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## **Which approach of total hip arthroplasty is the best efficacy and least complication?**

Nitiwarangkul L *et al.* Umbrella review for approaches of THA

### **Abstract**

#### **BACKGROUND**

Total hip arthroplasty is as an effective intervention to relieve pain and improve hip function. Approaches of the hip have been exhaustively explored about pros and cons. The efficacy and the complications of hip approaches remains inconclusive. This study conducted an umbrella review to systematically appraise previous meta-analysis (MAs) including conventional posterior approach (PA), and minimally invasive surgeries as the lateral approach (LA), direct anterior approach (DAA), 2-incisions method, mini-lateral approach and the newest technique direct superior approach (DSA) or supercapsular percutaneously-assisted total hip (SuperPath).

#### **AIM**

To compare the efficacy and complications of hip approaches that have been published in all MAs and randomized controlled trials (RCTs).

#### **METHODS**

MAs were identified from MEDLINE and Scopus from inception until 2023. RCTs were then updated from the latest MA to September 2023. This study included studies which compared hip approaches and reported at least one outcome such as Harris Hip Score (HHS), dislocation, intra-operative fracture, wound complication, nerve injury, operative time, operative blood loss, length of hospital stay, incision length and VAS pain. Data were independently selected, extracted and assessed by two reviewers. Network MA and cluster rank and surface under the cumulative ranking curve (SUCRA) were estimated for treatment efficacy and safety.

## RESULTS

Finally, twenty-eight MAs (40 RCTs), and 13 RCTs were retrieved. In total 47 RCTs were included for reanalysis. The results of corrected covered area show high degree (13.80). Among 47 RCTs, most of the studies were low risk of bias in part of random process and outcome reporting, while other domains were medium to high risk of bias. DAA significantly provided higher HHS at three months than PA [pooled unstandardized mean difference (USMD): 3.49, 95% confidence interval (CI): 0.98, 6.00 with SUCRA: 85.9], followed by DSA/SuperPath (USMD: 1.57, 95%CI: -1.55, 4.69 with SUCRA: 57.6). All approaches had indifferent dislocation and intraoperative fracture rates. SUCRA comparing early functional outcome and composite complications (dislocation, intra-operative fracture, wound complication and nerve injury) found DAA was the best approach followed by DSA/SuperPath.

## CONCLUSION

DSA/SuperPath had better earlier functional outcome than PA, but still could not overcome the result of DAA. This technique might be the other preferred option with acceptable complications.

**Key Words:** <sup>7</sup> Total hip arthroplasty; Total hip replacement; Approach; Supercapsular percutaneously-assisted total hip; Harris Hip Score; Intra-operative fracture

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**Core Tip:** Total hip arthroplasty (THA) is as an effective intervention to relieve pain and improve hip function. Many minimally invasive surgeries have been proposed to preserve soft tissue and promote early recovery. Direct anterior approach and direct superior approach, the most popular and the newest technique, respectively have been

explored about pros and cons to compare with previous conventional techniques. The results are still inconclusive. This is the first umbrella review that has included all systematic reviews and meta-analysis comparing the efficacy and complications among approaches of THA for patients in term of post-operative functional score and post-operative complications.

## 7

### **INTRODUCTION**

Total hip arthroplasty (THA) is an effective intervention for improvement of pain and hip function<sup>[1-4]</sup>. More than 1.4 million hip replacements are annually performed worldwide. Hip prosthesis has been established since 1950s<sup>[5]</sup>. Porous structure or bottom profile dimples of the ball type promote longevity, osteointegration and medullary revascularization<sup>[6-9]</sup>. Various bearing surfaces (*i.e.*, titanium on polyethylene, cobalt chromium molybdenum, ceramic, and polycrystalline diamond<sup>[10]</sup>), have been applied to optimize corrosive quality, stress reduction, contact pressure<sup>[11]</sup> and prevent osteolysis<sup>[2-4]</sup>. Survival of total hip replacement is not only influenced by deformation of prosthesis<sup>[2]</sup>, acetabular cup inclination, body mass index (BMI)<sup>[3]</sup> and effects of pressure during walking<sup>[12,13]</sup>, but it also depends on surgical approaches to the hip joint. Meanwhile, bleeding, wound problems, abductor muscle disruption and dislocation/instability were considered as common complications<sup>[7]</sup>.

Approaches of the hip have been exhaustively explored about pros and cons. A conventional technique is the posterior approach (PA) by cutting short external rotator muscles. This technique provides a good exposure, but increases risk of hip dislocation<sup>[14]</sup>. Many minimally invasive surgeries (MIS) have been proposed to preserve soft tissue; promote early recovery, and lessen complications<sup>[6]</sup>. Direct lateral approach (LA) preserves posterior joint capsule, but may jeopardize superior gluteal nerve. Direct anterior approach (DAA) through an intermuscular plane<sup>[14]</sup> is the most popular, and preferred technique. Two-incision method combined anterior, to allow the acetabular cup placement, and posterior directions<sup>[15]</sup>. Mini-lateral approach (LMIS) can be performed with a shorter oblique skin incision without splitting or detaching muscle.

Recently, direct superior approach (DSA) and supercapsular percutaneously-assisted total hip (SuperPath) are the newest MIS technique for PA by sparing the iliotibial band, obturator externus and quadratus femoris muscle<sup>[16,17]</sup>. An evidence from a randomized controlled trial (RCT) indicated that DSA was preferred to the posterolateral approach in terms of blood loss, gait, and muscle strength<sup>[18]</sup>. SuperPath technique allowed shorter incision length<sup>[19]</sup>, and early mobilization<sup>[17]</sup>.

Many systematic reviews and meta-analysis (MA) of THA<sup>[6,20-46]</sup> showed that DAA could be beneficial for early hip function, and post-operative pain than other techniques<sup>[6,23,28,30,34-36,42,44,45]</sup>. Contradictory, it came up with a higher incidence of nerve injury<sup>[28,32,42,45,47]</sup>, and inconsistent issues of other complications<sup>[6,31,37,39,44]</sup>. PA may be inferior to DAA, and other various hip approaches including DSA/SuperPath. A recent network MA reported conventional PA contributed to poorer hip function, insignificant complications, but had the advantage in shorter operative time when compared to DAA, DSA/SuperPath, MIS direct LA/anterolateral/PA<sup>[48]</sup>. Nevertheless, clinical important outcomes including hip dislocation, intra-operative fracture and wound complications were not considered. A comprehensive review of relevant MAs should lead to properly identify the best hip approach. This study hypothesized that various hip approaches provide different results. Therefore, <sup>1</sup>an umbrella review was aimed to systematically appraise the quality of previous evidences and re-estimate the treatment effects and complication rates among THA approaches by re-pooling data. Update searching was filtered by the last search of when the previous MA was done, and at least 13 RCTs were recently added. A risk-benefit assessment (RBA) was also performed.

## <sup>1</sup>**MATERIALS AND METHODS**

<sup>6</sup>An umbrella review of MAs was conducted with the following guidelines in the Preferred Reporting Items for Systematic Reviews and MA (PRISMA)<sup>[49]</sup>. The review protocol was registered in the international prospective register of systematic reviews; PROSPERO (CRD42017072580).

### ***Located studies and study selection***

PubMed and Scopus databases were used to identify data from an inception to the date of September 2023. Search terms were constructed according to patients (P), interventions (I), comparators (C), and outcomes (O), see Supplementary Table 1.

This study was divided into two parts, previous MAs exploration and update searching. First, previous MAs were explored and RCTs in those studies were retrieved. Previous MAs were eligible if they met the following criteria: systematic reviews of RCTs, use MA to obtain pooled effect size for outcomes that we are interested in among PA, LA, DAA, 2-incisions, LMIS, and DSA/SuperPath. One reviewer selected studies by titles and abstracts and another reviewer randomly checked about the accuracy. If a decision could not be made, the full texts were retrieved and reviewed. Any disagreement was resolved by discussion with a supervisor.

Second, updated searching was done and filtered from the last search of previous MA. Eligible RCTs were published in English language, studied in patients who underwent primary THA, compared with any pair among the hip approaches and reported at least one of the interested outcomes; Harris Hip Score (HHS), dislocation, intra-operative fracture, operative time, length of hospital stays, incision length, operative blood loss, wound complication, nerve injury, and visual analog scale (VAS). Studies were excluded if patients underwent bilateral THAs, or revision THA; had severe soft tissue damage; fracture or severe acetabular bone loss; computered navigation or robotic assisted surgery; modified techniques of each interested approach, *i.e.*, mini-posterior, modified PA; learning curve of surgeon; reported only long term outcomes; RCTs with randomization of other interventions rather than interested hip approaches, RCTs with randomization only of intervention groups comparing with one control group; and multiple publications.

### ***Intervention and outcome of interests***



The interested interventions were PA, LA, DAA, 2-incisions, LMIS, and DSA/SuperPath. The primary outcomes were HHS, dislocation, and intra-operative fracture. HHS ranged from 0 to 100, at follow up time of  $\leq$  three months, six months, and one year<sup>[50]</sup>. Dislocation was diagnosed if a femoral head was not in the acetabular cup within the six-month post-operative period. Intra-operative fracture was defined as any fracture which occurred in the operative field.

The secondary outcomes were operative time (time at incision to the last stitch of wound closure, minutes), length of hospital stay (d), incision length (cm), operative blood loss (mL), wound complication (dehiscence, infection), nerve injury and VAS (0-10).

### ***Risk of bias assessment***

Risk of bias assessment was performed using a Risk of Bias Assessment Tool for Systematic Reviews (ROBIS)<sup>[51]</sup>, which comprises three phases. Phase I assessed whether a systematic review/MA <sup>1</sup> clearly stated their PICOS. Phase II assessed bias in the review process of study eligible criteria, identification and study selection, data collection and study appraisal and synthesis/finding. They were rated as low, high or unclear. The last phase was an overall judgement.

For each RCT, study quality was evaluated using The Cochrane Collaboration's tool for assessing risk of bias in randomized trials<sup>[52]</sup> This includes random sequence allocation, allocation concealment, blinding patients and assessors, blinding outcome assessment, incomplete outcome data management, and selective outcome reporting.

### ***Data extraction***

<sup>1</sup> Characteristics of MAs were extracted including, databases used, last search date, number of included studies, type of intervention (PA, LA, DAA, 2-incisions, LMIS, and DSA/SuperPath), risk of bias assessment and outcomes of interest. <sup>2</sup> Specific methods and findings were also extracted including pooled effect size along with 95% confidence

interval (CI), pooling methods (fixed and random effects), heterogeneity assessment (i.e., I<sup>2</sup> and Cochran Q test) and publication bias.

Furthermore, characteristics of the individual RCTs included in MA were also extracted to re-pool with updated RCTs beyond the last searching of previous MAs. Data was extracted including with general characteristics of study, patients and intervention-outcomes. Additionally, contingency data of interventions and outcomes were extracted for pooling dichotomous outcomes. Number of patients and mean value along with standard deviation were retrieved for pooling with continuous data.

The data extraction was independently performed by two reviewers. Disagreement was resolved by discussion with a supervisor.

### *Statistical analysis*

The statistical methods of this study were reviewed by Sasivimol Rattanasiri, PhD, Associate Professor from the Department of Clinical Epidemiology and Biostatistics, Faculty of Medicine Ramathibodi Hospital, Mahidol University. Characteristics, results and risk of bias of MAs were summarized by using descriptive analysis. Overlapping studies were assessed using corrected covered area (CCA) to detect that previous individual RCTs were not included in previous MAs more than once. The citation matrix was constructed which assigned previous MAs in the first column and included individual RCTs in rows. The CCA was then classified as slight, moderate, high, and very high overlap if the CCA was 0% to 5%, 6% to 10%, 11% to 15%, and > 15%, respectively. Higher CCA reflects lower additional information across MAs.

This study also re-estimated the pooled effect size [e.g., risk ratio (RR) or unstandardized mean difference (USMD)] using the data from individual RCTs that were included in these MAs and adding more studies by updating from the last search in the year 2019 from previous MAs. A fixed-effects model was used, if there was no evidence of heterogeneity, otherwise, the random-effects model was applied. Heterogeneity was present if *P* value for *Q* test was < 0.100 and *I*<sup>2</sup> was 25% or higher. Publication bias was determined by asymmetrical funnel plots and significant Egger's



test. Constructed contour-enhanced funnel plots were further performed to distinguish between heterogeneity and publication bias.

A network MA (NMA) was conducted in the re-pooling process to estimate the mixed relative intervention effects by a two-stage approach: Six interventions (PA, reference, LA, DAA, 2-incisions, LMIS, and DSA/SuperPath) were coded as one, two, three, four, five, and six. Regression analysis with logit-link for dichotomous and identity-link for continuous outcomes was applied for each study. The coefficients and variance-covariance were then pooled using a multivariate MA with a consistency model, and estimated relative treatment effects. Inconsistency assumption was checked using a global Chi-square test. An adjusted funnel plot was constructed for publication bias assessment. <sup>3</sup> Probability of being the best intervention was estimated and ranked using surface under cumulative ranking curve (SUCRA). All analyses were performed using STATA version 17.0, StataCorp, College Station, Texas, United States. <sup>4</sup>  $P$  value < 0.05 was considered statistical significance.

## **RESULTS**

For the first part, 28 MAs<sup>[6,20-46]</sup> were identified from PubMed and Scopus according to PICOS, including 61 RCTs. Finally, 40 RCTs were retrieved from previous MAs after screening for the eligible criteria and removing duplicated studies. For the second part, a total number of 85 and 101 studies were identified from PubMed and Scopus according to PICO. Thirteen RCTs met the inclusion criteria, and six duplicated studies were found. Finally, 47 RCTs<sup>[18,19,53-97]</sup> from both parts were included (Figure 1). The results of estimated CCA showed high degree (13.80%) of overlapping of individual RCTs among previous MAs (Supplementary Table 2).

### **<sup>1</sup> *Characteristics of eligible studies***

The characteristics of 28 MAs are described in Table 1. Seventeen MAs included only RCTs. Twelve MAs including both RCTs and observational studies. These studies were

published between the year 2014 and 2023 and had total sample sizes which ranged from 475 to 283036.

<sup>4</sup> Flow chart of excluded studies with explanations according to PRISMA guidelines was constructed. Most studies were from USA, Europe and China. The numbers of included studies were thirteen PA *vs* DAA<sup>[53,54,56-58,69,75,84,85,87,88,94,96]</sup>, thirteen LA *vs* DAA<sup>[55,59,61,67,71,74,76,77,79,81,82,86,97]</sup>, seven PA *vs* LA<sup>[63,65,83,90-92,95]</sup>, one PA *vs* two-incision<sup>[60]</sup>, one PA *vs* LA *vs* two-incision<sup>[72]</sup>, three LMIS *vs* LA<sup>[66,70,80]</sup>, seven DSA/SuperPath *vs* PA<sup>[18,19,64,68,73,78,93]</sup> and two DSA/SuperPath *vs* LA<sup>[62,89]</sup>. The mean age was 51 to 76 years, BMI 21-31 kg/m<sup>2</sup>, 13%-65% male and 20%-100% had hip osteoarthritis (Table 2).

### *Risk of bias assessment*

<sup>3</sup> Among 47 RCTs, most studies were low risk of bias for random sequence generation (89.4%), allocation concealment (36.2%), blinding of participants (29.8%), blinding outcome assessment (46.8%), incomplete outcome of data (40.4%), and selective outcome reporting (85.1%) (Figure 2, Supplementary Table 3). The ROBIS results from multiple reviews is shown in Figure 3.

### *Direct MA*

**Primary outcomes:** According to functional outcomes, DAA significantly yielded the highest HHS at three months when compared with PA and LA (USMD: 2.79, 95%CI: 1.03, 4.55; and USMD: 3.76, 95%CI: 1.67, 5.85, respectively). There was no clinically significant difference of HHS at six months (DAA *vs* LA) and one year (DAA *vs* PA, DAA *vs* LA). All pairwise comparisons between hip approaches revealed no statistically significant dislocation and intraoperative fracture rate (Supplementary Tables 4 and 5).

**Secondary outcomes:** DSA/SuperPath and DAA had significant longer operative time than PA (18.55 min, 95%CI: 4.84, 32.27; and 17.17 min, 95%CI: 10.91, 23.42, respectively). DAA allowed shorter length of hospital stays than PA and LA (-0.39 d, 95%CI: -0.57, -0.21; and -0.57 d, 95%CI: -1.02, -0.11, orderly). Incision lengths of DAA and

DSA/SuperPath were significantly shorter than PA (USMD: -2.2; 95%CI: -4.21, -0.19; and USMD: -4.38, 95%CI: -5.61, -3.16, respectively). Furthermore, DAA also had significantly shorter incision length than LA with USMD of -1.27 (95%CI: -2.22, -0.33).

Among, the newer techniques (DAA and DSA/SuperPath) DAA encountered with higher operative blood loss than PA with USMD of 52.02 mL (95%CI: 3.77, 100.27), but DSA yielded a better result when compared to PA with USMD of -17.54 mL (-66.09, 31.01). DAA significantly increased nerve injury when compared to PA with pooled RR 13.57 (95%CI: 3.17, 58.10). There was no significant nerve injury and wound complication rates among other treatment pairs (Supplementary Tables 4 and 5).

Heterogeneity was detected and explored for source of heterogeneity (Supplementary Table 6). Funnel plots and countour enhanced funnel plot were constructed (Supplementary Figure 1).

#### **NMA**

Network maps were constructed according to the interventions and outcomes (Figure 4).

**Primary outcomes:** DAA significantly demonstrated higher HHS at three months and one year than PA (pooled USMD: 3.49, 95%CI: 0.98, 6.00; and pooled USMD: 1.76, 95%CI: 1.12, 2.40, respectively). DAA also contributed higher HHS at one year when compared to 2-incisions, DSA/SuperPath, LA, and PA with pooled USMDs 3.70 (95%CI: 0.62, 6.78), 1.34 (95%CI: 0.39, 2.29), 1.17 (95%CI: 0.20, 2.14), and 1.76 (95%CI: 1.12, 2.40), respectively (Table 3).

DAA was the best rank of HHS at three and twelve months with the SUCRAs of 85.9 and 90.7, respectively. Whereas at 6 mo, DSA was the best rank with the SUCRAs of 61.1. Six approaches demonstrated non-significant difference in dislocation and intraoperative fracture rates. The lowest dislocation rate was found in DAA (SUCRA: 61.5) followed by LMIS (SUCRA: 50.9) and the lowest intraoperative fracture rate was from DAA (SUCRA: 70.7) followed by PA (SUCRA: 67.3).

SUCRAs of benefit in improving HHS and risk in dislocation and fracture, indicated that DAA was the highest in HHS, dislocation and intra-operative fractures. PA was the worst in HHS with the third rank of dislocation and the second rank of intraoperative fracture.

**Secondary outcomes:** The newer techniques, LA, DAA, LMIS and DSA/SuperPath, took significantly longer operative time than the conventional PA with USMD of 10.38 (2.04, 18.71) min, 15.38 (8.64, 22.12) min, 23.86 (4.25, 43.47) min, and 18.74 (9.69, 27.79) min, respectively. In contrast, among the newer techniques, DSA took significantly shorter length of hospital stay than other approaches except for LMIS with USMD of -1.67 (-3.28, -0.06) d, -1.36 (-2.36, -0.35) d, -2.08 (-3.12, -1.04) d, and -1.56 (-2.44, -0.69) d when compared with 2-incisions, DAA, LA and PA, respectively.

For incision length, DSA/SuperPath was the shortest and PA was the longest one. Conversely, operative blood loss was higher among the newer techniques without statistical significance. Regarding to the complications, LMIS tended to have the highest wound infection rate. The 2-incisions and DAA had significantly more nerve injury rate than PA with USMDs of 18.97 (2.41, 149.62) and 9.82 (3.06, 31.58). Moreover, DAA was -1.35 (95%CI: -2.55, -0.14) and -0.70 (95%CI: -1.18, -0.23) significantly lower VAS at post-operative day one and two than PA. There was no significant difference between other approach pairs (Table 4).

The first and the second probability of being the best interventions were as follows: Operative time (PA and LA), length of hospital stay (DSA/SuperPath and DAA), incision length (DSA/SuperPath and LMIS), operative blood loss (LA and PA), wound complication (PA and 2-incisions), and nerve injury (PA and LMIS). Benefit in raising HHS and risks of operative outcomes were simultaneously plotted. A clustered ranking plot was constructed for comparing overall complications and early functional outcome of each approach (Figure 5).

Adjusted funnel plots showed no evidence of asymmetry except the results of HHS at twelve weeks, length of hospital stays and incision length (Supplementary Figure 2). No

evidence of inconsistency assumption was found among direct MA and NMA except those in HHS at six months, and incision length (Supplementary Table 7).

## **DISCUSSION**

This umbrella review summarized the findings of multiple MAs comparing each THA approach in terms of efficacy and complications. DAA was the highest rank for HHS, dislocation and intra-operative fractures. DSA/SuperPath might be beneficial for short incision length and length of hospital stay. PA diminished operative blood loss and operative time. On the other hand, PA was the worst in HHS with the third rank of dislocation and the second rank of intraoperative fracture.

For primary outcomes, HHS, which is the clinician-based outcome measure frequently used to evaluate patients following a THA, showed advantages in DAA from most of the previous MAs<sup>[30,34,44,98]</sup>. The results of this study re-pooled RCTs after adding DSA/SuperPath, the newest technique, showed that DAA remained in the first ranking without statistical significance from the second rank DSA/SuperPath. Even though DAA was significantly higher HHS at three months than PA (USMD: 3.49, 95%CI: 0.98, 6.00), the differences did not meet the minimally clinical significance (15.9-18.0 points)<sup>[99]</sup>. Positive properties of DAA in functional outcomes may be explained by (1) the approach through tensor fascia lata and sartorius interval without muscle dissection, (2) preserved posterior soft tissue, (3) less muscle damage supported by low level of creatinine kinase and inflammatory responses [Interleukin (IL): IL-6, IL-8, IL-10, and tumor necrotic factor (TNF)] as well as good soft tissue response in magnetic resonance imaging<sup>[59]</sup>, (4) less post-operative pain, excellent cadence, pelvic tilt and sagittal balance<sup>[96]</sup>, and (5) good recovery outcomes with unnecessary for physical therapy<sup>[74]</sup>. DSA/SuperPath preserved the gluteus minimus and tensor fasciae latae muscles<sup>[17,16]</sup>. This could promote post-operative ambulatory and functional status<sup>[16]</sup>. Without a learning curve, DSA allowed good prosthesis positioning and comparable functional outcomes to the mini-posterolateral hip approach<sup>[100]</sup>.

For dislocation rate, which is the most common complication of THA, especially in PA, DAA still provided the best result without significant difference from other approaches. Its effects in prevention of hip dislocation are from (1) the supine position allows anatomical pelvic alignment and precise acetabular cup positioning<sup>[96]</sup>, and (2) fluoroscopic guidance supports cup and stem placement and preserves posterior soft tissue. LMIS was the second rank for hip dislocation. This method avoids muscular detachment by approaching between the tensor fascia lata and gluteus medius. Preservation of the gluteus medius would preclude Trendelenburg gait, secure good hip function<sup>[66,70,80]</sup>, and might prevent hip dislocation.

Lastly, the intra-operative fracture rate showed disadvantages in DAA from most of the previous MAs studies<sup>[28,30,37]</sup>. The results from this study re-pooled RCTs stated in the opposite way. DAA became the first rank in lowering intra-operative fracture rate instead of PA. This could be surgoen's experience or familiarity with DAA to prevent fracture complication. DAA required performer's experience of at least 60-100 cases to achieve optimal operative time, blood loss, and acceptable complications<sup>[101-103]</sup>. Mastery in this technique may help in femoral canal broaching and component application to prevent intra-operative fracture. PA was the second rank for intra-operative fracture such as one calcar crack<sup>[53]</sup>. DSA/SuperPath still had higher rate of intra-operative fracture than DAA and PA without statistical significance. DSA/SuperPath may cause intra-operative fracture from limited proximal femoral exposure, and is unsuitable for proximal femoral deformity<sup>[17]</sup>.

For secondary outcomes, previous MAs show pros and cons between DAA and PA. DAA was better in terms of short length of hospital stay, incision length and decreased VAS pain. The downsides were raised nerve injury rate, operative time, and operative blood loss. Nerve injury can be avoided by (1) placing the incision more lateral than a traditional sartorius/tensor fascia lata interval, and (2) carefully performing fascial and subcutaneous layer closures to preclude the lateral femoral cutaneous nerve entrapment<sup>[104]</sup>. High blood loss was associated with long operation time<sup>[56]</sup>. Prolonged operative time and high blood loss may be caused by (1) the fracture table and



fluoroscopic set up time, (2) posterior capsular bleeding due to limited visualization, and (3) stretching and detaching the tensor fascia lata in MIS technique<sup>[85]</sup>. However, some studies<sup>[35,36,44]</sup> reported insignificantly different complications from other techniques. The results of this study re-pooled RCTs, which showed DSA/SuperPath allowed more advantages over PA, and could diminish length of hospital stay, incision length, wound complication and nerve injury rate more than DAA. For operative blood loss, DSA/SuperPath tended to have better results than DAA, but could not overcome PA. Even though SuperPath required shorter incision length than PA, soft tissue injury and long operative time contributed to high blood loss<sup>[19]</sup>.

This study has strengths in many aspects. First, this study summarized all MAs assessing hip approaches in terms of efficacy and complications. The recently proposed DSA/SuperPath was considered and ranked in the analysis. In addition, this study also re-pooled data and updated new studies since the last MAs in 2023 and added RBA. All included studies were RCTs, the best available evidences with good quality (low risk of biases). However, limitations could not be avoided. The quality assessment of included MAs and RCTs indicated that some included RCTs were at high risk of bias. The results cannot be considered as independent set of evidence due to high degree of overlap with CCA of 11.0%-15.0% (14.9%). Exclusion of mini-posterior and modified posterior techniques precluded evaluation of the results among these approaches.

For clinical application, the best approaches regarding the primary outcome and the major complication were DAA, followed by DSA/SuperPath with lower overall complication rate (Figure 5). Surgeons need to select according to their familiarity. For training program, the DAA and DSA/SuperPath techniques are recommended. Lastly, DSA/SuperPath might be the good choice for surgeons who are familiar with PA in order to achieve better outcomes and reduce major complications. Furthermore, DSA/SuperPath is another choice of MIS technique for surgeons who are not familiar in anterior direction, which can lead to many problems such as infection<sup>[105]</sup> or vascular injury<sup>[106]</sup>. Also, DSA has been reported as “no learning curve” compared to mini-PA<sup>[100]</sup>.

## **CONCLUSION**

This umbrella review and updated re-pooling data from RCTs published indicate that DSA/SuperPath which is the newest technique has better functional outcome (HHS) than PA, but still cannot overcome the result of DAA. In terms of complications, it is still in the middle between PA and DAA. Future study should be conducted to update the information of DSA/SuperPath and directly compare with DAA and PA.

## **ARTICLE HIGHLIGHTS**

### ***Research background***

Various hip approaches have been proposed for total hip arthroplasty. Many systematic reviews and meta-analysis (MAs) reported their benefits for hip function, and pain relief. The disadvantages, such as hip dislocation, intra-operative fracture, blood loss, and nerve injury, depended on types of surgical techniques. This is the first umbrella review comprehensively compared six approaches including direct anterior (DAA), direct superior (DSA)/supercapsular percutaneously-assisted total hip (SuperPath), lateral (LA), mini-lateral (LMIS), 2-incision, and posterior approach (PA) techniques.

### ***Research motivation***

Comparisons of different hip approaches, particularly DSA/SuperPath to PA in terms of important clinical outcomes and complications have not yet been in previous network MAs.

### ***Research objectives***

To compare hip approaches including DAA, DSA/SuperPath, LA, LMIS, 2-incision, and PA. The best approach is determined by constructing cluster ranking plots between benefits of Harris Hip Score (HHS), and risks of hip dislocation, intra-operative fracture, wound complication, and nerve injury.

### ***Research methods***

MA and updated randomized controlled trials (RCTs) were identified from large two databases (MEDLINE and Scopus) up to year 2023. Two evaluators independently assessed the quality, and extracted data from included studies comparing hip approaches, and reporting at least one outcomes of interest. This review was performed with robust methodology by re-pooling data, network MA, surface under cumulative ranking curve, corrected covered area for overlapping studies, and publication bias assessment.

### ***Research results***

Considering HHS, clinical important outcomes and complications, re-pooled 47 RCTs demonstrated DAA was the best hip approach followed by DSA/SuperPath. These evidences were from moderate quality RCTs without publication bias. High degree of CCA indicated overlapping between RCTs among previous MAs.

### ***Research conclusions***

DSA/SuperPath provided good functional outcome in the middle between PA and DAA. Without learning curve, this approach might be useful for surgeons who are familiar to PA or inexperienced in DAA to avoid adverse outcomes.

### ***Research perspectives***

Future study should be conducted to update the information of DSA/SuperPath and directly compare with DAA and PA.

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## **Figure Legends**

**Figure 1 PRISMA flow diagram of the included studies.** RCT: Randomized controlled trial.

**Figure 2 Risk of bias assessment of individual randomized controlled trial.**

**Figure 3 Chart of a Risk of Bias Assessment Tool for Systematic Reviews from multiple reviews.**



**Figure 4 Network map, the line's width is proportional to the numbers of studies and the node size is proportional to the sample size.** Numbers along the lines refer to numbers of studies/numbers of patients corresponding to direct comparisons. HHS: Harris Hip Score; DAA: Direct anterior approach; LA: Lateral approach; PA: Posterior approach; DSA/SuperPath: Direct superior approach or Supercapsular percutaneously-assisted total hip; LMIS: Mini-lateral approach; 2-incision: 2 incisions approach.

**Figure 5 Cluster rank for network meta-analysis.** Cluster rank between Harris Hip Score at 3 mo and composite outcomes of complication (dislocation, intra-operative fracture, wound complication, and nerve injury). HHS: Harris Hip Score; PA: Posterior approach; LA: Lateral approach; DAA: Direct anterior approach; 2-incision: 2 incisions approach; LMIS: Mini-lateral approach; DSA/SuperPath: Direct superior approach or Supercapsular percutaneously-assisted total hip; SUCRA: Surface under the cumulative ranking curve.

Table 1 Characteristics of the 28 included meta-analysis studies

Ref.	Last search	Study design	Number of included studies	Sample size	Intervention	Reference	Outcome
Putananon <i>et al</i> <sup>[37]</sup> , 2018	February, 2017	RCT	14	1201	PA//LA//DAA/PA2	PA	HHS, VAS, complications
Higgins <i>et al</i> <sup>[6]</sup> , 2015	February, 2014	RCT & nRCT	17	2302	PA/DAA	PA	HHS, VAS, blood loss, intra-operative fracture, operative time, length of hospital stay, dislocation
Miller <i>et al</i> <sup>[34]</sup> , 2018	June, 2017	RCT & nRCT	13	1044	PA/DAA	PA	HHS, dislocation, intra-operative fracture, wound infection
Wang <i>et al</i> <sup>[44]</sup> , 2018	June, 2018	RCT	9	754	PA/DAA	PA	HHS, VAS, incision length, operative time, length of hospital stay, operative blood loss, intra-operative fracture, dislocation
Miller <i>et al</i> <sup>[35]</sup> , 2018	June, 2017	RCT	7	609	PA/DAA	PA	Incision length, length of hospital stay,

operative time,  
operative blood loss,  
pain score,  
complication

Kucukdurmaz January, 2018 RCT & 17/1 1543 PA/LA/DAA PA  
*et al*<sup>[39]</sup>, 2019 nRCT  
 HHS, operative time,  
incision length, VAS,  
neurapraxia, intra-  
operative fracture,  
wound infection,  
dislocation

Jia *et al*<sup>[28]</sup>, August, 2016 RCT & 4/16 7377 PA//DAA PA  
 nRCT  
 HHS, length of hospital  
stay, operative time,  
VAS, dislocation,  
neurapraxia, intra-  
operative fracture

Wang *et al*<sup>[43]</sup>, October, 2018 RCT 5 475 LA/DAA LA  
 HHS, VAS, operative  
time, operative blood  
loss, length of hospital  
stay, complication

Migliorini *et* September, 2019 RCT & 20/39 10675 PA/LA/DAA PA  
*al*<sup>[32]</sup>, 2021 nRCT  
 Dislocation, nerve  
injury, revision

Migliorini *et* October, 2019 RCT & 13//23 4383 PA//LA//DAA PA  
*al*<sup>[33]</sup>, 2020 nRCT  
 Length of hospital stay,  
operative time,

Cha <i>et al</i> <sup>[22]</sup> , 2020	October, 2019	RCT	8	673	PA/LA/DAA	PA	operative blood loss
Peng <i>et al</i> <sup>[36]</sup> , 2020	November, 2019	RCT	7	600	PA/DAA	PA	Operative time, Operative blood loss HHS, VAS, operative time, operative blood loss, length of hospital stay, incision length
Docter <i>et al</i> <sup>[24]</sup> , 2020	June, 2019	RCT & nRCT	19//50	283036	PA//LA//DAA	PA	Dislocation, intra- operative fracture, infection
Yang <i>et al</i> <sup>[45]</sup> , 2020	June, 2019	RCT	11	932	PA/DAA	PA	VAS, neurapraxia, intra-operative fracture, infection, dislocation, operative time, operative blood loss, length of hospital stay
Chen <i>et al</i> <sup>[23]</sup> , 2020	2020	RCT & nRCT	4 /14	34873	PA/DAA	PA	HHS, VAS, operative time, operative blood loss, length of hospital stay, dislocation, intra- operative fracture
Sun <i>et al</i> <sup>[42]</sup> , 2021	June, 2019	RCT & nRCT	3 /6	22698	PA/DAA	PA	HHS, operative time, operative blood loss,

Awad <i>et al</i> <sup>[21]</sup> , 2021	RCT & 7/22 nRCT	8576	PA/DAA	PA	length of hospital stay, complication HHS, operative time, operative blood loss, length of hospital stay, complication
Huerfano <i>et al</i> <sup>[27]</sup> , 2021	RCT & 5/20 nRCT	7172	PA/DAA/	PA	Dislocation
Gazendam <i>et al</i> <sup>[25]</sup> , 2022	RCT	2339	PA/LA/ALA/DAA	PA	HHS, VAS, length of hospital stay, complication
Ge <i>et al</i> <sup>[26]</sup> , 2021	RCT & 3//3 nRCT	526	DSA/SuperPath/PA	PA	HHS, operative time, operative blood loss, incision length, VAS, length of hospital stay
Joseph <i>et al</i> <sup>[29]</sup> , 2022 2023	RCT	730	DSA/SuperPath/PA	PA	HHS, operative time, operative blood loss, incision length, VAS, length of hospital stay, complication
Lazaru <i>et al</i> <sup>[31]</sup> , 2021	RCT	998	DAA/PA	PA	HHS, operative time, operative blood loss, incision length, VAS

O'Connor <i>et al</i> <sup>[106]</sup> , 2021	No RCT	15	1872	DAA//non-DAA	PA, ALA, LA	Infection
Ramadanov <i>et al</i> <sup>[39]</sup> , 2021	RCT	16	1392	DSA/SuperPath//DA A/PA	PA	HHS, operative time, operative blood loss, incision length, VAS
Ramadanov <i>et al</i> <sup>[40]</sup> , 2021	RCT	24	2074	DSA/SuperPath//DA A/PA	PA	HHS, operative time, operative blood loss, incision length, VAS, complication
Ramadanov <i>et al</i> <sup>[41]</sup> , 2022	RCT	20	1501	SuperPath/DAA/PA	PA	HHS, operative time, operative blood loss, incision length
Ramadanov <i>et al</i> <sup>[38]</sup> , 2022	RCT	14	1021	SuperPath/PA	PA	HHS, operative time, operative blood loss, incision length, VAS, complication
Zhou <i>et al</i> <sup>[46]</sup> , 2022	RCT	15	1450	DAA <i>vs</i> PA DAA <i>vs</i> LA	PA & LA	HHS, operative time, length of hospital stay, complication
Ang <i>et al</i> <sup>[20]</sup> , 2023	RCT	24	2010	DAA <i>vs</i> LA <i>vs</i> PA	PA	HHS, operative time, length of hospital stay, complication

RCT: Randomized controlled trial; nRCT: Not randomized controlled trial; HHS: Harris hip score; VAS: Visual analog scale; PA: Posterior approach; LA: Lateral approach; DAA: Direct anterior approach; 2-incision: 2 incisions approach; LMIS: Mini-lateral approach; DSA/SuperPath: Direct superior approach or Supercapsular percutaneously-assisted total hip.



**Table 2 Characteristics of included 47 randomized controlled trials**

Ref.	Country	Mean age	BMI	Male (%)	ASA	F/U (wk)	Diagnosis (% OA)	Intervention
Li <i>et al</i> <sup>[68]</sup> , 2021	China	76.35	22.85	53.13	NR	NR	NR	DSA/SuperPath <i>vs</i> PA
Ulivì <i>et al</i> <sup>[18]</sup> , 2021	Italy	72.98	23.51	37.78	NR	26	NR	DSA/SuperPath <i>vs</i> PA
Meng <i>et al</i> <sup>[19]</sup> , 2021	China	64.90	23.09	42.50	2.35	52	NR	DSA/SuperPath <i>vs</i> PA
Rykov <i>et al</i> <sup>[84]</sup> , 2021	Netherlands	62.50	28.20	41.30	1.59	52	NR	DAA <i>vs</i> PA
Cao <i>et al</i> <sup>[56]</sup> , 2020	China	61.90	24.90	42.31	NR	26	NR	DAA <i>vs</i> PA
Nistor <i>et al</i> <sup>[76]</sup> , 2020	Romania	62.63	28.15	41.07	NR	52	NR	DAA <i>vs</i> LA
Meng <i>et al</i> <sup>[73]</sup> , 2019	China	51.00	21.49	100.00	1.66	52	NR	DSA/SuperPath <i>vs</i> PA
Wang <i>et al</i> <sup>[91]</sup> , 2019	China	55.39	23.09	59.26	NR	52	100.00	LA <i>vs</i> PA
Moerenhout <i>et al</i>	Switzerland	69.66	27.10	52.73	1.90	260	NR	DAA <i>vs</i> PA

*al*<sup>[75]</sup>, 2020

Li <i>et al</i> <sup>[67]</sup> , 2019	China	62.00	23.26	73.33	NR	26	42.00	DAA <i>vs</i> LA
Bon <i>et al</i> <sup>[54]</sup> , 2019	France	68.12	26.58	44.00	NR	NR	100.00	DAA <i>vs</i> PA
Ouyang <i>et al</i> <sup>[78]</sup> , 2018	China	56.00	23.19	70.83	2.21	NR	20.83	DSA/SuperPath <i>vs</i> PA
Zomar <i>et al</i> <sup>[97]</sup> , 2018	Canada	60.11	29.73	52.56	NR	12	100.00	DAA <i>vs</i> LA
Taunton <i>et al</i> <sup>[88]</sup> , 2018	United States	64.51	29.48	51.00	NR	52	100.00	DAA <i>vs</i> PA
Brismar <i>et al</i> <sup>[55]</sup> , 2018	Sweden	66.75	26.88	35.00	1.61	NR	51.00	DAA <i>vs</i> LA
Reichert <i>et al</i> <sup>[81]</sup> , 2018	Germany	62.58	28.20	NR	NR	NR	100.00	DAA <i>vs</i> LA
Takada <i>et al</i> <sup>[86]</sup> , 2018	Japan	62.60	24.40	13.33	NR	NR	100.00	DAA <i>vs</i> LA
Xie <i>et al</i> <sup>[93]</sup> , 2017	China	65.54	23.84	66.30	NR	52	100.00	DSA/SuperPath <i>vs</i> PA
Cheng <i>et al</i> <sup>[57]</sup> , 2017	Australia	61.28	28.01	45.20	1.96	12	100.00	DAA <i>vs</i> PA

Xu <i>et al</i> <sup>[94]</sup> , 2017	China	58.27	24.49	60.92	NR	NR	NR	DAA <i>vs</i> PA
Nistor <i>et al</i> <sup>[77]</sup> , 2017	Romania	63.75	28.04	40.00	NR	NR	100.00	DAA <i>vs</i> LA
Rosenlund <i>et al</i> <sup>[83]</sup> , 2017	Denmark	61.03	27.51	65.00	1.32	52	NR	LA <i>vs</i> PA
Rykov <i>et al</i> <sup>[85]</sup> , 2017	Netherlands	NR	NR	NR	NR	NR	84.80	DAA <i>vs</i> PA
Zhao <i>et al</i> <sup>[96]</sup> , 2017	China	63.53	NR	NR	NR	NR	NR	DAA <i>vs</i> PA
Anta-Díaz <i>et al</i> <sup>[59]</sup> , 2016	Spain	64.14	26.75	52.52	NR	52	100.00	DAA <i>vs</i> LA
Parvizi <i>et al</i> <sup>[79]</sup> , 2016	United States	NR	NR	NR	NR	NR	100.00	DAA <i>vs</i> LA
Lou <i>et al</i> <sup>[69]</sup> , 2016	China	NR	NR	NR	NR	NR	NR	LA <i>vs</i> PA
Christensen <i>et al</i> <sup>[58]</sup> , 2015	United States	64.71	30.78	47.10	NR	NR	NR	DAA <i>vs</i> PA
Mjaaland <i>et al</i> <sup>[74]</sup> , 2015	Norway	66.42	27.65	33.50	1.85	NR	100.00	DAA <i>vs</i> LA
Vicente <i>et al</i> <sup>[90]</sup> , 2015	Brazil	55.94	27.38	55.36	NR	24	52.68	LA <i>vs</i> PA



Restrepo <i>et al</i> <sup>[82]</sup> , 2010	United States	59.95	25.18	39.39	2.13	NR	NR	DAA <i>vs</i> LA
Mayr <i>et al</i> <sup>[71]</sup> , 2009	Switzerland	68.02	27.99	42.42	NR	NR	NR	DAA <i>vs</i> LA
Meneghimi <i>et al</i> <sup>[72]</sup> , 2009	United States	54.00	26.00	NR	NR	NR	NR	2-incision <i>vs</i> LA <i>vs</i> PA
Witzleb <i>et al</i> <sup>[92]</sup> , 2009	Germany	55.88	27.75	48.33	NR	12	56.70	LA <i>vs</i> PA
Tingti <i>et al</i> <sup>[89]</sup> , 2017	China	65.42	23.97	46.10	NR	60	NR	SuperPath <i>vs</i> LA
Yuan <i>et al</i> <sup>[64]</sup> , 2018	China	75.03	22.54	55.56	NR	72	NR	SuperPath <i>vs</i> PA
Dongwei <i>et al</i> <sup>[62]</sup> , 2016	China	58.21	NR	NR	NR	12	100.00	SuperPath <i>vs</i> LA

RCT: Randomized controlled trial; BMI: Body mass index (kg/m<sup>2</sup>); OA: Osteoarthritis; NR: Not reported; PA: Posterior approach; LA: Lateral approach; DAA: Direct anterior approach; 2-incision: 2 incisions approach; LMIS: Mini-lateral approach; DSA/SuperPath: Direct superior approach or Supercapsular percutaneously assisted total hip.

**Table 3 Network meta-analysis results of primary outcomes**

<b>Risk ratio/unstandardized mean difference (95%CI)</b>							
	<b>PA</b>	<b>LA</b>	<b>DAA</b>	<b>2-incision</b>	<b>LMIS</b>	<b>DSA/SuperPath</b>	
HHS ≥ 3 mo							
PA	[27.4; 0.0]	0.74 3.72)	(-2.24, 3.49 6.00)	(0.98, 0.83 9.16)	(-7.50, 0.02 10.17)	(-10.13, 1.57 (-1.55, 4.69)	
LA	-0.74 2.24)	(-3.72, [42.7; 0.5]	2.75 5.52)	(-0.02, 0.09 8.81)	(-8.64, -0.72 8.99)	(-10.43, 0.83 (-2.91, 4.57)	
DAA	-3.49 0.98)	(-6.00, - 2.75 0.02)	(-5.52, [85.9; 47.5]	-2.66 5.99)	(-11.31, -3.47 6.63)	(-13.56, -1.92 (-5.67, 1.83)	
2-incision	-0.81 12.24)	(-13.86, -0.09 8.64)	(-8.81, 2.66 11.31)	(-5.99, [45.5; 20.7]	-0.81 12.24)	(-13.86, 0.74 (-8.12, 9.61)	
LMIS	-0.02 10.13)	(-10.17, 0.72 10.43)	(-8.99, 3.47 13.56)	(-6.63, 0.81 13.86)	(-12.24, [41.0; 22.1]	1.55 (-8.85, 11.95)	
DSA/SuperPath	-1.57 1.55)	(-4.69, -0.83 2.91)	(-4.57, 1.92 5.67)	(-1.83, -0.74 8.12)	(-9.61, -1.55 8.85)	(-11.95, [57.6; 9.2]	
HHS 6 mo							
PA	[42.2; 3.0]	-0.21 1.25)	(-1.67, 0.22 1.39)	(-0.95, 1.85 17.84)	(-14.14, NR	0.35 (-0.84, 1.53)	
LA	0.21	(-1.25, [33.2; 4.1]	0.43	(-1.50, 2.06	(-13.94, NR	0.55 (-0.88, 1.98)	

	1.67)			2.36)		18.05)			
DAA	-0.22	(-1.39,	-0.43	(-2.36,	[55.9; 19.3]	1.63	(-14.41,	NR	0.13 (-1.62, 1.87)
	0.95)		1.50)			17.67)			
2-incision	-1.85	(-17.84,	-2.06	(-18.05,	-1.63 (-17.67,	[57.6; 55.2]	NR		-1.50 (-17.52,
	14.14)		13.94)		14.41)				14.51)
LMIS	NR		NR		NR		NR	NR	
DSA/SuperPath	-0.35	(-1.53,	-0.55	(-1.98,	-0.13 (-1.87,	1.50 (-14.51,	NR		[61.1; 18.4]
	0.84)		0.88)		1.62)	17.52)			
HHS 1 yr									
PA	[27.5; 0.0]	0.60	(-0.55,	1.76	(1.12,	-1.93	(-4.95,	1.43	(-2.16, 0.42 (-0.28, 1.12)
		1.74)		2.40)		1.08)		5.02)	
LA	-0.60	(-1.74,	[54.8; 0.0]	1.17	(0.20,	-2.53	(-5.75,	0.83	(-2.57, -0.18 (-1.52, 1.17)
	0.55)			2.14)		0.69)		4.23)	
DAA	-1.76	(-2.40,	- 1.17 (-2.14,	- [90.7; 55.4]	-3.70 (-6.78,	- 0.34	(-3.87,	-1.34 (-2.29,	-0.39)
	1.12)		0.20)		0.62)	3.20)			
2-incision	1.93	(-1.08,	2.53	(-0.69,	3.70	(0.62,	[6.0; 0.6]	3.36	(-1.32, 2.35 (-0.74, 5.45)
	4.95)		5.75)		6.78)			8.04)	
LMIS	-1.43	(-5.02,	-0.83	(-4.23,	0.34	(-3.20,	-3.36	(-8.04,	[70.8; 43.7] -1.01 (-4.66, 2.65)
	2.16)		2.57)		3.87)		1.32)		
DSA/SuperPath	-0.42	(-1.12,	0.18	(-1.17,	1.34	(0.39,	-2.35	(-5.45,	1.01 (-2.65, [50.2; 0.3]



# Dislocation

PA	0.28)	1.52)	2.29)	0.74)	4.66)	
	[50.8; 8.6]	1.01	(0.34, 0.90	(0.52, NR	1.00	(0.08, 1.28 (0.29, 5.57)
		2.97)	1.57)		11.81)	
LA	0.99	(0.34, [49.8; 15.2]	0.90	(0.29, NR	0.99	(0.11, 1.27 (0.20, 7.90)
	2.94)		2.74)		9.14)	
DAA	1.11	(0.64, 1.11	(0.37, [61.5; 21.9]	NR	1.11	(0.09, 1.41 (0.29, 6.82)
	1.92)	3.40)			13.27)	
2-incision	NR	NR	NR	NR	NR	NR
LMIS	1.00	(0.08, 1.01	(0.11, 0.90	(0.08, NR	[50.9; 37.3]	1.28 (0.07, 22.70)
	11.85)	9.28)	10.85)			
DSA/SuperPath	0.78	(0.18, 0.79	(0.13, 0.71	(0.15, NR	0.78	(0.04, [37.2; 17.0]
	3.42)	4.90)	3.41)		13.88)	
Intra-operative fracture						
PA	[67.3; 17.2]	1.33	(0.49, 0.96	(0.36, 1.84	(0.19, 2.19	(0.22, 1.75 (0.37, 8.35)
		3.58)	2.57)	18.35)	21.84)	
LA	0.75	(0.28, [49.0; 6.6]	0.72	(0.26, 1.39	(0.12, 1.65	(0.21, 1.31 (0.21, 8.36)
	2.02)		1.95)	15.36)	13.12)	
DAA	1.05	(0.39, 1.39	(0.51, [70.7; 30.3]	1.93	(0.17, 2.29	(0.23, 1.83 (0.29, 11.65)

2-incision	2.82)	3.78)		22.48)	22.94)
	0.54	(0.05, 0.72	(0.07, 0.52	(0.04, [41.5; 19.9]	1.19 (0.05, 0.95 (0.06, 15.27)
LMIS	5.39)	8.00)	6.03)		28.49)
	0.46	(0.05, 0.61	(0.08, 0.44	(0.04, 0.84	(0.04, [33.6; 15.1] 0.80 (0.05, 12.88)
DSA/SuperPath	4.55)	4.84)	4.36)	20.20)	
	0.57	(0.12, 0.76	(0.12, 0.55	(0.09, 1.05	(0.07, 1.25 (0.08, [37.9; 10.9]
	2.73)	4.84)	3.47)	16.97)	20.20)

Values are the risk ratio 95% confidence interval (95%CI) of dichotomous outcomes (dislocation and intra-operative fracture) or the mean difference (95%CI) of continuous outcomes comparing surgical intervention in column with surgical intervention in row (reference). Values of diagonal line in square brackets are surface under the cumulative ranking curve area and probability of being best surgical approaches (highest HHS and low risk of dislocation, intra-operative fracture). HHS: Harris Hip Score; PA: Posterior approach; LA: Lateral approach; DAA: Direct anterior approach; 2-incision: 2 incisions approach; LMIS: Mini-lateral approach; DSA/SuperPath: Direct superior approach or Supercapsular percutaneously-assisted total hip; NR: Not reported.

**Table 4 Network meta-analysis results of secondary outcomes**

Risk ratio/Unstandardized mean difference (95% CI)						
	PA	LA	DAA	2 incisions	LMIS	DSA/SuperPath
Operative time						
PA	[98.6; 93.2]	10.38 (2.04, 18.71)	15.38 (8.64, 22.12)	21.00 (-4.27, 46.27)	23.86 (4.25, 43.47)	18.74 (9.69, 27.79)
LA	-10.38 (-18.71, -2.04)	[70.7; 0.7]	5.01 (-2.66, 12.68)	10.62 (-15.99, 37.24)	13.49 (-4.26, 31.23)	8.36 (-3.12, 19.84)
DAA	-15.38 (-22.12, -8.64)	-5.01 (-12.68, 2.66)	[46.0; 0.0]	5.62 (-20.54, 31.78)	8.48 (-10.86, 27.81)	3.35 (-7.58, 14.29)
2-incision	-21.00 (-46.27, 4.27)	-10.62 (-37.24, 15.99)	-5.62 (-31.78, 20.54)	[33.8; 5.3]	2.86 (-29.13, 34.85)	-2.26 (-29.11, 24.58)
LMIS	-23.86 (-43.47, -4.25)	-13.49 (-31.23, 4.26)	-8.48 (-27.81, 10.86)	-2.86 (-34.85, 29.13)	[19.6; 0.8]	-5.12 (-26.26, 16.01)
DSA/SuperPath	-18.74 (-27.79, -9.69)	-8.36 (-19.84, 3.12)	-3.35 (-14.29, 7.58)	2.26 (-24.58, 29.11)	5.12 (-16.01, 26.26)	[31.4; 0.0]
Length of hospital stay						
PA	[45.5; 0.0]	0.52 (-0.36, 1.39)	-0.21 (-0.84, 0.43)	0.11 (-1.29, 1.51)	0.32 (-2.12, 2.76)	-1.56 (-2.44, -0.69)
LA	-0.52 (-1.39, 0.36)	[16.9; 0.0]	-0.72 (-1.52, 0.07)	-0.41 (-1.92, 1.10)	-0.20 (-2.48, 2.08)	-2.08 (-3.12, -1.04)
DAA	0.21 (-0.43, 0.84)	0.72 (-0.07, 1.52)	[61.3; 0.7]	0.31 (-1.17, 1.80)	0.52 (-1.89, 2.94)	-1.36 (-2.36, -0.35)
2-incision	-0.11 (-1.51, 1.29)	0.41 (-1.10, 1.92)	-0.31 (-1.80, 1.17)	[42.6; 3.0]	0.21 (-2.52, 2.94)	-1.67 (-3.28, -0.06)
LMIS	-0.32 (-2.76, 2.12)	0.20 (-2.08, 2.48)	-0.52 (-2.94, 1.89)	-0.21 (-2.94, 2.52)	[35.8; 6.3]	-1.88 (-4.38, 0.62)
DSA/SuperPath	1.56 (0.69, 2.44)	2.08 (1.04, 3.12)	1.36 (0.35, 2.36)	1.67 (0.06, 3.28)	1.88 (-0.62, 4.38)	[97.9; 90.0]
Incision length						
PA	[4.0; 0.0]	-1.53 (-3.86, 0.81)	-2.54 (-4.64, -0.45)	NR	-3.42 (-7.99, 1.16)	-5.15 (-7.29, -3.01)
LA	1.53 (-0.81, 3.86)	[31.1; 0.0]	-1.02 (-3.00, 0.96)	NR	-1.89 (-5.82, 2.04)	-3.62 (-6.52, -0.72)

DAA	2.54 (0.45, 4.64)	1.02 (-0.96, 3.00)	[55.4; 1.8]	NR	-0.87 (-5.27, 3.53)	-2.60 (-5.45, 0.24)
2-incision	NR	NR	NR	NR	NR	NR
LMIS	3.42 (-1.16, 7.99)	1.89 (-2.04, 5.82)	0.87 (-3.53, 5.27)	NR	[66.5; 24.5]	-1.73 (-6.62, 3.16)
DSA/SuperPath	5.15 (3.01, 7.29)	3.62 (0.72, 6.52)	2.60 (-0.24, 5.45)	NR	1.73 (-3.16, 6.62)	[92.9; 73.7]
Operative blood loss						
PA	[61.6; 10.7]	-25.66 (-117.26, 65.95)	23.03 (-56.18, 102.24)	46.00 (-185.02, 277.02)	59.67 (-177.38, 296.72)	23.02 (-56.58, 102.62)
LA	25.66 (-65.95, 117.26)	[75.9; 35.1]	48.69 (-47.77, 145.15)	71.66 (-176.86, 320.18)	85.33 (-133.30, 303.96)	48.68 (-62.19, 159.55)
DAA	-23.03 (-102.24, 56.18)	-48.69 (-145.15, 47.77)	[44.0; 5.6]	22.97 (-221.26, 267.19)	36.64 (-202.33, 275.61)	-0.01 (-108.84, 108.82)
2-incision	-46.00 (-277.02, 185.02)	-71.66 (-320.18, 176.86)	-22.97 (-267.19, 221.26)	[41.9; 24.3]	13.67 (-317.33, 344.68)	-22.98 (-267.33, 221.37)
LMIS	-59.67 (-296.72, 177.38)	-85.33 (-303.96, 133.30)	-36.64 (-275.61, 202.33)	-13.67 (-344.68, 317.33)	[34.4; 17.5]	-36.65 (-281.79, 208.49)
DSA/SuperPath	-23.02 (-102.62, 56.58)	-48.68 (-159.55, 62.19)	0.01 (-108.82, 108.84)	22.98 (-221.37, 267.33)	36.65 (-208.49, 281.79)	[42.2; 6.8]
Wound complication						
PA	[70.0; 16.2]	2.26 (0.72, 7.06)	1.31 (0.59, 2.88)	0.80 (0.04, 18.03)	5.45 (0.60, 49.61)	1.00 (0.15, 6.79)
LA	0.44 (0.14, 1.38)	[31.0; 0.9]	0.58 (0.18, 1.87)	0.36 (0.02, 7.11)	2.41 (0.36, 16.00)	0.44 (0.05, 4.11)
DAA	0.77 (0.35, 1.69)	1.73 (0.53, 5.62)	[54.8; 5.2]	0.62 (0.03, 14.29)	4.18 (0.45, 38.77)	0.77 (0.10, 6.09)
2-incision	1.24 (0.06, 27.95)	2.81 (0.14, 56.24)	1.62 (0.07, 37.72)	[68.8; 46.2]	6.79 (0.20, 234.54)	1.24 (0.03, 48.08)
LMIS	0.18 (0.02, 1.67)	0.41 (0.06, 2.75)	0.24 (0.03, 2.22)	0.15 (0.00, 5.09)	[12.5; 1.3]	0.18 (0.01, 3.41)
DSA/SuperPath	1.00 (0.15, 6.79)	2.26 (0.24, 20.99)	1.31 (0.16, 10.38)	0.80 (0.02, 31.03)	5.45 (0.29, 101.44)	[62.8; 30.2]
Nerve injury						
PA	[79.7; 25.6]	2.97 (0.89, 9.97)	9.82 (3.06, 31.58)	18.97 (2.41, 149.62)	1.08 (0.11, 10.20)	1.00 (0.02, 49.35)

LA	0.34 (0.10, 1.13)	[49.4; 0.5]	3.30 (1.22, 8.94)	6.38 (0.81, 50.31)	0.36 (0.05, 2.41)	0.34 (0.01, 19.93)
DAA	0.10 (0.03, 0.33)	0.30 (0.11, 0.82)	[17.9; 0.0]	1.93 (0.22, 16.92)	0.11 (0.01, 0.93)	0.10 (0.00, 5.96)
2-incision	0.05 (0.01, 0.42)	0.16 (0.02, 1.24)	0.52 (0.06, 4.54)	[9.0; 0.2]	0.06 (0.00, 0.94)	0.05 (0.00, 4.35)
LMIS	0.93 (0.10, 8.81)	2.76 (0.41, 18.42)	9.13 (1.07, 77.77)	17.63 (1.07, 291.08)	[75.1; 31.9]	0.93 (0.01, 83.77)
DSA/SuperPath	1.00 (0.02, 49.35)	2.97 (0.05, 176.30)	9.82 (0.17, 575.31)	18.97 (0.23, 1564.11)	1.08 (0.01, 97.00)	[69.0; 41.8]

Values are the risk ratio (95% confidence interval; 95%CI) of dichotomous outcomes (wound complication and nerve injury) or the mean difference (95%CI) of continuous outcomes [operative time (min), length of hospital stay (d), incision length (cm), operative blood loss (mL) comparing surgical interventions in column with surgical intervention in row (reference)]; Values of diagonal line in square brackets are surface under the cumulative ranking curve area and probability of being best surgical approaches (lowest operative time, length of hospital stay, incision length, operative blood loss and low risk of wound complication, nerve injury). PA: Posterior approach; LA: Lateral approach; DAA: Direct anterior approach; 2-incision: 2 incisions approach; LMIS: Mini-lateral approach; DSA/SuperPath: Direct superior approach or Supercapsular percutaneously-assisted total hip; NR: not report.

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