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TELEMEDICINE AND TELEPRESENCE FOR TRAUMA AND EMERGENCY CARE MANAGEMENT

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ABSTRACT

The use of telemedicine is long-standing, but only in recent years has it been applied to the specialities of trauma, emergency care, and surgery. Despite being relatively new, the concept of teletrauma, telepresence, and telesurgery is evolving and is being integrated into modern care of trauma and surgical patients. This paper will address the current applications of telemedicine and telepresence to trauma and emergency care as the new frontiers of telemedicine application. The University Medical Center and the Arizona Telemedicine Program (ATP) in Tucson, Arizona have two functional teletrauma and emergency telemedicine programs and one ad-hoc program, the mobile telemedicine program. The Southern Arizona Telemedicine and Telepresence (SATT) program is an inter-hospital telemedicine program, while the Tucson ER-link is a link between pre-hospital and emergency room system, and both are built upon a successful existing award winning ATP and the technical infrastructure of the city of Tucson. These two programs represent examples of integrated and collaborative community approaches to solving the lack of trauma and emergency care issue in the region. These networks will not only be used by trauma, but also by all other medical disciplines, and as such have become an example of innovation and dedication to trauma care. The first case of trauma managed over the telemedicine trauma program or "teletrauma" was that of an 18 month- old girl who was the only survival of a car crash with three fatalities. The success of this case and the pilot project of SATT that ensued led to the development of a regional teletrauma program serving close to 1.5 million people. The telepresence of the trauma surgeon,

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through teletrauma, has infused confidence among local doctors and communities and is being used to identify knowledge gaps of rural health care providers and the needs for instituting new outreach educational programs.

Key words: Teletrauma; telemedicine for trauma and emergencies; network; telemedicine in extreme condition; mobile telemedicine; rural trauma; Amazon Swim Expedition

INTRODUCTION

Telemedicine may be defined as the use of telecommunications and information technology to support the delivery of health care at a distance (1). Telepresence, on the other hand, is being present at distance during real time live experience. Telepresence has evolved as an important subset of telemedicine, yet has remained an underutilized technique when all its potential is considered. As applied to trauma and surgery, telepresence makes it possible for an experienced trauma surgeon or other specialist to assist or direct another less experienced physician and/or surgeon who is operating or attending a patient at a distance. In order for true telepresence to be perceived by all participants, and thus have successful telepresence, one should have technology that creates an environment that mimics flawless motion, audio and video transmission.

Management of trauma patients requires fast, definitive and precise care as well as major resources and continuous expertise. Trauma systems and major trauma centers have been shown to reduce mortality and morbidity (2), however, most trauma specialists and trauma centers around the world are concentrated in urban settings (3). Subsequently, most of the population of the world is not covered by specialized trauma systems. Although only 23%–25% of the population in the USA lives in rural America, 56.9% of deaths caused by motor vehicle crashes (MVC) occur in this population (4). In fact, patients involved in motor vehicle crashes in rural America have twice the rate of mortality when compared with those in an urban setting with the same injury severity score (5, 6). Many factors have been identified that explain this discrepancy (3, 5, 6, 7).

First, emergency room personnel of rural settings are low volume trauma care "centers" and often have limited experience with major traumas, which may lead to management errors and departures from the standard of care. In addition, many rural emergency rooms are not adequately staffed with properly trained personnel, because of limits in obtaining continuing medical education (CME) (8, 9). Another reason for poor outcomes for rural trauma patients is due to the lack of access to immediate multi-subspecialty care in remote locations. One of the most important challenges, therefore, arises in developing means to reduce the major discrepancies between urban and rural trauma care. Advances in technology including telemedicine and telepresence applications for trauma, emergency management, and intensive critical care may be the solution to reducing and/or eliminating the gap in trauma care between rural and urban areas, but the implications of telemedicine may be far beyond the simple video-teleconference. There are a plethora of examples of applications of telepresence and telemedicine in these fields, although at the current stage, most of them are only simple examples of progression in the look to future telemedicine in trauma care. As the technology becomes friendlier and less costly, the hope is that these modalities will become a norm, rather than an exception.

CASE DESCRIPTION:

When in July of 2003, Level 1 Trauma Center of the University Medical Center in Tucson, Arizona, became the only trauma center in the Southern Arizona, serving almost 1.5 million people of Southern Arizona, Northern Sonora, Mexico, part of New Mexico, and occasionally other states, we were faced with serious problems dealing with our ability to provide basic trauma care to the entire region. As we were becoming the only trauma center on the region, we needed to come up with a creative way to help the entire region with very limited resources. What we needed was a creative, yet sensible way to help the patients and doctors in the region. Inter-hospital telemedicine connection and telepresence of trauma surgeon in the rural emergency rooms became an obvious solution.

An 18-month-old girl was the only survival of a severe car crash with three fatalities in Aqua Prieta, Sonora, Mexico. She was brought to Douglas Hospital in Arizona, three hours after the car crash with three fatalities, in critical condition. She was hypotensive, oxygen saturation in 70%, Glasgow Coma Scale 7, multiple visible injuries to the head, and bilateral lower extremity fractures, and had no intravenous access.

I was on call that night when I received a call from a physician on duty asking for help, and if I would accept the child in transfer. When I asked to "put the telemedicine unit on," she paused for few seconds and, as if I did not know, she told that me that she is in Douglas, Arizona! "There is no telemedicine here"– she added with broken voice! It was her first day on the job, first working day as a physician, and first day in Arizona! She was scared, and when I saw what she was dealing with when we connected through state of the art telemedicine unit, within a minute or so, I realized why she was visibly shaken. She had a little girl dying in her hands. The patient was hypotensive, hypoxic, in a coma, with multiple visible injuries to her head, and fractures of bilateral lower extremities.

Forty- five minutes and a few occasionally nerve racking exchanges later, the child was resuscitated and stable enough to be placed on the helicopter for a 150 km flight.

The physician on call in Douglas intubated the patient successfully, but once she was intubated, the saturation was not coming up as expected. I could see the rising of the lower right chest wall with each manual ventilation. The chest radiography clearly demonstrated that the endotracheal tube was in right lower lobe (Fig. 1). Pulling the endotracheal tube back solved the problem of saturations. Grossly dilated stomach was decompressed with a nasogastric tube. Getting intravenous access in shocked patient is always difficult, as all the veins are collapsed. The only choice is accessing central veins, such as femoral, jugular, subclavian vein, or osseous access (Fig. 2). In a shocked patient, femoral access is the fastest and the safest. However, this was this physician's first "femoral stick" in kid! Using the telemedicine, I guided her successfully through femoral line placement. Once she gained access, we were able to transfuse patient with packed RBC. The arterial blood gas analysis showed severe acidosis (base deficit 10, from acute blood losses , hemoglobin 5.8 gr/dL). After the patient was placed on the helicopter for a 150 km ride, the joyful, but exhausted and pale-looking physician turned on to the camera, her face filling the screen and said: "Thank you so much for being with us here today. Without you, this child would have died." I thanked her, then congratulated her and her nursing staff and all others that were involved in saving this child's life, and told her that she had done great and heroic work. To this day, I remember her face and the hope in her eyes.** *(** This case was managed by R Latifi and T Valenzuela)*

Lessons learned from our first case

During our first teleresuscitation of a severely injured patient we learned many things about the teletrauma system and what we needed to have in ours "teletrauma room", such as dosing medication for kids and adults, headphones for a physician and not "a speaker phone", and the angle that we needed to place the camera to see the chest- X- ray. Most importantly, and personally, I re-confirmed it again: that calm, deliberate voice with clear directions and clear communication is key in handling major traumas and bad situation. During the 45 minutes, teleresuscitation and the long list of intervention that saved this little girl's life were possible only because I was able to see what was happening 120 miles away and how the patient was responding to each intervention, almost each second.

I left the "teletrauma" room, and went to trauma bay and waited for the patient. I was rapturous. I thought that I could have retired that day, having had a very rewarding career. We saved this child only because we had access to advanced technologies. Without the telemedicine technology (the doctor in Douglas was right) this patient undoubtedly would have died. No question about that! She was discharged to home after 14 days in the hospital. Her fractures were fixed, ARDS resolved, she was smiling and behaving like any other 18-month-old child. Luckily, her parents were not among the dead in that fatal car crash.

Fig. 1. Initial chest X-ray of an 18 month old female managed through teletrauma.

Fig. 2. Injured 18-month-old child managed via teletrauma system.

PRELIMINARY RESULTS

During the 13-month pilot project with the town of Douglas, 21 patients were managed through the system. In five of these patients, at least one life saving procedure was advised by the teletrauma surgeon. Five patients were managed at the local hospital without the need for transfer. In all these 10 patients, the recommendation given to local doctors would have been impossible through the phone only. The success and the acceptance by all involved has led to creation of region wide teletrauma system funded in part by Blue-Cross and Blue Shield insurance com-

Fig. 3. Senior author at the command and control center of teletrauma program at the University of Arizona, Tucson, Arizona.

pany of Arizona. As of the end of November 07, five hospitals have been added to the teletrauma network including Bisbee, Benson, Sierra Vista, and Holy Cross hospital in Nogales, all border towns and communities with Mexico. Others such as Wilcox, Sells, Safford and White River are in the process of adapting the program. The plan is for the network to be completed by the end of this year. Over the teletrauma system and through the command and control center (Fig. 3), (VitelNet™, McLean, VA, USA), trauma surgeons have video and audio access to events unfolding in trauma and emergency rooms throughout the "border belt" as well as other rural communities.

CURRENT TELEMEDICINE AND TELEPRESENCE PROGRAMS

Advanced technologies such as computers, diagnostic imaging, robotics, voice-activating machines, and remote controls have changed the operating theatres in hospitals around the Western world. Different types of technologies are routinely being adopted, yet there are few viable and sustainable programs in telemedicine for trauma, critical care and emergency management. At the Arizona Telemedicine Program, we have adopted three different systems (Table 1) to provide telemedicine for trauma, emergency and remote expeditions.

TABLE 1

Identified telemedicine functions for trauma and disaster management

Inter-hospital telemedicine and telepresence programs
Pre-hospital to hospital connectivity (digital ambulances and monitored patient transport)
Deployable mobile telemedicine systems

How one decides which system to use is based mainly on the environment and the situation of the region and/or mission of the project.

INTER-HOSPITAL TELEMEDICINE: THE SOUTHERN ARIZONA TELETRAUMA AND TELEPRESENCE PROGRAM

As described, this is a dedicated program using broadband T1 line of Arizona Telemedicine Program (10) which allows trauma surgeons to have video, audio and vital signs (blood pressure, pulse, and temperature and oxygen saturation) access to events unfolding in trauma and emergency rooms in the remote emergency sites, and can help guide the physician or nurse take care of the patient by being "virtually" present at the remote location. The trauma surgeon will remotely assist during the primary and secondary survey and directly take part in the decision-making processes regarding need for specific procedures, further diagnostics and/or transfer to a Level I trauma center. This is being done through specifically designed trauma management protocols using ATLS principles.

DIGITAL AMBULANCES AND MONITORED PATIENT TRANSPORT: TUCSON ER-LINK PROJECT

The Level I trauma center of the City of Tucson, Arizona, the University Medical Center, in collaboration with Tucson Fire Department and Tucson Transportation Department launched Wireless Mobile Telemedicine and Telepresence in prehospital setting by having video, audio and data access from 17 Advance Life Support (ALS) ambulances of Tucson Fire Department (TFD) since August of 2007 (Fig. 4A ,B). The City of Tucson Emergency Room Link or "ER-Link Tucson" project allows physicians to be virtually present at the scene and/or in the ambulance, while the patient is being transported to the trauma center. In addition, this program provides emergency dispatchers and responders a view of the incident scene(s) in order to optimally assign emergency first responders and other necessary resources for incident management. The system allows constant two-way audio-video and near-constant medical data transmissions between ambulance personnel and the trauma and emergency room personnel. The communications are provided via regional traffic control and city communications infrastructure and wireless technology. The telepresence at the scene of event is made possible from cameras mounted externally to the emergency vehicle. These cameras, in conjunction with the existing highway cameras (operating along the freeways or at intersections) provide command and control video to the regional 911 centers and emergency department (Fig. 5). The images facilitate the dispatch and management of emergency resources for incident command, accident management, and medical triage/mechanical assessment of the scene for the trauma team.

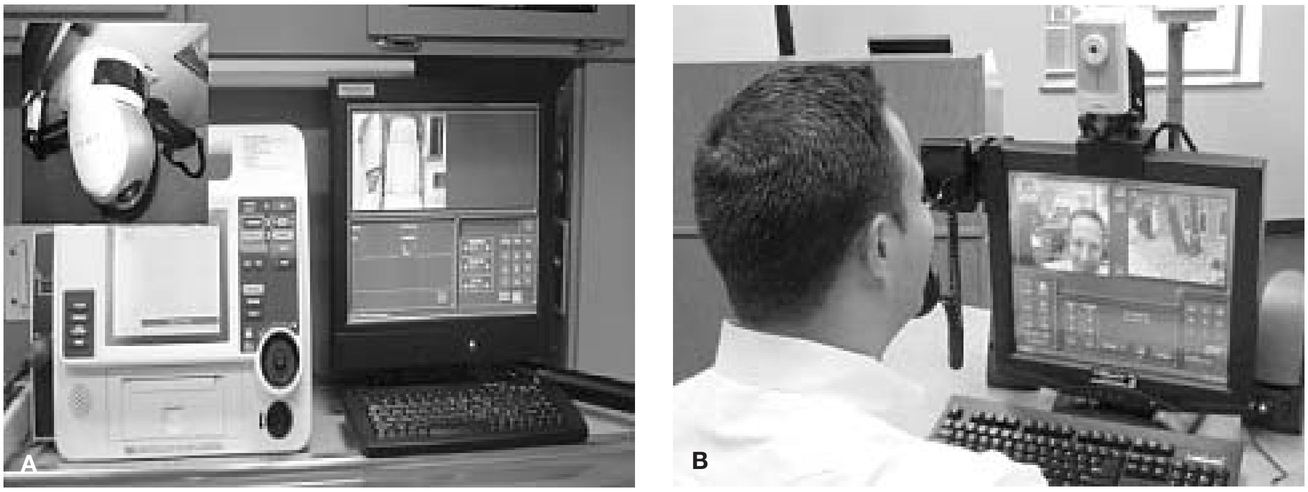

Figure 4A. Inside Tucson Fire Department Ambulances equipped with state of the art telemedicine technology. Fig. 4B. Telemedicine equipment in the Emergency department of the Trauma Center in Tucson, Arizona.

TECHNOLOGY OF ER LINK

This pioneering system (General Devices Rosetta Go-box, Ridgefield, N.J.) provides two-way video and voice communications between ambulances and emergency rooms, allowing early collaboration between paramedics and emergency room doctors to provide the best care for injured patients. It transmits vital medical data and real-time patient video to the emergency room, helping the hospital prepare for the patient's arrival. It also help reduce ER-Link traffic congestion related to accidents by helping to clear away accident scenes sooner and reducing the potential for secondary crashes. It provides real-time video of crash scenes to first responders, allowing them to prepare for the incident before the patients arrive. ER-Link uses wireless (Wi-Fi) technology to establish video and voice communications between the ambulance and the emergency room.

DEPLOYABLE MOBILE TELEMEDICINE SYSTEMS: AMAZON VIRTUAL MEDICAL TEAM EXPEDITION

A mobile portable model of ER-Link and other technologies has been used recently in the Amazon Swim Expedition Telemedicine Project that provided telemedicine services to the swim expedition.

The Amazon Swim Expedition (ASE) led by Martin Strel, Guinness world record holder in ultra marathon, was successfully completed on April 8, 2007, in Belém, Northern Brazil, at the mouth of Atlantic Ocean, after 67 days of swimming the mighty Amazon that started at the highland of the Andes, in Atalaya, Peru (Figs 6A, B, C). For this, we established the Amazon Virtual Medical Team (AVMT) a volunteer group of international physicians and experts in telemedicine from many countries around the world that consisted of trauma and general surgeons, neuroscientist, infectious and tropical disease specialists, a dermatologist, vascular surgeon, ophthalmologist, exercise physiologist, psychiatrists, and a pathologist. The Amazon Virtual Medical Team was contacted through email (mainly), telephone, live video consultation using Skype, and using store and forward techniques. The physician on board the boat of the expedition (Mateja de Leonni Stranonik, M.D., PHD, Fig. 6B) was able to upload prerecorded consultations via a low bandwidth satellite link. The objective of the AVMT was to ensure safety of Martin Strel and his team, including executive team, filmmakers, journalist and others, as well as the crewmembers of boat (all together 25–30 people) at any given time and to introduce and promote telemedicine along the Amazon jungle and throughout indigenous tribal villages through which the expedition passed. For this expedition we used the following deployable telemedicine equipment: Second Opinion- a real-time and store and forward software (Second Opinion, Torrance, CA) and the portable field deployable telemedicine system (General Devices Rosetta Go-box, Ridgefield, NJ). In addition, we had a vital signs monitor and defibrillator (Zoll, Chelmsford, MA) compatible with portable field deployable telemedicine system as well as a portable ultrasound machine (SonoSite, Bothell, WA). Connectivity to the boat was provided using a low bandwidth satellite link (BGAN, London, UK.

DISCUSSION

There have been many attempts to establish telemedicine (12–22). Nebraska Psychiatric Institute telemedicine program, NASA's project in Arizona called Space Technology Applied to Rural Papago Advanced Health Care (STARPAHC), and the project in Alaska(ATS-6 program in 1971) where among the first ones. Yet, it was not until 1978 that the first attempt to simulate the use of telemedicine in trauma resuscitation was recorded by Dr. R. Adams Cowley, who

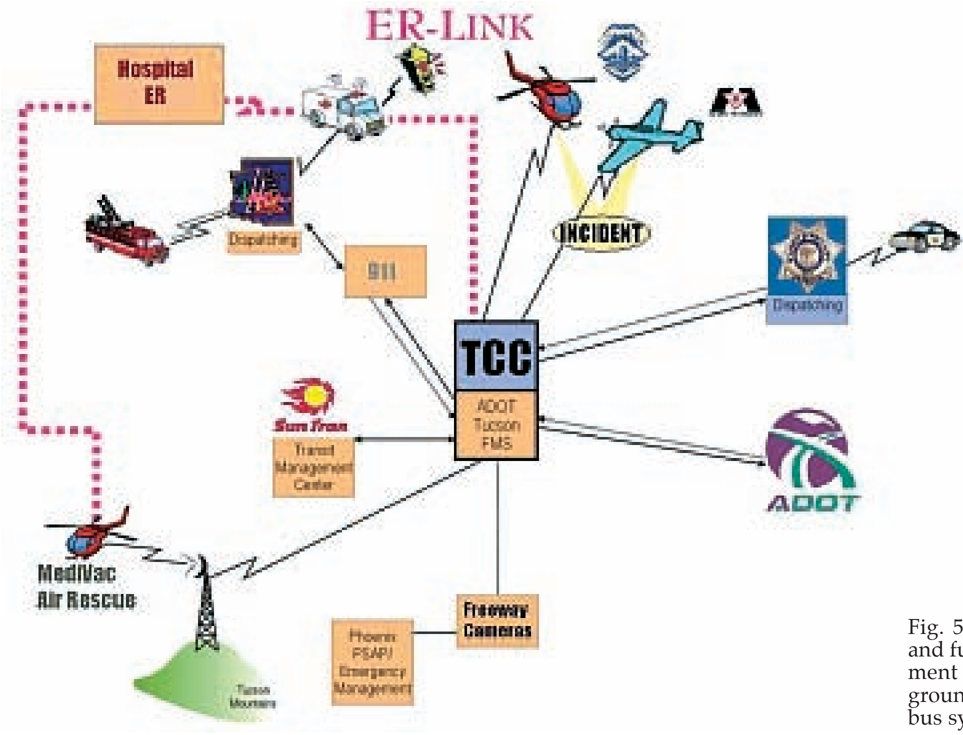

Fig. 5. Phase 2 of the ER Link. Current and future participants including department of transportation, air rescue, fire ground activities, fire dispatch, city wide bus system et cetera.

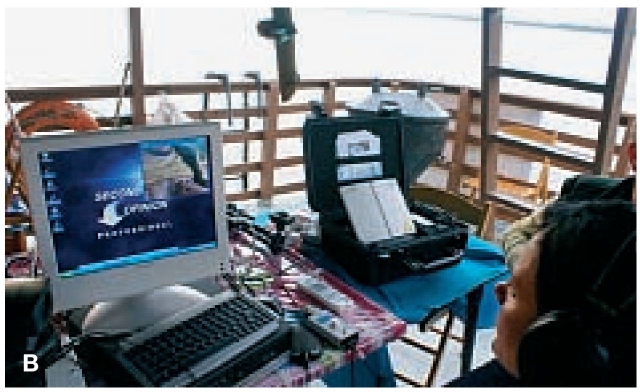

Fig. 6A . Telemedicine in extreme conditions. Amazon Swim Expedition, February – April, 2007 (www.amazonswim.com/medical-team). Fig. 6B. Amazon Swim Expedition team physician Mateja de Leonni Stanonik, MD, PHD, consulting Amazon Virtual Medical Team members on health issues of Martin Strel, World Record swimmer, who swims the Amazon River. Fig. 6C. Rifat Latifi, MD (right), Medical Director of Amazon Swim Expedition providing telemedicine in extreme condition in the Amazon River, near Teffe, Brazil with Bojan Premelč, IT Specialist with the expedition.

staged a disaster exercise at Friendship Airport in an aged DC-6 aircraft (23). He transmitted real-time images of burn victims via satellite transmission to San Antonio's Burn Unit and other medical centers around the Washington DC area. This was accomplished with old and cumbersome technology, yet it is the first successful attempt to use technology and telemedicine in trauma care. Since then, numerous efforts have been made to resuscitate trauma patients from a distance.

In the most modern era, Rogers et al (8,24) reported their use of a tele-trauma service in rural Vermont, where 68% of the population lives in rural areas. Their initial experience with 41 tele-trauma consultations was very encouraging. Ninety-five percent of the injuries were caused from blunt trauma, primarily MVC (49%), pedestrians/bicyclist struck by vehicles (10%) and injuries caused by all terrain vehicles (7%). Thirty-one of 41 patients that were seen via the tele-trauma system were transferred to the tertiary care center. In 59% of the cases transfer was recommended immediately, due to the critical condition of the patient; 41% of those transfers were accomplished by helicopter. While in three cases, tele-trauma consultation was considered life-saving, the most common recommendations from the tele-trauma consultant were regarding patient disposition. For example, in 15% of cases the trauma surgeon recommended keeping the patient at the referring facility. Other recommendations included suggestions for diagnostics such as obtaining or foregoing a CT scan, as well as recommendations for additional therapeutics (placement of an NG tube, or a chest tube, transfusion of blood, etc.). Other investigators have also reported various techniques to establish trauma teleconsultations in rural settings (25–28). In a study of 40 orthopedic trauma cases, radiographic images were photographed by a digital camera and transmitted via dedicated T1 based network to a consulting hub, where two orthopedic and two radiologists reviewed the cases (25). These and other reported studies have demonstrated that a simple digital camera can be used effectively in many cases, as long as the proper region of interest on the X-ray has been photographed and transmitted to the consultant.

Lambrecht et al also demonstrated the effectiveness of telemedicine technology in the evaluation and treatment of extremity and pelvic injuries (27). The most important element in this report was that 68 of 100 patients referred for tele-consultation remained in the rural community hospital. This certainly has major implications on the cost of transferring of these patients to major medical centers, increased utilization of local health care facilities, and other social and financial issues of treating these patients away from their families.

In addition to Vermont (24) and our Arizona tele-trauma program, to our knowledge, two other programs of telemedicine for trauma and emergency management are currently active. The programs are those of the University of California, Davis, California Telemedicine for pediatric critical care (29) and telemedicine program at the University of Mississippi in Jackson, Mississippi (30). Both of these programs serve rural, medically underserved communities, however the telemedicine program in Mississippi is unique as it uses advanced nurse practitioners to provide advanced emergency services. This is a well-run and structured program that has been shown to be of great benefit in providing care in the communities where there is no adequate physician coverage (30).

The clinical accuracy of telemedicine in evaluating trauma patients has been assessed, when telemedicine was used for minor trauma consultation and compared with face-to-face consultations in two hundred patients. Skin color changes were accurately defined in 97%, the presence of swelling or deformity in 98%, diminished joint movement in 95%, presence of tenderness in 97%, weight bearing and gait 99%, and radiological diagnosis was made correctly in 98% of cases (28). This application of telemedicine can make expert trauma care available to patients in hospitals and emergency rooms without advanced trauma systems, and potentially reduce costs, prevent unnecessary transfers, and promote early transfer when indicated.

Telemedicine tools have also been applied to the field of wound care management. In one study, bedside wound examinations of 38 wounds in 24 vascular surgery patients were done by onsite surgeons and were compared with viewing digital images of those wounds by remote surgeons (31). Agreements regarding wound description (the presence of edema, erythema, cellulitis, necrosis, gangrene, ischemia, and granulation), and management issues (such as the presence of problem wound healing, need for emergent evaluation, antibiotics and hospitalization) were analyzed and compared between onsite and remote surgeons. Agreement between onsite and remote surgeons matched for wound description and wound management. Sensitivity of remote diagnosis ranged from of 78% for gangrene to 98% for identification of problem wound healing respectively, whereas specificity ranged from 27% for erythema to 100% for ischemia. The agreement was influenced by the wound type ($p<0.01$), but not by the certainty of diagnosis or level of training ($p>0.01$). This combination of telemedicine and digital photography may prove to be very useful for outpatient wound care in complex vascular surgery and in trauma patients in their post-operative care.

A large number of trauma patients at Level I trauma center consists of patients who have been transferred from rural communities for definitive tertiary trauma care. At the University of Arizona Medical Center (the only Level I trauma center in Southern Arizona), of the 5000 trauma patients that are seen a year, 18–25% of patients are transferred from the rural, small emergency centers. In most current systems, the decision to transfer a patient to a trauma center is based on a phone call from the referring rural physician to the emergency room physician or trauma surgeon. Based on this example and the experience of many trauma centers, a large number of patients transferred to trauma centers could be adequately cared for in the rural or community hospital with the help or "telepresence" of a trauma surgeon in these remote hospitals from a central location. In order to accomplish this goal, small emergency rooms, or other centers in rural areas, need to have access to major trauma centers and trauma surgeons twenty-four hours a day, seven days a week with modern technology. This telepresence undoubtedly will have a major impact in major trauma centers that will evaluate and eventually manage most critically ill patients who need specialized and definitive trauma and surgical care (32, 33).

The concept of digitized emergency services with seamless integration of multiple video processing and wireless communication between the ambulances and the emergency and trauma center, when every second counts, is one of the most attractive aspects of telemedicine for trauma and emergency management. The program has been created using the input of each member of the multidisciplinary team and now represents a new paradigm of providing telemedicine services for trauma and emergency care. Furthermore, to insure program sustainability, we have created an operational document using a business model that includes an executive summary, vision and objectives, products, current and future services, and step-by-step operations. The operational procedures consist of how to operate the telemedicine system, how to initiate and complete teletrauma resuscitation based on ATLS protocols, trouble-shooting and avoiding system failures, staffing and scheduling, documentation and maintaining a database.

When the guidance of a trauma surgeon is requested, he or she can be virtually present at the remote location. The surgeon at a trauma center can remotely assist during the primary and secondary survey and directly take part in the decision-making processes regarding the need for specific procedures, further diagnostics, and/or transfer to a Level I trauma center. Special procedure and policies have been established to ensure trauma management protocols using ATLS principles during the teletrauma process. A call schedule reflecting attending on call for "telemedicine for trauma and critical care" as well as other logistical policies and procedures have been established. Moreover, we have overcome important issues such as physician acceptance at the rural hospital, trauma surgeon acceptance of the program at a tertiary center and "the big brother is watching" concept. Moreover, we have involved all structures in the process: doctors, nurses, administrators, public, and the community at large. Most importantly, we have created local champions. If any of these elements are missing these systems would be very difficult to sustain, and would undoubtedly fail.

CONCLUSION

Successful teletrauma program requires careful planning, sophisticated telemedicine network, technical support on a 24-hour basis, and a well-developed business plan, with a detailed operational procedure manual. Most importantly, it requires buy-in by everyone evolved, including physicians, nurses, administrators and the public itself. Telemedicine will become a major tool in trauma care and trauma education. Trauma resuscitation can be performed successfully and safely using telemedicine principles, when guided by and under direct supervision of a trauma surgeon. Furthermore, major trauma centers can render direct help in primary resuscitation of trauma victims to small hospitals without trauma specialists, potentially reduce cost, prevent unnecessary transfers, and promote early transfer when indicated to Level I trauma centers. There is a major need for investment in technology, creation of substantial networks, creativity among trauma surgeons, emergency medicine physicians, and other healthcare workers providing care to trauma and injured patients.

THE FUTURE

Telemedicine will become a major tool in trauma care and trauma education. Trauma resuscitation can be performed successfully and safely using telemedicine principles, when guided by and under direct supervision of a trauma surgeon. Furthermore, major trauma centers can render direct help in primary resuscitation of trauma victims to small hospitals without trauma specialists, potentially reduce cost, prevent unnecessary transfers, and promote early transfer when indicated to Level I trauma centers. There is a need for investment in technology and creation of substantial networks and for creativity among trauma surgeons, emergency medicine physicians and other healthcare workers providing care to trauma and injured patients.

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