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Exploring the Use of Robotics in Orthopaedic Surgery

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Over the last few decades, the use of robotics has dramatically increased across all surgical specialties. While initially only utilized in a few gynecological and urological procedures, robotics are now used in a wide range of surgical procedures ranging from general surgery, cardiovascular surgery, to otolaryngology and orthopaedic surgery. One study noted in the field of general surgery, roughly 15% of all surgeries are utilizing some form of robotics.[1] Surgical robotics assist in a variety of ways ranging from guiding procedures by creating 3D images of the anatomic landscape, to allowing physicians to operate through telemanipulating in a separate room. The use of robotics has aided in increasing the surgical accuracy and precision through smaller incisions, while reducing the risk of complications, radiation exposure, and overall surgical time.[1–3]

In orthopaedic surgical history, the TiRobot® has been noted as the first robot to reduce human errors in the implantation of screws during spine surgery. The system is multifaceted consisting of three main components: a robotic arm, an optical tracking device, and a surgical planning and controlling workstation. It works by first creating a 3D anatomical map of the procedure that the surgeon can view in the optical tracking device. Simultaneously, the robot utilizes its unique algorithm to calculate the precise screw trajectory with only less than 1 mm of inaccuracy.[4,5] In addition to these advantages, the robotic apparatus provides an arm that can precisely move to any planned position while providing the surgeons a stable trajectory to place the cannulated screws effortlessly.

The TiRobot® was first documented in spinal surgical studies placing pedicle screws in scoliosis surgery, as well as placing percutaneous sacroiliac screws in separate surgeries. One study notably found a 98.2% success rate while using the TiRobot® to place pedicle screws compared to a 91.6% rate for freehand fluoroscopy-assisted pedicle screw insertion using a traditional open technique.[6] Additionally, studies have shown significantly lower surgical time, less intraoperative blood loss and less postoperative drainage in robotic-assisted procedures compared to a traditional approach.[4–6] Following these studies, the TiRobot® was later trialed in placing screws in distal extremities; again, providing to be as efficacious as current traditional approaches, with increased accuracy, and reduced surgical complications.[7]

In addition to spine surgery, robotics have also been integrated and documented in both trauma and joint replacement surgery. As both specialties require high levels of precision and dexterity, robotics have been able to assist in reducing iatrogenic fractures and screw implant malpositioning. In joint surgery, the use of robotics have been studied particularly in both total knee arthroplasty (TKA) and hip arthroplasty (THA). One retrospective study examined robot-assisted total knee arthroplasties compared to conventional TKAs and found that while the clinical outcomes and survival rates were similar, the robot-assisted group had fewer postoperative leg malalignment, fewer radio-lucent lines, and significantly improved mechanical axes.[8] A separate prospective study found that although the robot-assisted TKAs had a higher rate of complications, the patients in this cohort noted better quality-of-life measures, including significant improvements in SF-36 vitality and role emotional, and a larger proportion of patient achieving SF-36 vitality minimum clinically important difference.[9] Lastly, a meta-analysis found similar pain, quality of life, satisfaction and clinical outcomes between robotically-assisted THAs and TKAs compared to conventional approaches.[10]

In hand surgery, the use of robotics has been shown to not only improving accuracy and precision, but decrease overall surgical time and complications. A randomized control trial comparing robotic-assistance screw fixation for acute scaphoid fractures to traditional scaphoid screw fixation found that robotic-assisted surgery had a significantly lower guidewire insertion time, increased accuracy in guidewire insertion, and decrease in the number of attempts at inserting the guidewire.[11] Additionally, multiple studies have also concluded that the use of robotics in percutaneous scaphoid fixations were comparable to conventional techniques by having similar postoperative outcomes, complications rate, and scarring.[12-14] Moreover, the robotic assisted cohorts were associated with significantly decreased surgical time and an overall 28% reduction in radiation used in the OR.[12-14] As a result, robotic-assisted hand surgery has been shown to not only provide comparable clinical outcomes for patients, but also improve the health and safety for the entire surgical team.

In addition to the benefits listed above, robotics can also reduce the physical strain on surgeons. This assistance might seem minimal, however even the smallest assistance over time helps improve the overall safety and efficiency of the procedure for the patient and surgical team involved. A study published in the Journal of the American Medical Association concluded that the use of a robotic system resulted in significantly less muscle fatigue for surgeons compared to traditional methods.[15] For all the reasons above, robotics has been documented to be comparable to current surgical approaches, while improve overall surgical efficiency.

Despite the potential advantages robotics provide, there are still large barriers to incorporating them into every OR. The largest barriers to instituting robotics are the cost and availability of the technology. Robotically assisted procedures have been noted to cost roughly $2,000 more expensive than non-robotically assisted procedures due to estimated increases of $1,866 for robotic specific instruments and accessories, $1,038 for robot systems, and $663 for the service contracts.[16] However, with all these incurred costs, robotically assisted procedure have been noted to decease surgical time, allowing for more procedures to be performed to offset the high overhead. Lastly, as the technology is constantly improving, this increases the availably of robotics in the marketplace and allowing for more hospitals to incorporate them into their practices. This is evident with the increase in rise and use of the new Tuoshou® robot, which has improved on the TiRobot® robotic arm, imaging, and interface within the workstation to increase precision and provide real time intraoperative e feedback.[17] As technology continues to advance and become more widely available, many of the initial barriers limiting use of robotic-assisted surgery in orthopaedics will begin to dissipate.

Regardless of the existing barriers, the current clinical evidence suggests the use of robotics in orthopaedic surgery is a promising trend. With the growth of technology in the OR, it is likely that more surgeons will adopt the new innovative approaches, leading to improved patient outcomes, and more efficient surgical procedures.

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