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Review Article

Role of robotics in trauma and orthopaedics

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ABSTRACT

There is always an ardent desire to obtain the best outcome in any surgery. To improve the quality of life of their patient is amongst the top priorities of most orthopaedic surgeons. It is a big challenge to accurately match a perfect pre-operative planning and obtain that intra operatively. Robotic technology is fast evolving in many surgical branches with orthopaedics as well, but limited with the price tag it comes with. Nevertheless, robotics is gaining momentum with some encouraging short-term results. Robotic surgery can offer significant improvement in surgical planning, accurate implant or prosthetic placement, which provide good outcomes that ultimately enhance patient safety. We review the various robotic advancements in the field of trauma and orthopaedic surgery.

Keywords: Advances, Robotics, Trauma and orthopaedics

INTRODUCTION

There is always an ardent desire to obtain the best outcome in any surgery. To improve the quality of life of their patient is amongst the top priorities of most orthopaedic surgeons. It is a big challenge to accurately match a perfect pre-operative planning and obtain that intra operatively. Robotic technology is fast evolving in many surgical branches with orthopaedics as well, but limited with the price tag it comes with.

Nevertheless, robotics is gaining momentum with some encouraging short-term results. Robotic surgery can offer significant improvement in surgical planning, accurate implant or prosthetic placement, which provide good outcomes that ultimately enhance patient safety. We review the various robotic advancements in the field of trauma and orthopaedic surgery.[1]

The common robotics used are the one's which can be surgeon driven. Insect-like arms are operated by the surgeon, who can control the booth. There are also autonomous surgical robots, wherein robots can operate independent of human control. The autonomous robotics are however, being specifically designed to suture or stitch up soft tissue now. Campaigners of robot-assisted systems boast of better patient outcomes through better pre-operative planning and improved execution of the same.[2]

Robotic surgery has been slow in penetrating the surgical practise, due to the huge cost involved, restricted availability, lack of long-term high-impact level 1-research studies regarding their efficiency and the safety of the robots itself.[2]

History of robots in medicine: Robot is a machine, which is expected to be able to perform complex tasks automatically. There have been many introduced and installed since the first industrial robot was used in 1961.

The first known robot to be used in medicine, PUMA 560 was used to perform a brain biopsy under computed tomography (CT) guidance in 1985. The same device was used later to perform a resection of prostate, 3 years later. Although, in 1986, the technology was first used in the United States (US), for adult reconstruction, it was not until 1994 that it was exported to Europe due to regulatory restrictions in the US, its actual practical use could be tested.

Table 1: The clinical applications of robots in orthopaedic surgery have been summarised.

Area of interest	Procedures	Robotic system
Knee	Unicompartmental knee arthroplasty (UKA)	Acrobot system (The Acrobot Co. Ltd., London, United Kingdom)
	Total knee replacement	Tactile guidance system (TGSTM; MAKO surgical corp., Fort Lauderdale, Florida)
Hip	Total hip replacement hip arthroscopy	The robot-assisted THA (ROBODOC; Integrated Surgical Systems, Davis, California
		Robot-assisted system (CASPAR, Orto-Maquet, Rastatt, Germany)
		Robotic hip arthroscopy using the three-armed da Vinci standard surgical system (Intuitive Surgical, Sunnyvale, California)
Foot and Ankle	Robot-guided intra-articular injections to the tibiotalar, talonavicular, tarsometatarsal, subtalar and calcaneocuboid joints	The INNOMOTION robotic assistance device (Innomedic, Herxheim, Germany)
Shoulder	Shoulder arthroscopy	da Vinci surgical system
Spine	Placement of pedicle screws	SpineAssist robot (Mazor Surgical) Technologies, Caesarea, Israel)
	Facet and sacroiliac joint injections	The INNOMOTION device
Trauma and general orthopedics	Navigation of the entry point and distal locking bolts in intramedullary nailing.	da Vinci surgical system
	Aiding the reduction of femoral and tibial fractures	
	Identification, dissection and primary repair of nerves in brachial plexus surgery	
Research	Tele-operative robot-assisted or autonomous robot-performed surgical stabilization of critically wounded patients particularly within the military sphere.	Trauma pod, a semi-automated tele-robotic surgical system

The concept of ROBODOC was introduced by Sacramento Veterinarian, Dr. Howard Paul and Dr. William Bargar, and orthopaedic surgeon (integrated surgical systems (ISS) Inc. of Sacramento, California, USA), who led to perform the first femoral machining during hip arthroplasty.

Germany was the place it was first popularised in the Europe and by the year 2000, roughly 50 centres were using ROBODOC. CASPAR, Germany was another competitor at the time.

In the year 2001, the first publication, describing surgery with robotic assistance in uni-compartmental knee arthroplasty (UKA) using the ACROBOT (Imperial college, London, UK) was noted. Mako surgical (Fort Lauderdale, FL, USA) made its first mark in 2006 with again an UKA and then patellofemoral arthroplasties with its RIO robotic arm device.

Robotic applications

Figure 1: Mako robotic arm which is used in hip surgery.

Hip: It is now possible to plan accurate placement of both the acetabular and femoral components and one that could match to a pre-operative template. A typical method is to perform a preoperative Computed tomogram (CT) scan of the pelvis and hip. A 3-D modelling then enables an accurate planning of implant placement, size and orientation. It has been claimed that, it shall also allow single stage reaming of the acetabulum. Information is fed into the robot and with the help of the surgeon, a pre-operative plan for prosthetic placement decided. This is then executed by the robot with the surgeon scrubbed in. This is as show in Figure 1.

There is also an advantage demonstrating, less post-operative stress shielding and bone loss in the proximal femur due to effective milling of the bone.[5] Comparison between non-robotic and robotic systems have been made and showed that the robotic implanted acetabular version and inclination were 100% accurate within the intended 10-degree position.[6] One hundred percent of robotic measured leg length change and 91.8% of robotic-measured global offset change were within 10 mm of radiographic measurements in a study performed by Bitar et al.[7] Studies have been published, which have demonstrated not only the accuracy but also, reduction in intra-operative pulmonary embolism.[8]

There is however a steep learning curve, which in the initial stages would mean, manual implantation in a planned robotic surgery as described in a few studies. Upto 18% of robotic implantation were converted to manual placement. The duration of the procedure also was longer. Although early results showed better Mayo clinical score and Harris scores at 12 months period, there was no difference in the same at 24 months, when compared with the conventional methods of surgery. It was also noted that, dislocation was more frequent in the robotic group.

Studies considering improved femoral and acetabular milling have been conducted. Domb et al published better radiographic cup positioning in the safe zones as describe ed by Lewinnek and Callnan, as opposed to 80-62% in the conventional group.[6] It is however, difficult to interpret these accuracies as far as the clinical outcomes are measured.

Figure 2: ROBODOC pre-operative planning.

Knee: This follows the same method of pre-operative planning by the surgeon using CT scan and execution intra operatively as shown in Figure 2. RoboDoc and Praxim are available for the use in Total knee arthroplasty.[9,10] The femur and tibia are rigidly fixed directly to the robot to work as shown in Figure 3. ROBODOC and CASPAR have been shown to have improved precision and accuracy compared with conventional methods.[11] It has been claimed to have a significant improvement in soft tissue balance with 90% versus 80%. As like the hip arthroplasty, this accurate and claimed better placement has not shown any advantage, when the clinical outcomes were measured.

Figure 3: Robotics in knee replacement.

In contrast to the hip systems, most studies in the knee arthroplasty robotic surgery have showed decreased time required to make femoral cuts, compared with the standard computer navigation techniques.[12] There was no difference in the overall tourniquet time. There are no randomised clinical trials or long-term studies to show any advantage of these systems over the conventional method of performing knee arthroplasty. Robotics have had a great relative influence in Unicondylar knee replacement, mainly due to the relative simplicity of soft tissue alignment needed and a smaller incision in these cases.[13] Mako system has also given an advantage of performing a patellar resurfacing in addition to the unicondylar section of these surgeries. There is also a diminished learning curve in unicondylar replacement with more surgeons performing the same in dry bones. Like the hip and knee arthroplasty, studies have showed better placement of the components in unicondylar replacement, but with no superiority in terms of clinical outcomes. More cases performed by robots now appear Australian joint registry, but it is too early to draw any conclusions before the patient reported outcome measures (PROMs) are published.

Spine: Better pedicle screw placement in 14 patients has been described using SpineAssist as shown in Figure 4.[14] It has performed successfully in 93% of cases, with 96% being placed within 1mm of preoperative planning.[15] In a larger multi-centric retrospective study, up to 98% of accuracy has been recorded, when assessed by fluoroscopic images performed intra-operatively.

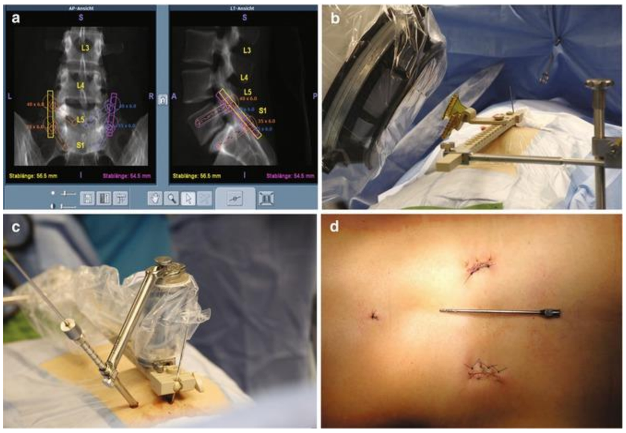

Figure 4: (a) Preoperative planning, (b) Placement of robot, (c) Insertion of Pedicle screw/Guide wire, (d) Minimal invasive

DISCUSSION

There is a perceived advantage of robotic surgery that it could be less painful, early recovery, early return to work and patient safety if used appropriately. The disadvantages could be listed as increased complications during the surgeon's learning curve, high blood loss, misalignment of the prosthesis, costs and unpredictable results.

More than 50,000 hip and knee surgeries have been performed in the last few years, but with little or no sufficient long term results.[1,16,17] Costs are to be blamed for any innovation and techniques that have to be introduced into any health care system in the world. Initial equipment costs for navigation can be up to $150,000 to $300,000 and up to $800,000 for robotics, not to mention the operations costs too that could be involved.[18] The learning curve for the surgery should also be considered and could have a major cost impact also in the training of many junior doctors.[19] Overall, there is more evidence now being published in support of robotic surgery, with its usefulness in minimally invasive spinal surgery.[2]

Results in the knee arthroplasty have been criticised, with some safety concerns in hip arthroplasty. These have been mainly due to the complications such as blood loss, dislocation, revision rate, heterotopic ossification and significant post-operative functional impairment. These improvements, have to be rectified before further use of the system in total hip arthroplasty.[20]

CONCLUSION

Although, the evidence and its efficacy have not been analyzed, robotics can be used for joint injections. Robotics in trauma surgery and arthroscopy are still in their infancy and no strong conclusions can be drawn yet, for their implication in clinical practice. A national registry that can define, improve and regulate the quality of care needed for patients receiving robot-assisted surgeries will need to be considered by the major health cares across the globe. There is a greater scope for wider and more meaningful applications for robot in trauma and orthopedics. More elevated level, prospective and randomized studies considering cost effectiveness, better outcomes and improved patient satisfaction are needed for a safe transition to robotics in trauma and orthopedics.

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