The Use of Robotic Assisted Surgery; the Current and Future Challenges

Reza Mafi¹,*, Pouya Mafi² and Marco Malahias³

¹Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences, University of Oxford, England, UK
²Barts and The London NHS Trust, Whipps Cross University Hospital, London, UK
³Department of Plastic Surgery, Heart of England NHS Foundation Trust, UK

Abstract:

Background:

Living with robots has always been regarded as a science fiction theme, however due to rapid advances in technology it is becoming more of a reality. The use of robots in surgery dates back to more than 25 years, and has previously been of great assistance to humans in the fields of Aeronautics and Armed forces. An evolutionary step was made after collaboration between the National Aeronautics and Space Administration (NASA), and the Stanford Research Institute in the field of robotic-assisted surgery. Thereafter, more surgical specialties incorporated this technology in surgical procedures. The objective of this article is to review different applications, challenges, and the future of robotic surgery.

Methods:

We have used a systematic approach to look at the most relevant published articles regarding robotic-assisted surgery. This review has taken 26 articles into consideration that have met the inclusion criteria of using of robotic-assisted technology in surgical procedures.

Conclusion:

Robotic surgery is being used in numerous surgical fields such as pediatrics, urology, cardiovascular surgery, gynecology, otolaryngology, general surgery and orthopedics. It has resulted in a reduction in length of stay, post-operative complication and scarring. However, for achieving optimal outcomes, further development in improving the sensory feedback and reducing the lag time during the transmission of long-range telesurgery is required.

Keywords: Robotic Assisted Surgery, Robotic Surgery, Telesurgery.
the robotic instruments [4]. Together, they were able to improve the telemanipulation by the surgeon. This achievement further advanced the minimally invasive laparoscopic surgery and led to development of telesurgery [5, 6]. This concept was initially funded by the Pentagon’s Defense Advanced Research Projects Agency (DARPA), with the goal of allowing a surgeon to treat a wounded soldier on the battlefield, from a remote safe haven with the surgeon’s hands controlling robotic arms [7 - 9].

Robots can now be classified under their characterization as automated arms, mobile devices, mills, or telerobotic devices. In addition to this, they can be active, semiactive, or passive. Active devices are totally programmable and carry out tasks independently. Semiactive devices and passive robotic devices function by translating movements from the operator’s hands into powered or unpowered movements of the robot end-effector arms [10].

THE DA VINCI SYSTEM

At present, the “da Vinci” is the most commonly used robotic system. Under the control of the surgeon the robot can be used to cut, suture, grasp and dissect [11]. Furthermore, when compared to traditional laparoscopic techniques there is significant improvement in dexterity, depth perception, camera stability, and surgeon ergonomics [6].

This system consists of four robotic arms of which three are instrumental and one is the endoscope. Trocars are attached at the end of each arm, which are inserted into patient through small incisions. The surgeon can manipulate these arms by cabled ‘endowrist’ instruments, which mimic the freedom of human hand and wrist motion, only by sitting at a console away from the operation bed. The wristed robotic instruments, along with the articulations of the robotic arms, allow the surgeon seven degrees of freedom: the external robotic arms provide three degrees of freedom (insertion, pitch, and yaw) and the Endowrist® mechanism provides four additional degrees of freedom (pitch, yaw rotation and grip) [12]. The console’s monitor provides a three-dimensional view of the surgical field and by using pedals the focus can be adjusted. This way the surgeon does not need to take his hands off the console to manually adjust the focus [13]. These advantages have resulted in significant improvement in performance and safety of intracorporeal suturing, which in turn make the surgical robot a powerful tool especially when a high degree of precision in a tight space is required [14]. Table I demonstrates the current applications of robotic-surgery.

ADVANTAGES AND CHALLENGES

Since the birth of the robotic-assisted surgery, there has been major improvement in the quality of the operations and outcomes when compared with laparotomy [13]. Among the most important are reductions in post-operative pain, recovery time and complications including blood loss, scaring, transfusion and wound infection. Furthermore, it reduces the length of stay and a quicker return to normal activities and work, which in turn can be of financial benefit to the hospital and economy. (1) According to recent cost analyses, efficiencies gained through robotic surgery may translate into significant operating room cost reductions. Therefore, the widely held belief that robotic surgery is ‘too expensive’ may not be true after all [13].

In a traditional laparoscopic operation, the surgeon is required to stand in an ergonomically contorted fashion following the operation on a two dimensional monitor, while holding two instruments at the same time and communicating camera maneuvers to a colleague over several hours. Consequently, these factors contribute to an increased level of fatigue and frustration for the surgeon, whereas the robotic surgeon is seated, has full control over a three-dimensional view and better precision of movement. It has been reported that the learning curve for the surgeon is much shorter compared to conventional laparoscopic surgery [15]. This could be explained as they need to work with long instruments through a fixed entry point, while watching a screen with reduced tactile feedback, leading to diminished fine motor control, tremor amplification and difficult hand-eye coordination [12].

All the benefits mentioned above come with a cost. These include the high cost of the robotic platform, disposable instruments and annual service contracts. Other limitations to robotic-assisted laparoscopic surgery include the lack of haptics, or tactile feedback [15], the fixed positioning of the operating table, the longer operative time compared to open surgery and the limited data on the outcome of operations [1].

One of the other challenges that this mode of surgery is facing is transmission delay over long distances. The maximum effective range seems to be approximately 30 miles by wireless communication and 200 miles via a cable connection [16]. At distances greater than this, the lag time between the surgeon's movements and the movement of the robotic arms can be quite disorienting [17].
Table 1. Current Applications demonstrates the use of robotic assisted surgery in various surgical fields.

<table>
<thead>
<tr>
<th>Surgical field</th>
<th>Nature of operation</th>
<th>Author</th>
<th>Outcome compared to traditional method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thoracic</td>
<td>Robotic assisted minimally invasive surgery for atrial septal defect correction</td>
<td>Poffo et al. [18]</td>
<td>N/A</td>
</tr>
</tbody>
</table>
|                | Robotic-assisted coronary artery bypass surgery. | Halkos et al. [19] | • Reduced bleeding  
• Effective alternative to traditional method |
| Gynecology     | Robotic-assisted laparoscopic hysterectomy | Holloway et al. [13] | • Fewer wound complications  
• Less post-op pain |
|                | Computer-assisted robotic antireflux surgery | Gould et al. [17] | • Safe and effective  
• Little advantage over standard laparoscopic approach |
| General surgery| Robotic-assisted colorectal surgery | Kim et al. [20] | • Lower intra-and post operative complications  
• Shorter LOS  
• Less blood loss  
• Comparable oncological outcome  
• Longer operation time (LOT) |
|                | Ablative and reconstructive robotic-assisted laparoscopic renal surgery. | Murphy et al. [21] | • Mechanical failure did occur  
• Safe method  
• Reducing LOS |
| Orthopedics    | Robotic Surgery in Total Hip Arthroplasty | Nobuhiki et al. [22] | • Better stem alignment  
• Less variance in limb-length inequality |
| Otolaryngology | Robotic-assisted salvage surgery for oropharyngeal cancer. | Dean et al. [23] | • Acceptable procedure for resection of both primary and recurrent oropharyngeal tumors.  
• Fewer gastrostomy tube dependent post operatively  
• Reduced LOS |
| Pediatrics     | Abdominal and thoracic robotic-assisted surgery | Meehan et al. [24] | • Safe and effective in complex neonatal cases  
• Ideal of hepatobiliary and thoracic cases. |
| Urology        | Robotic-assisted radical prostatectomy (RARP) | Watts et al. [25] | • Reduced LOS  
• Reduced transurethral catheter duration  
• Marginal reduction in operation time |

FUTURE DEVELOPMENTS

The future of the robotic-assisted surgery is looking very bright. Currently robotic engineers are working on devices with more streamlined platforms, smaller instrumentation, and remote telementoring. In addition, there is a great deal of research and funding spent on improving the sensory feedback on the telerobotic devices for creating better outcomes [26].

It is very likely that in the foreseeable future the cost of robotic surgery reduces with the inevitable advent of competitors in the market. Consequently, this factor would lead to a great cost saving to both patients and hospitals, as well as allowing more patients to benefit from this type of minimally invasive surgery.

CONCLUSION

Robotic surgery is being used in numerous surgical fields such as pediatrics, urology, cardiovascular surgery, gynecology, otolaryngology, general surgery and orthopedics. It has resulted in a reduction in length of stay, post-operative complication and scarring. However, for achieving optimal outcomes, further development in improving the sensory feedback and reducing the lag time during the transmission of long-range telesurgery is required.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

Declared none.
REFERENCES


