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Telesurgery prospects in delivering healthcare in remote areas

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Abstract

Feasibility and safety of performing remote surgery was first established by performing surgeries on pigs in later part of the 20th century. The first tele-robotic remote surgical system was set up in Canada in 2003 between two hospitals 400 kilometres away. The current review was planned to have a look at the current state of robotic surgery and its use in telesurgery. Literature search was conducted for articles related to "Robotic Surgery" and "Tele-Surgery". Our search included articles published in English literature, including case studies and review articles. We searched Google Scholar and PubMed to search relevant articles. Introduction of haptic feedback technology added significantly to safety robotic surgery. Tele-surgery, also called tele-robotics, combines the advantages of robotic surgery, including magnified view, augmented reality and improved ergonomics and dexterity, and provision of surgical care in remote areas and difficult-to-reach locations like spacecrafts and ships. Challenges, like cost, availability and legislations, remain to be addressed.

Keywords: Robotics, Tele-robotics, Medical education, Ethical issues, Cyber security.

Introduction

Concept of distance between the surgeon and the patient came with the advent of robotic surgery (RS). Having benefits of increased dexterity, accuracy and accessibility to difficult locations such as pelvis, RS was well received by urologists and colorectal surgeons in particular and abdominal and thoracic surgeons in general. Combination of rapid telecommunication and advancements in RS led to tele-surgery (TS) as a feasible option.

Feasibility and safety of performing RS was first established by performing surgeries on pigs in the later part of the 20th century. Successful cholecystectomies were performed on six pigs in Strasbourg while the operator was in New York, a transatlantic round-trip distance of over 14,000 kilometres. These operations established that time-lag did not impact surgical performance and the procedure was safe, including the use of electrocautry.[1] On September 7, 2001, professor Jacques Marescaux, along with his team, from the Institute for Research into Cancer of the Digestive System (IRCAD), successfully performed first human TS cholecystectomy in 54 minutes, and the operation was named as the 'Lindbergh Operation'.[2] The mean time-lag during the procedure was 155ms which is imperceptible to human eye.[3] Dr Marescaux commenting on the operation said, "The demonstration of the feasibility of a trans-Atlantic procedure - dubbed 'Operation Lindbergh' is a richly symbolic milestone. It lays the foundations for the globalisation of surgical procedures, making it possible to imagine that a surgeon could perform an operation on a patient anywhere in the world".[4]

Surgeon at a distant location can have a variable level of involvement depending upon clinical and educational needs. Tele-mentoring is distant supervision of surgical procedure with feedback given by the distant surgeon who is watching real-time video of the procedure. Tele-stration is the form tele-mentoring in which the mentor remotely illustrates and annotates on a monitor that is visible in the operating room. These graphical instructions are overlaid on the real-time picture of the operative field. This is important in RS training. Safety and feasibility of tele-mentoring has been demonstrated via some observational studies.[5]

Partial involvement of proctor in operation is called tele-assist in which the mentor performs or assists part of the operation from the distant location. Specifically designed robots, such as The Socrates™ Tele-mentoring System, are approved by the Food and Drug Administration (FDA) in the United States for mentoring purposes.[6]

Though RS owing to the magnified view, augmented reality and improved ergonomics and dexterity has revolutionised the minimally invasive procedures and training, tele-robotics is still in infancy.[7] The availability

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is poor in remote and rural areas. Major limitations are the cost of robotic systems and the rapid wireless connectivity.

The first tele-robotic remote surgical system was set up in Canada in 2003 between St. Joseph's Hospital in Hamilton and North Bay General Hospital 400 kilometres away using ZEUS-TS surgical system.[8] The operation was conducted using 15 Mbps of bandwidth network which was used for local internet services. Although the latency using this network was noticeable to the surgeon, it did not affect performance. A total of 21 surgeries were performed without major complications.

Challacombe B. et al. demonstrated that though robotic access to the kidney in percutaneous nephrolithotomy was slower than human insertion (56.5s vs 35s), accuracy was more (first attempt success: 88% vs 79%). Similar results were obtained when procedures were carried out using trans-Atlantic robot carried out via Integrated Services for Digital Network (ISDN) lines.[9] Ultrasound-guided renal biopsies have also been carried out successfully using tele-robots.[10]

Haptic Feedback Technology

The technology that enables transmission of tactile information to the tele-operator is termed 'haptic feedback'. During operation, haptic feedback is crucial as it allows the surgeon to feel the consistency of tissue and, hence, force on the instruments is adjusted accordingly. It is of particular importance while tying knots and dissecting between tissue planes as too much tension can potentially damage the tissues and too less tension can produce suboptimal results.[11,12] Early TSs were carried out relying solely on visual feedback.[13] The first TS prototype that implemented haptic feedback technology was Telelap Alf-X, which was introduced in 2015 in Italy. It successfully reduced the average time of experimental cholecystectomy by 60 minutes.[12]

Benefits

Because tele-robotic surgery operates through robotic surgical systems, it also takes advantage of all the existing benefits of general RS. These benefits include increased dexterity, more natural hand-eye movement than traditional laparoscopic surgery, filtering of hand tremors, customisable sensitivity settings, and high-quality three-dimensional (3D) visualisation with up to 10X magnification. In addition to benefits of RS as described above, operating at a distance can be beneficial in other areas as well.

Remote Areas: It promises to allow the expertise of specialised surgeons to be available to patients worldwide, especially underserved areas, without the need for patients to travel beyond their local hospital. This is particularly beneficial in situations where transfer has its own risks and time delay in transfer can be counterproductive.

Military Interest: Providing expert surgical care to mobile military units can be made possible through tele-robotics. A few surgeons with expertise in specific areas can provide care to multiple units from a distant location.

Naval and Space interest: Providing specialised surgical care to inaccessible units in space and on ships can be brought about through utilisation of advancement in tele-robotic technology.[14] Feasibility studies to operate in space have already been carried out by National Aeronautics and Space Administration (NASA). Major limitation remains the time latency due to long distances.[15]

Remote Surgical Training: Surgeons present at the site of operation can get benefit from the expertise of the remote surgeon.[16] Various degrees of interaction are possible between remote surgeon and the surgeon on site. In its least form, tele-mentoring can be in the form of instructions only by the proctor from the remote location who is watching the real-time video of the operation being performed. On the other hand, with the help of distant robotic arms, TS can be either demonstrated or assisted. This can potentially improve surgical training in remote areas, ultimately improving surgical care.[6]

Challenges

Latency: Time-lag between surgeon's initiation of movement and its actual appearance on console can arise due to delay in communication lines and/or coding and decoding of video signals. Increased latency can potentially increase surgical inaccuracies.[17,18] Ideally, latency time less than 100 msec is considered to be safe and more than 300 msec has been seen to be associated with technical difficulties.[19] In another instance, latency of 135-140 msec was noticed during surgery, but safety and effectiveness was not compromised due to surgeons' adaptability.[8,20] Latency of up to 200 msec is known to be acceptable.[19] Present day high-speed fibre optic cables along with dedicated asynchronous transfer mode (ATM) can achieve latency time of less than 100 msec but availability of this network remains a challenge.

Cyber Attack: As providing surgical care at a distance is dependent upon network communication, it is prone to cyber-attack and leakage of sensitive data.[21] Though end-to-end encryption provides security against information leak, backup systems are needed in case cyber-attack during operation either completely blocks the communication or alters command. This can be potentially harmful.

Cost: Affordability of robotic system and high-speed telecommunication network is also a concern, especially for developing nations. Though accurate assessment of the cost is not possible at the moment due to variable factors according to geographic locations, new-generation robots are likely to be cheaper as more and more companies get the license to produce them.

Legal and Ethical Concerns: Regulations and licensure requirements to practise medicine vary from country to country and providing surgical care across borders will require fulfilling geographic legal requirements. Standard operating procedures (SOPs) are needed to be defined for consenting of patients by surgeons operating from remote locations. This equally applies to the responsibilities of complications arising as a result of technical failure of communication lines. As laws differ across the globe, a consensus is needed and global laws are to be made which should be acceptable to participating countries.

Conclusion

Tele-surgery, also called tele-robotics, combines the advantages of robotic surgery that include magnified view, augmented reality and improved ergonomics and dexterity, and provision of surgical care in remote areas and difficult to reach locations like spacecraft and ships. Cost, availability and legislations to address legal and ethical issues remain to be addressed.

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