Accuracy of Cardiac Auscultation by Microwave

Raymond L. H. Murphy, M.D., F.C.C.P.;° Peter Block, M.D.;°°
Kenneth T. Bird, M.D., F.C.C.P.;† and Peter Yurchak, M.D., F.C.C.P.‡

Telemedicine, the practice of medicine at a distance, offers the opportunity to facilitate cardiac consultation in remote areas to alleviate existing shortages of qualified specialists. For such consultation to be useful, accurate transmission of auscultatory findings is essential. To study this accuracy, auscultation of the heart was carried out on patients with heart murmurs and normal controls through the use of a standard stethoscope and a telestethoscope. The telestethoscope allowed auscultation by an observer situated 2.7 miles away from the 50 subjects. The observer was unaware of the status of the subject with respect to "patient" or "control" at the time of the teleauscultation. All murmurs of grade 2/6 or more were easily and accurately described using telestethoscope. Two of the 32 grade 1/6 murmurs were not heard. This study indicates that the telestethoscope is a potentially useful tool for extending the availability of the cardiologist to medically disadvantaged areas.

Efforts to increase the availability of cardiologists assume extreme importance in view of the current shortages and the uneven distribution of such specialists. Application of currently available technology to facilitate cardiologic consultation in areas remote from medical centers is a promising avenue to pursue in this regard. Telemedicine, the practice of medicine with the patient at a distance from the responsible physician, utilizes two-way, closed-circuit television, supplemented by electronic instruments to simulate the usual situation in which the physician and patient are in the same room. Patient acceptance and the feasibility of this kind of physician-patient communication has been established. Indeed emergency medical care and direction has been provided to over 1200 patients at Logan Airport Medical Station by physicians located in the Emergency Ward of the Massachusetts General Hospital, a distance of 2.7 miles. The scope, objectives, and technical details of this system have been described elsewhere.[1,2] To apply telemedicine to cardiologic consultation, accurate transmission of auscultatory findings is essential. The purpose of this report is to present the results of a study designed to evaluate the accuracy of transmission of cardiac sounds via the existing telediagnosis system.

Materials and Methods

Fifty persons were examined by an observer in person and via the telediagnosis system. Twenty-seven were patients, whose diagnosis had been established by thorough evaluation by the cardiology service of this hospital; the remainder were volunteers from the Normative Aging Study of the Boston Veterans Administration Outpatient Clinic. The latter are persons considered to be normal on the basis of the following criteria: (1) no history or symptoms of heart disease; (2) a normal physical examination; (3) no abnormality of the heart or lung shadows on chest roentgenography; (4) a normal electrocardiogram; and, (5) a series of normal laboratory examinations.[3]

The electronic stethoscope used was simple to operate and will be described elsewhere. The basic control available to the telediagnosis physician was a conventional linear potentiometer which produced an apparent volume change to the ear proportional to the control potentiometer rotation. One examiner, who was unaware of the status of the study subject, *ie*, whether he was a patient or a normal volunteer, completed a standardized examination on each patient directly and by the telediagnosis examination system (Fig 1). The telediagnosis examination usually was performed within several days of the direct auscultation and preceded it in about

°Assistant Clinical Professor of Occupational Medicine, Harvard School of Public Health, Boston.
°°Instructor in Medicine, Harvard Medical School.
†Associate Clinical Professor of Medicine, Harvard Medical School.
‡Assistant Professor of Medicine, Harvard Medical School.
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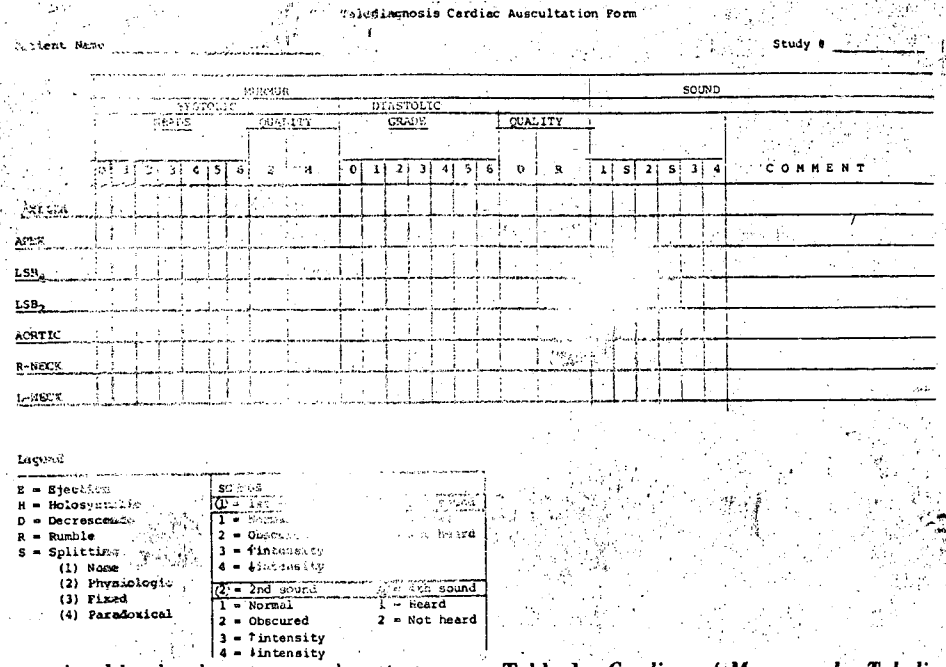

FIGURE 1. Form completed by the observer on each patient.

25 percent of the cases. To avoid recognition of a patient the observer had previously examined, the video portion of the microwave link was turned off during the telediagnosis examination. The examining physician thus heard only the heart sounds and murmurs before making his decision as to their characteristics. No clues as to the medical history or physical findings were provided during the teleauscultation. Positioning of the telestethoscope was done by a physician at the remote site.

RESULTS

Table 1 summarizes the results of the comparison between the direct and remote auscultation at the apex and the lower left sternal border. Each systolic murmur heard at the apex by direct auscultation was also heard via the telediagnosis system. In 26 cases, no systolic murmur was heard at the apex during either the telediagnosis or the direct auscultation. Despite the absence of false positives and false negatives, there were slight differences in grading. Nineteen of the 24 murmurs heard by direct auscultation were graded identically by teleauscultation. There was a difference of one grade in five cases; three of these were considered louder by direct auscultation. Similar results with regard to systolic murmurs were obtained at the left sternal border.

The results with respect to diastolic murmurs are more difficult to interpret. At the left sternal border all murmurs heard on direct auscultation were also heard by telediagnosis. Differences in one grade were present in two cases and two grades in one case. However, two of the eight diastolic murmurs heard at the apex on direct auscultation were not heard by the telediagnosis physician. Both were

Table 1—*Grading of Murmurs by Telediagnosis and by Direct Auscultation (25 Patients)*

A) Apex

Telediagnosis Auscultation

	SYSTOLE								DIASTOLE							
	0	1	2	3	4	5	6	Total	0	1	2	3	4	5	6	Total
0	26							26	42							42
1		6	1					7	2	1	1					4
2		1	7	1				9		2						2
3			5					5	1		1					2
4				2	1			3								
5																
6																
Totals	26	7	8	8	1			50	44	2	3	1				50

B) Left Sternal Border, 4th Intercostal Space

Telediagnosis Auscultation

	SYSTOLE								DIASTOLE							
	0	1	2	3	4	5	6	Total	0	1	2	3	4	5	6	Total
0	29							29	26							26
1		1	2	1				4		14	2	1				17
2			9	2	1			12			4	1				5
3			1	4				5				2				2
4																
5																
6																
Totals	29	1	12	7	1			50	26	14	6	4				50

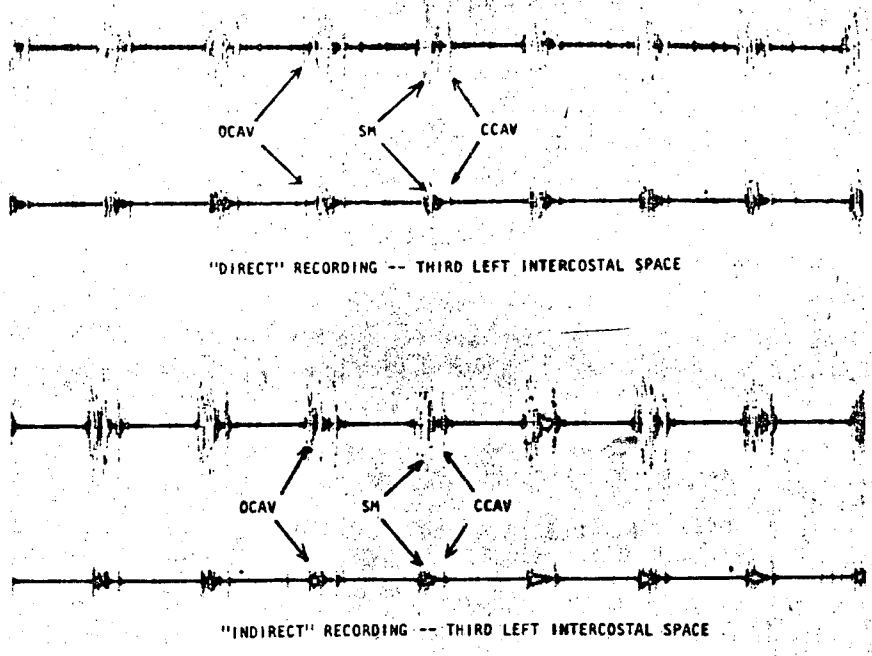

FIGURE 2. Two phonocardiograms comparing a "direct" recording from a patient with a prosthetic aortic valve (upper recording) and an "indirect" recording from the same patient recorded via the microwave system. Note the reproducibility of the "indirect" compared with the "direct" recording (OCAV=opening click aortic valve; SM=systolic murmur: CCAV=closing click aortic valve.)

faint (Gr 1/6), rumbling murmurs. These were the only two of the 32 grade 1/6 murmurs in this study missed by teleauscultation.

The classification of murmurs with respect to quality presented no significant problems. The findings at other sites of auscultation did not significantly differ from observations at the apex and left sternal border. Review of hospital charts on the patients in this study demonstrated that variations in classification of murmurs of one grade were not uncommon on direct auscultation by different observers and even the same observer on different days.

DISCUSSION

The accurate interpretation of all but the faintest heart murmurs transmitted by microwave offers evidence for the feasibility of providing cardiac consultation at a distance. The causes for the minor discrepancies noted in this study are not apparent at this time. The two diastolic rumbling murmurs missed were both missed in the early phases of this study when the medical station was located adjacent to an airport runway and ambient noise was high. After the site was moved to a less noisy area and acoustical drapes were installed in the examining room no faint murmurs were missed. Errors of grading became as frequent in the one grade higher category as in the one grade lower. Future systems should be designed to indicate when the sound intensity of the output of the telestethoscope is equivalent in intensity to the input at the stethoscope microphone.

FIGURE 3. Microscopic image of a positive Lupus prep transmitted 2.7 miles by microwave.

The accuracy of transmission over the 2.7 mile link is perhaps better illustrated by the phonocardiographic recording shown in Figure 2. The "direct" phonocardiogram made at the bedside in the standard manner, compares favorably with the "indirect" recording made with the patient at the airport facility and the phonocardiograph connected to the output of the microwave system in the hospital's telemedicine center.

Most of the important routine diagnostic techniques utilized by the cardiologist can be performed at a distance. Medical history can be easily and accurately obtained by interactive television. Indeed, currently the system is used extensively for psychiatric interviewing and counselling services. The system allows clear transmission of images magnified × 1000 (Fig 3) and instantaneous switching from one camera to another to permit viewing

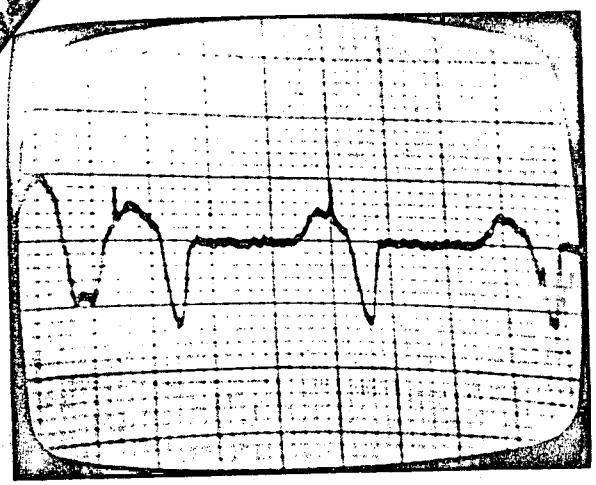

FIGURE 4. The appearance of an electrocardiographic tracing on a television monitor. The monitor in this case was 12 miles from the tracing.

from different angles. This permits close-up inspection of the chest. Electrocardiograms taken at the remote site can be readily viewed via the magnification system (Fig 4) or when necessary transmitted in realtime with less than a 2 percent variation in wave form. The accuracy of interpretation of chest roentgenograms viewed by microwave television has been shown to be within the limits of inter-observer and intra-observer variability.[4] The addition of auscultation at a distance can thus enable a centrally located cardiologist to provide specialized advice to patients managed by generalists (either physicians or nurse clinicians) in rural or other medically disadvantaged areas. In our opinion the minor discrepancies noted in the comparison between direct and teleauscultation, herein reported, should in no way interfere with the orderly introduction of this promising new health care resource into more widespread usage.

REFERENCES

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4 Murphy RLH, Barber D, Broadhurst A, et al: Microwave transmission of chest roentgenograms. Am Rev Resp Dis 102:771-777, 1970

Report of Task Force on Research in Respiratory Diseases*

The Division of Lung Diseases of the National Heart and Lung Institute has issued for general distribution a 243-page report on respiratory diseases. Prepared by a task force which was constituted to assist the Division of Lung Diseases in identifying problems and approaches that warrant a high priority in the Institute's immediate and long-range plans, the report assesses the magnitude of public health problems and the current state of knowledge relative to particular respiratory diseases. It also identifies disparities between what is needed and what is being done to combat these diseases, and it recommends operational steps to strengthen the present research effort.

In all, 188 biomedical scientists contributed to this report. Dr. Claude Lenfant, Director of the Division of Lung Diseases, NHLI, was chairman; the other members were Drs. David Ashbaugh, University of Colorado; Reuben M. Cherniack, University of Manitoba; Henry N. Claman, University of Colorado; Helen A. Dickie, University of Wisconsin; Harold L. Israel, Jefferson Medical College; Peter T. Macklem, McGill University; Alan K. Pierce, University of Texas; Hal B. Richerson, University of Iowa; Marvin A. Sackner, Mt. Sinai Hospital of Greater Miami; Irving J. Selikoff, Mt. Sinai Medical School; and Gerard M. Turino, Columbia University. Dr. Michael Grossman, National Bureau of Economic Research, Inc., served as economic consultant to the task force.

Single copies of the report may be obtained by writing to: Division of Lung Diseases, National Heart and Lung Institute, Bethesda, Maryland 20014. Multiple copies may be purchased through: Superintendent of Documents, U.S. Government Printing Office.

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