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Robotic-assisted compared with conventional total hip arthroplasty: systematic review and meta-analysis

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ABSTRACT

Background Robotic-assisted total hip arthroplasty (THA) allows for accurate preoperative planning and component positioning, potentially enhancing implant survival and long-term outcomes. The relative efficacy and safety of robotic-assisted and conventional THA, however, are unclear. This systematic review and meta-analysis compared the safety and efficacy of robotic-assisted and conventional THA.

Methods Medline, Embase and the Cochrane Library were comprehensively searched in September 2017 to identify studies comparing the safety and efficacy of robotic-assisted and conventional THA. Seven studies were included. Data of interest were extracted and analysed using Review Manager 5.3.

Results The seven included studies involved 1516 patients, with 522 undergoing robotic-assisted and 994 undergoing conventional THA. Compared with conventional THA, robotic-assisted THA was associated with longer surgical time (not significant); lower intraoperative complication rates (OR: 0.12, 95% CI: 0.05 to 0.34, $p < 0.0001$ I²); better cup placement, stem placement and global offset and a higher rate of heterotopic ossifications. Functional scores, limb length discrepancy and rates of revision and stress shielding were similar in the two groups. The relative amount of blood loss was unclear.

Conclusion The results of this meta-analysis suggest that robotic-assisted THA has certain advantages over conventional THA, including the results of component positioning and rates of intraoperative complications. Additional comparative studies are required to determine the long-term clinical outcomes of robotic-assisted THA.

INTRODUCTION

As the incidence of osteoarthritis and other degenerative diseases affecting the bones and joints increases,¹ so does the need for total hip arthroplasty (THA). Over 600 000 persons per year are expected to undergo THA by 2030,² emphasising the importance of prolonging the longevity of implants and reducing the risk of revision through reproducible surgery.

The use of robotics in assisting the surgical procedure was first introduced in the 1980s in orthopaedic surgery and neurosurgery. Since then, many robotic systems were developed to improve the accuracy and precision of surgical procedures. The most famous robotic system of today may be the da Vinci system, which is now widely adopted around the world and has been used to perform many surgeries, including gynaecological surgery,

thoracoscopic surgery, laparoscopic surgery and cardiomy procedures. Generally, robotic-assisted surgery is thought to be safer and more accurate than traditional surgery with fewer complications, less trauma and attainable superior long-term clinical outcomes.³ Robotic-assisted THA, first introduced in the 1990s, provides accurate and reproducible component positioning and balancing of soft tissue.^{4–7} These benefits may contribute to longer implant survival and a reduced need for revision surgery.^{4–7} However, the relative efficacy and safety of robotic-assisted and conventional THA remain unclear.

Most trials comparing robotic-assisted and conventional THA have involved small patient cohorts, and, to our knowledge, no previous meta-analyses have compared these techniques. Until now, the robotic-assisted THA has been at its early stage of application, and only a limited number of institutes and physicians have the equipment and the technique required to perform robotic-assisted THA. Therefore, available data were gathered with the aim to study the clinical outcome of robotic-assisted THA. In general, robotic-assisted surgery was considered safer and more accurate than traditional surgery. It has been reported that robotic-assisted surgeries provide more precise radiographic outcomes, less paraoperative blood loss and more important, lower risk for intraoperative complications compared with traditional surgery. Therefore, complication is designated as primary outcome. This systematic review and meta-analysis therefore compared the safety and efficacy of robotic-assisted and conventional THA.

MATERIALS AND METHODS

Search strategy

Medline, Embase and the Cochrane Library were comprehensively searched by two independent researchers in September 2017. Search terms included arthroplasty, replacement, hip [Mesh] with all entry terms, robotic surgical procedure [Mesh] with all entry terms and robotic-assisted. Additional studies identified through references of retrieved articles and other sources were manually searched.

Inclusion and exclusion criteria

Clinical trials were included if they (1) involved patients undergoing primary THA, (2) compared robotic-assisted and conventional THA, (3) included outcome variables related to the efficacy and safety of robotic-assisted and conventional THA and (4) were published between 2005 and 2017. Studies



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Table 1 Outcome and statistical methods

Outcome variable	Statistical method	Effect measure
	Inverse variance	Mean difference
Surgical time complications		
Intraoperative	Peto	Peto OR
Postoperative	Peto	Peto OR
Total	Peto	Peto OR
From randomised clinical trial	Peto	Peto OR
Functional outcome		
Preoperative	Inverse variance	Std mean difference
Postoperative	Inverse variance	Std mean difference
Radiographic outcome		
Limb length discrepancy (LLD)	Inverse variance	Mean difference
LLD >10 mm	Peto	Peto OR
Cup placement	Inverse variance	OR
Heterotopic ossification	Peto	Peto OR

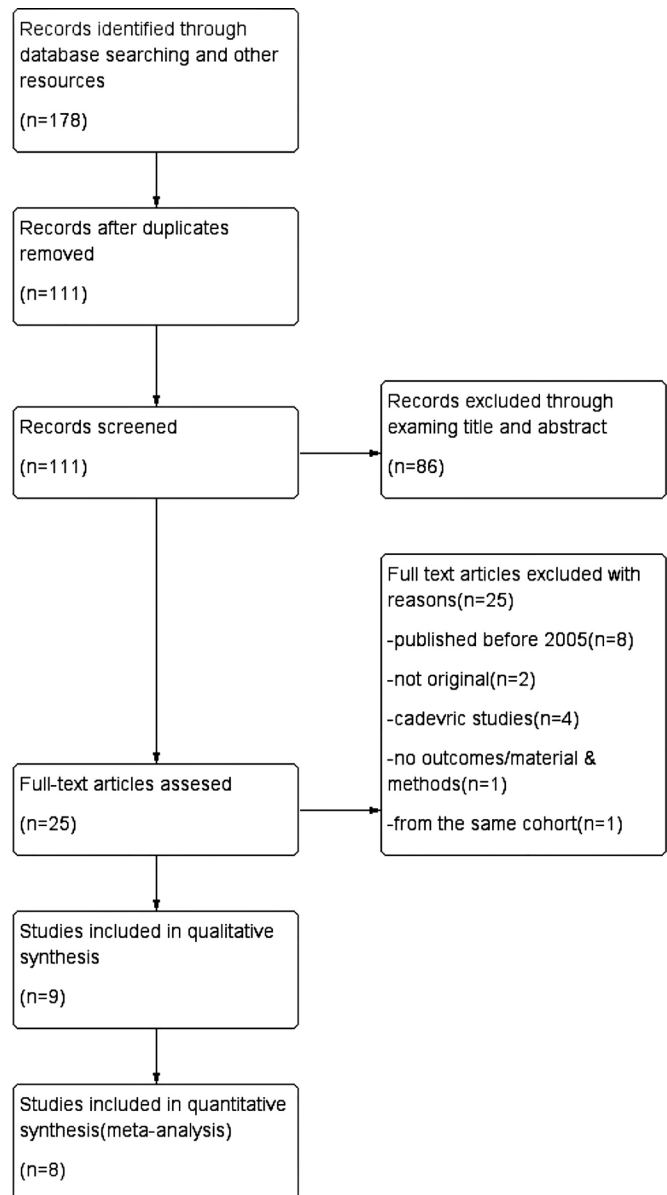
were excluded if they were (1) conference abstracts, animal studies, cadaveric studies, in vitro studies or articles published in a form other than clinical trials, (2) studies without quantitative data or (3) published before 2005. If multiple studies reported results from the same patient cohort, the study with a lower quality score was excluded.

Data extraction and quality assessment

Data of interest were extracted and analysed by two researchers. Basic information recorded included name of the first author, year of publication, sample size, study design, robot type, demographic characteristics and mean follow-up period. Outcome variables, including surgical time, blood loss, complications, reversions, conversions, functional outcome and radiographic outcomes, were recorded. Raw data and results were reviewed by two senior researchers in our facility. The level of evidence of studies was determined using the Centre for Evidence-based Medicine Level of Evidence 1 (2009), and the quality of studies was estimated according to the Newcastle-Ottawa Scale (NOS). The quality of the three randomised clinical trials (RCTs) included in the meta-analysis was analysed using the Cochrane Collaboration tool to assess risk of bias. Sensitivity analysis was performed where potential bias is detected.

Statistical analysis

Continuous and discontinuous variables acquired from included studies were analysed by weighted mean differences (WMDs) and ORs, respectively. Detailed techniques for each analysis are presented in table 1. Two studies failed to provide the SD or median of continuous data and were excluded from pooled analysis (recorded in chart). For each outcome variable, 95% CIs were recorded. Heterogeneity among the studies was assessed using the χ^2 test and I^2 . A fixed effect model was applied when $I^2 < 50\%$, and a random effects model when $I^2 > 50\%$. A p value < 0.05 was considered statistically significant in cases in which trials have no event in one arm or another. In the Systematic Reviews in Health Care: Meta-Analysis in Context, the authors suggested in these situations inverse variance, a small quantity (0.5) to the cell counts would be added to avoid division by zero errors. In cases in which the count is zero in both arms, the risk difference is zero. Publication bias is assessed by funnel plot, if needed. This meta-analysis was conducted using Review Manager 5.2 (Cochrane Collaboration, Oxford, UK).

**Figure 1** Flow diagram.

RESULTS

Study characteristics

A total of 178 potentially relevant articles were identified. After screening titles, abstracts and full texts, seven studies, including three RCTs,^{8–10} two prospective studies^{11 12} and two retrospective studies,^{6 13} involving a total of 1516 patients were included in this meta-analysis (figure 1). The baseline characteristics and quality assessment of included studies are shown in table 2. Outcome variables analysed included surgical time, blood loss, complications, revisions, conversions, functional score and radiographic outcomes.

SURGICAL ASPECTS

Surgical time

Surgical time was assessed in three studies, including one RCT.^{6 9 12} Although the results favoured conventional THA, pooled analysis showed no significant difference between patients who underwent robotic-assisted and conventional THA, with significant heterogeneity (WMD: 23.21 min, 95% CI: –3.76 to 50.09 min, $p=0.09$, $I^2=96\%$) (figure 2).

Table 2 Basic characteristics of included studies

Author	Evidence	Design	Matching	RA		CA		Follow-up	Quality score	Country
				No	Robot type	No				
Lim <i>et al</i> 2015 ⁸	2b	RCT	12 345	24	ROBDOC	25		24 months	RCT	Korea
Nakamura <i>et al</i> 2010 ⁹	2b	RCT	1234	75	ROBDOC	71		5 years	RCT	Japan
Nishihara <i>et al</i> 2006 ¹⁰	2b	RCT	12	78	ROBDOC	78		24 months	RCT	Japan
Hananouchi <i>et al</i> 2007 ¹¹	3b	RP	13	31	ROBDOC	27		24 months	★★★★★★	Japan
Siebel <i>et al</i> 2005 ¹²	3b	RP	12	36	CASPAR	35		17.9 months	★★★★★★	Germany
Domb <i>et al</i> 2014 ⁶	3b	R	12 345	50	MAKO	50		NS	★★★★★★	USA
Domb <i>et al</i> 2015 ¹³	3b	R	12	228	MAKO	708		NS	★★★★★★	USA

Design: R, retrospective; RP, retrospective design. Matching: (1) age; (2) gender; (3) body mass index; (4) aetiology; (5) single surgeon. CA, conventional arthroplasty; NS, not specified; RA, robotic-assisted arthroplasty; RCT, randomised clinical trial.

Blood loss

Blood loss was reported in only two studies.^{8 10} One study¹⁰ reported that blood loss was significantly lower in patients who underwent robotic-assisted THA, whereas the other⁸ found no difference between those who underwent robotic-assisted and conventional THA (table 3).

Complications, revisions and conversions

Intraoperative and postoperative complications were reported in five studies, including three RCTs.⁸⁻¹² Intraoperative complications included intraoperative femoral fracture and femoral cracks/fissure,⁸⁻¹² whereas postoperative complications included infection, nerve palsy, deep vein thrombosis (DVT) and dislocation.^{8-10 12} Complications were divided into four subgroups for comparison in patients who underwent robotic-assisted and conventional THA: intraoperative complications, postoperative complications, total complications and total complications in RCTs. The intraoperative complication rate was significantly higher in patients who underwent conventional compared with robotic-assisted THA (OR: 0.12, 95% CI: 0.05 to 0.34, $p < 0.0001$, $I^2 = 0\%$) (figure 3), whereas postoperative complication rates were similar. The total complication rates (intraoperative and postoperative) in all studies and in the three RCTs were higher in patients who underwent conventional than those who underwent robotic-assisted THA (table 4).

Some postoperative complications were not included in this meta-analysis due to their lack of inclusion in more than one study or because they were not considered major complications. For example, rates of thigh pain after 1, 3 and 12 months were similar in patients who underwent robotic-assisted and those who underwent conventional THA.^{9 10} Although one study¹² found that the rate of Trendelenburg signs was significantly higher in the robotic-assisted than in the conventional THA group (61% vs 26%, $p = 0.0014$), this outcome was not measured in the other six included studies.

The same study¹² reported that two patients who underwent robotic-assisted THA (6%) and one who underwent conventional THA (3%) required revision surgery. None of the patients in any other studies, however, required revision.⁸⁻¹¹

Three patients who underwent robotic-assisted THA required conversion to conventional arthroplasty due to technical problems, one in one study⁶ and two in another.⁹

OUTCOMES

Functional outcome

The Harris Hip Score, Merle d'Aubigne Hip Score, Japanese Orthopaedic Association (JOA) Score and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) scale were recorded preoperatively and postoperatively in five studies.⁸⁻¹² The Harris Hip Score,¹² Merle d'Aubigne Hip Score^{11 12} and JOA Score⁹ were included in our meta-analysis. Pooled analysis of functional scores found no significant differences between robotic-assisted and conventional THA, with significant heterogeneities both preoperatively (WMD: 0.12, 95% CI: -0.09 to 0.34, $p = 0.27$, $I^2 = 87\%$) and 24 months postoperatively (WMD: 0.09, 95% CI: -0.12 to 0.31, $p = 0.38$, $I^2 = 68\%$).

Radiographic outcomes

Limb length discrepancy

Three studies^{8 9 13} reported limb length discrepancy (LLD) in patients who underwent robotic-assisted and conventional THA. The results of two of these studies^{9 13} with required data were pooled. LLD did not differ significantly (WMD: -0.24, 95% CI: -0.61 to 0.12, $p = 0.19$, $I^2 = 0\%$). The rates of LLD greater than 10 mm were also measured in two studies,^{8 13} but there was no significant difference between patients who underwent robotic-assisted and conventional THA (OR: 0.72, 95% CI: 0.31 to 1.67, $p = 0.44$, $I^2 = 59\%$).

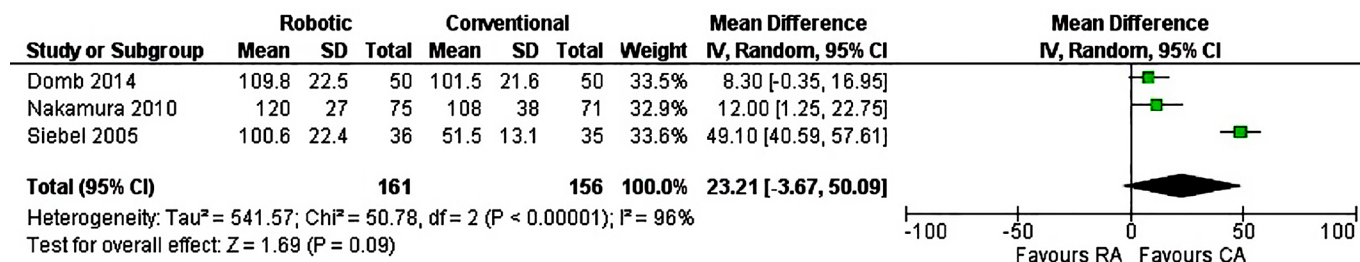
**Figure 2** Surgical time. CA, conventional arthroplasty; RA, robotic-assisted arthroplasty.

Table 3 Blood loss

Blood loss (mL)	RA		CA		P value
	Mean	Range	Mean	Range	
	Nishihara <i>et al</i> ¹⁰	527	150–1400	694	
Lim <i>et al</i> ⁸	1010	610–1800	895	410–1370	0.271

CA, conventional arthroplasty; RA, robotic-assisted arthroplasty.

Cup placement

Cup placement was assessed in two studies,^{6 13} which defined ideal cup placement as placement in Lewinnek's/Callanan's Safe Zone. This rate was significantly higher in patients who underwent robotic THA than those who had conventional THA (OR: 5.64, 95% CI: 4.10 to 7.74, $p < 0.00001$, $I^2 = 0\%$).

Stem placement and global offset (GO)

Two studies^{8 11} compared stem placement in patients who underwent robotic-assisted and conventional THA. One⁸ reported that the rate of stem alignment outliers was significantly lower in the robotic-assisted group ($p = 0.022$), whereas the other¹¹ reported that stem fit was far more satisfactory in the robotic-assisted group. Only one study compared mean global offset (GO),¹³ finding that mean GO was shorter in the robotic-assisted than in the conventional THA group, although this difference was not statistically significant.

Postoperative radiographic anomalies

Postoperative radiographic anomalies, including heterotopic ossification, radiolucent lines, stress shielding and stem loosening, were reported in four studies.^{8 9 11 12} One reported that the rate of heterotopic ossification was significantly higher in patients who underwent conventional THA (OR: 1.91, 95% CI: 1.02 to 3.55, $p = 0.04$, $I^2 = 0\%$) (figure 4). One study¹¹ found that radiolucent lines were absent from both groups, whereas another study⁹ found that the rates of stress shielding after 3 and 5 years were significantly higher in patients who underwent conventional than those who had robotic-assisted THA. One study assessed stem loosening, but it was not present in either group.⁸

Publication bias

Although the Cochrane Handbook mentions that at least 10 studies are required to conduct a publication bias analysis with funnel plots, we drew two funnel plots for which we suspected potential publication bias. The complications included in pooled

Table 4 Complications

	RA versus CA			
	OR	95% CI	P value	I ²
Intraoperative complications	0.12	(0.05 to 0.34)	<0.0001	0
Postoperative complications	3.35	(0.94 to 11.91)	0.06	0
Total complications	0.43	(0.19 to 0.94)	0.03	29%
Complications from randomised clinical trial	0.32	(0.12 to 0.85)	0.02	16%

CA, conventional arthroplasty; RA, robotic-assisted arthroplasty.

analysis were evaluated using a SE-based funnel plot. The funnel plot showed that, in terms of intraoperative complications, all studies were within the 95% CI and were symmetrical.

DISCUSSION

Robotic-assisted joint replacement surgery was introduced in the early 1990s, with the first robotic-assisted THA performed in 1992.³ Robotic-assisted surgery has since been extended to knee arthroplasty.^{3 7} The robotic-assisted system has been classified into two types: haptic/semi-active and autonomous/active. Both systems differ in that the haptic/semi-active system allows the surgeon to operate the robotic arm manually while constrained by the system. In contrast, the autonomous/active system requires the surgeon to set up the system, and then the system itself performs the operation autonomously based on preoperative planning.^{3 7 14} Three of the studies^{6 13 15} included in our meta-analysis used a haptic/semi-active robotic-assisted system (MAKO), whereas the remaining five^{8–12} used an autonomous/active robotic-assisted system (ROBDOC or CASPAR). However, the haptic robotic-assisted system MAKO is equally well developed for the cup placement but not for femoral preparation compared with the active robotic-assisted system. Two studies that used MAKO stated that the system helped guide femoral placement after registration, but they did not clarify whether the reaming was conducted by robotic arm or not. Concerns were raised that the active robotic-assisted system increased the risks of nerve damage and infection as well as increasing blood loss and surgical time during both knee and hip replacement surgeries.^{3 16–19} However, advances in technology have led to rapid improvements in robotic-assisted systems, including improvements in preoperative planning and intraoperative procedures.^{3 8 20} Therefore, only studies published between 2005 and 2017 were included in this meta-analysis, as only these reported current safety and efficacy outcomes of robotic-assisted THA.

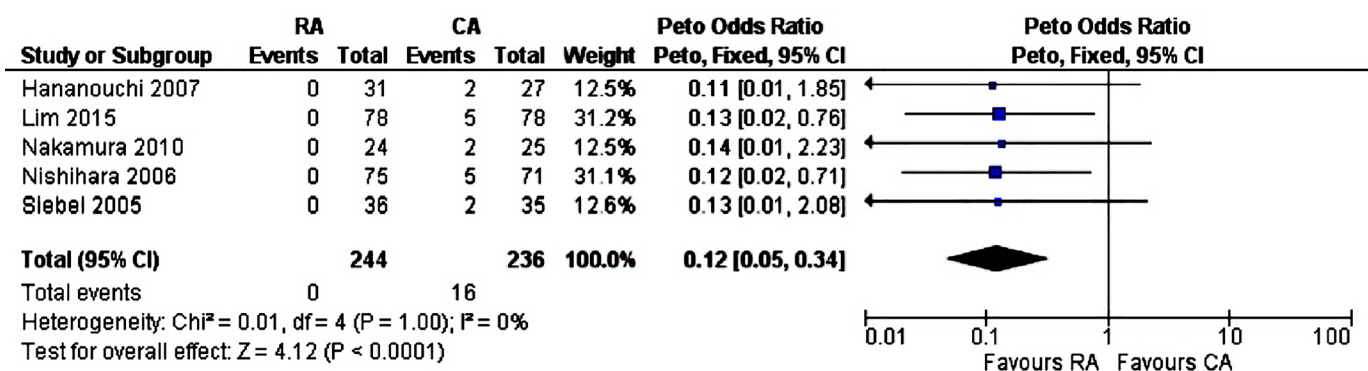


Figure 3 Intraoperative complications. CA, conventional arthroplasty; RA, robotic-assisted arthroplasty.

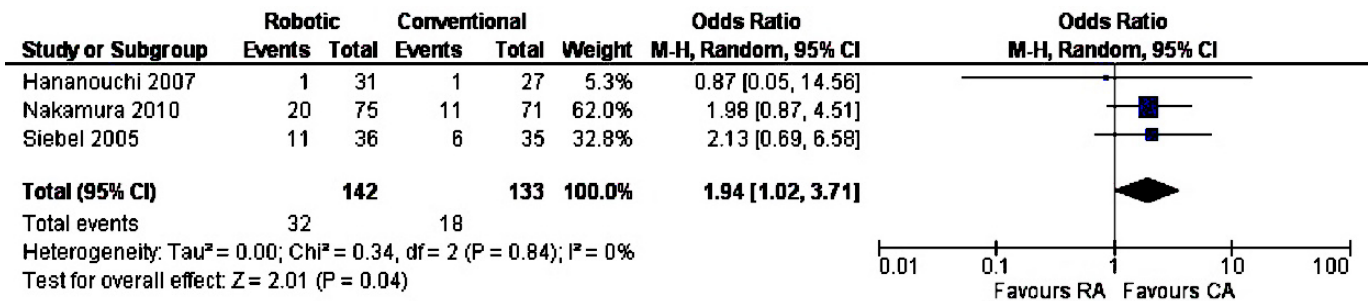


Figure 4 Heterotopic ossification. CA, conventional arthroplasty; RA, robotic-assisted arthroplasty.

Although the mean surgical time was longer in patients who underwent robotic-assisted THA, a pooled analysis showed no significant difference in surgical time. The longer surgical time for robotic-assisted systems^{6,8–10,12,21–23} may be due to the learning curve or the placement of navigation pins and registration.^{8,9,24–26} One study reported that surgeons unfamiliar with the robotic system had a mean surgical time of 79.8 min, which decreased to 69.4 min after 70 such operations.²⁶ The use of a pinless version of ROBODOC, which did not require placement of the locator pins, resulted in a mean surgical time of 103 min for robotic-assisted and 78 min for conventional THA.⁸ Only one included study reported a mean surgical time greater than 120 min, which may increase the risks of infection and revision for both THA and total knee arthroplasty.^{27,28}

Only two of the included studies reported blood loss data, with one reporting that blood loss was significantly lower in patients who underwent robotic-assisted than conventional THA,¹⁰ and the other reporting reduced blood loss during conventional THA, but with no significant between-group difference.⁸ Further studies are needed to determine whether a robotic-assisted system could reduce blood loss during THA.

Safety remains a major concern during the introduction of a new technology, which is also why complication was set to be the primary outcome. Since the complication rate is often quite low, we gathered data from each study to increase the sample size and to render a more reliable result on this matter. Our analysis consistently found that the rates of intraoperative complications, including intraoperative femoral fractures and femoral cracks/fissures, were significantly lower during robotic-assisted than conventional THA. The lower rate of intraoperative complications during robotic-assisted surgery may be associated with the precise bone milling process provided by the robotic system, allowing the surgeon to achieve a press fit with minimal wedging, which increases the risks of intraoperative femoral fracture. Alternatively, cancellous bone may become tight due to rasping, which may reduce the resistance to fracture in patients undergoing conventional THA.^{29–31}

We observed no significant difference in postoperative complication rates in patients undergoing robotic-assisted and conventional THA. In contrast, significant differences were observed in studies published before 2005.^{16,17} Our meta-analysis found that rates of infection, nerve palsy and DVT were similar, whereas the dislocation rate was slightly higher following robotic-assisted surgery ($p=0.08$). We observed a much lower dislocation rate than that in a previous study,¹⁶ which attributed dislocation to insufficiency in abductor muscles. The lower dislocation rate we observed may have been due to the inclusion in our analysis of five studies^{8–12} that used a posterolateral approach, which provides better retraction for the gluteus medius and minimus muscles anteriorly, allowing improved access for robotic milling.

Alternatively, the newly developed preoperative working station illustrates the optimal cutting paths, thereby avoiding injury to the abductor tendon and greater trochanter.⁹ However, the Trendelenberg sign rate was significantly higher with robotic-assisted than conventional THA.¹² The incidence of postoperative thigh pain did not differ between groups,^{9,10} whereas two patients who underwent robotic-assisted surgery experienced knee pain, perhaps due to placement of the locator pins.⁹

Two patients who underwent robotic-assisted and one who underwent conventional THA required revision surgery, rates much lower than reported in 2003.¹⁶ This finding was attributed to the insufficiency of abductor muscles. However, most included studies had a follow-up of only 24 months; the lack of long-term follow-up prevented determination of the potential for prolonged implant survival and reduced risk of revision in patients undergoing robotic-assisted THA.^{20,32,33}

Due to technical problems, three patients undergoing robotic-assisted THA required conversion to conventional surgery.^{6,9} One patient had a malpositioned cup, which was resolved by placing the cup manually.⁶

Functional scores did not differ significantly in the groups that underwent robotic-assisted and conventional THA. The studies included in our analysis used different scoring systems to measure the functional outcome of patients, making these outcomes harder to evaluate using pooled analysis. JOA Scores, however, were significantly higher after 2 and 3 years in patients who underwent robotic-assisted surgery, although the differences disappeared at 5 years.⁹ The potential advantages of robotic-assisted THA include long-term improvements in implant survival and functional outcomes. Although short-term functional outcomes were similar in the two groups, additional studies are needed to assess long-term outcome.

LLD is a common complication following THA,¹⁵ with patients who have LLD greater than 10 mm feeling discomfort.³⁴ Mean LLD was found to be higher after robotic-assisted than conventional THA, although no patient in either group had an LLD greater than 10 mm.¹⁵ LLD can be minimised by appropriate implant placement and preoperative planning, which can be achieved through a robotic-assisted system. However, we found that mean LLD and the rate of LLD outliers were similar in patients who underwent robotic-assisted and conventional THA, with LLD equally minimised in both groups.

One of the advantages of robotic-assisted THA is accurate implant placement.^{6,13} The use of a safe zone^{5,13} is one of the most common methods of gauging the accuracy of component positioning. Lewinnek's Safe Zone refers to cup placement within 30–50° of abduction and 5–25° of anteversion,⁴ whereas Callanan's Safe Zone applied more stringent criteria, with cup placement within 30–45° of abduction and 5–25° of anteversion.⁵ Cup placement outside the safe zone has been associated with a

number of complications, including dislocation, instability, LLD and revision surgery.^{4,5} Factors contributing to malpositioned cups include surgeon volume and body mass index. The robotic-assisted system can help surgeons evaluate cup placement intraoperatively, benefiting less experienced surgeons. The use of a robotic-assisted system for THA was found to provide accurate and reproducible acetabular cup placement within safe zones among obese patients.³⁵

Current studies on robotic-assisted THA lack a common standard for evaluating stem placement. Studies included in our analysis reported better stem placement with robotic-assisted than conventional THA.^{8,11} GO is crucial to hip function after THA, with shortened GO resulting in a lack of abductive force of the hip and a limp, and exacerbated GO leading to pain and early wear of the implant.^{36–38} Our analysis showed that satisfactory GO was attainable with the robotic-assisted system.¹³

Surprisingly, the rate of heterotopic ossification was significantly higher with robotic-assisted than conventional THA. Heterotopic ossification can lead to loss of range of motion, pain and fever. Risk factors associated with heterotopic ossification include aetiology, cement implant and muscle trauma.^{39,40} The increased risk of heterotopic ossification we observed with robotic-assisted THA may have been due to locator pin placement and potential bias in aetiology.

Our study had several limitations. First, the number of included studies was small. Only nine studies published after 2005 compared the safety and efficacy of robotic-assisted and conventional THA, with only seven of these studies, involving 1516 patients, included in our analysis. However, with only a limited number of studies that fit the inclusion criteria, the best evidence available was gathered and analysed. Second, patients in two of studies underwent surgery by the same surgeon during overlapping time periods, which may have led to bias. We therefore excluded the study with a lower NOS quality assessment score; that study was designed to compare LLD in patients undergoing robotic-assisted and conventional THA and was discussed narratively in our analysis. Third, both RCTs and non-RCTs were included in our analysis due to lack of data, which adds to potential bias to this study. Three of the included studies were RCTs, limiting the quality of our analysis. Fourth, some of the studies did not contain sufficient information for pooled analyses. Although we tried to contact the authors for raw data, we were unable to do so. Fifth, one study included in our analysis included 708 patients who underwent conventional THA but only 135 who underwent robotic-assisted THA, which may have led to bias. However, data from that study were only used to analyse cup placement and LLD, which yielded outcomes consistent with those of other studies. Sixth, two included studies^{9,10} used CT-based preoperative planning software, whereas the others used traditional radiograph-based preoperative planning. Finally, the mean follow-up period was insufficient to determine whether the robotic-assisted system enhances implant survival and reduces the risk of revision in the long term.

Our meta-analysis also had several strengths. First, to our knowledge, this is the first meta-analysis comparing the efficacy and safety of robotic-assisted and conventional THA and exploring the potential causes for any differences. Second, relevant articles in all languages were screened carefully by two independent researchers using a wide range of search terms. Third, clear exclusion and inclusion criteria were used. Fourth, the quality of all studies was assessed by either NOS quality assessment score or the Cochrane Collaboration tool. Fifth, a wide range of outcome variables were analysed and clinical outcomes were evaluated quantitatively.

CONCLUSION

In conclusion, complication rates were lower and radiographic outcomes superior with robotic-assisted than conventional THA. There were no differences in blood loss and short-term functional outcomes. However, robotic-assisted THA was associated with prolonged surgical time and an increased risk of heterotopic ossification. Further studies with long-term follow-up are needed to determine whether robotic-assisted THA improves long-term patient outcomes.

Main messages

- ▶ Complication rates were lower and radiographic outcomes superior with robotic-assisted total hip arthroplasty (THA) than with conventional THA.
- ▶ There were no differences in blood loss and short-term functional outcomes. However, robotic-assisted THA was associated with prolonged surgical time and an increased risk of heterotopic ossification.
- ▶ Further studies with long-term follow-up are needed to determine whether robotic-assisted THA improves long-term patient outcomes.

Current research questions

- ▶ Is there a learning curve for robotic-assisted total hip arthroplasty (THA)? Is it easier for young surgeons to learn and practice compared with traditional THA?
- ▶ More studies with longer follow-up are required.
- ▶ Why is the heterotopic ossification rate higher in the THA group?

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Contributors XC planned the study. JX and PW wrote the manuscript. WQ performed the statistical analysis and revised the methods. LY performed statistical analysis. SZ examined the data and included articles. HP provided guidelines on using the RevMan software. WQ supervised the study.

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