NASA/TM-2015-218562

Application of Advances in Telemedicine for Long-Duration Space Flight

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January 2015

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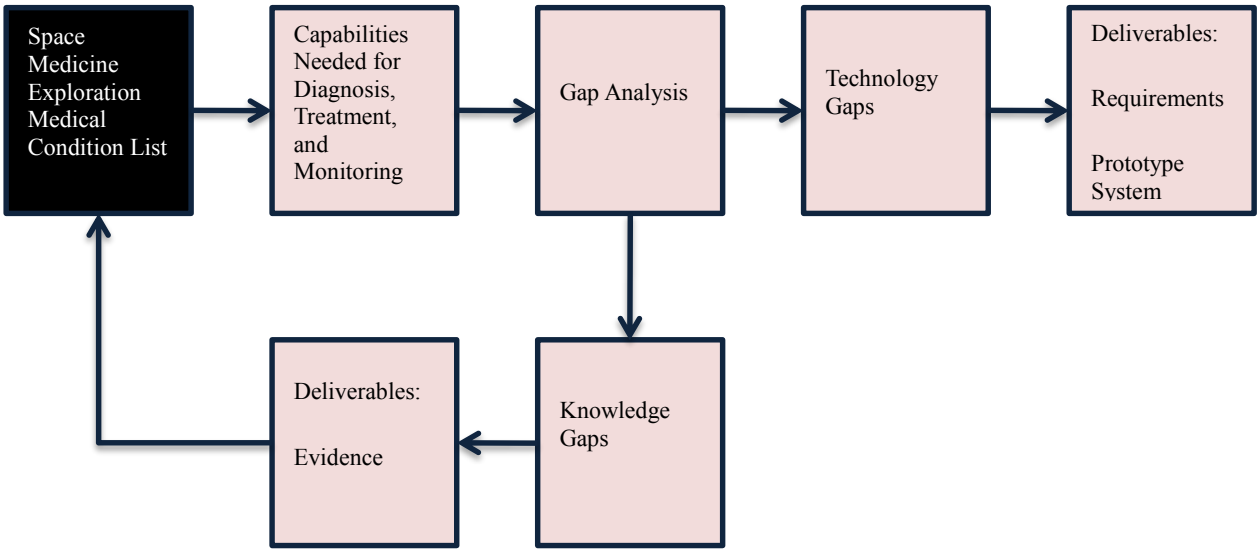
Objective

Adaption of advances in telemedicine are necessary for long-duration space flight. Current gaps in knowledge in telemedicine have been identified.

“ExMC 3.02: Lack of knowledge about the current state of the art in telementoring/telemedicine as a tool for assisting crewmembers to diagnose and treat medical conditions that occur in space flight.”



Telemedicine has been used to assist disaster areas (Merrel et al. 2008, Doarn 1998), deep sea (UNCW and NOAA 2010), high mountains (Otto et al. 2009), and ships at sea (Ferguson 1995). Technological advances currently developed for remote terrestrial medical care can be applied for this context in long-duration space flight.

Background

The definition of telemedicine evolves with its technological advances. Cipolat and Geiges (2003) define telemedicine as the:

> "Delivery of healthcare and the exchange of healthcare information across distances, it includes the whole range of medicine including diagnosis, treatment and prevention of disease, continuing education of healthcare providers and consumers, and research and evaluation, performed when distance is an issue."

Sood et al. (2007) evaluated 104 peer-reviewed definitions of telemedicine to formulate a scientific consensus:

> "A branch of e-health that uses communications networks for delivery of healthcare services and medical education from one geographical location to another. It is deployed to overcome issues like uneven distribution and shortage of infrastructural and human resources."

In 2010, The American Telemedical Association defines telemedicine:

> "As the use of medical information exchanged from one site to another via electronic communications to improve patients' health status."

Telemedical interaction is not confined to direct patient care and interaction (ATA 2010). Advances include: remote consulting between a rural general practitioner and a specialist (Easthouse 2007), collaboration among an ICU unit nurse and critical care specialists from multiple different locations (Nikus et al. 2009), remote monitoring of wound healing following an injury (Smith et al. 2002), real-time transmission of portable cardiac monitor data to a cardiologist's office (Burri and Senouf 2009), virtual attendance of continuing medical education (McGowan 2008, McGinnis 2002), triage of patients contacting call centers (Moscato 2007), and mental health appointments (Leigh et al. 2009).

Telemedicine focuses on the relay of communication. Unidirectional capabilities include email, file exchange, and prepared tutorials. Multidirectional relay includes live chat, telephone, radio, or videoconference. The data exchanged can be transmitted either synchronously (real-time) or asynchronously (store-and-forward) (Yao et al 2009). With radio relay delays of up to 40 minutes in long-duration space flight, focus is on semi real-time communication limitations.

Integrated medical devices with telecommunication capability (satellite, broadband, Wi-Fi, phone, etc.) are used to transmit audio, video, still images, and text between patient and physician. Telecommunications technology facilitates interactions among health care providers through the exchange of relevant medical information from a variety of sources: diagnostic devices (e.g. ultrasound, ECG machine), remote body sensors, vital signs monitors, smart computers, robotics and other intuitive machines, electronic health (data) records, data servers, and application software (ATA 2010, Dinevski and Pacnik 2009, Nageba et al. 2009, Zhang 2009).

Method

ATA's Krupinski et al. 2006 outlined four distinct research policy areas in telemedicine technical, clinical, human (human factors and ergonomics), and cost (economic analyses literature for advances in these divisions with possible application in long-duration space flight was evaluated).

Keywords telemedicine and telemedicine aerospace were searched separately through the PubMed database; 11,586 and 84 publications, respectively, were found. Of the 11,586, the first 400 most recent abstracts were reviewed and 171 were considered for full article review on their basis of applicability to the four research policy areas. After exclusion, 110 articles were included. Of the 84, 22 were considered, and 10 publications were included. A total of 120 PubMed publications on telemedicine and telemedicine aerospace are in this review. Articles were evaluated in the context of the four areas of research set for by the ATA as noted in Table 1.

Table 1: Primary Literature Search

Category	# of papers found per total (n=120)
Technical	23
Clinical	30
Human Factors and Ergonomics	22
Economics	7
Supportive:	38

Technical papers focus on available equipment, capability, connection, security, and quality. Clinical papers focus on efficiency and outcomes. Human Factors and Ergonomics papers focus on the following user experience, patient satisfaction, provider satisfaction, and adoption of practice. Economic analyses papers focus on cost issues to patients and providers. Other or supportive papers make up the remaining distribution of papers.

Supplementary and topical searches were performed. Thirty-two supplementary PubMed articles were considered (Table 2).

Table 2: Supplemental Literature Searches

Category	# of papers found per total (n=32)
Technical	3
Clinical	0
Human Factors and Ergonomics	3
Economics	2
Supportive:	24

In sum, a total of 152 PubMed publications and other search results were reviewed in this paper. Two non-English language articles were translated via Google Translate. Limitations include logistical constraints for authoritative comprehensive review of all significant work in the field.

Results

Technical

Adaptation of rapidly evolving consumer technologies and development of improved techniques for data storage and access are yielding usable, lower-cost systems with enhanced clinical functionality. Off-the-shelf consumer technologies have adaption for telemedical systems. Consumer technology capability varies but produces a cheaper and more reproducible counterpart. These developments are broadly grouped into the following categories.

Image, Video, and Data

Digital still imaging

Product cycles for consumer digital still cameras are measured in months with documented adaption to telemedicine. The Alaska Federal Health Care Access Network Telehealth Program developed a systematic review process to evaluate these cameras for store-and-forward imaging applications in its rural health programs (Patricoski et al. 2010). Criteria for evaluation included features, functionality, reliability, usability, color accuracy, and photographic detail. Practice guidelines were also issued for image acquisition, storage, retrieval, transmission, and display (image color, bit depth, compression, white balance, focus, and macro settings). Periodic evaluation of the marketplace was deemed necessary given the flux of technology.

Selected Model: Canon SD970IS (figure 1). Other High-Scoring Models: Fujifilm FinePix F200 EXR; Panasonic Lumix DMC-ZS3.

Figure 1: Selected digital still imaging modality by Alaska Federal Health Care Access Network Telehealth Program.

Video and streaming

The quality-to-cost ratio of consumer-level video webcams are evolving with improved video compression algorithms and increased computational power of computer hardware. Triunfo et al. (2010) assessed video and imaging capability across functionality, remote accessibility, and diagnostic capability for tele-echocardiology. Open-source software and low-cost commercial off-the-shelf appliances with simple browser-based interfaces were evaluated. Two simultaneous video streams (a direct digitization of ultrasound and live video of the clinical examination) were viewed from a web browser and digitally recorded for use in both consultancy and didactics. Preliminary assessment affirmed system functionality and the effectiveness of this low-cost approach.

Data storage and retrieval

Digital data must be securely and affordably stored in ways that optimize the utility of the content. Well-designed data architecture for storage of video and associated data reduces cost and increases the performance of associated hardware resources. It also serves as a multiplier for the content's usefulness by improving retrieval efficiency and by embedding clinically useful metadata with the primary content.

Wang et al. 2009 created a new data interface. Video imagery of medical procedures was synchronized with recordings from medical equipment settings. This created time-synchronous clinical data. Replayed sessions were enhanced by the consistent contextual link between changes in the image and the equipment settings that induced those changes.

Three-dimensional imaging

Proof-of-concept assessments and adoption surveys indicate that the technology has advantages over the two-dimensional (2-D) videoconferencing used today. Welch et al. (2009) proposed possible technologies, configurations, and procedures to enable remote three-dimensional (3-D) viewing. Viewing is controlled by head movements or by the motion of a portable viewing device, such as a PDA (figure 2.)

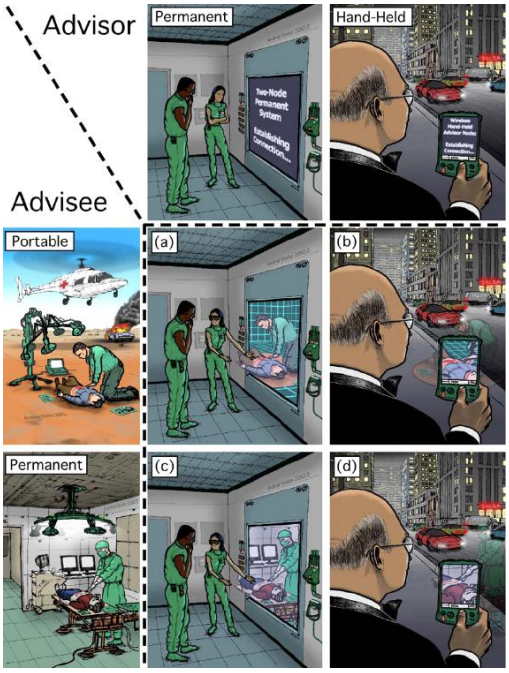


Figure 2: 3-D collaborations in healthcare. Images (a)-(d) illustrate the shared sense of presence for corresponding advisor/advisee scenarios. Journal of Biomedical Discovery and Collaboration.

Digital Transitions, Adaptations, and Robotics

Radiology and pathology push the forefront of digital task flow transition from an analog counterpart. Acquisition, manipulation, and viewing of images have progressed faster than most other dimensions of telemedicine. Remote viewing has grown to encompass remote manipulation. Advances in robotics, in conjunction with enabling technologies in imaging and networked communication, allow practitioners to go beyond seeing to actually interacting.

Transitioning to Digital

Digital slides and computer displays are rapidly displacing traditional glass slides and light microscopes. Radiologists have now resolved issues of display resolution, image compression, display calibration, and user interface design in their earlier transition to digital software (Krupinski 2009). The critical impact of image compression on diagnostic accuracy has been validated against human observers by Visual Discrimination Models (VDMs). VDM metrics exhibit high degrees of correlation with human diagnostic accuracy for the same test images and may ultimately be used to predict appropriate compression levels.

Evaluating the Digital Transition

In a 12-year study of the effectiveness of robotic telepathology, 11,533 cases involving remotely located pathologists working with on-site pathologist assistants and remote-controlled robotic microscopes showed concordance rates among pathologists (0.65%) and high patient satisfaction (Dunn et al. 2009).

Improving robotic control mechanisms

The robotic device control system defines the human-machine clinical effectiveness. Robotic devices, such as the pan-tilt-zoom cameras used for telepresence, require manual control of individual degrees of freedom in order to get the intended position or view of the patient. A proof-of-concept control mechanism applied visual feedback from an external camera into a robotic arm control loop (Dinevski and Pacnik 2009). Visual sensors effectively mimicked vision sense while the visual server automated the navigation process, simplifying the user's control task to one of selecting a desired target position. Continued development of control mechanisms will improve usability and feasibility of robotic telepresence cameras.

Robotic Telepresence and Teletrauma Support

Telepresence developments now transcend audio and visual observation and interaction. Ohta et al. (2006) combined remote-controlled laser pointer with a streaming live video. This technical adaption allowed remote operators to illustrate specific anatomical locations on a training mannequin. Inexperienced operators were instructed on thoracentesis. Statistically significant improvement was noted compared to standard educational conference.

Networks

Adaptive software and improved compression protocols take advantage of mobile phone and data networks. Protocols for ad-hoc networks are also being explored for remote locations where networks are unavailable. Network performance is defined per bandwidth, availability, and ubiquity. Limitations are generally in bandwidth and availability. Bandwidth-adaptive software, improved compression algorithms, and the Delay-Tolerant Networking protocol perform as effective means of maintaining clinically useful connectivity.

Adaptive Software

Hong et al. (2009) describe a portable emergency telemedicine system accessing Wi-Fi broadband and wideband 3G mobile networks. It is capable of exchanging useful triage data via video, biosignals, and text chat on wideband networks (in the absence of a voice communication option). Actual data rates of various mobile network protocols were measured to define appropriate baseline frame rates and compression levels. Real-time adjustments in frame rate in response to changing transmission speeds proved sufficient to maintain diagnostically useful video and data quality (Table 3).

Table 3: Measured Bandwidth on Mobile Networks

Network	Measured Bandwidth (kbps)	Max. Video Resolution	Orig vs. Transmitted PSNR (dB)	Biosignal Bandwidth (kbps, avg)
HSDPA	100–300	320x240	–	–
WiBro (WiMAX)	500–1000	320x240	33.7	11.7

Compression Algorithms

Frumento et al. (2009) performed initial testing of software that applies the MPEG-4 video compression standard to echocardiography video data. Improvements in bandwidth usage compared to the standard video compression in the DICOM protocol were noted. Near-real-time transmission of short video clips with acceptable clinical quality was achieved even with low-bandwidth (128 kbps) ISDN connections. Standard DICOM video would require 9×–10× transmission time for the same clip.

VoIP using the Delay-Tolerant Networking Protocol

Scholl et al. (2009) proposed an architecture for Voice-over-Internet-Protocol (VoIP) and Delay-Tolerant Networking to deliver store-and-forward voicemail services to remote locations with incomplete, intermittent or non-existent telecommunications infrastructure. Existing phone and data networks would be utilized when available, with gaps filled by Bluetooth-enabled mobile phones. The proposed capability is to be extended into other forms of telemedicine-related data. Clinical evaluations are forthcoming.

Internet/Web-Based Applications

The emergence of web-capable handheld devices drives the development of the access to medical data. Software technologies such as Rich Internet Applications (RIA) platform make telemedicine possible through handheld media. RIA minimizes the redundant transmission of web page data, reducing bandwidth and hardware resources. It also allows access from browser-capable devices. Constantinescu et al. (2009) demonstrated medical data access from simple text records to multi-slice PET-CT images. This was performed with multiple layers of security, simple customization, and real-time lag-free user interaction.

Mobile Applications

Field evaluations show mobile phones as adaptive to both clinical data acquisition and dissemination. Mobile phones serve as platforms for attaching sensors, microscopes, and ultrasound probes providing high-quality photography, telecommunications connectivity, and computing resources.

Mobile 12-lead ECG information system

Hsieh and Lo (2009) collected 12-lead ECG waveform data with patient records via mobile phone. Data were converted and made available per online database to off-site physicians. Statistically significant improvements in diagnostic accuracy and time lines were recorded.

Mobile teledermatology triage

Massone et al. (2009) proved high-quality mobile phone cameras 91% equivalent to face-to-face evaluation with dermatoscopes. The system also provided a store-and-forward capability for expert second opinion. Melanocytic skin neoplasm diagnosed remotely also showed a high accuracy (83%) compared to conventional histopathology.

Light microscopy via camera-enabled mobile phone

Breslauer et al. (2009) developed a microscope attachment for a camera-enabled mobile phone as a platform for high-resolution clinical light microscopy (figure 3). The prototype unit imaged diseased blood smears (malaria-infected and sickle cell anemia) in ambient and augmented light, along with fluorescence imaging of tuberculosis sputum. Sufficient resolution and quality was generated useful for diagnosis. The goal is a rapidly deployable solution for developing and rural areas with ubiquitous mobile phone networks.

Figure: 3: Mobile phone light microscopy.

Ultrasound probe for mobile smartphones

Richard and Zar (2009) demonstrated a compact USB ultrasound probe as an attached peripheral to a mobile smartphone. Ultrasound data could be viewed on the phone's native screen or forwarded to a remote clinic for expert diagnosis.

Reference Data Collection

A by-product of continuing trends in electronic medical records (EMRs) is a growing volume of data must be consolidated, organized, stored, and repackaged.

Merging remote sensor data for home care decision support

Marschollek et al. (2009) implemented a prototype architecture that integrates data acquired from remote vital signs and home environmental sensors in a database and decision support system based on the HL7 standard Arden Syntax for Medical Logical Modules. The integration of environmental data with vital signs proved the feasibility of using an Arden engine. Future development includes the integration of background medical knowledge to further enhance contextual support for decision making.

Data collection and GRID-based computing resource utilization

Sierdzinski et al. (2009) reported on the development of a telecardiological data collection architecture designed to integrate image data and other multimodal patient records. Systematized electronic data collected from remote facilities are processed with image data to generate 3-D and four-dimensional (4-

D) imagery. A secure, distributed GRID computing architecture generates a high-performance image processing capability at low cost.

Sensors and Wearable Monitors

Micropower medical sensors advance monitoring capabilities yet have limiting requirements in miniaturization, on-board data collection and signal processing, power management, and wireless networking integration.

Multiparameter wearable physiologic monitoring system

Mundt et al. (2005) demonstrated the Crew Physiologic Observation Device (CPOD) with an ability to record 9 hours of data to 32 Mb of on-board flash memory. Recorded data include two standard ECG leads, respiratory rate, heart rate, Hgb-O2 saturation, ambient and body temperature, and blood pressure, along with orientation/activity data from a built-in three-axis accelerometer, time stamps, and user-defined event markers. The data can also be streamed continuously to a base station via built-in Bluetooth RF link for real-time monitoring.

Bluetooth-based sensor network

Zhang and Xiao (2009) detailed the architecture and performance of a prototype Bluetooth-based sensor network for remote monitoring of patient's physiological signals and environmental conditions. The system is configurable with varying sensors to include a gateway for collecting and transmitting the data to a remote medical server. The resulting system infrastructure was found to both decrease the cost of patient monitoring and enhance the efficient exploitation of physiological data.

Long-Term Use of Body Sensors: Identifying Technical and Usability Issues

Benefits of long-term collection and monitoring are often limited by feasibility of use, comfort, and practicality. Dias et al. (2009) qualitatively assessed these issues for a suite of sensors and found that critical issues of battery life, ease of configuration and setup, and patient comfort – for example, skin irritation – must be addressed.

Security

Efforts exist to automate, simplify, and enhance the security of telemedicine data networks. Data security issues affect patient trust and malpractice. Traditional methods of securing data using passwords and PINs are cumbersome and vulnerable. Development currently exists for biometric and physiological data to automate, simplify, and enhance the security of the networks used to transmit telemedicine data.

Generating random encryption keys from biometric data

Zhang et al. (2009) used the physiological data (inter-pulse interval of a plethysmogram) acquired by a body sensor network (BSN) as a basis for generating high-quality cryptographic keys. Statistical analysis indicated resistance to privacy concerns.

Interoperability

Interoperability can simplify the operation and management and develops of new class of systems that can integrate the data and functionality of multiple devices.

As technology advances, the human management of this technology becomes complex. Interoperability simplifies inter-device communication, making data and records available across platform devices, and making it possible to develop smart devices that monitor the safe operation of other devices.

Krishan et al. (2009) proposed a system that implements interoperability between infusion pumps and relevant monitoring devices. A smart decision support system alerts remote clinical caregivers of patient-specific conditions that indicate crisis. The device can activate appropriate safety interlocks on the infusion pumps. The interoperability feature and decision support system were reliably proven through study in clinical encounters.

Extreme Environment Systems

Applications in extreme environments are often driven by advances in technology. However, human integration, as confined by environmental factors determines clinical usefulness. Continued functionality of equipment in extreme environmental conditions, the ability to establish adequate communication links, and the availability of expert infrastructure are especially critical in this subset of telemedicine.

End-to-end field testing on Mt. Everest

Otto et al. (2009) evaluated the feasibility of having novice on-site operators use a portable ultrasound unit on Mt. Everest. Diagnostic data on the respiratory status of climbers was shared with remote clinicians. The equipment performed nominally in the cold, hypobaric conditions, and the video stream generated by the ultrasound provided the remote experts with the necessary information to guide the novice operators and to identify acute changes in the actual lung fluid content.

Improved voice communication

Successful voice communication in extreme environments is limited. Huang et al. (2008) studied multichannel noise reduction methods that improved voice signal-to-noise ratios by 8-20 dB, potentially facilitating telemedicine communications in extreme environments.

Human infrastructure

Bonnardot and Rainis (2009) studied the value of unidirectional internet communication. Virtual cases were developed. Six potential experts (two NGOs, two personal acquaintances, and two institutions) generated responses from 13 hours to 7 days after case description. The most relevant support came from an NGO with existing infrastructure to handle the request. An automated message was forwarded to a team of specialists trained on advising doctors in remote locations. Responses were characterized by availability, reliability, and quality.

Clinical

Telemedicine is evaluated in terms of qualitative and quantitative measurements of patients' health outcomes. Telemedical literature puts emphasis on a patients' active participation in their care as the

critical element influencing outcome. Acceptable study designs and guides to clinical outcome studies were itemized by various health care agencies under this data construct. Concordance (using Kappa analysis) between traditional and telehealth models of diagnosis were deemed useful for establishing agreement.

Patient Outcomes: Care and Follow-Up, Monitoring

Statistical studies proving favorable patient care outcomes equivalent to or surpassing traditional methods are driving telemedicine systems into mainstream patient care.

Summary of Studies

Author	Condition	System	Study Type	Description
Nilsson et al. 2009	Primary hypertension	Video Internet	Randomized controlled trial (RCT)	• Patients with uncomplicated primary hypertension were followed via telemedicine (TM) or traditionally for 21 months • Both TM and control groups' BP improved • Higher proportion of improvement in TM group with BP reaching treatment goals • Treatment outcome as effective as face-to-face
Pervez et al. 2009	Cerebrovascular Accident (Stroke)	Telephone Specific TM system	Retrospective (RS) •	• Outcomes of patients treated with tPA at an outside "spoke" facility (OSH) before transfer to regional stroke center (RSC) "hub" compared vs. those directly treated at RSC • Outcomes of TM-intervened comparable to traditionally/ directly treated at RSC • TM approach feasible, safe, efficient
Piron et al. 2009	Post-stroke	Tele-rehabilitation (TR): VR via Internet	Randomized single-blind controlled trial (RCT sb) •	• Outcomes of patients with mild impairment of arm movements secondary to stroke in middle cerebral artery rehabilitated via TM vs. traditional • Both TR and traditional rehabilitation methods assessed effective in 2/3 scales: the ABILHAND and the Ashworth scales • Fugl-Meyer Upper Extremity scales better outcomes in motor performance via TR

				• Suggests early discharge
Ramaekers et al. 2009	Heart Failure (HF)	Specific TM system	Randomized •	• Ongoing large study: evaluate short-term impact of TM on HF patients' disease-specific knowledge, adherence to management recommendations, depression • Significant improvements of disease-specific knowledge in 2 of 3 hospitals for TM vs. standard care • Improved adherence to management recommendations • Potential to enhance proper self-management
Whitten and Mickus 2007	COPD CHF	Specific TM system adjunct to traditional	Experimental (ES)	• Patients receiving home health care via mix of conventional and TM visits vs. conventional care only • Telehealth not a significant predictor of health and well-being, positive or negative • Telehealth patients had worse ratings on SF-36 general health subscale • Patient satisfied with home telecare in terms of the technology and care delivery
Van den Brink et al. 2006	Head and Neck Cancer	Computer Specific TM system	Prospective controlled trial (PCT)	• Patients' quality of life (QoL) evaluated for those supported via TM vs. traditional care • Significant improvement in 5 of 22 QoL parameters (with recognized limitations) • 56% of participants no previous computer experience
Chambers 2009	Cancer (various types)	Specific Tele-psychology system	RCT two-arm (Ongoing)	• Evaluate efficacy and value of minimal contact self-management vs. tele-based cognitive behavioral intervention for people with cancer and their caregivers • Outcomes will be measured based on anxiety and depression, cancer specific distress, unmet psychological supportive care needs, positive adjustment, overall quality of life
Martinez-Ramos et al. 2009	Post-surgery, ambulatory	GPRS Mobile (Nokia 6600) Email	Pilot (PS)	• Post-surgical ambulatory patients followed via TM • TM increased efficiency of home follow-up care

		Images in JPEG PC, standard 17" monitor		• TM avoided unnecessary hospital visits, improved patient satisfaction
Cardozo and Steinberg 2010	Post-discharge (various cases), elderly	Home-based case managed TM + physical nurse visits	Observational (OS)	• Outcomes of home-based, case-managed telemedicine (CMTM) patients for 2 months post-discharge • Recently discharged patients visited by nurses 3x/week and monitored daily via TM • Majority met treatment goals and compliance • 9 quality of care measures, noted average improvement in majority • Majority with improved quality of health perception, better disease understanding, high satisfaction rates with TM
Holtz and Whitten 2009	Bronchial Asthma	Mobile SMS Web server Peak Flow Meter	Feasibility (FS) •	• Evaluated outcomes of asthma patients followed via TM • TM enhanced self-management with better compliance and outcomes • High patient satisfaction • May reduce adverse asthma events
Hayn et al. 2009	Psoriasis	Mobile phones Self-imaging (photos)	Feasibility (ongoing)	• patients captured photos of their own lesions and sent them to monitoring center • physician sends feedback w/recommendations • Preliminary results: improved compliance, better patient-physician communication
Dalfra et al. 2009	Gestational DM Type 1 DM in pregnancy	Telephone Voice message server Internet Mobile SMS, Glucometer with audio converter	Non-randomized controlled trial (nRCT)	• Gestational diabetics followed via TM and conventional methods (CM) were compared with Type 1 diabetics followed via TM and CM • No significant difference in improvement of clinical, metabolic, and pregnancy outcomes among gestational and Type 1 diabetics for both TM and conventional methods • Gestational diabetics better HbA1c, lower CS, lower macrosomia • TM groups for both gestational and Type 1 diabetics fewer unexpected clinic consults and significantly improved QoL • High satisfaction with telemedicine

Rossi et al. 2010	Diabetes Mellitus	Diabetes Interactive Diary (DID)	Standardized health questionnaire	• Effectiveness of online DID compared with standard carbohydrate counting for 6 months • DID as effective as traditional carbohydrate counting, safe • Required less time for education associated with lower weight gain • DID significantly improved treatment satisfaction and quality of life dimensions
Park et al. 2009	Hypertension Obesity	Mobile SMS Internet	nRCT	• Effectiveness of mobile phone SMS and internet-based monitoring as intervention for hypertensive obese evaluated • Significant decrease in BP in TM intervention group vs. no significant change in control • Significant decrease in body weight and waist circumference in TM group and significantly increased in control • HDL-C significantly increased in TM and insignificantly changed in control

Care and Follow-Up

Telemedicine as Effective as Traditional Approaches

The technological feasibility of telemedical care, with the resulting quality of patient outcomes, has been shown equivocal to traditional methods. Telemedical outcomes surpass those from traditional treatment in primary hypertension, acute stroke, and post-stroke rehabilitation.

Video consultations and remote data access for hypertension

Patients in rural Sweden with uncomplicated (primary) hypertension were included in a 21-month study evaluating remote monitoring. A telemedicine system allowed access to medical data and video linkage between physician and patients (Nilsson 2009). The experimental group was compared to control groups from similar rural areas and controlled for variables. The intervention group showed a higher probability of reaching the target BP than the reference group.

Telestroke/telephone consultation for acute stroke

Pervez et al. (2010) evaluated stroke outcomes within the telemedicine framework. Pervez compared those patients treated with IV tissue plasminogen activators (tPA) at outlying spoke hospitals (OSH) via telemedicine guidance prior to transfer to a regional stroke center hub (RSC) versus those directly treated at the RSC. OSH patients were generally younger with fewer severe strokes than RSC patients. Between the two study arms, mortality, symptomatic intracranial, and functional outcomes were not statistically different. Discharge status

was similar for all groups, and mean length of stay among survivors was shorter for OSH patients, with 75% of them walking independently at discharge. This 5-year study affirmed that outcomes in telemedically intervened OSH "drip and ship" patients treated in a spoke-and-hub network were comparable to those treated directly by traditional means at an RSC.

Post-Stroke Telerehabilitation

Patients requiring continuous post-stroke rehabilitation benefit from 4-week telerehabilitation (Piron et al. 2009). Cost and burden reduction is noted in travel, need for a travel care companion, and reduced in-patient hospitalization rate. A virtual reality-based system via internet provided motor tasks to patients from a remote rehabilitation facility. The control group was treated traditionally. Assessments of these patients were conducted 1 month prior to the start of the surgery, commencement, termination, and a month post-therapy using Fugl-Meyer Upper Extremity, the ABILHAND and the Ashworth scales. Fugl-Meyer UE scale showed better outcomes in motor performance using the experimental method.

Telemedicine and Patient Knowledge, Compliance, and Depression

Ramaekers et al. (2009) demonstrated the short-term impact of telemedicine on heart failure (HF) patients' disease-specific knowledge, adherence to pharmacological and non-pharmacological recommendations, and depression. Preliminary results of this ongoing large-scale study showed statistically significant improvements in disease-specific knowledge and compliance for those patients receiving telemedicine guidance. Guidance included recommendations on fluid restrictions, daily weighing, physical exercise, and alcohol restrictions. A trend but not statistically significant decrease in depression in the telemonitoring groups was observed. The preliminary results on patients' adherence demonstrated potential to enhance self-management. The final results of this study are forthcoming.

COPD/CHF Telehealth Outcomes and Patient Perceptions

Whitten and Mickus (2007) evaluated home telehealth care for patients with chronic obstructive pulmonary disease (COPD) and/or congestive heart failure (CHF). The patients in the experimental group received home health care through a combination of traditional face-to-face and telemedicine visits. The control group received only conventional home care. Evaluations were conducted via Short Form 36 (SF-36), Outcome and Assessment Information Set (OASIS), patient charts, and telephone interviews. The addition of telehealth to COPD/CHF patient was not a significant predictor of health and well-being. Notably, those receiving care via telehealth had worse ratings on the SF-36 general health subscale after the intervention. This result was deemed significant when controlling for a number of variables within the model. Home telecare patients were satisfied with the technology per the survey.

Telemedicine Support and Quality of Life Impacts for Cancer Patients

Van Den Brink et al. (2006) demonstrated significant quality of life (QoL) improvements in 5 of the 22 QoL parameters for head and neck cancer patients using a telemedicine-based support system. Results were established in those patients 6 weeks post-intervention compared to a traditional care control group. Given the technology-based telemedicine equipment, it was also noteworthy that 56% of the study group had no previous computer experience.

Tele-Based Psychological Intervention for Cancer Patients and Caregivers

Chambers (2009) is developing a two-arm randomized controlled trial to evaluate 280 cancer patients with elevated psychological distress. The study aims to compare minimal-contact self-management vs. an individualized tele-based cognitive behavioral intervention delivered by a psychologist. Efficacy and potential economic value will be assessed. Participants are enrolled after being identified as highly distressed via caller screening at two community-based cancer helplines. Randomization to the two method-specific groups will then occur. Baseline assessments with follow-ups at 3, 6, and 12 months will be done with outcomes compared.

Better Home Care and Follow-Up

Telemedicine as a method for follow-up post-operative and post-discharge care has demonstrated both qualitative and quantitative effectiveness compared to traditional care.

Tele-Evaluation of Surgical Wounds

Martinez-Ramos et al. (2009) studied 96 post-surgical ambulatory patients via a General Packet Radio Service (GPRS) mobile phone-based telemedicine system. Mobile phone cameras captured images of surgical wounds. Images were then sent via email and retrieved by the provider. Three physicians evaluated 225 images to assess surgical site complications and to test the efficacy of this method of follow-up. Thirty issues were reported with all physicians in agreement in their assessments of the clinical entity. Ten issues required follow-up images. One patient was advised to physically go to the hospital. Patient satisfaction was assessed by analysis of a nine-item questionnaire reply. The results showed that the system increased the clinical efficiency, avoided unnecessary hospital visits, and improved patient satisfaction.

Post-Discharge Monitoring and Education

Observational study documented the outcomes of a home-based case-managed telemedicine (CMTM) program for 2 months post-discharge (Cardozo and Steinberg 2010). Eight hundred fifty-one predominantly elderly recently discharged patients were visited by a nurse up to three times per week and monitored daily via telemedicine; weight, blood pressure, pulse rate, blood glucose, and oximeter recordings were taken. The visiting nurse provided patient education reinforced via telemedicine. Sixty-eight percent were females and 56% African Americans with a readmission rate of 13% and mortality of 2%. Sixty-seven percent met treatment goals and patient compliance rate was 77%. Nine quality of care measures were taken and average improvement was measured at 66%. A majority demonstrated improved quality of health perception, better disease understanding, and high satisfaction rates with telemedicine.

Monitoring

Telemedical monitoring of patients with these chronic illnesses has also shown analogous improvements in patient outcomes. Facilitation of doctor-patient communication allows an active patient participation role.

SMS Messaging for Tracking Bronchial Asthma Symptoms

Holtz and Whitten (2009) demonstrated the outcome value of the mobile phone SMS feature in tracking asthma symptoms. Inclusion parameters included those diagnosed with mild to moderate asthma under treatment from a primary care physician. Patients utilized their own peak flow meter (PFM) readings and sent it via SMS to a web server. If data were not sent by 11 a.m., a reminder was sent to the subject's cellular phone via an automated SMS. A confirmation was also sent by the same system. These patients had an individual asthma action plan provided by their physician with directions for action if results fell within certain color-coded ranges.

Mobile Phone-Based Telemonitoring of Long-Term Psoriasis Therapy

In an ongoing study, Hayn et al. (2009) demonstrated the feasibility of mobile phone-based telemonitoring for optimizing psoriasis therapy. Patients captured photos of their lesions with their mobile phones and sent them to a monitoring center allowing for physician evaluation. The same physician returned feedback with recommendations. Preliminary results show increased patient compliance due to optimization of patient-physician communication.

Diabetes in Pregnancy

A telemedicine system for glucose monitoring was shown to improve pregnancy outcomes in women with gestational diabetes and improve QoL in all diabetic pregnancies (Dalfra et al. 2009). The clinical metabolic variables and maternal-fetal outcomes of women with gestational diabetes and pregnant women with Type 1 diabetes improved after being followed up through either telemedical or conventional methods, without significant difference between methods. Gestational diabetics followed up telemedically had better HbA1c levels at the end of pregnancy, lower Caesarian section rates, and lower incidence of macrosomia compared to those followed up by conventional means. QoL assessments between methods of care showed general non-significant improvement. Only the telemedicine groups showed significant improvement in general health perception, energy, vitality, and mental health scores after delivery (suggesting positive effects of the said system on subjective health perception). The control group's emotional component score significantly improved. The telemedicine system introduced in the care of this study group was also positively reviewed (85%).

Diabetes in the General Population

Rossi et al. (2010) compared the effectiveness of an online Diabetes Interactive Diary (DID) with standard carbohydrate counting over a 6-month period. Metabolism, weight control, time required for education, quality of life, and treatment satisfaction were assessed among adults with Type 1 diabetes. The HbA1c results were similar, with no severe hypoglycemic episodes. DID was shown to be as effective as traditional carbohydrate counting. Responses to standardized health questionnaires showed that DID significantly improved treatment satisfaction and quality-of-life dimensions.

Hypertension and Obesity

Park et al. (2009) evaluated the effectiveness of mobile phone SMS and internet-based monitoring as an intervention to improve health in hypertensive obese patients. Over 8 weeks, blood pressure, weight control, and serum lipid levels were monitored for approximation to normal ranges. Participants in the

intervention group recorded blood pressure and body weight in a weekly web-based diary via internet or cellular phone. Researchers' optimization recommendations were sent to each patient weekly via cellular phone and internet notifications. Systolic and diastolic blood pressures decreased significantly for patients in the intervention group. The readings for those in the control group did not significantly change. Significant mean decreases in body weight and waist circumference were recorded for patients in the intervention group. Significant mean increases in body weight and waist circumference were noted for those in the control group. HDL-C also significantly increased in the intervention group and insignificantly changed in the control.

Diagnostic Outcomes: Accuracy, Sensitivity and Specificity, Agreement, Value and Quality

Telemedicine-supported diagnostics show high sensitivity and specificity compared to established gold standards. Many studies have established concordance and thus agreement between traditional methods of diagnosis and telemedicine.

Summary of Studies

Author	Condition	System	Study Type	Description
Murakami et al. 2009	Telemedicine screening for TW-ROP	RetCamII	Retrospective	• Evaluated screening for TW-ROP via TM and compared it with gold standard • High sensitivity and specificity (SS)
Ishioka et al. 2009	Teledermatoscopy (TD) versus in-person	Internet	Comparative	• face-to-face dermatological examination diagnosis compared with diagnosis via TD • High SS
Wilbur et al. 2009	Digital versus glass slides: broadening telepathology (TP)	Telepathology (digital slides)	Feasibility Concordance	• Feasibility of making digital whole slide reviews for broader TP subspecialty consults evaluated • Digital and glass slide readings compared • Feasible with high overall concordance

Patricoski 2003	Store-and-forward (SF) video otoscopy versus in-person (IP) microscopic examination	Video otoscope Store-and-forward	Concordance	• Diagnostic outcomes compared between physician review of video otoscope images (via SF) and IP microscopic exam • High concordance
Silva et al. 2009	Teledermatology (TD) consultations versus direct observation	Digital images	Concordance	• Diagnostic outcomes between regular outpatient dermatology consult and TD • Good agreement
Ciemins et al. 2009	Telehealth for cognitive assessment by MMSE	Specific telehealth system	Concordance	• Remotely recorded responses to telehealth MMSE were compared with on-site face-to-face recording • Good agreement
Chiao et al. 2005	Remotely guided ocular ultrasound (U/S) aboard the ISS	B- and M- mode ultrasound Space-to-ground video downlink Two-way audio Reference cards Hardware controls Target images	Field Experiment	• Diagnostic outcome of U/S done by a non-expert operator aboard the ISS was evaluated • Of diagnostic quality despite 2-second delay in communication and microgravity • Supports value for terrestrial TM applications of U/S during severe craniofacial trauma
Dyer et al. 2008	Real-time U/S (FAST, EFAST) and video communication between two sites	U/S Video	Field Experiment •	• Evaluated real-time U/S and video communication between distant terrestrial sites using NASA U/S protocol • Educational benefit for on-site operators • Feasible to use to address shortage of experienced personnel

Accuracy, Sensitivity, and Specificity

Innovative and proven solutions that address issues in diagnostics at a distance are now available.

Telemedicine Screening for TW-ROP

Murakami et al. (2009) determined that a telemedicine screening for identifying retinopathy of prematurity (TW-ROP) are of high sensitivity (100%) and specificity (99.4%) when compared with the gold standard of indirect ophthalmoscopy. Over a 2-year period, Stanford University Network for Diagnosis of Retinopathy of Prematurity (SUNDROP) identified and treated all cases with no adverse outcomes. Infants who met ROP exam criteria were screened with the RetCam II web camera system and subsequently evaluated remotely by the SUNDROP reading center. Nurses obtained five to six images of each eye. These patients received a dilated exam within a week from discharge. All cases of treatment-warranted disease were captured through this method.

Teledermatoscopy

Diagnoses of dermatological conditions via traditional methods were compared to teledermatoscopy (i.e. medical records and images transferred through the web by Ishioka et al. (2009). Two dermatologists evaluated 64 diagnosed pigmented skin lesions. There was 72% agreement between the in-person diagnoses and the gold standard biopsy results, compared with 66% agreement between telediagnoses and biopsy results. The telemedicine methods in this study demonstrated high sensitivity (87%) and specificity (73%) with four false negatives. Web-based dermatoscopic diagnostic service was shown to be feasible and able to address needs for access to specialized services in rural areas.

Agreement

Concordance studies have demonstrated agreement between traditional and telemedicine diagnostics.

Digitization Continues to Expand, Following Radiology

Radiology transitioned to digital formats 2 decades ago. Pathology is demonstrating feasibility. Digitizing glass slides for pathology can facilitate easy collaboration and unbounded distance diagnosis.

Digital versus Glass Slides: Broadening Telepathology

Wilbur et al. (2009) demonstrated the feasibility (overall 91% concordance between digital and glass slide readings) of digital whole slide reviews for telepathology subspecialty consults. Challenging pathology slides in digital and glass formats were diagnosed by two specialty pathologists independently and compared with reference slides. Out of the 53 case pairs, 43 pairs (85%) found agreement between glass and digital readings. Five digital case diagnoses (9%) were discordant with both glass and reference readings, indicating an incorrect whole slide reading after review. Better correlation (93%) among cases was noted for the neoplastic specimen than the non-neoplastic (88%).

Store-and-Forward Video Otoscopy versus In-Person Microscopic Examination

A study associated with the Alaska Federal Health Care Access Network (AFHCAN) demonstrated comparable diagnostic outcomes between physician review of video otoscope images (via store-and-forward video otoscopy) and in-person microscopic examination. Forty patients were independently examined (in-person) by two otolaryngologists and imaged with a video otoscope (640 X 480 pixels, still) telemedicine software package post-tympanostomy tube placement. At 6 and 12 weeks, images were

reviewed. Intraprovider diagnostic concordance between in-person examination and the corresponding image review ranged (89%-99%). These rates were shown to be similar to the interprovider concordance between two physicians independently examining the same patient in-person for PE findings (88%-96%). Interprovider diagnostic concordance for in-person exam was 88% and interprovider diagnostic concordance when two providers independently reviewed all images was 84% (Patricoski 2003).

Teledermatology Consultations versus Direct Observation

A prospective study comparing the diagnostic outcomes between regular outpatient dermatology consult (direct observation) and teleconsultation showed agreement at 86.6% - 91.6%. Sixty patients were evaluated in a primary care unit by a dermatologist. These patients' digital images and clinical histories were recorded by a medical student. A telemedicine system was used by two other dermatologists for remote diagnosis. (Silva et al. 2009). Statistically strong agreement was also noted between two different telemedicine diagnose (via K analysis of 0.62).

Utility of Telehealth for Cognitive Assessment by MMSE

MMSE via telehealth was performed on patients with the help of an on-site face-to-face collaborator. Responses were recorded remotely and on-site. Subject's scores were compared, visual items assessed, percent agreement and total score calculated, and correlations between scores determined by Pearson correlation coefficients. Eighty percent of items had statistically significant agreement between remote and in-person methods with high correlations. Reliability testing and continued studies are warranted to ensure the equivalence in quality of telehealth care to in-person care (Ciemins et al. 2009).

Value and Quality

Effective technology is supported by the dedicated training of medical professionals (such as the remote specialist) to develop effective means of communicating in the telemedicine model.

Quality Achieved through Training and Scenario-Specific Protocol

Quality images and thus quality care can be ensured through the use of task support aids and quality checks in a telemedical system. The remote ultrasound system used in the International Space Station (ISS) had multidimensional support from physicians and engineers in the form of reference cards, hardware controls, and target images. The NASA protocol has since been replicated terrestrially.

Remotely Guided Ocular Ultrasound Aboard the ISS

Chiao et al. (2005) evaluated the diagnostic outcome of ultrasound imaging performed aboard the ISS by a crewmember with remote guidance from an expert on the ground at the Mission Control Center (MCC). As a non-expert operator, the crewmember completed a high-quality comprehensive ocular examination using B- and M- mode ultrasound (U/S), the first ever conducted in space. This endeavor demonstrated the capacity to assess physiologic alterations, trauma, and pathology during long-duration space flights. This multipurpose ultrasound was linked with a space-to-ground video downlink and two-way audio. Reference cards with topological reference points, hardware controls, and target images were used to facilitate the examination.

Multiple views of the structures of the eye were captured through closed eyelid and through modified light exposure of the contralateral eye. The ocular ultrasound images obtained were determined to be of diagnostic quality despite the environmental limitations of space. Data, observations, and techniques developed from this study have supported value for terrestrial telemedicine applications of ultrasound.

Real-Time Ultrasound (FAST, EFAST) and Video Communication Between Two Sites

Using the NASA ultrasound protocol for trauma, Dyer et al. (2008) used real-time ultrasound and video communication between Banff (the remote site) and Calgary (the base site). Despite technical challenges, FAST exams were completed in all 20 acute clinical examination cases and EFAST in 14 cases. The critical anatomic features were identified by the mentored non-experts 98% of the time for FAST and 100% for EFAST. Apart from educational benefits for the on-site operators, five hemoperitoneum and two pneumothoraces cases were also identified.

Collaboration, Integration, Outreach

Telemedicine is establishing connection and enhancing communication across disciplines and populations. EMRs are being integrated into telemedical systems. The development of telemedical tools enhances delivery of care to medically underserved populations.

Summary of Studies

Author	Program	System	Study Type	Description
Helck et al. 2009	Interdisciplinary expert consultations via teleradiology	Teleradiology	Prospective	• Provided fast and efficient expert care • Improved and accelerated patient management • Improved utilization of services of hospital
Qaddoumi and Bouffet 2009	Consultations via email of pediatric cancer	Email Video Web	Retrospective	• Promoted effective communication, personal relationships • Enabled discussion of complex cases, organization of teleconferences and workshops • Aid other research activities
Froehlich et al. 2009	Consultations via email of pediatric infectious diseases	Email Web	Case report	• Led to a more accurate diagnosis of this specific case after telemedical consult with pediatric specialists from another country • Led to more effective disease-specific treatment post-consult, with patient improving within 24 hours

				versus prior non-improved condition due to inaccurate presumptive diagnosis
Kanthraj 2009	Author-based, second-opinion teledermatology	Email	Survey	• Good alternative to online discussion groups for second-opinion teledermatology practice in the absence of an expert in the same group. • Need international laws to govern this method of telemedical care for difficult-to-manage cases
Morin et al. 2009	EMR integrated with TM monitoring of diabetes	Specific TM system	Structured interviews	• No effect on DM patients' HbA1c, BP, LDL-cholesterol, and BMI
Switzer at al. 2010	TM emergency neurovascular consultation	Spoke and hub TM system	Retrospective	• Broadened enrollment of patients into time-sensitive acute stroke trials via telemedicine • Delays in study initiation due to transfer time of subjects to the hub

Collaboration

Interdisciplinary Expert Consultations via a Teleradiology Platform

Helck et al. (2009) prospectively evaluated 69 interdisciplinary expert consultations and admissions via a teleradiology platform from five secondary centers. Fifty-four percent were referred to the university hospital for further management. Nine acutely life-threatening emergencies were identified and received fast and focused treatment with a 130-min noted average time to treat. These referred admissions led to improved utilization of facilities. Conclusions demonstrated that interdisciplinary expert consultation using a teleradiology platform can provide fast and efficient expert care with improved and accelerated patient management and improved utilization of service-providing hospital.

Email and Quality of Care for Children with Cancer and Infectious Diseases in Developing Countries

Qaddoumi and Bouffet (2009) conducted a retrospective review of 356 email exchanges between the King Hussein Cancer Center and Hospital for Sick Children located in Toronto, Canada, for 29 months. Evaluation of the impact on the development of a neuro-oncology twinning program between these centers was performed. Subjects of the emails were specific consults (88), videoconferences (65), general neuro-oncological questions (54), personal (45), exchange visits related (44), research projects related (28), articles or treatment guidelines (21), and web site translation (11). This study suggested that emails promoted effective communication, enabled discussion of complex cases, organization of teleconferences and workshops, aid other research activities, and further personal relationships between partners.

Froehlich et al. (2009) documented the telemedical assistance in the treatment of an 8-month-old girl admitted to the Angkor Hospital for Children in Siem Riep, Cambodia. Presentation included fevers, bilateral eye discharge, and an extensive body rash that consisted of large, fluid-filled bullae with significant desquamation. The patient was prescribed intravenous cloxacillin for bullous impetigo. The patient's condition did not improve. Telemedicine consultations via email between Angkor Hospital for Children and pediatric specialists in the United States led to a diagnosis of chronic bullous dermatosis of childhood (CBDC), a rare sub-epidermal blistering disease. The child was subsequently started on disease-appropriate medications. The lesions significantly improved and fevers resolved within 24 hours.

Integration

Integration of Electronic Medical Records and Telemedicine

Integration of EMRs into a diabetes telemedical system for patients of primary care physicians in underserved rural areas demonstrated no effect on diabetic patients' HbA1c, blood pressure, LDL-cholesterol, and body mass index (Morin et al. 2009).

Outreach

Enhanced Recruitment of Participants from Remote Areas in Clinical Trials

Switzer at al. (2010) studied the impact of telestroke networks on recruitment into acute stroke clinical trials. Previously, this was only available at academic centers. Switzer demonstrated the enhanced enrollment of patients into time-sensitive acute stroke trials; clinical trial subjects were enrolled and administered the drug to themselves at the remote site under telemedicine guidance.

Extreme Environment Outcomes: Space, Aviation

NASA continues to demonstrate the utility of telemedical applications in space and aviation with space technologies and protocols that can be applied on Earth.

Summary of Studies

Author	Program	System	Study Type	Description
Sargasyan et al. 2005	Real-time U/S (FAST) and video in space and microgravity	Ultrasound (FAST) Private real-time 2-way audio Private space-to-ground video downlink Reference card Hardware controls	Field experiment	• FAST feasible aboard the ISS with minimally trained non-expert sonographer operator and remote guidance from an expert at MCC • Excellent diagnostic outcome
Weinlich et al. 2009	Teleconsultation in flight	Specific TM system Telephone	Prospective	• Patient outcome and care efficiency advantages were demonstrated by availability of teleconsultation aboard an aircraft.

Space

FAST in Microgravity

Focused assessment with sonography for trauma (FAST) was demonstrated as feasible with excellent diagnostic outcome and speed aboard the ISS (Sargasyan et al. 2005). An ISS crewmember performed FAST examination while being guided remotely by an ultrasound imaging expert on the ground using private, real-time, two-way audio and a private space-to-ground video downlink at 7.5 frames/second. A 2-second audio-video satellite delay was noted. The crewmember had prior but minimal sonography training. Identical reference cards with topologic reference points and hardware controls were in place and available for both the astronaut in space and the consulting physician on Earth. Excellent quality and content of images were obtained without significant differences between FAST done in orbit and those in terrestrial scenarios (according to the radiologist or surgeon team in the study). This method was noted as efficient for use in an actual trauma scenario. Microgravity did not affect visualization of the conventional FAST windows. Examination was completed in 5 minutes and 35 seconds.

Aviation

Emergency Care in Flight

Weinlich et al. (2009) prospectively demonstrated the advantages of simple teleconsultation in medical emergency cases aboard commercial aircraft. 3364 Three thousand three hundred sixty-four medical incidents were reported during the 3-year study period, 57% (2310) of which were associated with patient collapse. In 9% (323) of the cases, telemedicine was used. Twenty-seven percent (83) of the telemedical cases were neurologically related. Twenty-seven cases warranted diversion and it was noted that none of those in the non-diversion group deteriorated. Physicians on board utilized telemedical consultation in severe cases while non-physicians also used it in less acute cases.

Human

Telemedicine is evaluated by users' perceptions and measured feedback. There is increasing need to develop infrastructure and define general adoption details. The human context of telemedicine develops international and local laws governing telemedical practice, standardizes support for electronic medical records, adjusts for culture-specific considerations, and integrates with existing workflow. When technologies are developed a multidimensional, multicultural, case- and scenario-specific, age-specific, group-specific, and even person-specific package is the goal.

Patient Satisfaction

Patients express acceptance and general satisfaction with telemedical approaches to care. While many still prefer in-person consultations, the results show sufficient acceptance (and objective merit) to justify the continuation of telemedicine as a means of providing care.

Summary of Studies

Author	Program	System	Study Type	Description
Agha et al. 2009	IP vs TM on perceived patient-physician communication	Specific TM system	Noninferiority randomized clinical trial (patients' self report)	• Patient satisfaction with patient-centered communication, clinical competence, interpersonal skills similar for IP and TM • TM not inferior • Greater satisfaction with convenience for TM • Patient satisfied with physician's rapport, use of shared decision-making, patient-centered communication during both IP and TM
Agha et al. 2009	IP vs TM on observed patient-physician	Specific TM system	Roter Interaction Analysis System	• TM more physician-centered • Physician controls dialogue,

	communication	Video	(RIAS)	patient relatively passive • No difference in length • Physicians used orientation statements during IP • More request for repeats from patients during TM
Lee at al. 2010	Parents' perception about digital imaging and telemedicine for care of retina of prematurity (ROP)	Specific TM system Digital retinal imaging	Questionnaire evaluated using five-point Linkert-type scale	• Patient satisfaction with patient-centered communication, clinical competence, interpersonal skills similar for IP and TM • TM not inferior • Greater satisfaction with convenience for TM • Patient satisfied with physician's rapport, use of shared decision-making, patient-centered communication during both IP and TM • Though parents in study group expressed some preference for face-to-face care, overall positive perceptions about telemedical ROP diagnosis.
Sevean et al. 2009	Patients and family satisfaction using video telehealth in rural communities	Specific video telehealth system	Qualitative (semi-structured video interviews)	• Patients, families report reduced health care burden, increased support and adaptability of systems to meet needs
Whitten and Mickus 2007	COPD/CHF patients' perceptions of home telecare + traditional vs. traditional alone	Specific telecare system Video	Randomized clinical trial (patients' self report)	• General health outcomes in the telemedicine group not better than traditional group • Patients satisfied with the technology and the telehealth method of care.

Perceived Patient-Physician Communication

Patients from pulmonary, endocrine, and rheumatology clinics at a Veterans Administration hospital were randomized to in-person (IP) or telemedicine (TM) consultation. Communication between patient and physician was measured using a validated self-report questionnaire with 33 items measuring satisfaction, patient-centered communication, clinical competence, and interpersonal skills. Satisfaction with physician traits was similar for both consultation types and the non-inferiority of TM was confirmed. Greater satisfaction with convenience for TM versus IP was also reported. Patients were equally satisfied with physician's rapport ability, use of shared decision-making, and willingness to uphold patient-centered communication during both TM and IP consultations. Despite physical separation during TM consultations, the patients did not deemed it to be inferior to IP communications. (Agha et al. 2009).

Observed Patient-Physician Communication

The quality of verbal and nonverbal physician-patient communication during clinical TM consults was compared with IP consults in video recordings using codes from the Roter Interaction Analysis System (RIAS). Assessment indicated differences between the two in terms of communication. TM visits in the study were determined to be more physician-centered. There were no differences in length of TM and IP consults (22.2 and 21.9 minutes, respectively). Physicians were more likely to use orientation statements during IP consults. There were also greater requests from patients for repetition during TM, likely indicating perceptual difficulties (Agha et al. 2009).

Parents' Perceptions of Digital Imaging and Telemedicine

Lee et al. (2010) studied the perception of parents in digital imaging and telemedicine for retina of prematurity (ROP). For 1 year, a parent of each patient whose retina was under wide-field imaging for ROP was given a questionnaire designed to evaluate perceptions using a five-point Linkert-type scale. Five items for assessment of perceptions toward digital retinal imaging and 10 items for assessment of attitudes toward telemedicine were assessed. Descriptive and correlation statistics were used to summarize responses. Factor analysis was used to examine validity of questionnaire. Two factors explained 79% of total variance in digital retinal imaging items and three factors explained 63% of total variance in telemedicine. For digital imaging, highest mean score was for "digital pictures of my child's retinopathy should be included in the permanent medical record" and lowest for "digital cameras and computers are reliable." For telemedicine, highest mean score resulted for "technology will improve the quality of care for my child" and lowest was for "technology will make it harder for a patient and doctor to establish a good relationship." Though parents expressed some preference for face-to-face care, this shows overall positive perceptions about telemedical ROP diagnosis.

Benefits of Telehealth Services in Rural Communities

Experiences of patients and families using video telehealth in rural communities illustrated telemedicine lessened burden, maximized support, and indicated that the e-health systems were successfully tailored to specific patient and family needs. Telehealth programs can positively impact the quality of health care along with provider-specific benefits. Sevean et al. (2009) concluded that integrating telehealth in the physician's practice enhances the coordination, organization, and implementation of health care services.

COPD and CHF Patients' Overall Perceptions

Whitten and Mickus (2007)] evaluated outcomes and patient perceptions on a home telecare method for COPD/CHF. Patients were followed with a combination of home telehealth and traditional home health services while others received only the traditional method. Though general health outcomes in the previous group were not better than the latter, patients noted satisfaction with the technology and the telehealth method of care.

Provider Satisfaction

Provider satisfaction encompasses general satisfaction with direct patient care, collaboration, accessible consultation, and general satisfaction of specialists on being able to provide expertise. Additional studies are needed on the perceptions and comfort of generalists who consult specialists via telemedicine while in front of patients.

Summary of Studies

Author	Program	System	Study Type	Description
Sandberg et al. 2009	TM-based diabetes management	TM for DM care Video Phone	Qualitative	• Satisfied by more frequent and relaxed patient contact, timely monitoring, data management • Problems with technology, lack of physical contact
Van den Berg et al. 2009	TM in general practice, with home visits by nurses supported by TM.	TM monitoring system: Scale sphygmomanometer Intraocular pressure (IOP) measurment devices Phone Video	Feasibility	• Acceptable to patients and GP • Analysis of consultations, calls and videoconferences between GPs and nurses • TM found feasible for general practice
Varkey et al. 2008	TM at the work site	Otoscope Microscope Stethoscope Video monitor visible to patients	Pilot (patient-physician survey)	• Doctors report telemedicine feel similar to face-to-face; both parties report positive effect on doctor-patient relationship •
Al-Kadi et al. 2009	Tele-ultrasound links rural hospital to trauma center to telementor Acute Trauma Resuscitations	FAST EFAST	Pilot	• Clinicians satisfied with interaction, see benefits for patients and own skills
Lopez et al. 2009	Virtual slide telepathology program part of TM-enabled rapid breast care service bundling telemammography, telepathology, teleoncology	Specific TM system	Survey	• Increased job satisfaction of subspecialty pathologists who covered general surgical pathology service

Direct Providers of Diabetes Management via Telemedicine Report High Satisfaction

Experience and satisfaction of diabetes care management illustrated a high satisfaction with telemedicine. The same providers also noted unique benefits associated with telehealth delivery: more frequent contact with patients, greater relaxation, increased ability to reach the underserved, timely and accurate medical monitoring, and improved management of data (Sandberg et al 2009). The identified disadvantages in the study were technology problems and a lack of physical contact with patients.

Telemedicine in General Practice Leaves Patients and Physicians Satisfied

The AGnES concept (general-practitioner-supporting, community-based, e-health assisted systemic intervention). One hundred sixty-two patients used a telemedical monitoring system (e.g. scale/sphygmomanometer and IOP measurement devices). Consultations, calls and videoconferences between general practitioners (GPs) and AGnES employees were analyzed. This study expressed the feasibility of implementing telemedicine in general practice and its acceptability to both patients and GPs (van den Berg et al. 2009).

Patients and Physicians Satisfied with Telemedicine at Work Site

A pilot study at the Mayo Clinic evaluated the feasibility and patient/physician satisfaction with telemedicine at the work site. In 99 out of 100 visits, telemedicine felt similar to a face-to-face visit. Sixty-seven patients strongly agreed or agreed that telemedicine has a positive effect on their physician-patient relationship. Physicians have strongly agreed or agreed to the same conclusion in 86 visits. In 55% of the visits, otoscope, microscope, stethoscope were deemed important. All patients and all four physicians in the study said they would use telemedicine again (Varkey et al 2008).

Telementoring Acute Trauma Resuscitations

Al-Kadi et al. (2009) set up a pilot tele-ultrasound system between a rural referring hospital and a tertiary care trauma center to facilitate telementoring during acute trauma resuscitations. Twenty-three tele-ultrasound examinations were done over a 12-month study period. Focused Assessment with Sonography for Trauma (FAST) and Extended FAST for pneumothoraxes were evaluated. Twenty exams were conducted during acute trauma resuscitations and three during live patient simulations. All 23 cases were completed for FAST and 17 for EFAST. Out of 18 clinical users, 14 completed a survey (76% response rate). Ninety-three percent of respondents were satisfied or very satisfied with telemedicine interaction and agreed or strongly agreed that this technology could benefit the injured patients in the study area. Ninety-three percent of respondents also felt that the project improved the collegiality between the two institutions and 71% agreed or strongly agreed that it also improved their U/S skills. Researchers claim that tele-U/S proves to be important to the care of remotely injured or ill patients.

Virtual Telepathology Increases Job Satisfaction

A virtual slide telepathology program was shown to increase job satisfaction of subspecialty pathologists who covered a general surgical pathology service at a satellite university hospital. The UltraClinics Process is part of telemedicine-enabled rapid breast care service that bundled telemammography, telepathology, and teleoncology in a 1-day process (Lopez et al. 2009).

Adoption

Electronic health records (EHR), emails, electronic publication databases, internet (social) tools, applications, videoconferencing, digital imaging technologies, and mobile phones (SMS, video, audio) are some of the popular aspects of modern applied technology used in telemedicine. Adoption of telemedicine extends well beyond user experience with technology.

Summary of Studies

Author	Program	System	Study Type	Description
Hoerbst et al. 2010	Use of EHR and electronic exchange of health-related data among health care providers	HER	Standardized interview	• General positive attitude about EHR • Raised concerns about data security • Desired more information about data protection
Shachak and Reis 2009	EMR impact on patient-doctor relationship	EHR email electronic publication databases internet	Literature review	• Positive impact on information exchange • Negative influence on patient centeredness • Need better EMR design, communications training
Whitten 2006	Full adoption of EMRs enhances knowledge about outcomes on efficacy of telehealth interventions	EMR local EMR national EMR integration		• EMRs must be fully adopted and seep through the local systems first, diffuse fully and then eventually transmitted nationally before analysis for telehealth functions can take effect.
Shirts et al. 2009	Physicians' use of URLs	Internet Lab test results with URLs		• No decline in hit rate 9 months after the URLs were removed. • Web site hit rates were from 0-3% per month with higher rates for specialty and rare tests • indicates use and access of links to reference material by clinicians.

Weaver et al. 2009 Anderson 2004	Internet use and TM adoption	Internet	Prevalence / Survey	• Prevalence of internet health or internet medical information seeking adults in the United States from 13.2% - 80%
Nageba et al. 2009	Knowledge model driven solution for web-based TM applications	Internet TM tasks ontology		• Proposal of a knowledge model—enable intelligent, ubiquitous telemedicine tasks management to support quality of telemedical services via web-based telemedicine applications. • Based on telemedical tasks ontology—represent concepts and their interrelations • Can be used for decision-making.
Mahapatra et al. 2009	Free bandwidth to encourage TM educational projects	Specific TM system		• Possibly help in infrastructure set up for TM educational projects in a developing country
Lai et al. 2009	Training patients for TM	REPETE TM system		• Qualitative and quantitative • Remote training tool for older adults in the telemedicine environment • Significant improvement in performing tasks
Maybury and Farah 2009	Electronic literacy to prepare current students for expertise	Computer Microscopy		• Transition from light to virtual microscopy requires electronic-literacy or electracy • Critical to learners and teachers. • Practical applications in computer simulations and telemedicine areas in which current medical students will need to acquire expertise

Vuononvirta 2009	Attitudes towards adoption diverse among different professionals	Specific telehealth network	Qualitative	• Qualitative study • Attitudes diverse in relation to time, situation, profession, health center, and telehealth application. • 10 different types of adopters—enthusiastic, positive, critical, hesitant to participants who are positive, hesitant, critical, neutral, and negative and to non-participants who are positive. • Attitudes from negative to enthusiastically positive with positive overall • Use well accepted in continuing education and in diabetes consultations. • Negative attitude not a definite barrier to adoption
Buck 2009	Nine human factors that contribute to "user acceptance" of telemedicine	General TM system		• 9 factors more connected to the cognitive-emotional than the cognitive-rational side of processing information. • Suggested that developers focus on user acceptance early on in the exploratory phase before the start of the project, during the process of development, actual implementation, and follow up stage.
Visser et al. 2009	Adoption Rate and Implementation	Video		• Video consultation service for regional group of pediatric physiotherapists: 75% adoption rate, implementation longer than planned •
Rural Consult 2010	Legality of physician-patient			• Applied laws surrounding physician-patient

Richards 4/19/2009	relationship in TM		relationship currently in place adaptable to use of telemedicine in patient care and would depend on the particulars of the relationship

Use of EHR and Electronic Exchange of Health-Related Data among Health Care Providers

Two hundred three Austrians and 293 Germans were interviewed about the use of EHR. Seventy-five percent collect and store paper-based medical documents at their homes without an internet-based personal health record; 80%-90% supported an electronically exchanged health-related data link. Data security issues were raised (Hoerbst 2009).

EMR Impact on Patient-Doctor Relationships

Shachak and Reis (2009) studied the impact of electronic medical records on patient-doctor communication during consultations. EMRs had a positive impact on information exchange. It had a negative influence on patient-centered interaction. Physician's level of computer skill and behavioral style assisted in overcoming this negative influence. The negative impacts are overcome by better designs of EMR systems and medical education interventions.

Full Adoption of EMRs Enhances Knowledge of Outcomes in Telehealth Interventions

Whitten (2006) highlighted the advantages of data repositories, databases, and EMRs for telemedicine in enhancing knowledge about outcomes and efficacy of telehealth interventions. Useful data on utilization, efficacy, cost advantages, and health outcomes for telehealth can be mined from registries and databases. Policy such as the HIPAA addresses concerns about inadvertent release of confidential information. The most effective means of data capture and transfer is via electronic means at the local level via EMR.

Physicians' Use of URLs

Shirts et al. (2009) tracked the frequency and duration of physicians' access to supplemental web information through the universal resource locator (URL) links provided with the results of seven laboratory tests done at ARUP Laboratories in Salt Lake City, Utah. The study tracked usage from the time the links were initially set up to after its modification 7 months later. There was no decline in hit rate 9 months after the URLs were removed. Web site hit rates were from 0%-3% per month with higher rates for specialty and rare tests. This indicates use and access of links to reference material by clinicians.

Internet Use and Telemedicine Adoption

Different studies show varying figures regarding the prevalence of adults seeking internet health or medical information in the United States, ranging from 80% in one to 13.2% in another (Anderson 2004, Weaver et al. 2009). This field is a potential source of focus and further studies on the possible correlation with telemedicine adoption, given its association with use of technology and new media communication.

Knowledge Model Driven Solution for Web-Based Telemedicine Applications

Nageba et al (2009) propose a knowledge model that would enable intelligent, ubiquitous telemedicine tasks management to support the quality of telemedical services via web-based telemedicine applications. This program would be based on a telemedical tasks ontology representing the concepts and their interrelations, and can be used for decision making. This can supposedly map out the concepts and the relationships between available data, for example, optimize the messages exchange among the different actors in the telemedicine systems, capable of more rapid and reliable telemedicine assistance.

Free Bandwidth to Encourage Telemedicine Educational Projects

Mahapatra et al. (2009) identified some implications for telemedicine technology in India. Decade-long studies across the country have led to the gradual adoption of telemedicine and tele-education in health sciences. There is currently a government policy providing free bandwidth for society development and this helps in the set-up of infrastructure for telemedicine educational projects.

Training Patients for Telemedicine

Another study evaluated an architecture for remote training of senior patients in a telemedicine environment or REPETE (remote patient education in a telemedicine environment). Responding to the growth of home healthcare technology in rural areas, this particular project focused on training Medicare beneficiaries with diabetes in New York State on how to efficiently use their home telemedicine units. Qualitative and quantitative evaluation was done to measure the effectiveness of training on web skills competency, to survey user satisfaction, and to analyze cognitive tasks and interactions related to their usage. This specific training tool was shown to be effective as a remote training tool for older adults in the telemedicine environment. These same patients showed significant improvements in their performance of tasks on their home telemedicine units (Lai et al. 2009).

Prepare Current Students for Expertise

Technological literacy is advocated by Maybury and Farah of the University of Queensland School of Dentistry. As a development of the mandatory exposure of undergraduates to the use of light and optical microscopes, the emergence of virtual microscopy (which digitizes slide specimens, allowing a computer to mimic the functions of a light microscope) is one of the significant development in education. The transition requires electronic literacy, or electracy, and is critical to both learners and teachers. The practical applications of this knowledge in computer simulations and telemedicine are areas in which current medical students will need to acquire expertise (Maybury and Farah 2009).

Attitudes Toward Adoption Remain Diverse Among Professionals

A study was conducted on identified health centers in Northern Finland describing attitudes of multiprofessional teams to telehealth adoption. Seven health centers, a local university, and the university hospital in the Olu Arc Subregion in rural northern Finland comprised the study telehealth network. Videophone was used from 2004-2007 for orthopedics, psychiatry, diabetes, and rehabilitation consultations, continuing education, patient care, and administrative meetings. Thirty professionals—physicians, nurses, psychiatric nurses, and physiotherapists were observed and interviewed as part of the qualitative research in 2007 to assess their attitudes toward telehealth and how these attitudes affected

usage. Attitudes were diverse in relation to time, situation, profession, health center, and telehealth application. Attitudes ranged from negative to enthusiastically positive, with a net result of positive overall. Use of telehealth was notably well accepted in continuing education and in diabetes consultations. The study also showed that the negative attitude was not a definite barrier to adoption (Vuononvirta 2009).

Nine Human Factors that Contribute to User Acceptance of Telemedicine

The users of telemedicine systems are the care and cure providers and receivers, or physicians (and other health care providers) and patients. Buck (2009) attributed nine human factors that contribute to user acceptance of telemedicine. These nine factors were demonstrated in this study to be more connected to the cognitive-emotional than the cognitive-rational side of processing information. The author further suggested that developers focus on user acceptance early on in the exploratory phase before the start of the project, during the process of development and implementation, and in the follow-up stage. The nine factors—aim and usefulness, respect, control, retaining the care provider's status, user profile (expectations, skills, restrictions), emotional condition of the patient, leveling of communication, traceability of information, and information selection, must be incorporated into requirements engineering, development processes, and product life cycles. These nine factors help the user appreciate and cope with telemedicine adoption. By understanding and anticipating the way the user thinks and acts, adopters can have more success in the process of change involved. The technicality of the applications can then be experienced as "useful," inspiring confidence, and allowing users to "enjoy the acceptance of both care and cure."

Adoption Rate and Implementation

Visser et al. (2009) evaluated the implementation of a video consultation service in a regional community of pediatric physiotherapists. Twenty-two pediatric therapists in primary and rehabilitation care settings participated in a study and were evaluated according to satisfaction with regard to the implementation procedure (introduction, learning, consultation phases), education received, technical help desk support, and usage of application in practice. It took the participants 12 months finish the learning phase and only 14 of them entered the actual consultation phase. They then expressed satisfaction with the education received and helpdesk. During the study period, 24 video consultations were done. Average time to compose and answer questions are 115 and 43 minutes, respectively. Adoption of this video consultation option was at 75% and researchers noted longer implementation time than they have foreseen.

Legality of Physician-Patient Relationship in Telemedicine

Applied laws surrounding physician-patient relationship that are currently in place are adaptable to the use of telemedicine in patient care, and they would depend on the particulars of the relationship. For example, the status of the local practitioner or referring provider, whether the patient is cared for by a local physician or directly by a telemedical provider, if the patient's or telemedical physician's local contact is or is not a physician, and even the nature and purpose of the telemedical equipment used would all be factored into the legal considerations (Richards 4/19/2009, Rural Consult 2010).

Cost

Rationale for telemedicine supports its cost reduction without compromise in patient outcomes and care efficiency. In 2006, an ATA economic analysis panel, supported more recently by a 2009 study by health economists, observed a lack of rigor and depth in the cost analysis components of many telemedicine studies. Recently, increased emphasis has been put on cost analysis. Telemedicine is associated with additional implementation costs and other infrastructure-related overhead. However, cost advantages such as decreased travel time for patients and providers, reduced travel-related costs to obtain care, and time saved by all actors in providing and receiving care result in overall cost-saving potential.

Summary of Studies

Authors	Program	System	Study	Description
Latifi et al. 2009	Teletrauma (TT)	Specific telemedicine (TM) system	Retrospective analysis	• TM trauma and surgery consults from hub to rural spokes resulted in saved lives, improved outcomes • Over $21k in avoided transportation costs per instance.
Kokesh et al. 2009	Tele-Otolaryngology (TO)	Store-and-forward TM	Field experiment	• Audiologist travelled to remote Alaska • Remote specialist made treatment and triage recommendations • 85% of cases avoided unnecessary travel • Resulted in cost savings
Rand et al. 2009	Telecardiology (TC)	Army Knowledge Online TM system Text paging	Prospective analysis	• 3 ½ years of TC consults • deployed medical providers linked with subspecialty consultants • average response time 4 hours and 54 minutes • 207 cardio consults managed • Top 3 reasons: ECG abnormalities, chest pain, syncope • 6 evacuations avoided → cost savings • 29 evacuations facilitated • $144,000 saved from unnecessary evacuations

Davalos et al. 2009	Telemedicine Economic Analysis	General TM systems	Comprehensive literature review	• Health Economics Research group at University of Miami • Lack of concrete evidence to demonstrate economic impact of TM • Recommends research guidelines for cost-benefit studies of TM programs • Recommend that economists be involved early in study design and economic evaluation of TM programs • ATA should reach out to health economics professional organizations • Researches must undertake new benefit-cost analyses
Grant et al. 2009	Tele-echocradiogram	Image transmission via ISDN	Prospective studies	• Between 3 district general hospitals (DGH) and a regional pediatric cardiology unit • On-site pediatrician obtained infants' echocardiograms while guided by pediatric cardiologist • 124 infants total seen • 5 scans inadequate • Follow up echo on 109/119 cases • 39/109 (36%) major CHD • 45/109 (41%) minor CHD • Accuracy in 96% of cases (K=0.89) • 93/124 (75%) avoided unnecessary transfers • TM high implementation costs but less than standard care • £728/patient saved
Wang 2009	Cost in TM evaluation	General TM systems	9 year Survey: Health Indicator of life expectancy at birth (generalized methods of moments	• 10% increase in ratio of telehealth (TH) services relative to conventional services increase life expectancy at birth by 0.00019% • Cost of each telehealth service do not influence

			estimators STATA v10.0)	population's health status • Current life expectancy in Taiwan is 76.25 years • Increase in TH services by 243 times reduce cost of conventional health care by 69.5% • Availability of TM save medical resources
Bergmo 2009	Economic evaluations of TM	General TM systems	Literature review	• 33 literatures on quality, validity, generalizability of economic evaluations associated with TM • Evaluations showed high diversity in context of study • Economic evaluations not in accordance with standard evaluation techniques • Future studies should demonstrate valid and generalizeable results
Gates 2007	Cost savings	Alaskan TM system	Magazine article citing TM publications	• Medicaid reimbursement in Alaska saves about $7 per dollar spent on telemedicine
Vastag 2007	Determine cost benefit of TM physician video consultation for company employees vs. traditional	Video		• 90% of consults for general and family medicine • Significant time/salary savings and increased employee productivity—27 minutes average for TM consult vs. 2 hours traditional • High patient satisfaction

Teletrauma: Life-Saving and Cost-Saving

Latifi et al. (2009) analyzed trauma and general surgery consults via telemedical methods between five rural spoke hospitals and a Level 1 trauma center hub. The telepresence of a trauma surgeon helps in the initial evaluation, treatment, and care of patients. The study observed improved outcomes and reduction of costs in trauma care. Fifty of the patient cases studied came from the first hospital where teletrauma was established. Six patients benefited from potentially life-saving consults. Seventeen cases (eight trauma, nine surgery) were able to avoid traveling and were instead treated at the rural hospitals. These were shown to save an average of $19,698 per air and $2,055 per ground transports.

Remote Specialist's Treatment and Triage via Teleotolaryngology

An audiologist traveled to a remote area in Alaska with instructions to image appropriate parts of an otolaryngology exam, document clinical histories, capture images, perform audiograms, tympanograms, otoacoustic emission tests, and then work with an otolaryngologist via store-and-forward electronic consult. The remote specialist made treatment and triage recommendations. Eighty-five percent of cases identified did not need to travel for further treatment, resulting in cost savings for patients and the healthcare system (Kokesh et al. 2009).

Deployed Medical Providers Linked to Specialists via Telecardiology

Rand et al. (2009) analyzed 3.5 years of cardiology teleconsultations under the Army Knowledge Online Telemedicine Consultation Program initiated by the Office of the Surgeon General. This program linked deployed medical providers with subspecialty consultants to assist in management and to guide triage and disposition. With an average response time of 4 hours and 54 minutes, 207 cardiology consults were managed during the period. Electronic consults from remote and austere environments sent a text page to an on-call cardiologist at Brooke Army Medical Center. ECG abnormalities, chest pain, and syncope were the top three presenting symptoms. A total of six evacuations were avoided (and subsequent cost savings noted), with 29 others facilitated. Investigators noted an estimated $144,000 saved from unnecessary evacuations.

Lack of Rigorous Economic and Cost-Benefit Analysis

Davalos et al. (2009) of the Health Economics Research Group at the University of Miami conducted a comprehensive review of literature concluding a lack of "concrete evidence" to demonstrate the economic impact of telemedicine. Specific recommendations and research guidelines for cost-benefit studies and analyses of telemedicine programs were outlined including opportunity cost estimates and monetary conversion factors to translate outcomes to dollar values. The authors further recommended that economists be involved early in the study design and in subsequent economic evaluation of the telemedicine programs. It was suggested that the American Telemedical Association (ATA) reach out to health economics professional organizations to explore mechanisms for interaction between the telemedicine and health economics communities. In 2006, the ATA published a policy on research recommendations including the area of economic analysis. This study, 3 years later, extensively highlighted the need (and the advantages) of an improved measurable economic evaluation.

Cost Savings in Specialist-Guided Remote Diagnosis

Grant et al. (2009) compared echocardiograms in patients at risk for significant congenital heart disease (CHD). The investigators determined the accuracy of remote diagnosis of CHD by transmitting echocardiography images by the Integrated Services Digital Network (ISDN) lines. The impact on patient management and cost was assessed. The studies were done between three district general hospitals (DGHs) and a UK regional pediatric cardiology unit. Infants' echocardiograms were obtained by a pediatrician at a DGH while guided by a pediatric cardiologist. The resulting echocardiogram was transmitted via ISDN. As a final step, the hands-on evaluation of the echocardiogram was done by the pediatric cardiologist. The cost of patient care between those treated under the telemedicine service and a hypothetical control group was compared. Tele-echo diagnosis demonstrated accuracy in 96% of cases (K=0.89). Seventy-five percent (93/124) cases avoided unnecessary transfer. Telemedicine service

demonstrated high implementation cost but was shown to cost less than standard care with a savings of £728/patient.

Cost of Telemedicine and Population's Health Status

Wang (2009) showed that a 10% cost increase in each conventional health service increased population life expectancy at birth by 0.12%. A 10% increase in gross domestic product (GDP) of the country increased the population's life expectancy by 0.0023%. A 10% increase in population increased the population's life expectancy at birth by0.0004%. A 10% increase in the ratio of telehealth services relative to conventional medical services increased the population's life expectancy at birth by 0.00019%. The cost of each telehealth service does not influence the population's health status. Increasing telehealth services by 243x can reduce the cost of conventional health care by 69.5%. Telemedicine service cost does not determine allocation of medical resource but can save medical resources.

Economic Evaluations Not in Accordance with Standard Evaluation Techniques

Bergmo (2009) systematically reviewed 33 studies for quality, validity, and applicability of economic evaluations associated with telemedicine. The evaluations reviewed showed high diversity in context of study and their applied methods. The majority of economic evaluations found were not in accordance with standard evaluation techniques.

Cost Savings in Alaska

Gates (2007) compared the benefits and challenges of telemedicine for patients who have limited access to vital services. Medicaid reimbursement in Alaska was noted to save approximately $7 in travel costs for every dollar spent on telemedicine.

Cost Savings in Texas

Vastag (2007) reported on a telemedicine project by UTMB Galveston and America National Insurance Co. to determine whether telemedicine cut cost. A video link was set up at a clinic in the company headquarters for employees to seek consult. Of 100 consultations, 90% were for general or family medicine. Average time spent by these employees for their visits via telemedicine was 27 minutes versus 2 hours for face-to-face visits. After 300 total visits, $13,000 in direct salary savings were noted by the company with 423 total hours of increased employee productivity.

Conclusion

Telemedicine is a technologically driven field that encourages innovation and creative solutions. The literature highlights advancements in the field of telemedicine in each of four categories suggested: technical, clinical, human, and cost. Significant progress is being made toward the adoption of smart machines, high-quality applications, ergonomically sound devices, and cost-effective interoperable systems that improve the delivery of care.

Solutions have resulted in patients with healthier outcomes, improved processes for provider care delivery, and extension of healthcare to remote areas. The current reach and breadth of telemedicine show substantial capacity to address the healthcare needs of remote areas, extreme environments, and the medically underserved.

As telemedicine evolves, it is important that the needs of the patient and operator remain in the foreground. New technologies and processes are developing. Systems continue to become more interoperable. Costs of implementation decrease. Human operation must remain the foundation. Telemedicine is the result of collaboration of minds, interest groups, and specialized interests. The goal is to increase human resources for the purpose of better and preserve human life in extreme environments.

Recommendations

Telemedicine offers a broadening application within medical informatics. The changing shape and direction of this technical movement centers on the maximum implication of technology for patient care. Unidirectional and multidirectional advances in telemedicine must be applied in the context of long-duration space flight.

Successful telemedicine implementations models include technologies: digital imaging (including video, streaming, and emerging 3-D remote viewing systems), improved robotics, remotely controlled pointing devices, bandwidth-sensitive system design, improved data compression, co-opting of ubiquitous mobile devices, adoption of improving sensor technology, and improved EMRs. Successful implementation adopts off-the-shelf technologies, open standards, and cross-disciplinary approaches to problem solving.

Clinical studies broaden the scenarios and medical management cases important and necessary to the technology. The focus of technology needs to be on user application and outcome. Technology alone does not represent the success of a telemedical endeavor. User feasibility must be combined with patient-oriented clinical outcomes that matter. Telemedical endeavors must work toward multicultural adaptation, flexibility, cost effectiveness, and effective integration into traditional health delivery. In the context of user-focused outcomes, telemedicine can be applied to long-duration space flight.

Those involved in developing the telemedicine system must not consider only the available technologies and clinical data. A from-the-ground-up human factors approach where need drives technology is essential.

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APPENDIX

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Exploring the Currents of Telemedicine Online

Galactic Pub. wwwgalacticpub.com/telemedicine. Created February 18, 2010.

REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave Blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	January 2015	Technical Memorandum

4. TITLE AND SUBTITLE
Application of Advances in Telemedicine for Long-Duration Space Flight

5. FUNDING NUMBERS

6. AUTHOR(S)
Karina S. Descartin; Richard P. Menger; Sharmila D. Watkins

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Lyndon B. Johnson Space Center
Houston, Texas 77058

8. PERFORMING ORGANIZATION REPORT NUMBERS
S-1177

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
TM-2015-218562

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified/Unlimited
Available from the NASA Center for AeroSpace Information (CASI)
7115 Standard
Hanover, MD 21076-1320 Category: 52

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
Telemedicine is a technologically driven field that encourages innovation and creative solutions. The literature highlights advancements in the field of telemedicine in each of four categories suggested: technical, clinical, human, and cost. Significant progress is being made toward the adoption of smart machines, high-quality applications, ergonomically sound devices, and cost-effective interoperable systems that improve the delivery of care. Solutions have resulted in patients with healthier outcomes, improved processes for provider care delivery, and extension of healthcare to remote areas. The current reach and breadth of telemedicine show substantial capacity to address the healthcare needs of remote areas, extreme environments, and the medically underserved. As telemedicine evolves, it is important that the needs of the patient and operator remain in the foreground. New technologies and processes are developing. Systems continue to become more interoperable. Costs of implementation decrease. Human operation must remain the foundation. Telemedicine is the result of collaboration of minds, interest groups, and specialized interests. The goal is to increase human resources for the purpose of better and preserve human life in extreme environments.

14. SUBJECT TERMS	15. NUMBER OF PAGES	16. PRICE CODE
long duration space flight; aerospace medicine, telemedicine; medical equipment; health monitoring	62	

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited