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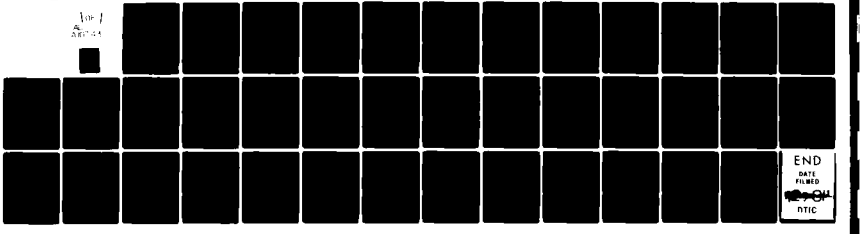

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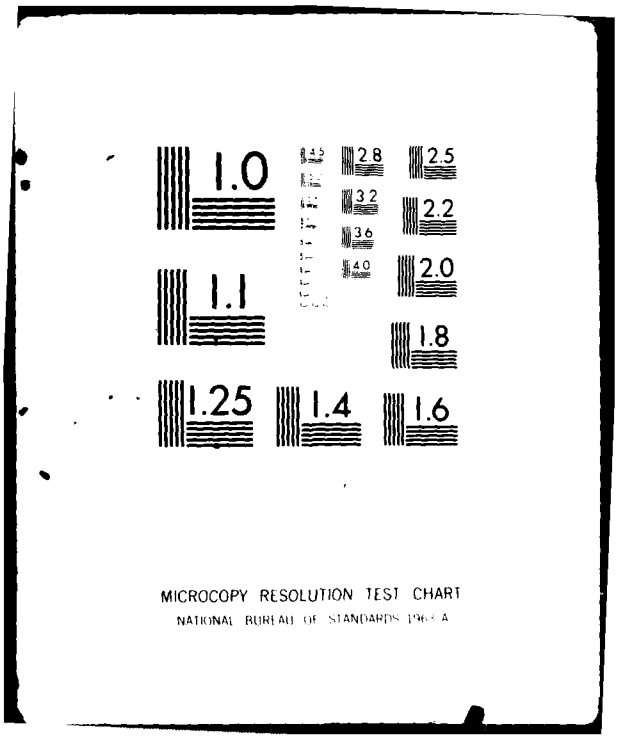
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TELERADIOLOGY

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Radiographic studies representative of the spectrum of trauma cases that might presented to an emergency room were selected from actual cases presenting to the emergency room at Brooke Army Medical Center (BAMC) in San Antonio, Texas. The studies were then transmitted from a local television studio via satellite back to BAMC and three other Army Hospitals on two separate occasions. The transmitted images were viewed on commercial grade television sets by panels of physicians (radiologists and other specialties) at the receiving hospitals. The panel members were asked to give their diagnostic impressions regarding

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the specific cases and to comment on the applicability and usefulness of teleradiology. Overall, it was found that an image of diagnostic quality could be transmitted for most, but not all, radiographic cases and that the participating physicians felt this approach had great potential for the practice of radiology both in field and fixed AMEDD facilities.

Dental Applications

Five maxillo-facial surgery cases were presented by the Oral and Maxillo-Facial Service, BAMC. The quality of the images was reviewed by six dentists. All were board certified or qualified in the specialties of oral surgery, oral medicine or periodontology. The video images reviewed were rated in terms of their usefulness in the hospital and field environment. A simulated forensic dental application was also presented. The ratings indicate that there may be great potential for the use of this concept in both clinical and forensic applications.

TABLE OF CONTENTS

LIST OF TABLES

TABLE

Teleradiology

1. INTRODUCTION.

a. Problem. To determine the diagnostic quality of televised video images of radiographs interpreted by radiologists and non-radiologist physicians.

b. Purpose. The investigation will consider the adequacy of viewing time, image clarity, quality, and acceptability of teleradiology for consultation in the hospital and/or the field environment.

c. Background.

(1) Health Services Command has used satellite communication for education since November 1979. Daily telecasts of case history presentations, seminars, lectures originate from Brooke Army Medical Center. This educational system has enabled physicians at smaller Army hospitals to receive continuing graduate medical education in specialties not available locally.

(2) Telemedicine uses telecommunications to improve the efficiency and/or effectiveness of the delivery of medical services. In general, pertinent information (clinical, laboratory, radiologic, etc) is collected, transmitted, processed and interpreted off-site, and transmitted back to the point of origin to assist in patient care. Specific applications of telemedicine have been numerous and varied (Bashshur et al., 1975; Bennett et al., 1978) with perhaps the most extensive efforts having been applied in support of mobile emergency cardiac care units by base-station emergency medical departments utilizing radio and telephone communications (Bennett et al., 1980). Successful provision of consultation services by critical care specialists via an audiovisual link has also been demonstrated (Grundy et al., 1977).

(3) Another area of telemedicine that promises to significantly impact on the practice of emergency medicine is teleradiology which is concerned with the feasibility of producing, storing, transmitting, and reconstituting electronic radiographic images. Given the fact that in the United States there are some 125,000 medical x-ray machines used to perform almost 200 million x-ray examinations per year at a cost of over six billion dollars (Willforth, 1980), coupled with the magnitude and importance of radiology in the practice of emergency medicine (Rhea et al., 1979), developments in teleradiology should be of interest to emergency department physicians. To date, several clinical applications have already been demonstrated.

(4) Murphy et al (1970), based on their experiences with the transmission of 100 sets of chest films via microwave over a distance of 4.35 km, concluded that this was an acceptable method for providing care to persons in remote and medically disadvantaged areas. The ability to manipulate (zoom and contrast) the electronic image was found to be an advantage over conventional image-reading. Observed error rates in readings could be largely accounted for by the degree of intra- and inter-observer variability normally associated with roentgenographic interpretation as demonstrated

earlier by Smith (1967). In 1972, Andrus and Bird made the important observation that "the question is not whether teleradiology is preferable to direct visualization when either is available, but rather whether teleradiology offers an acceptable universally applicable method to augment the usefulness of the radiologist." Webber et al (1973), describing a television system used to link two hospitals 16 km apart, addressed some of the important technical considerations impinging on teleradiology. They noted that in order to produce a video image roughly equivalent in resolution to a standard x-ray, a 2000-line television screen with a gray-scale* range of 32 or greater would be required as contrasted to the 525-line, 10 gray-scale level available in commercial television. Importantly, the authors demonstrated that this inherent limitation could be largely overcome for most types of x-ray studies through magnification and other image manipulating techniques afforded by a video system.

(5) Lester et al (1973), in reporting on the transmission of radiographic images via satellite in 1973, concluded that "satisfactory radiographic transmission is clearly possible." Jelaso et al (1978) reported their experiences with the transmission of radiographs via telephone lines utilizing commercially available slow-scan television. Of 290 cases evaluated, 82 percent were false-negative readings, 27 percent false-positive, and 19 percent were considered indeterminate. Other studies (Gayler et al., 1979; Rappaport et al., 1979) on slow-scan television and telephone image transmission have replicated these findings and have demonstrated that the nature of the specific film examined affects the diagnostic accuracy. Overall accuracy rates for a panel of 12 radiologists viewing 100 radiographic examinations in both film and video modes were 94 and 85 percent, respectively (Gayler et al., 1979). In addition (Rappaport et al., 1979) Rappaport has shown that the production of a high quality digital image (512 x 512 picture elements and a gray-scale of 256) requires approximately two million bits of information which, using standard telephone lines, would take approximately seven minutes to transmit.

(6) Carey et al (1979) reported on a teleradiology project in which remote radiological consultation services were provided by a Canadian medical center to an outlying 120-bed base hospital and a nursing station via satellite. Between October 1966 and February 1977, 270 radiological exams were transmitted to a panel of radiologists for interpretation; the original films were later reviewed for comparison. In terms of diagnostic accuracy, the teleradiology readings were 90 percent as effective as traditional readings. On average, teleradiology examination time was found to require 6.28 minutes per case.

(7) The potential implications of these developments on the daily practice of radiology are profound, particularly when coupled with the availability of high density digital storage devices (White 1980), filmless x-ray systems (Curtis et al., 1979), and the soaring cost of standard x-ray film.

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* The gray scale level of a given system indicates the number of specific shades utilized in traversing from white to black. For example, this printed page has two levels, white and black.

Consequently, the role of radiology in the practice of emergency medicine will also be affected, especially in those practice environments not supported by a full-time, on-site radiologist. This is of particular importance in military health care where it is envisioned that the emergency medicine specialist will function in forward areas frequently separated by time and distance from essential radiology support services. It is important therefore to attempt to define the relative capabilities of the emergency physician in a teleradiology environment, and to better define the specifics of that environment in terms of the radiological support required.

2. OBJECTIVES.

The objectives are:

a. To determine if a video image generated on commercial level television is of diagnostic quality.

b. To determine how the interpretations of videoimages by non-radiologist physicians compare with those of radiologists?

3. METHODOLOGY.

a. Overall approach. The study was conducted in two phases. Phase 1 was conducted in September 1980 and Phase 2 in November 1980.

b. Phase 1.

(1) Arrangements were made to acquire an hour of broadcast time from an already developed telemedicine link at Fort Sam Houston, Texas. This link, utilized primarily for health education and teaching purposes, provides a capability for programs to be transmitted from a studio at Brooke Army Medical Center (BAMC), a major teaching hospital, via satellite to three outlying Army Community Hospitals and back to BAMC. The outlying hospitals were located at Fort Hood, Texas; Fort Sill, Oklahoma; and Fort Polk, Louisiana. The Westar satellite, in geostationary orbit over the equator approximately 37,760 km from earth, provided the space link. The earth stations at the three outlying hospitals were of the receive-only mode, and a two-way audio link was not otherwise provided for during the demonstration because of the number of panel participants.

(2) For the one-hour teleradiology demonstration, two consulting radiologists were asked to select for transmission eleven cases of varying difficulty representative of the broad spectrum of radiologic practice. One radiologist presented the cases with a brief history in the studio while the second radiologist, also in the studio but seeing only the televised image, was responsible for controlling the camera view and "manipulating" (changing the magnification and contrast) the image to enhance it as necessary.

(3) The first seven cases consisted of seven back-lit radiographs, the eighth a polaroid film of a nuclear medicine study, and the last three were 35 mm slide reproductions of radiographs projected on a screen. Appendix A contains the case sequence, history provided, views shown, and

diagnosis. All of the images were televised on studio-grade cameras, transmitted via the satellite, and reconstituted on standard commercial-grade TV monitors at the four hospitals. A panel of 18 radiologists and 23 other physicians representing a variety of medical specialties viewed the images on TV and completed a survey sheet on the demonstration. A viewing time of three minutes per case was arbitrarily set, and, because of other program requirements, this limited the number of cases that could be transmitted to eleven.

(4) Data collected for each case by individual physician included diagnostic impression, confidence level in diagnosis, and evaluation of the image for clarity, contrast, and brightness. Overall, the panel of viewers was asked to evaluate the demonstration on adequacy of viewing time, image clarity and the acceptability of teleradiology for consultation, teaching and diagnosis in the hospital and/or the field environment. General comments were also requested. Appendix B contains the survey instrument.

(5) All diagnostic entries were scored as either correct, incorrect, or no diagnosis given (indicating an inability to reach a diagnostic conclusion base on the information provided) against criteria provided by the consulting radiologists. The Statistical Package for the Social Sociences (Nie et al., 1975) was used to compare the responses of radiologists and non-radiologists for significant differences in diagnostic accuracy for each case.

c. Phase 2.

(1) Radiographs from 25 BAMC emergency room cases presenting with an injury complaint were selected by a consulting radiologist and the emergency department medical staff for satellite transmission. All 25 were actual cases that had presented to the emergency room of Brooke Army Medical Center and were specifically selected to represent the spectrum of trauma cases that might be expected to present at a "typical" emergency room. Cases with positive findings were purposefully over-selected for the purposes of the demonstration and seventeen "positives" and eight "normals" were eventually transmitted. The 25 cases were presented in random sequence by the consulting radiologist who also provided a brief clinical history for each one (See Appendix C for list). A second physician, also in the studio but seeing only the televised image, actually controlled the camera view and could manipulate the image by changing the magnification and contrast in order to enhance it as he perceived necessary. Based on findings from the previous teleradiology test (Phase 1) a viewing time of one and half minutes per case was established.

(2) A panel of 29 physicians (11 radiologists, seven emergency department physicians, and 22 clinicians from other specialties) individually viewed the televised images and completed a survey sheet which asked for a specific diagnosis for each of the 25 cases. Appendix D contains the instrument. When not sure of the diagnosis, panel members were asked to give their "best guess" and were encouraged to comment on all findings noted in the images. In addition, each of the respondents was requested to provide comments on his/her evaluation as to the acceptability, usefulness and

limitations of teleradiology as a diagnostic, consultative and/or teaching aid; these responses were unstructured. The diagnostic entries were scored as either correct or incorrect against criteria provided by the consulting radiologist. For the positive cases, the overriding criterion for a correct response was the recognition of a clinically significant finding as opposed to the provision of a precisely correct diagnosis. For example, in case #18 which represented a chance fracture of L2, an interpretation of lumbar fracture would have been scored as correct. It was anticipated that there would be a number of incomplete entries due to panel members leaving [illegible] and/or being called away for other duties. These incomplete entries were excluded from the analysis of results, but all actual entries from the partially completed survey sheets were retained. Statistical significance was determined by chi square ($p<.05$) and all analyses were run using the Statistical Package for the Social Sciences (Nie et al., 1975).

4. FINDINGS.

a. Phase 1.

(1) Statistical analyses showed no significant differences in diagnostic accuracy either between facilities or within the set of non-radiologists when classified by specialty such as primary care vs. surgical specialties vs. medical specialties. Table 1 shows the results for comparing radiologists vs. non-radiologists for diagnostic accuracy by individual case and overall. No apparent differences in image quality were detected or reported for those cases represented by back-lit films vs. those represented by 35 mm slides and/or polaroid prints.

(2) Table 2 presents the opinions of the radiologists and non-radiologists as to the potential uses of teleradiology for both hospital and field environments. The commentary submitted by both groups of physicians showed them to be quite receptive to teleradiology overall, with only five physicians reporting generally negative attitudes. Interestingly, although given the opportunity, neither group of physicians registered significant ($p < .05$) differences in opinion as to the relative acceptability of teleradiology as a teaching, consultative and/or diagnostic modality. There were several critical observations made by a majority of the respondents: (a) a viewing time of three minutes per image is excessive, (b) overall, the images are of acceptable clarity, but maximum image-manipulation is required to compensate for the decreased resolution of the TV image vis-a-vis a radiograph, (c) a two-way audio-link is essential, (d) multiple views should be shown, and (e) the ability to render a confident diagnosis is very dependent upon the specific type of case viewed.

b. Phase 2.

(1) Out of a possible 725 responses there were 695 (96%) completed entries. There were three cases for which significant differences in responses were found between the physician groups. These are indicated by an asterisk in Table 3 and included one normal and two positives. Overall, as a group, the radiologists were significantly more accurate (86%) in their responses ($X^2 = 9.87$, df = 1, $p < .001$). There were only two cases for which

the incorrect responses outnumbered the correct - case #20 which was a barely discernible Colle's fracture at the wrist and case #12 - an incidental finding of a congenital odontoid defect. Among the eight normal studies, the facial view was misinterpreted most frequently receiving an equal number of correct and incorrect responses.

(2) Table 4 depicts the breakout of correct and incorrect responses for positive versus normal cases for all respondents and for each physician sub-group. There were no significant differences found between response rates for normal cases by physician group, but for the positive cases, the radiologists scored significantly higher ($X^2 = 13.52$, df = 2, $p < .001$). Response rates were also analyzed by hospital for the overall panel and by group, but no significant differences were found.

(3) Of the 29 respondents, 25 (86%) provided comments on the acceptability, usefulness, and limitations of teleradiology. Of these, eight (32%) were generally negative or felt that teleradiology was of limited usefulness. Generally, recurrent criticisms were: poor resolution, limited contrast for soft tissue shadows, inadequate image manipulation due to inability to directly control, and comments best summed up by one of the respondents: "We could see the obvious, but we don't need help with that. the subtle things came through poorly." Four of the eight negative respondents did feel that with technical improvements the technique would be acceptable especially as a teaching and/or consultative tool. The overall accuracy rates calculated for the negative respondents was 73 percent.

(4) Seventeen (68%) of those providing comments were generally positive about teleradiology, especially for use in teaching and consultation. Only six of the 17 felt that the approach would be acceptable as a diagnostic tool at the present stage of development. A majority of the 17 indicated that, in the absence of an on-site radiologist, the video-consultation format would be beneficial and/or a welcome improvement in radiology support services. Several of the positive respondents also noted that the technique tended to enhance obvious findings but was not as helpful in interpreting more subtle ones. The overall accuracy rate calculated for the positive respondents was 83 percent which was significantly higher than that of the negative respondents.

5. DISCUSSION.

The findings demonstrate that a video image of diagnostic quality can be transmitted over great distances via satellite for a wide range of radiographic studies, although the results show that for some studies the transmitted image is probably not of diagnostic quality. From the data available, it cannot be determined whether this is due to poor image quality, case difficulty, or simple observer error, but is most likely the result of an interaction between these variables. From an overall perspective, it is interesting to note that the error rates for both the radiologists and the non-radiologists in phases 1 and 2 (Tables 1 and 3) are compatible with reported rated (20 to 40%) from a review of studies looking at error rates in conventional radiography settings (Rhea et al., 1979). However, because of the many variables such as error-

definition, film selection, etc, any conclusion based on this observation would be tentative. Also, the distinct differences in accuracy scores by case and physician group irrespective of hospital location suggest that the error rates are more a function of individual case and physician subgroup than overall error.

In Phase 2 of the present study the emergency room physicians did well on all cases except for a fracture of the intercondylar eminence on a knee film (#4), a normal facial (#6), an incidental finding of congenital dysplasia of the odontoid process in an accident victim (#12), and a barely discernible Colle's fracture in a 12 year old (#20). Although the cases shown were not scaled [illegible] cases, especially for non-radiologists. The important consideration is the impact of this type of error experience on overall patient care. In the narrow context of this study the impact in cases #6, #12, and #20 would be negligible and only in case #4 would the error be potentially significant. As an offset to this, it is important to note that for the pneumothorax (#22), the type of case regarded most difficult to read in video format (Murphy et al, 1970; Webber et al, 1973; Carey et al, 1979), the emergency room physicians significantly outperformed the radiologist. However, from a general perspective, to more accurately define the potential impact of teleradiology, an evaluation of the overall radiographic experience in a given setting by number and mix of specific studies versus false-positive and false-negative error rates along with their clinical implications would have to be accomplished for both video and film formats.

Without such data, the benefits to be accrued through providing real-time radiology consultation via teleradiology at a given cost to a specific medical setting cannot be assessed. The data from these studies show that, for the 11 and 25 cases transmitted, the radiologists' accuracy rate (87% and 86%) was significantly better statistically than that for the non-radiologists (87% and 77%); this difference was only apparent for positive cases in Phase 2 (radiologists: 90%; non-radiologists: 76%). In a practical sense, if these findings can be reconfirmed and generalized, this difference in accuracy and its clinical implications must be weighed against the cost of a given teleradiology system to determine if such an alternative should be adopted. The medical-legal implications of the emergency room physician performing his/her own radiological studies is another issue and one which must be looked at on an area by area basis. Certainly the precedent for this exists in that an estimated 75 percent of all non-hospital radiologic studies in the United States are performed by non-radiologists (HEW, 1973), 48 percent of internists alone perform their own procedures (Abrams, 1979), and physician assistants with special training have been utilized to differentiate between normal and abnormal roentgenograms (HEW, 1977).

Overall, the physician participants expressed positive attitudes concerning the acceptability and applicability of teleradiology. Both radiologists and non-radiologists felt that the approach was most useful as teaching or consulta- aids and that with some refinements it would be even more useful as a diagnostic tool. Interestingly, the respondents made no differentiation on potential applications of teleradiology in field vs hospital settings.

If a teleradiology approach is opted for, there are essentially four alternative systems to consider: 1) a closed-circuit system utilizing a direct cable link-up, 2) a micro-wave transmission system requiring linked transmitter-receiver towers, 3) a slow-scan television interface with

commercial telephone lines, and 4) a satellite transmission network. The first two alternatives are not really practical given the prohibitive expense for transmissions over extended distances and the regulatory environment governing video broadcasts (Bennett et al, 1978). In terms of alternatives three and four, there is a tradeoff between cost and real-time responsiveness. A slow-scan system can be set up for approximately $15,000 per terminal plus telephone usage charges (Bennett et al, 1978), but the significantly limiting factor is transmission time which is approximately seven minutes per image (Reppert et al, 1973) (
must increase the information transmitted and this increases transmission time). The satellite system, being essentially a broadband system, allows for the real-time, two-way transmission of images and voice, and is therefore the preferred alternative. However, the cost of each transmitting terminal approaches $50,000 to which must be added the current charges for satellite transmission time which are approximately $200 to $400 per hour (Koncel, 1974). It should be noted that both of these costs should substantially decrease as satellite availability and usage increases.

6. CONCLUSIONS.

Current telecommunications technology allows for the transmission of radiographic images of diagnostic quality in real-time over great distances for a great variety of radiographic studies. This enables the provision of radiological consultation services to emergency medicine practices functioning with an onpsite radiologist. In order to determine if a teleradiology system would be cost-effective in terms of improved patient care in a given practice many factors would have to be taken into account. Among these would be the number and mix of x-ray studies performed, the level and training of individuals normally reading the studies and their associated error rates, the comparative error rates for a radiologist interpreting a video image, and the impact of the difference in error rates on the overall level of patient care provided. The present study, although limited in scope, indicates that only a 12 percent net gain in diagnostic accuracy would result by providing a teleradiology consultation. This difference would be even less if only cases in which a clinically significant error were to be compared and if the 77 percent accuracy rate for the emergency room physicians was to be adjusted upward reflecting the fact that they would be viewing the actual roentgenograms and not the video images from which the rate herein was calculated. This latter point is especially important in that if the 10 percent increase in accuracy for radiologists reading a film vs a video image found in previous studies (Gayler et al, 1979; Carey et al, 1979) were to hold true for emergency room physicians, then the relative accuracy rates for radiologists viewing video and emergency room physicians viewing film would be 86 percent and 85 percent respectively.

7. RECOMMENDATIONS.

1. Developments in teleradiology should continue to be monitored and reported to appropriate AMEDD agencies for possible implications on fixed facility and/or field clinical practice/doctrine.

2. A study be considered to measure the overall number and mix of radiographic studies versus false-positive and false-negative error rates and the clinical implications of these error [illegible] formats by type of provider within different care-settings.

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Table 1

Phase 1: Diagnostic Accuracy of Radiologists vs. Non-radiologists by Individual Case and Overall

Case	Radiologists (n = 18) Correct	Incorrect	Not Given	Non-Radiologists (n = 191) Correct	Incorrect	Not Given	X^2	* P
One	10	2	6	11	0	12	0.45	NS
Two	16	1	1	14	0	9	0.009	NS
Three	16	2	0	20	0	3	0.64	NS
Four	0	12	6	1	10	12	0.002	NS
Five	12	2	4	19	0	4	0.92	NS
Six	10	1	7	17	2	4	0.25	NS
Seven	16	0	2	22	1	0	0.03	NS
Eight	15	0	3	22	0	1	0.0001	NS
Nine	17	0	1	14	3	6	1.46	NS
Ten	14	1	3	10	7	6	3.38	NS
Eleven	16	0	2	17	1	5	0.003	NS
Total	142	21	35	167	24	62	0.005	NS

Overall % correct	72%	66%
% correct of diagnoses attempted	87%	87%

*No significant differences (corrected chi square, df = 1) Comparing only correct and incorrect responses of radiologists vs. non-radiologists.

Table 2

Phase 1: Radiologists' and Non-radiologists' Views as to Potential Applications of Teleradiology*, **

Respondents	Acceptable for Hospital Use			Acceptable for Field Use		
	#Yes(%)	#No(%)	#?(%)	#Yes(%)	#No(%)	#?(%)
Radiologists (18)	9(50)	8(44)	1(6)	10(55)	7(39)	1(6)
Non-Radiologists (23)	13(57)	7(30)	3(13)	12(52)	7(31)	4(17)
Overall (41)	22(54)	15(36)	4(10)	22(54)	14(34)	5(12)

* No significant differences in responses between radiologists and/or non-radiologists for field or hospital use.

** The respondents were also asked to differentiate between relative potential uses in teaching, consultation and/or diagnosis, but no significant differences were recorded.

Table 3.

Phase 2: Cases With Diagnosis and Overall Responses by Physician Groups

Case	Diagnosis	Radiologist Responses +	Radiologist Responses -	Non-Radiologists Responses +	Non-Radiologists Responses -	Total Responses +	Total Responses -	X^2	p
1	Dislocat.-4th Fing	10	0	18	0	28	0	0.00	NS
2	Fx.-Navicular	10	0	18	0	28	0	0.00	NS
3	Normal-Cervical Spines	9	2	14	4	23	6	0.04	NS
4	Fx.-Intercond. Emin., Knee	9	2	7	11	16	13	3.49	.07
5	Normal Skull	10	1	16	2	26	3	0.20	NS
6	Normal Facial	7	4	7	10	14	14	0.59	NS
7	Fx.-Pubic Rami	11	0	17	1	28	1	0.06	NS
8	Fx.-Phalange, Salt. II	11	0	18	0	29	0	0.00	NS
9	Normal Chest	10	0	15	3	25	3	0.53	NS
*10	Fx.-Dist. Radius, Linear	10	1	8	9	18	10	3.84	.05
11	Fx.-Lat. Malleolus	11	0	15	3	26	3	0.64	NS
12	Odontoid Dysplasia-Cong	4	7	6	11	10	18	0.11	NS
13	Fx.-Skull, c Diastasis	11	0	18	0	29	0	0.00	NS
14	Fx.-Facial, tripod	11	0	15	2	26	2	0.18	NS
15	Fx.-L2 & L3	10	1	13	4	23	5	0.22	NS
16	Fx.-Phalange, Salt. I	11	0	17	0	28	0	0.00	NS
17	Normal Knee	9	2	9	6	18	8	0.57	NS
18	Fx.-L2, Chance	11	0	13	3	24	3	0.81	NS
*19	Normal elbow	4	7	13	3	17	10	3.87	.05
*20	Fx.-Dist. Radius	9	1	1	15	10	16	14.86	.001
21	Normal Foot	11	0	13	3	24	3	0.81	NS
22	Pneumothorax-Rt., 50%	4	6	10	6	14	12	0.51	NS
23	Fx.-Ankle, Salt. II	11	0	15	1	26	1	0.03	NS
24	Normal Hand	8	3	15	1	23	4	0.92	NS
25	Fx.-Calcaneus	11	0	13	3	24	3	0.81	NS
	Totals	233	37	324	101	557	138	9.87	.001
	Correct %	86%		76%		80%			

*Significant difference in correct response rate between groups (chi-square, $p < .05$).

Table 4

Phase 2: Correct vs Incorrect Responses for Physician Category and by Full Panel

Respondents	Positives N (%)	Normals N (%)	Overall N (%)	χ^2	P
Radiologists					
Correct	165 (90)	68 (78)	233 (86)		
Incorrect	18 (10)	19 (22)	37 (14)	6.20	$p < .02$
Non-Radiologists					
Correct	222 (76)	102 (76)	324 (76)		
Incorrect	69 (24)	32 (24)	101 (24)	0.00	NS
Full Panel					
Correct	387 (82)	170 (77)	557 (80)		
Incorrect	87 (18)	51 (23)	138 (20)	1.82	NS

APPENDIX A

Phase I

Cases with Diagnosis

Case #	History	Views*	Diagnosis
1	Right upper quadrant pain	Supine, AP-Abdomen	Gallbladder stones
2	Pain in multiple joints	AP-Hand	Rheumatoid arthritis
3	Right flank pain & fever	IVP, AP-Abdomen	Ureteropelvic junction stone with pylonephritis and papillary neurosis
4	Trauma to leg several months previously	AP-Knee	Pellegrini-Stieda disease
5	Pre-induction physical, routine examination	PA-Chest	Normal chest film
6	Mid-epigastric pain relieved with food	Spot Film, Upper GI	Duodenal ulcer
7	54 year old male with transient ischemic attacks	RPO, Aortic Angiogram	Stenotic ulcer at origin of right common carotid ulcer at carotid bifurcation, and aberrant right subclavian artery
8	45 year old female with colon carcinoma	Liver Scan**	Liver metastases
9	Fell on outstretched arm, now with pain	AP-Wrist***	Torus fracture of radius
10	Trauma to face	PA-Chest***	Aspiration of tooth
11	Chest pain and shortness of breath	AP-Chest***	Tension pneumothorax

* Abbreviations: AP = anterior-posterior, PA = posterior-anterior, IVP = Intravenous pyelogram, GI = gastrointestinal, RPO = Right posterior oblique

** Transmitted from polaroid film

*** Image transmitted from 35 mm slide projection

APPENDIX B

DEPARTMENT OF THE ARMY
ACADEMY OF HEALTH SCIENCES, UNITED STATES ARMY
FORT SAM HOUSTON, TEXAS 78234

HSA-CHC

29 August 1980

Dear Doctor:

Thank you in advance for your participation in this teleradiology demonstration and evaluation. As this is our initial study effort in this area we expect that there will be several previously unrecognized complications that will probably result in this demonstration being somewhat less than optimal. However, if you can bear with us and take the time to constructively complete the attached survey sheets, I can assure you that any follow-up evaluations will be better planned and executed and will incorporate your input.

There are 11 separate survey sheets, one for each case that will be presented during the demonstration. The cases have been carefully selected to represent studies of varying difficulty as to radiological interpretation. Also, each case has been selected (and reviewed) so that a specific diagnosis or a reading of normal can be made. This is the information we would like you to record in the diagnosis block of the survey sheet. The survey sheets are arranged sequentially and case #1 is the first case that will be presented and so forth. The guest radiologist at the studio who will be presenting the cases will give the case number for each study and will give the appropriate history at that time. In the event we do not have adequate time to televise all 11 cases the evaluation will be accomplished on those completed.

Also in the studio at the time of the case presentations will be a second guest radiologist who will be viewing the same TV image that you will be seeing. This second radiologist will be able to directly interface with the camera operator in order to divert close-ups and changes in contrast as he sees fit. In the ideal teleradiology set-up, you, the individual viewer, would have this same capability.

As a final note, we have not put a space on the survey sheets for your name in order to remove any connotation of this being a "test" of your reading ability. However, if you would like direct feedback on the results of this teleradiology evaluation please feel free to give your name and I assure you that your confidentiality will be rigidly protected and you will receive complete results on the evaluation as soon as they are available.

Again, thank you for your participation and cooperation.

JAMES J. JAMES, M.D.
LTC, MC
Chief, Health Care Studies Division
Academy of Health Sciences (HSA-CHC)
Building 2000
Fort Sam Houston, TX 78234
Phone: AV 471-3116/6514

TELERADIOLOGY SURVEY SHEET

CASE # _____ Facility Code _____

Physician: Specialty _____ Training Level _____
(Resident, Level ; Intern, etc.)

Patient History:

Diagnosis (be specific):

Please indicate your impression of the items listed below by circling one of the numbers on the scales. The number one (1) indicates the greatest confidence, acceptability, etc., and the number seven (7) indicates no confidence, unacceptability, etc. The midpoint is four (4).

a. The level of confidence in your diagnosis of this case:
Very confident — Not confident
1 2 3 4 5 6 7

b. The clarity of the image presented:
Excellent — Inadequate
1 2 3 4 5 6 7

c. The contrast of the various elements of the image:
Excellent — Inadequate
1 2 3 4 5 6 7

d. The brightness of the image presented:
Excellent — Inadequate
1 2 3 4 5 6 7

e. Were you provided sufficient time to view the image:
More than adequate — Inadequate
1 2 3 4 5 6 7

Is the video imaging of this specific type of x-ray study acceptable for: [circle response(s)]

	Hospital Environment			Field Environment		
a. Consultation	Yes	?	No	Yes	?	No
b. Teaching	Yes	?	No	Yes	?	No
c. Diagnosis	Yes	?	No	Yes	?	No
d. Other (specify) _____						

The ability to examine the image in close detail and to vary the contrast may be critical in making an adequate diagnosis. Was the ability of the camera to zoom in and vary the contrast on the image helpful? Please elaborate on this subject:

Comments on this particular case:

AHS Form 377 (OT)
29 Aug 80

Comments on overall project:

1. Opinion on using this method of diagnosis at fixed facilities and for combat operations:

2. General comments: advantages, disadvantages, suggestions, limitations (why?):

3. How receptive are you to teleradiology? How comfortable are you in using this approach?

APPENDIX C

Phase 2

Cases with Diagnosis

Case #	Diagnosis
1	Dislocat.-4th Fing
2	Fracture-Navicular
3	Normal-Cervical Spines
4	Fracture-Intercond. Emin., Knee
5	Normal Skull
6	Normal Facial
7	Fracture- Public Rami
8	Fracture-Phalange, Salt. II
9	Normal Chest
10	Fracture-Dist. Radius, Linear
11	Fracture-Lat. Malleolus
12	Odontoid Dysplasia-Cong
13	Fracture-Skull, c Diastasis
14	Fracture-Facial, tripod
15	Fracture-L2 & L3
16	Fracture-Phalange, Salt. I
17	Normal Knee
18	Fracture-L2, Chance
19	Normal Elbow
20	Fracture-Dist. Radius
21	Normal Foot
22	Pneumothorax-Rt., 50%
23	Fracture-Ankle, Salt. II
24	Normal Hand
25	Fracture-Calcaneus

APPENDIX D

DEPARTMENT OF THE ARMY
ACADEMY OF HEALTH SCIENCES, UNITED STATES ARMY
FORT SAM HOUSTON TEXAS 78234

HSA-CHC

14 October 1980

Dear Doctor:

Thank you for participating in our second teleradiology demonstration. The format for this hour will be somewhat different from that used in the first effort in which you may have participated.

It is hoped that a series of twenty-five cases will be presented with a viewing time for each case of approximately one and a half minutes. The cases have been selected to represent the type of trauma cases that might be expected to present at a typical emergency room. Cases with positive findings have been over-represented but a significant number of "normals" have also been included.

For each case we would like you to record your specific diagnostic impression; if you are unsure in a particular case it would be most helpful to us if you write down your best guess. We would also appreciate your completing the second page of the survey sheet which relates to teleradiology overall.

One of the consistent criticisms of the first demonstration was a lack of image manipulation. This has been addressed and will be corrected. For your information the diagnoses and presenting histories for the eleven cases previously transmitted are attached. The survey sheets have been compiled and analyzed and the results will be made available in the near future.

Again, thank you for your participation.

1 Incl
as

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Academy of Health Sciences (HSA-CHC)
Building 2000
Fort Sam Houston, TX 78234
Phone: AV 471-3116/6514

TELEMED SURVEY INSTRUMENT FACILITY CODE

Physician Specialty _____

Training Level _____
(Staff, Resident, (by year level), Intern)

Case #	Diagnosis (if unsure make best guess)	Please indicate your percent confidence in your diagnosis from 0% (no confidence) thru 100% (absolute confidence)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		

On a scale of zero through ten please note the acceptability of teleradiology for the following (zero = totally unacceptable; ten = totally acceptable). Circle the appropriate number on the scale:

	Fixed Hospital											Field Medical Unit										
a. Diagnosis	0	1	2	3	4	5	6	7	8	9.	10	0	1	2	3	4	5	6	7	8	9	10
b. Teaching	0	1	2	3	4	5	6	7	8	9	10	0	1	2	3	4	5	6	7	8	9	10
c. Consultation	0	1	2	3	4	5	6	7	8	9	10	0	1	2	3	4	5	6	7	8	9	10

Please comment on the following items for the overall presentation:

1. Clarity and brightness of images.

2. Resolution of images.

3. Usefulness of image manipulation (contrast and zoom).

4. Time allocated to view images.

5. Usefulness of teleradiology.

6. General comments.

DENTAL ANNEX

Dental Applications of Teleradiology

1. Background.

The use of a satellite communications system for transmission of radiographic images appears to have great potential as a teaching, diagnostic, and [illegible]. A review of the medical literature has shown that several studies have been conducted in the field of teleradiology. Carey et al. reported teleradiology readings to be ninety percent as accurate as traditional readings. The dental literature does not indicate that teleradiology has been evaluated in terms of its possible clinical and forensic applications. Because of this, a pilot project was undertaken to evaluate the potential of teleradiology in the field of military dentistry, particularly with respect to applications in the clinical and forensic areas.

2. Objectives.

a. To obtain the opinions of dentists concerning the quality and utility of video images generated on commercial grade television for consultative, diagnostic, and teaching purposes in the clinical environment.

b. To obtain the opinions of dentists concerning the usefulness of video images generated on commercial television for use in remote site forensic dentistry applications.

3. Methods.

a. Overall. The dental portion of this study consisted of a one hour teleradiology program in which maxillo-facial surgery and forensic radiographic cases were presented. Six raters evaluated the quality of the images received at the Dental Activities at Forts Hood, Polk, Sam Houston, and Sill. Dental specialty areas represented were oral surgery, oral medicine, and periodontology. All raters were either board qualified or board certified in their specialties.

b. Maxillo-Facial Applications.

(1) Five maxillo-facial cases were selected by the Chief, Oral and Maxillo-Facial Surgery Service of Brooke Army Medical Center, Fort Sam Houston, Texas. Each of the five maxillo-facial cases were introduced with a narrative history, followed by a series of radiographic images. Pre and post-operative sequences were shown and discussed by the presenter. The raters were asked to indicate their level of confidence in the video images on a seven point scale. "One" represented a "Very Confident" response while "seven" indicated "Not Confident." The scales were applied to the overall series of images reviewed for each case presented and not to individual video images. Rating scales were applied to five characteristics: confidence in diagnosis, clarity of images, contrast of the images, brightness of the images, and adequacy of viewing time. Yes - No responses were used to report overall adequacy of the video images for hospital and military field environments as they related to consultation, teaching, and diagnostic application. Additional space was provided for additional comments.

(2) The following types of maxillo-facial cases were presented:

Case 1. Fractured right mandible with subsequent osteomyelitis and multiple sequestrae.

Case 2. Bilateral fracture of the left angle and right body of the mandible with bilateral fractures of the condyles.

Case 3. LaForte I and II fractures, nasal fracture, and blow out fracture of the orbit.

Case 4. Multiple fracture of the mandible.

Case 5. Work-up and post-surgical follow-up of a mandibular osteotomy.

This section of the program was presented in 45 minutes and consisted of approximately 40 video images being transmitted.

c. Forensic Dental Applications.

(1) One simulated forensic dental case was presented by an experienced forensic odontologist. The presenter was the Dental Health Officer, United States Air Force, School of Aerospace Medicine, Brooks Air Force Base, Texas. Two of the six raters had experience in forensic dentistry.

(2) To simulate the forensic case, bite wing radiographs were sent to the remote sites prior to the program for use as post-mortem acquired radiographs. Raters also had available to them a blank Standard Form 603, Dental Health Record, for use in charting. The raters' roles were to serve as on-site forensic data collectors. The presenter had available pre-mortem bite wing and panagraphic films as well as the completed dental chart (SF 603). The presenter's role was to serve as the professional source of past dental experience for the documentation process. This simulation was designed to test the feasibility of using the voice/video image mode to transmit dental information for remote site identification of remains.

(3) The presenter dictated the entries from the dental record for charting by the remote site raters on their SF 603 charts. This was followed by a thorough review and evaluation of the pre-mortem bite wing and panagraphic films. A close-up camera provided full-screen enlarged video images of all areas of the films. The presenter directed the raters concerning their ability to detect a number of subtle but important conditions and/or defects which appeared on the pre-mortem films. Following this radiographic review the raters completed their evaluation forms for the case.

d. Data Handling.

Evaluations were submitted to the Dental Studies Office, Directorate of Combat Developments and Health Care Studies, Academy of Health Sciences, US Army for tabulation and analysis.

4. Findings, Results, and Discussion.

a. The mean value for each factor and the number of raters responding is shown in Table 1. It should be noted that not all raters rated every case. There is no explanation for why some raters chose to exclude themselves from certain cases. Case 4 received the highest mean values for each factor rated, therefore it represents the case that had the lowest level of acceptability. Narrative comments of raters indicated that the images for diagnosing the blow-out fracture were of especially poor quality and were primarily responsible for the poor overall rating. The forensic case received consistently high scores indicating that this application also has potential for further utilization. Table 2 depicts the degree of acceptance for the use of the transmitted video images for consultation, teaching and diagnosis, and demonstrates that Case 4 was the least acceptable case presented.

b. The overall quality of the images transmitted and the performance of the dental panelists indicates that teleradiology has definite potential for dental application. Further studies to evaluate the quality of individual images are a necessity. The ability of dentists to make a diagnosis at remote locations, and for remote stations to send images of diagnostic quality to specialists must also be evaluated. The potential usefulness of teleradiology in the field of forensic medicine and dentistry appears very promising, especially if centralized storage of dental records on high-density digital discs becomes a reality.

5. Conclusions.

a. Video images transmitted and viewed on commercial grade television equipment received favorable overall evaluation by dental specialists for diagnostic, teaching and consultative applications in both the hospital and field environment.

b. Video images transmitted and viewed on commercial grade television equipment have potential value for remote site forensic dentistry applications.

6. Recommendation.

Recommend that further studies be conducted to document and refine the dental applications of telecommunications technology.

Table 2

Rating of Acceptability of Video Images in Hospital and Military Field Environments

	Case 1		Case 2		Case 3		Case 4		Case 5		Forensic Case	
Hospital Environment	Rating	N	Rating	N	Rating	N	Rating	N	Rating	N	Rating	N
a. consultation	2.0	5	2.0	5	2.00	5	1.00	6	2.00	3	2.00	4
b. teaching	2.0	5	2.0	5	2.00	5	1.00	6	2.00	3	2.00	4
c. diagnosis	2.0	5	2.0	5	1.80	5	1.00	6	2.00	3	2.00	3
Field Environment												
a. consultation	2.0	5	2.0	5	2.00	3	1.20	5	2.00	3	2.00	4
b. teaching	2.0	5	2.0	5	2.00	3	1.20	5	2.00	3	2.00	3
c. diagnosis	2.0	5	2.0	5	2.00	3	1.20	5	2.00	3	2.00	3

Yes = 2
No = 0

Table 1

Dental Teleradiology Image Ratings
(Mean values for levels of confidence
for video images evaluated.*)

	Case 1		Case 2		Case 3		Case 4		Case 5		Forensic Case	
FACTOR	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N
a. level of confidence	1.33	6	2.00	5	3.00	5	3.60	5	1.66	3	1.25	4
b. clarity	1.50	6	1.50	6	2.20	5	3.50	6	1.66	3	1.25	4
c. contrast	2.00	6	1.66	6	2.00	5	3.66	6	1.66	3	1.25	4
d. brightness	1.50	6	1.83	6	1.80	5	4.16	6	1.66	3	1.25	4
e. time	1.80	5	1.66	6	2.00	5	2.66	6	2.00	3	1.50	4

* Mean values derived from a seven point rating scale ranging from "1" representing "Very Confident" to "7" representing "Not Confident."

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