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Telemedicine and telementoring in the surgical specialties: A narrative review

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ABSTRACT

Background: The field of telemedicine has grown tremendously over the last decade. We present a systematic review of publications on telemedicine as it pertains to surgery, addressing six facets: 1) telerobotics, 2) telementoring, 3) teleconsulting, 4) telemedicine in post-operative follow-up, 5) tele-education, and 6) current technology.
Data sources: A search of relevant literature querying PubMed, Web of Science, and Science Direct was performed using the following keywords: telecommunication, telemedicine, telehealth, virtual health, virtual medicine, general surgery, surgery, surgical or surgical patients.
Conclusions: Telemedicine is being used to care for patients in remote areas, to help expert surgeons assist other specialists in the office or novice surgeons in the operating room, as well as to help teach the next generation of surgeons. There are many opportunities for surgeons to utilize this technology to optimize their practice.

Introduction

Telemedicine is the field of utilizing telecommunications for the purpose of diagnosing and treating patients in remote locations. This technology has gained increased popularity in recent years, both in medicine and surgery. With the advancement of computer science and engineering, telemedicine now affords surgeons even greater opportunities for patient care, mentoring, collaboration and teaching without being limited by geographic boundaries.

Telesurgery and telerobotics, including pre- and post-operative video telecommunication, offer opportunities for surgical procedural care on patients in remote areas. It also allows sharing knowledge with consultants to direct patient care as well as to educate trainees.

Telementoring in surgery promises to address some of the field's most pressing issues, such as the growing disparity of access to surgical care, rapid knowledge transfer of innovative surgical techniques, and fostering resident autonomy and career readiness. Surgical telementoring utilizes technology to facilitate the distribution of surgical knowledge by means of both technical assistance and real-time guidance between an experienced surgeon and a novice in a different geographical location. Telementoring has been shown to be comparable to onsite mentorship when knowledge and skill acquisition are analyzed, thereby reinforcing it to be a cost-effective and reliable educational tool.[1,2,3] These reports are especially encouraging with present day challenges of providing subspecialized surgical care and mentorship in geographically remote locations.

Herein, we present a systematic review of publications on telemedicine as it pertains to surgery, specifically discussing six

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facets relevant to surgeons, namely: 1) telerobotics or direct surgical intervention, 2) telementoring (surgeon to surgeon), 3) teleconsulting (surgeon to other specialists or primary care physicians), 4) telemedicine for post-operative follow-up, 5) tele-education, especially in resource-limited regions, and finally, 6) current telemedicine technology.

Materials and methods

An experienced research librarian performed a search of the relevant literature in October 2017, querying PubMed, Web of Science, and Science Direct using the following search strategy: ((telecommunication[tiab] OR telemedicine[mh] OR telemedicine [tiab] OR telehealth[tiab] OR virtual health[tiab] OR virtual medicine[tiab])) AND (general surgery[mh] OR general surgery[tiab] OR surgery[tiab] OR surgical[tiab] OR surgical patients[tiab]). A total of 551 citations were found. The abstracts and titles were screened for relevance and consideration for quantitative review with meta-analysis or qualitative systematic review. We excluded 436 articles for lack of relevance to our topic; these included opinion papers, editorials, and user surveys unrelated to telemedicine. The remaining 115 full-text articles were examined and their references scanned to determine if other articles should be included or if, upon review, these articles were not relevant to our inquiry. No comparative data were found; most published papers were case studies and case series. For this reason, we proceeded with a narrative review of the most informative and illustrative articles ($n = 54$), to provide an overview of the state of the science on this topic and identify areas for future research.

Results

Telerobotics or direct surgical intervention

There were nine primary publications in the area of telerobotics identified in our search. Five articles discussed telesurgery utilizing animal models or trainers. Three publications reported results from telesurgery in patients. Of the publications on telesurgery in non-humans, the first was published in 1998 by Bowersox et al.[4] The authors assessed a telemanipulator system which allowed a surgeon to see, hear and manipulate a remote operative field, which, in this study, was 5 m away. Several procedures, such as gastric repair, cholecystectomy, liver laceration repairs and enterotomy repairs were performed by trained surgeons on swine. The authors concluded that surgical procedures could be completed using this technology; however, a significantly longer length of time, specifically 2.7 times, was needed. Fabrizio et al.[5] utilized the Aesop 1000 TS robot to examine the effect of time delay on telesurgical performance using the game *Operation*. They found that the time needed to complete each task, as well as the error rate, correlated with increased time delays. Challacombe et al.[6] studied human versus robotic needle access of a percutaneous kidney trainer in order to examine the usability of telerobotics for accessing the kidney for percutaneous nephrolithotomy. They found that the robotic insertion was slower but more accurate than human insertion, and it performed equally well locally and trans-Atlantically.

In 2008, two studies were published which assessed the viability of utilizing the Da Vinci telesurgery-enabled surgical robot for remote surgery.[7,8] Utilizing porcine models, both studies successfully performed surgeries remotely, one from California to Ohio and the other had data routed from London, Ontario to Halifax, Nova Scotia. In the study by Sterbis et al.,[7] four nephrectomies were performed; in one case, loss of the visual packet occurred which required the local surgeon to complete the bulk of the procedure. Latency rates were between 450 and 900 ms and found to be significantly cumbersome at 900 ms. In the Nguan et al. study,[8] six pyeloplasties were performed, and no network failures were noted. Latency rates of 350 ms were seen, which did not appear to affect physical-visual asynchrony. Nevertheless, real-time Da Vinci continued to outperform telesurgical Da Vinci, with regards to speed (10.9 ± 1.1 min. vs. 20.7 ± 4.7 min, $P < 0.01$).

Three studies reporting telesurgery in patients were identified. The first described the establishment of a telerobotic remote surgical service, which was based in Hamilton, Ontario.[9] Using the Zeus TS microjoint system, the author performed 21 telerobotic cases in North Bay, Ontario. The local environment required a surgeon trained in laparoscopy but did not require experience in advanced laparoscopy. Cases included laparoscopic Nissen fundoplication, laparoscopic inguinal hernia repair and laparoscopic colectomies and were performed collaboratively with both the remote and local surgeon. The overall latency rate was 135–140 ms and was noticeable for the telerobotic surgeon. A temporary disturbance in signal transmission occurred during the first colectomy, but a switch to a second telecommunication line solved this problem with a less than 1 s delay. The second publication,[1] reported the work of the Centre for Minimal Access Surgery (CMAS) with two community hospitals. The Zeus TS microjoint system was used, and 18 cases were performed (7 telerobotic, 11 telementoring) with good outcomes. The last publication reporting telesurgery in patients was a case report of a telesurgical fetoscopy performed from Tampa, FL to Santiago, Chile on a female with a twin pregnancy with an acardiac twin.[10] This patient successfully underwent ultrasound and laser photocoagulation under the guidance of the Tampa-based expert in order to occlude blood flow to the acardiac twin.

These studies show that with current technology, remote telesurgery is a highly attainable feat. However, network performance continues to pose an area of concern as latency rates affect the accuracy and speed of surgery. Furthermore, lost audio or visual input could disrupt care. Higher grade networks and system redundancy may help protect against this risk. Lastly, additional improvements in 3D visualization, refining of robotic instrument movements and decrease in unsteadiness will also assist in improvement of telerobotic surgery.

Telementoring, surgeon to surgeon

Telementoring facilitates the safe transfer of knowledge from an experienced surgeon to a novice and allows the expert to guide the novice through a procedure in which they previously had minimal experience.[3] Telementoring has, and continues to be, utilized within a wide range of surgical subspecialties, including but not limited to neurosurgery, urology, vascular surgery, ophthalmology, otolaryngology, and subspecialties of general surgery such as pediatric, transplant, endocrine, and trauma surgery. In fact, in a 2010 review of clinical outcomes and educational benefits of telementoring, 33 telementored surgical procedures spanning 11 subspecialties were reported to have been documented in the literature.[11,12]

Telementoring intra-operatively facilitates an experienced surgeon unfamiliar or with limited practice in a particular operation, to be guided through the procedure by an expert surgeon. Teleconsultation (also referred to as teleconferencing and teleassistance) on the other hand takes on a more collaborative dynamic, whereby two surgeons both experienced in a procedure, work together through a complex case.[13,14]

Should surgeons wish to acquire new skills, the traditional approach was, and for the large part remains, on-site mentoring in conjunction with hands-on course training and conferences.

However this can be challenging for two main reasons: disproportion between the number of trained experts and the number of surgeons in need of training, and significant time and resources required when surgeons are travelling from remote locations. Telementoring is an innovative strategy to overcome these challenges. It should come as no surprise that the countries that are leading the way in both telementoring and telerobotics are those with significant geographical spread. Canada, for example, has utilized telementoring to facilitate both simple and complex laparoscopic surgeries in remote rural communities since 1999.[1,15] In the United States, individual hospital systems have developed mentoring systems with resource limited institutions or those lacking significant exposure to complex subspecialized case load, including South America, United Kingdom, Europe and beyond.[10,16–22]

Numerous case reports have been published outlining the utility and successes of telementoring, allowing patients to receive subspecialized care, in fields such as fetal, bariatric, and endocrine surgery, without leaving home.[10,16–21] Feedback from surgical mentees involved in such cross-continental and trans-oceanic operations has been positive, reporting increased confidence in performing procedures and, most vitally, learning the choreography of operations, including the positioning of the patient and assistant, identifying planes of dissection, and the chronological steps. Some of the most interesting outcomes of these mentorship models have been the development of collegial relationships between academic and community surgeons, thereby reducing the sense of professional isolation that surgeons operating in remote communities would report.[1,15]

The investment into developing telementoring programs also reduces the need for patients to migrate to larger centres, meaning that, not only can they undergo procedures in their communities, but they can also ensure follow-up with the same surgeon.

The term teleproctoring describes a situation where an experienced surgeon strictly observes the surgeon performing the operation in order to assess adequacy of skills and, in some cases, to help confer privileges to perform the procedure independently.[14] Telementoring in the setting of laparoscopic surgery in particular has been studied thoroughly, as not only are these skills paramount in today's surgical practice, but they also lend themselves well to remote mentoring.

Teleconsulting, surgeon to other specialists or primary care physicians

Patient care is increasingly being addressed in a cross-disciplinary approach, especially with the trend away from general practitioners and towards subspecialists. At major institutions across the world, numerous teams work towards the care of the patient, including but not limited to primary care physicians, subspecialists of all disciplines, dieticians, physical therapists, etc. While this strategy strives to provide a comprehensive approach for patient care at these institutions, many care centers around the world, in particular rural areas, lack the trained personnel or equipment to approach care in such a manner. The emergence of telemedicine and telecommunication has created opportunity for these care centers, lacking resources, to offer their patients such comprehensive and multidisciplinary care.

Long distance: rural, military medicine, and more

A major barrier to adequate healthcare both domestically and internationally is lack of proximity to major facilities, particularly in rural areas and zones of conflict. Steps have been taken in the past using telemedicine as an approach to overcome such barriers. The University of Florida Pediatric Neurosurgery Department participated in a telemedicine program to supply care to a rural area within Georgia.[23] The Department arranged a monthly clinic using audiovisual telemedicine equipment to connect with patients and parents in Georgia, which was facilitated by trained nurses. Through the program they were able to order adequate diagnostic tests for the patients and provide appropriate care and referrals. Not only is telemedicine being applied within the boundaries of one's country, it has also been applied transcontinentally. The Japan Antarctic Research Expedition has been present in Antarctica since 1956, although medical care to the expeditioners has not always been as robust as it is today. With the increasing popularity of telemedicine and telecommunication, they have updated their technology to include weekly consultations where specialists can communicate in real-time with the Antarctic-based physician and patients.[24] This is especially paramount for critical injuries where any lag in communication could increase morbidity. In addition, they have upgraded their system so medical photos can be shared.

Other applicable areas where telemedicine has been shown to be beneficial in distant areas are war zones and correctional institutions. The military showed decreased resource utilization including aeromedical evacuations, costs, and duty time and decreased time to treatment through the use of orthopedic telemedicine consultations to soldiers deployed in Afghanistan, Iraq, and Navy Afloats.[25] The military has also shown successful application of telemedicine for relief efforts both within Africa and Pakistan.[26] Virginia Commonwealth University Health System collaborated with the Department of Corrections in Virginia to provide improved perioperative care to their patients. Facilitated by a nurse at the correctional facility, they were able to use electronic stethoscopes/dermascopes in addition to real-time video to perform physical exams, obtain informed consent, and provide appropriate preoperative care.[27] With improvements in technology, telemedicine will become more accessible to rural areas and other locations where medical care is not easily accessed; in addition, the quality of healthcare provided in these locations should also increase with improved technology.

Telemedicine for post-operative follow-up

In traditional surgical care, patients are not continuously followed up after hospital discharge except for a few pre-scheduled time-limited outpatient visits. Moreover, the period following a surgical intervention presents increased risk for complications, which are often diagnosed late as patients and caregivers are not formally trained to look for early signs of problems. As a result, the risk of hospital readmissions and mortality also tend to increase in a similar manner.[28]

A systematic review conducted by Gunter et al.[29] investigated the current role of telemedicine in facilitating postoperative recovery after hospital discharge in the United States. In this review, telemedicine showed a wide variety of uses in postoperative care across different specialties including, but not limited to, endocrine surgery, orthopedics, ENT, colorectal surgery, vascular surgery, neurosurgery, transplant, oncologic surgery, urology and plastic surgery. In the literature, there are also references to the use of telemedicine for stoma care,[30] in which a specialized nurse remotely examines the stoma and advises a local nurse on how to change dressings and provide follow up care.

In respect to the benefits associated with the use of post-discharge telemedicine, it allows for access to specialty care in rural or medical shortage areas as well as reduces costs, both to the patient and the healthcare system.[28–31] For patients, telemedicine presents a convenient alternative, which reduces the need for taking time off work for outpatient consults. In one study, telemedicine reduced costs up to US$176 by reducing average miles traveled (from 79.6 miles to 367.2 miles), and saved time (77.5 min–317 min).[29] Hence, telemedicine may present a good alternative to the management of an aging population with limited mobility.

For the healthcare system, postoperative telemedicine can reduce costs as it can liberate clinic appointments for other use, help decrease unnecessary hospital transfers as well as decrease need for hospital readmission.[28,29]

Telemedicine has also been implemented using smartphone applications for postoperative follow up. In one study,[28] the application was used in vascular surgery patients for monitoring wounds and surveillance for surgical site infections (SSI). This was accomplished by having patients photograph incisions and answer simple questions on the quality of fluid leakage. These would then be reviewed and interpreted by a designated team of healthcare providers. Among 40 patients that completed the full study protocol, there were 8 SSIs, 7 of which were detected through visual and written information from the application. There was one false negative SSI that was detected at an early follow-up visit, and there were no false positives.

In France, Teot and colleagues created a telemedicine wound care system called Home Hospital Wound Healing Network (CICAT) in 2005.[31] Similarly, they use self-photographing by the patient to obtain information and analyze wounds, which were mostly pressure ulcers (44%), arterial/venous/mixed leg ulcers (24%), and trauma wounds (10%). Results from 10 years of experience of CICAT showed a 75% rate of improved or healed wounds, a 72% decline in the number of hospitalizations and a 56% reduction in ambulance transfers to wound healing centers.

Overall, studies on the use of telemedicine for postoperative care and follow-up have demonstrated high levels of satisfaction by both patients and physicians.[28,29]

Tele-educating, especially in resource-limited regions

Tele-educating, or the act of receiving instruction, guaidnace, or teaching by means of telecommunication, has the potential to be of particular value in serving populations with limited resources or in remote areas. Many have piloted programs to connect expert specialists often in large academic centers with smaller surgical centers both for teaching purposes and for diagnostic purposes. Tele-education allows more remote centers to offer a greater breadth of medical services as well as a higher standard of care.[15] At the same time, it saves time for both the trainee and the surgeon, decreases costs involved with taking time out of practice and traveling, and avoids cumbersome privileging issues.[10–12] Furthermore, the technology has been validated using remote tele-education of general surgery residents, demonstrating objective improvement in specific surgical skills.[3] Remote web-based audiovisual tele-education has been widely explored in laparoscopic and robotic urological procedures[18,19,21,32,33] and to a lesser extent in robotic neurosurgical procedures.[34] There are several specific examples of tele-education allowing for complex surgical care in remote locations that would otherwise require extensive travel or inability to treat patients optimally. Datta et al.[35] piloted a model to train and empower local rural international surgeons to perform inguinal hernia repair using wearable technology, American pediatric surgery specialists used tele-education to perform cases with pediatric surgeons in France,[36] and an orbital specialist in Hawaii was able to use real-time telecommunication to guide a general ophthalmologist in the removal of an orbital tumor over 200 miles away on another island.[37] In perhaps the most extreme example, Cubano et al.[38] describe using telecommunication in order to successfully perform laparoscopic inguinal hernia repairs on a military aircraft carrier in the Pacific Ocean, obviating the need for a shore visit.

Tele-education also has important implications in surgical training and education. Several studies have been performed demonstrating the equivalence of in person versus virtual training of simple surgical techniques to medical students, more complex laparoscopic procedures to residents, and even competence-based assessment of residents performing laparoscopic procedures.[39–41] Potentially even more important, tele-education allows for practicing surgeons to learn new surgical techniques and procedures after their formal years of training, especially for those working in institutions or locations that lack available mentors. In performing complex surgeries with telecommunication, local surgeons perceived improved surgical exposure, more complete tumor resections, and shorter operating room time.[42] Given the potential benefits of tele-education for the use of surgical training and guiding, one group has even developed a structured surgical tele-education curriculum with several formal models for training and even a program to "train the trainer".[11,12]

Current technology

Smart phones and gadgets

A picture is worth a thousand words and a video can tell a story. The ubiquotous presence of smart phones in every physician's life has changed the way we communicate with each other when taking care of patients. In the surgical teaching environment it has proven of great relevance when making important decisions for surgical intervention. The on-call intern who may struggle for words to describe complex computer tomography findings may send a video of the scan to the supervising senior resident or attending, facilitating a treatment discussion. A picture can provide detailed characteristics of an infected wound, breast abscess, exophytic tumor or x-ray study that can expedite work up or decision making.

Most of us agree with the benefits provided by sharing these images; however, the issue of how to transmit sensitive patient information while abiding by privacy guidelines is raised. Different institutions have different regulations when it comes to sharing patient's images. Some institutions may provide approved devices to their physicians and clinical staff, while others may provide encrypted software to be used on smart phones to facilitate such ommunication, while others may ban the practice all together. But one way or the other the technology is *at hand* and is being used frequently in medical practice, changing paradigms in training and communication among clinicians and in their patients as well.

There have been different studies showing the benefits of using smart phone technology to aid in clinical diagnosis and treatment, for example, the use of smart phones with a thermal camera (FLIR ONE IRT) to diagnose diabetic ulcers. The complete system's implementation comprises three major steps: image acquisition, image processing, and results display (image interpretation)[43] or the ability of a smart phone pulse pressure variation and cardiac output application to predict fluid responsiveness in patients undergoing cardiac surgery.[44]

High definition smart-phone-adaptable dermatoscopes can be used to provide tele-consultation for malignant lesions among not only trainees and regional colleagues, but at the international level where access to subspecialties may not be readily available. Fig. 1A, B and 1C show a dermatoscope that could be mounted on a smart phone.

A pilot study simulating medical emergencies in 11 different countries using smart phone GPS (global positioning system), Wi-Fi (wireless LAN network) and LBS (location based system) found significant acceleration of emergency response by 2 or more hours with use of geolocation data and a worldwide emergency call support system.[45]

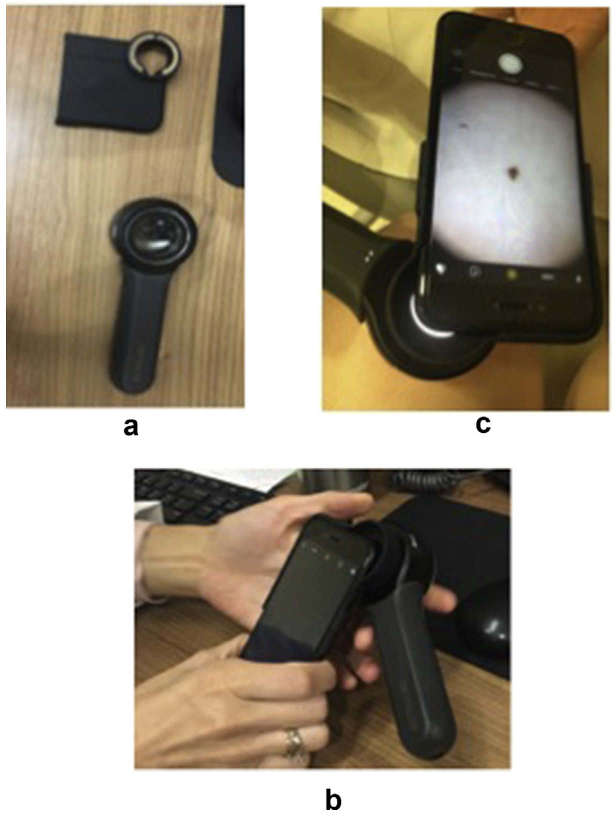

Fig. 1. A: Dermatoscope and lens adapter to smart phone camera. B: Device ensemble. C: Picture of suspicious mole is uploaded into smart phone and ready to be transmitted.

Applications

In a review by Kulendran et al.[46] on surgical smart phone applications across different platforms in 2014, there were 621 surgical applications for Apple iPhone iOS and 97 identified on Android's Google Play. Of those 126 were dedicated to plastic surgery, 79 to orthopedics, 41 to neurosurgery, 180 to general surgery, 36 to cardiac surgery, 121 to ophthalmology, and 44 to urology. The applications ranged from simple flashcard review to virtual surgery applications that provided surgical exposure and familiarization with common operative procedures. The authors concluded that despite the surplus of surgical applications available for smart phones, there was no taxonomy for medical application and only 12% of those were affiliated or associated with an academic institution highlighting the need for greater regulation of surgical applications.

Robotics and telesurgery

Telesurgery was a pivotal motivation in the early development of surgical robots. In 2001 the first transatlantic laparoscopic cholecystectomy was performed in a 68-year-old female who was in Strasbourg and the surgeons in New York.[47]

Since then there have been many more robotic telesurgery procedures, including a laparoscopic cholecystectomy on pigs between Korea and Japan, ablation of an atrial fibrillation between Boston and Milan, and even a demonstration using a robot on the ocean floor by a surgeon on land and the first remote telesurgery experiment involving tentacle-like concentric tube manipulators done by a surgeon in Nashville, Tennessee, controlling a robot located approximately 800 km away in Chapel Hill, North Carolina.[48]

Robotic remote controlled slit lamp biomicroscope allows three dimensional stereo viewing and recording of patient's examination using local area internet and satellite, allowing multiple examiners in different countries to control and discuss diagnosis and treatment.[49]

A study of robot-assisted surgical ward rounds (ASWRs) for a three-month period in Dublin, Ireland showed this to be technically feasible (>90% completed without technical difficulty) and a majority of patients (96.08%, n = 25) agreed that RASWR was a satisfactory alternative when an attending consultant's physical presence was not possible.[50]

Virtual reality

Virtual Interactive Presence and Augmented Reality (VIPAR) is a recently developed technology that allows surgeons to deliver real-time virtual assistance and training in locations where standard internet connection is available. The technology provides a combined perspective of local and remote video feeds, allowing the remote surgeon to be able to digitally reach into the operating field, with delineation of the anatomy and providing a visual demonstration of complex surgical techniques.[51]

VIPAR has been used in neurosurgery and in orthopedic surgery for training of resident surgeons and has been shown to be feasible for long-distance and international telecollaboration in neurosurgical procedures in locations where highly skilled surgeons are not readily available. This technology has been successfully used among surgeons in Alabama USA and surgeons in Ho Chi Minh City in Vietnan. Their financial investment of establishing an international telecollaboration system for one year was calculated at $14,930.39, which included expenses for the visiting team, local station hardware, distant station hardware, proprietary software, internet connection, and technical support.[51]

In neurosurgey, VIPAR has been studied for remote surgical assistance of residents. It is a novel platform that could be used for remote expert assistance and surgical training. The system is composed of local and remote stations, one station located over a surgical field and the other over a blue screen. Cameras for stereotatic capture are used as well as a high definition viewer to display the virtual field, along with digital renderings from volumetric MRI, which help with spatial guidance for both the attending and the resident performing the cadaveric carotid endarterectomy and pterional crianiotomy.[52]

Combined floating autostereoscopic three-dimensional (3D) display approach in telesurgical visualization has been shown to reproduce live surgical scene in a realistic and intuitive manner. The floating autostereoscopic display presents 2D and 3D fusion images. These are presented floatingly around the center of the display device through reflection of semitransparent mirrors. Intraoperative surgery information is fused and updated in the 3D display, so that telesurgical visualization could be enhanced remotely. The glasses-free IV 3D display have full parallax and can be observed by multiple people from surrounding areas at the same time. It has been proposed as a tool to enhance operative cooperation and efficiency during surgery.[53]

Virtual reality (VR) smart phone game applications have been shown to improve laparoscopic skills in a study of 45 medical students. Participants were asked to play a different smart phone application game daily for two months between the two laparoscopic sessions. They were divided into gamers (previous VR game experience), non-gamers and controls. There was significant improvement in the laparoscopic skills of non-gamers independent of the type of game practiced.[54]

Telemedicine billing

Even though a virtual visit isn't the same as an in-person visit, most insurances are required by law to cover telemedicine visits at a comparable rate to in-person visit. Nonetheless these visits must be coded in a different manner as insurances may have distinctive requirements for how you log the visit. Before submitting a claim it is important to make sure the physician is adhering to the insurance company's specific guidelines for the service, such as the type of services covered, type of provider, limitations on the number of telemedicine consultations that can be claimed and any other specific conditions.[55]

Generally, the CPT code that the office would use for an in-person visit can be used for a telemedicine visit, but there are some exceptions. Outpatient codes 99201 to 99215 can be used for telemedicine, but they need to meet two of the three following requirements: 1) the visit has to be a low complexity medical-decision-making visit; 2) an expanded, problem-focused exam must be documented; and 3) an expanded, problem-focused medical history must be documented and the physician must have spent at least 15 min face-to-face with the patient.[55]

Medicare has defined a specific CPT codes 99444 for telethealth that specifies the visit was an "online evaluative and management service". *But different* from private insurances, Medicare requires the call to originate from a hospital setting, a physician's office, a critical access hospitals or rural health clinics.[55,56]

Using the appropriate CPT code or calling from a medical facitly is not enough, modifiers GT or GQ are required. Their use depends on the type of service provided. GT modifier is used for interactive audio and telecommunications system visits. GQ modifier is used for asynchronous telecommunication system visits.[55,56] For more resources visit the center for Medicare and Medical services webpage: https://www.cms.gov/Medicare/Medicare-General-Information/Telehealth/

Discussion

This narrative review provides the most current state of telemedicine and telecommunications for surgical care and surgical education. These data can help practicing surgeons make more educated decisions when they choose to invest in technology to support their professional work.

Our review showed that teleconsultation and telementoring have been successfully used by many different surgical subspecialities, in many different environments (both for clinical evaluation as well as operative assistance), in several different countries crossing different continents, and in the military as well as private/public sectors. Tele-education as a field has also grown tremendously over the last decade and will likely continue to grow as a result of increasing available content as well as additional innovations on how that content is delivered. Many organizations are using this technology to educate trainees and/or to keep practicing surgeons up-to-date or to help them acquire new skills. This technology is extremely beneficial in helping democratize access to knowledge and information. The challenge of the future may involve appropriate codification of this large volume of data and to assess its quality.

The area of telemedicine that continues to be limited in development because of cost and technical capability is the area of telesurgery. Although some successful case reports have been published utilizing telesurgery, its use is affected by current technology limitations, such as the data transmission speed requirements needed in order to minimize latency rates and optimize data quality for real-time surgery. In addition, redundant systems need to be built in order to minimize risks associated with network failures. Nevertheless, these physicial and technical challenges are likely to be overcomed in time as technology improves.

Patient safety and quality implications continue to be a major topic in surgery today, and this is expected to carry over into telemedicine and telesurgery as it also continues to advance. Areas within the field of telesurgery that are not yet clearly defined include, if it were to present, the need to convert a remote telesurgical case into an open procedure, regulation of pre-/post-operative care, informed consent when intraoperative telementoring/teleconsulting is used, and the medico-legal aspect of telesurgery.. Currenty there is no qualitative measure regarding patient safety and risk versus benefit, and this poses a field of needed research in the future. In addition, to promote optimal patient safety, improved telemedicine/telesurgical training, and a multifaceted telemedical guidance to practicing surgeons, it may be of benefit to create a governing body, potentially within the American College of Surgeons or other leading surgical organizations.

The future for telemedicine and surgery is bright. Advances in technology will allow for capture of a greater variety of data useful for patient care, such as video and physiologic data captured by sensors. Development of new mobile applications may also change how we capture and utilize data for patient care and education. Future visualization capabilities such as three dimensional telesurgical viewing can enhance the viewing experience for operating surgeons, and virtual interactive presence and augmented reality can allow teaching surgeons to digitally reach into operating fields to help and direct a surgery in progress. There will continue to be opportunities to optimize the work we do as surgeons with the advancement of technology.

Conclusions

Telemedicine has grown tremendously over the course of the last decade. This technology has been used successfully to care for patients in remote areas, to help expert surgeons assist other specialists in the office or novice surgeons in the operating room, as well as to help teach the next generation of surgeons.

Conflicts of interest

The authors have no conflicts of interest to declare.

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