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By

SCI SYSTEMS, INC.

Biomedical Engineering Department

8330 Broadway

Houston, Texas

Contract NAS 9-13118

Video Requirements for Remote Medical Diagnosis

Final Report

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1.0 INTRODUCTION

The scarcity of practicing physicians in certain rural and urban sections of the United States has led to the development of several programs which use paramedical personnel to provide a first tier health screening service. Health programs utilizing nurse practitioners and physician's assistants in increased responsibility medical support roles have begun. The physician's skill is brought to bear only where it is required; supporting data gathering and treatment is handled by allied health personnel whose training qualifies them for a primary medical assistance role. Patient accessibility to health care service and the physician's ability to see more patients with better utilization of his time have been improved by these "task allocation" programs.

In addition to the use of paramedical personnel, the physician's efficiency can also be increased by the implementation of information systems utilizing present day technology and system engineering techniques. A television system for remote visual examination is part of this evolving telemedicine technology. In general, it is felt that basic television technology exists with sufficient performance to satisfy telemedicine requirements, but the detailed characteristics of a television system for strictly medical purposes have not been objectively studied (under controlled conditions) except in a few limited areas.

A major technical problem has been the lack of a television system specifically designed to meet minimum medical requirements and to be compatible with existing low cost voice-grade transmission links; i.e., VHF/UHF radio systems, telephone systems, etc. Technology presently exists to implement high resolution visual transmission systems which could meet the telemedicine requirements; however, the wideband communications links required are very expensive. Even if wideband communications are feasible or affordable, there are not sufficient data on the minimum pictorial requirements to design a medical television system in order to fit specific usage applications. Analysis and design relative to the number, type, and placement of TV cameras/lenses/ monitors, lighting, human factor relationships, communication link characteristics (bandwidth, signal/noise, linearity, etc.), cannot be effectively completed without a full knowledge of pictorial requirements.

NASA was motivated to perform this study due to the related transmission and cost problems requiring solutions if telemedicine is to become a practical reality for both manned space missions and terrestrial applications. With the rapidly expanding usages for telecommunications, the RF spectrum is very congested in many areas with the cost of transmission being very dependent on the data bandwidth requirements. Therefore, for those who for practical cost reasons can implement only a minimal system, it is important to know the pictorial and diagnostic limitations as related to such technical characteristics as scene resolution, motion rendition, contrast ratio dynamic range, colorimetry, signal-to-noise ratio, etc.

NASA therefore contracted SCI Systems, Houston Division, to conduct a study to determine the minimal television system requirements for telediagnosis. The experiment was conducted with the aid of a simulated telemedicine system. The first step involved making high-quality videotape recordings of actual medical examinations conducted by a skilled nurse under the direction of a physician watching on closed circuit television. These recordings formed the "baseline" for the study. Next, these videotape recordings were electronically degraded to simulate television systems of less than broadcast quality. Finally, the baseline and degraded video recordings were shown (via a statistically randomized procedure) to a large number of physicians who attempted to reach a correct medical diagnosis and to visually recognize key physical signs for each patient. By careful scoring and analysis of the results of these viewings, the pictorial and diagnostic limitations as a function of technical video characteristics were to be defined.

2.0 EXPERIMENT DESIGN

In order to determine the minimum television requirements for remote visual examinations (telediagnosis), SCI utilized a well-controlled, simulated telemedicine system for the basic data gathering.

It was felt that this approach would lead to a set of patient data which was truly representative of a working telemedicine system -- a requirement considered to be imperative for valid results. The determination of the minimum television requirements for telediagnosis thus involved four distinct activities:

1. Utilization of a simulated telemedicine system to generate high-quality videotapes of patient examinations and other aspects of the patient/physician interaction. Physicians utilized in this part of the program were called the Examining Physicians. These recordings formed the baseline for the study.

2. Generation of precisely-controlled electronic degradations of these videotapes to simulate various types and qualities of television systems.

3. Viewing of the baseline and degraded videotapes by a large number of physicians working on an independent basis. Physicians utilized in this part of the program were called the Reviewing Physicians.

4. Scoring and analysis of the results of these viewings. Physicians utilized in this phase of the program were called the Grading Physicians.

Each of these four activities is detailed in the following corresponding section (2.1 through 2.4).

2.1 Examining Physician - Patient Transactions (Baseline Recording)

The videotaping of the various patient cases is discussed in the two sections below.

2.1.1 Patient Selection

Three sources of patients were utilized for this phase of the program as no one source was able to provide the quantity or variety of patient cases required for the study. These sources were:

1. Clear Lake Hospital, Emergency Room
   500 Medical Center Boulevard
   Webster, Texas

2. Aerospace Medical Consultants
   Intercontinental Airport Facility
   Houston, Texas

3. Medical Diagnostic Films
   From various medical film libraries

The exact number and type of patient cases was of considerable concern during the initial formation of the experimental design. It was agreed that a group of 45 patient cases spread over a wide medical spectrum would provide an adequately representative base for study. The final list of cases used is shown in Table 1 with the assigned case numbers (1-45) appearing in parentheses.

2.1.2 Patient Videotaping

The videotaping sequence for patients from the first two sources involved, for the most part, drop-in patients to the Clear Lake Hospital Emergency Room, and the Intercontinental Airport Clinic. Each patient was screened for suitability to program requirements by the study physician. If the case met the study needs, the patient was approached by the study physician and asked to read the Patient Briefing. This was a short summary of the study background, operation and goals and is included as Appendix A to this report. If the patient agreed to participate (patient acceptance was over 95%), he or she signed a Patient Consent form (Appendix B) and completed a Medical History Questionnaire. Some initial treatment was provided prior to videotaping for those cases where the time delay was a medical factor.

MEDICAL CATEGORIES/PATIENT CASES

1. Extremity Injuries
   a. Ulnar Nerve Palsey (13)
   b. Wrist Fracture (4)
   c. Dislocated Finger (5)

2. Exanthematous Diseases
   a. Chicken Pox (17)
   b. Measles (42)
   c. Scarlet Fever (43)

3. Flesh Wounds
   a. Lacerated Finger (1)
   b. Lacerated Leg (3)
   c. Gunshot Wound (2)

4. Bone & Joint Disorders
   a. Osgood Schlatter's Disease (15)
   b. Arthritis (19)
   c. Osteomyelitis (& Renal Disease)(20)

5. Endocrine/Renal Disorders
   a. Cushings Syndrome (ITP)(21)
   b. Hyperthyroidism (37)
   c. Nephrosis (38)

6. Dermatological Problems
   a. Moniliasis (11)
   b. Giant Urticaria (6)
   c. Chronic Mild Eczema (31)

7. Oral/Throat Disorders
   a. Abscessed Tooth (8)
   b. Tonsilitis (14)
   c. Vocal Cord Cyst (16)

8. Respiratory Problems
   a. Emphysema (& Myxedema)(25)
   b. Pleurisy (30)
   c. Newborn (Irregular but normal respiration)(36)

9. Eye Diseases
   a. Vernal Conjunctivitis (39)
   b. Episcleritis (40)
   c. Keratitis (41)

10. Cardio/Cerebral Vascular Disorders
    a. CVA (& RHD) (32)
    b. Aortic Aneurysm (34)
    c. RHD (& Herpes Zoster) (24)

11. Suspected Malignant Tumors
    a. Cirrhosis (Possible Hepatoma) (23)
    b. Bronchogenic Carcinoma (28)
    c. CA of Breast (& Diabetes) (33)

12. Neuro/Muscular Disorders
    a. Lead Encephalopathy (35)
    b. Multiple Sclerosis (12)
    c. Post-Traumatic Hemiplegia (27)

13. Acute Infectious Diseases
    a. Meningitis (22)
    b. Infectious Mononucleosis (18)
    c. Syphilis (44)

14. Miscellaneous Conditions
    a. Mild Head Trauma (9)
    b. Muscular Dystrophy (26)
    c. Hysterical Aphonia (29)

15. Miscellaneous Conditions
    a. First Degree Burn (7)
    b. Second Degree Burn (10)
    c. Rhinitis (45)

TABLE 1.

Each examining physician and the nurse or paramedical assistant was thoroughly briefed and informed of certain guidelines to be followed during the examination. The purpose of these Guidelines (Appendix C) was to assure a thorough examination and to help minimize the need for videotape editing.

The patient was next taken to the examination area which is detailed in Figure 1. (Note that two separate, isolated rooms were involved, with the patient in one and the physician in the other.) This configuration simulated a working telemedicine system where the patient is located remotely from the examining physician who is viewing the patient via television.

The patient was examined by a nurse under the direction of the remote Examining Physician viewing the examination on a degraded resolution black and white video monitor. The patient was shown in black and white and resolution of the picture was degraded in order to force the physician to elicit more detailed descriptions (sign characteristics, color features, etc.) from the nurse. Since the Reviewing Physicians were subsequently to attempt diagnosis from degraded video presentations, it was necessary to have the audio description more complete.

A technician operated the color camera and two videotape recorders (VTR's); one for full NTSC color and one for high-quality monochrome. In addition, the technician was responsible for seeing that all data called for on the Videotaping Data Sheet including Patient Data, Examining Personnel Data, Physician's Diagnosis, Tape Data, and Comments were registered. The Videotaping Data Sheet is attached as Appendix D.

The need for views through various endoscopes (otoscopes, opthalmoscopes, laryngoscopes, etc.) arose during the videotaping. The interfacing between television cameras and these instruments presents difficult technical problems whose resolutions are still in the experimental and development phases and beyond the scope of this experiment. It is expected that efficient interface systems will be developed, and therefore the SCI approach was to simulate what could reasonably be expected of these future systems. To create the simulation,

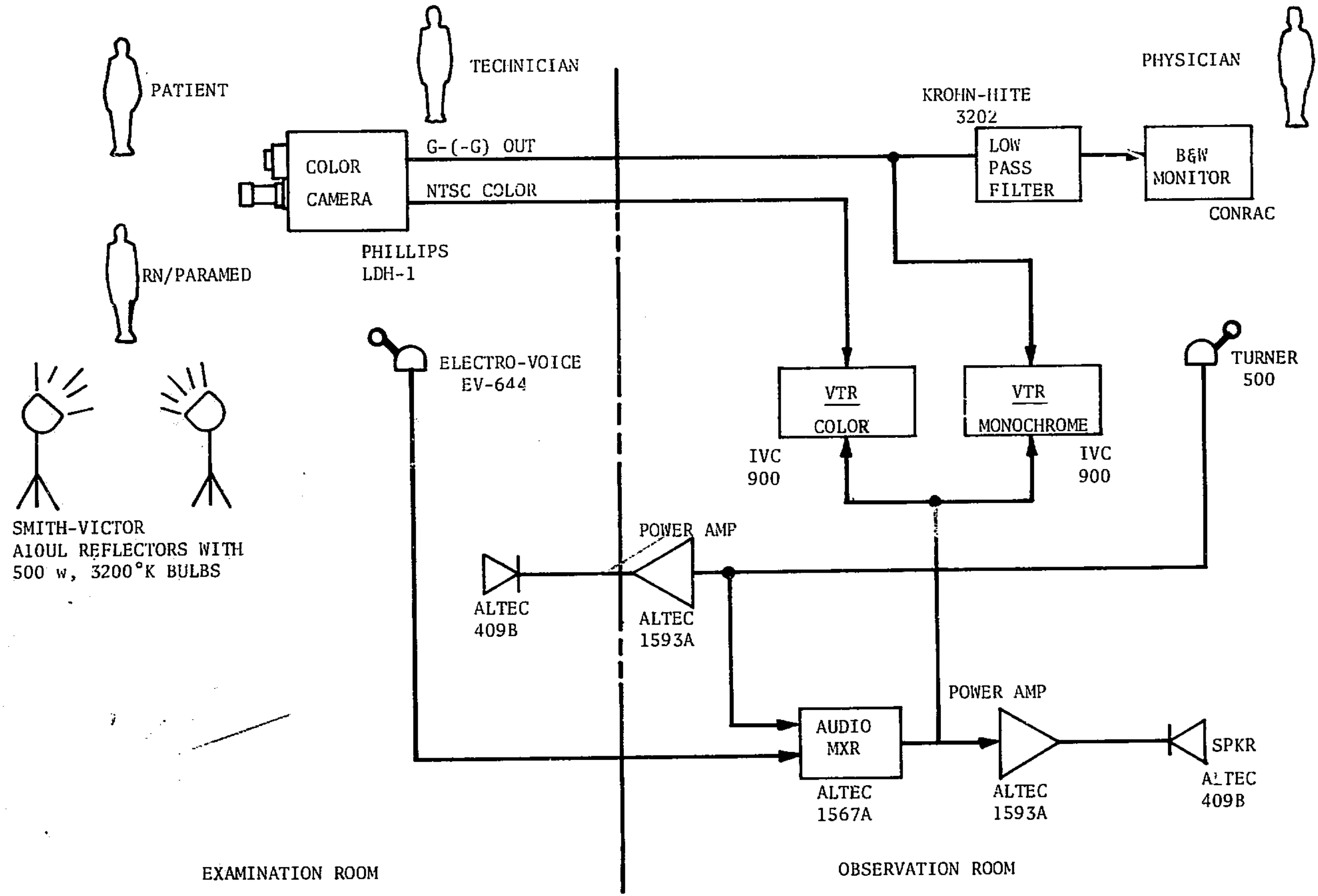

PATIENT
TECHNICIAN
PHYSICIAN
KROHN-HITE
3202
COLOR
CAMERA
G-(-G) OUT
NTSC COLOR
LOW
PASS
FILTER
B&W
MONITOR
CONRAC
PHILLIPS
LDH-1
RN/PARAMED
ELECTRO-VOICE
EV-644
VTR
COLOR
VTR
MONOCHROME
TURNER
500
IVC
900
IVC
900
SMITH-VICTOR
A10UL REFLECTORS WITH
500 w, 3200°K BULBS
POWER AMP
ALTEC
409B
ALTEC
1593A
POWER AMP
AUDIO
MXR
SPKR
ALTEC
1567A
ALTEC
1593A
ALTEC
409B
EXAMINATION ROOM
OBSERVATION ROOM

FIGURE 1

endoscopic views available from various medical film sources were videotaped to represent the view actually observed by the examining nurse. Microscopic slides were treated in the same manner, X-rays were viewed with the video camera and videotaped directly.

It was found that careful attention to lighting techniques was required for good visualization in general, and especially for dermatology problems. The flat lighting used for most patients tended to "wash out" skin problems and therefore more oblique lighting was required.

Good visualization of oral/throat views was obtained by moving the two floodlights very close to the sides of the camera and using close-up lens adapters.

In order to generate a high-resolution monochrome signal (higher than that obtainable with the composite color signal) without the use of a second camera, the output of the color camera was used. This signal is equivalent to a normal monochrome signal because of the broad-bandpass optical filter used in the green channel.

2.1.3 Medical Film Usage

The use of filmed patients presented a new problem into the study because of the requirements that these patients be presented (to the reviewing physicians) in the same format as the videotaped patients. The conversion of the films to videotape required only the use of a commercial film chain. However, certain of the films did not contain the normal audio interchange between the physician and nurse. It was therefore necessary to dub in this audio exchange. This was done by allowing a physician and nurse to watch the film and act the roles of the examining physician and nurse. The conversation between the two was simultaneously recorded on the finished videotape, thus producing a finished tape in the same format as the actually-videotaped patients.

2.2 Selected Television Systems (Video Parameter Variations)

The video parameters to be varied in this study were colorimetry, frame rate, and horizontal resolution. (Signal-to-noise ratio variation was also done on a supplementary basis.) It was immediately evident that vast numbers of feasible television systems could be specified. For instance, allowing the parameter of frame rate to assume only three values, resolution only three values, and colorimetry two values, a total of 18 discrete systems could be specified. A thorough investigation of even this small portion of all possible systems was clearly impossible. The task therefore was to judiciously choose a realistic set of systems for investigation.

Several factors aided in this selection. First, it was desirable to select a set of television systems which covered a large section of the spectrum of possible television systems. Secondly, it was desirable that both baseline tapes (broadcast-quality color and broadcast-quality black and white) be investigated. And finally, the total number of investigated systems had to be small enough that a significant amount of data could be gathered on each system by the limited group of Reviewing Physicians. Taking all factors into consideration, five feasible telediagnosis systems were chosen for the prime study. A sixth television system (very low resolution black and white) was also done on a supplementary basis as was as an audio-only test.

Table 2 is a list of these six television systems. Systems 4 and 5 (the baseline videotapes) are compatible with transmission over a full bandwidth television channel. The other four systems allowed more detailed investigation of the frame rate (motion rendition) and horizontal bandwidth (scene resolution) required for each medical case.

The exact methods used to vary each of the parameters are discussed below.

2.2.1 Colorimetry

The colorimetry parameter had two possible states, that is, either full NTSC color or black-and-white. No intermediate values were used as it was felt that should color prove a necessity, the color quality produced in an NTSC type system would be required as a minimum.

SELECTED TELEVISION SYSTEMS

Color/B&W	Hor. Luminance Bandwidth into Standard Monitor (MHz)*	TV Lines from Retma Chart	Frame Rate (Frames/Sec)	Description
0. B&W	0.50	100	10.0	Monochrome system with very low scene resolution (supplementary configuration)
1. B&W	4.0	400	0.2	Monochrome system with no motion rendition
2. B&W	1.3	200	10.0	Monochrome system with reduced motion rendition and scene resolution
3. B&W	4.0	400	10.0	Monochrome system with reduced motion rendition only
4. B&W	4.0	400	30.0	Baseline recording, standard monochrome system
5 Color	3.0	250	30.0	Baseline recording, standard color system

TABLE 2

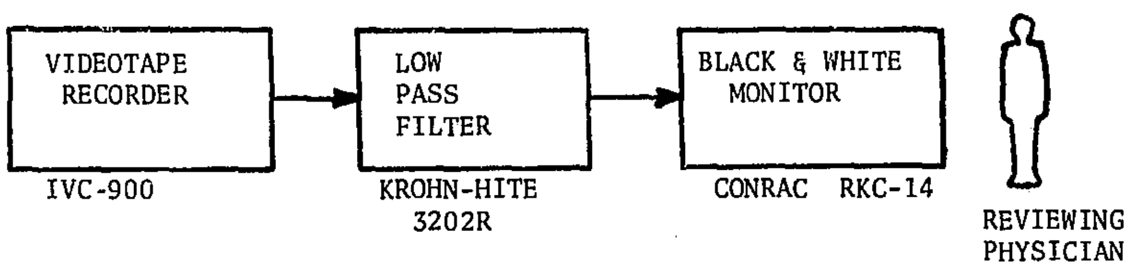
* 3 db bandwidth with 24 db/octave rolloff.

2.2.2 Frame Rate Variation

Frame rate variation was done by the method shown in block diagram in Figures 2a and 2b. All frame rate variation was accomplished starting with the baseline black-and-white recording (as used for System 4 in Table 2). This tape was played back on VTR 1, Figure 2a, into the Ampex HS-200 Stop-Action Disc System. The Ampex HS-200 stop action disc system can be programmed for specific time intervals (animation mode) between recording commands and was therefore programmed to record only every n^{th} frame. Now, because the video ultimately had to be evaluated on standard video monitors, which required 60 Hz field updating, a second step was required. (See Figure 2b) The HS-100 disc was filled to capacity (approximately 1800 fields or 900 frames) and then, utilizing the slow motion mode, each frame was played back n times (at the standard 30 frames/second rate) before progressing to the next new frame. Thus, the recording on VTR 2 is standard 30 frames/second but the new frame is updating at 30/n frames/second. Therefore, on the standard monitors, a flicker-free picture appeared to be snapshot updated every n/30 seconds. The recording on VTR 2 thus became the recording used for System 1 or 3, depending on the frame rate selected at the HS-200.

2.2.3 Resolution Variation

To produce lower resolution videotapes, such as that required for System 2, the videotape of System 3 was passed through a low pass filter (4 pole Butterworth response) on a real time basis as the Reviewing Physicians watched. See Figure 3.



RESOLUTION VARIATION

FIGURE 3

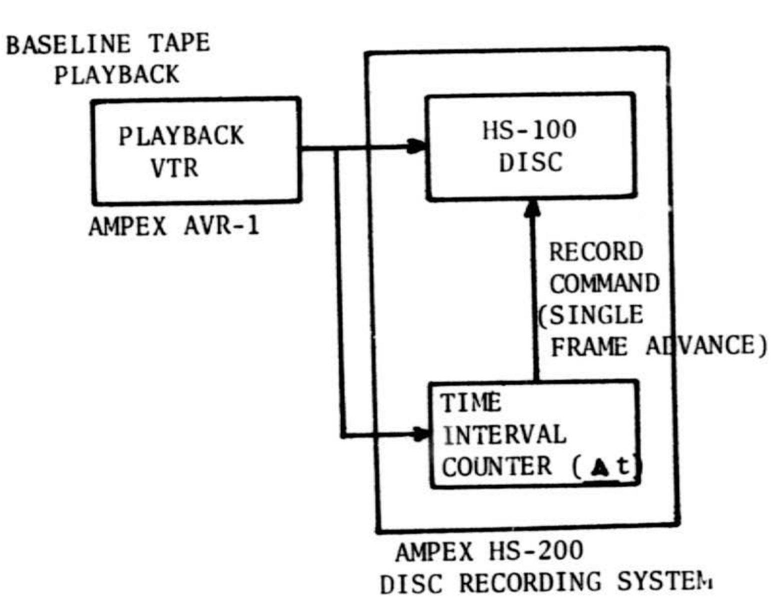


FIGURE 2a

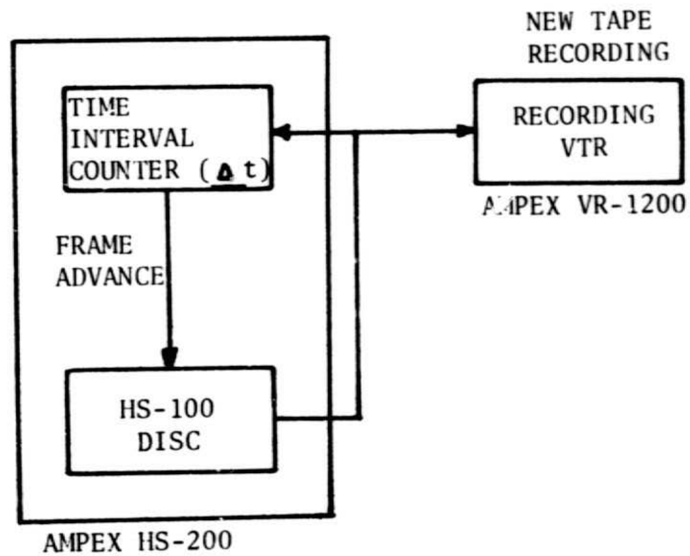


FIGURE 2b

FRAME RATE VARIATION

2.2.4 Signal/Noise Ratio (SNR) Variation

The SNR was not varied during the main study. The video tape playbacks resulted in high SNR levels of approximately 35-40 db. The film-to-video transfer cases had the most noise. The effects of SNR variation were examined in a supplementary study detailed in Section 2.3.2.4.

2.3 Reviewing Physician Evaluations

Testing involved the viewing and evaluation of many videotapes by many physicians. Physicians involved were almost entirely General Practitioners, with a few specialists utilized as required. At this point in the experiment, five videotape "degradations" (one for each system in Table 2) had been generated for each of the 45 patients. Thus, a total of 225 videotaped medical examinations required evaluation by the viewing physicians. The task was, therefore, to define a logical, statistically-randomized evaluation procedure. This is described in Section 2.3.1.

Aside from the main line of testing, several supplemental tests were run where it was decided that more detailed examination would be beneficial. A test was run where the Reviewing Physician had no video information, but was only given an audio description by a physician's assistant. Supplementary tests were also run examining video systems with extremely low resolution, SNR, and frame rate. Lastly, a test was devoted solely to the examination of x-rays. These supplemental tests are described in Section 2.3.2.

2.3.1 Principal Testing - Diagnostic Evaluation

The major portion of the main testing program was conducted with the aid of General Practitioners. The design of this testing program is discussed in Section 2.3.1.1. The aid of specialists was required in a few specific cases. The use of these physicians is described in Section 2.3.1.2.

2.3.1.1 General Practitioner Diagnostic Evaluations

To provide order to the viewing sequence, it was initially decided to use a "balanced" design utilizing only General Practitioners. As an example, balance was possible with any of these designs:

	Number Configurations (Degradations) Per Patient	Number of GP's
(i)	4	4, 8, 12, etc.
(ii)	5	5, 10, 15, etc.
(iii)	8	8, 16, 24, etc.

An example of a viewing matrix based on four television configurations (c_1-c_4) per patient, eight viewing GP's (viewing independently) and eight patients is presented in Table 3.

This matrix completely defines the hypothetical experiment design and, in addition, is completely balanced. Therefore, any one of the 64 data points (viewings) has the same significance as any other point.

Secondly, it was desirable that learning factors be controlled as much as possible in the experiment. An obvious situation which had to be avoided was that of allowing a given doctor to view more than one TV system (and also hear the audio track again) on a given patient. This problem is not present in the sample design of Table 3 as each doctor sees each patient only one time.

Thirdly, it was desirable from a statistical standpoint (reduced variability) that more than one judgement be obtained on each degradation of each patient. For instance, referring to Table 3, GP2 and GP6 both view the number 3 configuration on patient 2.

It was decided that a total of five television systems (Table 2, Systems 1-5) should be primarily studied and that the following experimental design be implemented (see Table 4). It is seen that 15 GP's were to view all 45 cases with each of the five degradations for each patient being reviewed 3 times. (For example, it is seen that degradation c_1, for patient 1 was seen by doctors 1, 6, and 11). Multiple showings were intended to cancel out the variable of physician skill. Table 4 was computer randomized and is included as Table 5. In Table 5, the Randomized Comprehensive Viewing Matrix, the first number in each set is the patient number and the second is the particular degradation (1 through 5 as listed in Table 2) to be used. Hence, the first case viewed by doctor #3 would be patient 34, degradation 4, which is the Aortic Aneurysm case as presented by a standard monochrome system.

Each doctor viewed the TV presentations on an individual basis due to the high degree of randomization in the experimental design. For each patient, the

Patient # / GP #	1	2	3	4	5	6	7	8
1	C_1	C_2	C_3	C_4	C_1	C_2	C_3	C_4
2	C_2	C_3	C_4	C_1	C_2	C_3	C_4	C_1
3	C_3	C_4	C_1	C_2	C_3	C_4	C_1	C_2
4	C_4	C_1	C_2	C_3	C_4	C_1	C_2	C_3
5	C_1	C_2	C_3	C_4	C_1	C_2	C_3	C_4
6	C_2	C_3	C_4	C_1	C_2	C_3	C_4	C_1
7	C_3	C_4	C_1	C_2	C_3	C_4	C_1	C_2
8	C_4	C_1	C_2	C_3	C_4	C_1	C_2	C_3

TABLE 3

SAMPLE VIEWING MATRIX

(Before Randomization)

Entity	Patient	GP # 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	1	C_1	C_2	C_3	C_4	C_5	C_1	C_2	C_3	C_4	C_5	C_1	C_2	C_3	C_4	C_5
1	2	C_2	C_3	C_4	C_5	C_1	C_2	C_3	C_4	.....						
	3	C_3	C_4	C_5	C_1	.....										
	4	C_4	C_5	C_1	.....											
2	5	C_5	C_1	.....												
	6	C_1	.....													
	.															
	.															
	.															
	.															
	.															
	.															
	.															
	.															
	.															
	43	C_3	C_4	C_5	C_1	C_2	...									
15	44	C_4	C_5	C_1	C_2	...										
	45	C_5	C_1	...												

TABLE 4 - FINAL VIEWING MATRIX
(Before Randomization)

VIEWING #	DOCTOR 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	17-5	16-2	34-4	29-1	27-1	10-3	38-1	33-1	28-4	1-4	41-1	27-4	8-4	13-3	40-1
2	10-2	44-1	10-5	22-3	40-3	38-5	18-1	17-4	36-1	36-4	19-4	28-1	43-4	36-4	16-4
3	32-5	4-4	19-4	17-5	5-2	13-2	16-5	30-3	14-2	32-2	37-4	16-4	10-2	41-5	30-5
4	40-5	5-3	12-3	44-2	41-1	16-4	19-3	12-4	11-3	44-4	3-1	6-4	32-5	39-5	24-2
5	35-4	2-5	38-2	1-2	16-1	40-1	44-4	7-4	30-3	25-2	10-5	35-5	30-4	45-2	20-3
6	8-4	17-4	31-1	23-2	4-3	36-3	36-4	14-2	4-4	20-4	28-3	21-5	41-3	1-4	15-3
7	11-4	30-3	2-4	20-2	19-4	23-3	32-2	32-4	6-2	37-5	21-2	24-2	29-1	22-5	37-2
8	12-5	14-2	16-1	3-3	3-1	5-5	12-2	38-3	21-3	16-5	44-5	1-3	1-2	14-5	42-2
9	31-3	27-2	23-5	13-1	42-4	28-1	22-5	41-2	15-1	42-3	4-3	31-4	11-4	12-2	25-1
10	34-1	42-5	22-1	16-3	22-1	4-1	20-4	45-4	10-1	19-3	34-4	4-1	25-5	30-1	3-4
11	21-4	19-5	36-5	35-4	25-3	29-2	2-3	31-2	17-4	13-3	24-4	12-1	4-5	10-4	21-5
12	18-4	26-1	29-4	21-4	32-3	34-2	17-2	35-3	18-3	5-1	25-3	17-1	15-2	26-4	18-5
13	3-3	8-3	25-3	6-3	18-2	21-5	3-5	6-2	8-3	6-5	29-4	2-2	20-2	5-1	2-2
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22	42-1	20-1	45-3	28-5	26-5	8-5	11-1	37-5	5-3	8-1	16-1	42-2	5-4	24-3	5-5
23	24-1	23-1	28-3	19-1	33-5	25-1	1-4	26-1	43-3	26-4	26-5	36-3	22-3	29-3	35-5
24	38-4	31-2	27-1	33-2	2-4	33-3	42-3	10-1	19-5	22-5	11-2	20-3	24-1	23-4	8-5
25	22-3	1-1	30-2	40-5	31-1	7-1	35-1	40-4	44-1	21-1	20-5	8-5	26-2	37-3	17-1
26	27-3	28-4	32-3	10-2	12-3	42-2	4-2	1-1	33-1	45-2	14-1	13-2	7-5	6-5	29-2
27	9-1	7-4	4-3	18-4	23-5	15-3	9-3	9-5	40-4	23-4	43-2	5-5	36-2	38-1	33-3
28	14-3	33-1	24-4	32-5	45-3	24-2	7-2	13-5	35-3	29-3	27-1	9-2	37-1	32-2	34-2
29	44-2	34-5	20-5	7-5	34-4	32-1	31-5	25-4	3-2	38-1	1-5	33-3	44-2	31-5	9-2
30	20-2	25-4	8-2	24-1	35-2	26-5	25-2	42-5	16-2	31-5	45-3	14-4	16-3	21-1	38-5
31	33-2	22-2	11-2	4-5	17-3	9-2	40-2	44-1	42-5	39-5	42-4	32-1	34-1	2-3	1-3
32	13-1	13-5	37-4	15-2	13-4	14-4	6-5	34-5	12-4	10-4	38-2	11-5	35-4	44-4	7-1
33	36-2	11-3	21-2	26-2	21-2	39-4	43-1	21-3	13-5	4-2	39-1	30-5	6-3	43-1	10-3
34	4-5	32-4	26-5	25-5	30-2	43-5	29-3	2-5	27-2	24-3	13-4	29-2	9-1	28-2	45-1
35	2-1	36-1	43-2	31-3	6-1	20-3	34-3	23-1	7-4	17-2	2-4	18-5	19-1	40-2	6-4
36	29-1	10-1	39-1	11-4	9-4	35-5	37-3	18-3	38-3	43-1	23-5	15-3	28-5	15-4	26-3
37	45-5	21-3	13-4	41-3	37-4	31-4	30-1	8-3	20-1	3-5	12-3	7-1	2-1	35-1	23-3
38	28-5	18-3	14-1	45-5	36-5	6-4	23-4	3-2	32-4	9-3	9-4	19-2	38-4	27-5	31-4
39	25-5	40-4	35-2	14-3	15-5	41-4	13-3	39-2	29-5	28-2	8-2	40-1	3-3	42-3	39-4
40	39-3	41-2	17-3	38-4	1-5	37-2	45-2	24-5	41-2	33-4	35-2	41-4	23-2	9-3	11-5
41	43-4	43-3	6-1	8-4	8-2	45-1	21-1	19-5	45-4	18-1	7-3	22-4	45-5	4-2	4-1
42	37-1	6-2	18-2	43-4	7-3	2-2	15-4	27-2	23-1	15-4	33-5	26-3	21-4	20-4	27-4
43	23-2	9-5	42-4	42-1	43-2	11-5	8-1	36-1	34-5	35-1	15-5	39-4	39-3	3-5	13-2
44	19-1	45-4	44-5	2-1	10-5	17-1	24-3	4-4	22-2	40-2	17-3	37-2	18-4	8-1	43-5
45	16-3	37-5	41-1	34-1	39-1	1-3	33-4	16-2	25-4	34-3	32-3	38-5	14-3	7-2	32-1

TABLE 5

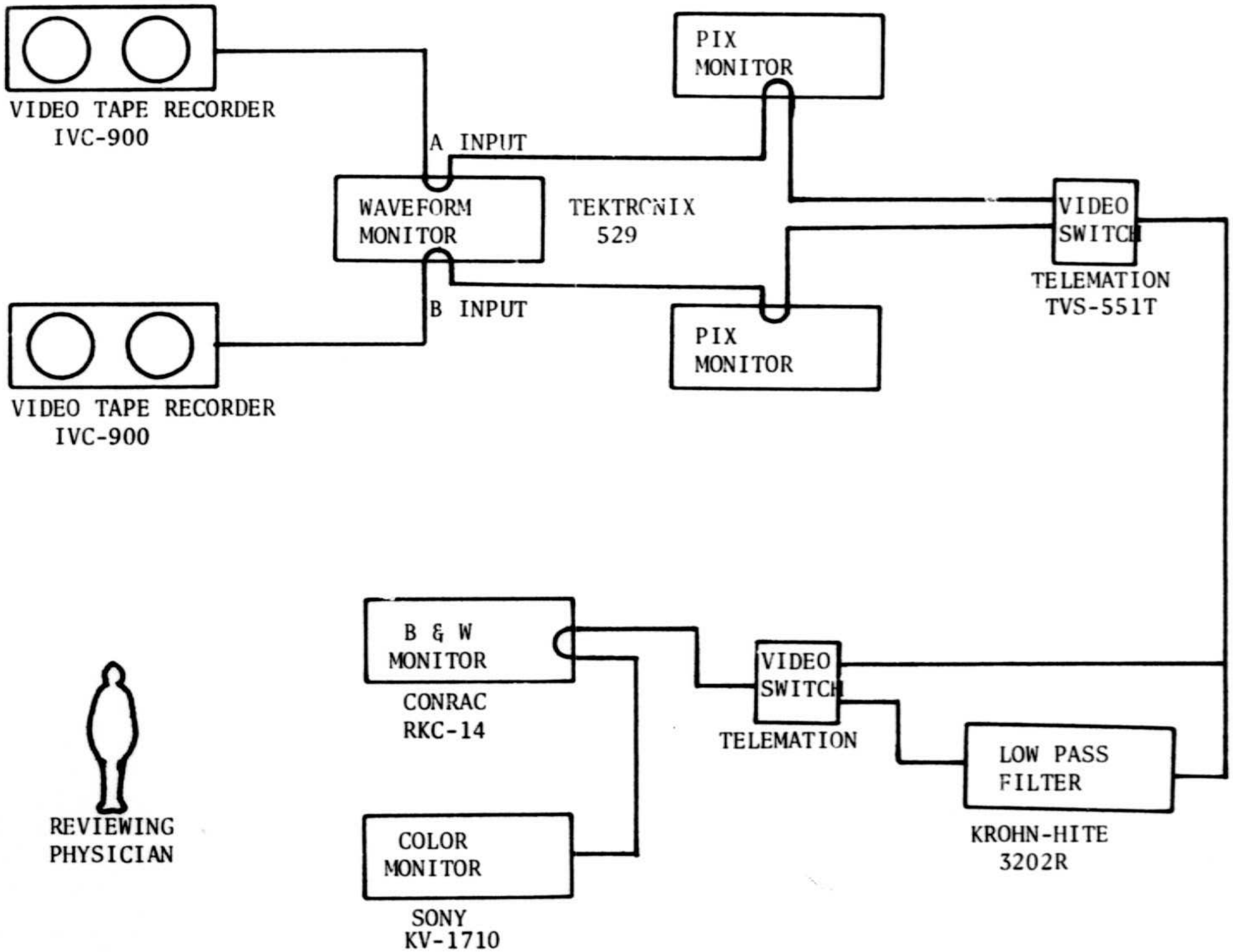
doctor evaluated the television system by completing the Reviewing Physician's Evaluation form (Appendix E). Evaluation was first done by each doctor after viewing only the patient interview. A second evaluation was performed by the doctor after viewing the entire patient data pack. The evaluation form was designed to answer several basic questions. Of primary importance, of course, was whether the doctor could form a clinical opinion(s) from the data presented. If he could not, he was asked to explain. It was anticipated that this question would identify reasons other than lack of a high-quality video presentation. Several possible responses are listed for check-off on the evaluation form.

For many patients, the doctor also completed a Physican Signs Recognition Chart. An example of one of these charts (for patient 37) is included as Appendix F. A different chart was provided for each patient, the difference depending upon the particular physical signs present. These charts were designed to aid in the TV system evaluation by providing specific information on the medical data provided exclusively by visual means.

Figure 4 is an equipment block diagram for the physician reviewing phase of the program. Two IVC-900 video tape recorders (VTR's) were used for playing back the degraded tapes to the reviewing physicians. Approximately 25 one-hour reels were required to hold all the variations for the 45 patients. Because of the randomized showings, it was necessary to change tape reels quite often and therefore it was found to be advantageous to be changing one recorder while the physician viewed a patient being played on the other recorder. A video switch was used to control which VTR output was being presented to the physician. The video signal was passed through a low-pass filter to produce the lower resolution system 2 and 0. Two video monitors were fed simultaneously with the brightness control being turned fully off on the monitor not being used. The black and white monitor,was, of course, used for Systems 0 through 4 and the color monitor for System 5.

2.3.1.2 Specialist Diagnostic Evaluations

In the early program phases, it was unknown exactly what amount of participation by specialists would be required for thorough examination of the study problem.



REVIEWING EQUIPMENT

FIGURE 4

It was agreed that the degree of their involvement would depend on the performance of the GP's. If the GP's tended to produce very low scores, it would have been necessary to utilize many specialists in order to determine whether the low scores were caused primarily by lack of video quality, physician unfamiliarity with the particular entity, or insufficient diagnostic data, etc.

As the study progressed, the ability of the General Practitioners to arrive at correct diagnoses even under very poor video conditions became quite evident. In only a few cases was it felt that a review by specialists would be required. These cases were numbers 39, 40, and 41 in Table 1. These three cases involving the eye caused the General Practitioners considerable difficulty and were therefore examined spearately by a group of Ophthmalmologists.

The tests involving the Ophthalmologists were conducted in a somewhat less formal manner than had been used on the GP's. For expediency, the three Ophthalmologists were allowed to view the cases as a group; however, independent work was still required. They were also allowed to view more than one degradation of the same case, primarily because a large number (15-20) of Ophthalmologists was not readily available. The presentation began with audio only, then the lowest quality video picture, and then progressed upwards.

The diagnoses of the Ophthalmologists were graded in exactly the same manner (and using the same guidelines) as were those of the GP's. The Ophthalmologists' scores (rather than the GP's) were used in the final averages because these scores represented a more realistic evaluation of the television system.

2.3.2 Supplementary Evaluations

It became apparent during the early testing phase that the General Practitioners were, in general, doing much better than had been expected. In fact, a significant number of incorrect diagnoses was not being induced by even the worst quality TV picture being used (System 1, Table 2). It was decided, therefore, that data points should be taken on even lower-quality systems and several abbreviated tests (single physician evaluations) were devised for this purpose.

2.3.2.1 Audio Only Evaluation

The first of these was the ultimate in picture degradation; that is, audio only. In this case, the Reviewing Physician received only an audio narrative from a well-trained and experienced physician's assistant (P.A.) who was watching the videotaped patient. This test was conducted over a telephone link between the NASA Johnson Space Center, Houston, (The location of the P.A.) and a physician (General Practitioner) in Tuscon, Arizona. The physician filled out essentially the same evaluation form (Appendix E) as all other GP's and these forms were graded in the same manner as the forms for all other physicians in the main testing program. Test results for this "system" are presented under the system heading of A.O.

Also during this test, the P.A. was asked to evaluate the cases prior to physician contact and provide his personal diagnoses on a separate set of evaluation forms. These evaluations were later graded in the same manner as those of all other physicians. .

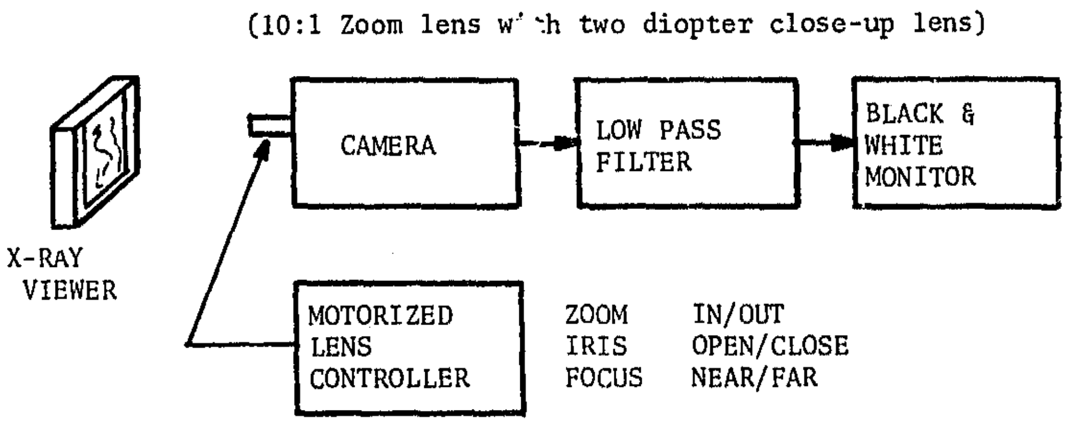
2.3.2.2 Very Low Resolution Television Evaluation

A second test was more similar to the normal testing procedure. In this test, the picture resolution was reduced drastically by further lowering the cutoff frequency of the low-pass filter (Figure 4). The basic degradation used was that of System 3 (Table 2) which is a 10 frame/second presentation. The 3-db frequency of the low-pass filter was set at 0.5 MHz (100 TV lines on Retma Chart) which produced an extremely "de-focussed" picture. Each patient was evaluated once with this system although three different physicians were used in the course of evaluating the 45 cases. This system is referred to as System 0, being of poorer quality than any of the five systems listed in Table 2.

2.3.2.3 X-Ray Film Evaluation

During the course of the principle testing program, televised x-ray films were presented in conjunction with several patient cases. These x-rays were always presented at the same degradation as the patient. It was decided that a more detailed study of television requirements for x-ray viewing would be in order since the number of films associated with the patient cases was small. For this third supplementary test, three radiologists were initially involved. These physicians viewed 25 televised x-ray films, listed in Table 6, representing a wide variety of radiological problems of varying degrees of complexity.

The viewing set-up was as shown in Figure 5.



X-RAY TESTING SET-UP

FIGURE 5

1. Fx - C6 Spinous Process
2. Fx - Glenoid Cavity
3. Fx - Prox. Radial Head
4. Fx - 5th Metatarsal
5. Fx - Tibial Plateau
6. Fx - Radial Head
7. Fx - Sep. Medial Epicondyle
8. Fx - Navicular
9. Fx - Phalanx, Chip Fx
10. Fx - 3rd Metatarsal, Healing March Fx
11. Apophysiolysis, Left Lesser Trochanter
12. Fx - Transverse Process L-3, L-4
13. Osteomyelitis - Left Femur
14. Posterior Dislocation of Shoulder
15. Substernal Goiter
16. Echinococcus Cyst
17. Bulbous Emphysema
18. Myositis Ossificans
19. TB Cavity
20. Pneumothorax
21. Syphilitic Aortitis
22. Fx - Nasal Bone
23. Cyst - Left Maxillary Antrum
24. Cyst - Left Maxillary Antrum
25. Fx - Skull

X-Ray Film Cases

TABLE 6

Each radiologist viewed each x-ray with four different resolutions (Table 7).

TV System	Horizontal Resolution (TV Lines)	Vertical Resolution (TV Lines)	Comments
A	200	350	Standard EIA Rates
B	400	350	Standard EIA Rates
C	800	350	Standard EIA Rates
D	1200	800	Hi-Res. Scan

X-RAY TEST CONDITIONS

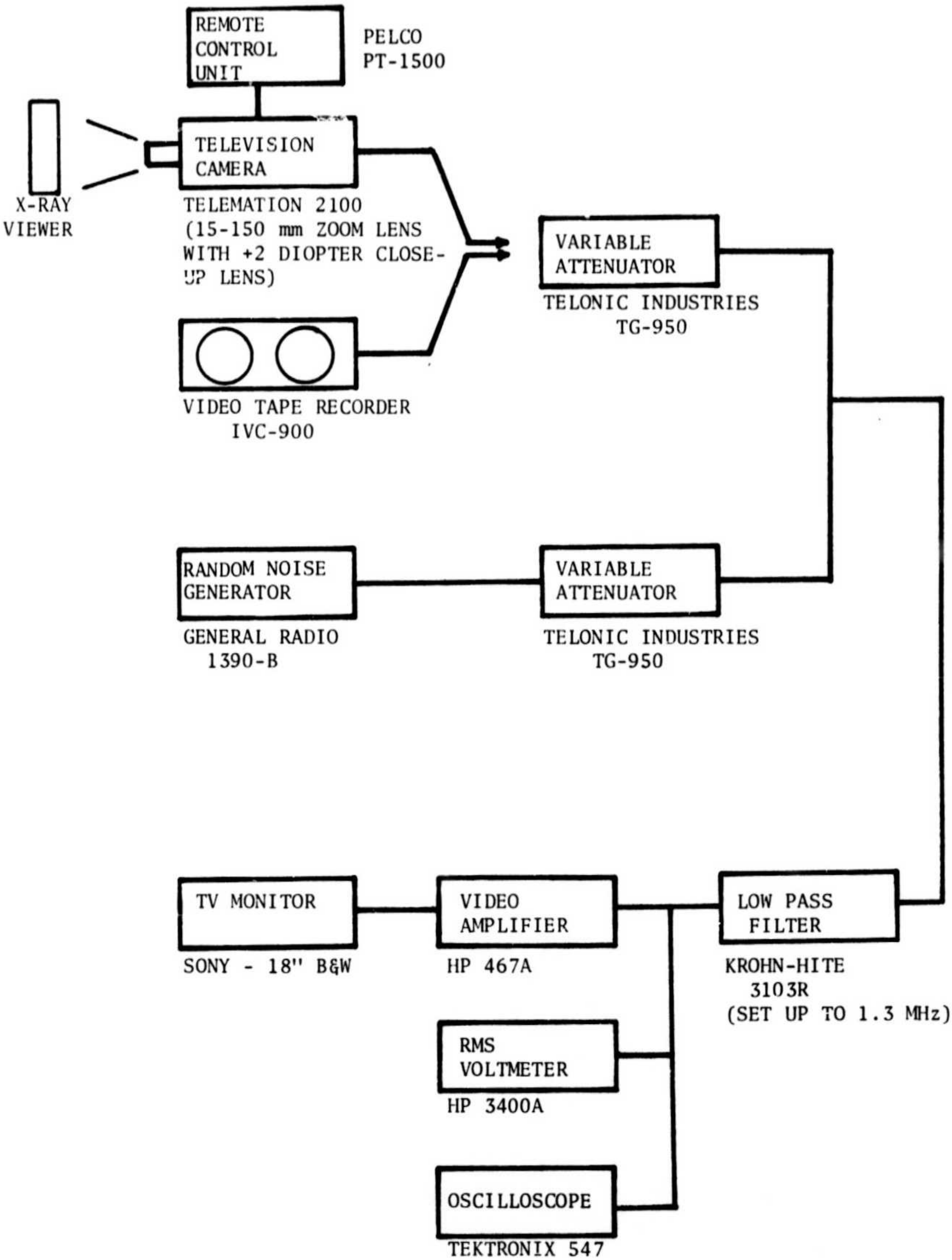
TABLE 7

After examination of each system, the radiologist was asked to write his diagnosis and attach a confidence level (1-10) to that diagnosis. Each x-ray was always started at the lowest resolution (System A) and progressed upward to System D. The radiologists, while viewing the TV monitor, directed the camera technician to give them whatever close-up views of the x-rays were desired.

As in the case of the principle testing program, the examiners were again surprised at the ability of the radiologists to correctly diagnose x-rays with what was considered to be a low resolution TV system. The diagnoses were possible at the low TV line resolution due to the scene resolution improvement made possible by an optical close-up lens. Therefore, a fourth radiologist was asked to review the 25 x-rays at lower than 200 TV-line horizontal resolution. The low-pass filter was set to allow resolutions of 40, 70, 100, and 140 TV lines (horizontal).

2.3.2.4 Signal-to-Noise Ratio (SNR) Evaluation

The fourth test was designed to provide a few data points on systems of significantly lowered SNR. Lowered SNR runs were made on both selected x-rays (from the group of 25 used above) and actual patients (from the 45 videotaped cases). Only the worst case films and patients were selected. The test set-up was as shown in Figure 6. For x-ray examinations, the video source was the Telemation



SIGNAL-TO-NOISE RATIO TEST SET-UP

FIGURE 6

2100 camera and for patient examination, the IVC 960 Video Tape Recorder. There were four levels of SNR used in this test. These are shown in Table 8.

	SNR (p-p video/RMS Noise, db)	
Test Condition	Camera Video Source	VTR Video Source
1	14.1	14.7
2	16.5	18.6
3	20.5	24.0
4	25.1	30.1

SNR TEST CONDITIONS

TABLE 8

For this test, 11 x-rays and three patients were examined. These are shown in Table 9.

X-Ray Film Cases	Patient Cases
1. Chip Fx, Right Fibula	1. Chronic Mild Eczema
2. Pneumothorax	2. Conjunctivitis
3. Bulbous Emphysema	3. Moniliasis
4. Fx, 2nd Metatarsal	
5. Fx, Proximal Radial Head	
6. Fx, Radial Head	
7. Fx, Tibial Plateau	
8. Chip Fx, Middle Finger	
9. Fx, Transverse Process, L-3, L-4	
10. TB Cavity	
11. Cyst, Left Maxillary Antrum	

CASES USED FOR SNR TEST

TABLE 9

Each case was examined by one physician, starting with the lowest SNR (Test Condition #1) and working upward. For each presentation the physician assigned a diagnosis and a confidence factor (1-10) for that diagnosis.

3.0 DATA EVALUATION PROCEDURES

Evaluation of the data derived from the testing described in Section 2.3 was divided into two major activities:

1. Grading of Physical Signs Questionnaire Data
2. Grading of Diagnostic Data.

The bulk of the data (well over 90%) was generated in the Principal Testing - Review by General Practitioners. Therefore, most of the evaluation and grading activity was devoted to this area.

3.1 Physical Sign Data Evaluation

Physical sign evaluation sheets were included as a part of the reviewing physicians' questionnaire for patients 19-29 and 32-38. Scoring of the results initially indicated that even a small consensus on the presence of a particular sign was lacking in about a third of the cases. A review of these cases revealed that disagreement was probably due to a variety of reasons such as: inadequate questionnaire specificity, insufficient baseline examination, inadequate duration of visualization, medical terminology problems, sign equivocality, relative insignificance of sign, inadequate portrayal of sign due to TV camera work technicalities, etc.

In order to form a good baselir for comparison of TV systems, final scoring was based on only those physician signs where a significant level of agreement was present. A group of 125 signs were selected from the total group of 190. The recognizability of each of these signs had been evaluated by 16 physicians (three physicians each for TV systems 1-5 and one physician for system 0). The score for each sign was determined by assigning values of 100 and 50 if the correct sign was checked as being "definitely" or "marginally" recognizable, respectively. If the sign was checked as "not recognizable" or if a non-present sign was checked as being "definitely" or "marginally" recognizable, a zero score was given. The scores of the applicable three physicians were averaged together to arrive at one composite score per sign per TV system. The mean score for each TV system was determined by averaging the scores from 125 signs.

For a more detailed study of the effects of the various television parameters on the recognition of physical signs, the signs were divided into three categories for evaluation purposes. These categories are listed below, Table 10, with examples of specific signs within each.

A - MOVEMENT SIGNS (40 Total)	B - GENERAL SHAPE/FORM SIGNS (48 Total)	C - SKIN/VEINS/TISSUE/ETC. SIGNS (37 Total)
1. Deep Tendon Reflexes (Bicep, Patellar, Achilles)	1. Habitus	1. Hands
2. Plantar Reflex	2. Facial Features	2. Edema
3. Kernig's Sign	3. Eye/Eyelid Features	3. Striae
4. Neonate Reactions	4. Tongue/Gums/Teeth	4. Eccymosis, Discoloration, Pallor
5. Hand Tremor	5. Neck Features	5. Hemosiderosis, Keratosis, Pigmentation
6. Facial Movements (Cranial Nerves)	6. Extremity Features (Deformity, Atrophy, Paralysis)	6. Vascular Insufficiency Lesion
7. Heart Rhythm (External Signs)	7. Abdominal Features (Ascites, Hernia, Hepatomegaly)	7. Vein Distention
8. Chest Movement and Respiration	8. Neonate Features (Non-motion)	8. Skin Thickness
9. Gait		9. Skin Moisture
10. Nervousness/Awareness		10. Cheilosis
		11. Tissue Necrosis
		12. Hirsutism
		13. Herpes Zoster
		14. Breast CA Lesion
		15. Fundus Features
		16. Laryngoscope Features

PHYSICIAL SIGNS CATEGORIES

TABLE 10

3.2 Evaluation of Diagnosis Data

Evaluation of the diagnosis data was based on the physician responses as elicited on the Reviewing Physician's Evaluation form, Appendix E. These forms were graded for correctness of diagnosis by two physicians (independently) with the aid of carefully prepared Grading Guidelines, Appendix G. These Guidelines are largely self-explanatory, however, a few comments about specific aspects of the grading procedure are in order. First, the grading physicians were given the total data package in a randomized form. That is, the hundreds of Reviewing Physician's Evaluation forms were grouped according to patient case number only. Within each case there were up to 18 evaluations utilizing the various TV systems (approximately 15 for principal testing and three for supplemental tests). These were randomized such that the grading physician had no knowledge of the specific television system being used for any given viewing.

Secondly, it was stressed to the grading physicians that they should rigidly adhere to the grading guidelines. It was realized that no absolute value could be placed on the adequacy of a particular television system; however, by following the guidelines, it was anticipated that valid relative values of the adequacy of the various television systems should be indicated if the physicians consistently followed the guidelines through the entire set of cases.

Thirdly, it became clear, from the information supplied to the reviewing physicians, that a high-confidence differential diagnosis was not possible for some patient cases. In these cases several diagnoses were possible; however, some were more probable than others. Therefore, to assist the grading physician, a tabulation of "correct" and "partially correct" diagnoses were made. This tabulation is shown in Appendix H, Listing of Correct and Typical Alternate Diagnoses.

The grading physicians graded the reviewing physicians diagnoses by filling out a Summary Evaluation form, Appendix I, for each patient case. This form, when completed, therefore contained the score for each of the 18 evaluations of that patient. The form also required the grading physician to make a judgement as to whether the diagnosis was adequate for performing a remote screening function. Finally, the grading physician provided a yes/no answer to the question of whether or not the television system for each evaluation was adequate for the supervision of remote treatment. This answer was provided on most Reviewing Physician's forms in Section III.

After the grading physicians had completed the Summary Evaluation form for each of the 45 cases, the type of TV system was entered in the last column of the form. It was then possible to average the diagnostic grades and arrive at a "score" for each of the five television systems listed in Table 2.

Scores for the first two supplemental tests (Audio Only and Very Low Resolution) were also available on these Summary Evaluation forms. The evaluation of these tests is described in Section 3.3

3.3 Evaluation of Supplementary Test Data

The evaluation of each of the four supplementary tests is described below.

3.3.1 Evaluation of the Audio Only Test

Evaluation of the Audio Only (A.O.) test was accomplished in the same manner and at the same time as the evaluation of the main body of Diagnosis data (Section 3.2). The data for these tests were interspersed throughout the data for television systems 1-5 and were graded at the same time by the same physicians. The grading physicians again had no knowledge of the test conditions associated with these data.

3.3.2 Evaluation of the Very Low Resolution Test (System 0)

Evaluation of this test data was done in the same manner as that of the Audio Only test.

3.3.3 Evaluation of the X-Ray Test

The x-ray test data were evaluated in two ways. The first evaluation was based solely on the diagnosis assigned to each x-ray by the physician as he viewed the television presentation. For each quality of presentation (Resolution-wise) of each x-ray, each radiologist assigned a confidence level to his diagnosis. The second evaluation was based on the average confidence levels.

3.3.4 SNR Test

The SNR tests were evaluated by considering how high the SNR had to be in each of the cases evaluated before the physician could make the correct diagnosis with high confidence. This was straightforward and, although based on data from a single physician, the results are believed to be representative.

4.0 RESULTS

Results of the Physical Signs tests, Diagnosis test, and all Supplemental tests are presented in the following sections.

4.1 Physical Signs Results

The results of the physical signs testing is presented in several figures. The first of these Figures 7a, 7b, and 7c show the physical signs in their subclassis (A-Movements, B-General Shapes, C-Skin Features) versus frame rate, resolution and television system. From Figure 7a it is evident that, as frame rate decreases, the Movement Signs become less recognizable much earlier than either the General Shape or Skin Signs. Because the recognition of Movement Signs showed a sharp decrease between 10 frames/second and 0.2 frames/second, a more detailed investigation of intermediate values was carried out. Utilizing a single physician to view several of the worst case signs (fine tremor, newborn irregular breathing, irregular heart rhythm, and bicep reflexes) at frame rates of 10, 7.5, 5, and 2.5 frames/second, it was found that the recognizability decreased as shown on Figures 7a. The curve remained essentially flat down to 7.5 frames/second.

From Figure 7b it is evident that recognition of Skin Signs is most sensitive to lowered resolution with General Shapes being less sensitive and Movements still less. Figure 7c is a bar graph depicting the recognizability of the subclasses for each of the six television systems.

Figure 8 is a graph of the mean physical sign scores (all three subclasses considered) for each television system. Standard deviations are also shown. It is significant that as picture quality increases (higher system numbers), the mean scores for physical sign recognizability <u>increases</u> while the standard deviation <u>decrease</u>. Statistical significance of the mean scores is generally present between the system types except 4-3 thru 4-2. It should be noted that the standard deviations on even the full-quality black-and-white and color systems are relatively large. This is due to the large residual error which is present. This error is the cumulative result of problems caused by the inherent subjectiveness of sign characteristics, the difference in conservatism between

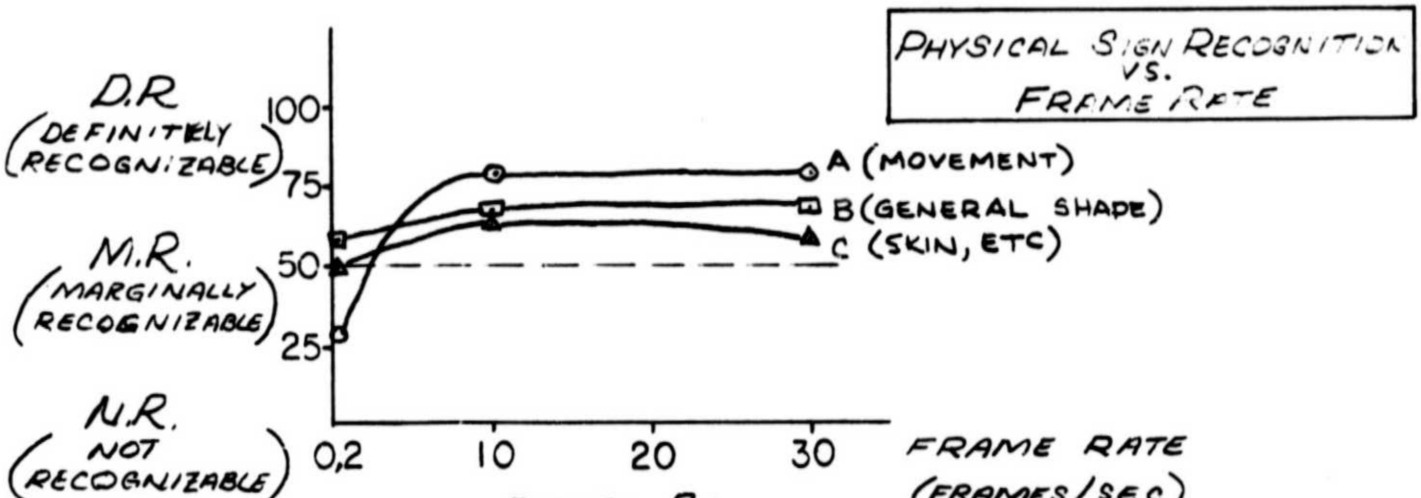


FIGURE 7a

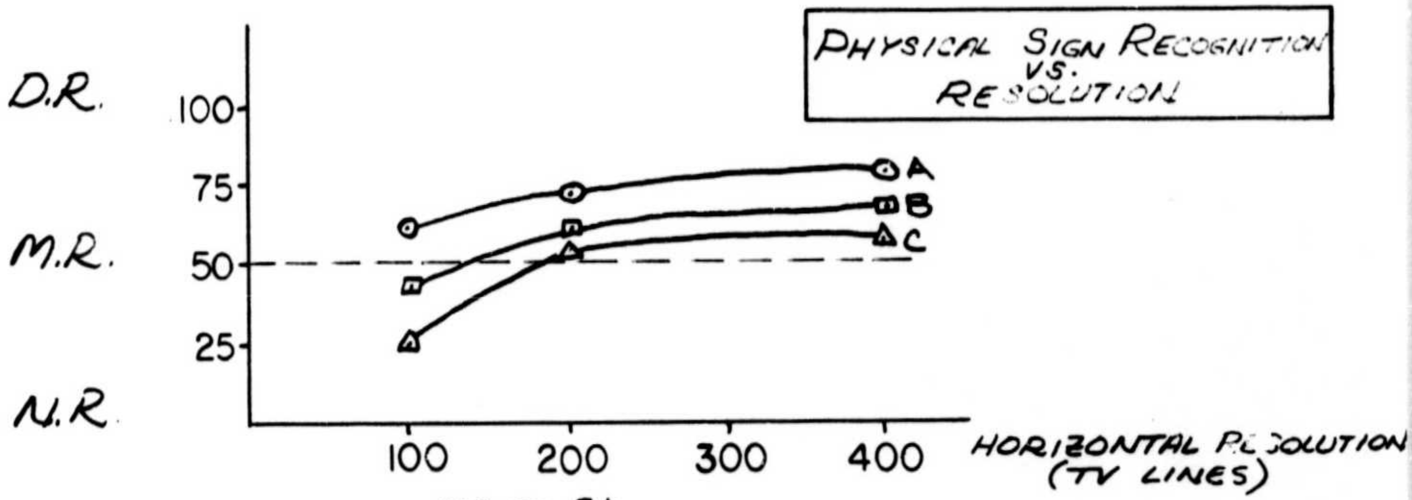
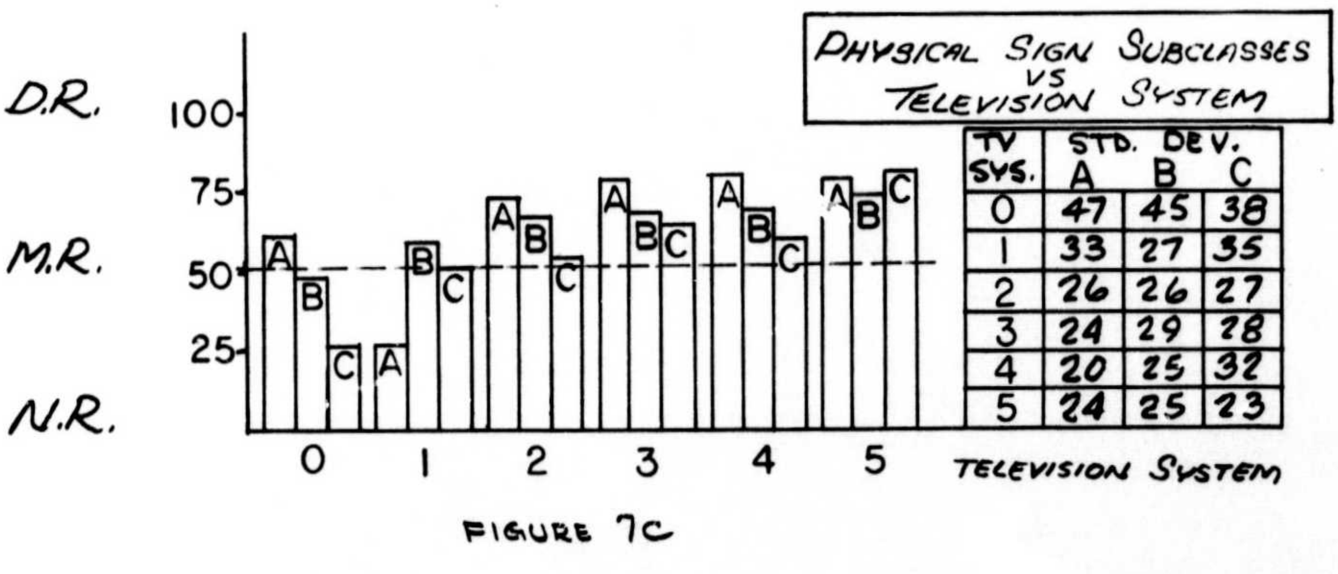


FIGURE 7b



TV SYS.	STD. DEV. A	B	C
0	47	45	38
1	33	27	35
2	26	26	27
3	24	29	28
4	20	25	32
5	24	25	23

FIGURE 7c

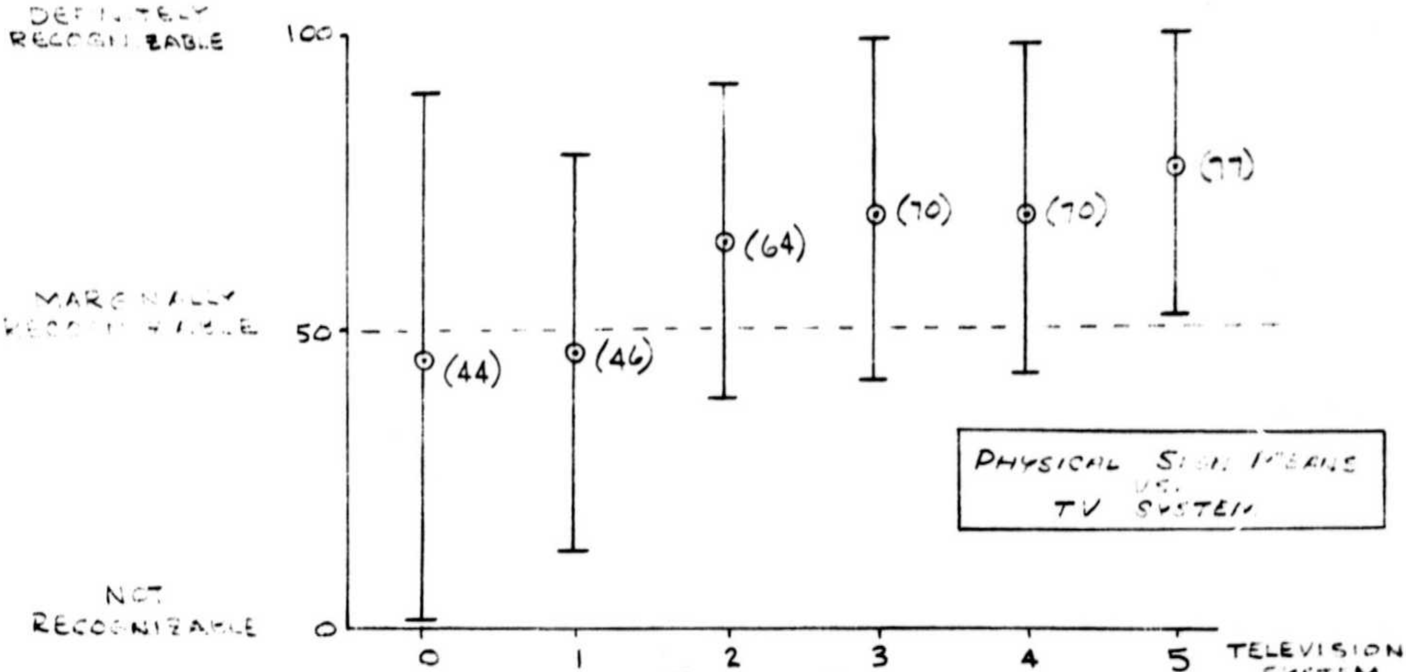


FIGURE 8

Television Systems Compared	Statistical Significance Overall	A	B	C
5 to 4	yes**	n.s.	n.s.	yes**
5 to 3	yes**	n.s.	n.s.	yes**
5 to 2	yes***	n.s.	n.s.	yes***
5 to 1	yes***	yes***	yes**	yes***
(5 to 0)	yes***	yes*	yes***	yes***
4 to 3	n.s.	n.s.	n.s.	n.s.
4 to 2	n.s.	n.s.	n.s.	n.s.
4 to 1	yes***	yes***	yes**	n.s.
(4 to 0)	yes***	yes**	yes**	yes***
2 to 1	yes***	yes***	n.s.	n.s.
(2 to 0)	yes***	~~yes*~~ n.s.	yes**	yes***
(1 to 0)	n.s.	yes***	n.s.	yes**

( ) - indicates relatively few data points
* - P < .05
** - P < .01
*** - P < .001
n.s. - not significant

STATISTICAL SIGNIFICANCE OF PHYSICAL SIGN MEAN SCORES

TABLE 11

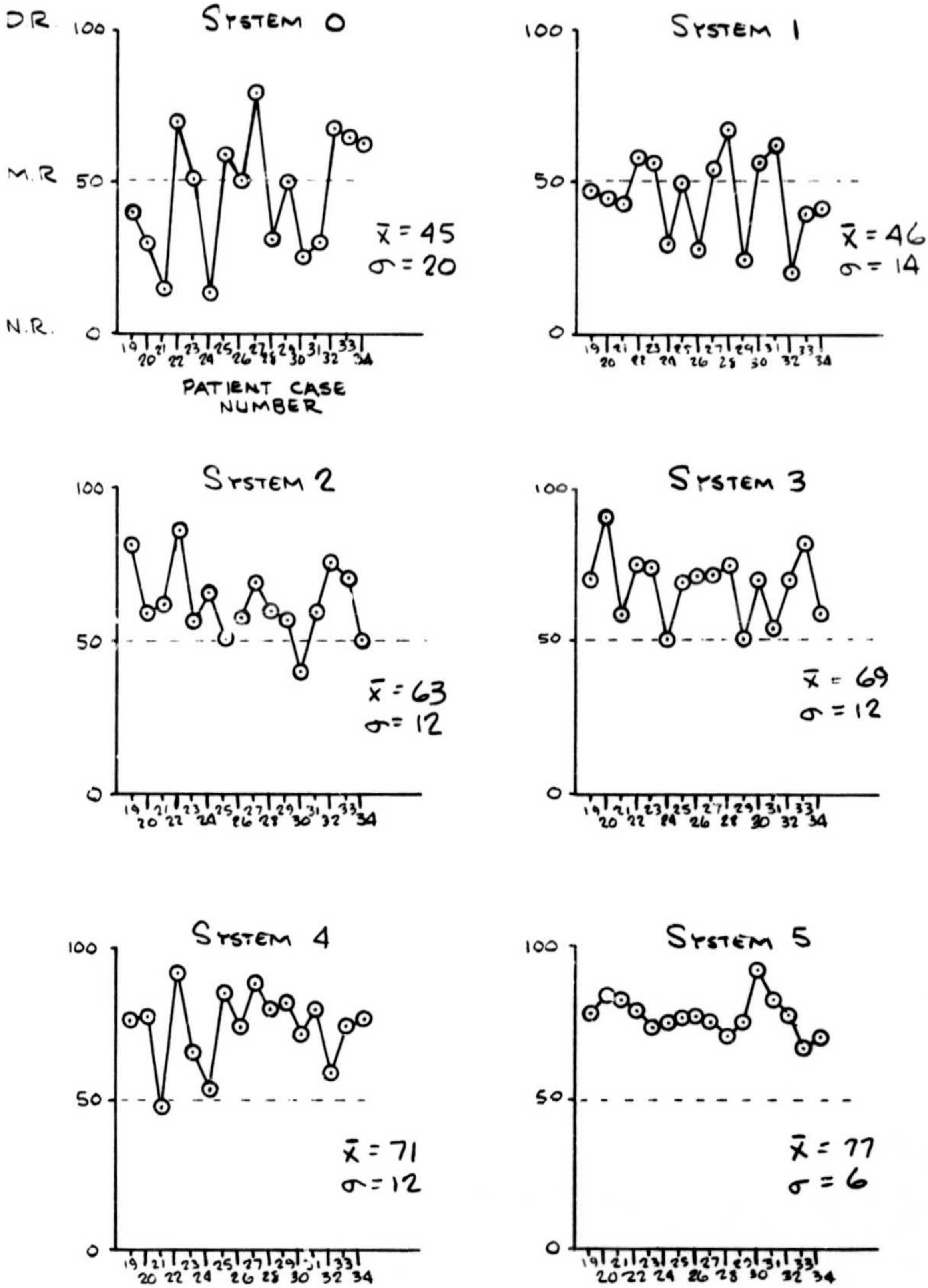
physicians, and the study procedure utilized. This latter factor was by far the most significant since the video playback of each patient was limited to one continuous showing per physician. Evaluation of sign recognition reliability was a secondary goal. Many times a physician failed to observe a particular sign since he was looking at the patient elsewhere or thinking about diagnostic possibilities or filling out the questionnaire form for a previous sign. In these cases, the physician checked "not recognizable" and consequently received a zero score. Since the video playback was randomized among TV system types and physicians, the residual errors are, however, believed to have been randomized.

The mean scores should be interpreted as comparative data and not as absolute measures of the sign recognition capability of a particular TV system. If the primary emphasis of this study had been on individual physical signs rather than overall clinical diagnosis, then, without question, the mean scores would have been increased. In an interactive telemedicine system, the remote examining physician would be able to dwell on each patient examination area (face, chest, extremities, etc.) until he was personally satisfied. For example, he might wish for the nurse to repeat certain tests or to change camera/lens position if the initial TV visualization was equivocal.

In the procedure for this study, direct clinical impressions by the examining nurse were purposely restricted so that the remote physician would be forced to make an independent judgement based solely on the TV visualizations. Of course, in any actual telemedicine setting, the clinical impression of the nurse would be of great assistance, and consequently the physician's success in sign recognition and clinical diagnosis would be improved. During the special audio-only test that was done for a no-TV data point, a "physician assistant" (graduate of Physician Assistant Program) made his personal observations of each patient from the color video playback. By telephone, a voice consultation was then held between the assistant and a remote physician. The assistant, prior to physician consultation, completed the same physical sign evaluation forms as had other physicians viewing the color TV system. From a total of 119 signs evaluated, the assistant's score was 91 signs correct, as compared to the random physician score of 98 signs correct.

Computation of the statistical level of significance between the various mean scores has been done and is presented in Table 11.

As a final representation of the physical signs data, it is interesting to plot the scores on an individual patient basis for each television system. This is done in Figure 9a thru 9f. These curves graphically show the variation that occurs from patient-to-patient for a given television system. Ideally, it would be desirable that all physical signs for all patients be Definitely Recognizable. However, this value was not attained due largely to the restraint of allowing each physician to view each patient only once. Therefore, the criteria for examination of these curves is the relative mean level and the consistence of recognition from patient-to-patient. The increase in mean level and consistency is readily evident as the system pictorial quality increases.



PHYSICAL SIGN RECOGNITION
VS.
PATIENT CASES

FIGURES 9a-9f

4.2 Results of Patient Clinical Diagnosis Test

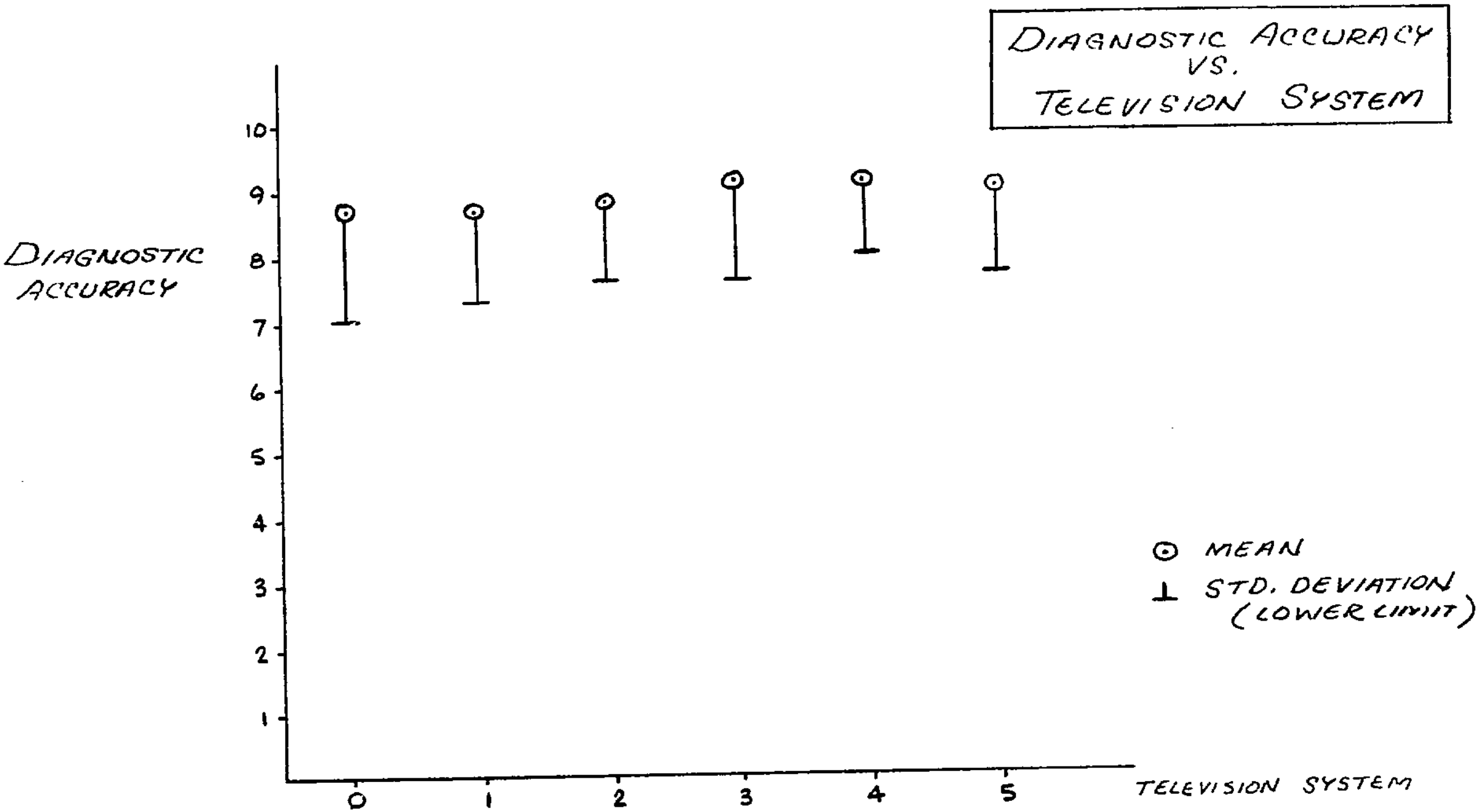
The results of the Diagnosis test are shown in Figure 10 and tabulated in Table 12. Figure 10 is a plot of diagnosis grades (on a scale of 10) versus system type. Systems 1 thru 5 are as described in Table 2. System 0 is the Very Low Resolution System (a supplementary test) as described in Section 2.3.2. The six systems are ranked in order of increasing pictorial quality ranging from very low resolution black and white to full color (System 5). Also shown on the graph are the lower limits on the standard deviations.

Although care must be exercised in the analysis of Figure 10 because of the rather large deviations, the graph still indicates several things. First, there is no significant difference in the physician's diagnostic accuracy utilizing any of the six systems. The rather large standard deviation supports the hypothesis that more variation is caused by varying physician responses or judgements than by changes in the television picture quality. In general, however, note that the trend is toward lower scores and higher deviations for the lower quality presentations.

Because of the relatively small mean differences in the six systems, an attempt was made to display more subtle differences by examining the performances of the various systems for the worst case patients. For this analysis, this was all patients with a mean score for the six systems of less than 8.0. Eleven patients were in this category. The mean scores for these eleven patients is shown in Table 12. This analysis reveals a greater numerical spread for the mean scores and the overall ranking is as shown.

Table 13 is the distribution of scores for the various television systems. The numbers in the body of the table indicate the number of occurences of scores within the groups shown in the left column.

Because of the unexpected general equivalency of the various television systems (based on patient diagnosis testing alone) other criteria should be considered in order to determine a minimum usable television system for a specific medical application; e.g.,criteria such as patient physical signs and radiographic transfer. This is discussed in the next report section.



SYSTEM	0	1	2	3	4	5
MEAN	8.70	8.72	8.88	8.06	9.05	8.94
STD. DEV.	1.77	1.46	1.22	1.39	1.04	1.21

FIGURE 10

OVERALL CLINICAL DIAGNOSIS SCORES VS. TV SYSTEM TYPE

(MAXIMUM POSSIBLE SCORE = 10)

TV SYSTEM	MEAN SCORE (45 Patients) (Total Population)	MEAN SCORE (11 Patients) (Most Difficult Population)
5 - STANDARD COLOR SYSTEM 30 frames/second 250 line resolution	8.9	7.8
4 - STANDARD B&W SYSTEM 30 frames/second 400 line resolution	9.0	7.8
3 - REDUCED FRAME RATE B&W SYSTEM 10 frames/second 400 line resolution	9.0	7.4
2 - REDUCED FRAME RATE/RESOLUTION B&W SYSTEM 10 frames/second 200 line resolution	8.9	7.4
1 - SLOW-SCAN SYSTEM .2 frames/second 400 line resolution	8.7	6.8
0 - GREATLY REDUCED RESOLUTION B&W SYSTEM 10 frames/second 100 line resolution	8.7	7.2

TABLE 12

TABLE 13

DIAGNOSTIC SCORING DISTRIBUTION

SCORES	TV SYSTEM 0	1	2	3	4	5
<4	0	0	0	0	0	0
≤ 6	6	4	3	3	1	2
7-10	39	40	42	42	44	43
8-10	34	33	37	40	38	39
9-10	31	30	27	30	31	24
10	23	16	15	22	12	19
Mean	8.7	8.7	8.9	9.1	9.1	9.0

4.3 Results of Supplementary Tests

The results of the four supplementary tests are presented and discussed below.

4.3.1 Results of the Audio Only Test

The audio only test was accomplished by a physician assistant observing the color TV monitor while verbally describing the examination to the physician by telephone. This may have been a disadvantage to the physician assistant since he could not observe the patient directly. In some cases, the patient playback was viewed by the physician's assistant several times, first for his own observations and then a second time while describing the signs to the physician and responding to his questions. In addition, the assistant was allowed to state his clinical impression to the physician. The results of the audio only test are equivalent to the TV system results. Since the procedure utilized for the single-trial test was, by necessity, different from the TV procedure, the detail results cannot be legitimately compared with the TV results. In a study where ranking of systems is to be done, the procedure must be strictly controlled.

With the above procedural differences noted, the results are as follows.

	Physician	Assistant
Mean Score	9.0	7.7
Standard Deviation	1.5	3.1

Scoring Breakdown	Physician	Assistant
0	0	4
≤ 6	4	14
7-10	41	31
8-10	39	29
9-10	32	26
10	26	23

One remarkable thing about the audio evaluation was the fact that there was only one case (Osgood Schlatter's Disease) where referral was specified (due to incorrect clinical impression) but would not have been actually necessary.

4.3.2 Results of the Very Low Resolution Test

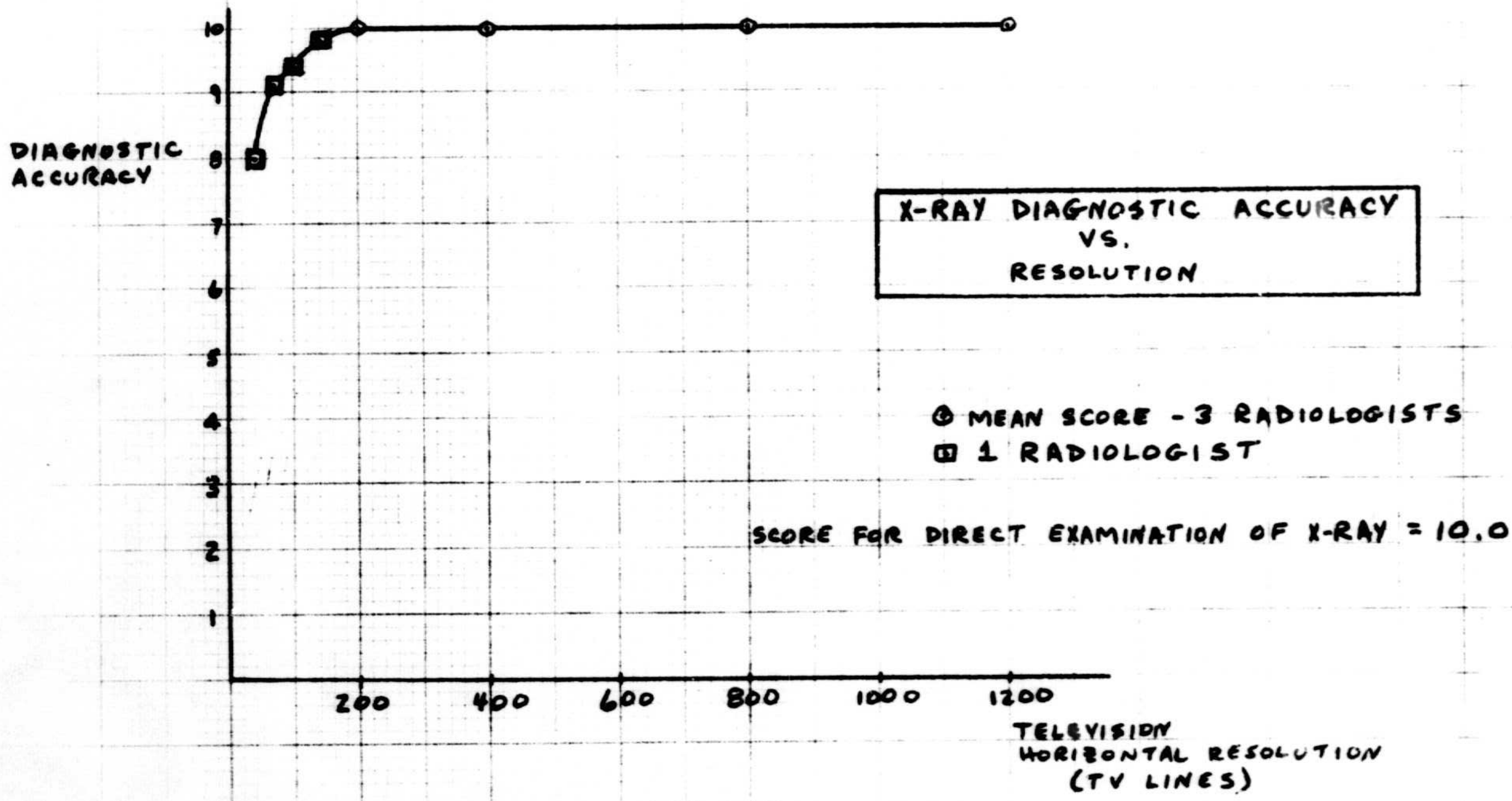
The results of the very low resolution test (System 0) are presented on Figure 10. Note that this system scored lowest of all six television systems and had the largest deviation.

4.3.3 Results of the X-Ray Test

Results of the x-ray test are presented in two figures. Figure 11 is a graph of the Diagnostic Accuracy versus TV resolution while Figure 12 is a graph of the radiologist Confidence Level (confidence in his diagnosis) versus resolution.

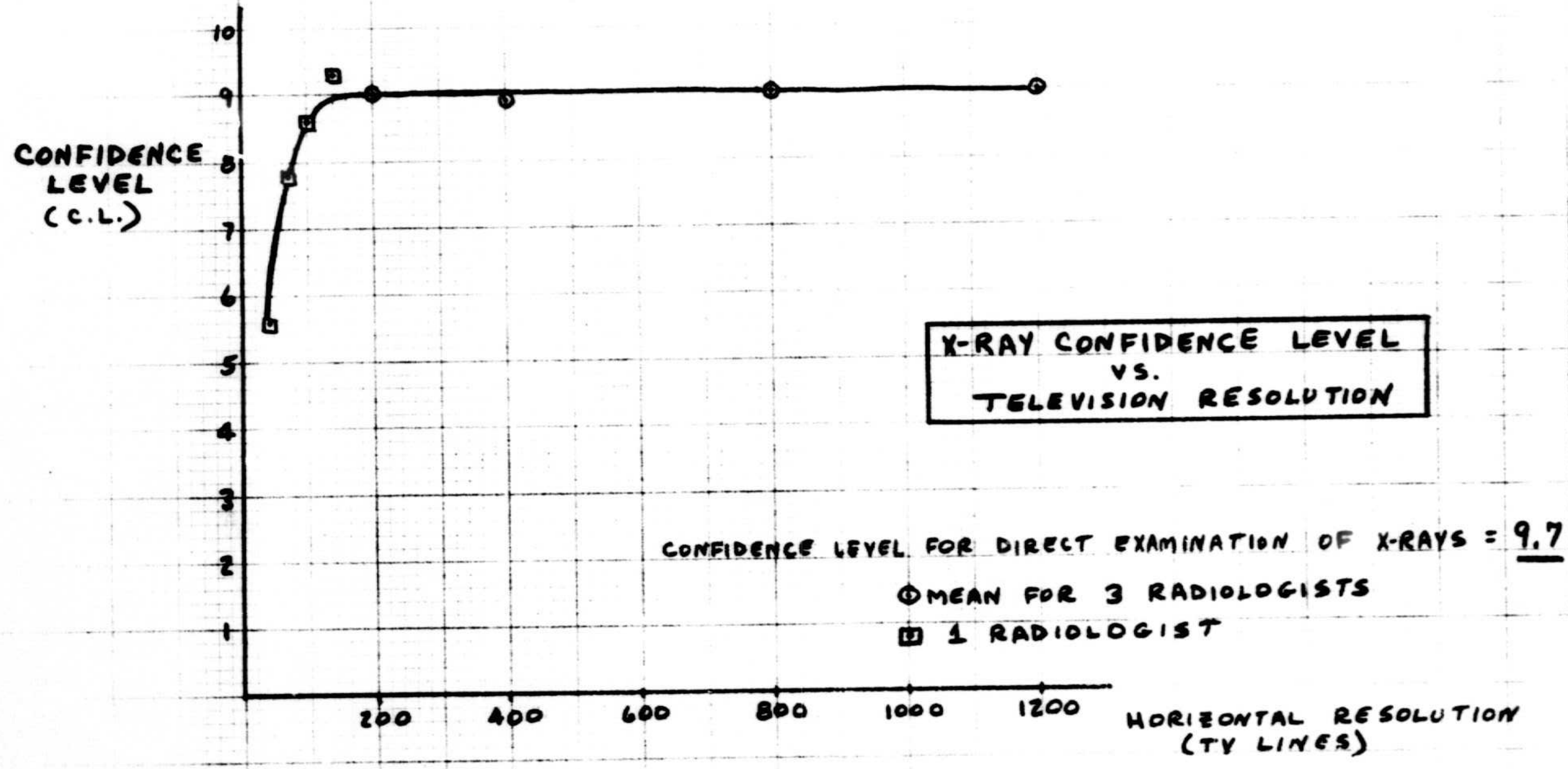
Figure 11 indicates that the Diagnostic Accuracy begins to drop appreciably for resolutions below 200 lines. The fact that the three radiologists were able to maintain a "perfect" score for resolutions down to 200 lines was somewhat surprising to the investigators. However, it should be noted that the radiologists were allowed to call for close-up views (zoom-in's) of the x-rays whenever desired, thus increasing the scene resolution without changing the actual electronic resolution. It is also significant that the diagnostic accuracy decreased below the 200 line resolution even with the zoom-in capability. Although only one Radiologist was used for the resolution below 200 lines, his data correlate with those of the other three radiologists. Figure 12 indicates the same trend as shown in Figure 11 in that the Radiologists Diagnostic Confidence Level decreases below 200 lines. The slight anomaly at the 140-line resolution point is probably due to the use of different radiologists for the below 200 and above 200 line testing.

The smallest radiographic features of 1/2 MM (bony trabeculae, lung markings, hairline fractures, etc.) can be discerned with a 200-line TV system by using a camera close-up lens which gives a full TV screen presentation covering a 4 inch high film area. Since 1/2 MM features require 50 TV lines/inch resolution, the area viewed must be 4 inches or less in height ($\frac{\text{200 TV Lines}}{\text{4 inches}}$ = 50 TV lines/inch). The optimum lens configuration is a remote controlled (iris, focus, zoom) zoom lens (15-150 MM) with a +1 diopter close-up lens attachment. With the camera positioned from about 22 inches to 40 inches from the x-ray film, the zoom-in scene width will vary from 1-1/2 inches to



TV LINES:	40	70	100	140	200	400	800	1200
SCORE :	8.0	9.1	9.4	9.8	10.0	10.0	10.0	10.0

FIGURE 11



TV LINES :	40	70	100	140	200	400	800	1200
C.L. :	5.6	7.8	8.6	9.3	9.0	8.9	9.0	9.0
STD. DEV. :	3.8	2.7	1.9	1.4	1.3	1.2	1.2	1.2

FIGURE 12

3 inches and the zoom-out width from 15-28 inches, respectively. This range adequately covers overall 14 x 17 inch film views plus allows adequate close-ups for magnified image views.

A contrast ratio dynamic range of 25-30:1 is required to provide adequate visualization of subtle radiographic density variations. This range provides TV monitor recognition of 10 grey scales.

The x-ray film type, camera lens configuration, and procedural scanning method are all critical items for TV radiographic diagnosis. The recommended techniques are as follows:

a. For chest x-rays utilize medium contrast, medium speed film with proper screens and exposure settings. (Proper exposure should result in maximum contrast ratio [bright mediastinum to dark lung field] of less than 25:1. High contrast films give ratios greater than 100:1).

b. Utilize adequate illumination x-ray film viewer. This depends on the camera low light sensitivity level of the lowest f-stop of the lens. For the equipment and camera-film distance used in this study, a viewer with 400 foot lamberts of illumination sufficed for all films. (Secondary sign soft tissue swelling adjacent to fractures could not be observed in several cases except by using a high-intensity lamp and masking the adjacent bright bony area.) When viewing an overall x-ray film, do not allow the light around the edges of the x-ray film to be encompassed in the TV scene due to the adverse effect from the camera's Automatic Light Control (ALC) circuitry. In the presence of bright light the grey film areas will appear dark due to the ALC operation.

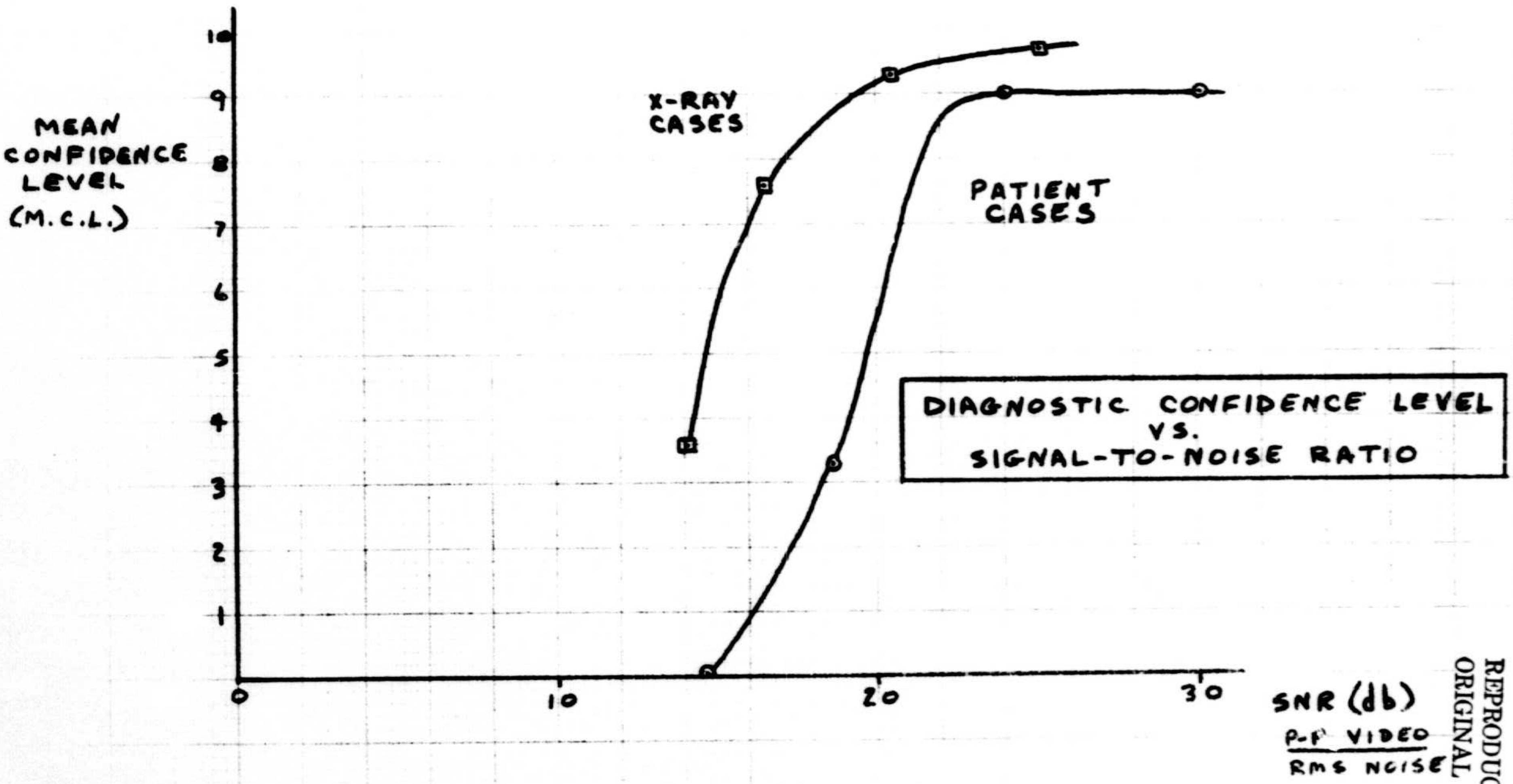
c. Utilize a film scanning method where the bright translucent areas are examined first and then the darker areas are examined by pointing the camera and zooming-in until a segmented view is shown without any bright elements. This technique is mandatory for satisfactory visualization of lung fields and other soft tissue areas. Masking of bright elements may be required in a few cases.

d. Utilize a remote controlled 10:1 zoom lens (15-150 MM) with a +1 diopter close-up lens to insure ability to provide a small examination area free of peak white elements.

Appendix J gives verbatim summary remarks by the radiologists concerning their observations and conclusions.

4.3.4 Results of the SNR Test

Results of the SNR test are presented in Figure 13 as a graph of the mean diagnosis confidence level versus the signal-to-noise ratio of the presentation. Note that there is an abrupt drop in confidence level below approximately 20 db. The importance of Figure 13 is that it indicates that a "plateau" on confidence level is reached by the time the SNR is up to approximately 25 db. This is gratifying as SNR's of 30 db and greater are readily achievable. The 25 db value is for random noise in a 1.3 MHz bandwidth and is defined as ratio of video black-to-white signal level to RMS noise level.



SNR	14.1	14.7	16.5	18.6	20.5	24.0	25.1	30.1
M.C.L., PATIENT CASES		0		3.3		9.0		9.0
M.C.L., X-RAY CASES	3.6		7.6		9.3		9.7	

FIGURE 13

5.0 DISCUSSION

The primary objectives of this study were (1) establish the variability of visual medical information flow from patient to physician as a function of television design parameters, (2) establish the effect of that variability on the physician's ability to arrive at a proper diagnostic impression, and (3) establish the effect of that variability on the physician's ability to properly designate the patient for remote treatment or referral to a central medical facility.

There are different applications for telemedicine systems, and the requirements would be expected to vary. For example, telemedicine has been used for psychiatric therapy, speech therapy, hospital-to-hospital specialized consultations, continuing medical education, in-service training, etc. The objective of this study was to determine what type or types of television systems are applicable when used to care for a wide spectrum of patients by a remotely located medical assistant (registered nurse skill level) and a general practitioner.

Theoretically a telemedicine system could be used to make entry into the health care system more accessible to patients located at a location remote from physician-attended medical facilities. For the purposes of this study it was not considered essential for the telemedicine system to provide a capability for final diagnosis on every incoming patient. It is not reasonable to assume that the remote location would have adequate lab test facilities, treatment facilities, trained personnel, etc. to gather a wide spectrum of medical data necessary to completely treat complex medical cases. The requirement for the telemedicine system must be balanced with remote data gathering and treatment capabilities. The critical task for this telemedicine system is to provide capability for a medically-correct decision regarding the separation of those patients which can be treated remotely from those which must be referred for direct examination by a general practitioner or specialist. In theory, the majority of incoming patients could be treated remotely, thereby eliminating the inconvenience, work time loss, and expense of traveling to a distant medical facility.

A major goal of a telemedicine system should be to provide remote health care services at an acceptable cost to the patient or to the applicable governmental agency. The cost to implement a television system is, in part, dependent on the technical design parameters. This report is intended to provide some objective insight into the television technology requirements as a function of medical diagnostic efficiency.

The first objective was studied by having physicians indicate their degree of recognition of patient physical signs as a function of television system type. The results show a decreasing ability to recognize signs as the television quality is decreased. Figures 7, 8, and 9 graph the results. Using the criteria of "marginal recognition" as a minimum acceptable level, the very low resolution system and the slow scan system are not acceptable for a remote health care service system as defined herein. For specialized applications where no motion is needed, e.g. radiographic transmissions, slow scan television is satisfactory if the minimum design specifications are met.

The second objective was studied by having physicians indicate their diagnostic impression of patients as a function of television system type. The results show no significant decrease in diagnostic accuracy as the television quality is decreased. For the total population of 45 patients, the difference between the highest and lowest scoring TV system is less than 5%. For the most difficult patient cases (set of 11 patients), the scoring difference is less than 15%.

In observing the results of each patient case, the ranking of TV systems is not obvious. Each TV system score for each patient case is the mean of 3 physician scores (except system 0). Normal variability between the physicians generally has a larger effect on the single patient results than does the variability between TV systems. Only when the results of a group of patients are compared does a bias become evident in favor of the better TV systems. This physician variability factor is also present for the physical signs but to a lesser degree.

Due to the minor diagnostic variations in contrast to the visual variability of TV systems 1-5, the real value of direct patient visualization by the physician appeared to be less than anticipated. Apparently the physician obtained much of the information required from the medical history, patient symptoms, verbal descriptions from the nurse, and rudimentary lab data. To confirm this apparent result, two supplementary tests were performed. The idea of these tests was first to reduce the picture resolution until it was subjectively unacceptable due to visual blurriness, and second to eliminate the picture entirely by performing an audio-only test. System 0 was the label given to the very low resolution picture (100 hor. TV lines, 10 fps), and System 6 to the audio-only test. Due to cost and time limitations, both of these tests were performed on the 45 patients using only one physician evaluation (although on System 0 tests, 3 different physicians were used, each case being seen by only one of the three). The System 0 results were essentially equivalent to the System 1 (slow-scan TV) results.

The audio-only test results showed no significant difference in diagnostic success as compared to the televised systems. There was only one case (episcleritis) in which remote treatment was designated with an incorrect diagnosis. (Refer to paragraph 4.3.1 for procedural conditions that could have affected the results in relation to the TV results.) It therefore appears that if the medical assistant can perform an independent physical examination and recognize and describe physical signs to the physician, the necessary visual information can be verbally relayed to the physician. The physician assistant used in the audio test was able to correctly recognize 91 signs out of 119, which is not significantly less than the random physician score of 98 signs correct. A TV link largely functions as a parallel method for transfer of visual information for the cases where the medical assistant is highly competent. (In this study, a medical assistant is either a registered nurse or a "physician assistant" (P.A.). The PA was used only in the audio-only test.)

To insure that the audio-only results are not overly emphasized, it should be pointed out that remote location populations may have the same difficulty in obtaining highly competent medical assistants as they do physicians. The transfer of visual information via television would allow a lesser skilled medical assistant to be utilized since the physician can see the patient directly. Another potential benefit is that the physician could give better instructions and could monitor the medical assistant's performance during critical aspects of the physical examination or treatment. (During the base-line examinations there were a number of instances where the physician, using the TV monitor, had to correct or instruct the assistant in his method of physical examination.) Another advantage of TV is the capability of radiographic image transfer. Recognition of x-ray film injuries or pathologies is a specialty of radiologists which should be preserved in telemedicine applications. That is, if radiographic equipment and a TV link are available to the medical assistant, evaluation should initially be performed by a radiologist from the TV image. The film should subsequently be shipped to the radiologist for confirmation of his findings. In certain cases the immediate TV evaluation of x-ray information would be of significant benefit for the initial remote medical treatment.

The third objective of the study was met by analyzing the variability of treatment adequacy (location designation) as a function of TV system type. This was done by determining from the physician evaluation forms whether remote treatment was specified in conjunction with incorrect or incomplete diagnosis. This condition could be detrimental to the patient, and therefore the TV systems should be compared in this regard. Refer to Table 14.

From the 700 physician evaluations that were made on Systems 1-5, there were only 14 cases (Group 1) for which "treat remotely" was designated with an incorrect or incomplete diagnosis. Of these 14 cases, 6 of the physicians called for more medical data; e.g., x-rays, medical history, etc., that could well have caused them to change their initial diagnosis. In two of the cases (episcleritis), detriment to the patient was indeterminate since the specific treatment could have been correct (if a cortisteroid preparation had been specified) even though the diagnosis was incomplete (conjunctivitis). The remaining six cases (Group II) were of potential hazard to the patient. These six cases were all from one patient, age 84, who had emphysema and myxedema. The physicians diagnosed the former but missed the latter. The summary by TV system type is given below. No significant comparison difference is evident.

REMOTE TREATMENT POTENTIAL HAZARD CASES

TV System	Group I	Group II
1	4	1
2	3	2
3	3	0
4	2	2
5	2	1
	14	6

TABLE 14

In this study all of the patients (except normal newborn) had clinical problems. Therefore, the use of the term "false positive" could apply only to incorrect diagnoses. "False Positive" diagnostic impressions reduced the score for the particular TV evaluation. (Refer to scoring guidelines in Appendix G.) For those patients that were designated for referral, incorrect telediagnoses were not of hazard to the patients. For the patients designated for remote treatment, there were four "false positive" (single incorrect diagnosis) cases in Group I but none in Group II. The results of diagnoses/designated treatment locations speak very highly both for the telemedicine systems employed and for physicians involved in the study.

The results indicate that for the purpose of remote diagnosis by a general practitioner and a remotely located PA that a TV system for visual medical information transfer to a physian could be usable with minimum horizontal resolution of 200 TV lines per picture height, a frame rate of at least 10 frames/second and a signal-to-noise ratio (S pp/Nrms) of at least 25 dB (random noise). The standard commercial specifications (EIA and NTSC) for monochrome and color systems are recommended for use. For applications where the implementation of the standard specifications is not technically feasible or cost acceptable, then some compromise is possible as indicated by the usable parameters given above. Subjectively, a 200 TV line horizontal resolution and 10 frames/second (60 field/second refresh rate) picture would not be recognized as degraded by a casual observer. A noise (snowy picture) level of 25 dB would be noticed and probably considered to be an unpleasant characteristic. An increase to 34 dB should result in a subjectively acceptable picture.

Vertical resolution was not a parameter altered in the study. This parameter depends on the number of scanning lines across the TV monitor. Generally, the vertical resolution is balanced with the horizontal resolution. For 200 TV line vertical resolution, the number of scanning lines would be approximately 300. Grey-scale resolution and luminance dynamic range were other parameters not altered in the study. Since for radiographic film viewing some problems are evident with the standard 10 grey-scale specification, degradation below that level was considered to be unacceptable. Due to Automatic Light Control (ALC) in TV cameras, the average level of incident illumination is processed as mid-scale brightness and any incident illumination greater than about 15 times less will appear black on TV monitors even though the eye would see the actual scene element as grey. The result of this dynamic range limitation presents a major problem in radiographic TV viewing. This problem can be alleviated by utilizing special set-up techniques as described in Section 4.3.3.

Figure 14 summarizes the minimum acceptable TV design parameters for a rudimentary telemedicine system using a remotely-located medical assistant.

If a special camera system was developed based on the minimum requirements, the video transmission bandwidth could be reduced to 0.3 MHz, which is an order of magnitude less than the standard video bandwidth.

ACCEPTABLE MINIMUM VERSUS STANDARD SPECIFICATIONS

TV DESIGN PARAMETER	ACCEPTABLE MINIMUM	STANDARD SPECIFICATIONS (TYPICAL)
1. Horizontal Resolution	200 TV lines/picture height	400-800 TV lines (Monochrome) 250-300 TV lines (Color)
2. Vertical Resolution	200 TV Lines (300 Scanning lines)	350 TV Lines (525 Scanning lines)
3. Frame Rate	10 Frames/second (Non-Interlaced) (60 Fields/second monitor refresh rate)	30 frames/second (60 fields/sec)
4. Contrast Ratio	30:1 (10 Grey shades)	30:1 (10 Grey shades)
5. Signal/Noise Ratio*	25 dB Spp/Nrms (34 dB for aesthetic acceptance)	40-48 dB
6. Video Transmission Bandwidth	1.3 MHz (200/350 Lines, 30 fps) 0.3 MHz (200/200 Lines, 10 fps) (3 dB Bandwidth, 24 dB/octave Rolloff)	4 MHz (Color) 5-10 MHz (Monochrome)
7. Colorimetry	Monochrome	

* Slow-scan TV may have objectionable transient non-linearity and noise features which are not covered in the general S/N spec referenced above.

FIGURE 14

6.0 SUMMARY

1. Significant differences occurred in the physician's recognition of individual physical signs as pictorial information was altered. Statistical significance of the mean scores for the 125 physical signs occurred between the standard color system and the monochrome system. Statistical significance between the means of the standard monochrome system and the lesser quality systems did not occur until the resolution was reduced below 200 lines or until the frame rate was reduced below 10 frames/second. Even though the mean differences are "statistically significant" between the color and monochrome systems, systems 2-5 all had mean scores above the "marginally recognizable" level and therefore were considered acceptable using that criteria. Systems 0 and 1 were below that point, and therefore were considered unacceptable for general application. Slow-scan television (System 1) would be acceptable if no motion signs were required, e.g. x-ray film images.

2. There was no significant difference in the overall diagnostic results as the pictorial information was altered. Some differences did occur as the pictorial information was reduced. The standard color and monochrome systems were equivalent. Horizontal TV resolution could be reduced to 200 TV lines per picture height, and frame rate reduced to 10 frames/second with minor diagnostic degradation. (TV monitor "refresh rate" must remain at 30 frames/second to eliminate flicker.) Grey scale resolution of 10 steps is recommended if x-ray images are transmitted. The signal-to-noise level should be at least 34 dB for a subjectively pleasant picture, but a 25 dB level is medically usable.

3. There was no significant difference in remote treatment designations as a function of TV system type that would cause detriment to patients.

4. The supplementary study of radiographic film televised transmissions (25 representative cases) showed that no diagnostic differences occurred between the TV evaluations and the direct film evaluations for TV resolutions above 200 lines if special optical lenses and scanning techniques were utilized.

APPENDIX A
PATIENT BRIEFING

PATIENT BRIEFING

Your doctor, along with a number of doctors in this area, is participating in a study commissioned to SCI Systems, Inc. by the NASA Manned Spacecraft Center. The purpose of the study is to help define engineering standards for a new television system; a system to transmit medical information from remote patient care facilities to central medical centers. This program promises to make an important contribution to the task of making health care more accessible to our population at a reasonable cost, through the use of space-age technology.

The key to this study program is the collection of high-quality television recordings of actual patient examinations. A doctor viewing on television will question you about your symptoms as the investigation of your medical problem is carried out with the aid of a trained assistant. Any x-rays and special laboratory tests ordered by your doctor for the actual diagnosis of your condition will also be recorded by the television camera.

These videotapes will then be reviewed by a panel of practicing doctors from this community who will analyze the television displays to determine the minimum level of clarity and fine detail at which they can effectively evaluate each medical condition. When all of these displays have been reviewed and scored by the doctors participating in this study, NASA will use the results to help define quality standards necessary for remote television medical systems. Thus, by volunteering to participate in this program, you will be helping in a very direct manner to improve the means of delivering high quality medical care to people in isolated locations.

The television recordings will, at all times, be maintained under careful security so that only the authorized physicians and technicians working on this research project have access to them. At the conclusion of this study, the complete set of records will be delivered to the National Aeronautics and Space Administration, where all medically-sensitive material will be carefully safeguarded and destroyed when no longer required for analysis of the study result.

Your participation in this study will require about 30 minutes of your time after you have been seen and treated by the doctor. If you have any questions or reservations whatever, the project supervisor is available to answer questions and discuss this project with you to your full satisfaction. Thank you for your attention and consideration of this very worthwhile research program.

APPENDIX B
PATIENT CONSENT FORM

PATIENT CONSENT AND AUTHORIZATION FORM FOR PARTICIPATION IN NASA CONTRACT NAS 9-13118, VIDEO REQUIREMENTS FOR REMOTE MEDICAL DIAGNOSIS

____
Date and hour

I, ______________________________ (Patient) hereby certify that I have read the attached Patient Briefing and that I have been informed of the objectives and procedures to be followed in the NASA study program, under contract to SCI Systems, Inc., to evaluate video requirements for remote medical diagnosis and I voluntarily agree to participate as a patient in this study program. I understand that this study program is not intended to provide me any medical diagnosis or treatment. My participation in this study is incidental to normal medical care and has not affected any medical examination or treatment. I release the __________ (Medical Institution) from all liability connected with this experiment.

I authorize the recording on video tape of an interview and medical examination conducted by a registered nurse/physician's assistant under the direction of a medical doctor and I authorize the processing of this videotape record as required in the conduct of the experiment that has been described to me. I understand that duplicate copies of all or selected portions of the video recording of my interview and examination will be electronically processed and subsequently shown to approximately 20 medical doctors, who are participating in this study program.

I further authorize review by the physicians specifically participating in this study of my responses to the health screening questionnaire and of the results of any and all laboratory analyses and x-ray films obtained at the direction of the medical doctor supervising my examination as a participant in this study.

I authorize the release of all recorded information, including videotape records, x-rays, laboratory reports, and written medical records resulting from my examination as a participant in this study program to the NASA Manned Spacecraft Center at the conclusion of this research project.

____
(Witness)

____
(Patient)

Consented to:

____
(Witness)

____
(Spouse, Parents, or Legal Guardian)

APPENDIX C

GUIDELINES FOR EXAMINING PHYSICIAN AND NURSE/PARAMED

GUIDELINES

for

The Examining Physician and the Nurse/Physician Assistant

The examining physician and his assistant play crucial roles in the program to determine the minimal television system for remote medical diagnosis. It is very important for each to understand the total program and his or her contribution to it. The attached Patient Briefing provides an overall view and should be read at this time if you have not already done so.

It should be evident that the basic role of the physician and his assistant is to conduct a videotaped diagnostic exam which will be used to generate other videotapes of degraded video quality. A complete audio track consisting of all conversation will also be recorded. There are, however, some subtleties to be observed during the videotaping. These are outlined below.

1. The examining physician should conduct a very thorough fact-finding examination such that any other physician viewing the videotape would be provided sufficient information. However, do not state any conclusions or mention any diagnosis during the recording.

2. It is important to remember that later physicians may be viewing poor quality video presentations and they would, if conducting the examination first-hand, depend heavily on the nurse for descriptive commentary. Answers to questions they would ask must be provided. The physician therefore, is free to ask the assistant any questions calling for a description only and is encouraged to do so.

3. The nurse should not volunteer any information unless asked to do so by the physician. Specifically, do not state any opinion or conclusions during the taping.

4. Important: Whenever motion of any type is being observed, the physician should ask his assistant for a verbal description of that movement even though the physician deems a verbal description redundant and unnecessary. Remember that some later physicians viewing degraded tapes will not have the same amount of motion rendition that you are seeing.

5. Similarly, whenever a color is important, ask the assistant for a description of said color.

6. The doctor is free to converse with and direct the cameraman at all times; ie., asking for closeups, full views, etc.

APPENDIX D

VIDECTAPING DATA SHEET

BASELINE VIDEOTAPING DATA

PATIENT DATA

NAME: ____
LAST FIRST MIDDLE INITIAL

DATE: ________________ AGE: __________ M / F

TIME: ________________

TAPING LOCATION: ______________________

PATIENT SOURCE: ______________ EMERGENCY ROOM

(CHECK ONE) ______________ REFERRED (BY ______________)

EXAMINING PERSONNEL

PHYSICIAN ____________________

NURSE ____________________

TECHNICIAN ____________________

OTHER ____________________

TAPE DATA

	REEL #	START TAPE	STOP TAPE	PROGRAM #
COLOR	_____	_____	_____	_____
B&W	_____	_____	_____	_____

COMMENTS

Classification: ______________________________

EXAMINING PHYSICIAN'S DATA

I. B&W, 2 MHz Bandwidth

1) Clinical Opinion (Write Out)

2) What treatment would you prescribe?

II. Full Resolution

With the higher resolution picture, is your clinical opinion changed?

Yes ________ No ________

If yes, write your new clinical opinion.

III. Color

With the color picture, is your clinical opinion changed?

Yes __________ No __________

If yes, write your new clinical opinion.

SUPPLEMENTARY DATA USED IN EXAM

LABORATORY TESTS (Attach copy of each)

TEST	RESULTS
1. ______	______
2. ______	______
3. ______	______

MICROSCOPIC SLIDES SEEN BY PHYSICIAN (Describe each fully)

1.

2.

3.

X-RAYS

VIEW	ABNORMALITY (If none, so state)
1. ______	______
2. ______	______
3. ______	______

ENDOSCOPIC VIEWS (Describe each fully)

1.

2.

3.

APPENDIX E

REVIEWING PHYSICIAN'S EVALUATION FORM

Program No.:____________________

Date:____________________

Physician No.____________________

REVIEWING PHYSICIAN'S EVALUATION

I. <u>EVALUATION #1: Patient Interview and Inspection Data</u>

A. Write your clinical opinion or clincal impression(s):

1. Clinical Opinion:

2. Clinical Impression(s): (If opinion not relatively firm or data inadequate for differential diagnosis)

B. If you can't form a clinical opinion (or make differential diagnosis), why not?

1. Need lab data (List):____________________

2. Need additional medical history:____________________

3. TV presentation definitely inadequate: (Use check mark)

a. Need color
b. Need higher resolution
c. Need better motion rendition
d. Other (Describe):____________________

4. Other (Describe):____________________
5. Unfamiliar with this medical entity

C. Make any additional comments into tape recorder (e.g. why differential diagnosis cannot be made)

II. EVALUATION #2: Addition of Medical History and Mensuration Data to Interview and Inspection Data Evaluated Above

A. Can you now form a clinical opinion? Yes______ No______
If not, why not?

B. Write your clinical impression.

C. Make any additional comments into tape recorder.

III. EVALUATION #3: Remote Treatment Potential

A. Would it be feasible to treat this patient remotely or would it be necessary to bring the patient into another medical facility for treatment?

Treat Remotely__________ Bring In__________

B. If treated remotely, was this presentation adequate for you to recommend and to supervise procedures for treatment and follow-up examinations?

Yes________ No________

IV. EVALUATION #4: Recognition of Physical Signs

(Place X mark in applicable column)

Physical Signs	Definitely Recognizable	Marginally Recognizable	Not Recognizable
1.			
2.			
3.			
4.			
5.			

V. EVALUATION #5: Additional Comments After Being Informed of Diagnosis Made By Direct Examination

A. Make any additional comments into tape recorder concerning TV/Voice/data presentation as related to direct diagnosis.

APPENDIX F

SAMPLE PHYSICAL SIGNS RECOGNITION CHART

(PATIENT 37)

PHYSICAL SIGN EVALUATION
(Place X mark in applicable column)

Patient 37
Physician
Program
Date

EXAM AREA	PHYSICAL SIGNS (Circle sign only if visually identifiable; certain signs listed are not present)	DEFINITELY RECOGNIZABLE	MARGINALLY RECOGNIZABLE	NOT RECOGNIZABLE
1. Neck	Normal or diffuse anterior enlargement or unilateral enlargement			
2. Eyes	a. Normal or poor convergence			
	b. Widening of palpebral fissures, or upper lid lag or neither			
	c. Normal or exopthalmos, or enopthalmos			
3. Hand Movement	Normal or gross tremor or fine tremor or choreiform			
4. Cardiac Movements	Normal sinus rhythm or ectopic beats, or artial fibrillation			
5. Skin	Normal, or dry or perspiring			
	OTHER SIGNS (List as Desired) 1. 2. 3. 4. 5.			

APPENDIX G

GRADING GUIDELINES

GUIDELINES FOR MEDICAL GRADING OF DIAGNOSES FROM TV PRESENTATIONS

1. Evaluation forms should have top right corner blanked out so that grading can be accomplished without any possible bias from knowledge of the TV system utilized.

2. The "correct diagnosis or diagnoses" for each patient is given in attachment along with credit values for typical alternate "equivalent" diagnoses.

3. Grading should follow these guidelines:

   a. Grade 10 - Correct diagnosis without any incorrect diagnoses also given in that block.

   b. Grade 9 - Correct diagnosis listed first but with other incorrect diagnosis also given in that block.

   c. Grade 8 - Like b above except correct diagnoses listed second.

   d. Grade 7 - Like b above except correct diagnosis listed third.

4. Diagnosis that are not correct or equivalent should be graded lower than the maximum grades listed above for the various situations. The lower grade given by the medical grader is somewhat subjective and therefore more than one physician will perform the grading.

5. The physical sign recognition listing should be used by the medical grader as supplementary and secondary information only. The assigned grade should be primarily based on the concluding diagnosis. However, the physical sign listing can be used for further information where a subjective grade must be assigned.

6. A separate score will be assigned for physical sign recognition . The score should consist of two parts. The first part is the primary value and will be based on visually distinctive primary signs. Points 2, 1 and 0 should be assigned for checks in the "Definitely Recognizable", "Marginally Recognizable" and "Not Recognizable" columns, respectively. The second part of the score should be based on degree of overall physical sign recognition, regardless of distinctiveness. (The physical sign grading will be accomplished by NASA personnel since this effort is not covered in the SCI contract.) The scoring should be converted to a percent basis.

7. The diagnosis given on the evaluation form should also be given a yes/no grading as to whether it, as a minimum, provides an adequate screening function for determining whether a remote patient needs referral to a physician-based clinic or hospital.

8. Adequacy of TV presentation for remote treatment supervision by a physician should also be given yes/no check on summary grading form (attachment #2). This yes/no evaluation is found on Reviewing Physician's Evaluation Form, Part III. Write N/A if the patient was to be brought in.

9. Certain of the patient cases have two or three separate disorders. The attachment gives the grading credit divisioning. For example: For Patient #21, if only Cushings Syndrome was listed without any incorrect diagnoses, the grade would be 6.0 (10 x 60%).

APPENDIX H

LISTING OF CORRECT AND TYPICAL ALTERNATE DIAGNOSES

LISTING OF CORRECT AND TYPICAL ALTERNATE DIAGNOSES
(Credit for other alternate diagnoses left to grader's discretion)

PATIENT NO.	CORRECT DIAGNOSIS (100% Credit)	ALTERNATE DIAGNOSIS	CREDIT
1	Superficial Finger Laceration		
2	Gunshot Wound, Comminuted/Compound Fx of Distal Phalanyx (Lead Contamination)		
3	Superficial Leg Laceration		
4	Compression Fx of Radius at Wrist Epiphysis		
5	Dislocation of Middle Phalanx		
6	Allergic Urticaria (Hives), (Probable Drug Reaction)		
7	1st. Degree Burn (< 10% Body)		
8	Abcessed Tooth (Lymphatic Involvement)		
9	Mild Concussion		
10	2nd Degree Burn (< 3% Body)	2nd & 3rd Degree Burn	100%
11	Moniliasis	Monilia	100%
		Candida	100%
		Candida Albicans	100%
		Fungal Skin Rash	80%
12	Multiple Sclerosis	Neurological Disorder (GP's)	100%
13	Ulnar Nerve Palsey	Median (Corpal Tunnel Syndrome)	50%
		Radial	50%
14	Acute Tonsillitis		
15	Osgood-Schlatter Disease	Osteochondrosis of Tibial Tuberosity	100%
		Osteochondritis, Healed	70%
		Epiphyseal Fx, Healed, Tibial Tuberosity	50%

PATIENT	CORRECT DIAGNOSIS (100% Credit)	ALTERNATE DIAGNOSIS	CREDIT
16	Vocal Cord Cyst (Polyp)	Singer's Nodule Chronic Laryncitis CA	100% 90% 100%
17	Varicella (Chicken Pox)		
18	Infectious Mononucleosis		
19	Senescent (Degenerative) Arthritis	Any Chronic Debilitating Disease Arthritis Tubercular Arthritis	75% 100% 100%
20	a. Chronic Osteomyelitis (60%) b. Renal Disease (30%) c. Brachial Plexus Congenital Injury (10%)	 Liver Disease (30%)	
21	a. Cushing's Syndrome (Secondary to Steroid Therapy) (60%) b. Idiopathic Thrombocytopenic Purpura (40%)		
22	Meningitis	Subarachnoid Hemorrhage	100%
23	Cirrhosis (Laennec's or Alcoholic or Portal)	Hepatoma	100%
24	a. Chronic RHD (70%) b. Herpes Zoster (20%) c. Tongue Lesion-Hemangioma (10%)		
25	a. Emphysema (50%) b. Myxedema (50%)		
26	Muscular Dystrophy (Pseudohypertropic, or Duchenne's or Erb's type)	Neuromuscular Disorder (GP's)	100%
27	Right Hemiplegia (Trauma to Left Cerebrum)		
28	Bronchogenic Carcinoma	Pulmonary TB	100%

PATIENT	CORRECT DIAGNOSIS (100% Credit)	ALTERNATE DIAGNOSIS	CREDIT
29	Hysterical Aphonia	Primary TB	25%
30	Pleurisy (Complication from Viral URI)	Acute Bronchitis Viral URI	50% 80%
31	Chronic Mild Eczema	Chronic Dermatitis Psoriasis	100% 90%
32	a. CVA (Stroke, Cerebral Embolus) (90%) b. RHD (10%)		
33	a. Breast Carcinoma		
34	Aortic Aneurysm		
35	Lead Encephalopathy		
36	Normal Newborn		
37	Hyperthyroidism – (Graves Disease, exopthalmic goiter)		
38	Childhood (Lipoid) Nephrosis	Nephrotic Syndrome Glomerulonephritis	100% 90%
39	Vernal (Allergic)Conjunctivitis (Palpebral Type)	Hay Fever	100%
40	Episcleritis	Scleritis	80%
41	Keratitis	Corneal Inflammation Corneal Ulcer	100% 100%
42	Measles (Rubeola, Morbilli)		

PATIENT	CORRECT DIAGNOSIS (100% Credit)	ALTERNATE DIAGNOSIS	CREDIT
43	Scarlet Fever		
44	Primary Syphillis	Penile Chancre	100%
45	Allergic Rhinitis	Hay Fever	100%

APPENDIX I

SUMMARY EVALUATION FORM

SUMMARY EVALUATION FORM

Patient No. ______ (Medical Diagnosis)

Evaluation No.	Diagnostic Grade				Visualization Grade Physical Signs		Adequacy of Diagnosis for Remote Screening		Adequacy of TV For Remote Treatment Supervision		Type of TV System
	Phys.1	Phys.2	Phys.3	Avg.	Primary	Secondary	Yes	No	Yes	No	
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											

APPENDIX J

TV X-RAY STUDY SUMMARY REMARKS BY RADIOLOGISTS

TV X-RAY STUDY SUMMARY REMARKS BY RADIOLOGISTS

Radiologist No. 1 (RI): My general impression is that I saw the abnormalities on each of the systems, and my confidence for all practical purposes did not increase with increase in the resolutions of the system. The only time that I was in doubt, that is, when I had a lower confidence level, it was due to trying to interpret the pathology that I saw. But virtually everything that we could see we saw on the lowest resolution system. Occasionally with things that were smaller, it took us a little bit longer to find it using TV, although I don't think there was an excessive amount of time there. We agree that the areas that were most troublesome to us were in trying to evaluate the soft tissues where such things as abnormal fat pads and other secondary signs would direct our attention to look more closely for such things as small radial head fractures, etc. These secondary features we could not see on the current TV system as well as we would like, and I think that proper masking and bright lighting would possibly correct that. Also in the cervical area of the neck and the skull, evaluation of the soft tissues was somewhat difficult.

Project Engineer (P.E.): Are you saying your confidence level did not go up between system A and system C?

RI: Yes, in general it stayed the same.

P.E.: I thought you observed some secondary features in C which perhaps you couldn't see in A.

RI: My confidence level was usually very high, particularly on things like fractures where I put my confidence at ten. The times that I think TV changes helped was not so much from the difference in the system but rather in coning down or the shielding to pick up some soft tissue changes. For example, there was the child skull fracture that we saw, and you could see the soft tissue swelling when you used masking, which is a reassuring thing to us, but to me it didn't make much difference whether it was A. B. C or D. Occasionally on C we could see some trabecular detail than we couldn't see on A or B, although I used the confidence level rating to mean did I see the abnormality, and I saw it adequately, I think, on all of them on A. While a few points might have been a little clearer on C, it didn't mean that I was going to alter my diagnosis.

P.E.: Obviously what we have been doing is a technical study but would you be satisfied with system A if this were an operational system, if in fact, you were the radiologist being consulted where you had to actually make the initial diagnosis from the TV X-ray presentation?

RI: On the basis of this, I would have to say yes, although we always want something better. I think you would like for it to be a little better, but I think that's from a philosophical standpoint. I think we demonstrated to ourselves that we always made the diagnosis on A. So I would have to say yes, we can live with it. Particularly as you point out there are some things that can be done optically by zooming in that really do improve the resolution, but still I think we could do with system A (200 lines). One area that I was questioning before we started was that of the chest, primarily due to my experience previously in a similar project over a much longer period of time. We had tremendous trouble with the chest. The bones were very similar in fact, but I think that today's work with evaluating the chest, from the overview evaluation of the cardiac silhoutte, the general rib structure and the costa-phrenic angles, and then with your zooming in and panning the lung fields and mediastinam separately, I think we saw that we could evaluate the chest films.

P.E.: Let's assume that you were looking at the TV trying to make a remote consultation type of diagnosis, and a G.P. actually was looking at the film, say at the locale that the film was taken. Do you think with system A a practicing radiologist would be able to do ten percent better than the G.P. at the location? What's your feeling on that? Does the TV have some value at getting the X-ray to a remotely located radiologist?

R1: Well (jokingly), I would hope that the radiologist would do at least a 100 percent better. I think that it's the interpretation of the findings that is difficult. So I think that the fact that the G.P. was there, and a lot of the times, obviously, he will be able to pick out what bothers him. Our experience with interpretation of the observed abnormality is going to be what helps them out. Also, we can pick up some things that he won't see. I think that it would be helpful to have a local physician there not only to point out directly on the film what is bothering him but also to give some clinical influence.

R2: We evaluated four different resolutions and on each one you could make the diagnosis. We all got it correct on system A. I could not see much difference between the different systems. Perhaps system C was a little better we have concluded. And system D was also a little better than C. But these differences did not really affect my ability to make a diagnosis. When you get down to it, system A was good enough to see the abnormality. To some extent my confidence level went up as we saw the subsequent systems merely because I was seeing the abnormality and thinking about it for a longer period of time.

P.E.: Even though you made the correct diagnoses, were there some features that you would have liked to have seen better?

R2: Our using the negative image mode seemed to enhance some of the findings. The calcification of the ascending aorta as well as the pneumothorax case were examples where the negative image made the abnormality really stand out.

R2: Every radiologist has a certain way of looking at a film and I think we are somewhat limited in the way we can see a film via TV. For example, the overall view of a chest X-ray did not give us the presentation that we are accustomed to. By coning down and panning the sectional areas of the chest, we were able to see the pathology. But not being able to see distinctly the overall view of the chest film might be a problem in certain cases.

P.E.: What subjective adjective rating would you place on system A, B, and C - fair, good, or excellent? How satisfied are you with the TV image?

R2: That depends on what your criteria is? We got all of the diagnoses on system A. In comparing C with A, there was a little finer detail, but I am not sure what benefit it would give us. For example, you could see the bony trabecular pattern detail better on C than A. Considering the fact that we got all the diagnoses using system A, we would have to rate it as excellent. (The other two radiologists agreed).

R3: (Concurred with the above opinions.)