

Review

Current Feasibility of Urologic Telesurgery in Low/Middle Income Countries

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Abstract: It is estimated that nearly five billion people do not have access to surgical care. Approximately 94% of individuals in low- and middle-income countries (LMICs) lack access to surgery in comparison to 14.9% in high-income countries (HICs). There are several urologic conditions requiring surgical intervention that are not treated because of the limited number of expert urologists in LMICs. Telesurgery is a concept that connects patients and surgeons in different locations through the use of a robotic surgery system. In this review, we explain the origins of telesurgery as well as the benefits and obstacles to its global implementation. Telesurgery can reduce travel times and the dangers associated with traveling for surgical care in LMICs. Additionally, telesurgery allows patients in LMICs to gain access to expert urologists while also providing effective training to upcoming surgeons. However, LMICs require substantial investment to improve digital infrastructure that will support urologic telesurgery. There will also be ethical, legal, and policy considerations that will need to be resolved for safe and equitable urologic telesurgery to occur. There have been multiple successful applications of urologic telesurgery, suggesting that the technology for this to become routine is already available. The time for international collaboration must begin now to reduce global disparities in access to urologic surgery.

Keywords: urologic telesurgery; surgery in LMICs; telementoring; latency; telesurgery infrastructure



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1. Introduction

1.1. Surgery in Low- and Middle-Income Countries

Of the nearly eight billion individuals on Earth, it is estimated that five billion do not have access to safe, affordable surgical care. According to the World Bank, countries are categorized by income level based on the national income per person, or GNI per capita (in USD). Low-income countries have a GNI per capita of $\leq \$1145$, while lower-middle-income countries have a GNI per capita of $\$1146$ – $\$4515$ [1]. Furthermore, 94% of individuals in low- and middle-income countries (LMICs) lack access to surgical treatment, compared to 14.9% in high-income countries (HICs). Only 6.3% of the nearly 313 million procedures performed globally each year occur in the poorest countries, which contain over 37% of the world's population. Experts suggest that an additional 143 million surgical procedures are needed annually to prevent disability and fatalities in LMICs [2]. There are several factors that may explain why there is such a drastic disparity in access to surgery between HICs and LMICs. These include, but are not limited to, accessibility, availability, affordability, and acceptability of surgical intervention in LMICs [3].

Many LMICs use a tiered access system in which patients are triaged to a primary health center, a first-level hospital, or a higher-level institution. Unqualified health workers typically see patients in primary health centers before being connected to providers in first-level hospitals. Such hospitals are usually short-staffed and manned by general surgeons with limited surgical capabilities and expertise in urologic procedures [4]. Some of the most common urologic conditions seen in African LMICs include benign prostatic

hyperplasia, urolithiasis, urethral stricture, and bladder and prostate cancer. Due to the lack of screening capabilities and access to primary care services, many of these conditions become advanced and require surgical care. Even when surgical care is available to patients in LMICs, open surgical intervention is most common, as few hospitals have the resources to accommodate robotic surgery [5]. Telesurgery is one method to mitigate some of the limitations to expanding robotic surgery in LMICs, as well as addressing inequities in access to surgical care.

1.2. Telesurgery: From Concept to Reality

Telesurgery is defined as using a surgical robot for operations in which the surgeon and patient are in distant locations. In the 1970s, the National Aeronautics and Space Administration (NASA) explored remote surgery for treating astronauts in space through the use of robotic operative systems [6]. The concept arrived in the operating room in 1985 with the PUMA 200 robot for CT-guided brain biopsy. This was subsequently followed by the PROBOT in 1988, an ultrasound-guided independent robotic system for prostatic resection [7]. However, the origins of telesurgery can be traced back to the United States (U.S.) military wanting to combat the primary causes of death in soldiers, those being hemorrhagic shock and polytrauma [8]. In 1986, Dr. Phil Green and his team began creating early concepts of dexterous manipulators for the surgical intervention of wounded servicemen at the Stanford Research Institute (SRI). Such prototypes included head-mounted displays and DataGloves to remotely control operative instruments. These proved to be inadequate for remote surgery as the gloves had suboptimal dexterity and the display did not provide safe operative visualization [9]. Following Green's departure from the project in 1987, Dr. Richard Satava and his team began constructing a robotic surgery system that included a workstation consisting of actual surgical instruments, as well as a stereoscopic monitor [10]. More specifically, the surgeon would sit at a stereoscopic display with a pair of instrument manipulators that transmitted their hand movements to a remote surgical unit. In 1989, Satava convinced the SRI to develop their system for laparoscopic surgery to reduce the fulcrum effect of minimally invasive tools, reduce hand tremors, and improve dexterity, as well as operative visualization [11].

The early 1990s yielded ex vivo and in vivo validation as well as further development of robotic surgery systems. In 1996, the ZEUS system[®] (Computer Motion, Goleta, CA, USA) became the first complete robotic surgery system [11]. In 1999, the first version of the Intuitive da Vinci[®] surgical system (Intuitive Surgical, Sunnyvale, CA, USA) became available in Europe, subsequently obtaining FDA approval approximately 18 months later [12]. After decades of robotic surgery and telecommunications development, Dr. Jacques Marescaux performed the first telerobotic surgery in history, deemed the Lindbergh Operation. In September 2001, Dr. Marescaux performed a telesurgery-assisted cholecystectomy on a patient in Strasburg, France, from New York City, USA, using the ZEUS system. This was completed in 54 minutes without any complications, all through the use of transatlantic fiber optic cables [13]. In the time since the Lindbergh Operation, telesurgery advancements have gradually progressed. This ranges from applications of routine general telesurgery between Canadian hospitals located 400 km apart to telerobotic spinal surgery between Chinese hospitals nearly 2800 km away from one another [14,15].

More recently, there have been numerous telesurgery applications in urology. In 2021, surgeons from Qingdao, China performed 29 robot-assisted laparoscopic radical nephrectomies, with a median distance between the primary hospital and the surgeon being 187 km [16]. In 2022, a robot-assisted laparoscopic radical cystectomy was performed in China with a network communication distance of nearly 3000 km [17]. Within the last year, Dr. Vipul Patel and his team traveled from the U.S. to China and Japan to perform robot-assisted laparoscopic radical prostatectomies. The largest distance between the patient and surgeon was approximately 2500 km [18]. Given the examples above, it is important to recognize that the technology to successfully perform routine urologic telesurgery already exists. Nonetheless, multiple obstacles will need to be overcome for

the implementation of urologic telesurgery, especially in LMICs. In this review, we discuss how telesurgery will revolutionize urologic care in LMICs, as well as the barriers to its implementation.

2. Material and Methods

A MEDLINE search was performed to examine articles related to telesurgery and urologic robotic surgery in LMICs. The pertinent keywords employed to stratify the results were “telesurgery”, “urologic telesurgery”, “surgery in LMICs”, and “urology in LMICs”. Publications were included in this review based on their discussions surrounding the origins of telesurgery, their correlation to surgical access and urologic care in LMICs, as well as the technological, moral, and feasibility concerns of telesurgery. Three articles were not available on PubMed but were included because of their relevance to this topic.

3. Implications of Urologic Telesurgery in LMICs

3.1. Preventing Long-Distance Travel for Urologic Care

Patients in LMICs typically have to travel long distances for surgical care. Previous studies have approximated such distances in LMICs: 25 km in Bangladesh; 30 km in Uganda, Liberia, and Rwanda; 42 km in Mozambique; 56 km in Haiti; 85 km in Bolivia; and 144 km in Ethiopia [19]. In the U.S., the median driving distance to surgical care is about 14 km [20]. It is evident that patients in LMICs typically have to drive tens to hundreds of km more for surgical care compared to those in HICs. Telesurgery could allow patients requiring urologic surgery to be seen at local health centers instead of central, high-level institutions. This would effectively reduce the need for patients to travel tens or hundreds of km for urologic care. The financial and safety burdens associated with travel in LMICs could also be removed [21].

3.2. Access to Expert Surgeons and Specialized Emergent Care

LMICs do not have a sufficient number of surgical training opportunities and practicing urologists to care for their population [22]. While the urologist-to-patient ratio in HICs like Italy is relatively low (1:15,000), it is estimated that this ratio in LMICs is one in a million [5]. Telesurgery can allow well-trained surgeons to perform procedures on patients in remote or underserved areas where there is limited access to specialized medical care. Therefore, patients in LMICs who may otherwise face barriers to receiving specialized surgical treatment would be able to undergo complex or challenging procedures at the hands of a skilled urologist. Furthermore, telesurgery allows for real-time collaboration among physicians in different locations when more expertise is required. Additionally, patients in LMICs requiring urgent surgical care can be connected to a remote urologist when rapid, expert medical care is warranted [23]. This, in effect, could reduce unnecessary fatalities and prevent serious complications in hospitals that lack adept urologists.

3.3. Potential for Urologic Telementoring in LMICs

Urologic telementoring could revolutionize how surgeons are trained in LMICs. In a study by Shin et al., urologists used Connect to mentor 55 robotic prostate and renal surgeries, of which 26 were telementored. Shin et al. reported that telementoring resulted in similar operative times between telementored and non-telementored cases. There were also higher satisfaction rates among surgeons and trainees where mentors preferred remote over in-person training [24]. El-Asmar et al.'s study used Proximie to compare perioperative outcomes of 59 cases of Aquablation, of which 21 were telementored. The authors reported similar operative outcomes and complications between onsite and telementored cases, demonstrating the efficiency and practicality of using such interfaces for surgical training [25]. Given the similar operative outcomes and complications, telementoring interfaces can be used to train urologists in LMICs. These can be used to teach simple and complex robotic procedures that may not be readily available or accessible in LMICs.

4. Barriers to Urologic Telesurgery Implementation

4.1. Latency

A technical barrier to telesurgery's implementation is latency: the time it takes for an image to be visible on a surgeon's monitor after a particular movement is initiated. The ideal latency time should be between 100 and 200 ms to reduce major inaccuracies in instrument handling [26]. Several telesurgery operations have been performed where latency has not been an issue due to the use of dedicated fiber optic cables or 5G networks [21]. While the issue of latency delay is minuscule for urologic telesurgery, it is highly dependent on internet connectivity, which is insufficient in many LMICs.

4.2. Global Network Coverage and Connectivity

Data from existing studies investigating telemedicine shed light on the limitations associated with virtual healthcare and telesurgery. For example, several studies have shown that a lack of infrastructure, equipment, technical support, and poor internet connection are barriers to telehealth adoption in LMICs [27]. In regard to infrastructure, it is estimated that steady electricity was present in only 81 (35%) of 231 district hospitals in 12 sub-Saharan African LMICs [28]. This is a prominent issue, as stable electricity is vital for secure network connection and proper instrument function to maximize the safety and efficacy of urologic telesurgery. Furthermore, urologic telesurgery would require widespread internet connectivity in LMICs. However, people in LMICs tend to have difficulty accessing the internet, while those in HICs have much greater coverage. There are about 1360 secure internet servers per million people in LMICs, in comparison to 65,000 per million people in HICs [29]. This presents a major limitation, as many public and private hospitals in LMICs may not have access to the fiber optic cables or 5G networks required for urologic telesurgery [30]. Given that successful urologic telesurgery would require 5G-compatible computers, cell phones, and robotic surgical systems, major investments would need to be made in improving LMIC broadband internet connection. Until urologic telesurgery is routinely done in LMICs, it may be necessary to have backup surgical teams onsite if a 5G connection is hindered or lost [31].

Companies that design and manufacture robotic surgery systems are beginning to realize the value of telesurgery. It is important to note that systems from different manufacturers may have varied software and design elements than their competitors. Given that hospitals across the world use a variety of surgical robotic systems, this poses an issue regarding interoperability. As global companies and governments forge the path for telesurgery, they will need to decide whether robotic surgery systems will allow for interoperability.

4.3. Ethical, Legal, and Policy Considerations

Given that the urologist is not in direct contact with the patient, there is some skepticism about the ethics of telesurgery. Remote surgeons need to ensure that they abide by the ethical principles or duties owed to their patients, regardless of geographical location [32]. Another limitation to urologic telesurgery implementation is related to legislation and health policy. Since this will be a global effort, collaboration from multiple consortiums of approval boards will be needed. These organizations will have to decide who gets to operate as well as where they get to operate.

It is important to recognize that the qualification and accreditation process for physicians will require standardization [33]. For example, there are several ways to perform a robot-assisted laparoscopic prostatectomy [34]. Surgeons and approval boards must establish one or a few standardized procedures for each urologic condition to ensure that there is oversight and regulation of such procedures. Ultimately, surgeons must also bear responsibility for patient outcomes. Due to the complications that can arise during urologic telesurgery, a highly skilled team of technicians and assistants will need to be at the disposal of the surgeon to prevent any issues from occurring. The details regarding physician responsibility need to be further discussed, and conversations addressing this matter should be held at future robotic and telesurgery conferences.

4.4. Funding, Billing, and Insurance Considerations

There are significant difficulties when discussing the financial constraints of telesurgery. Beyond that, there is a lack of clarity about reimbursement for telesurgery cases and who should bear the financial burden. Robotic platforms entail exceedingly high costs (purchases, training, consumables, and maintenance) without even considering the additional expense of telesurgery functionality. Common sources of funding have occurred through government support and non-governmental organizations. Insurance payers have been reluctant to extend reimbursement for telesurgery, and this has posed a significant barrier to its widespread adoption.

As mentioned earlier in this review, some hospitals in LMICs do not have the capacity to support telesurgery at this time. It is unclear how these LMICs will obtain surgical robots and where the funds to purchase and maintain these systems will be sourced. Additionally, the question of where financial support for on-site surgical staff will come from must be addressed. Until hospitals in LMICs acquire the resources to support telesurgery, patients may have to continue traveling long distances to facilities capable of robotic surgery.

5. Initiatives Taken to Advance Urologic Telesurgery

Telesurgery Consensus Meeting and Artificial Intelligence

The Society of Robotic Surgery (SRS) organized the first Telesurgery Consensus Conference in February 2024. The world's top surgical and robotic technology leaders discussed various issues regarding telesurgery implementation. More specifically, the congress explored surgical training, credentialing, reliability, patient safety, and ethical and legal issues regarding telesurgery. Members of Telecom, the World Bank, healthcare insurers, surgical robotics companies, and other stakeholders were also present. The goal of this conference was to facilitate and shape advancements in technology and health policy that will be needed to reduce global disparities in access to surgery. As telesurgery develops, solutions for generating equality in healthcare and surgical education will present themselves. Technical advancements are crucial to accommodate innovative technologies in mainstream healthcare.

Artificial Intelligence is rapidly growing and has become a key component in contemporary medical care. Real-time imaging analysis is one proposed use of AI technology in telesurgery. In addition, surgical planning is another possible application that is gaining widespread interest. AI has already been shown to improve intraoperative image quality by denoising, deblurring, and color-correcting real-time camera imaging in surgical robotic systems. Additionally, AI platforms have been designed to enhance surgical margin management by delineating tumor tissue from tumor-unaffected tissue in a variety of surgical specialties [35]. Therefore, implementing AI in telesurgery may yield increased intraoperative safety and more efficacious treatment outcomes.

6. Conclusions

The global disparity in access to surgical care between high-income countries (HICs) and low- and middle-income countries (LMICs) leaves billions without necessary treatments, exacerbating preventable disabilities and mortality. Telesurgery, leveraging advanced robotic systems for remote operations, offers a promising solution to this issue. Since its inception, telesurgery has demonstrated feasibility and safety, notably through the Lindbergh Operation in 2001 and subsequent advancements in robotic surgery. In LMICs, telesurgery can reduce travel burdens, provide access to expert care, and facilitate surgical training through telementoring. However, challenges such as latency, infrastructure deficits, and the need for standardized ethical and legal frameworks must be addressed. Despite these obstacles, the potential benefits of telesurgery in LMICs are significant, and with the right investments and international collaboration, it can be scaled to provide equitable surgical care globally. Telesurgery presents itself as a realistic approach to revolutionizing urologic surgery, illustrating a new era for medical care in areas of the world that have lacked modernity and consistent alleviation.

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