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SYSTEMATIC REVIEW

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Safety and efficacy of orthopedic robots in total hip arthroplasty: a network meta-analysis and systematic review

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Abstract

Background With the increasing demand for total hip arthroplasty (THA) and the inevitable trend of orthopedic robots and artificial intelligence in the future, it is necessary to explore the safety and effectiveness of orthopedic robots in THA. Currently, most orthopedic robots are in the early stages of development, and evaluating their clinical efficacy can assist in making informed decisions for practical use.

Objective To explore the advantages of 7 types of robot-assisted THA with respect to 5 indicators.

Methods Literature from databases such as CNKI, PubMed, and Web of Science was retrieved up to July 17, 2024. Literature evaluation was conducted via Review Manager 5.4, and a network meta-analysis was performed via RStudio (version 4.4.1).

Results A total of 17 studies involving 1741 patients were included. In direct comparisons, the operation time was longer for MAKO (MD = 19; CI = 6.7, 31), TRex (MD = 37, CI = 20, 54) and YUANHUA (MD = 35, CI = 4.2, 66) than for C-THA. The leg length discrepancy (LLD) was smaller for TRex (MD = −3.4, CI = −6.6, −0.36) and RO (MD = −4.3, CI = −8.7, −0.064) than for C-THA. In the comprehensive best probability ranking, operation time [C-THA (96%) > TJ (68%) > RO (53.2%) > MAKO (53%) > LA (45%) > YU (21%) > TR (13%)], blood loss [TJ (89%) > C-THA (50%) > LA (49%) > YU (42%) > MAKO (20%)], LLD [RO (83%) > TR (75%) > MAKO (61%) > TJ (51%) > YU (43%) > JJ (40%) > C-THA (24%) > LA (22%)], HHS [RO (65%) > C-THA (55%) > LA (51%) > TR (50%) > JJ (48%) > YU (46%) > MAKO (37%)], and infection [TJ (77%) > C-THA (67%) > MAKO (44%) > RO (10%)].

Conclusion Each of the seven types of RA-THA and C-THA has its own advantages, with TJ and RO RA-THA being slightly more prominent. Overall, in terms of safety and effectiveness, RA-THA is generally superior to C-THA, although further development is still needed.

Keywords Orthopedic robot-assisted, Total hip arthroplasty (THA), Efficacy, Safety, Network meta-analysis

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Introduction

Total hip arthroplasty (THA), initially described by the renowned German surgeon Carl Heuter in 1881 [1, 2], is now one of the most commonly performed joint replacement surgeries. The primary clinical indication for THA is hip osteoarthritis [3], although it is also widely used for hip fractures [4], symptomatic advanced osteonecrosis of the femoral head [5], and sequelae of pyogenic arthritis of the hip [6]. With over 50 million osteoarthritis patients in China and a growing trend [7], the demand for THA is expected to rise significantly. Accurate and precise biomechanical reconstruction is crucial for long-term success [8, 9], but postoperative infections can have catastrophic consequences [10].

Robot-assisted orthopedic surgery has been used clinically for more than 20 years [11]. The use of robot-assisted THA (RA-THA) is subject to significant debate. This technology has the potential to increase accuracy and reproducibility, optimize component positioning, and improve patient outcomes [12]. However, Samik Banerjee [13] reported in 2016 that RA-THA has a complication rate as high as 9%. Advances in robotic-assisted orthopedic research include ROBODOC and Mako [14], as well as Chinese systems such as Tianji and Jianjia [15, 16]. RA-THA technology is still in its early stages. Therefore, this study aims to conduct a network meta-analysis to systematically evaluate the advantages of seven RA-THA systems, including MAKO, TRex-RS (TRex), ROBODOC (RO), TianjiRobot (TJ), LANCED (LA), YUANHUA (YU), JIANJIA (JJ) and C-THA, in terms of safety and efficacy.

Methods

The study was designed and conducted in strict accordance with the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).

Literature search and inclusion criteria

We conducted a comprehensive search of the electronic databases PubMed, Web of Science, Embase, Cochrane Library, CBM, CNKI, Wanfang, and VIP from their inception through July 17, 2024. The search was limited to publications in English and Chinese. Keywords such as “robot-assisted”, “manipulator-assisted”, “total hip arthroplasty”, “randomized”, and “random” were used in both subject terms and free text across all fields. Two researchers (WU Zhenhua and ZHENG Yin) independently screened and verified the studies, with any disagreements resolved by a third researcher (ZHANG Xiwei).

The inclusion criteria were as follows: (1) randomized controlled trials (RCTs) and retrospective cohort studies (RSs); (2) studies involving patients undergoing THA (total hip arthroplasty); (3) comparisons of clinical efficacy and surgical safety between RA-THA (robot-assisted THA) and C-THA (conventional THA); (4) the specific robot-assisted systems mentioned in the studies; (5) the robot-assisted system was involved in preoperative planning, localization, osteotomy, acetabular reaming, and acetabular component placement; (6) studies reporting at least one of the following outcomes: operative time, blood loss, leg length discrepancy (LLD), Harris Hip Score (HHS), or infection rates; and (7) a follow-up period of more than 3 months.

The exclusion criteria were as follows: (1) non-RCT or non-RS studies, (2) lack of specific outcomes reported, (3) absence of specific mention of robot-assisted systems, (4) incomplete data, (5) publications not in Chinese or English, and (6) duplicate reports.

Data extraction and quality assessment

Two researchers (WU Zhenhua and ZHENG Yin) independently screened and verified the studies, with any discrepancies resolved by a third researcher (ZHANG Xiwei). The screening process included removing duplicates, conducting a preliminary review of titles, reviewing abstracts and keywords, and conducting a comprehensive review of the full text to ensure data integrity. For data extraction, the following information was collected: first author, year of publication, country, sample size (male/female), average age, follow-up duration, intervention measures (including C-THA, ROBODOC, TianJi, etc.), and outcomes.

A risk of bias assessment was performed for the included studies via Review Manager 5.4 [17]. The evaluation criteria included blinding procedures, randomization methods, allocation concealment, and the completeness of the outcome data. The quality of included studies can influence the quality of the analysis; excessive high-risk factors may affect the credibility of the study results. Therefore, in the risk of bias assessment for included studies, we can allow a maximum of one high-risk factor per article.

Statistical methods

We conducted a network meta-analysis via RStudio (version 4.4.1) with the "gemtc" package [18]. Bayesian Markov chain Monte Carlo (MCMC) computations were performed via JAGS via the "rjags" package. Our modeling employed four chains, with an initial value set to 2.5. The expected number of iterations was 5000, but the actual number reached 20,000 [19]. For the four continuous outcome measures (operative time, blood loss, LLD, and HHS), we used the mean difference (*MD*) with 95% confidence interval (*CI*). For the single binary outcome (infection), we used the odds ratio (*OR*) with 95% *CI*. A random-effects model was applied to obtain pairwise comparisons and rank probabilities. Additionally, we used the node-splitting method to evaluate consistency. The Brooks–Gelman–Rubin diagnostic plot and potential scale reduction factor (PSRF) were generated via software to assess model convergence [18].

Results

Literature search results

A total of 154 studies were retrieved from all the databases. After the titles and abstracts were assessed, the full texts were reviewed, and duplicates were removed, 17 studies were included in the network meta-analysis. The process is illustrated in Fig. 1.

Basic information of included studies

A total of 17 studies were included [20–36]. The basic information of these studies is presented in Table 1.

Results of risk of bias assessment

A small number of the analyzed studies were classified as having a high risk of bias, while the majority had low and moderate risk of bias. Only three studies [22, 23, 25] were identified as high risk due to the absence of randomization. The remaining studies are classified as low or moderate risk, with three studies [27, 29, 35] utilizing single-blind designs, and one study [36] employing centralized randomization and allocation concealment. As shown in Fig. 2:

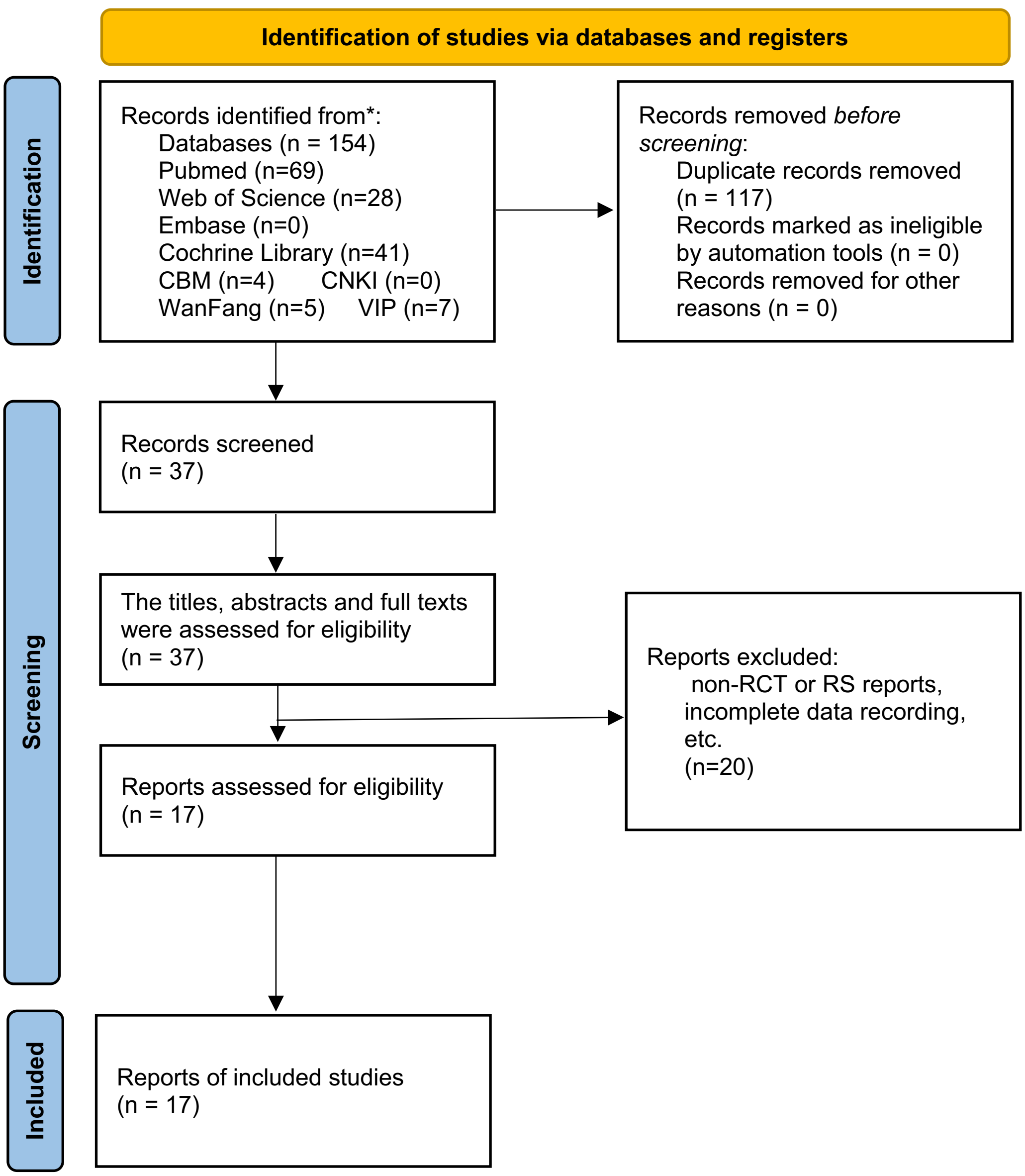

Fig. 1 Flow chart of PRISMA. Note: Data from two of the studies were obtained from journal articles

Table 1 Basic information of the studies

Studis	Country	Samplesize male/female		Average age		Interventions		Outcome
		T	C	T	C	T	C	
Alessio-Mazzola [20]	USA	30/27	27/23	65.2±11.3	68.3±10.0	MAKO	C-THA	①③④⑤
Guo [21]	CHN	24/20	24/23	53.2±12.5	52.7±11.8	MAKO	C-THA	①②③④
Zhang [22]	CHN	47/32	40/40	52.49±11.0	89±12.64	MAKO	C-THA	①③④
Zhang [23]	CHN	12/12	11/13	54.0±11.4	53.0±10.1	MAKO	C-THA	①②③④
Guo [24]	CHN	16/7	14/9	52.8±12.7	51.3±11.2	MAKO	C-THA	①③④
He [25]	CHN	42/58	47/53	66.89±5.96	67.29±4.28	MAKO	C-THA	①②③④
Huang [26]	CHN	34	36	57.10±10.1	56.26±10.50	TRex-RS	C-THA	①③
Lu [27]	CHN	35/37	44/29	58.14±9.04	55.26±10.69	TRex-RS	C-THA	①③④
Wang [28]	CHN	18/17	23/13	57.20±9.60	56.28±10.20	TRex-RS	C-THA	①③
Zhang (2024) [29]	CHN	36/37	43/29	58.1±9.0	55.0±10.7	TRex-RS	C-THA	③
Honl [30]	USA	24/37	24/56	71.5±7.1	70.7±8.3	ROBODOC	C-THA	①③④⑤
Nakamura [31]	USA	13/56	10/51	57±10	58±9	ROBODOC	C-THA	①③
Wang [32]	CHN	20/10	19/11	66.4±3.7	65.8±4.0	TianJi	C-THA	①②
Wang [33]	CHN	19/11	17/13	67.48±1.47	67.32±1.2	TianJi	C-THA	①③⑤
Xu [34]	CHN	27/29	17/38	58.51±13.6	60.42±11.7	LANCED	C-THA	①②③④
Sun [35]	CHN	13/17	9/20	56.10±12.2	56.57±11.7	YUANHUA	C-THA	①②③④
Tian [36]	CHN	30/17	28/23	56.57±11.7	56.74±10.2	JianJia	C-THA	③④

T: Research groups; C: Control groups; ① Operative time; ② Blood loss; ③ LLD; ④ HHS; ⑤ Infection

Network meta-analysis

In the network plot for Operative Time, 15 studies and 1498 patients were included, directly comparing MAKO vs. C-THA, TRex vs. C-THA, RO vs. C-YHA, TJ vs. C-THA, LA vs. C-THA, and YU vs. C-THA. These comparisons allowed for indirect comparisons among MAKO, TRex, RO, TJ, LA, and YU. For Blood Loss, 6 studies and 569 patients were included, involving direct comparisons between MAKO vs. C-THA, TJ vs. C-THA, LA vs. C-THA, and YU vs. C-THA, thus enabling indirect comparisons among MAKO, TJ, LA, and YU. For LLD, 16 studies and 1681 patients were analyzed, including direct comparisons between MAKO vs. C-THA, TRex vs. C-THA, RO vs. C-THA, TJ vs. C-THA, LA vs. C-THA, YU vs. C-THA, and JJ vs. C-THA, facilitating indirect comparisons among MAKO, TRex, RO, TJ, LA, YU, and JJ. In terms of HHS, 11 studies and 1205 patients were reviewed, with direct comparisons involving MAKO vs. C-THA, TRex vs. C-THA, RO vs. C-THA, LA vs. C-THA, YU vs. C-THA, and JJ vs. C-THA, allowing indirect comparisons among MAKO, TRex, RO, LA, YU, and JJ. Finally, for Postoperative Infections, 3 studies and 308 patients were analyzed, with direct comparisons between MAKO vs. C-THA, RO vs. C-THA, and TJ vs. C-THA, which permit indirect comparisons among MAKO, RO, and TJ, as shown in Fig. 3.

Network meta-analysis results

We conducted a network meta-analysis on the data from the studies, including operative time, blood loss, leg length discrepancy (LLD), Harris Hip Scores (HHS), and infection rates.

Operative time

Fifteen studies [20–28, 30–35] reported the operative time. The results indicated that C-THA pigs had shorter operative times than MAKO (MD = 19; CI = 6.7, 31), TRex (MD = 37, CI = 20, 54) and YU (MD = 35, CI = 4.2, 66) pigs did ($P < 0.05$), while the other comparisons were not significantly different. According to the comprehensive best probability ranking results, C-THA had the highest probability of the shortest operative time (96%), followed by TJ (68%), RO (53.2%), MAKO (53%), LA (45%), YU (21%), and TRex (13%).

Blood loss

Six studies [20, 23, 25, 32, 34, 35] reported blood loss, with no statistically significant differences found in any of the pairwise comparisons. According to the probability ranking results, TJ had the highest probability of being the best (89%), followed by C-THA (50%), LA (49%), YU (42%), and MAKO (20%).

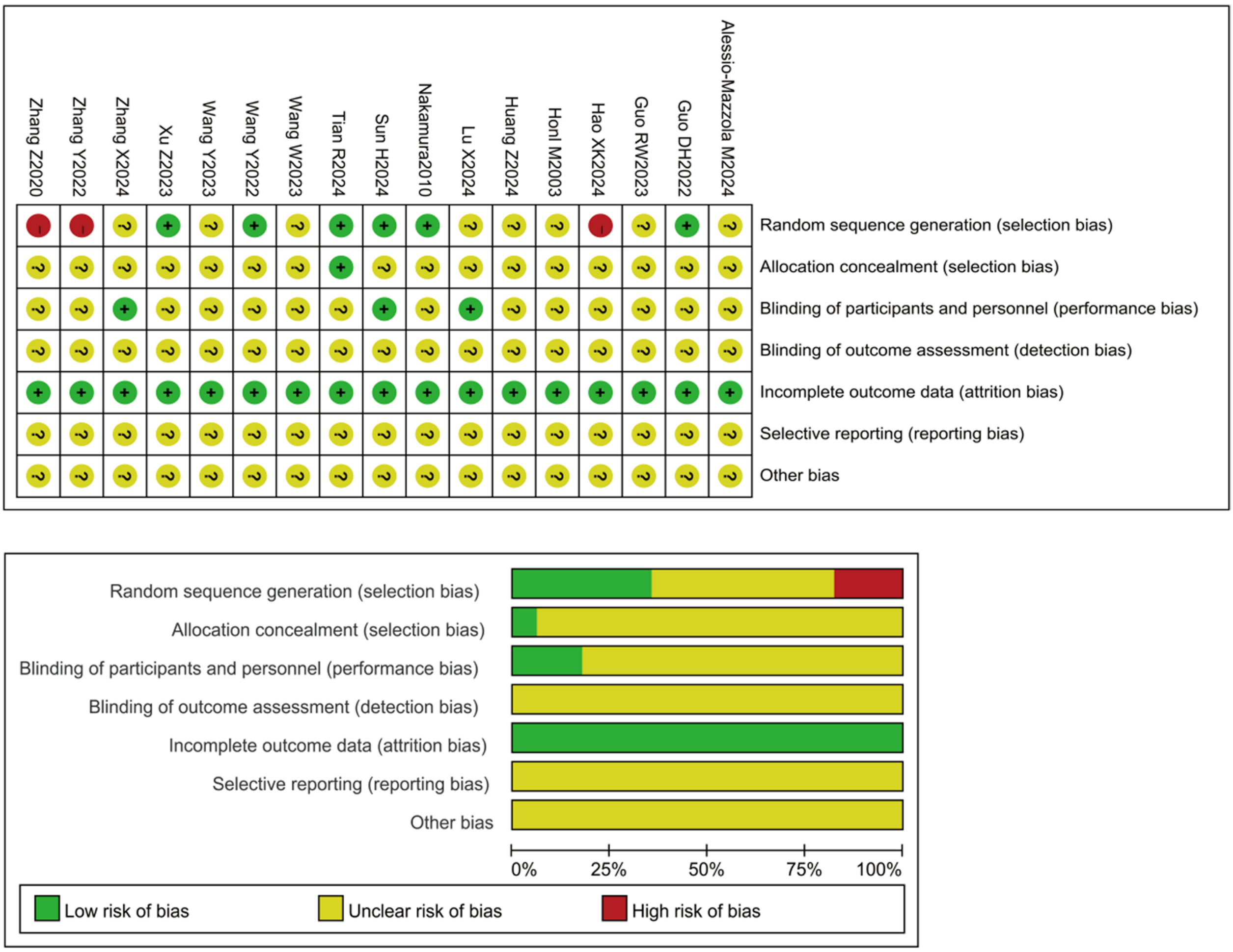

Fig. 2 Risk of bias assessment proportion plot

LLD

Sixteen studies [20–31, 33–36] reported LLD, revealing that TRex (MD = −3.4, CI = −6.6, −0.36) and RO (MD = −4.3, CI = −8.7, −0.064) had smaller LLDs than C-THA did ($P < 0.05$), whereas other comparisons revealed no significant differences. According to the probability ranking results, RO had the highest probability of being the best (83%), followed by TRex (75%), MAKO (61%), TJ (51%), YU (43%), JJ (40%), C-THA (24%) and LA (22%).

HHS

Eleven studies [21–25, 27, 30, 34–36] reported Harris hip scores, with no statistically significant differences observed in any pairwise comparisons. According to the probability ranking results, RO had the highest probability of being the best (65%), followed by C-THA (55%), LA (51%), TR (50%), JJ (48%), YU (46%) and MAKO (37%).

Postoperative infections

Three studies [20, 30, 33] reported postoperative infections, with no statistically significant differences found among the comparisons. According to the probability ranking results, TJ had the highest probability of being the best (77%), followed by C-THA (67%), MAKO (44%) and RO (10%) (Figs. 4, 5 and Table 2).

Consistency and convergence testing

We assessed the consistency of the 5 studies via the node-splitting method. However, there were no comparisons available in this study to evaluate inconsistency. The convergence of the five studies was evaluated through the Brooks–Gelman–Rubin diagnostic plot and the potential scale reduction factor (PSRF). The results indicated the following: (1) The median shrinkage factor tended toward 1 after 10,000 iterations and stabilized. (2) The 97.5th percentile of the shrinkage factor approached 1 and stabilized after 10,000

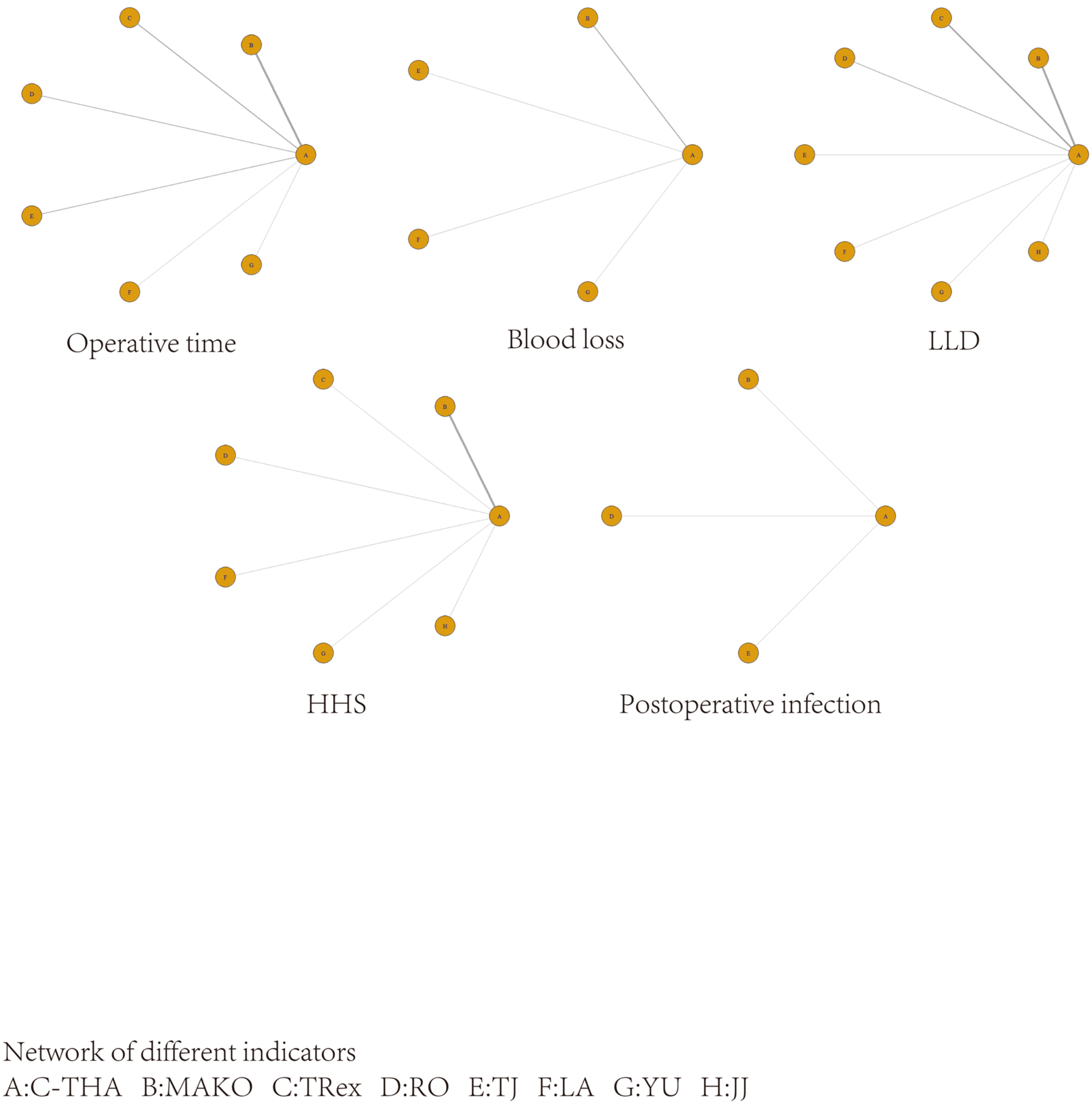

Fig. 3 Network plot. Note: Each node represents a different intervention and the thickness of the lines between nodes represents the number of comparisons between them

(See figure on next page.)

Fig. 4 Network meta-analysis forest plot. Note: Each point represents the OR or MD of the intervention, and the lines on the points indicate the 95% CI. When the OR was used as the effect size, an OR and 95% CI < 1 or > 1 indicated a statistically significant difference. When the MD was used as the effect size, an MD and 95% CI < 0 or > 0 indicated a statistically significant difference. The results in the figure show that, in terms of operative time, the MAKO, TRex, and YU procedures had longer durations than the C-THA procedure did. For LLD, the postoperative LLD was lower in the TRex and RO groups than in the C-THA group. No other comparisons revealed statistically significant differences

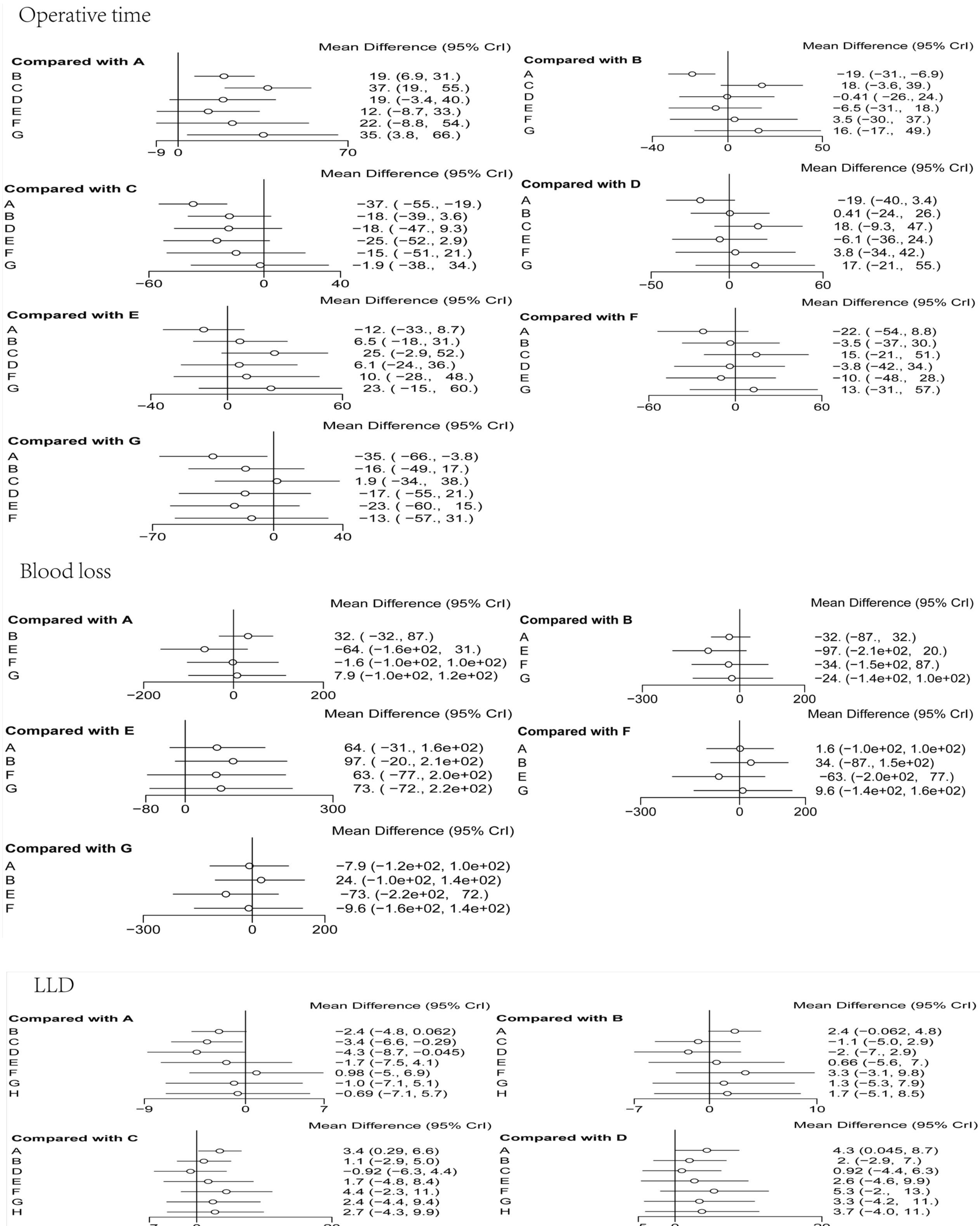

Fig. 4 (See legend on previous page.)

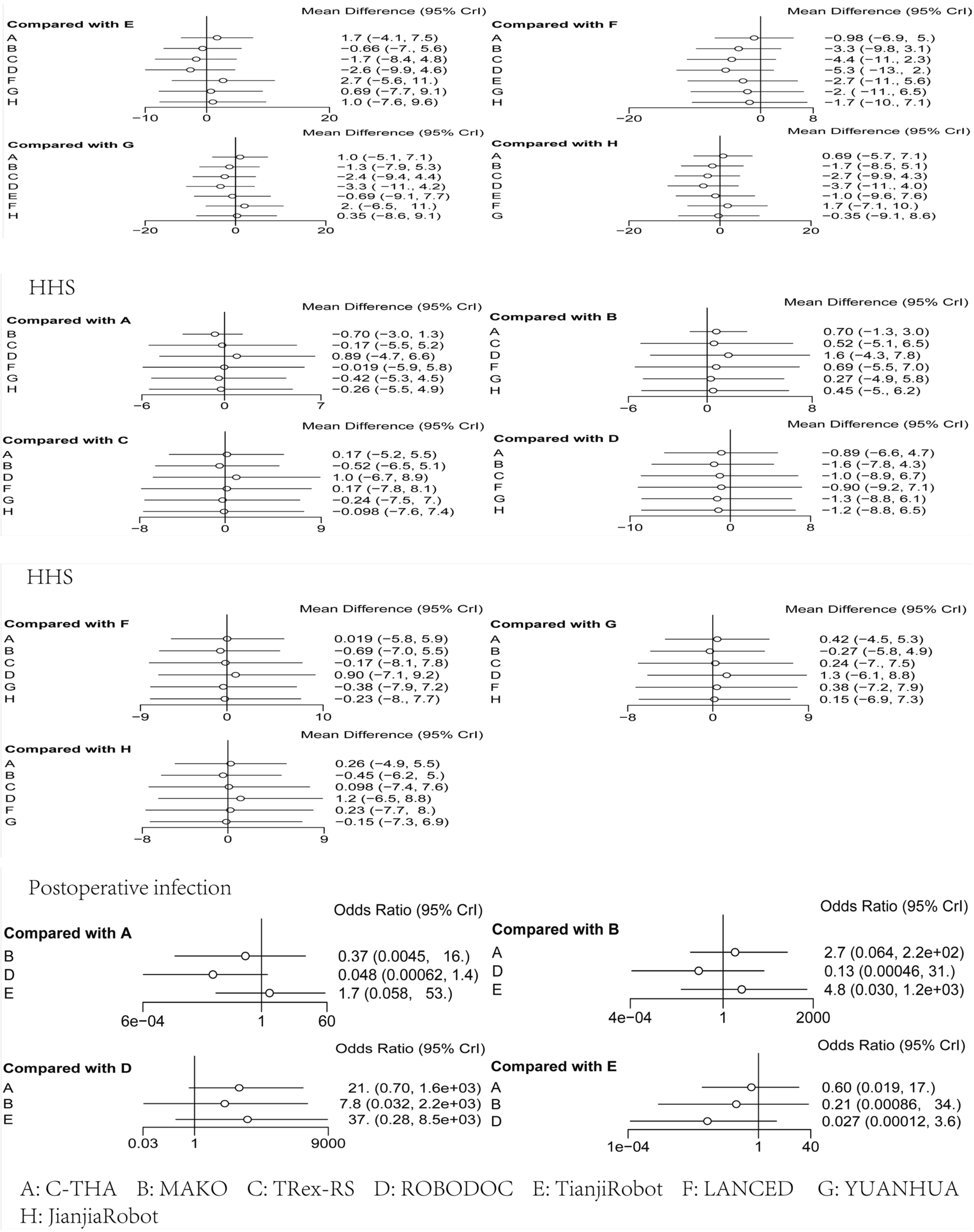

Fig. 4 continued

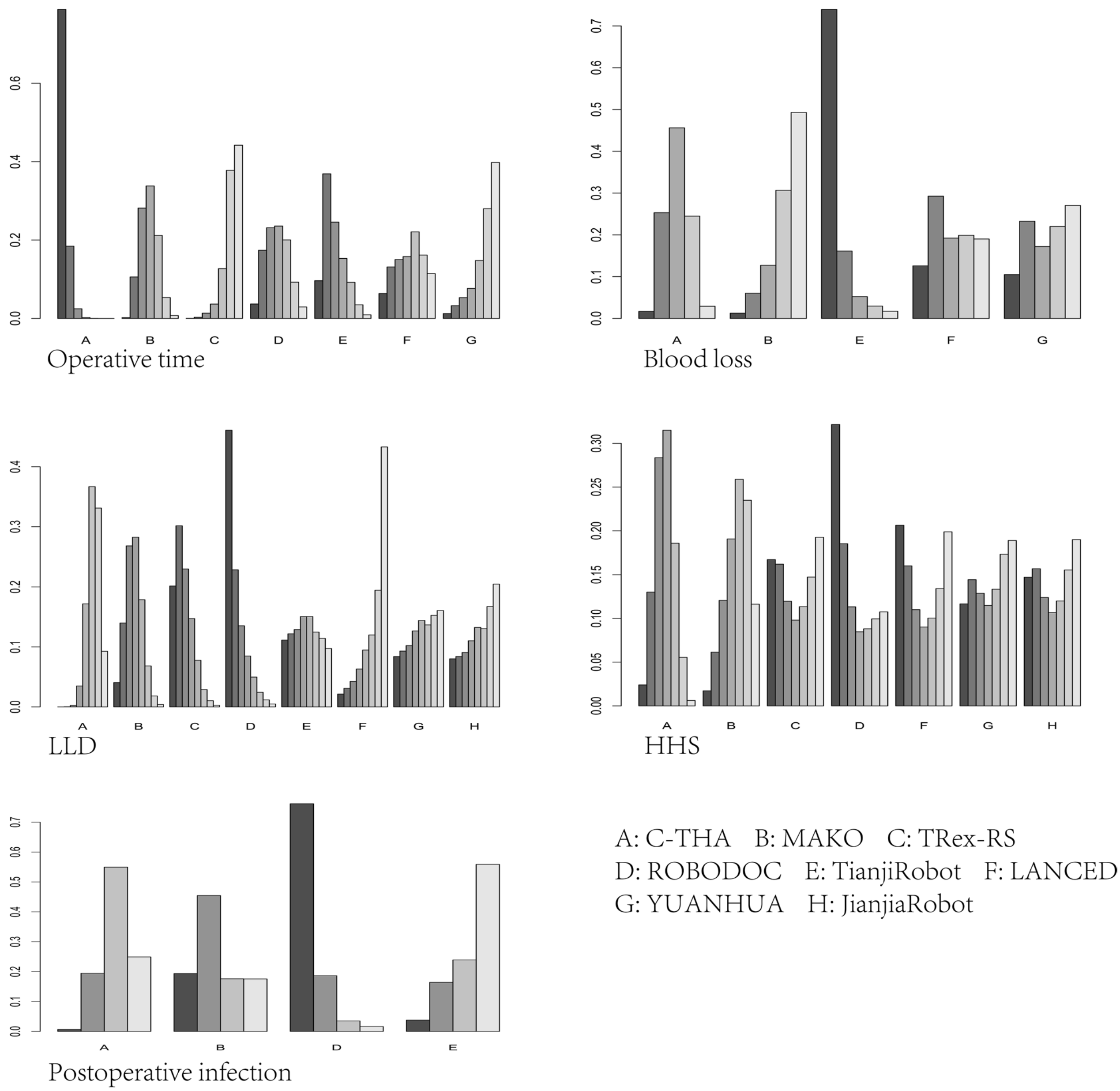

Fig. 5 Optimal probability ranking diagram. Note: The horizontal axis represents the interventions, and the vertical axis represents the probability values. The bar chart represents the ranking of effectiveness, with darker colors indicating better performance, and black representing the best. The results in the figure show that for surgery time, the highest black bar corresponds to C-THA, indicating that C-THA has the highest probability of being the best intervention. For blood loss, the highest black bar corresponds to TJ, indicating TJ as the best intervention. For LLD, RO has the highest black bar, indicating the highest probability of being optimal. In HHS, RO also has the highest black bar, suggesting the highest probability of being the best. For infection, TJ has the highest black bar, indicating it as the best intervention

iterations. (3) The PSRF values ranged between 1.00 and 1.02. These findings suggest that the five studies exhibit good model convergence. The above assessments indicate that these five studies can be reliably conducted (Fig. 6 and Table 3).

Discussion

To our knowledge, this study is the first network meta-analysis of different RA-THAs. Previous studies have focused more on meta-analyses of RA-THA and C-THA. However, the results differ with the assistance of different orthopedic robots, which will undoubtedly produce bias. Given the inevitable trend of integrating orthopedic

Table 2 Comprehensive best probability ranking table

	C-THA	MAKO	TRex	RO	TJ	LA	YU	JJ
Operative time	0.9614833	0.5300750	0.1348583	0.5321000	0.6796500	0.4522083	0.2096250	–
Blood loss	0.4974500	0.1984250	–	–	0.8924750	0.4929875	0.4186625	–
LLD	0.2448500	0.6093643	0.7506143	0.8314714	0.5133714	0.2198357	0.4292786	0.4012143
HHS	0.5483333	0.3682000	0.4961083	0.6452417	–	0.5071250	0.4578250	0.4771667
PJI	0.68526667	0.44053333	–	0.09931667	0.77488333	–	–	–

"–" indicates that the intervention was excluded from this metric. Each value represents the overall probability for the corresponding intervention in this specific metric

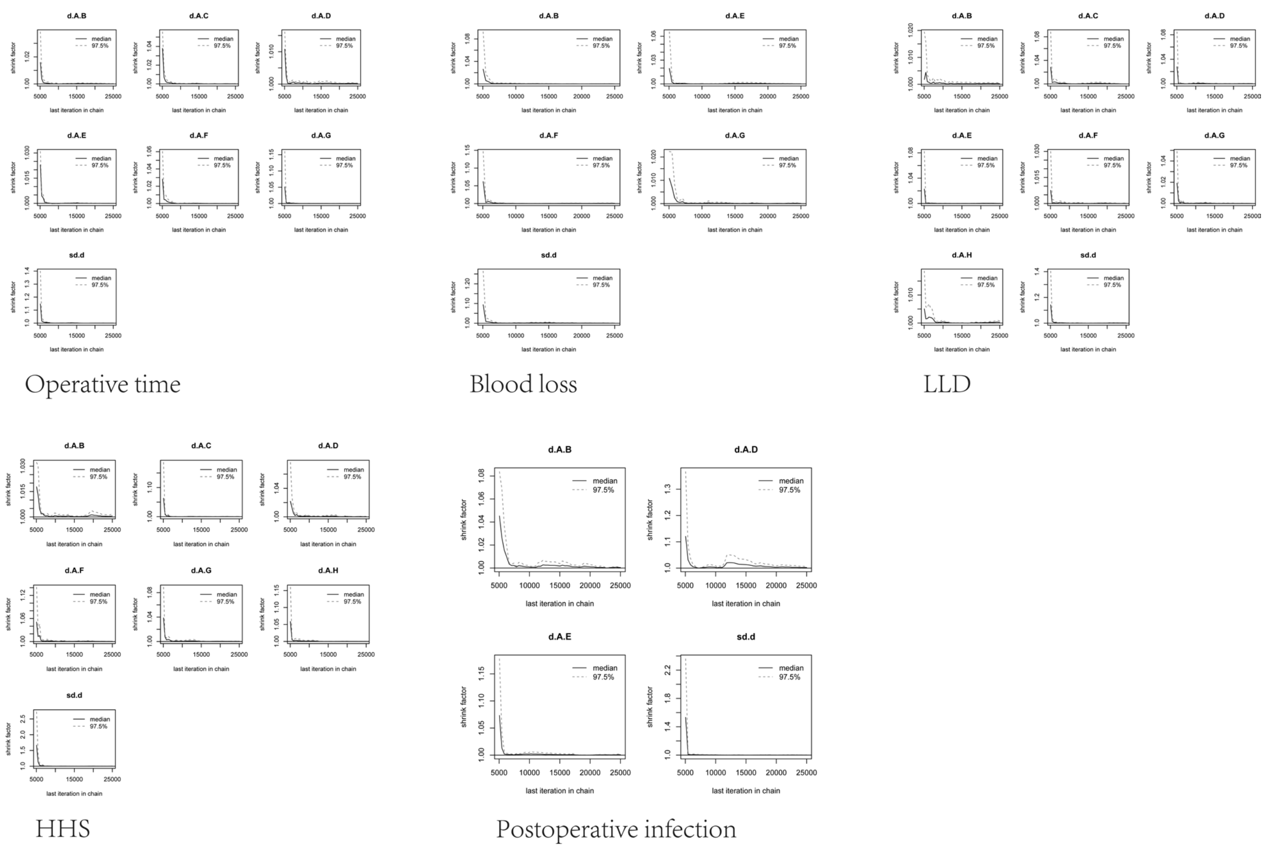

Fig. 6 Brooks–Gelman–Rubin diagnostic plot. Note: The horizontal axis represents the number of iterations in the chain, and the vertical axis represents the convergence factor. The solid black line represents the median value of the shrinkage factor, whereas the red dashed line represents the 97.5% value of the shrinkage factor. Good convergence is indicated when both the median and 97.5% of the shrinkage factor approach 1 and stabilize after iterations. Fewer iterations indicate better convergence. The results in the figure show that all the iterations exhibit good convergence

surgical robots and artificial intelligence into clinical practice, the significance of this study lies in the indirect comparison of the safety and efficacy of seven different RA-THA techniques through direct comparisons with C-THA. This study addresses two critical questions: (1) the individual advantages of the seven RA-THA techniques in terms of safety and efficacy and (2) the differences between various RA-THA techniques and C-THA. These findings provide valuable guidance for clinical practice and future THA decisions, as well as offer clinical insights into the shortcomings and potential improvements of RA-THA.

The best probability ranking results of this study indicate that C-THA is significantly superior to RA-THA in terms of operative time. The complexity of THA involves factors such as prosthesis selection, osteotomy

Table 3 Potential scale reduction factor

	Point estimation	Upper 95%CI
Operative time		
A.B	1.00	1.00
A.C	1.00	1.00
A.D	1.00	1.00
A.E	1.00	1.00
A.F	1.00	1.00
A.G	1.00	1.00
Sd.d	1.00	1.01
Blood loss		
A.B	1.00	1.00
A.E	1.00	1.00
A.F	1.00	1.00
A.G	1.00	1.00
Sd.d	1.00	1.00
LLD		
A.B	1.00	1.00
A.C	1.00	1.00
A.D	1.00	1.00
A.E	1.00	1.00
A.F	1.00	1.00
A.G	1.00	1.00
A.H	1.00	1.00
Sd.d	1.00	1.00
HHS		
A.B	1.00	1.01
A.C	1.00	1.00
A.D	1.00	1.00
A.F	1.00	1.00
A.G	1.00	1.00
A.H	1.00	1.00
Sd.d	1.01	1.02
Infection		
A.B	1.00	1.00
A.D	1.01	1.01
A.E	1.00	1.00
Sd.d	1.00	1.00

For each comparison group, the point estimate and upper 95% CI values are equal to or close to 1, indicating a high degree of convergence in the study results. The table shows that all values range between 1.00 and 1.02, demonstrating excellent convergence

technique, overall offset, and intraoperative fluoroscopy [37, 38]. C-THA has developed significantly over nearly a century, and by 2020, the number of annual THA procedures in China had reached 300,000–400,000 [39]. The technical maturity of surgeons and their ability to address surgical challenges precisely contribute significantly to reduced operative times. In contrast, the development of orthopedic robots is relatively nascent. For example, the TJ robot (introduced in 2016) and the Mako robot (introduced in 2011) have only been applied in clinical settings for the past decade [40, 41]. These robotic systems are still evolving, and issues such as equipment optimization and maturity have not yet been fully addressed. The literature indicates that robotic malfunctions during surgery can lead to prolonged operative times [30]. Additionally, the level of familiarity and experience of the surgeon with orthopedic robots also affects the surgical duration. For example, Sun et al. (2024) reported that RA-THA performed during the proficiency stage was, on average, 30 min shorter than that performed during the learning stage [35].

Surgical blood loss is a crucial indicator of surgical safety. Among the groups ranked for the best probability, TJ had the highest probability of being the optimal choice, followed by C-THA.

Studies have reported that the average perioperative blood transfusion volume for total hip arthroplasty is 5.04 ± 4.06 units, with most bleeding originating from occult sources [42, 43]. One significant factor influencing blood loss is the duration of the surgery [44], which is positively correlated with the operative time rankings of C-THA and TJ. The goal of RA-THA is to increase surgical precision, improve efficiency, shorten operative time, and improve patient outcomes. Both TJ and C-THA may exhibit slight advantages in these aspects.

Leg length discrepancy is one of the most direct indicators for assessing the prognosis of THA and is a common complication impacting patient outcomes. According to the best probability ranking, RO has the highest probability of being optimal, followed by TRex.

The functional LLD post-THA is influenced by various factors. One common approach to managing severe femoral head dislocation and extensive soft tissue contracture is to use an ostomy incision to reduce leg length to protect the sciatic nerve [45]. Li et al. (2017) reported an average postoperative LLD of 3.5 ± 3.0 mm in 78 patients [46]. RO, with its earliest development dating back to 1992 [47], is one of the pioneering orthopedic robots and may be relatively advanced in terms of technical refinement. A multicenter clinical trial conducted in 1993 involving 300 patients demonstrated that, compared with C-THA, RO significantly improved femoral component positioning [48, 49]. Although there is limited literature on the newer tactile TRex, the results indicate that it is slightly less effective than RO is, suggesting that this system also has distinct advantages in controlling LLD.

The Harris hip score encompasses pain, function, deformity, and range of motion and assesses the severity of pain, its impact on activities, and the need for analgesics [50]. In the ranking for HHS, RO has the highest probability of being optimal, followed by C-THA.

However, the differences among the RA-THA systems are relatively small. Therefore, each RA-THA system has its own advantages in controlling postoperative efficacy as measured by the HHS.

Prosthetic joint infection (PJI) in THA is a devastating complication, with reports indicating that the incidence of PJI in THA patients ranges from 1 to 2% [51]. Risk factors for PJI in THA include preoperative assessment, preoperative and postoperative infection prevention, sterile technique during surgery, and factors such as operative time and wound drainage duration [10]. Among the best probability rankings for this indicator, TJ has the highest probability of being optimal, followed by C-THA. However, some studies [27, 34, 35] reported no occurrence of PJI or other complications postoperatively, making it challenging to determine a clear advantage on the basis of this indicator. Overall, the incidence of PJI is low across all RA-THA systems and C-THA. If other factors are not significantly different, reducing the operative time and blood loss to shorten the drainage duration could further lower infection rates.

Conclusion

This study concludes the following regarding orthopedic RA-THA and related clinical issues:

Overall, RA-THA is superior to conventional THA. Among the seven RA-THA systems, TianjiRobot RA-THA and ROBODOC RA-THA may have slightly more advantages.

No large-scale intraoperative or postoperative complications were reported with RA-THA in this study, with complication rates within acceptable ranges. This technique provides a certain level of safety assurance for patients undergoing THA, both during the surgery and in the postoperative period.

In the analysis, RA-THA did not significantly reduce the operative time to improve surgical efficiency. The results of this study indicate that RA-THA did not significantly reduce operative time to enhance surgical efficiency.

This study suggests that orthopedic robotic assistance in THA still requires development, particularly in reducing the operative time.

Limitations

① As a new clinical technology, RA-THA currently has limited published controlled studies, resulting in a relatively small number of included articles.

② While this study provides an analysis based on the available research, future investigations will require more extensive sample data for a more comprehensive exploration.

③ In this study, the blood loss indicator was based on the intraoperative and postoperative drainage volumes. However, some articles reported total blood loss (including occult bleeding), which led to the exclusion of TRex, RO, and JJ from this analysis.

④ Similarly, for the infection indicator, some included studies either did not report complications or did not observe postoperative complications, resulting in the exclusion of TRex, LA, YU, and JJ from this analysis. Despite these exclusions, the overall comparisons of safety and efficacy remain valid, except for JJ, which was not reflected in the safety indicators.

⑤ In the operative time, JJ was not included. Similarly, in the HHS, TJ was not included.

⑥ The study did not assess angular deviation of the prosthesis.

⑦ In the risk of bias assessment, a small portion of high-risk factors still exists.

Explanation of the above limitations: ①②Orthopedic robots have a relatively short history, with most RA-THA procedures being introduced into clinical practice only within the past two decades. Additionally, many hospitals have yet to adopt this technology, resulting in limited research on the topic. ③④⑤Some indicators were not included in the original studies, which may have contributed to certain limitations in this analysis. ⑥Assessing prosthesis angular deviation is not well-suited for meta-analysis. However, to address this limitation, the authors used LLD and HHS indicators. This choice is based on the assumption that if there were angular deviations in the prosthesis postoperatively, these deviations could be indirectly reflected in LLD and HHS scores, which capture leg length discrepancy, postoperative pain, deformities, and limitations in function and range of motion. ⑦This may be due to certain design limitations in the original studies, the omission of relevant risk factors by the authors in their writing, or the retrospective nature of the original studies, which may not be suitable for randomization.

Abbreviations

C-THA	Conventional total hip arthroplasty
RA-THA	Robot-assisted total hip arthroplasty
TRex	TRex-RS robot-assisted total hip arthroplasty
RO	ROBODOC robot-assisted total hip arthroplasty
TJ	Tianji robot-assisted total hip arthroplasty
LA	LANCED robot-assisted total hip arthroplasty
YU	YUANHUA robot-assisted total hip arthroplasty
JJ	Jianjia Robot-assisted total hip arthroplasty
MD	Mean difference
OR	Odds ratio
CI	Confidence intervals
LLD	Leg length discrepancy
HHS	Harris hip score

CBM Chinese biomedical literature database
CNKI Chinese national knowledge infrastructure

Author contributions
Wu Z. H and Zheng Y. drafted the main manuscript, and Wu Z. H. prepared all the figures. Wu Z. H., Zheng Y., and Zhang X.W. screened and evaluated the literature. Zhang X. W. revised the article and provided research guidance. All authors reviewed the manuscript.

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Declarations

Consent for publication
All the authors of this study have given their consent to publication.

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