Assessing Technological Barriers to Telemedicine: Technology-Management Implications

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***Abstract*— Telemedicine, the use of information technology to deliver health care from one location to another, has the potential to increase the quality and access to health care and to lower costs. This growth of telemedicine installations is occurring even as the utilization rates for installed telemedicine projects are falling well below expectations. Drawing on data collected from three operational telemedicine projects involving different clinical telemedicine applications, we examine how the technological barriers to telemedicine are impacting telemedicine utilization rates. Addressing technological barriers is a necessary but not sufficient condition if telemedicine is to fulfill its promise, and it is predominantly only after such barriers are addressed that the other barriers—professional, legal, and financial—come to the fore. Our findings support end-user and technical training as major barriers but do not support the quality of the video, system reliability, or the perceived inconvenience for physicians to use the equipment as barriers to telemedicine. The mismatch between the sophistication of the technology and end-user requirements for clinical activities and patient confidentiality and privacy issues were supported as barriers, but how they impacted telemedicine utilization was different than expected. Finally, unsatisfactory sound quality of the telemedicine equipment was identified as a frequent and unexpected barrier to telemedicine utilization rates.**

***Index Terms*— Medical informatics, technology management, telemedicine.**

> (T)he emphasis placed on high technology systems without sufficient consideration of the specific clinical and health care requirements and infrastructure capabilities in each setting has created a poor fit between telemedicine system design and end-user needs [1, p. 70].

TELEMEDICINE, the use of information technology to deliver health care from one location to another, has the potential to increase the quality and access to health care and to lower costs [2]–[8]. It has been earmarked as a strategic component of the National Information Infrastructure [2], [3] and is at the center of Department of Defense plans to provide better health care to its remotely located active forces [9] and revamp its network of veterans hospitals [10].

In the United States, at least 35 federal organizations were involved in telemedicine projects, and between 1994 and 1996, the federal government provided over $600 million to fund telemedicine projects. Over 400 rural health care facilities in 40 states were involved in telemedicine projects in 1996, and another 500 facilities expected to be offering telemedicine services over the next few years [5].

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I. Disappointing Telemedicine Patient Volumes

> The reported low utilization, clinical and nonclinical, [of installed telemedicine projects] in the face of abundant equipment and substantial financial commitment, is puzzling [5, p. 58].

This growth of telemedicine installations was occurring even as the utilization rates for installed telemedicine projects was falling well below expectations. Over 65% of the rural health care facilities equipped for telemedicine averaged just over eight clinical telemedicine sessions per month [5]. Overall system usage, which includes administrative and educational applications as well, averaged fewer than 16 sessions per month for 70% of the facilities [5].

Technological barriers are often cited as a significant cause of the disappointing telemedicine adoption and utilization rates [2]–[4], [6]–[8]. Technological barriers are those instances where the use of the technology is perceived as not being sufficient to perform the tasks or accomplish the objectives for which the technology was initially utilized. They include uncertainty about the adequacy of a system to support clinical activities, system reliability, ease of use, and concerns about patient privacy and confidentiality using an electronic medium [2]–[8], [11]. Drawing on data collected from three operational telemedicine projects involving different clinical telemedicine applications, we examine how the technological barriers to telemedicine are impacting telemedicine utilization rates. We focus on telemedicine clinical activities involving consultations (teleconsultations) between health care professionals located at different health care facilities in order to understand how technology barriers inhibit their ability to provide health care via telemedicine.

Addressing technological barriers is a necessary but not sufficient condition if telemedicine is to fulfill its promise, and it is predominantly only after such barriers are addressed that the other barriers come to the fore. Reducing technological barriers to telemedicine is by itself unlikely to result in major increases in telemedicine adoption and utilization rates because numerous other barriers—professional, legal, and financial [2]–[8], [11]—would still exist. Legal and financial barriers are likely to be primarily administrative in nature. However, the professional barriers will involve changing the institutionalized nature of expertise and values of professional life [12]–[14]. It should be noted that the utilization of telemedicine is driven not only by the presenting problem, but also by new opportunities that become apparent only after initial uses of the technology have been explored. Information technology often has the property that its utilization drives demand rather than demand driving utilization [15]. However, understanding how technological barriers inhibit the utilization of telemedicine is important because technological barriers were largely responsible for the failure of the first wave of telemedicine projects in the 1970's and early 1980's [4], [7].

The next section provides a brief overview of telemedicine and the technology barriers faced. The methodology used in this study is then covered. Our findings are presented, and the technology-management implications of our findings are then discussed.

II. TELEMEDICINE

Telemedicine is broadly defined as the use of information technology to deliver health care services and information from one location to another, geographically separated location [1], [2], [4]–[7]. The second wave of telemedicine is in its emergent phase, as indicated by the relatively short duration of operational telemedicine projects. Over 40% of the operational telemedicine projects had been in existence for less than two years [5].

While there is much disagreement about definitions,[1] telemedicine generally involves three major areas: teleconsultations; teleradiology; and distance learning. Both teleradiology and distance learning are excluded in this research. Distance learning, the use of information technology to provide education by linking educators with geographically separated students [7], is excluded because it does not generally involve the clinical use of the technology, while teleradiology, the transfer of radiographic images from one site to be read at another location [4], [7], is excluded because it has been widely accepted and the technological barriers have been largely overcome. Further, the process in teleradiology is very different than that of teleconsultations, as human interaction in teleradiology is minimal and the technology involved, asynchronous file transfers, is less complex. This study does not, however, exclude the transfer of radiographic images using the video cameras that are part of videoconferencing and specialized telemedicine systems because image quality sufficiency has yet to be established and because these images can be important in the telemedical clinical consultations.

A. Teleconsultations: Clinical Applications of Telemedicine

A teleconsultation, or telemedical consult, is a consultation between two or more geographically separated physicians connected through the use of information technology [4], [5], [6], [7]. Generally, a teleconsultation is between a family practice physician located at a local hospital or clinic and the relevant specialist or subspecialist, who is a member of the clinical faculty at a university-affiliated health sciences center (HSC). The patient or patients may or may not be present during the teleconsult. Table I exhibits the clinical activities included in teleconsultations.

TABLE I
TELECONSULTATION SPECIALTIES AVAILABLE

Cardiology	Ophthalmology
Dentistry	Orthopedics
Dermatology	Pathology
HIV/AIDS	Pediatrics
Internal Medicine	Psychiatry
Neurology	Social Services
Nuclear Medicine	Substance Abuse
Nutrition Services	Surgery
OB/GYN	Therapies (PT & OT)
Oncology	

B. Technology in Telemedicine

From a technology standpoint, telemedicine is the application of telecommunications and computer technologies that are already in use in other industries [1], [2], [4]–[7]. The technology includes the hardware, software, and communications link of the telemedicine project. The technology infrastructure is a telecommunications network with input and output devices at each connected location. Table II summarizes the range of technology used in telemedicine.

Both the most simple and complex technologies involved in telemedicine have been excluded from this study. Telephones and faxes are excluded because they are widely accepted and involve no major technology-management issues. Technologies such as robotics and virtual gloves, used in telesurgery and virtual examinations, are excluded because they are not currently deployed in ongoing telemedicine projects and are unlikely to become a standard component for a number of years.

1) Technology Barriers—Technological Capabilities Versus Clinical and End-User Needs: Potential technology barriers to telemedicine include whether the technological capabilities of the equipment are sufficient to meet clinical requirements [2], [4], [7] and whether features related to using the technology inhibits health care professionals from engaging in teleconsultations [1], [2], [4]–[7]. One potential technological barrier concerns the quality of video images transmitted being sufficient to meet the clinical needs of the health care professionals [3], [4], [5], [7]. Teleconsultations often require physicians to examine transmitted radiographic images, yet the video cameras used to transmit the images do not meet the minimum resolution standards for digitized radiographic images set by the American College of Radiology,[2] nor does the teleconsultation equipment include digitizing scanners capable of transmitting such images [4], [5]. Another concern

[1] There is not a generally agreed-upon definition for telemedicine, with most of the controversy centering around what activities are included in telemedicine, and whether the term telemedicine or telehealth should be used. See [1], [4], and [5] for more details.

[2] These American College of Radiology has set standards of 2000 $\times$ 2000 pixels per square inch for mammographies and 1000 $\times$ 1000 pixels per square inch for all other digital radiographic images. These standards are for all digitized radiological images and not just teleradiology.

TABLE II
TELEMEDICINE EQUIPMENT AVAILABLE

Type of Media Used
Copper Telephone Lines
Fiber Optic Lines
Satellite
Microwave
Radio
Co-Axial Cables
Telecommunication Services Available
Switched
Switched 56K
ISDN
ATM
Dedicated
Fractional T1
Full T1 (or multiple T1)
DS-3 or T3 (45 Mbps)
Peripherals
Endoscope
Electronic Stethoscope
Otoscope
Ophthalmoscope
Dermascope
Microscope
X-Ray Scanner
Document Camera
Remote Monitoring Equipment
Real-Time Videoconferencing
Studio Videoconferencing
Desktop Videoconferencing
Full-Motion Uncompressed
Video Full-Motion Compressed
Video Analog Transmission
Digital Transmission
Data/Image Transfer Systems
Real Time
Full-Motion Interactive Video
Still Images with 2-way Audio
Video "clips" with 2-way Audio
Store and Forward
Still Images for Later Review
Video "clips" for Later Review
Text E-Mail
Types of Cameras Available
1-chip CCD Camera
3-chip CCD Camera
Analog Video Camera
Digitizing Still Image Camera
Document Camera
Macro Lens Camera with Peripheral Scope
Laser Scanner

is the sufficiency of real-time continuous motion images when teleconsultations involve illnesses or injuries where motion is needed to make diagnosis or monitor patient progress, and whether the images resulting from the use of peripherals are sufficient [2], [3], [4], [7].

Other potential technological barriers center around the ability of health care professionals to use the equipment [2], [5], [7]. The technological sophistication of health care professionals vary, and rural health care professionals, the primary users of the technology, are perceived as being the least technologically proficient [5]. Further, physicians may be reluctant to admit they do not know how to use the telemedicine equipment. End-user training is needed to overcome these barriers, but end-user training is difficult, especially for rural health care professionals [2], [7]. Insufficient end-user training of both the rural health care professionals and the specialists at the health sciences centers has the potential to be a significant barrier to teleconsultations.

The inconvenience of using the telemedicine equipment is also a potential barrier [2], [7], [11]. Teleconsultation equipment at health sciences centers is often located at a telemedicine studio, which is some distance away from the physicians' offices and inconvenient for them to use. Desktop teleconferencing units would solve the inconvenience problem, but concerns about their image quality abound [2], [7], [11]. Lastly, the perceived vulnerability of electronic patient records and the teleconsultation transmission to unauthorized access provides another technological barrier to engaging in teleconsultations [1], [2], [4]–[7]. The next section presents our methodology for researching how these barriers impact teleconsultation utilization rates.

III. METHODOLOGY

Three telemedicine projects, each involving a health sciences center and a rural health facility, were researched. Multiple case studies, relying on semistructured interviews of key informants, were used in this research. The case study method is used when:

> A how or why question is being asked about a contemporary set of events over which the investigator has little or no control [16, p. 9].

Case studies are in-depth studies of a few instances of the phenomenon of interest geared toward providing the thick description required to understand and explain emerging phenomenon [16]–[18]. Multiple cases can provide the researcher with an even deeper understanding of the phenomenon of interest, and validity and generalizability can be enhanced through the replication of results using multiple cases [16], [18]–[20]. Further, while controlled observations of a control and treatment group may not be possible, the deliberate selection of cases can result in natural controls [16]. Therefore, this research project used the multiple case study design.

A. Sample

Three teleconsultation projects were researched. Given the emergent nature of telemedicine, literature on specific clinical teleconsultation applications is scarce and the literature that does exist often focuses on different aspects of teleconsultations, making across similar clinical application comparisons difficult [4], [7], [21]. To overcome this limitation, our sample included teleconsultations that make up the majority of the situations: primary care physician to multiple specialists; specialist to specialist; specialist to patient; and specialist relying on technology to nonphysician primary care provider. Each project involved a telemedicine relationship between an HSC and a rural health care facility. Telemedicine projects involving health sciences centers were selected to be part of the sample because they are involved in the majority of

TABLE III
SITE INFORMATION

	SITE I	SITE II	SITE III
Date Started	• 1995	• 1996	• 1989
Clinical Activity	• Infectious Diseases • Pediatric Oncology	• Oncology—Bone Marrow Transplant	• Multiple Specialties
Site Location	• Southwest United States	• Western United States	• Southwest United States
Distance To HSC	• 200 Miles	• 300 Miles	• 400 Miles (200 To Nearest HSC)
HSC Equipment Location	• Telemedicine Studio And Desktop Unit	• Transplant Administrative Area	• Telemedicine Studio
Telecom Link	• Full T1	• Full T1	• Full T1
Rural Facility Type	• Hospital	• Physicians' Clinic	• Hospital
Rural Telemedicine Equipment Location	• Administrative Conference Room • (2nd Unit Being Installed In Clinical Area)	• Administrative Area • (Originally In Reception Area)	• Administrative Conference Room
Rural Facility Telemedicine Equipment	• VTEL Videoconferencing Equipment • 3 Chip CCD Camera • Echo Canceling Audio • Document Camera • Otoscope • Opthalmoscope • Electronic Microscope • Dermascope • Electronic Stethoscope	• PictureTel Videoconferencing Equipment • 1 Chip CCD Camera • Echo Canceling Audio	• Own System Using Non-Proprietary Hardware • 1 Chip CCD Camera • Push To Talk Audio • Backlit Shelf • Document Shelf • Xenon Light Source With Dermascope, Otoscope, and Opthalmoscope Accessories
System Utilization	• Multiple Times Per Week	• 1 Per Week	• 1-2 Times Per Week

nonmilitary telemedicine projects [4], [5], and they provide a means of natural control of nontechnological barriers to teleconsultations. Health sciences center had the benefit of not having a number of the legal, cultural, and financial barriers associated with teleconsultations. Licensure was not an issue as our sample included only intrastate telemedicine, and liability issues were minimized because the physicians were covered by the HSC's umbrella liability policies and were engaging in HSC-sanctioned telemedicine projects, minimizing their personal risk. The HSC's in this study had embraced telemedicine, and physician participation in these telemedicine projects was voluntary, reducing cultural issues. The cost of the systems and the telecommunications link had already been funded, usually through grants, eliminating cost considerations as a barrier to utilization during the time these projects were studied. The physicians at the HSC's were not reimbursed for their teleconsultations; however they were employed by the state and paid a salary. Further, each HSC was charged in its charter to improve the access and quality of care of the rural population in their respective states.

Each of the telemedicine projects had to be operational for a minimum of six months to allow the inevitable technological and procedural bugs to be addressed and to allow the novelty of telemedicine to pass. Each of the sites was connected by a T1 line. Site I used VTEL equipment, and the primarily clinical activities involved pediatric oncology and infectious diseases. Site II used PictureTel equipment initially to screen and follow up with oncology patients undergoing bone marrow transplants. Site III used a system it designed and built itself to provide access to multiple medical specialties. Table III provides a summary of information about each site and its teleconsultation activity.

1) Site I—Pediatric Oncology/Infectious Diseases: Site I was located in the southwestern part of the United States. The telemedicine project began in 1995 and involved a local hospital approximately 200 mi from HSC I. The teleconsults initially focused on monitoring pediatric oncology patients. An infectious diseases specialist was located at another facility and initially once a week drove 45 min to the main HSC I campus for telemedicine consultations. A VTEL desktop videoconferencing unit was installed in the specialist's office in 1996. The telemedicine equipment at the rural hospital was located in the hospital's conference room, which was used for activities other than telemedicine. The rural hospital had recently received another telemedicine unit, which it had installed in the clinical area of the hospital. This equipment was not connected to the network at the time of the researchers' visit.

2) Site II: Oncology—Bone Marrow Transplant: Site II was located in the western part of the United States. The telemedicine project became operational in Fall 1996. It involved a private oncology clinic approximately 300 mi from HSC II, and the bone marrow transplant unit at HSC II, which was ranked as one of the top ten in the United States. Bone marrow transplant procedures require a one to three month stay in isolation at a hospital and cost between \$40 000 and \$120 000 per patient (depending on the type of transplant performed). Prior to telemedicine, the clinic sent approximately half its bone marrow transplant patients to HSC II, and the rest to a facility in another state that was equidistance from the clinic. In addition, once a month a bone

TABLE IV
SUMMARY OF FINDINGS

TECHNOLOGY BARRIERS	Expected	Not Expected
Supported	• End-User Training	• Audio Transmission Quality
Not Supported	• Convenience	
	• System Reliability	
Supported But Not As Expected	• System Design	
	• Patient Privacy And Confidentiality	

marrow transplant specialist from HSC II would drive or fly down to the clinic to monitor patients and determine which patients were candidates for a bone marrow transplant. Both geography and weather often made such travel difficult. In Fall 1996, HSC II installed at their cost a telemedicine system at the clinic, with the agreement that HSC II would have first referral of the clinic's future bone marrow transplant candidates, which averaged roughly 12 per year. The telemedicine equipment was in the bone marrow transplant conference room at HSC II. At the clinic, the equipment was initially in its waiting room but was later moved to an administrative area when the clinic expanded. Teleconsults occurred roughly three to four times per month on Thursday afternoons.

3) Site III—Multiple Specialties: Site III was located in the southwestern part of the United States. The local hospital was approximately 400 mi from HSC III, and 200 mi from the nearest HSC (which was affiliated with HSC III). The telemedical relationship began in 1989 and involved multiple specialties, including but not limited to neonatology, surgery, orthopedics, nephrology, and physical therapy. The equipment at HSC III was located in a special telemedical broadcast setting, while the equipment at the local hospital was located in an administrative conference room. Consultations were usually held on an as-needed basis, approximately twice a week, and were scheduled two to three days in advance.

B. Data Collection

Triangulated data collection was used to enhance the reliability and validity of case studies [16], [17]. Triangulated data collection was achieved in this study by two means. First, different perspectives were obtained by interviewing multiple key informants from three different functional groups at both the local health care facility and the health sciences center involved in each of the telemedicine project studied. Second, additional data sources other than interviews were used. We observed telemedicine consultations or videotapes of such teleconsultations when possible and collected archival data such as grant proposals and follow up, needs assessments, and strategic plans when available.

Fifty-one health care professionals were interviewed, and the interviews were audiotaped and transcribed. Issue-focused, semistructured interviews of key informants were used in order to provide the thick and richly textured data needed [12]. These interviews focused on the actual usage of the telemedicine equipment. The key informants were intentionally selected based on their current or past direct involvement in their organization's telemedicine project and their availability. Key informants were members of one of three groups—health care providers (physicians, physician assistants, or nurse practitioners), administrators, and information technology professionals. Each site was visited by a researcher, and all interviews of the health care professionals at both the health sciences centers and the rural health facilities were face-to-face.

An emergency teleconsultation involving infectious diseases was observed, and a videotape of parts of ten telemedicine sessions involving neonatology, surgery, and nephrology were viewed. Grant applications and status reports, telemedicine need assessments, and organizational strategic plans for telemedicine also provided data about the relevant telemedicine projects. To validate findings from the case studies, a half day teleconsultation involving HSC III and three correctional facilities were observed.[3] Section IV presents our findings.

IV. FINDINGS: TECHNOLOGY-RELATED BARRIERS

Table IV presents a summary of the findings. The findings were classified into one of four categories. The first category was those barriers that were identified in the literature and supported by our findings. These includes end-user and technical training. The second category was those barriers expected to be in effect but which were not supported by our findings. These included: the quality of the video images transmitted, both real-time full motion and still image; the convenience or inconvenience for physicians to use the equipment; and the reliability of the system. The third category involved those barriers that were expected and supported by our findings, but they acted as barriers to utilization in a manner that was not expected. The mismatch between the sophistication of the technology and end-user requirements for clinical activities, and patient confidentiality and privacy issues made up this category. Finally, the last category included an unexpected barrier identified during the course of our study: the sound quality of the teleconsultation equipment.

A. Expected and Supported

1) End-User Training: While some information technology professionals believe the teleconsultation equipment was so easy to use "a child could operate it," a number of physicians believed the lack of end-user training resulted in a barrier to the usage of the teleconsultation equipment. For other physicians, the lack of end-user training prevented them from taking full advantage of the equipment's features. One

[3] These correctional sites were not part of the sample; however, the technology, the specialties offered, the specialists involved, and the consultative process were identical to the telemedicine consults involving the rural facilities. The only major differences were the ratios of specialties utilized.

physician who frequently used the equipment had not been trained how to use it, other than how to turn it on. She was frustrated by her inability to control the system and her lack of training.

> Another limitation of this piece of machinery is that no one showed me how to run it—other than, I can turn it on and turn the volume up and down and that is about it...they give me all this and I don't know what it's for.

Her experience was common. Another common problem resulting from the lack of end-user training was that the physicians would sometimes believe the system was not working, when it actually was. As one information systems professional at Site I explained:

> If the physicians do not know how to use the equipment, or if they are afraid of the equipment, they say the equipment doesn't work when actually the physicians don't know how to use it.

B. Expected and Not Supported

1) The Quality of Video Images Transmitted: The quality of the video images captured and transmitted, either real-time full motion or radiographic images using the video camera, was not a barrier to using the telemedicine equipment for clinical activities. Peripheral device images were a barrier in some cases, but otherwise video image quality was almost universally judged to be sufficient for clinical needs, and in most cases exceeded expectations.

a) Real-time full-motion video: The real-time full-motion video images were judged satisfactory not only for consultations involving primarily conversation, but for physicians who needed to evaluate motion in order to make diagnosis. A pediatric specialist found the quality of the video images sufficient to identify the source of a patient's gait disturbance as neurological and refer the patient to a neurosurgeon. Another pediatrician found the video images useful because children sometimes are unable to verbalize how they feel, and seeing whether a child was active or lethargic helped the physician. One physician used the system to provide a handicapped child access to speech and physical therapy sessions not available locally.

b) Radiographic images: The transmission of radiographic images was expected to be a major barrier to using the teleconsultation equipment because none of the three sites had a digital scanner, nor did they have cameras with resolutions that met the standards for digital radiographic images set by the American College of Radiological Society. However, the physicians still found the quality of still radiographic images transmitted using either the video camera focusing on a backlit image or a standard Elmo document camera were more than sufficient for their needs. An oncologist involved in the transplant project at HSC II stated:

> Looking at the (patient's) X-rays directly over the [telemedicine setup] has been very helpful. They come through clearer than I ever imagined they could.

The radiologists were ambivalent about the quality of the images transmitted. Some of the physicians had asked radiologists on occasion for their interpretation of images transmitted via the teleconsultation equipment. The infectious diseases specialist at HSC I gave the following example.

> I had the radiologist come over here and he said he would not be willing to give a formal, legal reading off of it but he could give what they sometimes call a wet (preliminary) reading. It would be similar to if they were doing an upper GI and they were watching a fluoroscopy, they would be watching it on a screen but not the printed sinofilm. So he was also able to make a wet reading, but legally, he felt uncomfortable reading films off of it.

The physicians felt the ability to zoom the cameras in on a particular part of the x ray more than compensated for any loss of resolution that might occur using the video or document camera. One physician felt one feature lacking from these systems was the ability to project on the screen multiple images at the same time. She wanted the ability to examine the progression of a disease over time by saving images and retrieve them and displayed them simultaneously.[4] Otherwise images transmitted were sufficient.

> For me as a clinician, most of the time now if I had actually the film in the office wouldn't be anymore helpful than seeing it on the screen when they are able to zoom in on an area.

c) Peripherals: Peripherals did in some cases prove to be a barrier to teleconsultations. Two oncologists found using a direct ophthalmoscope unacceptable for their needs. The oncologists needed an electronic indirect ophthalmoscope (which was available but expensive) to see the whole eye to be comfortable with their conclusions.[5] The other frustration specialists at the HSC's expressed was their inability to freeze an image being projected. Only the local health care professional had the ability to freeze an image, and the specialist telling the remote site when to freeze was not workable due to the slight delay in transmitting the message.

2) Convenience—The Location of Telemedicine Equipment: While the inconvenience the physicians had to incur had the potential to be a major barrier, the teleconsultation projects studied had managed to avoid this barrier. The major source of inconvenience for specialists at the HSC's was unscheduled, emergency teleconsultations that required them to interrupt what they were doing and walk to the telemedicine studio, which at two HSC's was quite a distance from the physicians' offices. However, these emergencies did not materialize, because there were not many emergencies that required immediate teleconsults, and because teleconsults were considered a poor way to address such emergencies. As one physician at HSC III argued:

> How many emergencies do you have? That's what you publicize and you show and all that sort of stuff. ...In the emergency room in the (rural areas) as far as I'm concerned, there has always been one decision: I keep or I send. And if they send they shouldn't be screwing

[4] The desktop VTEL system she was using may have had the capabilities to save and display multiple images simultaneously, but she had not been trained to use the system.

[5] One of the earliest signs of a relapse in pediatric leukemia is the appearance of abnormal clusters of cells in the eye. Therefore the oncologists needed to be able to examine the whole area of the inner eye.

> around with all this, all this consultative service and all that sort of thing...Now if I'm a surgeon out there and I have the facilities, I might decide to keep the patient, but if I'm a general practitioner with no surgical experience, or if I'm a physician assistant or a nurse practitioner—I don't care how great my facilities are, I'm going to ship. I'm going to get them out of there. And if I'm a surgeon and I don't have the facilities, I'm going to get them out of there anyway because I have nothing to work with.

Instead, most quasi-emergencies required a consult with a specialist within a few days, and these consults were scheduled one to three days beforehand, or dealt with during the regularly scheduled teleconsults. This enabled the physicians to schedule their day, and made the travel worthwhile because they would often see multiple patients at one teleconsult.

The physicians at the rural facilities were satisfied with this arrangement. They too felt the concept of using the telemedicine equipment for emergencies was overblown, although they generally agreed that if there was an emergency where transferring the patient was not an option, the HSC's would do what they could to assist the local physicians. As one rural physician described:

> Well, I don't use it much for emergency-emergencies, like "Oh my God" emergencies. I use it for urgent things when people are in the hospital and you want to have an answer before you discharge them. Most of them are scheduled a day or two down the way, but if you need to, you know, pull out the stops and get somebody from the other end, it's not hard. They'll find someone by wandering the halls if they need; but, you know, I don't abuse that at all, because you know, you don't cry wolf.

The telemedicine equipment was also made more convenient by the installation of a desktop unit for one specialist who was a 45-min drive away from the health sciences center. Desktop videoconferencing units were correctly viewed as a means for overcoming convenience barriers to using telemedicine equipment, but the cost and performance of such units prevented them from being widely installed. However, the features needed for desktop videoconferencing equipment tended to be overestimated, and HSC II found basic desktop videoconferencing units sufficient.

A VTEL desktop unit based on a personal computer running Microsoft Windows 3.1 was installed in the office of the infectious diseases specialist. It had a small camera attached on top of the computer, and an omnidirectional microphone attached to a cord. She used the equipment to teleconference with another physician and to look at x rays. She found the desktop machine to be satisfactory for her purpose. She felt the video was just as good as that of the equipment at the studio, but the sound on the desktop machine was markedly inferior. Her assessment was:

> I can see the X-rays as well on the small equipment as I could on the larger equipment. I don't seem to be able to hear as well so I more frequently have to ask them to repeat themselves so that I can hear what's being said. I also don't discern the words as well...There's also more of a delay with this machine. Its very distracting. I never noticed it or it never bothered me with the equipment at the Health Sciences Center but the small unit really does seem to have a significant problem with that delay factor.

3) System Reliability: System reliability, contrary to what was expected, was not perceived as a barrier to telemedicine consultations. This was in spite of the poor reliability experienced with earlier telemedicine hardware/software configurations. The newer systems installed were judged to be quite stable. Despite the stability, there were major concerns with the reliability of the telecommunications link. While all the sites had experienced problems with the telecommunications link once or twice (usually involving the T1 line being accidentally severed), they felt problems with the telecommunications link were very rare. What concerned them was the potential for failure they could not address. All three projects involved rural sites in different local access transport areas (LATA's) than the health science center with which they were affiliated. As a result, the telecommunications link involved more than one telecommunications provider, which increased the likelihood of a telecommunications failure and made addressing such failures a much more complicated task. Information technology professionals were particularly concerned as they could not realistically prevent such problems from reoccurring. As one information technology professional described the problem:

> Let's say I want to go from [Town A] to [Town B]. It's about 100 miles or so, but it crosses into another LATA. So to get there I have to take [local RBOC] and backcall to [City 1] for whatever my bandwidth is going to cost me. I have to then buy a local loop to AT&T and incur a certain expense. Then I have to hop on to AT&T to get to [City 2], which is across a LATA boundary from City 1. Then I have to buy a local loop from AT&T to the local RBOC again. Then I have to backcall almost to Town B where I have to hop from local RBOC to [Rural Telephone Company]. And other than being expensive it's fine. Except if something goes wrong, how do I fix it? It will get fixed—maybe in a couple of days. But, first of all, nobody will admit that it is their problem. Second of all, I can't fix it permanently—I can't prevent it from happening again. It's a horror story.

C. Expected and Supported in Unexpected Manner

1) System Design and User Requirements: The ability of telemedicine equipment to effectively support teleconsultations was indeed a barrier to its usage, but in an unexpected manner. The expected barrier was the technology being incapable of supporting teleconsultations. The actual barrier was the "gold-plated systems" [7] being installed, which were overly sophisticated and difficult to use. There was agreement among the different sites that the systems being developed and sold had expensive capabilities not really necessary. There was also a tendency for the system manufacturers to oversell the systems' capabilities, compatibility, and ease of use. These gold-plated systems often required significant training time to use, and physicians frequently did not have the time to attend such sessions. As a result, physicians often did not know how to use the system, and, as one information systems professional described, they had "egos larger than life" which prevented them from asking for assistance. He described what often happened.

> He (a physician) developed a relationship with a few vendors and learned just enough about the technology to be dangerous with it. Every time he went to conferences in his own field there were vendors out there that were trying to sell something and he'd pick up information on it and say "Oh yes, this will work great." And from his point of view it's a great fit. Now many product manufacturers made comments about capabilities of products that weren't possible. They oversold the product. They also tried to simplify in such a way that it confused people about what the reality of the products were. They didn't mention that their product compatibility within their own suite of products just wasn't there yet. But when they sell this to someone who is eager to buy into the concept they eliminate—they don't mention these problems. Now you have someone walking through the door who says, "Oh no the vendor says this will work great and this is the way it is used and look how easy it is." Now you have to sit them down and expose them to reality and one of two things will happen. Either you instantly lose credibility and he storms out the door and you become—it's a negative encounter and you try and recover from it if you can. You get the stigma of being nonresponsive and resistive. Or in this case we were fortunate—he acknowledged and was gracious enough to accept the fact that maybe we knew a little more about this than he did and at that point we turned it into a learning experience.

The information technology professionals at the HSC's preferred to start with basic systems and then upgrade as the users became more sophisticated. The use of basic systems avoided situations where the system itself worked, but the physician did not know how to operate it. Finding basic systems were difficult, however. A physician at HSC III expressed the frustration his institution had in trying to find the right telemedicine system. Vendors attempted to sell expensive systems with features not needed. Ultimately, the institution decided to develop and build their own very basic modular telemedicine system which used no proprietary parts. As the physician described:

> One of the premises we went on was we didn't want a whole bunch of equipment. Everybody's trying to sell all this crap. No! We're going to tell you what we need and no more. So therefore the [telemedicine system] was designed to our specifications. I need just what I need to have a consultative service with the provider concentrating on what he is doing and he has very little equipment to manage. I don't need two cameras and I don't need this and I don't need that and I don't need a technician on either end.

This system, while using basic technology, was upgradable and scalable. The system had a modular design and used standard input and output ports. New peripheral devices could be added as they were developed, and each part of the system could be replaced as the technology evolved.

2) Patient Confidentiality and Privacy: Each site felt the concerns about patient confidentiality and privacy when using an electronic medium to conduct consultations and store patient records were exaggerated and not a barrier to telemedicine usage. The sites interviewed acknowledged the confidentiality and privacy issues and had taken steps to address these concerns. They also believed the ease of accessing traditional paper-based records was underestimated and the ease of accessing electronic patient records was overestimated. One physician felt electronic records could be done in a manner to help ensure privacy by keeping track of who accessed what records.

> All you need to do is have an electronic record of access. You do physical security—hey, my door locks, okay. You can do password, you can do encrypting, you can do dedicated T1 lines but the bottom line is we actually have better security here because you'll leave a finger print on that piece of data that you touched, and if you're not supposed to be touching it, that's the last time that you'll get into any of the data bases that run in this hospital. In health care you're depending on somebody's integrity as a professional from a confidentiality standpoint. Well, this is an electronic record of that integrity.

Yet patient privacy in telemedicine added degrees of complexity and was threatened in ways not usually considered nor faced in the traditional consultation. Privacy concerns increased when a second person was needed in the room to operate the equipment, and when technicians at the receiving end monitored telemedicine activities. The equipment at all three rural sites was situated in a conference room or other nonclinical areas of the hospital, which unexpectedly created patient privacy issues. An information technology professional described one particular teleconsultation.

> One of the problems that we do run into is that some of the nurses don't want to operate the equipment, so they have either myself or (another information technology professional) in there and it's very uncomfortable because the patient is crying, or the mother crying. . .I was in a situation where we were doing a pediatrics [exam] on a young man. He was about 14 years and had some kind of lesions on his back that went down to his buttocks. The doctor needed to see the ones on his lower back. The mother started crying and she walked out the door to get a hold of herself. So she walked out the door [leaving it unlocked]. The guy had his pants down and his shirt off. He was standing up and the nurse was using the dermascope to show the lesions to the doctor, when, low and behold (the facility director) walks in with a group [the local chamber of commerce] giving a tour. And he starts giving his talk and meanwhile the young man is standing there with his pants down. So the nurse stands up and looks at the director and said, "Excuse me but we're having a consultation here." But the director is still talking away, and (finally) the nurse yells at the manager, "Excuse me but we're having a consultation

> with a patient here!" And the director turned red because he finally figured out that this was not a demonstration but an actual consult. . . .The kid was embarrassed, super embarrassed. . . (Later) they said, "Well you should have locked the doors." "Hey wait a minute, the doors were locked. It's not our fault the mother walked out and left the back door unlocked."

D. Unexpected Barriers

1) Audio Transmission Quality: The quality of the video images transferred was consistently identified in the literature as a barrier to the usage of telemedicine equipment, while the quality of the audio transmission was assumed satisfactory. Yet it was the quality of the audio portion of the teleconsultations that was frequently viewed as an inhibitor to engaging in more teleconsults. The audio transmission was judged as being substandard or unacceptable when a large room or more than three people were involved in a teleconsult, or if the patient had an accent. The main audio complaints for teleconsultations involved the poor sound quality overall. One physician complained about the sound giving her a headache and limiting the time she could spend using the system; often she would mute the sound and use the telephone instead. A major contributor to the poor sound quality was that the rooms being used almost always were not designed to be studios, and whose acoustics were naturally poor. Improving a room's acoustics can be very expensive. As an information technology professional at HSC I described:

> You didn't architecturally build the room for teleconferencing. So if you expect good acoustics from a hollow concrete box, you've got another thing coming.

Local sites also had problems with loose microphone connections creating static during the consult, and the inability for the microphone to reach all parts of the room. Further, equipment settings were often changed at sites where people used the equipment for other purposes, such as education and administration. Another problem was the slight time delay in receiving the audio made natural conversation difficult and impeded the ability to exchange ideas. Feedback and the echo canceling features not working were common complaints, as were missed comments when large groups were involved.

V. Discussion and Conclusion

Interesting surprises about technological barriers to teleconsultations were identified in the research project. First, the technology creating the most problems was the one most taken for granted. Sound quality was considered a given; it was the quality of video images that was supposed to be a major barrier. Instead the video quality exceeded expectations, and it was the audio portion that was a barrier to utilization.

Second, the mismatch between technological capabilities of the telemedicine equipment and end-user needs was a barrier, but instead of the technology being insufficient, it was too complex and sophisticated for some health care providers to use effectively. Third, the aspects of teleconsultations which created threats to patient confidentiality and privacy came not from the technology itself, but from training and facility issues those involved in the management of the technology should be able to address.

Our findings supported a well-recognized barrier to telemedicine utilization: the training provided the physicians, physician assistants, and nurse practitioners who were the primary end users of the telemedicine equipment. What made our support of this seemingly obvious barrier interesting was the extent to which the lack of end-user training negatively impacted teleconsultation utilization. The lack of end-user training inhibited some health care providers from using the equipment, and others from maximizing the value the teleconsultations could provide. It also increased the technical support needed to address minor or nonexistent technical problems a trained end user could have dealt with on his or her own.

One implication for management of the technology is the telemedicine equipment needed, and its cost, appears to be substantially less than previously thought. Our research indicates teleconsultation projects should begin with only very basic equipment. As the physicians use and become more familiar with it, and as the telemedical clinical activities for that location evolve, additional equipment can be added. One physician suggested a basic videoconferencing unit and a document camera (which could double as a dermascope), would be sufficient to start a teleconsultation service.

Further, the simple technologies should not be taken for granted. Audio problems caused more complaints and more disillusion with the telemedicine equipment than the other barriers. In addition, end-user training must be included in any telemedicine project.

Unfortunately, those whose position it is to support these programs are likely to get blamed for problems over which they do not have control. Information technology professionals are concerned about system reliability and have the knowledge to address these problems, but they are unable to deal with such issues until after the system goes down. System reliability, in particular, problems involving multiple telecommunications companies, will continue to be a concern.

This research project has identified a number of mismatches between the technological capabilities of the telemedical equipment and clinical needs or end-user training. The sophistication of the equipment appears to have advanced faster and further than expected. The technological barriers expected were based on the assumption the capabilities of the technology trailed the clinical needs. Our research indicates the opposite may have occurred and raises an intriguing question of whether the technology has advanced faster than the standards meant to govern its usage. There appears to be a mismatch between the capabilities of the technology and the standards set. While none of the systems studied met the American College of Radiology image resolution standards, all of the teleconsultations used the video cameras to read radiographic images. This research project has examined how technological barriers impact telemedicine utilization rates. Reducing technological barriers to telemedicine is a necessary but not sufficient condition if telemedicine is to fulfill its potential; however, this will not in and of itself increase the utilization of telemedicine because other barriers—professional, legal, and financial—will still exist. It is an important area of research because technological barriers were largely responsible for the failure of the first wave of telemedicine projects in the 1970's and early 1980's. One area future research on technological barriers to telemedicine should address is whether the standards by which the technology is governed are appropriate and whether they act as unnecessary barriers to the increased utilization of telemedicine.

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