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**Telemedicine and International Disaster Response:
Medical Consultation to Armenia and Russia
Via a Telemedicine Spacebridge**

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ABSTRACT

Introduction: The Telemedicine Spacebridge, a satellite mediated audio-video-fax link between four U.S. and two Armenian and Russian medical centers, permitted remote American consultants to assist Armenian and Russian physicians in the management of medical problems following the December 1988 earthquake in Armenia and the June 1989 gas explosion near Ufa. **Methods:** During 12 weeks of operations, 247 Armenian and Russian and 175 American medical professionals participated in 34 half-day clinical conferences. 209 patients were discussed, requiring expertise in 20 specialty areas. **Results:** Telemedicine consultations resulted in altered diagnoses for 54, new diagnostic studies for 70, altered diagnostic processes for 47, and modified treatment plans for 47 of 185 Armenian patients presented. Simultaneous participation of several U.S. medical centers was judged beneficial; quality of data transmission was judged excellent. **Conclusion:** These results suggest that interactive consultation by remote specialists can provide valuable assistance to onsite physicians and favorably influence clinical decisions in the aftermath of major disasters.

INTRODUCTION

On 7 December 1988, the Republic of Armenia suffered an earthquake of massive proportions. With over 25,000 early deaths—including many health care workers, and over 125,000 survivors in need of medical attention—Armenia's crippled medical care system initially was overwhelmed (1). Wishing to utilize space communications technology to facilitate medical assistance in the aftermath of the earthquake, the co-chairmen of the U.S./U.S.S.R. Joint Working Group on Space Biology and Medicine proposed a satellite mediated medical telecommunications network to permit physicians at U.S. medical centers to provide consultation to physicians in Armenia. This project was called Telemedicine Spacebridge. On 4 June 1989, near the city of Ufa in northern Russia, 2 trains, each carrying over 500 passengers, passed each other within a cloud of natural gas arising from a pipeline leak. The gas exploded; most of the passengers in one train were killed outright; hundreds of passengers in the other train—many of them children returning from summer camp—suffered severe burns. The Spacebridge was extended to permit American burn specialists to provide remote assistance to Russian physicians caring for burn victims in Ufa.

TELEMEDICINE BACKGROUND

Simply defined, telemedicine is medicine at a distance. The history of distant health care providers exchanging information about patient and topic oriented medical problems parallels the

history of medicine and technology. In the first half of this century, where telephone communications were unavailable or inadequate, medical radio networks were created to link onsite health care workers with urban medical centers. Health care providers in the Canadian northern territories and the Australian "outback" were early users of such networks. In the second half of the century, video image and fax transmissions greatly improved information transfer. Interactive video systems further increased the ability of remote consultants to guide clinical decision making in real time; the settings just cited were early beneficiaries of this expanded capability (2,3).

While didactic education has been (4-6) and remains (7,8) the most common medical use of video teleconferencing, the technology has been applied to clinical care activities in wide geographic distributions, varied practice settings, and many specialties (9,10). Concepts often were proved in urban environments: Teleradiology experiments began as early as 1950 (11). In 1964 in Nebraska, neuropsychiatric consultations were provided via two-way closed circuit television, demonstrating adequacy of transmission of neurological physical examinations and electroencephalograms (12). Beginning in 1967 in Boston, video mediated remote consultations in psychiatry, radiology, and dermatology were provided by physicians at Massachusetts General Hospital to employees and passengers at Logan Airport (13). Yet probably the most essential contributions of interactive telemedicine have been realized in clinical practice (14,15) and continuing medical education (16,17) in rural settings. The more remote and extreme environments particularly have benefitted (18-20).

Video mediated interactive consultations have been provided in anesthesiology (21,22), cardiopulmonary medicine (23), critical care (24), dental forensics (25), dermatology (13), emergency medicine (26,27), family practice (28), ophthalmology (29), and pediatrics (30). However, the specialties that stand out among early, frequent, and comprehensive providers of video mediated remote consultation are pathology (31,32), psychiatry (13,33,34), and radiology (35-37). Particularly within these last three specialties, remote diagnostic accuracy has been evaluated repeatedly (38-44) and found to be generally satisfactory. Although there are prior reports of the use of satellite mediated telecommunications for intercontinental clinical consultation (31) and international medical education (7), the Spacebridge project appears to represent the first use of interactive video telemedicine to provide remote multidisciplinary consultation to physicians in post disaster settings abroad.

TELEMEDICINE SPACEBRIDGE ORGANIZATION AND PROTOCOLS

In March 1989, representatives of the National Aeronautics and Space Administration (NASA) and four U.S. medical centers traveled to the U.S.S.R. In Armenia, visits to Spitak, the largest city near the earthquake epicenter, and the Republic Diagnostic Center in the capital city of

Yerevan, provided the Americans an opportunity to appreciate first hand the extent of destruction, understand the existing health care system, and meet Armenian physicians. In Moscow, meeting under the auspices of the U.S./U.S.S.R. Joint Working Group on Space Biology and Medicine, representatives of NASA and the U.S.S.R. Ministry of Health agreed to proceed with the Spacebridge project, and a general operations protocol was written. In April 1989, representatives of the Ministry of Health and the Republic Diagnostic Center visited NASA and the four U.S. medical centers, and a medical implementation plan was written.

The general operations protocol identified NASA Headquarters (Washington, DC) as the point of administrative coordination for U.S. activities, "Soyuzmedinform" of the Ministry of Health (Moscow) as the point of administrative coordination for Russian and Armenian activities, NASA Goddard Space Flight Center (Maryland) as the point of coordination for a satellite mediated telecommunications network, and the four U.S. medical centers shown in Table 1 (adjacent to their locations) as the primary sources of clinical consultation. The protocol specified two-way audio and fax and one-way video transmissions to link the Republic Diagnostic Center in Armenia to the four U.S. medical centers and NASA Headquarters until 1 July 1989. The Americans agreed to provide a portable satellite Earth station and video teleconferencing equipment, with "scrambled" signals to protect patient privacy. The Russians and Armenians assumed responsibility for language translation.

The medical implementation plan identified the categories of medical problems and topics for which the Armenians desired clinical consultation and medical education sessions, specified protocols for requesting and rendering consultations, and described protocols for radio transmission and use of language interpreters. The plan included a tentative 2-month schedule of operations with a nominal broadcast schedule of 4 hours daily (0900-1300 EDT; 1800-2200 in Yerevan), 5 days weekly. Clinical consultations and educational presentations were emphasized on Tuesdays-Thursdays; administrative planning and fax transmissions of patient data and medical literature were emphasized on Mondays and Fridays. (The voice terminating equipment of the communications system precluded simultaneous fax and voice transmissions.) Prescheduling the clinical problem areas and educational topics to be discussed permitted prospective designation of a "primary" and "secondary" U.S. medical center for each session, according to the expertise of centers (Table 1), availability of key specialists, and intent to maximize participation.

For each patient-specific clinical consultation desired, the Republic Diagnostic Center physician coordinator was expected to organize (and translate) the appropriate clinical information in a standard format and, on the Friday or Monday preceding the consultation session, transmit the information via fax to the U.S. medical center designated as "lead" for that session. Standard medical nomenclature and clinical laboratory units were agreed upon in advance. American consultants were encouraged to identify relevant medical journal articles and, on the Monday

TABLE 1. TELEMEDICINE SPACEBRIDGE PARTICIPANTS

<u>Telemedicine Spacebridge Centers</u>	<u>Institutions</u>	<u>Specialty emphases</u>	<u>Number of M.D. & Ph.D. participants</u>
ARMENIA:			
Yerevan	Republic Diagnostic Center	Tertiary care, diagnostic imaging, hyperbaric medicine	233
	Multiple Armenian hospitals	Multiple specialties and clinics	
RUSSIA:			
Ufa	Hospital 21	General hospital, burn care	14
UNITED STATES:			
Baltimore, Maryland	Maryland Institute for Emergency Medical Services Systems	Trauma, burns, critical care	18
Bethesda, Maryland	Uniformed Services University of the Health Sciences	Casualty management, psychiatry, epidemiology	64
	National Institutes of Health	Multidisciplinary tertiary care	
	National Naval Medical Center	Multidisciplinary tertiary care	
	Walter Reed Army Medical Center	Multidisciplinary tertiary care	
Houston, Texas	The University of Texas Health Science Center at Houston	Multidisciplinary tertiary care, trauma, burns, critical care	45
	The University of Texas M.D. Anderson Cancer Center	Oncology	
	Texas Institute for Rehabilitation Research	Rehabilitation medicine	
	U.S. Army Medical Center, Ft. Sam Houston, San Antonio	Burn care	
	Shriners Burn Institute, Galveston	Burn care	
Salt Lake City, Utah	LDS Hospital	Multidisciplinary tertiary care, trauma, critical care	45
	Primary Children's Hospital	Multidisciplinary pediatric care, pediatric trauma, critical care	
	University of Utah Medical Center	Multidisciplinary tertiary care, trauma, burns, critical care	
Washington DC	NASA Headquarters	Operational medicine, administration	3

preceding or the Friday following the consultation session, transmit the articles via fax to the Republic Diagnostic Center. It was understood that each Armenian physician presenting a patient and requesting consultation retained full responsibility as the physician managing that patient; American physicians rendering consultation functioned as consultants to the Armenian physicians, without direct responsibility for patient care.

SPACEBRIDGE OPERATIONS

The Spacebridge was operational almost daily, weekends and national holidays excepted, from 4 May to 28 July 1989. This was a month longer than originally planned: Following the gas explosion near Ufa, a mutual desire to utilize telemedicine consultation to aid management of the burn victims prompted extension of Spacebridge operations through July. As shown in Table 1, a total of 422 M.D.'s and Ph.D.'s and 34 communications specialists participated in the Spacebridge sessions. Among the Armenian physician participants, more than 60 were lecturers at the Yerevan Medical Institute of Advanced Physician Training, and 50 were directors of medical institutions.

As shown in Table 2, over the 12 weeks of Spacebridge operations, there were 34 clinically focused and 19 administratively oriented conferences, each of approximately 4 hours duration; 48 originated from the Republic Diagnostic Center in Yerevan; 5 originated from Hospital 21 in Ufa. Full motion color video was transmitted from Yerevan via Earth station satellite uplink; slow scan black and white video was sent from Ufa via land line to Yerevan, and thence via Earth station uplink. In one session, Salt Lake City and Yerevan were linked with two-way full motion color video. Only 2 of 55 intended broadcasts were canceled or deferred due to technical difficulties.

In Yerevan and Ufa, conference rooms were configured for video teleconferencing, with special attention to the demonstration of findings on physical and psychological examinations and diagnostic images. For some patients whose hospital status or outpatient location made it inconvenient or impossible to appear in real time, a video camcorder was used in Yerevan and a still camera was used in Ufa to prerecord salient points for replay during consultation sessions.

As Table 2 indicates, 209 individual patients were discussed. The 185 cases selected by the Armenians exhibited characteristics common to people seeking medical attention following a major disaster. The problems most frequently presented related to infectious disease, psychological decompensation, and surgical interventions. However, many of the most perplexing problems in these and other categories were endemic to the population or otherwise unrelated directly to the earthquake; after the earthquake, their management was compromised by other heavy demands on the crippled medical care system. Population subgroups that, due to local customs

TABLE 2. SUMMARY OF TELEMEDICINE SPACEBRIDGE CONFERENCES AND IMPACT ON PATIENT MANAGEMENT

Clinical problem category introduced	No. of 4 hour conferences	No. of patient consults	No. of diagnoses altered	Interpretation of studies altered	New studies suggested	Diagnostic process altered	Treatment plan altered	New treatment method
Burn management	5	24					**	**
Burn wound care; nursing care	[3]							
Multiple trauma care	[1]							
Psychological support	[1]							
Endocrinology	1	5	1		2		2	2
Imaging	3	33	10	15	12	12		
Infectious disease:	5	15	2	2	7	5	4	1
Epidemiology and public health	[3]							
Specific disease management	[2]							
Internal medicine	1	5	1	1	2	2	2	
Laboratory diagnostics	1			4		5		
Neurology	1	5	1		2	2	3	1
Ophthalmology	1	6	2				1	1
Psychiatry and psychology	7	25	8		3		17	3
Renal failure and dialysis	1	6	1					
Surgery and trauma management:	6	44	21	2	30	16	12	5
Orthopedic reconstructive surgery, use of prosthetics, rehabilitation	[2]							
Plastic and reconstructive surgery, microvascular techniques	[1]							
Head and spinal injury, rehabilitation	[2]							
Neurosurgery (non traumatic)	[1]							
Urology	1	25			7	1	5	2
Vascular surgery	1	16	7	3	5	4	1	1
Clinical totals:	34	209	54	27	70	47	47**	16**

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Administrative category

Operations planning, interim critique	6
Yerevan operations	[2]
Ufa operations	[2]
Overall operations; wrap up	[2]
Disaster response organization	1
Fax	12
Administrative total:	19
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Total Spacebridge sessions:	53

**** Note:** American burn treatment teams were present at Hospital 21 in Ufa within the second week after the gas explosion; this resulted in introduction of new burn treatment methods and significant changes in treatment plans, prior to Spacebridge consultation.

and ethnic conflicts, under-used the medical care system before the earthquake also were under-represented in their receipt of formal care after the disaster.

SUMMARY OF CONFERENCES AND CONSULTATIONS

Burn Management. Five conferences were devoted to management of major thermal injury. Three of these focused on early and late management of burn wounds. Among American burn specialists who had travelled to Ufa the previous month were surgeons and nurses from the Brooke Army Burn Unit in San Antonio and the Shriners Burns Institute in Galveston; they had provided onsite instruction, equipment, and supplies for early excision and grafting procedures. Several of these surgeons and nurses participated from Houston in Spacebridge conferences and thus were able to follow patient progress. Of the 104 burn victims received by Hospital 21 in Ufa, 24 remained hospitalized. With the aid of slow scan video images and exchange of specific questions and answers, the remote consultants were able to provide recommendations for further management of these patients. Skin grafting technique, use of antibiotics, parenteral and enteral nutrition, and nursing care were central issues. One conference was directed to management of concomitant injuries, including brain and eye trauma. Another session addressed psychological issues, including the increased stress on mass casualty care providers when the predominant injuries are severe burns, the impact of reduced support when mass casualties—particularly children—must be cared for at great distances from their homes, and the long term consequences of burns involving the face and hands.

Imaging. Paralleling previous telemedicine experiences, diagnostic images were among information most frequently discussed in the course of consultations for a broad spectrum of clinical problems. In addition, three conferences were devoted specifically to imaging techniques, choice of studies for particular problems, and interpretation of results. Beyond plain film radiography, there was emphasis on computed tomography (CT), ultrasound, doppler techniques, angiography, and nuclear scintigraphy. Image transmission was noted to be of high diagnostic quality; remote consultants were able to distinguish relatively subtle lesions in the brain, lung, liver, and pancreas. Of particular value to Armenian radiologists were discussions regarding use of contrast to enhance CT studies, and use of radioisotopes in nuclear medicine diagnostics.

Infectious Disease and Epidemiology. Public health in Armenia was a matter of grave concern because the earthquake had disrupted sanitation systems and forced relocation of thousands of survivors to temporary shelters. Therefore, one of the first conferences, attended by directors of the Republic of Armenia Epidemiological Service, was devoted to discussion of epidemiology and other public health issues. It was agreed that the communicable diseases most likely to be activated in large numbers after a disaster are those known to be endemic before the

disaster or those for which the causal agents have been identified. Thus reference to identified patterns of incidence and causes of infectious diseases prior to the earthquake offered the best guide to infection control solutions in the post disaster setting.

Specific diseases addressed were meningitis, upper respiratory infections, food poisoning, bacterial and amoebic dysentery, salmonellosis, viral enteritis with diarrhea, and viral hepatitis. Disruption of water supplies, food supplies, waste disposal systems, and prophylactic and therapeutic services were identified as major causal factors. Also contributory were the death of a large number of animals, and an increase in the population of rats and other rodents. The Armenians described measures already instituted on a broad scale; these included inhalation of gamma interferon to prevent upper respiratory infections, and bacteriophage treatment of intestinal infections. The role of antibiotics and immunization was addressed. Specific consultations for 15 patients were directed to differential diagnosis and management of meningitis, encephalitis, tuberculosis, hepatitis, herpes infection, and HIV infection.

Psychiatric and Psychological Rehabilitation. Seven conferences were devoted to discussion of the extensive psychiatric and psychological problems associated with major disasters. Topics included post-traumatic stress syndrome, major depressive reactions, the effects of loss of or separation from family members and homes, differential responses of young children and elderly adults, the impact of preexisting psychiatric disease and drug and alcohol abuse, the consequences of a major disaster on the mental health of the population at large, the ability of preexisting mental health services to respond to psychological decompensation following a major disaster, and the roles of pharmacotherapy, psychotherapy, psychoanalysis, group therapy, and outpatient care. To improve consultation effectiveness, the Uniformed Services University psychiatrists promptly communicated standardized approaches to psychiatric examination and diagnosis.

The psychological responses of several population subgroups received particular emphasis; these included children who had lost family members and homes, rescue workers who had encountered mangled bodies day after day, and medical personnel who had worked for extended intervals in the disaster zone. For the last group, work capacity and professional capability were of special interest.

Among the 25 patients presented, several demonstrated classical findings of post-traumatic stress disorder, major depression, and medication-induced toxic psychosis. Consistent with the previous observation that problems endemic to a population demand significant attention after a disaster, many of the cases involved situations that predated or otherwise were not related directly to the earthquake. A special example of this phenomenon was the psychological impact of repeated trauma: Some of the earthquake survivors previously had been involved in violent regional ethnic conflicts.

Pre- and post-disaster organization of mental health services was addressed, with emphasis upon ability to provide psychological and psychiatric aid to the population of a disaster zone. Prior to the earthquake, a comprehensive psychological service for the Republic of Armenia was still in the developmental stage; existing personnel and resources were incapable of coping with the impact of the earthquake on the mental health of the population. Hence a Republic Mental Health Center was established after the earthquake; the newly appointed director of that Center was one of the most active participants in the teleconferences. The final psychiatry and psychology conference included a review of the mental health care systems in both the U.S. and the U.S.S.R.

Renal Failure Management. Relative to many disaster settings, the Armenian earthquake produced a high incidence of renal failure among the injured. Many cases appeared related to crush syndrome, resulting in myoglobinuria, with inability to achieve timely expansion of vascular volume. Inability to initiate resuscitation promptly was a consequence of delayed rescue and delayed access to definitive treatment. Those delays, respectively, related to widespread destruction of the emergency services infrastructure and local medical care infrastructure.

Prior to the earthquake, there was a growing interest in hemodialysis in Armenia. New dialysis equipment, requiring shorter dialysis intervals and permitting treatment of more patients, had been provided as a component of international disaster response. A number of dialysis centers had been established; many specialists were engaged in training at these centers. A conference on renal failure management, at which six patients were presented, offered an opportunity for those physicians to ask questions of American colleagues experienced in dialysis and transplantation.

Surgery and Trauma Management. Many (in some towns, most) buildings collapsed in the Armenian earthquake, creating numerous casualties with crush injuries and polytrauma. At the time of Spacebridge operations, initial treatment of that population had been completed. The Armenian medical care system remained challenged, however, by a large number of patients with post trauma complications including chronic wounds, malunited fractures, and musculoskeletal and neurological functional deficits. As expected in the disaster recovery setting, discussion of trauma and other surgical problems (exclusive of burns) occupied the largest number of Spacebridge conferences (9), produced the largest number of patients presented for consultation (91), and involved the broadest spectrum of participating specialties (general surgery, neurosurgery, ophthalmology, organ transplantation, orthopedic surgery, pediatric surgery, plastic and reconstructive surgery, rehabilitation medicine).

Two conferences were directed to evaluation and management of musculoskeletal injuries, with emphasis on options for orthopedic and plastic surgical reconstruction, use of prosthetics, and the role of rehabilitation efforts. A separate conference focused on plastic and reconstructive surgery, with emphasis on microvascular surgical techniques and tissue transfer. Two conferences were devoted to evaluation and management of head and spinal injuries, with discussion of

paraplegia and quadriplegia, prevention and treatment of decubitus pressure ulcers, and the role of rehabilitation. These sessions were particularly valuable to several young specialists at the newly established Center for Spinal Rehabilitation in Yerevan. Separate conferences addressed evaluation and management of non traumatic central nervous system lesions and seizure disorders, eye injuries and diseases, genitourinary tract injuries and diseases including malignancies, and peripheral vascular disease. In this last session, intermittent claudication was a major issue and choice of vasodilation versus endarterectomy versus bypass grafting were central topics of discussion.

Recommendations for surgical treatment were based upon careful evaluation of patient status. Real time audio and full motion color video enabled consultants to request demonstration of and effectively observe location and character of wounds, motion and strength of limbs, and gait and neurological function. Thus remote consultants were able to guide examination and elicit specific findings. For several patients unable to appear in the conference room in Yerevan, a video camcorder was used to prerecord physical findings for later demonstration. For a pediatric orthopedic surgeon unable to be present in the conference room in Salt Lake City, a video recorder was used to record a patient's physical findings and diagnostic images for later review. In two cases involving musculoskeletal deformities—1 congenital, the other post traumatic, recommendations for complex orthopedic procedures led to referrals to the consulting surgeons who performed the operations *pro bono* in Salt Lake City and Houston.

Other Clinical Conferences. A conference was devoted to endocrinology, with discussion of five patients exhibiting difficult to manage problems including diabetic neuropathy and thyrotoxicosis. A separate conference on other internal medicine problems involved discussion of five patients with glomerulonephritis, osteogenesis imperfecta, systemic lupus erythematosus, fever of unknown origin, and Behcet's syndrome. A conference on laboratory diagnostics produced in depth discussion of the measurement and interpretation of immunologic, blood chemistry, and coagulation variables, and the role of laboratory studies in diagnosis of liver and pancreatic disease. Flow cytometry was a technique of particular interest to the Armenians. A conference devoted to neurology involved presentation of five patients, generating discussion of diagnosis and treatment of seizure disorders, use of evoked potentials, use of anticonvulsant medication during pregnancy, and management of multiple sclerosis.

Administrative Conferences. Two conferences were used to critique and revise Yerevan operations, 2 conferences were used to plan the urgent transition to operations in Ufa, 1 conference reviewed disaster management organization, 2 conferences were devoted to a final critique of operations and closing ceremonies, and 12 sessions were devoted largely to fax transmissions. Early in the course of Spacebridge operations, two facts were recognized: First, priorities of patient problems and availabilities of key physicians changed frequently. Second, for the U.S.

medical centers, Spacebridge transmissions were the only practical means by which to communicate with Armenia (establishing telephone contact required hours; mail delivery requires weeks to months) and the most convenient means by which to communicate with each other. Thus it was necessary at intervals to revise conference topics and reschedule participants; satellite mediated dialogue between centers helped to effect the changes promptly and accurately.

EVALUATIONS OF SPACEBRIDGE CONSULTATIONS

Armenian Physician Evaluation. The physician coordinators of the Spacebridge project at the Republic Diagnostic Center in Yerevan, Doctors Haik Nikogossian and Ashot Sarkisian, recorded the changes in patient evaluation and management which occurred as a result of telemedicine consultations. The results of this evaluation are shown in Table 2. Significantly, diagnoses were altered for 54, new diagnostic studies were recommended for 70, diagnostic process was altered for 47, and treatment plans were altered for 47 of the 185 Armenian patients presented. Within the surgical subgroup, the impact was even more dramatic: Diagnoses were altered for almost half, additional studies were recommended for almost three quarters, and treatment plans were modified for more than one-quarter of the 44 patients discussed.

American Physician Evaluation. Subsequent to rendering consultations, American physicians were asked to evaluate Spacebridge operations. The issues addressed and the responses obtained are summarized in Table 3. Early in the course of telemedicine operations it was evident that quality of consultation depended directly upon prior knowledge of cases to be presented and questions to be asked. The quality with which diagnostic images were transmitted using standard video equipment was a pleasant surprise.

DISCUSSION

Initiation of Operations Relative to Disaster Occurrence. While Spacebridge operations were timely relative to the Ufa train disaster, the project clearly represented a late phase response relative to the Armenian earthquake. By mid December 1988, within a week after the earthquake, it had been determined that clinical faculties of the U.S. medical centers, the telecommunications units of these institutions, and the telecommunications center at NASA Goddard were willing and ready to participate. However, negotiations at higher levels of government to achieve the necessary bilateral international agreements were not completed until April 1990. This experience parallels that of other international response teams lacking contingency agreements prior to a disaster.

**TABLE 3. CLINICAL AND TECHNICAL QUALITY OF SPACEBRIDGE CONSULTATIONS:
AMERICAN PHYSICIAN EVALUATION**

<u>Issue</u>	<u>Consensus</u>
Adequacy of clinical background information	More than adequate, when provided in advance via fax. In several cases, absence of relevant information in advance resulted in unavailability of the appropriate specialty expert during the consultation session.
Adequacy of laboratory and imaging studies	Generally comparable to U.S. medical centers, particularly with addition of certain techniques common to U.S. practice (e.g., greater use of contrast to enhance CT imaging).
Accuracy and effectiveness of language translation	Excellent.
Diagnostic quality of audio transmission	Excellent.
Diagnostic quality of video transmission	Full motion color video quality was excellent. The clarity of transmission of diagnostic images using standard video equipment exceeded expectations. Black and white slow scan video quality was adequate for images. It sometimes was inadequate for evaluation of the extent and severity of burn injury.
Accuracy and appropriateness of consultations	Consultations were perceived to be highly accurate and appropriate.
Comfort and confidence in providing consultation in this format	A high degree of comfort and confidence was expressed.
Acquisition of information professionally useful to consultant	Most consultants felt they gained from the experience.
Willingness to participate in similar telemedicine projects in the future:	Almost all consultants expressed a desire to be involved in similar projects in the future.

An additional minor delay was incurred waiting for an Aeroflot aircraft of sufficient size to transport a large van-mounted satellite Earth station from Houston to Yerevan. Subsequent inability to move the van conveniently and rapidly from Yerevan to Ufa resulted in the absence of full motion color video during Ufa operations.

Language Translation. An initial concern was potential compromise of consultation effectiveness due to inaccurate or inefficient language translation, differences in medical technology and nomenclature, and influence of cultural differences. With rare exception, the effects were negligible. The translation skills of the Armenians and Russians were excellent.

Participation of Several Medical Centers. With simultaneous telemedicine consultation from several medical centers, there were concerns about potential difficulty coordinating sequential input from remote consultants unable to see each other or read each other's "body language," and conference disharmony or primary physician confusion created by forceful expression of conflicting clinical opinions. Fortunately, these problems were not encountered. Instead, concurrent participation repeatedly assured cross coverage when specific expertise was absent in the conference room at the "lead" center. More importantly, from the consultants' point of view, clinical problem solving interaction with colleagues at other institutions was one of the most enjoyable aspects of the Spacebridge. For example, following transmission of a challenging question from an Armenian physician, a typical "off line" comment in Houston was "I hope Utah will take that one first," or "I wonder what Maryland will say about that"; following transmission of an answer, a typical off line comment was "I wonder if Utah and Maryland will agree with that." The learning process clearly was multidirectional and collegial. When Spacebridge ended, some consultants expressed feeling a loss of valuable contact.

Participation of Physicians. As noted, quality of consultation related directly to presence and preparation of the consultants. Consistent presence of the right people with the right information at the right time required at least two things: First, it was necessary for primary physicians to identify patients, topics, and questions with sufficient lead time for coordinators to schedule appropriate specialists to be present (or alternatively, it was necessary to know where the experts were scheduled to be so that questions could be directed to them at that place and time). Second, once an expert was present in the conference room, it was important that specialty specific problems be presented promptly, before the consultant was called away to do something else or departed because of disinterest.

The most productive clinical consultation sessions were those for which these principles were followed. Conversely, the least productive sessions were those for which patients had not been identified or information and specific questions had not been transmitted in advance, or new patients or new questions were introduced ad hoc during the session. For example, body CT radiologists were reluctant to answer questions regarding head CT findings; they wished to defer

those questions to a neuroradiologist. When questions regarding therapeutic intervention were mixed with discussion of imaging, the radiologist wished to defer to the appropriate surgeon (e.g., a neurosurgeon). Once present, these specialists became anxious to leave when unrelated topics were discussed.

Another failure mode for clinical conferences was deviation from case discussion to lecture oriented format. Consultants' interest was captured and maintained by concise presentation and focused discussion of specific patient problems; conversely, interest waned when Armenian physicians or U.S. consultants drifted into speeches or lengthy tangential analyses. Consultations of a truly emergent nature often were among the most successful, despite minimum time for preparation. Requests for those consultations usually were accompanied by specific information and questions, permitting identification and preparation of the appropriate consultants even on short notice; discussions of such cases usually remained well focused on relevant clinical issues.

As with face to face consultation, periodic failure to bring key studies (e.g., radiographs) to the conference room reduced success. In Spacebridge operations, it often was inconvenient or impossible to present such data to the appropriate consultant at a later date.

Ability to Convey Ideas Graphically. The ability to convey ideas graphically in real time has been found to be important in other applications of teleconferencing. Indeed, a number of times in Spacebridge operations, remote consultants wished to point to an anatomic finding on a patient, demonstrate (rather than describe) a physical examination maneuver, point to a detail on a diagnostic image, diagram a reconstructive surgical procedure being considered, or point to details in a journal article. This was impossible or inconvenient because video transmission was not two-way, the system was not equipped with an electronic pointer or pen, and fax transmission required interruption of the conference dialogue.

It was necessary to dedicate significant time to fax transmissions for several reasons. Quality of consultations related directly to availability of written patient information in advance. Because many medical journals are not conveniently available in Armenia and Russia, providing copies of (rather than referencing) selected journal articles was the most effective means for consultants to augment information they wished to convey. Fax was the only practical means by which to exchange written and graphic information in a timely manner. Hundreds of pages of patient information and over a thousand pages of journal articles were exchanged. As previously noted, the communications system did not permit simultaneous fax and voice transmissions.

Physicians and patients in Armenia repeatedly expressed a desire to see the American physicians providing consultation. Since this was precluded by absence of two-way video link, the Armenians requested photographs of the consultants and openly referred to them during consultations.

CONCLUSIONS AND RECOMMENDATIONS

Telemedicine and International Disaster Response

The Spacebridge project demonstrated that interactive consultation by remote medical specialists, via satellite mediated telecommunications on an international scale, can provide valuable assistance to onsite physicians in the aftermath of major disasters. Telemedicine can bring to physicians working in a distant disaster zone the expertise of scores of top specialists who simply cannot all travel to the site in person. This assistance can favorably impact clinical decision making in the late phase of post disaster medical response.

For the future, an important question is: How soon after a major disaster may telemedicine consultation be of benefit? A possible first impression is that remote consultation can be of little or no value until the inevitable confusion associated with the first few days has been resolved. However, this impression appears to conflict with several accepted principles of trauma management and specialty consultation: For major trauma, initial evaluation and management often determine final outcome. In mass casualty situations, triage often is performed in forward locations by senior surgeons, in order to maximize accuracy of initial decisions. For complicated clinical problems, the earlier an appropriate specialist is consulted, the more likely it is that complications can be prevented or minimized. Therefore, appropriately planned and organized, it is anticipated that telemedicine consultation by selected specialty experts will more favorably impact process and outcome if provided relatively early in the post disaster interval. In addition to providing access to remote specialty expertise, early telemedicine communications may assist in-country teams of external responders by providing information to guide optimum deployment of their resources.

Several steps can be taken to enhance opportunity to provide effective telemedicine assistance in the early post disaster interval: To reduce delays related to government negotiations, international agreements for entry and operation of telecommunications equipment should be in place prior to a disaster. To reduce delays related to assembly or transport of telemedicine communications equipment, modular portable telecommunications units, capable of transport on commercial aircraft, should be available pre disaster. To reduce failures related to equipment reliability and consultant availability, telecommunications equipment and medical specialists should be engaged in telemedicine operations, domestically or internationally, on a routine basis.

Interaction with Onsite Physicians. Following most major disasters, the majority of medical care will be provided by local physicians and health care workers rather than external disaster response teams who travel to the site. Therefore, the prior training and organization of local medical professionals, and the ability of external consultants to interact smoothly with local physicians, are major determinants of the outcome of national and international disaster response

efforts. Language barriers, differences in medical technology and terminology, and cultural differences may limit success of international telemedicine operations; agreements regarding language translation protocols and medical terminology standards may reduce that impact. The high quality and professionalism of the Armenian physicians and the excellent translation abilities of the Russians were major contributors to the immediate success of the Spacebridge.

In the longer term, if the development and orientation of a local health care system permit the medical information base to be enhanced by remote consultation and education, then telemedicine interactions can favorably impact regional health care for years after a disaster response. That appears to be the case in Armenia and Ufa.

Selection and Participation of Remote Consultants. To provide telemedicine assistance to a major disaster zone where there exist a broad spectrum of health care demands and a disrupted health care infrastructure, concurrent participation of several remote consultation centers may be beneficial. To coordinate communications requests and operations, an "action center" may be helpful; this may be located at one of the participating medical centers, or elsewhere.

Quality of consultation depends upon timely presence of appropriate consultants prepared with the appropriate information. In turn, for nonemergent cases, availability and preparation of consultants depends upon foreknowledge of patients to be presented and questions to be asked. Thus for scheduled consultations, information should be transmitted in a standard format with sufficient lead time to permit optimum consultant selection and preparation.

Frequent changes in priorities of patient problems and availabilities of key physicians represent the rule rather than the exception. Flexibility to revise topics and reschedule consultants promptly and accurately is critical to clinical success.

Maximum value from consultation sessions is derived from concise presentation and focused discussion of specific patient problems, avoiding lengthy lectures and tangential analyses. When a number of patients are presented or several specialty areas are discussed, use of consultants' time is optimized by identification, in advance, of the order in which specific areas will be discussed and how much time will be devoted to each. Once present, a consultant's expertise should be "used" promptly, before the expert is called away or loses interest.

Telemedicine Communications Systems. For interactive medical consultation, bidirectional audio is essential, unidirectional video is adequate, and bidirectional motion color video is desirable. Bidirectional video is desired to permit primary physicians and patients to see their consultants, and allow consultants to demonstrate as well as describe certain maneuvers and procedures. Motion video is desired to allow evaluation of musculoskeletal, neurological, and psychological performance. Color video is desired to permit appreciation of subtle features of wounds and skin lesions. During many consultations, the ability to convey ideas graphically in real time is desired; therefore, telemedicine systems should incorporate the electronic pointer and

pen components that are available in several teleconferencing systems. Fax is a valuable means by which to exchange information before, during, and after consultation. It is important to be able to fax without interrupting dialogue. At appropriate transmission rates, digital compression technology may combine the convenience of digital data storage and recall with the advantages of motion video just cited. For disaster response teams that travel to provide care in-country, a modular portable critical care workstation with computer assisted data acquisition and interpretation may provide a convenient "front end" interface to telemedicine systems.

Future Directions. A Telemedicine Implementation Team was defined at the conclusion of the Spacebridge project, with the intent to incorporate many of the foregoing recommendations and features in a follow-on demonstration project. In early disaster response efforts, telemedicine should attempt to complement and assist—not substitute for—external teams who travel to provide care onsite. Interface with rapid response teams, such as those recently organized and equipped by the Society of Critical Care Medicine, should be a primary goal of future global telemedicine efforts.

Global telemedicine may play an important role preceding as well as following disasters. Ability of the international medical community to respond to acute major disasters should be enhanced by the permanent presence of a world-wide medical telecommunications network that is able to track endemic infections and "ongoing disasters" (e.g., cholera and yellow fever in South America, HIV in Central Africa), monitor the capabilities and limitations of medical care infrastructures within many countries, and promptly and accurately report early damage following sudden catastrophes.

Extraterrestrial telemedicine capability will be key to achieving the goal of expanded human presence in the solar system. Timely reliable access to remote medical specialty consultation will be a central feature of the health care systems of space stations, lunar bases, and Mars missions. A global medical telecommunications network will be required to facilitate effective multinational responses to catastrophes in extraterrestrial settings. As with other medical devices and techniques, spaceflight telemedicine systems will require critical evaluation with real patients in order to be considered qualified. Thus the space programs of the U.S., Russia, and other nations have vested interests in the development and validation of telemedicine systems.

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