REVIEW ARTICLE

Robotic Surgery from Earth to Space!

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Abstract

Robotic surgery is an innovation that has yielded a multitude of applications within the realm of surgery. This approach has allowed for the performance of more complex procedures with the promise of improved outcomes. Although the availability of this surgical operating system depends on market and financial elements within healthcare organizations, it has shown its value in clinical practice. This ranges from reduced complication rates resulting in decreased hospital stay and return to baseline activity. The ability to operate this system remotely is fascinating and can allow the involvement of experts from around the world. We aim to shed light on the value of robotic surgery, particularly when it comes to the surgical management of patients participating in missions in outer space.

Keywords: Da Vinci robotic surgery, Emergency surgery, Robotic.

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Introduction

Minimal access surgery has become the standard of most elective surgical procedures and recently the use of robotic surgery and artificial intelligence assistance is recommended. This paper is a collaborative work assemblage of a literature review on the usage of robotic surgery in future space missions.

Discussion and Review

In 1921, the term robot was first used in a theatrical play, and since then, people have moved from the concept of the robot being an inanimate slave to its human master to a more intellectual creation capable of artificial intelligence.[1]

Robots were initially invented to assist humanity with basic activities such as manufacturing until they eventually found their way to the medical field. Interest was compounded following the evolution and popularity of laparoscopic procedures where they showed improvements in length of the stay, postoperative pain, improved cosmesis, and earlier return to normal work and activities of daily living.[2]

The first robotic surgery was performed in the field of Neurosurgery by obtaining accurate biopsies, done in 1985 using the Puma 560 robot.[3] Using this robotic innovation helped in creating another robotic system (ROBODOC) to perform urological procedures including transurethral prostatectomy, which at the time, was the first robotic system to be approved by the Food and Drug Administration (FDA).

Intensive research was done to improve this new technique, and the new concept of tele-surgery became a reality. This was proven when surgeons began performing procedures remotely with the aim of assisting with injured military personnel during the conflict. This allowed for further innovations and improvements in robotic design, culminating in the Da Vinci surgical system.[1]

The Da Vinci robot is fully based on telepresence surgery. Robotic arms are operating remotely from the console with enhanced 3-D visualization, thus giving the surgeon a sense of augmented reality.[4]

The advantages of robotic surgery are not yet fully established in all surgical fields as it continues to find applications for use. The primary difficulty faced by healthcare providers has been the associated cost of running the system, along with maintenance and replenishment of required system components.[5] Nevertheless, numerous applications have allowed for drastic improvements in the management of many pathologies that have traditionally been performed through the open and laparoscopic surgical technique.

Astronauts are highly trained, healthy individuals. They undergo numerous tests and rigorous training before being sent into space. The near future, however, will see people traveling to space as part of commercial activities or tourism. Therefore, space travel may no longer be monopolized by healthy astronauts, and thus medical emergencies may occur at any time despite the relatively low incidence.[6] This can be extrapolated from missions to the Antarctic continent at research stations, where we occasionally have patients completely isolated from advanced medical facilities. Tremendous resources are required to bring in such patients at times of emergency to undergo testing and surgical procedures.[7]

It may be prudent to predict medical emergencies rather than risking the astronauts' life, or jeopardizing the mission through early abortion and return to earth, especially since sending a rescue team might not be feasible. Some studies suggest astronauts undergo prophylactic surgeries like appendectomies and cholecystectomies prior to their long space travel, particularly since the effect of

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prolonged space travel on human physiology, wound healing, and the immune system has not been fully explored yet. Therefore, the risk of developing appendicitis or other surgical emergencies during the mission might be higher than the normal population on planet earth.[8]

Other studies have suggested that performing prophylactic surgery might result in the development of other potential complications such as small bowel obstruction implying that prophylactic surgery may not be worth the associated risk.[9]

Other surgical emergencies that may arise in outer space include blunt and penetrating trauma. In zero gravity situations, objects may appear light but can still cause significant physical injury particularly, at high speed.[10]

An alteration in physiological response may occur due to the prolonged loss of gravity to the injured individual. Such changes may include a decrease in circulating blood volume and circulating red cell mass, reduced cardiac output, alterations in neuroendocrine function, and others.[11,12]

Applying the advanced trauma life support (ATLS) protocol in space can save the lives of injured personnel.[13] Nevertheless, the challenge would be controlling intra-abdominal or intra-thoracic bleeding. This was studied in 1998 on rats during the STS-90 Neurolab Shuttle mission, where they were able to perform a thoracotomy, laparotomy, craniotomy, and lower extremity dissection. Findings noted in this study include the prolonged length of time required in the manipulation of instruments, however, it did conclude the feasibility of performing these procedures in space.[14]

In concept, applying damage control principles, such as intra-abdominal packing, re-alignment of fractured limbs and others can help in saving time and saving the life or limb of the injured person. In selected patients, penetrating or blunt abdominal injuries can be managed using minimally invasive techniques in both diagnosing and managing certain injuries.[15]

Others have suggested the utility of a medical team present as a part of the team of astronauts heading to space. This may help in recognizing signs and symptoms at an earlier stage and begin early treatment. This is particularly true since many inflammatory conditions such as appendicitis or cholecystitis have been treated conservatively with considerable success utilizing broad-spectrum antibiotics. While this might be considered the safest, medical personnel would still not have the necessary diagnostic tools needed to confirm the diagnosis. Nevertheless, it is still feasible to operate in space with the appropriate instruments as has been shown in studies involving microgravity situations within underwater laboratories.[6,16]

Since surgery in outer space has been shown to be technically feasible, further studies involving the performance of emergency operations at the international space station using tele-surgery such as robotic surgery should be considered. We hypothesize that it is a matter of time before this becomes a reality as more space missions are being launched by numerous nations around the world. This is particularly true as the commercial aspect of space tourism becomes a reality. The development of improved technology such as higher speed, improved resolution, and faster connection systems can help astronauts and their companions get the treatment they may eventually require.

The largest space corporation, NASA, has always been aware of the importance of providing better healthcare for space travelers to ensure their ability to endure long duration flights and missions. This led to the development of the NASA Extreme Environment Mission Operations (NEEMO) missions. NASA is utilizing an underwater laboratory for astronauts to live and acclimate to low gravity conditions.[17] NASA extreme environment mission operations missions are conducted with the sole target of studying telemedicine. Several robots were studied like the AESOP robot (ZEUS), M7 Robot, and the RAVEN Robot. All of these studies were completed utilizing crews with minimal surgical training, mimicking the latency in connection speeds between Earth and the moon, and even experimenting on real-time procedures like suturing while the surgeons are in a remote location. All of the experiments have shown the possibility and the importance of using telemedicine in the near future.[17–20] In fact, MIRA will be the first surgical robot to be sent to the international space station by NASA in 2024.[21] This is considered a significant leap forward in furthering surgical robotics in outer space.

Conclusion

Robotic surgery might be an asset in the future of space surgery, regardless of mission duration. Procedures that may be performed include management of acute abdominal pathologies or even blunt or penetrating trauma. More studies and investment in robotic surgery will be required—and as we know, the sky is not the limit. Reaching the moon once again, and the establishment of the human presence will be the first step in the space adventure. We advocate the need to continue researching the role of surgical robotics in space. We believe that surgeons will continue to have a role to play in these endeavors.

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