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FOREWORD

This book contains the complete set of papers presented at the Third United States-Japan Science Cooperation Seminar on the Subject of Holographic Imaging and Information Processing, held at Hawaii, January 8 to 13, 1973, under the joint sponsorship of the National Science Foundation and the Japan Society for the Promotion of Science. The papers present the latest advances and state of the art in areas ranging from ultrasonic holography, radar and sonar to ultrasonic pulse-echo imaging, acoustic microscopy and image processing in biomedical engineering. Computer processing of ultrasonic images is extensively discussed. Several papers describe the remarkable applications of ultrasonics in medical diagnostics. One describes new features in R & D management that are particularly relevant to the field as a result of recent changes in national science and technology policies. We also present the most recent advances in the powerful methods of image improvement (sharpening, deblurring) which have been made possible with the aid of holograms used as computing elements; the holographic image deblurring method is capable of an astonishing improvement of images that are still unattainable with even the most powerful digital computer methods. The book follows the 1971 Plenum Publishing Company book, "Applications of Holography", which comprised the papers presented at the Second U. S.-Japan Seminar held in Washington, D. C., October 13 to 18, 1969. In both these seminars, the discoverer of holography, Professor Dennis Gabor who received the 1971 Nobel Prize in Physics for his work, was an active participant. All three seminars (the first having taken place in Japan from October 2 to 6, 1967) were sponsored jointly by the National Science Foundation and the Japan Society for the Promotion of Science. The singular role of Gilbert B. Devey, Program Director, National Science Foundation, Washington, D. C., in stimulating the three meetings is noted with much gratitude.

22. Okujima, M., and Motooka, S., Experiment in Scale Model for Geological Survey from Ground Surface, Reports of the 6th International Congress on Acoustics, No. K-5-4, 1968.

23. Okujima, M., and Motooka, S., Investigation of Geological Survey from Ground Surface by Impulsive Sound Wave, Proceedings of the 7th International Congress on Acoustics, No. 23-U-2, 1971.

24. Katakura, K., Kobayashi, M., Tannaka, Y., and Koshikawa, T., High Speed Ultrasonic Imaging System, Report of Japan Society of Ultrasonics in Medicine, the 20th Meeting, No. 20-28, 1971. (in Japanese)

25. Katakura, K., Kobayashi, M., Tannaka, Y., and Koshikawa, T., High Speed Ultrasonic Imaging System using Fan Beam Scanning, Reports 1972 Spring Meeting, Acoustical Society of Japan, No. 3-1-13, 1972. (in Japanese)

26. Katakura, K., Kobayashi, M., Tannaka, Y., and Koshikawa, T., High Speed Ultrasonic Imaging System Using Fan Beam Scanning, Report of Japan Society of Ultrasonics in Medicine, the 22nd Meeting, No. 22-8, 1972. (in Japanese)

27. Katakura, K., Kobayashi, M., Tannaka, Y., and Koshikawa, T., Underwater Viewing System, Preprints of the 2nd International Ocean Development Conference, P. 427, 1972.

ULTRASONO-CARDIO-TOMOGRAPHY

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I. INTRODUCTION

In obtaining ultrasonic tomograms of the heart and great vessels, there are, unlike other organs, some particular conditions: The pulsation of movement of all the echo sources, and the anatomical situation that the heart is covered by the lung and the costa. The positions of the echo sources repeatedly vary with time in the thoracic cavity. To obtain the stationary tomograms of the living heart at various cardiac phases, there have been proposed several methods. To overcome the pulsation movement, a synchronization method, a high speed scanning method and a tomo-kymographic method have been introduced. To solve the anatomical situation, an intra-cardiac, intra-esophagal, intra-tracheal and transthoracic methods have been developed. Those methods will be described in this paper, by placing some emphasis on the methods which the present authors have developed within the present clinical routine.

II. SYNCHRONIZED ULTRASONO-CARDIO-TOMOGRAPHY

Figure 1 shows the schematic diagram of the ultrasonic apparatus which operates in synchronization with the cardiac cycle.[1, 2] For the synchronizing signal, the usual ECG meter is utilized. Although any wave of ECG can be used for the signal, the R-wave of ECG is used primarily for the purpose at present. As shown in the figure, the R-wave of ECG is first detected by the R-wave detector, and its waveform is shaped into a pulse which is used for the signal of time origin. Then, in accordance with the required phase for the stationary tomogram, a time delay is given to the signal of origin by the delay circuit. This signal is used as the synchronizing signal for operating the ultrasonic apparatus.

1. Intracavitary Methods

a. Intra-Cardiac Method[3] - Omoto, Atsumi and others have developed a method of detecting and measuring an atrial septal defect by using a catheter type ultrasonic probe which is inserted into the right atrium through the external jugular vein or the femoral vein. They tried various ultrasonic intravenous probes called "cardiac sonde". One cardiac sonde consists of a 18/8 stainless steel tube, 1.2 mm in diameter and 750 mm in length, with an ultrasonic transducer at the tip of the tube. The transducer is 3.2 mm in diameter and is used at five Megahertz. A modified C-scan indication system with ECG synchronizing circuit and a variable gate circuit has been employed as shown in Figure 2. An X-Y recorder is to be used in recording the image of the septal defect. The cardiac sonde was inserted into the superior or inferior vena cava as shown in Figure 3A, and it scanned the interatrial septum as shown in Figure 3b, at a number of different levels. An example of the obtained pattern is as shown in Figure 4. In this case, the authors reported that the estimated size of the defect from the pattern was 2.5 cm x 1.5 cm, and the measured size under surgery was 2.7 cm x 1.6 cm.

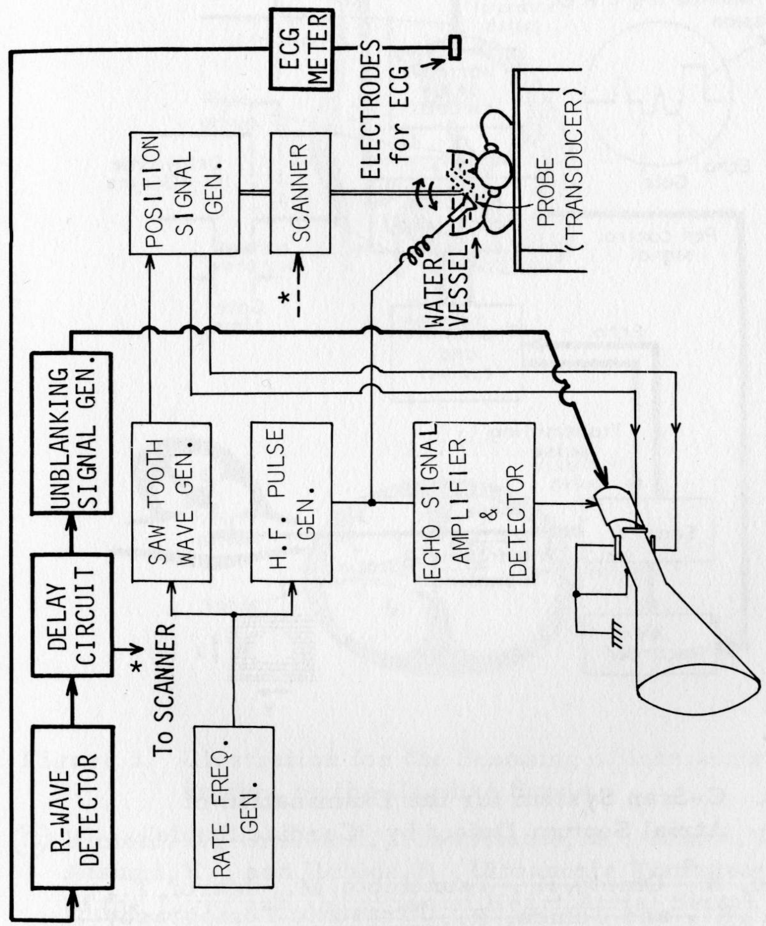

Figure 1. Schematic Diagram of an Apparatus for the Synchronized Ultrasono-Cardio-Tomography

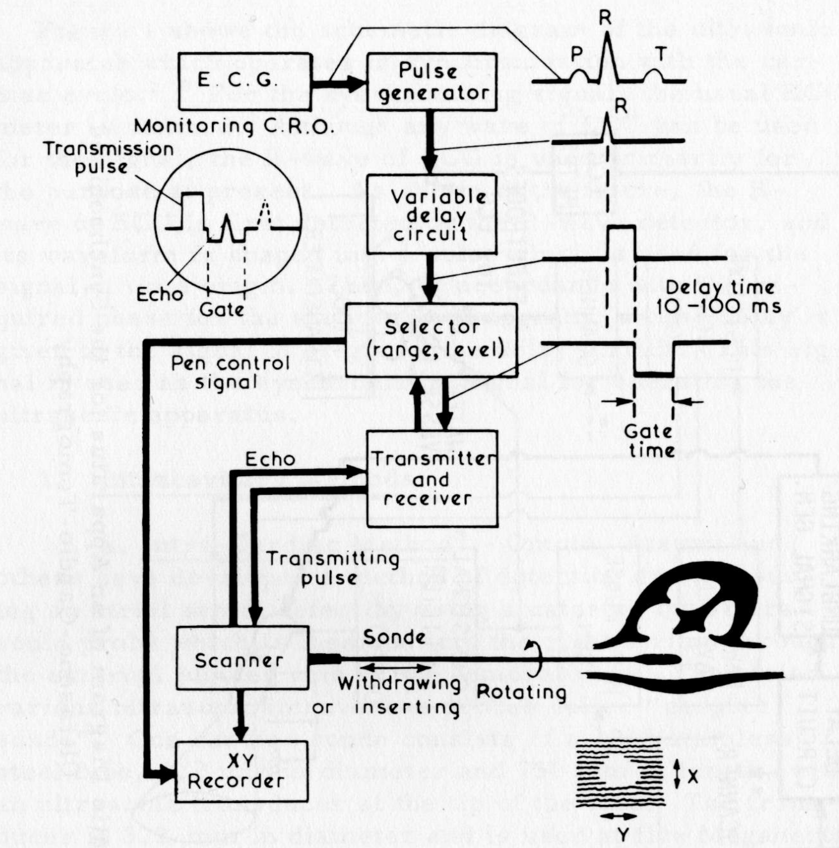

Figure 2. C-Scan System for the Examination of Atrial Septum Defect by "Cardiac Sonde"

© Kimoto, S.,* Omoto, R., Tsunemoto, M., Muroi, T., Atsumi, K., and Uchida, R., Ultrasonic Tomography of the Liver and Detection of Heart Atrial Septal Defect with the Aid of Ultrasonic Intravenous Probes, Ultrasonics, Vol. 2, P. 85, 1964, Figure 7.

* Dr Seiji Kimoto, Mitsui Memorial Hospital, Kanda Izumi-cho, Chiyodaku, Tokyo, Japan 101

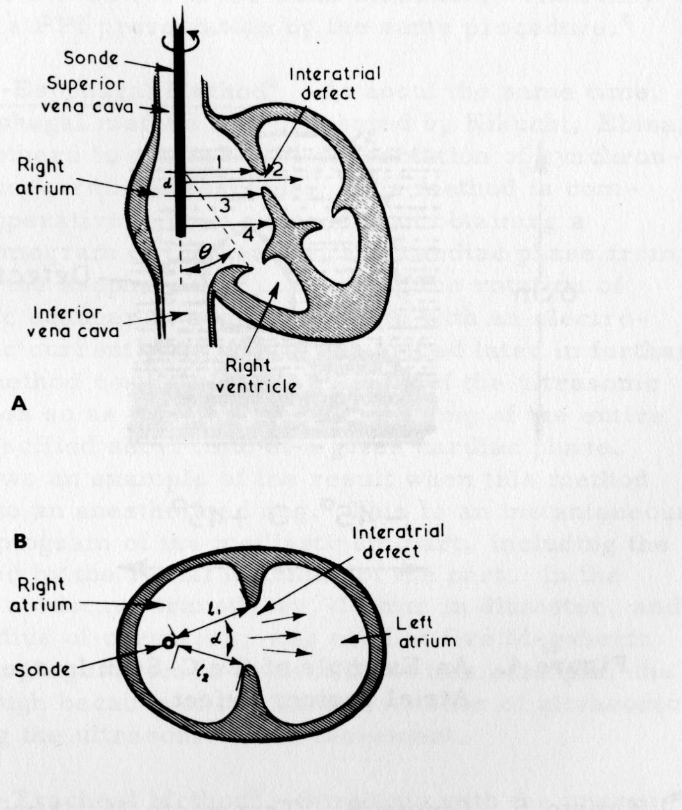

Figure 3. Illustration for the Scanning of Interatrial Septum by the Cardiac Sonde

© Kimoto, S., Omoto, R., Tsunemoto, M., Muroi, T., Atsumi, K., and Uchida, R., Ultrasonic Tomography of the Liver and Detection of Heart Atrial Septal Defect with the Aid of Ultrasonic Intravenous Probes, Ultrasonics, Vol. 2, P. 85, 1964, Figure 6.

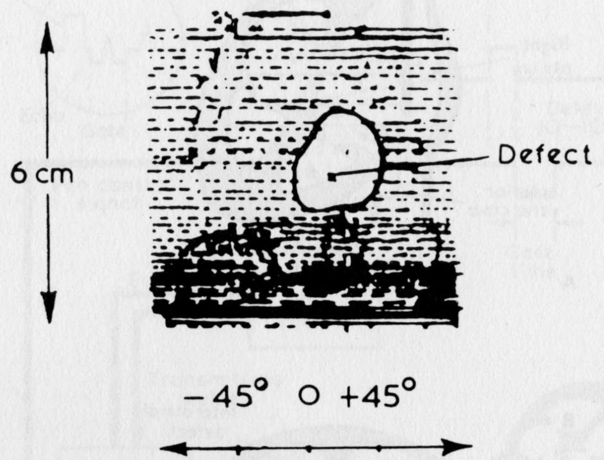

Figure 4. An Example of the C-Scan Image of Atrial Septum Defect

© Kimoto, S., Omoto, R., Tsunemoto, M., Muroi, T., Atsumi, K. and Uchida, R., Ultrasonic Tomography of the Liver and Detection of Heart Atrial Septal Defect with the Aid of Ultrasonic Intravenous Probes, Ultrasonics, Vol. 2, P. 86, 1964, Figure 9.

The C-scan indicator, however, is not suitable for an intuitive observation, because the abscissa of the pattern is the azimuth angle, and the ordinate is the distance of the cardiac sonde movement in the axial direction. Then they began to use a PPI presentation by the same procedure.[4]

b. Intra-Esophagal Method[5] - At about the same time, an intra-esophagal method was presented by Kikuchi, Ebina, Tanaka and others to obtain a PPI presentation of synchronized ultrasono-cardio-tomograms. This method is completely non-operative. They succeeded in obtaining a stationary tomogram of the heart at any cardiac phase from the inside of the esophagus by controlling the rotation of the ultrasonic scanner in synchronization with an electrocardiographic current. As will be described later in further detail, the method consists in the shifting of the ultrasonic beam direction so as to complete the scanning of the entire heart in a specified short time at a given cardiac phase. Figure 5 shows an example of the result when this method was applied to an anesthetized dog. This is an instantaneous ultrasono-tomogram of the mediastinum part, including the heart obtained by the radial scanning of the part. In the experiment, a concave transducer, 10 mm in diameter, and 60 mm in radius of curvature, was used at five Megahertz inside the esophagus. As is evident from this example, the pattern is rough because of the limited number of ultrasonic pulses during the ultrasonic beam movement.

c. Intra-Tracheal Method[6] - Similarly with the preceding method, an intra-tracheal PPI transducer has been developed so that the mediastinum organs can be ultrasonically scanned from the inside of the trachea. Experiments were reported as being successful with a dog.

d. Intracardiac Catheter for an Electronic High Speed Scanning[7] - Recently, Bom has shown a new type of intracardiac ultrasonic catheter. The catheter consists of a multi-element cylindrical acoustic transducer whose elements are to be switched electronically. When electronic scanning is fast, with a corresponding display, an instantaneous image of the echo structure is obtained.

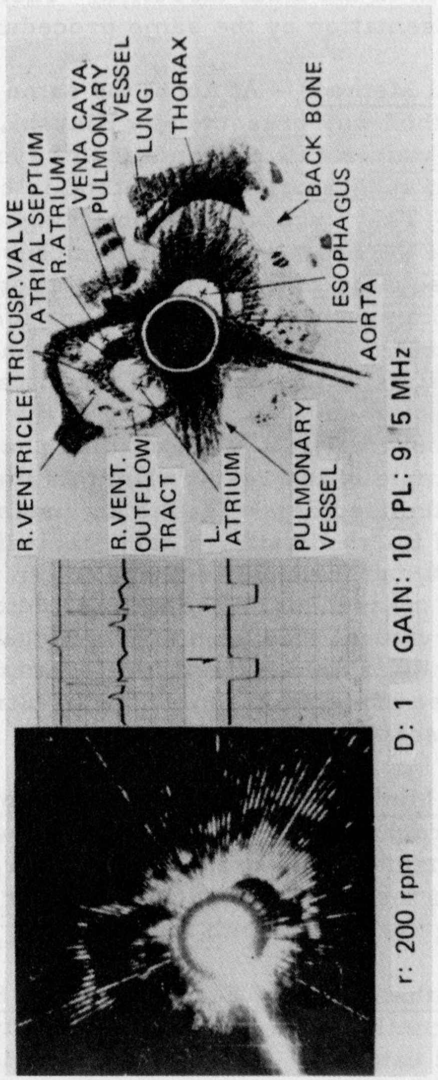

Figure 5. Ultrasono-Cardio-Tomogram of the Mediastinum of an Anesthetized Dog Obtained by the Intraesophageal Method

The picture of the catheter is shown in Figure 6. The echo pattern of a cylindrical mesh reflector is as shown in Figure 7. No data for clinical use, however, have been reported.

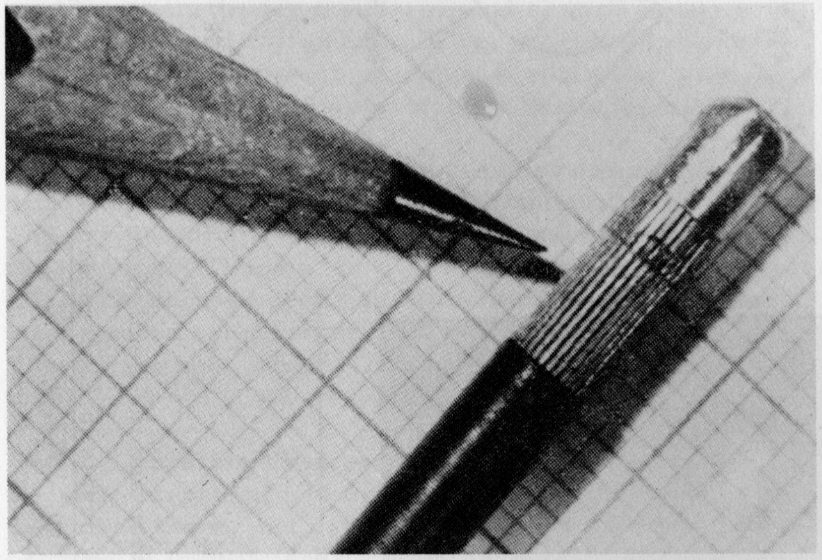

Figure 6. Photograph of a 32 Element Catheter

* Dr Ir. N. Bom, Department of Cardiology, University of Rotterdam, The Netherlands.

2. Transthoracic Method[1,2] - Some transthoracic methods of synchronized ultrasono-cardio-tomography were proposed around 1963 by Kikuchi, Ebina, Tanaka and others, and developed accordingly. The principle is based

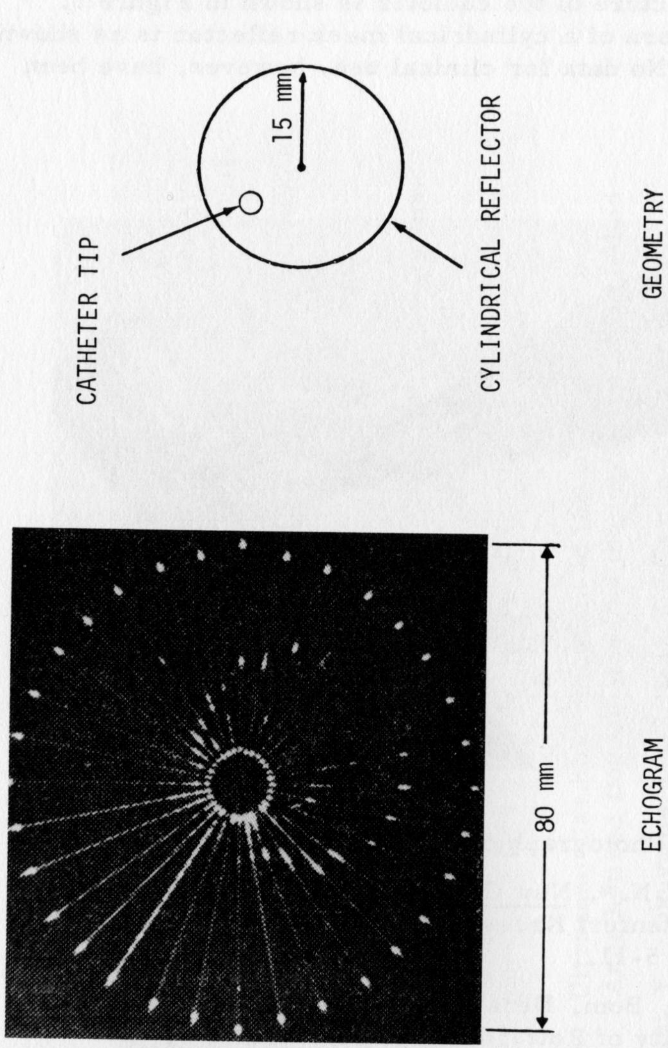

Figure 7. An Echo Pattern and the Configuration of a 32 Element Catheter

Ⓒ Bom, Ir N., New Concepts in Electrocardiography, H. E. Stenfert Kroese, N. V., Leiden, 1972, P. 55, Figures 5-12.

on an idea that an ultrasonic apparatus for the usual ultra-sonotomography is so modified that it is operated only within a short interval at a selected instant of a cardiac cycle.

Ultrasono-cardio-tomography by cardiac sychronization is the method for describing ultrasono-tomograms synchronously at any phase of the cardiac cycle by operating the apparatus for a short period of time in which the heart is deemed stationary. When the description of a wider area is required, a method similar to a panorama photographic method is combined with the former.

The principal points in these systems consist in the detection of the cardiac phase and instantaneous operations. Three types of apparatus operations have been proposed by the authors. These are: (1), synchronized single scanning; (2) synchronized repetition of the single scanning; and (3), the repeated synchronized unblanking of the echo display. These have been named Operations I, II, and III, respectively.

Operation I has been mentioned in the paragraphs on intra-esophagal and intratracheal methods. As was described there, the patterns obtained are usually rough because of insufficient density of the cathode ray sweeps.

The aim of Operation II is to make a smoother pattern by repeating the synchronized single scanning several times at the same cardiac phase of successive pulsations so as to fill the sweep gaps left during the preceding scannings.

In Operation III, though the short, unblanking of the display is repeated at a given cardiac phase, the transducer position, consequently the ultrasonic beam position, is free running; so one complete scanning of a given area in a human organ is made by patching a certain number of partial tomograms of the area. The clinical operator (physician) can adjust the free running phase and speed so that the required time may be minimized with a compromise to the cathode-ray sweep density for obtaining a smooth pattern. In this operation, however, the identical succession of the cardiac cycle must be assumed.

In the case of the transthoracic method, the ultrasonic beam travels through the intercostal space from an ultrasonic transducer that is located in very close vicinity to the chest wall, as shown in Figure 8. This method is named "proximity-immersed method". In this case, Operation III is usually employed, and the ultrasonic transducer makes sector swings continuously without being in synchronization with the heart movement; but the unblanking of the cathode ray tube is repeated for a short period of time at the selected phase of every cardiac cycle determined by the output signal of the delay circuit as already shown in Figure 1. As generally described in the foregoing, only a partial tomogram of the heart is obtained for a single cardiac cycle; so the repetition over 20 to 30 times covers the whole heart, and the pattern thus obtained is a positionally patched pattern of several numbers of partial tomograms for a given cardiac phase. Figure 9 represents an example of the application of this method to a normal heart. Figure 9A shows the tomograms for the systolic phase, and 9B is for the diastolic phase. Figures 9C and 9D are roentgenograms showing the plane of scanning. The arrow indicates the plane scanned by the ultrasonic beam in the thoracic cavity.

Figure 10 shows a set of the stationary tomograms for one cardiac cycle when the cycle is divided into nine intervals. The phase relation of each tomogram to ECG is given on the lower left, each with a dot. In this figure, (1) is for early systole, (6) is for late systole, (7) is for early diastole, and (9) is for late diastole. When this set of tomograms is compared with one after another in the numbered order, one can observe the movement of various parts of the heart.

Numerous interesting findings were observed on a set of the stationary tomograms.[8] The movement of each part of the heart in relation to the movement of the whole heart can be clarified; any movement, not only the movement in the ultrasonic beam direction, but in the other directions, is observable. This is not possible by a single UCG. When attention is focused on the mechanical movement of the left ventricle, both in the case of normal and of atrial septal defect, it is observed that the displacement amplitudes of the left ventricular wall and septum are almost equal in magnitude, and that the function of the right ventricle is largely affected by that of the left ventricle. The motion of the left ventricle is almost concentric in both the systole and the diastole in normal function, as seen in Figure 11A, whereas the motion is eccentric in the case of atrial septal defect as seen in Figure 11B.

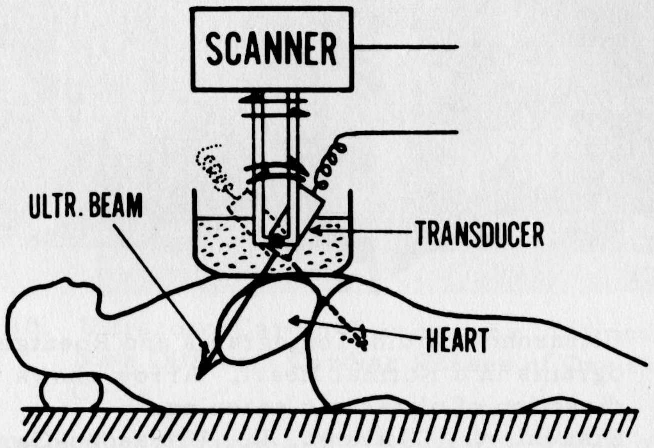

Figure 8. Schematic View of the Configuration of the Transducer for "Proximity-Immersed Method"

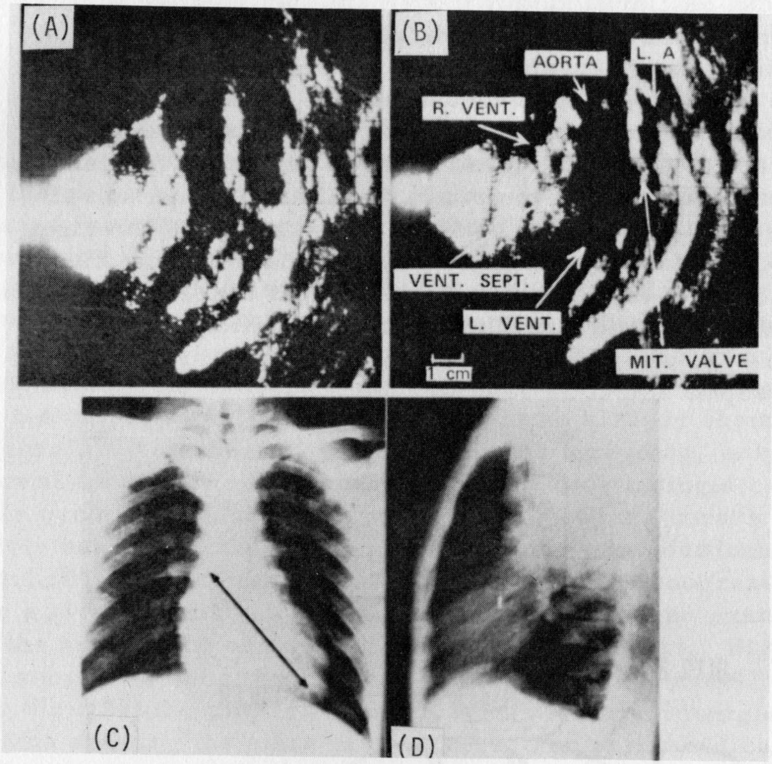

Figure 9. Ultrasono-Cardio-Tomograms and Roentgenograms in a Normal Heart. Arrow shows the direction of ultrasonic scanning.

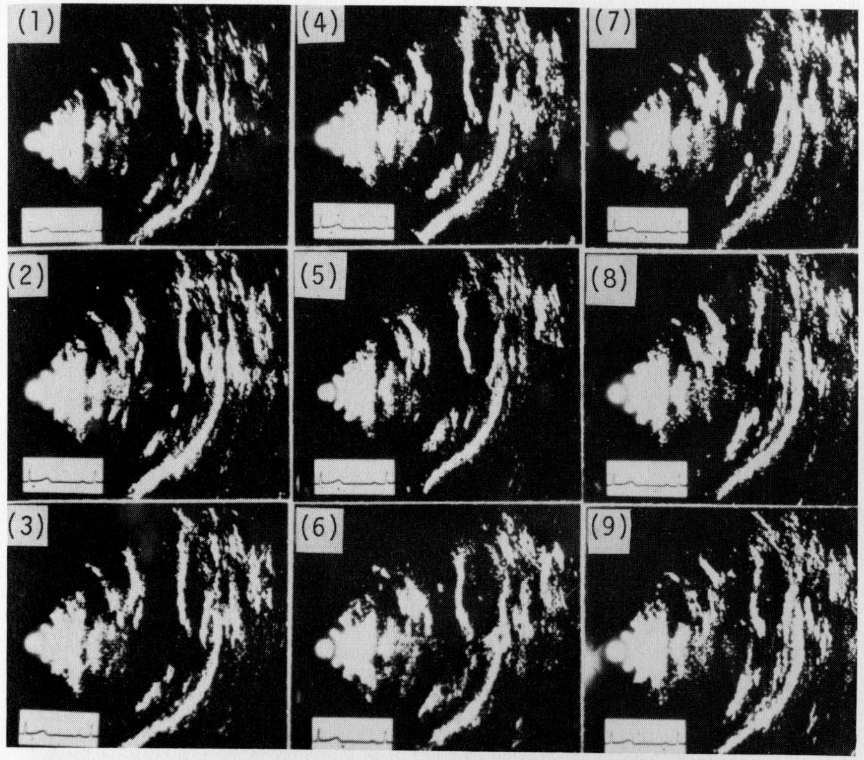

Figure 10. Ultrasono-Cardio-Tomograms Obtained at Nine Different Cardiac Phases of One Cardiac Cycle

* Dr Yoshimitsu Kikuchi, Res. Inst. of Electrical Communication, Tohoku University, Senda, Japan 980.

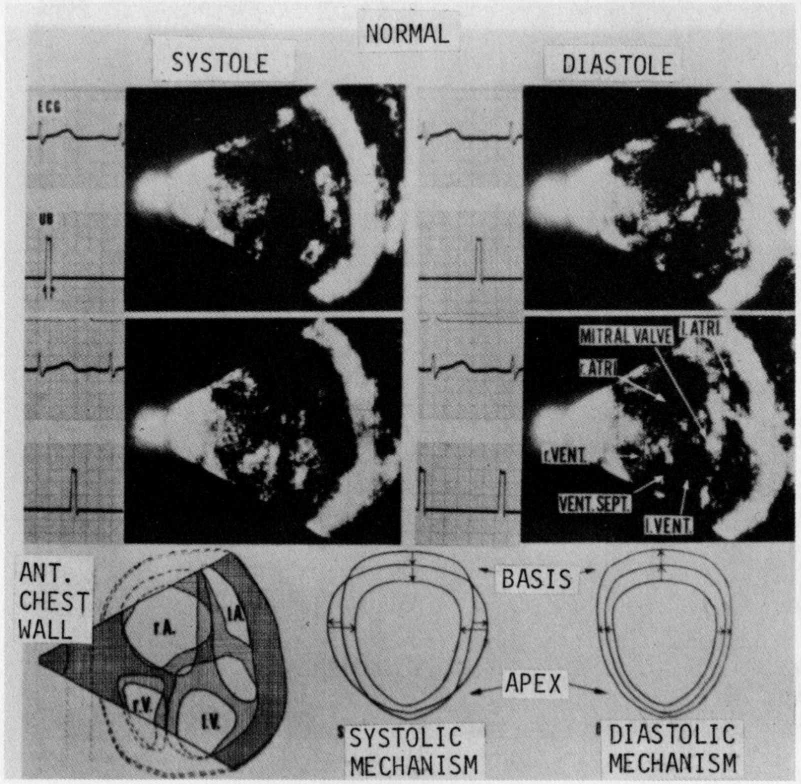

Figure 11A. Analysis of the Left Ventricular Movement, Motion is concentric in a normal heart

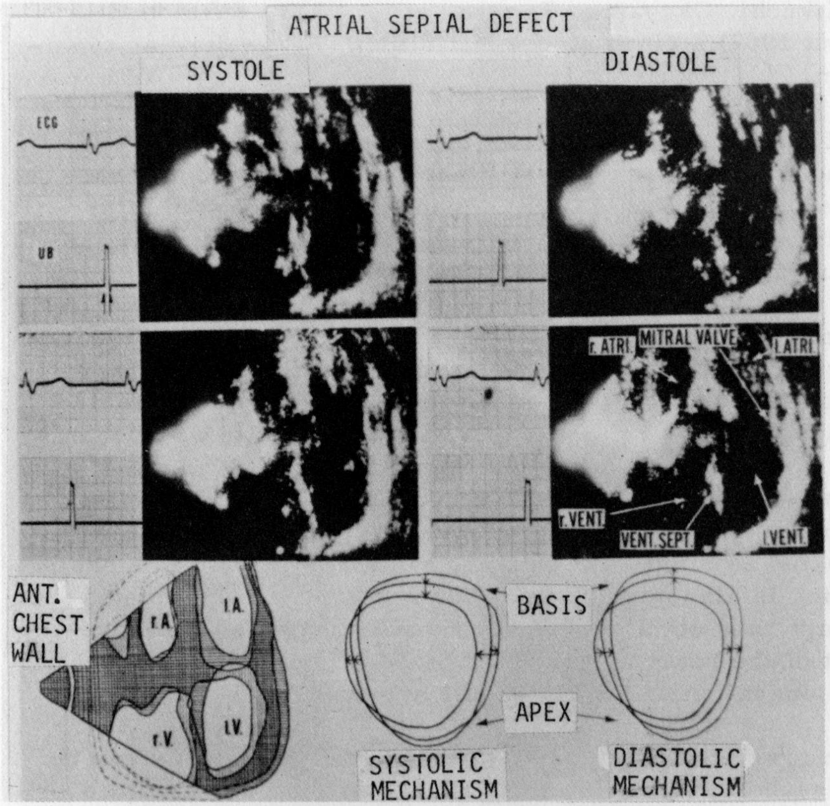

Figure 11B. Analysis of the Left Ventricular Movement, Motion is eccentric in a case of atrial septal defect.

III. KINETO-ULTRASONO-TOMOGRAPHY[9, 10]

Kikuchi, Okuyama, Tanaka, et al., have developed (about 1967) a cinematographic display of the cardiac tomogram.

If the set of synchronized ultrasono-cardio-tomograms is made into an animation as shown in Figure 12 and projected on a screen, the movement can be observed intuitively. In this chapter, the technique for making the cinematograph is illustrated briefly.

In the first step, ultrasono-cardio-tomograms of the heart in action are taken at a number of different phases for one cardiac cycle by means of the synchronized tomography already described. Each tomogram is then taken by a cine camera, one by one; thus, one series of animations is made for one cardiac cycle. In order to observe the heart movement on a cinematograph, this one series is repeated as often as necessary for observation. Endless filming is also advantageous for repetition. The cinematograph thus obtained gives a representation of the movement of the heart section as if it were presented by a real time operation of the ultrasonic apparatus.

In practice, the number of individual tomograms can be decreased when each tomogram is used for two or three frames of successive animation. In normal speed observation, 10 to 20 individual tomograms are suitable for one cardiac cycle when dual or triple use is employed. Figure 12 is an example of this triple use. If both the numbers of the tomograms and multiple use are increased, a slow-motion picture is obtained, although the motion appears somewhat unnatural. (At the meeting at which this report was presented, the result was shown by a roll of 16 mm film on which the cases of normal, atrial septal defect, the tetralogy of Fallot, and patent ductus arteriosus had been edited.)

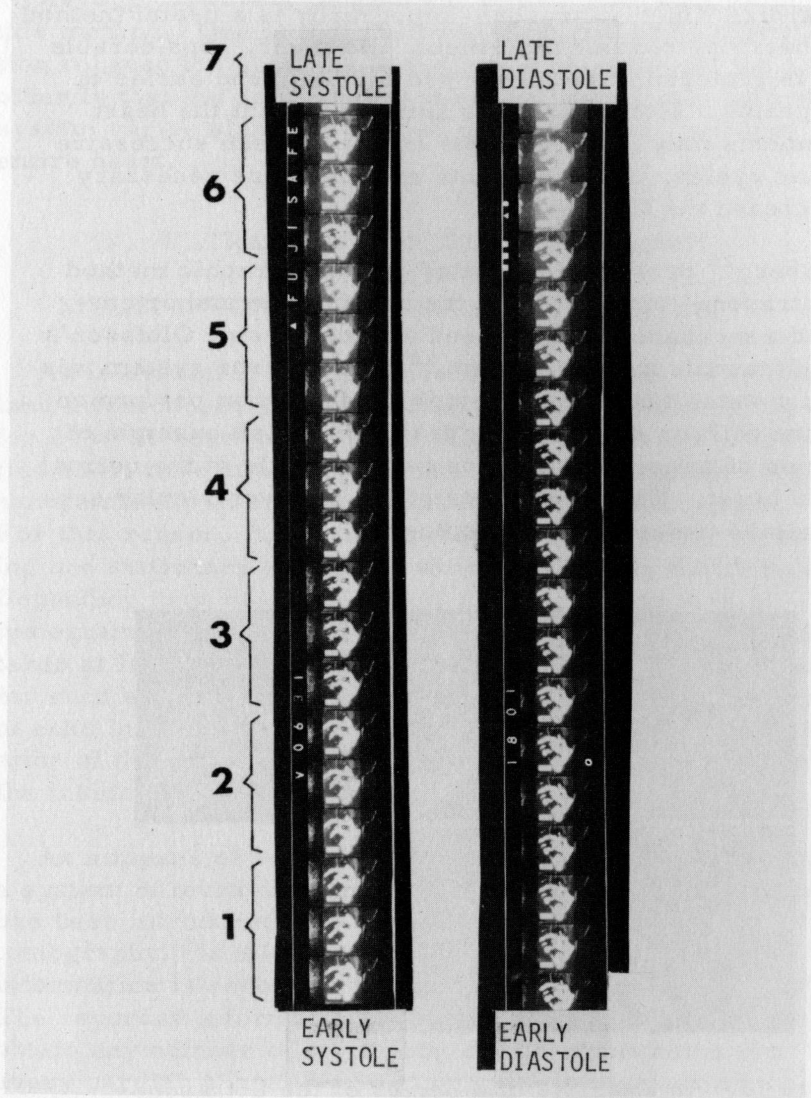

Figure 12. A Part of Kineto-Ultrasono-Tomographic Film to be Presented Cinematographically

Cardiac Kineto-ultrasono-tomography is a useful method for observing cardiac movement. However, considerable time is required at the clinic bed to obtain one series of tomograms. Moreover, it is anticipated that the heart movements may differ to some extent between successive cardiac cycles. Improvements are therefore necessary to decrease the time needed.

Asberg[11] presented a sort of cinematographic method for ultrasono-tomography of the heart. The author employed a mechanical high-speed scanner, using Olofsson's type ultrasonic mirror system.[12] The mirror system was set in a water tank, and a sector scanning was performed with the mirror system. Figure 13 shows an example of a series of tomograms for one cardiac cycle of the normal human heart. The movements of the interventricular septum can be observed in the tomogram.

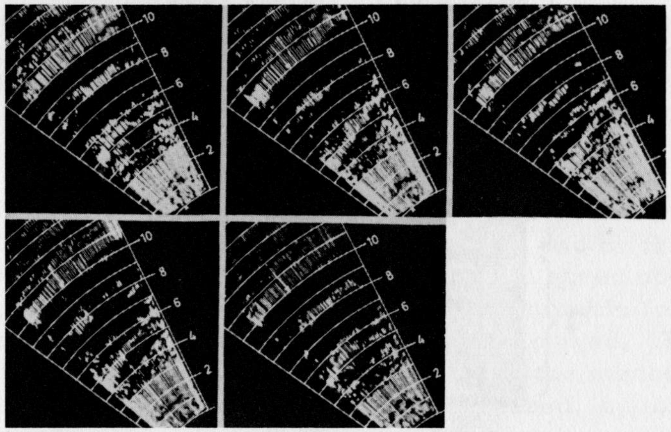

Figure 13. An Example of a Series of the Ultrasono-Cardio-Tomograms during one Cardiac Cycle Obtained by the Ultrasonic Mirror System (11)

© Asberg, A., Ultrasonic Cinematography of the Living Heart, Ultrasonics, Vol. 5, P. 116, 1967, Figure 6.

* Dr Asberg, Department of Electrical Measurements Lund Institute of Technolography, Lund, Sweden.

Asberg, however, pointed out some disadvantages in this method. One is that the tomogram has some distortion because the scanning speed is not fast enough; the other is that the azimuthal resolving power of the mirror system varies along the mirror axis too much, to cover an entire heart.

IV. ULTRASONO-CARDIO-TOMOGRAPHY BY MEANS OF MULTI-INFORMATION RECORDING SYSTEM[13]

As is evident from the preceding paragraph, in syncronized ultrasono-cardio-tomography the partial tomograms for 20 to 30 heart beats, each of which is taken in a specified short time at a required phase, must be patched together panoramically in order to obtain a complete tomogram. For this reason, 0.5 to 1.0 minute is required for obtaining one stationary tomogram which covers the entire heart. Depending upon heart diseases, necessary numbers of tomograms become a few dozen in some cases;[13] thus, it takes at least two to three hours for one patient. The cause for such a long examination is based on the intermittent use of echo information, despite the fact that some echo information of the ultrasonic pulse is continuously coming from the inside of the beating heart.

As a means of solving the problem of information loss, a system of multi-information recording and reproduction has been introduced into synchronized ultrasono-cardio-tomography. In this method, the entire ultrasonic echo information is recorded, together with the ECG at the clinic. The recorded information is repeatedly reproduced later to obtain any number of stationary cardio-tomograms for every cardiac phase, by employing the synchronization method in which the recorded ECG is, of course, used for the reproduction signal for synchronization. Even when a number of tomograms for various phases are required for a certain cross-section of the heart, the time required at the clinic would be only that required for obtaining a single tomogram, no matter how many phases might be required.

The block diagram of the system is shown in Figure 14. In the figure, the diagram below the broken line is the usual apparatus for the synchronized ultrasono-cardio-tomography, while the unit above the broken line consists of the information recording and reproduction device, and the ECG signal processing device. When the changeover switch at the center of the figure is shifted to RECORDING, the recording of information takes place, while at the same time, the display unit serves as the monitor.

Figure 15 shows both examples of the original tomogram obtained with the usual apparatus and the reproduced tomogram thereof. It may be considered as being satisfactory.

V. ULTRASONO-TOMO-KYMOGRAPHY[14]

In addition to the method of ultrasono-cardio-tomography, kineto-ultrasono-tomography, and the combination of tomography with time-position-indication, a method in which the displacement amplitudes of cardiac parts can be presented in a superimposing way on an ultrasonic tomogram has been developed, also by Kikuchi, Okuyama, Tanaka, et al., and named, "Ultrasono-Tomo-Kymography". The cardiac mobility, the maximum displacement of various parts of the heart, the variation in radii of the cardiac chambers, the curvature change of the ventricular wall, etc., can be represented in a single sheet of the tomogram; which is, therefor, useful for the analysis of the mechanical movement of the heart. This method is simpler in a clinical sense than the ultrasono-cardio-tomographical analysis, and it still gives more information[14] than the usual UCG.

By using the usual ultrasonic apparatus for tomography, the heart is now scanned by the ultrasonic beam in a very slow, angular velocity (in the case of sector scanning) as slow as three to five degrees per one cardiac cycle; or in a very slow linear velocity, in the case of linear scanning. On the cathode ray screen, every part of the heart is represented by a wave pattern indicating its maximum and minimum positions for one cardiac cycle. The entire pattern, however, still shows the tomographical section of the heart.

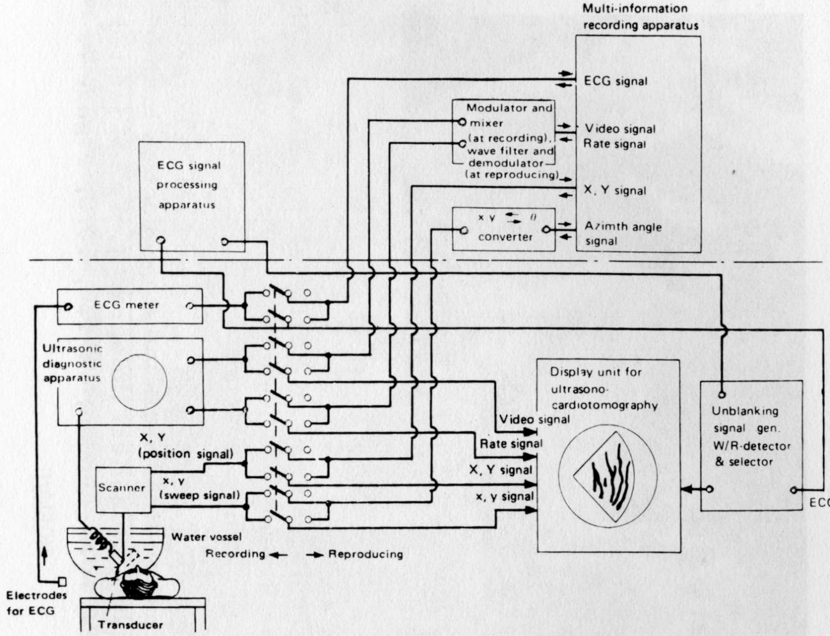

Figure 14. Schematic Diagram of Equipment for Ultrasono-Cardio Tomography when "Multi-Information Recording System is Employed

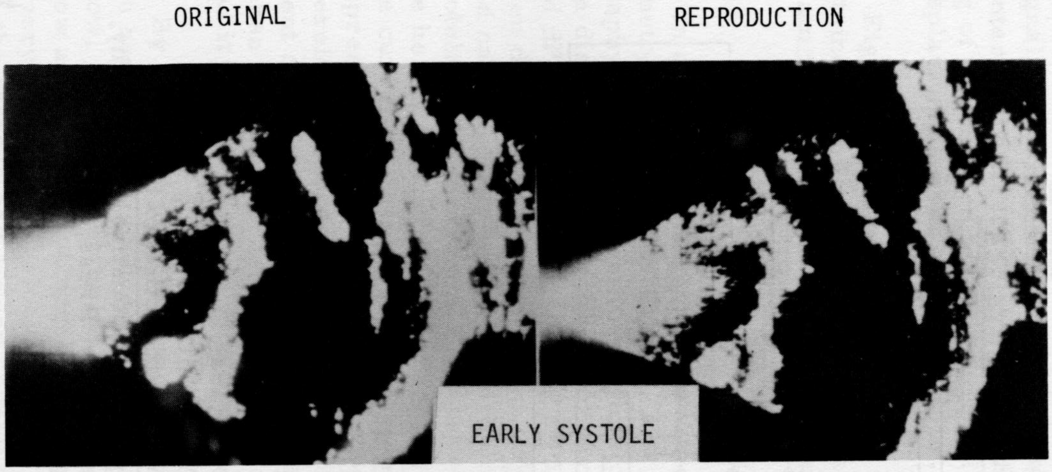

Figure 15. Ultrasono-Cardio-Tomograms at an Early Systole, Showing the Comparison with the Reproduced Tomogram by Means of the "Multi-Information Recording System."

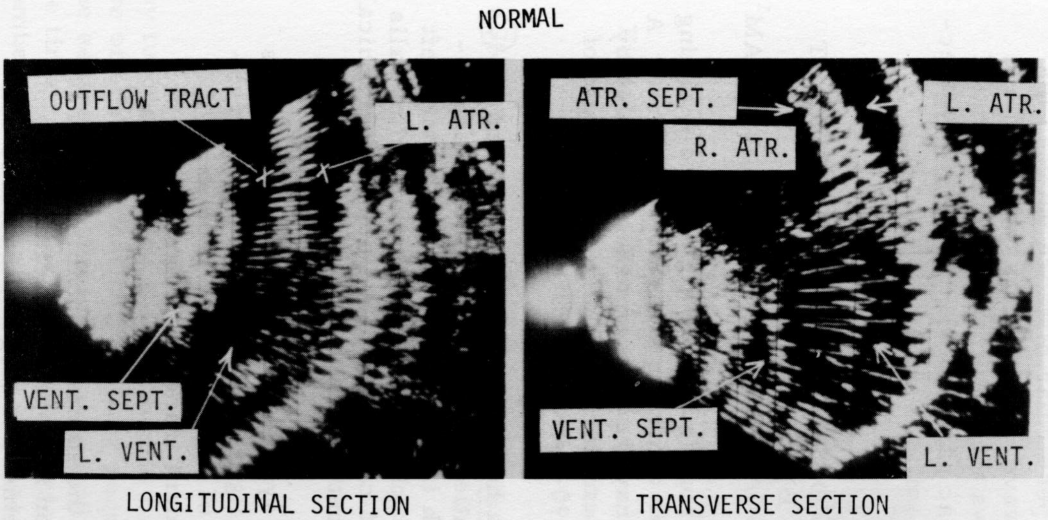

Figure 16. Ultrasono-Tomo-Kymograms of the Beat in a Normal Heart

Figure 16 shows the wave tomograms for a normal heart obtained by the proposed method. As the method is based on the accumulated recording of the positions at which the echoes of the ultrasonic pulses occur, and changing with cardiac motion, the perpendicular distance between the envelopes touching the wave pattern at its maximum and minimum positions shows the maximum displacement of the corresponding cardiac part, notwithstanding the direction of the ultrasonic beam.

VI. INSTANTANEOUS OBSERVATION OF THE HEART BY MEANS OF HIGH-SPEED LINEAR SCANNING OF ULTRASONIC BEAM[15]

Recently, Bom has proposed to use high-speed scanning of an ultrasonic beam for obtaining a cardio-tomogram. A multi-element linear array transducer to be controlled by the electronic switch is employed. The repetition rate of electronic scanning is 190 frames per second.

Some interesting data have already been obtained in vivo on a small number of patients. With the transducer centered over the left fourth intercostal area, the moving left ventricular structures such as posterior and anterior walls were recognized in most cases, and a moving tomographical pattern was displayed continuously.

Figure 17 shows one systolic frame of the tomograms video-recorded. In the figure is also shown the corresponding sagittal section of the thorax and the heart. In this case, a fifteen-element transducer was used at 4.5 Megahertz.

Bom pointed out that the limitation of this system is caused by poor resolution and specular reflection, and that only the gross movement of larger structures can be viewed with the present apparatus. However, he also mentioned that it might be stated that there is much to be learned in the interpretation of the obtained data.

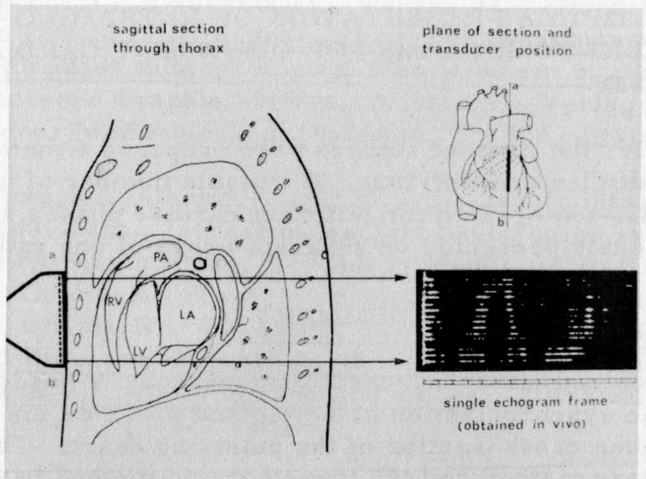

Figure 17. An Example of a Resulting Single Frame Tomogram and the Corresponding Sagittal Section and the Heart

ray tube screen. As this method is based on the multiplex use of echo information, the time required for obtaining one series of tomograms for one cardiac cycle is equal to the time required for any one tomogram, regardless of the number of parts in a series. As is easily understood from the preceding articles, the required time is around 0.5 to one minute in the case of the transthoracic method described in Operation III. The details will soon be published in a separate paper.

VII. MULTIPLEX PRESENTATION OF ULTRASONO-CARDIO-TOMOGRAMS FOR DIFFERENT CARDIAC PHASES

Recently, the present authors have proposed a method named multiplex presentation. A suitable number of ultrasono-cardio-tomograms for different cardiac phases are simultaneously presented on separate areas of one cathode-

VIII. SUMMARY

Synchronized ultrasono-cardio-tomography is based on the cardiac synchronization principle and presents the instantaneous cross-section of the pulsating heart. The intracavitary method and the transthoracic method have been proposed and developed for clinical examination by this principle.

Kineto-ultrasono-tomography is a useful method for intuitive observation of the heart movement.

Ultrasono-cardio-tomography by means of a multi-information recording system eliminates the problem of the comparatively prolonged clinical examination.

Ultrasono-tomo-kymography in an asynchronized cardiac method is simpler than the synchronized ultrasono-cardio-tomography. It can also be used for clinical examination.

High speed scanning methods are tried for use in ultrasono-cardio-tomography.

Multiplex presentation of cardio-tomograms is proposed to overcome the prolonged clinical examination.

REFERENCES

1. Kikuchi, Y., and Tanaka, M., Some Improvements in Ultrasonotomograph for the Heart and Great Vessels, Part II, Tomography Synchronized with any Cardiac Phase, 1966 IEEE Symposium on Ultrasonics, J-3, Cleveland, Ohio, October 12-14, 1966.

2. Kikuchi, Y., Okuyama, D., Tanaka, M., Ebina, T., and Oka, S., Ultrasono-Cardio-Tomography and Its Application to Mophological Measurement of the Heart, Ultrasono Graphia Medica, Volume III, Verlag Der Wiener Medizinischen Akademie, P. 423, 1971.

3. Omoto, R., Atsumi, K., et al., Ultrasonic Intravenous Sonde, Japan Journal of Medical Electronics and Biological Engineering, Volume 1, P. 90, 1963; Kimoto, S., Omoto, R., Tsunemoto, M., Muroi, T., Atsumi, K., and Uchida, R., Ultrasonic Tomography of the Liver and Detection of Heart Atrial Septal Defect with the Aid of Ultrasonic Intravenous Probes, Ultrasonics, Volume 2, P. 82, 1964.

4. Omoto, R., Ultrasonic Tomography of the Heart-An Intracardiac Scan Method, Ultrasonics, Volume 5, P. 80, 1967.

5. Ebina, T., Oka, S., Tanaka, M., Kosaka, S., Kikuchi, Y., Uchida, R., and Hagiwara, Y., The Diagnostic Application of Ultrasound to the Disease in Mediastinal Organs, Science Rep. Research Institute, Tohoku University, Series C., Volume 12, P. 199, 1965.

6. Haneda, Y., Tanaka, M., et al., Ultrasonic Visualization of Mediastinal Tumor (Especially Regarding the Transtracheal Method), Medical Ultrasonics, Volume 6, No. 1, P. 54, 1968.

7. Bom, Ir. N., New Concepts in Electrocardiography, H. E. Stenfort Kroese, N.V., Leiden, P. 44, 1972.

8. Kikuchi, Y., Okuyama, D., Tanaka, M., Ebina, T., and Oka, S., Kineto-Ultrasono-Tomography of the Heart, Ultrasono Graphia Medica, Volume III, Verlag Der Wiener, Medizinischen Akademie, P. 475, 1971.

9. Tanaka, M., Oka, S., Kikuchi, Y., Okuyama, D., Ebina, T., et al., Cardiac Kineto-Ultrasonotomography (in Japanese), Reports of the 13th Meeting of the Japan Society of Ultrasonics in Medicine, P. 7, 1968.

10. Kikuchi, Y., Okuyama, D., Ebina, T., Oka, S., and Tanaka, M., Cardiac Kineto-Ultrasono-Tomography, Reports of the Sixth International Congress on Acoustics, Tokyo, M-1-8, 1968, and Reference 8.

11. Asberg, A., Ultrasonic Cinematography of the Living Heart, Ultrasonics, Volume 5, P. 113, 1967.

12. Olofsson, S., An Ultrasonic Optical Mirror System, Acoustica, Volume 13, P. 361, 1963.

13. Kikuchi, Y., Okuyama, D., Kasai, C., Ebina, T., Oka, S., Tanaka, M., Terasawa, Y., and Uchida, R., Ultrasono-cardio-tomography for the Heart and Great Vessels by Means of "Multi-information Recording System" (in Japanese), Reports of the 17th Meeting of the Japan Society of Ultrasonics in Medicine, P.23, 1970;

Kikuchi, Y., Okuyama, D., Kasai, C., Ebina, T., Tanaka, M., Terasawa, Y., and Uchida, R., Multi-information Recording and Reproduction in the Ultrasono-cardio-tomography, Acoustical Holography, Volume 4 (edited by G. Wade), Plenum Press, New York-London, P. 113, 1972.

14. Kikuchi, Y., Okuyama, D., Tanaka, M., Ebina, T., and Oka, S., Ultrasono-Tomo-Kymography of the Heart, Ultrasono Graphis Medica, Vol. III, Verlag Der Wiener Medizinischen Akademie, P. 481, 1971.

15. Ibid (Reference 7), P. 34.

COMPUTER PROCESSING OF ULTRASONIC IMAGES

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I. INTRODUCTION

No ultrasonic image system gives an image of perfect quality. There is much room for improvement of its quality by either optical or digital image processing. Advantages of digital processing are accuracy, repeatability and flexibility, whereas, a large memory capacity required to store whole picture elements, and a great length of time required for serial processing are often mentioned as disadvantages. Professors Stroke and Lohmann have demonstrated well the superiority of optical processing over digital processing in speed and parallel processing capabilities.[1] Indeed, digital processing of images has been both expensive and time consuming, but the situation has been changing rapidly in recent years.

First, the cost of digital computation is sharply decreasing because of the advent of larger and faster computers supported by better software. In a table shown by Professor Stroke the acceleration of processing time from two hours to some 20 minutes, even for images consisting of 1,000,000 picture elements, was witnessed.