G 61 – Are patients undergoing robotic assisted orthopedic procedure at higher risk of subsequent SSI/PJI?

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Response/Recommendation: No. At present, there is no definitive evidence to suggest that the rates of SSI/PJI are increased in robotic assisted orthopedic procedures.

Level of Evidence: Limited

Delagate Vote:

Rationale:

The introduction of robotic assisted technology in orthopedic surgery has attracted significant attention in recent years, especially in spinal surgery, hip and knee arthroplasty. Initially introduced in the 1980s to enhance implant positioning accuracy and alignment while reducing complications compared to manual techniques, robotic systems have evolved considerably. Despite these advancements, concerns persist regarding prolonged operative times, increased surgical site complexity, and the potential impact on rates of surgical site infections (SSI) and prosthetic joint infections (PJI).

This systematic review was conducted to evaluate whether patients undergoing robotic assisted orthopedic procedures are at higher risk of subsequent SSI/PJI. Searches of PubMed and SCOPUS databases were performed in October 2024 using PRISMA guidelines. From 268 identified articles, 69 studies were included following full-text screening. Notably, 50% of the included studies were published in 2023 and 2024, underscoring the contemporaneity of the evidence.

The majority of studies evaluating robotic assisted orthopedic procedures predominantly focus on radiological and functional outcomes, with only a limited number examining the incidence of SSI/PJI. Among the studies analyzed, only three had a minimum follow-up period of 10 years. In 2020, Kim et al. published a randomized controlled trial (RCT) with the longest follow-up period of 13 years, reporting no statistically significant differences in infection or complication rates between robotic assisted and manual total knee arthroplasty (TKA) [1]. Similarly, retrospective studies by Jeon et al. and Lee et al. supported these findings, demonstrating comparable PJI rates across surgical techniques [2,3]. These findings emphasize that, at least in the limited literature available to date, long-term outcomes, including infection rates, remain comparable between robotic-assisted and conventional surgical techniques. In 2023, Alrajeb et al. published a systematic review and meta-analysis of randomized controlled trials (RCTs) comparing robotic assisted and conventional knee arthroplasties. This significant study analyzed 7 RCTs encompassing 1,942 knees. The findings indicated that both clinical and functional outcomes, as well as complication rates, including infections, were statistically similar between robotic assisted and conventional knee replacement surgeries [4]. All other included studies, RCTs, prospective and retrospective, had shorter follow-up periods but consistently reported no significant differences in infection rates between robotic assisted and conventional arthroplasty surgery [5-20]. In 2024, Burgio et al. published a retrospective study focused exclusively on PJI in the context of robotic assisted TKA without comparation to manual TKA. It was the only study which clearly defined the criteria used for diagnosing PJI, highlighting the importance of standardizing criteria and definitions for PJI [21]. Certain studies highlighted procedural aspects unique to robotic assisted surgeries that could influence infection risks. Honl et al. observed that prolonged surgical durations associated with robotic TKA were initially linked to SSI. However, the increased rate of early complications diminished as surgeons overcame the learning curve associated with the technology [5]. Li et al. reported comparable PJI rates between robotic and conventional TKA groups, despite robotic assisted procedures having increased operative times [22,23]. Other publications from LaValva et al., emphasized potential concerns related to equipment use. While pin-site complications were infrequent, they, along with increased operating room traffic and extended operative times, were identified as potential contributors to contamination risk [24,25]. Several retrospective studies, including those by O'Rourke et al., Aggarwal et al., Katzman et al. and Khanna et al., reported lower rates of PJI in robotic assisted surgeries when compared to conventional techniques [26-29]. However, the unknown follow-up periods in these studies limit the interpretability of their findings. While the results suggest a potential advantage of robotic systems in minimizing infection risks, the absence of robust longitudinal data prevents drawing definitive conclusions about their long-term effectiveness. In contrast with those studies, in 2024, Piple et al. published that robotic assisted total hip arthroplasty was associated with increased rates of medical complications, including PJI [30]. Despite these complexities, most studies suggest that robotic assisted joint arthroplasty does not inherently increase the risk of PJI compared to conventional approaches. Factors such as learning curve improvements and advancements in robotic technology appear to address earlier concerns, as reflected in the findings of St Mart. These studies reported higher infection rates with earlier robotic systems, attributing them to technical and procedural limitations rather than inherent flaws in robotic technology [31-32]. The heterogeneity in study designs, follow-up period, and definitions of infection combined with the limited number of long-term studies, underscores the need for further research with standardized methodologies to validate these findings.

In spinal surgery, the impact of robotic assistance on infection risks and surgical outcomes has been variable across studies. Yang et al. reported an increased risk of complications, including surgical site infections (SSI), associated with robot-assisted lumbar spinal fusion compared to conventional techniques [33]. However, other studies have highlighted significant benefits of robotics in spinal procedures. Keric et al. demonstrated that robotic systems reduced infection rates in minimally invasive spine surgery, particularly in high-risk populations, suggesting that the precision and minimally invasive approach afforded by robotics may contribute to better outcomes [34]. Interestingly, unlike joint arthroplasties, robotics in spinal surgery has been associated with reduced operative time, which may play a critical role in minimizing intraoperative contamination risks [35-37]. Zawar et al. similarly found that robotic guided open spine surgeries achieved lower infection rates compared to conventional open procedures, further supporting the notion that robotics can enhance overall outcomes in spinal surgery [38]. While there are differences in infection-related outcomes reported in the literature, the growing evidence suggests that robotic assistance in spinal surgery may offer distinct advantages, particularly in terms of procedural efficiency and reduced operative times. These benefits contrast with findings in joint arthroplasties, where robotic procedures often prolong surgical time. The divergence underscores the importance of tailoring robotic applications to the unique demands of specific surgical fields to optimize their potential benefits.

Conclusion:

At present, there is no definitive evidence to suggest that the rates of SSI/PJI are increased in robotic assisted orthopedic procedures. Robotic joint arthroplasty may have longer operative times and increased operating room traffic, which are well-established risk factors for contamination events, however these potential risks have not yet been demonstrated to have an effect on rates of PJI. Future studies with a longer follow-up period, preferably a minimum of 10 years, are necessary to assess complications and revision rates. Furthermore, most of the included studies were not RCTs and had small sample sizes, increasing the possibility of publication bias. Despite these limitations, robotic assisted techniques continue to evolve. As robotic technology becomes more prevalent, rigorous long-term studies are essential to substantiate its clinical benefits.

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