The Journal of Arthroplasty 40 (2025) S5–S7

Contents lists available at ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

World Expert Meeting in Arthroplasty 2024

Does the Use of Robotics Increase the Rate of Complications After Total Hip, Total Knee, or Unicondylar Knee Arthroplasty?

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ARTICLE INFO

Article history:
Received 20 September 2024
Received in revised form
17 October 2024
Accepted 20 October 2024
Available online 28 October 2024

Keywords:
robotics
robotic arthroplasty
TKA
UKA
THA

Does the use of robotics increase the rate of complications after total hip, total knee, or unicondylar knee arthroplasty?

Response/Recommendation: Based on the current literature, incorporating robotics into total hip arthroplasty, total knee arthroplasty, and unicondylar knee arthroplasty does not increase general complications while increasing the risk for other complications related specifically to techniques for robotic methods.

Level of evidence: Moderate.

Expert vote: Agree 63.6%, disagree 29.4%, abstain 7.0%.

Rationale

The recent introduction of robotics in hip and knee arthroplasty intends to enhance patient outcomes through improved precision and accuracy in implant placement and limb alignment [1]. A large number of robotic devices and technologies exist in the market for total hip arthroplasty (THA), total knee arthroplasty (TKA), and unicondylar knee arthroplasty (UKA), resulting in considerable variability in surgical techniques [2–4]. Nevertheless, despite these differences in platforms, the technical objectives remain fundamentally similar [5].

A thorough search encompassing PubMed, Scopus, and the CINAHL database was undertaken to assess the utilization of robotics versus conventional methods in hip and knee arthroplasty. The reviewed studies were predominantly comprised of small prospective and retrospective investigations with limited follow-up. The majority of the studies in the literature are conducted by surgeons or investigators who have a strong interest in robotics.

One or more of the authors of this paper have disclosed potential or pertinent conflicts of interest, which may include receipt of payment, either direct or indirect, institutional support, or association with an entity in the biomedical field which may be perceived to have potential conflict of interest with this work. For full disclosure statements refer to https://doi.org/10.1016/j.arth.2024.10.109.

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https://doi.org/10.1016/j.arth.2024.10.109

Based on the current literature, incorporating robotics into THA, TKA, and UKA does not appear to result in higher complications compared to conventional methods. However, robotic techniques are associated with increased operative time, especially during the learning curve period, and complications related to tracker pin sites.

Total Hip Arthroplasty (THA)

Adopting new techniques in THA has historically involved a learning curve that can lead to increased complications during the initial phase [6]. However, robotic-assisted THA appears to mitigate this risk, as evidenced by studies indicating no significant increase in complications during the critical learning period, typically encompassing approximately 12 to 20 cases [7,8]. Following a thorough review process, 27 studies were included in a final analysis comparing complication rates between robotic-assisted THA and conventional THA.

The findings revealed a reduced overall risk of complications associated with robotic-assisted THA (relative risk (RR) 0.64; 95% confidence interval (CI) 0.49 to 0.85) compared to conventional THA. Specifically, robotic-assisted THA demonstrated a lower risk of dislocation (RR 0.33; 95% CI 0.14 to 0.78) and periprosthetic fracture (RR 0.22; 95% CI 0.11 to 0.46). However, the incidence of periprosthetic joint infection was comparable between the two groups (RR 0.77; 95% CI 0.40 to 1.21). Furthermore, nerve injuries in the form of neuropraxia were reported more frequently in robotic-assisted THA using an older active autonomous robotic system [9]. Additionally, there was a higher incidence of postoperative heterotopic ossification in robotic-assisted THA [10].

Total Knee Arthroplasty (TKA)

The integration of robotics in TKA has enabled surgeons to access intraoperative parameters irrespective of alignment philosophy or patient anatomy. Among the various arthroplasty procedures, TKA has seen the most widespread adoption of robotic platforms, with a large number of TKAs now being performed with robotic assistance [11].

A substantial body of evidence compares robotic-assisted versus conventional TKA, with 30 studies included in this review. Overall, the analysis indicated comparable rates of overall complications between robotic-assisted and conventional TKA (RR 1.20; 95% CI 0.88 to 1.63). Upon closer examination of major complications, there were no significant differences observed in infection rates (RR 0.92; 95% CI 0.54 to 1.55), thromboembolic events (deep vein thrombosis/pulmonary embolism) (RR 1.56; 95% CI 0.88 to 2.76), periprosthetic fractures (RR 0.49; 95% CI 0.15 to 1.63), or incidents of joint stiffness requiring manipulation/arthroscopy (RR 0.74; 95% CI 0.44 to 1.25). Specific to the techniques requiring tracker placement, superficial pin site infection is reported to be 0.6%, which is not inherent in conventional techniques [12].

Unicondylar Knee Arthroplasty (UKA)

The utilization of robotics in UKA has experienced a large increase, rising from less than 10% in 2015 to over 40% by 2022 [13]. Among the 21 studies comparing robotic-assisted and conventional UKA, there is a notable bias toward a single robotic platform, particularly the Mako system (Stryker, Mahwah, New Jersey, USA), which accounts for 62% of the studies.

Robotic-assisted UKA demonstrates reduced rates of overall complications (RR 0.67; 95% CI 0.53 to 0.84). Specifically, patients undergoing robotic UKA are less likely to require revision due to loosening or disease progression (RR 0.44; 95% CI 0.29 to 0.66). However, the risk of periprosthetic fracture (RR 3.32; 95% CI 0.14 to 9.66), subsequent arthroscopy/arthrotomy for adjacent compartment disease/arthrofibrosis (RR 1.66; 95% CI 0.78 to 2.39), and periprosthetic joint infection (RR 0.94; 95% CI 0.59 to 1.49) compared to conventional UKA remains equivocal.

Longevity of Robotic Versus Conventional

Long-term evaluation of revision risks in robot-assisted THA remains limited in the literature. A 14-year follow-up study following robotic-assisted THA showed no significant difference in survivorship for any reason across all observed time points [4].

Similarly, recent data from the Australian Orthopaedic Association National Joint Replacement Registry and the American Joint Replacement Registry reveal comparable outcomes for TKA regardless of the method used. The Australian data show that at the 5-year mark, the cumulative percent revision rates for robotic-assisted and conventional TKA are 2.2 and 2.7%, respectively [13]. The American Joint Replacement Registry found no significant difference in the odds of revision between robotic and conventional TKA at two years (odds ratio 1; 95% CI 0.8 to 1.3). These findings suggest that both techniques offer similar 2- to 5-year efficacy in terms of revision rates [14].

Regarding UKA, the Australian registry indicates that robotic-assisted procedures have a lower cumulative percent revision rate at 7 years—5.1% for robotic-assisted compared to 6.8% for conventional approaches [13]. This is further supported by additional research, which shows improved up to 9-year survival for robotic-assisted UKA, with implant retention rates of 96.4% at 9 years compared to 87.3% for conventional UKA [15].

These findings underscore the ongoing evaluation of robotic-assisted techniques in joint arthroplasty, highlighting comparable early-term outcomes and the need for ongoing research into longer-term revision risks. Based on the available literature, robotic-assisted techniques do not seem to result in higher complication rates compared to conventional methods. However, they are associated with longer operative times and may introduce unique challenges associated with pin tracker placement and the presence of large equipment in the operating room. A key limitation in drawing a definitive conclusion about robotic technology is that each system has its specific characteristics and should be evaluated individually for its own merits.

CRediT authorship contribution statement

Minjae Lee: Writing – review & editing, Writing – original draft, Investigation, Data curation. **Claudia Arias:** Writing – review & editing. **Vittorio Bellotti:** Writing – review & editing. **Goran Bicanic:** Writing – review & editing. **Kelvin G. Tan:** Writing – review & editing. **Joshua Bingham:** Writing – review & editing. **Sébastien Lustig:** Writing – review & editing. **Pietro Randelli:** Writing – review & editing, Writing – original draft.

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