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

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Response/Recommendation: Based on the current literature, incorporating robotics into Total Hip Arthroplasty (THA), Total Knee Arthroplasty (TKA), and Unicondylar Knee Arthroplasty (UKA) appears to reduce some complications while increasing the risk for other complications related specifically to techniques for robotic method.

Level of evidence: Moderate

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 THA, TKA, and 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 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 with a strong interest in robotics. Based on the current literature, incorporating robotics into Total Hip Arthroplasty (THA), Total Knee Arthroplasty (TKA), and Unicondylar Knee Arthroplasty (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 the need for the insertion of tracker pins, which could potentially increase the risk of infection for all of these procedures.

Total Hip Arthroplasty

Adopting new techniques in total hip arthroplasty (THA) has historically involved a learning curve that can lead to increased complications during the initial phase. [6] However, robotic-assisted total hip arthroplasty (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 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 (RR 0.64; 95% CI 0.49-0.85) compared to conventional THA. Specifically, robotic-assisted THA demonstrated a lower risk of dislocation (RR 0.33; 95% CI 0.14-0.78) and periprosthetic fracture (RR 0.22; 95% CI 0.11-0.46). However, the incidence of periprosthetic joint infection was comparable between the two groups (RR 0.77; 95% CI 0.40-1.21). Furthermore, while nerve injuries were infrequent, nerve injuries were reported more frequently in robotic-assisted THA.[9] Additionally, there was a higher incidence of postoperative heterotrophic ossification in robotic-assisted THA.[10]

Total Knee Arthroplasty

The integration of robotics in total knee arthroplasty (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 significant 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 0.88-1.63). Upon closer examination of major complications, there were no significant differences observed in infection rates (RR 0.92; 95% CI 0.54-1.55), thromboembolic events (DVT/PE) (RR 1.56; 95% CI 0.88-2.76), periprosthetic fractures (RR 0.49; 95% CI 0.15-1.63), or incidents of joint stiffness requiring manipulation/arthroscopy (RR 0.74; 95% CI 0.44-1.25). 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

The utilisation of robotics in Unicondylar Knee Arthroplasty (UKA) has experienced a significant 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 notable bias towards a single robotic platform, particularly the Mako system (Stryker, Mahwah, NJ, USA), which accounts for 62% of the studies.

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

Longevity of Robotic vs Conventional

Long-term evaluation of revision risks in robot-assisted THA remains limited in the literature. A fourteen-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 long-term 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 2 years (OR 1; 95% CI 0.8-1.3). These findings suggest that both techniques offer similar long-term efficacy in terms of revision rates. [14]

Regarding Unicompartmental Knee Arthroplasty (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 long-term 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 long-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 definitive conclusion about robotic technology is that each system has its own specific characteristics and should be evaluated individually for its own merits.

1. Jacofsky, D.J. and M. Allen, *Robotics in Arthroplasty: A Comprehensive Review.* J Arthroplasty, 2016. **31**(10): p. 2353-63.
2. Ma, N., et al., *Comparison of the efficacy and safety of MAKO robot-assisted total knee arthroplasty versus conventional manual total knee arthroplasty in uncomplicated unilateral total knee arthroplasty a single-centre retrospective analysis.* Int Orthop, 2024.
3. Rajasekaran, S., et al., *Comparison of imageless robotic assisted total knee arthroplasty and conventional total knee arthroplasty: early clinical and radiological outcomes of 200 knees.* J Robot Surg, 2024. **18**(1): p. 151.
4. Bargar, W.L., et al., *Fourteen Year Follow-Up of Randomized Clinical Trials of Active Robotic-Assisted Total Hip Arthroplasty.* J Arthroplasty, 2018. **33**(3): p. 810-814.
5. Leelasestaporn, C., et al., *Comparison of 1-year outcomes between MAKO versus NAVIO robot-assisted medial UKA: nonrandomized, prospective, comparative study.* Knee Surg Relat Res, 2020. **32**(1): p. 13.
6. de Steiger, R.N., M. Lorimer, and M. Solomon, *What is the learning curve for the anterior approach for total hip arthroplasty?* Clin Orthop Relat Res, 2015. **473**(12): p. 3860-6.
7. Hecht, C.J., et al., *Contemporary analysis of the learning curve for robotic-assisted total hip arthroplasty emerging technologies.* J Robot Surg, 2024. **18**(1): p. 160.
8. Buchan, G.B.J., et al., *The learning curve for a novel, fluoroscopy-based robotic-assisted total hip arthroplasty system.* Int J Med Robot, 2023. **19**(4): p. e2518.
9. Honl, M., et al., *Comparison of robotic-assisted and manual implantation of a primary total hip replacement. A prospective study.* J Bone Joint Surg Am, 2003. **85**(8): p. 1470-8.
10. Nakamura, N., et al., *A comparison between robotic-assisted and manual implantation of cementless total hip arthroplasty.* Clin Orthop Relat Res, 2010. **468**(4): p. 1072-81.
11. Sherman, W.F. and V.J. Wu, *Robotic Surgery in Total Joint Arthroplasty: A Survey of the AAHKS Membership to Understand the Utilization, Motivations, and Perceptions of Total Joint Surgeons.* J Arthroplasty, 2020. **35**(12): p. 3474-3481.e2.

12. Thomas, T.L., et al., *Pin-Related Complications in Computer Navigated and Robotic-Assisted Knee Arthroplasty: A Systematic Review.* The Journal of Arthroplasty, 2022. **37**(11): p. 2291-2307.e2.
13. AOANJRR, *Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR). Hip, knee and shoulder arthroplasty: 2023 Annual Report.* . 2023, Adelaide: Australian Orthopaedic Association.
14. Kirchner, G.J., et al., *Robotic-assisted TKA is Not Associated With Decreased Odds of Early Revision: An Analysis of the American Joint Replacement Registry.* Clin Orthop Relat Res, 2024. **482**(2): p. 303-310.
15. Foissey, C., et al., *Better accuracy and implant survival in medial imageless robotic-assisted unicompartmental knee arthroplasty compared to conventional unicompartmental knee arthroplasty: two- to eleven-year follow-up of three hundred fifty-six consecutive knees.* International Orthopaedics, 2023. **47**(2): p. 533-541.