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REVIEW ARTICLE

Telerobotic Surgery: Transcending Barriers

J Rohan Krishna

ABSTRACT

Telerobotic surgery has the potential to revolutionize the field of medicine and health care delivery in the near future. Rapid technological advancements have been made in the field of robotic surgery, and telerobotic surgery in particular. Through telerobotic surgery, it is possible to provide advanced surgical care to patients even in the remotest of places and for experienced surgeons to guide young surgeons to perform complex surgeries. The aim of this study is to trace the origin, implementation, and developments in the field of telerobotic surgery.

Keywords: Minimally invasive surgery, Robotic surgery, Telerobotic surgery, Telesurgery.

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INTRODUCTION

Technological advancements continue to occur at a rapid pace in all walks of life, and the field of surgery is no exception to it. Minimally invasive surgery that has revolutionized the field of surgery offering distinct advantages over open surgery also has limitations like loss of dexterity and two-dimensional vision of the operative field. Robotic surgery and telepresence surgery have addressed the limitations of laparoscopic procedures and have revolutionized the field of minimal access surgery. In the early 1970s, NASA commissioned a project to perform surgeries on astronauts using remotely controlled robots.[1] Kwoh et al[2] used a Robot-Puma 200 and performed neurosurgical biopsies with greater precision. In 1988, ultrasound-guided prostatic resection[3] was done using PROBOT, a robotic system. Real breakthrough in telerobotic surgery came in 2001 when Professor Marescaux performed the first transatlantic telesurgical procedure (Operation Lindbergh) on a patient in France. Professor Marescaux et al[4] performed laparoscopic cholecystectomy on a 68-year-old lady in Strasbourg, France, using a Zeus robotic system located in New York. Following this landmark event, telerobotic surgery has been performed in various places around the world with successful results.

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AIM

The aim of this article is to study the origin, implementation, and latest advancements in the field of telerobotic surgery.

MATERIALS AND METHODS

A literature search was performed using PubMed and search engine Google. The following keywords were used "telerobotic surgery," "robotic surgery," and "telesurgery." Selected papers were screened for further references with respect to the origin, implementation, and latest advancements in the field of telerobotic surgery.

RESULTS AND DISCUSSION

A telerobotic system primarily consists of surgeon's "master" console from where the surgeon operates and a patient-side "slave" unit that performs surgery on the patient using robotic arms. In telerobotic surgery, the surgeon operates from the surgeon's console, which is thousands of miles away from the slave robotic arm mounted on the patient; the surgeon's commands are relayed to the slave manipulator via fiberoptic cables. Two major factors impacting the outcome of telerobotic surgery are data transmission speed[1] and communication latency. Round-trip latency[5] represents the time interval between the initiation of movement by the surgeon and the appearance of image on the monitor.

Professor Marescaux et al[4] performed the first successful telerobotic surgery on September 7, 2001, which was famously known as Operation Lindbergh. This surgery was completed using a commercially available robotic surgery system, called Zeus T, which featured a robotic endoscope positioning system called AESOP (Automated Endoscope System for Optimal Positioning). Professor Marescaux et al[4] were able to minimize latency using a dedicated multiservice transmission network provided by France Telecom. First trial simulations of telesurgery took place in 2000 with a transmission delay of 200 ms. Subsequent work reduced the time delay to 150 ms even though the round-trip distance was 14,000 km. Flawless network quality with guaranteed bandwidth of 10 megabits per second and transmission delays of less than 200 ms

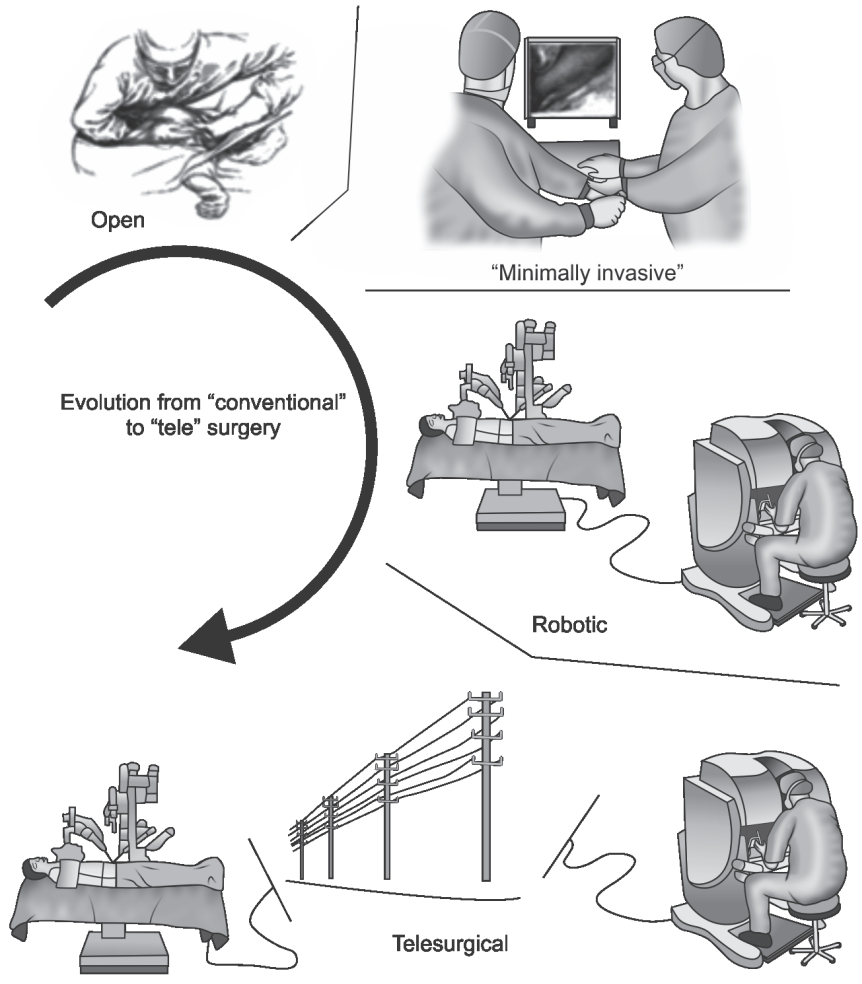

Fig. 1: Evolution from "conventional" to "Tele" surgery

made this achievement possible. Asynchronous transfer mode (ATM) technology was used with a dedicated fiberoptic network. But dedicated ATM lines were expensive, ranging from $100,000 to $200,000 (Fig. 1).[6]

In addition to the high cost of ATM lines, the availability is poor in remote and rural areas. Most commonly available networks are satellite connections (with latency of about 500 ms) and virtual private networks (VPN) with variable latency.

Anvari et al[7] established the first dedicated telerobotic remote surgical setup between St. Joseph's Hospital in Hamilton and North Bay General Hospital 400 km north of Hamilton on February 28, 2003. A Zeus TS microjoint system was used and a total of 21 surgeries[6] were performed with no major complications. Unlike "Operation Lindbergh" which used a dedicated fiberoptic network with ATM technology, Anvari et al[6] used a commercially available Internet protocol (IP)/VPN fiberoptic network. It had an active line and a fully redundant (backup) line. The overall latency experienced by the telerobotic surgeon was 135 to 140 ms. Of this, 14 ms was due to network and the rest was due to compression and decompression of the video signals by the MPEG CODECs. During each surgery, the telerobotic surgeon in Hamilton and the laparoscopic surgeon in North Bay collaborated to perform the surgeries.

In 2007, NASA[8] commissioned a series of NEEMO (NASA Extreme Environment Mission Operations) projects to conduct research related to remote health care of astronauts on space missions with special emphasis on telerobotic surgery. The experiment was conducted in the Aquarius Underwater Habitat, a 20 m underwater facility about 16 km from Key Largo, Florida. Two surgical robots were deployed into the Aquarius habitat: The RAVEN and the SRI, international M7 robot. Surgeons and researchers were able to operate the robotic arms using the controllers linked across several thousand miles (Fig. 2).[6]

Challacombe et al[9] performed the first randomized controlled trial on human *vs* telerobotic access to the kidney during percutaneous nephrolithotomy and concluded that robotic access was more accurate though slower compared with human access.

Telerobotic surgeries in space is another exciting new frontier where lot of research and experiments are

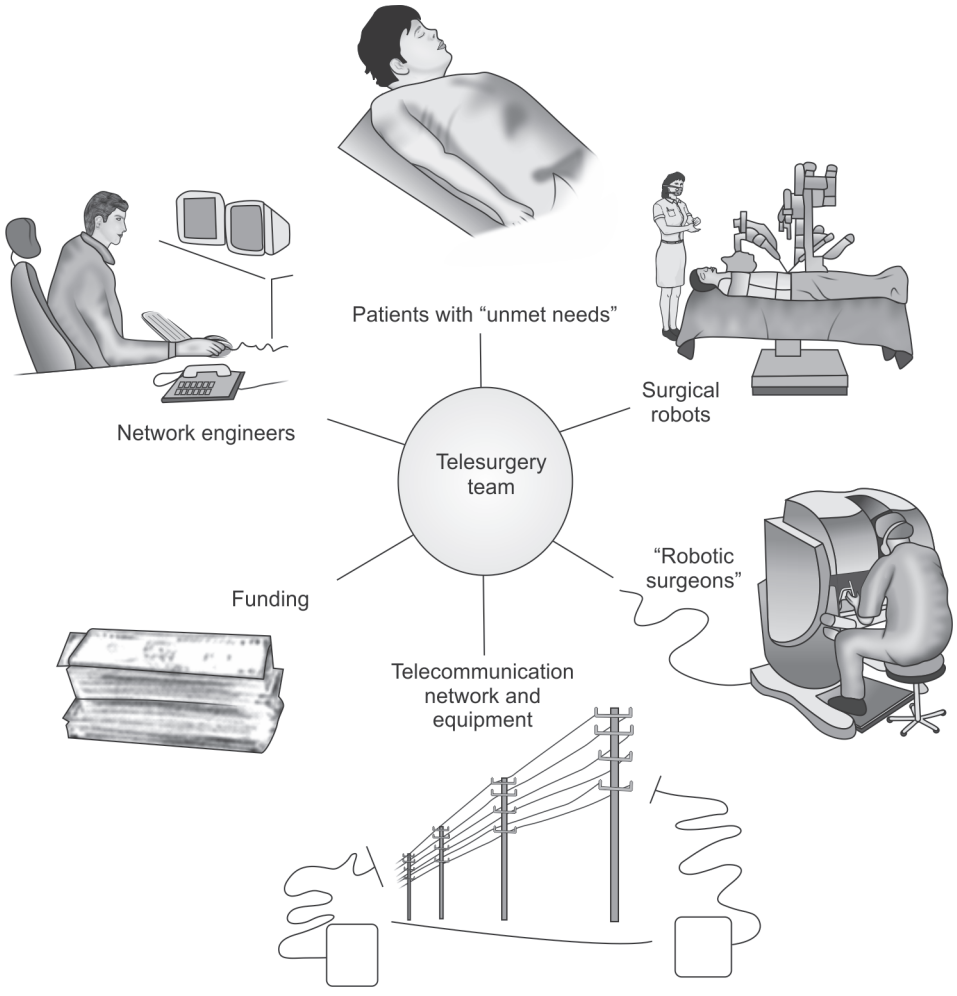

Fig. 2: Necessary elements of a telerobotic surgery team

being carried on. The world's first human operation[10] was a cyst removed from a patient's arm, on board the European Space Agency's Airbus A-300 Zero-G aircraft. The plane performed 25 parabolic curves, providing 20 to 25 s of weightlessness every time. NASA carried out its first zero-gravity robotic surgery experiment in September 2007. On a DC-9 aircraft, suturing tasks were performed using the M7 robot and results were analyzed. The experiments showed that humans can better adapt to extreme environments; however, advanced robotic solutions performed comparably.

CONCLUSION

Telerobotic surgery has the potential to change the landscape of health care delivery in the future. Providing advanced surgical care to patients even in farthest of locations with decreased cost and improved outcomes becomes possible with telerobotic surgery. Through telementoring experienced surgeons can mentor and guide new surgeons to perform even complex surgeries with confidence. Major limitations of telerobotic surgery at present are its high cost and time latency, which can be improved in the foreseeable future. Although robot-assisted remote telesurgery is feasible, more prospective randomized trials evaluating efficacy and safety must be undertaken to revolutionize and change health care delivery and the field of surgery.

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