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Telesurgery and telementoring[☆]

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ABSTRACT

Telemedicine has revolutionized the field of surgery, with telemonitoring and telesurgery being 2 of its most promising applications.

Telesurgery and telemonitoring are revolutionary applications that have the potential to change the way surgical operations are performed. These applications can allow surgeons to perform operations, enable surgeons to perform operations by assisting or supervising others through mentoring from a different location (telementoring).

Despite the potential benefits of telemedicine and telementoring, there are still challenges that must be overcome before they can be widely used in clinical practice. For example, latency in data transmission can be a problem in telemedicine, as even a small delay in data transmission can affect the accuracy of the operation. Additionally, a sophisticated and expensive technological infrastructure is required, which can limit their use in some clinical settings. Although we need to work on its development technologically, ethically and legally, it is a promising tool.

Telecirugía y Tementorizacion

Palabras clave:
Telemedicina
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Cirugía mínimante invasiva
Cirugía robótica formación

RESUMEN

La telemedicina está revolucionando el campo de la cirugía. La telemonitorización y la telecirugía son dos de sus aplicaciones más prometedoras. Ambas, son aplicaciones revolucionarias que pueden cambiar la forma de ver el manejo perioperatorio y la propia cirugía. Pueden permitir a los cirujanos realizar operaciones ayudando o supervisando a otros mediante la tementorización, favoreciendo todo ellos la seguridad del paciente.

A pesar de los beneficios potenciales, quedan retos por superar antes de que se utilice de forma generalizada. La latencia en la transmisión de datos puede ser un problema, ya que un pequeño retraso en la transmisión de datos puede afectar a la precisión de la intervención. Además, la telemedicina necesita una infraestructura tecnológica sofisticada y costosa, lo

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que puede limitar su implantación en algunos entornos. Aunque debemos trabajar en su desarrollo tanto tecnológico como de aspectos éticos o medicolegales, es una herramienta prometedora.

Telesurgery and telementoring

In recent years, great technological advances have been made in the field of medicine. As a result, innovations have emerged in medical care, which have also been largely favored by the requirements derived from the SARS CoV-2 pandemic. These advances, including telesurgery and telemonitoring, are revolutionizing the way healthcare is delivered, allowing for more efficient and accurate care, without traditional geographic limitations. Both are grouped within a larger group known as telemedicine.

The World Health Organization (WHO) defines telemedicine as, ''*The provision of health care services, where distance is a critical factor, by all health care professionals using information and communications technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interest of advancing the health of individuals and their communities.*''[1]

Although the pandemic favored the development of telemedicine, this tool is still not deeply rooted in our country. In addition, legal and ethical implications have been debated due to the lack of well-defined regulations and issues regarding the protection of patient data as well as informed consent.[2]

Telesurgery

Telesurgery is a surgical system that uses wireless networks and robotic technology to connect surgeons and patients remotely. It can be divided into 3 main components: telesurgery, teletutoring or telementoring, and teleconsultation.[3]

The concept of distance between the surgeon and patient is not a new idea. It was already explored in 1970 by NASA (US National Aeronautics and Space Administration), which had a particular interest in treating astronauts in space based on the notion of remote surgery or telesurgery.[4] The first applications were on the battlefield and on US Navy ships in the 1990s. Many laparoscopic surgeries were performed by robotic devices controlled remotely by surgeons at the military hospital in Landstuhl, Germany (4000 km away). The first case of robotic surgery was performed in Milan in 1995 by urologist Enrico Pisani, who performed a prostate biopsy on a patient located at a hospital 5 km away.[5]

The emergence of robotic surgery has made it possible for surgeons to operate with greater dexterity, precision, and accessibility.[6] Advances in telecommunications and robotic surgery that occurred during the 1980s and 1990s led to telesurgery being considered a practical option. Thus, in 2001, Professor Jacques Marescaux performed the first telesurgery in general surgery, known as the ''Lindbergh Operation''. It was a laparoscopic cholecystectomy, during which the mechanical arms of a surgical robot were controlled by a team of surgeons in New York City, located more than 6000 km away from the patient in Strasbourg (France). A high-speed fiber optic service provided the link between the robotic system and the surgeon. The surgery lasted 54 min, and the patient presented no complications.[7] This was a symbolic milestone in surgery, which led to the foundations being laid for globalized surgical procedures.

Telesurgery can provide several benefits (Table 1: Benefits/limitations of telesurgery). Traveling to receive or provide medical care is not a feasible option for many patients and surgeons due to financial limitations, travel-related health risks, travel restrictions, or time delays, which can be counterproductive in some cases. Telesurgery is an excellent solution to obtain medical care without patients having to travel beyond their local hospitals, and surgical experts could provide surgical care to patients anywhere in the world, especially in remote areas, battlefields, and inaccessible areas like spaceships.[11]

The evolution in engineering and robotics applied to the healthcare field has resulted in improved technologies, such as high-definition cameras with 3D vision and robotic systems that allow surgeons to access complex areas with stability and dexterity, while also canceling out physiological tremor. Together, these technologies provide improved surgical precision, thereby reducing some of the risks derived from surgery (blood loss, surgical infection, pain).[12,13]

Furthermore, the evolution of telesurgery facilitates collaborations between hospitals, surgeons, and surgical specialties, which can occur in real time. Patients can simultaneously benefit from the expertise of more than one specialist, and surgeons themselves can benefit from the training provided by

Table 1 – Benefits and limitations of telesurgery.

Benefits	Limitations
Ambulatory surgery in medically underserved areas	Requires a global network
Eliminates the need for long-distance travel of patient/doctor	Acquisition and maintenance of equipment
Enables real-time surgical collaboration among surgeons from different hospitals	Infrastructures that support the parallel use of the necessary technology
Continued education through telementoring or teletutoring	Ethical and legal factors

these specialists, as indicated above. Also, at a time when there appears to be a shortage of specialists (surgeons, anesthetists, etc) in certain geographical areas, telesurgery could be a potential solution.[14]

The coronavirus disease (COVID-19) caused by Sars-CoV-2 was declared a global pandemic on March 11, 2020 by the WHO. During this time, surgical interventions were reduced to a minimum of essential procedures (only critical patients) due to the risk of viral transmission. The development of telesurgery and its consolidation make it a viable alternative for the protection of both the surgeon and patients.

Despite the current and future benefits of the combination of artificial intelligence and telesurgery, we must also consider a series of limitations that must be addressed before they can be widely implemented in clinical settings. Some of these limitations include:

-Training

There is a lack of quality skills and training programs. Telesurgery requires specialized training and protocols for equipment maintenance, which are not yet fully developed.[15]

-Technical limitations

Telesurgery has several technical limitations, such as the need for high-speed internet connections and the risk to patients stemming from delays or interruptions in communication. To resolve this limitation, high-speed network connections are necessary, as well as optimized hardware and software for the telesurgery system.[16] Currently, the maximum theoretical speed of 5 G is up to 10 Gbps, which means that it is 100× faster than 4 G, whose theoretical maximum speed is 100 Mbps. The incorporation of high-speed 5 G internet with telesurgery will reduce the current latency period from 0.27 to 0.01 s. This improved latency may resolve the issue of delayed reactions, which is an issue of concern in telesurgery. Furthermore, 5 G networks also enable haptic applications to come to life. All these improvements mean that it will likely be a crucial technology for telesurgery.[14–17]

-Ethical and legal limitations

Telesurgery is still being developed, as are the related legislation and ethical considerations. This requires secure communications networks to protect patient privacy and prevent cyberattacks, as well as regulatory challenges for licensing, or liabilities arising from its use.[18]

-Costs

The price of obtaining and maintaining telesurgery equipment is currently high, which greatly limits its accessibility for many healthcare providers and patients, especially in economically disadvantaged geographical locations.[15]

The rapid evolution of technology has resulted in the development of new applications in the field of telesurgery. Two of the closest in their application seem to be the presence of haptic feedback and the inclusion of the Internet of Things (IoT) in the surgical field:

Haptic feedback and tactile robots

Telesurgery systems already utilize high-resolution 360-degree 3D-vision cameras. However, current robotic systems only provide visual sensations, but not tactile sensations. The development of this technology will allow for better control over the instruments and further increase surgical skills. Haptic technology is able to transmit tactile information to the operator. The invention of artificial intelligence, along with new augmented and virtual reality surgical training programs, could use these technologies to further improve the robotic arm[19] and make it more precise with the integration of advanced touch sensors. A clear example of how AI has advanced in the field of minimally invasive surgery was recently published by Amin et al., who explained in detail the use of an AI system during laparoscopic cholecystectomy. This system is capable of recognizing the anatomy, phases of the procedure, and critical situations, while even providing the surgeon support during the procedure.[20]

Internet of Things (IoT)

IoT is the new technological revolution that aims to connect everyday physical objects to the internet, creating a global network of unique things that can share information with each other and complete programmed tasks. The use of IoT in surgery will allow us to visualize and standardize procedures to improve results, and its development is expected to bring multiple advances in medicine and surgery.[21] What better example of IoT than telesurgery or telementoring, in which different devices, cameras, microphones or computers are necessary to transmit information over the internet? Another good example is surgery with stereotactic navigation or image overlay, where the surgeon is assisted by remote devices during the procedure.

Apps (software applications) are also an impressive field of current development. Several companies in the technology sector are launching apps that allow us to know in real time the number of procedures performed with their devices, how we use them, and what the workflow is during our minimally invasive procedures, which at the same time are recorded in video format in the app, such as with My Intuitive® (Intuitive Surgical, CA, USA) or Touch Surgery® (Medtronic, CT, USA).

Telemonitoring

Like telesurgery, telemonitoring is part of telemedicine and complements patient monitoring.

Telemonitoring is the process of continuous or non-continuous monitoring that allows a healthcare professional to remotely interpret the data necessary to medically monitor a patient and, if necessary, make decisions about the patient's health status (for example, in the case of remote monitoring of a cardiac patient with a defibrillator).

Telemonitoring has become widely accepted for postoperative patient care in particular because it enables remote monitoring and management of patients' basic vital signs, symptoms, and recovery, which reduces hospital stays and increases patient satisfaction.

However, telemonitoring is much more than the simple communication of health data through a ‘‘remote connection’’. In the past, devices that were often voluminous and expensive recorded simple observations of patient clinical variables, which were subsequently sent to the specialist’s office. Today, this data is collected and stored in a cloud system, which the doctor can consult remotely at any time to possibly modify treatment recommendations based on the results.

The rapid evolution of monitoring systems means that new systems can be equipped with artificial intelligence (AI) and are capable of acquiring data and preparing reports for patients and specialists on the need for therapeutic modification, hospitalization or approach to emergencies. Along with this technology maturation process, the device market has also experienced significant changes,[22] which has led to the use of conventional ‘‘wearable’’ devices in the healthcare sector.

Some years ago, the systems were too expensive, and widespread dissemination was quite difficult. Each system was tied to its own platform and could not interoperate with other systems in use. The devices were impossible to customize to meet user needs. Furthermore, these devices were designed to operate in selected environments, with a very limited range of actions. Current telemonitoring designs have changed the focus, trying to work towards a system that is ubiquitous, efficient and sustainable.

Nowadays, like the mobile devices that we use in our daily lives (smartphones, smartwatches, applications, etc), the number of medical devices that have an internet connection has doubled in the last 5 years and is currently growing at double this rate. Many state-of-the-art sensors/devices are capable of detecting, recording and suggesting actions to be taken regarding the patient’s physical condition.[23] This also opens the doors to new forms of telemonitoring.

There are also many applications (apps) available for different healthcare systems, both nationally and internationally, that allow patients to consult their electronic healthcare records and interact with their physicians or specialists, and where telemonitoring systems can be integrated.

The minimally invasive surgical approach, particularly robotic surgery, has contributed significantly to reducing postoperative hospital stay and improving functional recovery. These results have been further improved by perioperative enhanced recovery after surgery (ERAS) guidelines that help further minimize surgical stress, reduce morbidity derived from surgical procedures, and therefore shorten the hospital stay.[24,25]

With the aim of further reducing hospitalization times, telemonitoring offers the opportunity to monitor the recovery of patients after surgery, at home.

Telemonitoring during the postoperative period has different advantages, such as allowing patients direct contact with the surgical team to receive individualized care from the comfort of their own homes. It facilitates doctor-patient communication through videoconferencing, improves patient satisfaction results, and allows for improved health outcomes and costs. However, it also has some limitations, such as technical failures, connectivity problems, and patient isolation, while also requiring secure communication networks due to the high content of confidential data being shared. Likewise, these programs may not be suitable for certain patients (Table 2).

Current scientific evidence shows excellent results when telemedicine is included in the postoperative protocol, and clinical outcomes are similar to traditional clinical follow-up.[26]

Several studies have described the usefulness of postoperative telemonitoring in patients treated with cardiac or trauma surgery, but there has been recent interest in the field of abdominal surgery. Although prospective studies are still needed to support its use, practically all studies conclude that telemonitoring is safe, with a high rate of event detection and treatment, which results in high satisfaction rates among patients and medical professionals.[24,27–30]

Telementoring

The challenges of training in robotic surgery have grown, and this has led to the development of new teaching tools, such as:

- Case observation programs
- Workshops using physical or virtual surgical simulation
- E-learning with multimedia teaching material: videos, PDF presentations, slides, etc.
- Online seminars (‘‘webinars’’)
- Live transmission of surgeries through video streaming
- In-person programs
- Fellowship programs of varying durations

Table 2 – Advantages and limitations of postoperative telemonitoring.

Advantages of telemonitoring	Limitations of telemonitoring
Facilitates hospital/patient connection, and individualized care at home.	Technology failures (networks or physical systems) that may cause a failure to identify complications.
Facilitates contact between patient and doctor through the use of remote monitoring technology.	Patients may feel isolated or disconnected due to lack of physical interaction
Can improve patient outcomes by detecting early complications and enabling timely interventions.	Telemonitoring requires stable and secure communication systems.
Can reduce the cost of medical care by minimizing hospital readmissions and emergency room visits, as well as hospitalization costs.	Expenses derived from the implementation of the program (applications, physical monitoring systems, etc.)
May provide patients with greater convenience and flexibility to manage their postoperative care.	It may not be suitable for all patients, such as those with complex medical conditions or limited use of technology.

Due to the constant evolution of technologies applied to surgery, the adaptation and training of surgeons has become a priority. Although training in these techniques during postgraduate surgical education is now a standardized requirement, there is a large population of practicing surgeons who have not received the education required to perform these procedures safely and smoothly.

The vast majority of trained surgeons and those in training need to develop the skills necessary to mitigate the adverse effects that the implementation of new technologies could have on patients undergoing these procedures. In 2015, an independent review by the ECRI Institute about the dangers of health technologies identified insufficient training in robotic surgery as one of the top 10 risks to patients.[8]

In a recent systematic review about the experience of telementoring in surgery, a total of 66 studies were identified for inclusion. In total, 48% of the studies were performed in general surgery, and 22 (33%), 24 (36%), and 20 (30%) of the studies reported telementoring that occurred within the same hospital, outside the hospital, or outside the country, respectively. Sixty-four (98%) of the studies used video and audio, and 38 (58%) used Telestration®. Twelve separate studies directly compared remote tutoring with in-person tutoring. Seven (58%) showed no differences in the results between remote tutoring and face-to-face tutoring. No studies found that telementoring resulted in worse postoperative outcomes. The results of this review suggest that telementoring has a safety profile and effectiveness similar to in-person tutoring. Future analyses are required to determine the potential benefits and dangers of surgical education through telementoring to determine the exact role it will play in the future. Technological advances to improve remote connectivity would also promote the implementation of teletutoring on a larger scale.[9]

Minimally invasive surgery (MIS) has been widely applied to laparoscopic and robotic surgery. However, the learning curve for MIS is estimated to be longer than that of many other procedures. Furthermore, this learning process has been shown to influence clinical and economic outcomes. In this context, it become more important to optimize outcomes during the learning curve by using rigorous mentoring for surgeons and residents with less experience in MIS. Fellowships in MIS provide sufficient experience to overcome these obstacles, but not all students may have similar training opportunities. This is even more common for surgeons whose hospitals do not have access to the technology or where access to adequate training in advanced MIS is limited. This can be a major problem even in the developed world, especially in countries with large geographic areas with low population density, such as the United States or Australia.

Technological advances have opened new types of long-distance communication through telemedicine, which could respond to the unmet need for adequate mentoring in MIS. Thanks to this technology, an expert surgeon can actively observe and supervise a procedure performed by a surgeon-in-training at another institution. The recently launched 5 G mobile networks offer this possibility in a way that was not possible until now.

Telementoring can be classified into 4 different levels: verbal guidance, telestration guidance, teleassistance guidance, and telesurgery. Although surgical telementoring and telesurgery take on various forms, they can be stratified according to the increasing level of interaction between mentor and student. Tutor instruction can be as simple as verbal guidance while the tutor watches a real-time video of the operation. In more advanced interactions, telementoring may progressively involve the indication of target areas on the local monitor screen (telestration), assuming the role of an assistant by controlling the surgical camera or an instrument using robotic arms (tele-assisted surgery), or actually performing remote surgery (telesurgery).[10]

Telecare and telesurgery in minimally invasive surgery are increasingly practical and economically profitable to facilitate the teaching of advanced surgical techniques around the world, while also providing surgical care in medically underserved regions. However, there are still many challenges to overcome. The maturity of these methods depends on economic incentives, favorable legislation, and collaboration with cybersecurity experts to ensure safety and profitability.

Today, digitalized surgical procedures have made remote interaction a reality, and there have been successful telesurgery experiences with the da Vinci surgical system (Intuitive Surgical, Inc), as we have already mentioned.

This scenario allows for further development of a telecare program by expert surgeons, who simultaneously help other surgeons acquire this level of experience. Such programs benefit patients by providing them with potentially safer surgery and giving them access to the possibilities offered by the surgical advances of minimally invasive surgery. Due to technological reasons and the lack of experience of surgeons/teams, it is probably early to explore tele-assisted surgery and telesurgery on a larger scale, but there is no doubt that they will be used on a daily basis in the near future.

Conclusion

Telemedicine has become one of the most rapidly expanding components of the healthcare system. In recent years, its role in perioperative and intraoperative care has become very important, demonstrating excellent clinical results, a high degree of patient satisfaction, and shorter hospital stays and waiting times, which lead to cost savings for both patients and healthcare systems. Likewise, telemedicine has contributed to the evolution and implementation of systems that allow surgeons to safely develop and consolidate new knowledge, with faster and safer implementation of new technologies.

Future perspectives must focus on patient confidentiality and the widespread dissemination and implementation of telemedicine in its different forms. For surgeons, these technologies support standardizing telementoring programs to complement current in-person training systems.

Conflict of interest

The authors declares that they have no conflict of interest.

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Glossary

Telesurgery: surgical system that uses wireless networks and robotic technology to connect surgeons and patients remotely.

Telementoring or Teletutoringremote: training that uses different educational strategies, either at a single moment or as part of a training curriculum.

Telemonitoring: continuous or non-continuous monitoring process that allows a healthcare professional to remotely interpret the data necessary for the medical follow-up of a patient and, if necessary, to make decisions about the patient's health status.

Telestration®: a technique that allows for freehand mark-ups to be drawn on static or moving images (video), in either real time or delayed time.