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A Network-based Telemedicine Service

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Abstract

Surgical telementoring represents an advanced form of telemedicine, whereby an experienced surgeon can guide and teach practicing surgeons new operative techniques utilizing current enabling video, robotics, and telecommunications technology. In the Pacific Northwest, concentration of subspecialty expertise in the only major medical school servicing the WWAMI (named after 5 states: Washington, Wyoming, Alaska, Montana, and Idaho) region offers a compelling opportunity for developing a surgical telemedicine program. This paper reports on a surgical telementoring initiation of a regional telemedicine network as the surgical telemedicine service aiming at eventual projection of surgical expertise in the WWAMI region based on the SOCRATES^{TM}, a FDA-approved robotic telecollaborative system. A collaborative research project with University of Washington (UW) Office of Telemedicine, UW Surgery and Electrical Engineering, UW Medical Center (Seattle, WA, USA), and Grays Harbor Community Hospital (Aberdeen, WA, USA), is introduced in this paper.

Keywords: Telemedicine, WWAMI network, Surgical telementoring

1. Introduction

Telemedicine usually refers to the use of information-based technologies, such as computer and communications systems, to provide healthcare across geographic distances [1]. It is becoming an important component in the provision of healthcare by improving access, quality of services, and reducing cost. Even though the cost of the equipments and technologies is getting lower, today's use of telemedicine is still cost-dependent; however, the fast growth of the Internet and telecommunication makes its globalization more feasible and effective.

Surgical telementoring represents an advanced form of telemedicine, whereby an experienced surgeon can guide and teach practicing surgeons new operative techniques utilizing current enabling video, robotics, and telecommunications technology (This is becoming a broad meaning of surgical telementoring; robot-assisted surgical telementoring is emerging as a new field of surgical telementoring with advanced robotics technology). Surgical telementoring is very significant because it can offer a technological solution to surgically underserved areas by potentially increasing the availability of expert consultation to surgeons serving a rural community during their actual operative procedures. It can also potentially enhance surgeons' education, increase patients' access to experienced surgeons, and decrease the complications due to inexperience with new procedures. In the recent decade, efforts to implement the concept of surgical telementoring have greatly increased.

Surgical disease is a particular problem in rural or surgically underserved communities as it is often urgent in nature and may require treatment at the nearest available facility with an on-call surgeon and limited preoperative investigations. To date, surgeons dealing with these problems in their communities have relied on their own skills, the resources of their facility, and experienced surgeon's limited consultation via telephone. Expert advice provided during this telephone (voice) discussion, usually without imaging data or a view of the operative field, cannot address effectively subtle aspects of patient anatomy or the organic basis of disease process faced by the surgeon on the site.

Robot-assisted surgical telementoring is becoming a new field of surgical telementoring supported by the advanced robotics technology. It may be defined as an experienced surgeon's active involvement (assistance) in a operative-site operation. One example of such active involvement is that an experienced surgeon assists an operation in a operative area by manipulating instruments through the use of remotely controlled robots for handling the laparocopic view. With the increasing accessibility of telecommunication, telementoring has been demonstrated that it improves medical decision making, patient outcomes and medical training [2]. Rosser *et al.* [3] gave an overview of telementoring and teleprotoctoring, and Eadie *et al.* [4] reviewed the current effects on telementoring in surgery. Hoznek *et al.* [5] also reviewed the use of telementoring and it especially focused on the advantages and limitations of all available training modalities in minimally invasive surgery. Marescaux *et al.* [6] provided an overview of the most important advances and issues developing from the use of computer and robotic technologies in surgery as well.

Initial reports of surgical telementoring introducing robotics technology were published in 1994 by Kavoussi *et al.* [7]. They used a purpose-built AESOP®, the robotic arm to manipulate a laparoscopic camera during cholecystectomy, bladder suspension and a varix ligation procedure. Moore *et al.* [8] performed in-house telementoring in 23 urologic laparoscopic procedures (14 advanced and 9 basic). A telesurgical system was created to allow an endoscopic specialist at a remote site to offer guidance and assistance to a surgeon during laparoscopic surgery. The remote and operative sites were connected by a single T1 link with robotic arm control of the laparoscope. Seven patients underwent successful procedures using the system without complications, demonstrating the feasibility, effectiveness, and safety of robot-assisted surgical telementoring [9,10]. There are also a variety of intercontinental operations introducing surgical telementoring based on robotics technology [11-14]. In most cases, the surgeon remotely operates one or two robots, assisting the surgical team at the site. The surgeon controls only the laparoscope held by the robot to obtain an internal view of the surgical anatomy field. He/she also uses a telestrator to illustrate incision lines, anatomical structures or critical areas visually to the local team. The lag times for transmission of data have all been reported to be less than 200 milliseconds, which is hardly noticed during the procedure [15]. Jannson *et al.* [16] used teleparamedic and telementoring communication platforms and robotic systems to offer full-duplex 2D/3D wireless communication based interactive telepresence, as well as telementoring. Lee *et al.* [17] used a PC-based system utilizing public telephone lines to telementor 27 laparoscopic surgeries between Johns Hopkins Bayview Medical Center and Johns Hopkins Hospital. They also performed three successful international surgical telementoring operations, one in Innsbruck (Austria), and two in Bangkok (Thailand) (which was more than 11,000 miles away). They extended the work to determine the

clinical utility of delivering remote subspecialty surgical care using a novel telesurgical mentoring system, and a remote robotic manipulation designed for Percutaneons Access of the Kidney (PAKY) [18]. In the work of Rodrigues *et al.* [19], two procedures between Baltimore (USA) and Sao Paulo and Recife (Brazil) were carried out to assess the safety and feasibility of transcontinental telementored and telepresence surgery. AESOP® was attached to a laparoscope, and the remote surgeon drove the robot via a controller on the remote computer. In the second case, another robot (PAKY) was used for percutaneous needle placement into the renal collecting system. Bove *et al.* [20] reported 17 procedures telementored between two sites 9230km apart: a primary operating room at the Policlinico Casilino "Tor Vergata" University of Rome (Italy) and a remote site at the Johns Hopkins Medical Institutions in Baltimore (USA) from September 1998 to July 2000. All procedures were performed with the help of two robots: the first robot, AESOP®, for the orientation of the laparoscope, and the second one, PAKY, to perform the percutaneous renal access as well as the remote control of the electrocautery and the telestrator.

In the Pacific Northwest, concentration of subspecialty expertise in the only major medical school servicing the WWAMI (named after 5 states: Washington, Wyoming, Alaska, Montana, and Idaho) region offers a compelling opportunity for developing a surgical telemedicine program. The University of Washington School of Medicine (UWSOM) took on the dual commitment of community-based teaching and rural healthcare over 30 years ago with an innovative experiment in regional medical education. Today, that experiment is a well-established program - the WWAMI program - that provides community-based medical education for those five states [21].

This paper proposes a telemedicine service initiation, a surgical telementoring initiation of a regional telemedicine network as the surgical telemedicine program, aiming at eventual projection of surgical expertise in the WWAMI region based on the SOCRATES^{TM}, a FDA-approved robotic telecollaborative system by Intuitive Surgical.

It is believed that this is the first effort to combine an existing regional telemedicine network with a FDA-approved surgically-dedicated industrial system for surgical service initiation. Such a program may have potential to substantially improve patient outcomes and provide patient-specific education to the regional surgical communities. The ultimate goal of the proposed network-based system introduced in the paper is to create a upgradeable backbone of the telemedicine service infrastructure on the existing WWAMI network in order to allow the program to be more powerful through the incorporation with the robot-assisted surgical telemedicine. With the first stage of this robot-assisted surgical telementoring network, the feasibility and effectiveness of surgical telementoring assisted by the system is investigated: explore the issues in clinics and technologies, facilitating timely consultation on all aspects of the patient data and projecting specialty expertise to the hand of the operative surgeon.

2. The Proposed Network-based Telemedicine System

The remote site is located at University of Washington Medical Center (UWMC) in Seattle, Washington (USA). The operative site is about 115 mile across the state in the operating room (OR) at Grays' Harbor Community Hospital in Aberdeen, Washington (USA). A surgically dedicated industrial system, the SOCRATES^{TM}, has been provided to the both sites: the both sites are enhanced with experienced surgeon's active involvement in a operation by using the system. Our research partner, Intuitive Surgical

(http://www.intuitivesurgical.com/), has the first surgically dedicated system (called SOCRATES^{TM}) cleared by the Food and Drug Association (FDA) in 2002 in the newly created category of robot-assisted telecollaborative devices. The SOCRATES^{TM} allows a collaboration using audio and video conferencing, shared control of an endoscopic camera implemented with the AESOP® robotic camera control system (cleared by FDA in 1994), and video annotation of the surgical endoscopic image in the OR. The system as telemedicine link is installed between Grays Harbor Community Hospital in Aberdeen which is the regional partner in the first stage of the project, and the UWMC in Seattle. Another experts including Harbor surgical associates and members of the hospital OR leadership at Harbor Community Hospital are also served as our partners in this research project. Figure 1 shows the proposed WWAMI network-based telemedicine service initiation.

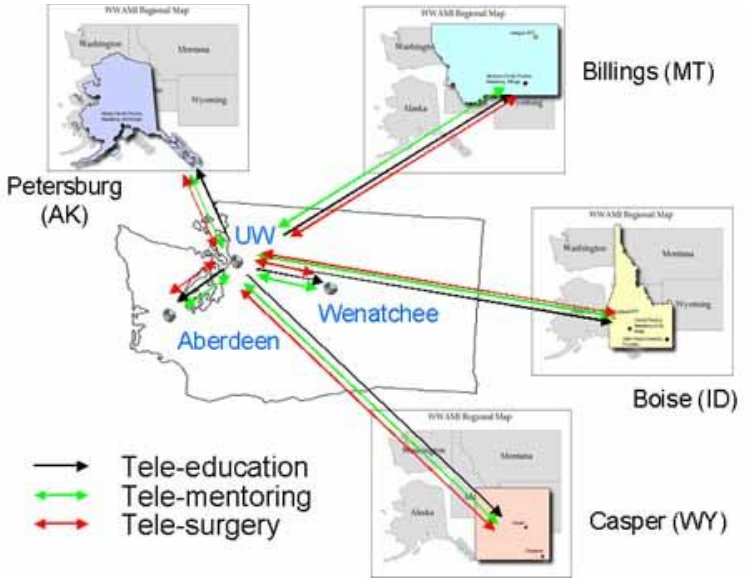

Figure 1. Overview of WWAMI network-based telemedicine service initiation

The SOCRATES^{TM} links the both sites with a PolyCom FX: PolyCom FX has four ISDN lines with 512 kilo-bits per second (Kbps). The PolyCom FX was chosen because it independently bridges up to four sites, and has the capability to utilize H.320 (i.e., ISDN or T-1 lines) or H.323 (i.e., internet) protocols. This helps each site provide video teleconferencing over the internet, which would be of great value if any of these sites decide to implement an intranet-based video teleconferencing system within their institutions. It is also supported for mobile use and PolyCom Viewstations.

The SOCRATES^{TM} at the remote site is equipped with Pentium 933EB PC, a video Coder/DECoder (CODEC) which provides real-time audio/video interaction, and annotation system which can telestrate (telementor) [22]. An additional 200 giga-byte hard drive was added to the current system to record the procedures in real time up to 61 hours (with LP video mode, Mpeg type, 352x240 frame size, and 30fps frame rate).

The operative site has two cameras for internal view and external view. The camera for internal view is provided by the shared control of an endoscopic camera implemented with the AESOP® robotic camera control system. A overhead lights (PrismAlix® Lighting Systems [23]) in the OR at the operative site is installed in order to enable the surgeons at the remote site to properly view procedures and activities taking place in the OR. It supports zoom-in/out functionality for the external view, but controlled by the surgeon in the OR by the request from the surgeon at the remote site.

Through the surgical telementoring at both sites, expert surgeons at the remote site can mentor the surgeons at the operative site while they are actually performing open and endoscopic general surgical procedures, and have the ability to view a procedure both from the operative surgeon's perspective (by the external camera) and from the endoscopic view (by the internal camera). Moreover, the surgeons at the remote site can communicate with the surgeons at the operative site via interactive video teleconference, with an added telestration capability for instructional precision (Figure 2).

Figure 2. The SOCRATES^{TM} Robotic Telecollaboration system used for the proposed network-based telemedicine (surgical) service: The system can give the remote surgeon direct access to the operative environment and key patient information. The system also provides the remote surgeon with uncompromised operative visualization and the ability to remotely control the position of the endoscope. Operation in OR collaborated with surgical telementoring using SOCRATES^{TM} system (large) and surgical specialist's dialogue with a telestration feature for annotation of a shared video image at remote site (inset). Photo Courtesy of the Intuitive Surgical Inc.

3. Results and discussions in clinics and technologies

The systems for surgical telementoring including the SOCRATES^{TM} system and the telecommunications lines were in place between Seattle and Aberdeen. However, because the objective was focused on the clinical trials, there were numerous administrative hurdles to overcome prior to initiation of the project. In addition, because the project has attempted to combine the existing WWAMI telemedicine program with robotics technology, which is a new effort for surgical telementoring initiation and expansion, interaction is both quantitatively and qualitatively different than anything that had been done in the past. It required new processes to be developed and legal and liability issues to be addressed. In effect, the project is treated as a pilot study, one for research and examination of a new effort to provide healthcare services by using the surgically dedicated industrial system. As a result, it required the development of research questions, new patient consent forms, and approval from institutional Human Subjects Boards at each institution. Besides the consent form (as well as public relations issued between the two institutions), we have developed a series of specific goals and questionnaires for quantifying the data metrics on the both sites: two types of questionnaires (the telementoring encounter data and weekly follow-up data) are developed for the analysis. Most of the questionnaires are based on the Likert scales. Data in real-time operation, bedsides surgical telementoring consultation from clinical trial include technical issues of connectivity, etiquette for surgical telementoring consultation, cultures of both mentor and mentee, patient factors including patient notification and consent, cost-benefit calculations to both patient and referring physician, and ancillary benefits including educational benefits, to the UW surgeons, residents, and to the Academic Medical Center. Questionnaires used for the above data metrics include:

Clinical questionnaries: the easeness of contacting the consultant by phone; the time interval of the operative equipment (between the consultation decision to its transmission); the length of time required to make a surgical telementoring connection satisfactorily; the worthiness of the extra effort to set up a surgical telementoring consultation; the degree of the mentor/mentee's satisfaction with the video resolution to the consultation questions, with the color fidelity, and with the telestration capabilities; effective comparison with a MedCon telephone audio connection on the same answered; significant differences made by surgical telementoring consultation; significant contributions to the patient care by surgical telementoring consultation; educational value to the consultation, independent of any effect on this patient's care,

Engineering questionnaries: equipment setup time at operative site; need of any steps beyond the protocol to establish connection; the degree of audio/video latency; the degree of lag interference with the consultation; any technical problems with connection including inability to achieve audio/video connection; the degree of poor video resolution and poor color fidelity perceived; failure of telestration.

The above research questionnaires were collected by handout form, and will be electronic form which allows on-line data collection and analysis through Internet (Note that the detailed patient information were not be collected for the security and privacy issues). The following issues in both procedural issues and etiquette, and engineering issues were considered to develop the above questionnaires to evaluate feasibility, utility, and economic viability of such system and incorporated in the framework of one year clinical trial:

Procedural issues and etiquette: confidentiality; consent; security and safety; cost for services; set-up; maintenance; electronic protocol for medical documents; responsibility; liability; patients' preference (teleservices vs in-person services),

Engineering issues: communication/networking: latency due to time delay, bandwidth, traffic prioritization; efficiently shared surgery environment for cooperation and telecollaboration; bandwidth; fidelity; movement scale.

Three surgical telementoring cases (clinic trials) between Seattle and Aberdeen were performed as the telemedicine services. The first was a case of bowel obstruction, the second a laparoscopic cholecystectomy, and the third umbilical hernia repair. Surgeons at both locations were able to see the tissues accurately enough to discriminate the color and texture quite well. The zoom capability of the overhead camera for external view allowed excellent close-up views with adequate lighting, and the telestrator, a software and hardware system that allows annotation and drawing on the screen, also worked satisfactorily. Overall, the internal camera (laparoscopic) connection was satisfactory, showing details regarding anatomy, relationships, tissue properties, color, and texture clear; this allowed effective consultation between the two sites. Both the external and internal camera functions, light, and at least at baseline, resolution effectiveness have been demonstrated. The lag times for transmission of data were hardly perceptible during the procedures.

The clinical focus of surgical telementoring is general surgery for chronic and acute conditions, including advanced gastrointestinal endoscopic procedures (such as Nissen fundoplication for gastroesophageal reflux), procedures involving the gallbladder and biliary tract, pancreas, liver, colon, and rectum for oncology patients, ventral hernia repair, surgical treatment for acute inflammatory or infectious disorders. The procedures took place approximately 4 to 5 times per month initially, with an anticipated increase in utilization over the period to 8 to 10 times per month.

4. Conclusions

In this paper, a telemedicine service initiation, the surgical telementoring one (specifically, a robot-assisted surgical telementoring) was presented based on the networks collaborated with UW Office of Telemedicine, UW Surgery and Electrical Engineering, UW Medical Center (Seattle, WA, USA), and Grays Harbor Community Hospital (Aberdeen, WA, USA). Three surgical telementoring cases (clinic trials: a bowel obstruction, a laparoscopic cholecystectomy, and an umbilical hernia repair) between Seattle and Aberdeen were performed as the telemedicine services, and various issues required for the proposed service were investigated in clinics and technologies. This ongoing, long-term project has attempted to combine the well-established telemedicine networks (the WWAMI network) with a FDA-approved, surgically-dedicated industrial system for improving patients' healthcare and enhancing surgical educations in the operative sites. This program is a part of a larger plan to evaluate the feasibility of robotic surgical telemedicine in the five state regions as a pilot study of the clinical and engineering issues related to surgical telementoring based on the system, which could be very important in many settings, including places with a shortage of rural surgeons and other isolated sites. This proposed network-based surgical service has potential to bring enormous benefits to patients who will, in effect, be obtaining

consultation and supportive care from highly experienced surgical specialists, while remaining within the care of their local surgeons and institutions.

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