		
	Studies	Rate ratio (95% CI) [a]	Studies	Rate ratio (95% CI) [a]	p-value [b]
Infection	6	0.66 (0.16–2.7)	1	0.55 (0.37–0.80)	0.8
Thromboembolic event	4	0.59 (0.14–2.4)	0	–	–
Heterotopic ossification	3	0.58 (0.30–1.2)	1	0.81 (0.24–2.7)	0.6
Dislocation	8	0.55 (0.17–1.8)	3	0.74 (0.39–1.4)	0.7
Reoperation	12	1.03 (0.60–1.8)	4	0.83 (0.72–0.95)	0.5
Wound	5	0.93 (0.54–1.6)	0	–	–
Fracture	9	1.7 (0.79–3.7)	1	0.93 (0.66–1.3)	0.2
Patient-reported nerve injury	1	5.0 (0.24–104)	1	2.2 (1.2–4.3)	0.6

[a] Rate ratio > 1 indicates higher complication incidence rate with anterior approach; RR < 1 indicates lower complication incidence rate with anterior approach.
[b] Comparison of rate ratio in comparative studies versus registries, derived from Knapp–Hartung random effects meta-regression model.

sensory and motor involvement (Amlie et al. 2014). For each complication, heterogeneity among studies was low and publication bias was not evident (Table 3).

Post hoc meta-regression
Post hoc meta-regression was performed to assess the possible influence of study design, median surgery year, inclusion of learning cases, and follow-up duration on complication risk. No covariate was statistically significantly associated with the risk of any complication. In comparative studies, there was no statistically significant difference between A vs. P in the rate of any complication. In registries, the rate of patient-reported nerve injury was higher with A while the rates of infection and reoperation were lower with A (Table 4).

Discussion
We conducted a systematic review and meta-analysis of comparative studies of A versus P primary THA with at least 1-year mean follow-up. An anterior approach was associated with a lower risk of reoperation, dislocation, and infection, but higher risk of patient-reported nerve injury. No difference was seen in the rate of thromboembolic event, heterotopic ossification, wound complication, or fracture. While heterogeneity or publication bias was not evident for any outcome, the possibility of such influences cannot be ruled out given the small number of studies reporting each complication.

A criticism of the A in primary THA is the presence of a learning curve, during which complication rates may be elevated. In an analysis of over 5,000 THA procedures, 50 or more A procedures were required to overcome the learning

curve (de Steiger et al. 2015). In a single-surgeon experience with the first 500 A cases, the most dramatic reduction in complication rates occurred after the first 100 cases (Hartford and Bellino 2017). We identified no substantial influence of learning case inclusion on complication rates in meta-regression although this analysis was limited since it was not possible to determine the percentage of the entire sample comprising learning cases.

We identified a higher rate of patient-reported nerve injury with A. In the study of Amlie et al. (2014), nerve injury was self-reported in 5.9% of A patients at 24 months follow-up and 3.3% of P patients at 30 months follow-up; however, there was no distinction between sensory or motor involvement. In another comparative study (Luo et al. 2016), sensory deficit was 3.8% with A and 0% with P at 14 months' follow-up. While comparative nerve injury data were limited to these 2 studies, a high incidence of sensory deficit with A has been reported in other studies (Bhargava et al. 2010, Goulding et al. 2010). This is primarily attributable to likely iatrogenic injury of the lateral cutaneous femoral nerve. Despite the higher patient-reported nerve injury rate with A, long-term functional limitations or higher reoperation rates are unlikely with these events based on the findings from other studies (Bhargava et al. 2010, Goulding et al. 2010).

In a meta-analysis comparing A and P (Higgins et al. 2015), there were no group differences in risk of intraoperative fracture and lower risk of dislocation with A. More recently, a systematic review compared anterior, posterior, and lateral approaches in primary THA (Meermans et al. 2017). In that review, complications were not systematically evaluated although the authors concluded that there were similar rates of complications between surgical approaches. In a network meta-analysis of randomized controlled trials (Putananon et al. 2018), complication risk was reported to be lower with P vs. A (1.0% vs. 1.4%); however, specific complications were not described. Among these reviews, follow-up duration varied considerably and was generally less than 1 year. Key differences in our meta-analysis are inclusion of only those studies with mean follow-up of at least 1 year, reporting of multiple specific complications, and statistical adjustment to account for differential follow-up periods among studies.

Several aspects of our meta-analysis are novel including the longest duration follow-up of any A versus P review and a comprehensive assessment of complication rates. There are also several limitations. First, despite the longest mean follow-up of any review on this topic, it must be acknowledged that data derived from 16 (A) to 18 (P) months median follow-up must be considered preliminary. Further, while the RR statistic allows for group comparison of event rates on a common scale (per person-year), event rates that are nonconstant with respect to time may complicate interpretation of these results. Second, while osteoarthritis was the predominant diagnosis in each study, reporting of THA indications was inconsistent and may have confounded outcomes.

Third, due to the small number of studies reporting certain complications, some complication estimates reported in this review may change with the addition of data by future studies. Further, the influence of study design on complication rates should be interpreted cautiously given the small number of studies for subgroup comparisons. Fourth, complication reporting was generally inconsistent among studies. Adherence to standardized complication reporting guidelines would greatly improve data transparency and consistency in the THA literature. Fifth, no conclusions regarding complication risk with anterolateral or lateral approaches in THA may be derived from this review. Finally, 14 of 19 included studies were retrospective in nature, which are inherently prone to bias.

In summary, comparing A with P in primary THA, A was associated with a lower rate of reoperation, dislocation, and infection, but a higher rate of patient-reported nerve injury.

Amlie E, Havelin L I, Furnes O, Baste V, Nordsletten L, Hovik O, Dimmen S. Worse patient-reported outcome after lateral approach than after anterior and posterolateral approach in primary hip arthroplasty. A cross-sectional questionnaire study of 1,476 patients 1–3 years after surgery. Acta Orthop 2014; 85(5): 463-9.

Balasubramaniam U, Dowsey M, Ma F, Dunin A, Choong P. Functional and clinical outcomes 244 following anterior hip replacement: a 5-year comparative study versus posterior approach. ANZ J Surg 2016; 86 (7-8): 589-93.

Barrett W P, Turner S E, Leopold J P. Prospective randomized study of direct anterior vs postero-lateral approach for total hip arthroplasty. J Arthroplasty 2013; 28(9): 1634-8.

Batailler C, Fary C, Batailler P, Servien E, Neyret P, Lustig S. Total hip arthroplasty using direct anterior approach and dual mobility cup: safe and efficient strategy against post-operative dislocation. Int Orthop 2017; 41 (3): 499-506.

Bhargava T, Goytia R N, Jones L C, Hungerford M W. Lateral femoral cutaneous nerve impairment after direct anterior approach for total hip arthroplasty. Orthopedics 2010; 33(7): 472.

de Steiger R N, Lorimer M, Solomon M. What is the learning curve for the anterior approach for total hip arthroplasty? Clin Orthop Relat Res 2015; 473(12): 3860-6.

Fransen B, Hoozemans M, Vos S. Direct anterior approach versus posterolateral approach in total hip arthroplasty : one surgeon, two approaches. Acta Orthop Belg 2016; 82 (2): 240-8.

Goulding K, Beaule P E, Kim P R, Fazekas A. Incidence of lateral femoral cutaneous nerve neuropraxia after anterior approach hip arthroplasty. Clin Orthop Relat Res 2010; 468(9): 2397-404.

Hailer N P, Lazarinis S, Makela K T, Eskelinen A, Fenstad A M, Hallan G, Havelin L, Overgaard S, Pedersen A B, Mehnert F, Karrholm J. Hydroxyapatite coating does not improve uncemented stem survival after total hip arthroplasty! Acta Orthop 2015; 86(1): 18-25.

Hartford J M, Bellino M J. The learning curve for the direct anterior approach for total hip arthroplasty: a single surgeon's first 500 cases. Hip Int 2017; 27(5): 483-8.

Higgins B T, Barlow D R, Heagerty N E, Lin T J. Anterior vs. posterior approach for total hip arthroplasty, a systematic review and meta-analysis. J Arthroplasty 2015; 30(3): 419-34.

Higgins J P, Altman D G, Gotzsche P C, Juni P, Moher D, Oxman A D, Savovic J, Schulz K F, Weeks L, Sterne J A, Cochrane Bias Methods G, Cochrane Statistical Methods G. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ 2011; 343: d5928.

Higgins JP, Thompson S G, Deeks J J, Altman D G. Measuring inconsistency in meta-analyses. BMJ 2003; 327(7414): 557-60.

Knapp G, Hartung J. Improved tests for a random effects meta-regression with a single covariate. Stat Med 2003; 22(17): 2693-710.

Luo Z, Chen M, Shangxi F, Hu F, Ni Z, Cheng P, Ji X, Wu K, Zhang X. [Comparison of clinical efficacy of total hip arthroplasty and lateral posterior approach for total hip arthroplasty]. Chinese J Med Sci 2016; 96: 2807-12.

Makela K T, Matilainen M, Pulkkinen P, Fenstad A M, Havelin L I, Engesaeter L, Furnes O, Overgaard S, Pedersen A B, Karrholm J, Malchau H, Garellick G, Ranstam J, Eskelinen A. Countrywise results of total hip replacement: an analysis of 438,733 hips based on the Nordic Arthroplasty Register Association database. Acta Orthop 2014; 85(2): 107-16.

Malek I A, Royce G, Bhatti S U, Whittaker J P, Phillips S P, Wilson I R, et al. A comparison 287 between the direct anterior and posterior approaches for total hip arthroplasty: the role of an 'Enhanced Recovery' pathway. Bone Joint J 2016; 98-B (6): 754-60.

Meermans G, Konan S, Das R, Volpin A, Haddad F S. The direct anterior approach in total hip arthroplasty: a systematic review of the literature. Bone Joint J 2017; 99-B(6): 732-40.

Mjaaland K E, Svenningsen S, Fenstad A M, Havelin L I, Furnes O, Nordsletten L. Implant survival after minimally invasive anterior or anterolateral vs. conventional posterior or direct lateral approach: an analysis of 21,860 total hip arthroplasties from the Norwegian Arthroplasty Register (2008 to 2013). J Bone Joint Surg Am 2017; 99(10): 840-7.

Newman E A, Holst D C, Bracey D N, Russell G B, Lang J E. Incidence of heterotopic ossification in direct anterior vs posterior approach to total hip arthroplasty: a 298 retrospective radiographic review. Int Orthop 2016; 40 (9): 1967-73.

Putananon C, Tuchinda H, Arirachakaran A, Wongsak S, Narinsorasak T, Kongtharvonskul J. Comparison of direct anterior, lateral, posterior and posterior-2 approaches in total hip arthroplasty: network meta-analysis. Eur J Orthop Surg Traumatol 2018; 28(2): 255-67.

Rathod P A, Bhalla S, Deshmukh A J, Rodriguez J A. Does fluoroscopy with anterior hip arthroplasty decrease acetabular cup variability compared with a nonguided posterior approach? Clin Orthop Relat Res 2014; 472 (6): 1877-85.

Rodriguez J A, Deshmukh A J, Rathod P A, Greiz M L, Deshmane P P, Hepinstall M S, et al. Does the direct anterior approach in THA offer faster rehabilitation and comparable safety to the posterior approach? Clin Orthop Relat Res 2014; 472 (2): 455-63.

Sheth D, Cafri G, Inacio M C, Paxton E W, Namba R S. Anterior and anterolateral approaches for THA are associated with lower dislocation risk without higher revision risk. Clin Orthop Relat Res 2015; 473 (11): 3401-8.

Sugano N, Takao M, Sakai T, Nishii T, Miki H, Nakamura N. Comparison of mini-incision total hip arthroplasty through an anterior approach and a posterior approach using navigation. Orthop Clin North Am 2009; 40 (3): 365-70.

Taunton M J, Mason J B, Odum S M, Springer B D. Direct anterior total hip arthroplasty yields more rapid voluntary cessation of all walking aids: a prospective, randomized clinical trial. J Arthroplasty 2014; 29 (9 Suppl): 169-72.

Tripuraneni K R, Munson N R, Archibeck M J, Carothers J T. Acetabular abduction and dislocations in direct anterior vs posterior total hip arthroplasty: a retrospective, matched cohort study. J Arthroplasty 2016; 31(10): 2299-302.

Tsukada S, Wakui M. Lower dislocation rate following total hip arthroplasty via direct anterior approach than via posterior approach: five-year-average follow-up results. Open Orthop J 2015; 9: 157-62.

Watts C D, Houdek M T, Wagner E R, Sculco P K, Chalmers B P, Taunton M J. High risk of wound complications following direct anterior total hip arthroplasty in obese patients. J Arthroplasty 2015; 30 (12): 2296-8.

Zhang X L, Wang Q, Jiang Y, Zeng B F. [Minimally invasive total hip arthroplasty with anterior incision]. Zhonghua Wai Ke Za Zhi 2006; 44 (8): 512-5.

Zijlstra W P, De Hartog B, Van Steenbergen L N, Scheurs B W, Nelissen R. Effect of femoral head size and surgical approach on risk of revision for dislocation after total hip arthroplasty. Acta Orthop 2017; 88(4): 395-401.