Role of Robotics in Orthopaedic Surgery: *Will they give better outcomes?*

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Introduction

Robots have been in use since the late 1980s in different surgical specialities. The first use was PUMA (Programmable Universal Manipulation Arm) in 1985 for a neurosurgical biopsy[1]. Robotic technology in Orthopaedic surgery began in 1992, with the introduction of ROBODOC[2]. This was for the planning and performance of total hip replacement. The use of robotic systems has subsequently increased, with promising short-term radiological outcomes when compared with traditional orthopaedic procedures. The skeletal anatomy lends itself well to preoperative planning, intraoperative registration and navigation.

Classification

Robotic systems can be classified into three categories: autonomous (active), semi-active and passive. The active system can independently perform tasks without the surgeon's intervention, as they are pre-programmed for bone resection. The first active system in use in Orthopaedics has been the ROBODOC[2]. Once programmed the surgeon could not interfere during the surgical procedure. The semi-active systems robots constraint surgical manipulation through feedback to restrict what can be done surgically. The MAKO Robotic-arm assisted surgery (Stryker) is in use in current times[3]. Passive surgery systems, which represent a third type of technology, have also been adopted recently by orthopaedic surgeons, in particular arthroscopic shoulder surgery. While autonomous systems have fallen out of favour, tactile systems with technological improvements have become widely used.

Robotic bone cutting can be designed into 3 types. The autonomous variety is independent and cuts bone without the human intervention (e.g. ROBODOC). In the haptic type, the surgeon allows the robot to move and cut, but the movement is constrained as soon as it reaches the border (e.g. MAKO system). In the boundary control variety, the surgeon's intervention is required to move the robot and then it remains free to move anywhere in space but cutting is deactivated by some means if it travels beyond a boundary (NAVIO). The current robotic systems are designed and may be classified based on these features.

Specific Indications
Unicompartmental knee replacement

Specifically, the use of tactile and passive robotic systems in unicompartmental knee replacement (UKR) has addressed some of the historical mechanisms of failure of non-robotic UKR. These systems assist with increasing accuracy of the alignment of the components and produce more consistent ligament balance. Short-term improvements in clinical and radiological outcomes have increased the popularity of robot-assisted UKR[4].

There are several studies, which endorse Robotic-assisted medial UKR results. In one recent study two hundred and six patients (232 knees) who underwent medial robotic-assisted UKR were retrospectively studied[5]. Femoral and tibial sagittal and coronal alignments were measured in the post-operative radiographs and were compared with the equivalent measurements collected during the intra-operative period by the robotic system. Mismatch between pre-planning and post-operative radiography was assessed against accuracy of the prosthesis insertion.

The results showed accurate prosthesis position. Inaccuracy may be attributed to suboptimal cementing technique.

Total knee Replacement (TKR)

Clinical studies in total knee arthroplasty have demonstrated better gap balancing and implant alignment using the ROBODOC system compared with conventional techniques[6,7]. While the ROBODOC system is no longer in use, there are now new robotic systems in the market.

The MAKO system devised by Stryker is considered the leading system robot-assisted knee and hip surgery. This robot-assisted system develops a 3D model of the joint, which surgeons use to evaluate bone structure, joint alignment and surrounding tissue. It provides real-time range-of-motion data during surgery and uses a robotic arm to remove the bone and cartilage from the knee and place the implant.

Smith & Nephew already has a hand-held robotic surgical system on the market. It recently introduced new software for that system, known as the Navio 7.0 for partial and total knee replacements.

Johnson & Johnson's DePuy Synthes acquired the Paris based Orthotaxy system in 2018. According to their brochure, "It's is the size of a shoebox, attaches to an operating table and includes a saw, but does not do the sawing for the surgeon. Instead, the Orthotaxy platform will design the surgery plan and lock the saw into a plane, allowing the surgeon to do the cutting."

The ROSA knee platform (Zimmer Biomet) includes 3D pre-operative planning tools and real-time data on tissue and bone anatomy during procedures. This can improve bone cut accuracy and result in a more precise range of motion analysis, which can help knee replacements feel more natural.

Initial outcomes have been promising but we must await long-term results with respect to clinical outcomes and survivorship. The costs are an important factor, as the hardware may require regular updates. There is also increased radiation to patients with the need of imaging.

Total Hip Replacement (THR)

Acetabular component placement in total hip arthroplasty is key to this surgery. The semi-active robotic systems allow the surgeon to control the robotic arm to ream the acetabulum to a specified depth and size, without having to sequentially ream larger acetabular sizes. Accurate acetabular component placement can reduce the likelihood of dislocation, leading to fewer revision procedures[8]. Long-term follow-up at 14 years demonstrated no stem-loosening failures, less pain, and lower Western Ontario and McMaster Universities

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Osteoarthritis Index (WOMAC) scores in the robotic total hip arthroplasty group, with similar complications and reoperations for polyethylene wear as compared to the conventional methods[9].

Spine

Spinal surgery involves complex procedures and intricate placement of instruments and screws[10]. The Mazor X Stealth Robotic assisted spinal platform (Medtronic) uses software to plan a spinal procedure, helping surgeons visualize everything down to the trajectory of each screw[11]. During the surgery, a robotic arm guides implants and surgical instruments. Real-time imaging helps surgeons ensure the procedure is being carried out properly.

The ROSA One a surgical navigation system marketed by Zimmer Biomet helps surgeons perform minimally invasive and complex spine procedures[12]. This system expands the functionality of robotic systems previously approved for brain and knee surgeries, making Zimmer the first company in the world to offer all three procedures on one platform.

Trauma

There have been experimental developments with robotic systems to assist with closed fracture reduction and reconstruction and in performing surgery remotely. There is still insufficient evidence for recommendation for or against use of the systems. Robotic techniques in the military sphere, either autonomously or in a telemedicine mode, can be used to perform critical acute surgical procedures and medical stabilization of soldiers on the battlefield, where immediate assistance may not be available[13]. We have to wait to find out whether these would be applicable to the civilian hospitals or not.

Shoulder

Robotic shoulder arthroscopy[14] and robot assisted shoulder girdle surgery for micro-neural repairs[15] seems feasible in a cadaveric model but has some significant limitations at this time.

Limitations

Increased costs with need for updated software at regular intervals would remain a hurdling block until it becomes more popular. For clinical applications, there is requirement of imaging for preoperative templating, which may cause increased radiation for patients. The other initial limiting factors are surgeon's learning curve and increased operative time. These factors will eventually iron out with increased use of these systems and greater training opportunities.

Conclusion

Robotic surgery shows great promise to transform Orthopaedics[16] and many other specialities, contributing to better outcomes and potential cost-savings for hospitals. However, more clinical trials and post-market data collection are needed to ensure that benefits outweigh the risks.

What is most important is to understand that robot-assisted surgery may not be appropriate for every application. Therefore, appropriate training of surgeons in the use and applications of these systems are vital. This would bring about a better understanding of their limitations as well.

Acknowledgement: The author wishes to state that he has no experience of using the robotic system. The documents for the article have been collated from a wide literature search.
The author has no conflict of interest to declare.

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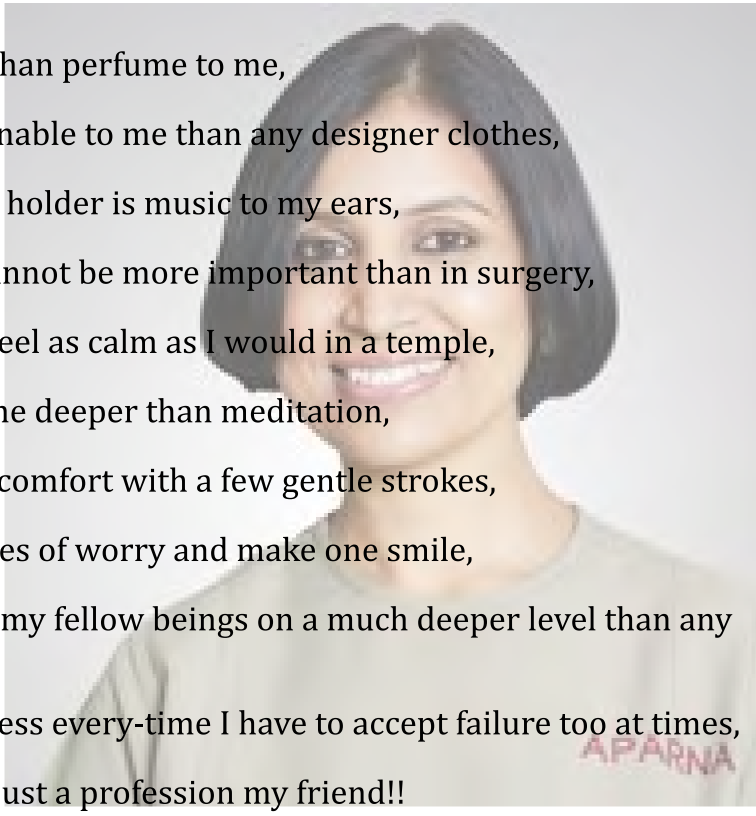
The other day one of my dear patients asked me a question before getting into a procedure-

DOCTOR WHY DO YOU CONSIDER SURGERY AS AN ART?

I guess,



- Because the smell of spirit is sweeter than perfume to me,
- Because my ot scrubs feel more fashionable to me than any designer clothes,
- Because the clicking sound of a needle holder is music to my ears,
- Because proportions and symmetry cannot be more important than in surgery,
- Because when I walk into a hospital I feel as calm as I would in a temple,
- Because when I operate I get into a zone deeper than meditation,
- Because I can convert discomfort into comfort with a few gentle strokes,
- Because I know that I can erase the lines of worry and make one smile,
- Because I can make a connection with my fellow beings on a much deeper level than any other profession,
- Because although I may strive for success every-time I have to accept failure too at times,

And that is why surgery is an art and not just a profession my friend!!

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