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T E C H N I C A L   W O R K S

ATTEMPTS AT THE ULTRASONIC VISUALIZATION OF THE HEART IN REAL TIME

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In recent years several papers have been published aimed at the visualization of the heart by means of an ultrasonic method giving a geometrical picture of the distribution of tissues in a selected area of examination.

The first work on the visualization of the heart was carried out by Kikuchi [5] but it was not until Bom [1] developed a method for visualization of the heart in real time that more extensive clinical application was found (Fig. 1, I).

The pioneer of ultrasonic analysis in real time was Somer [6] who was the first to examine biological structures by means of a multielement transducer

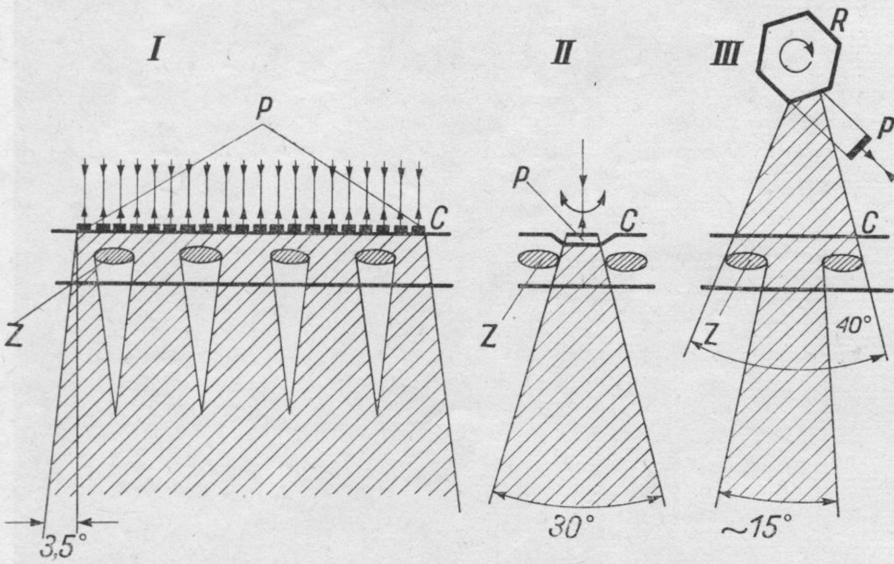

Fig. 1. Various methods of ultrasonic visualization of the heart in real time: *I* – with a transducer array [1, 7], *II* – with one oscillating transducer [2, 4], *III* – with one revolving reflector (IPPT-PAN)

P – piezoelectric transducers, *C* – body surface, *Z* – ribs, *R* – revolving reflector

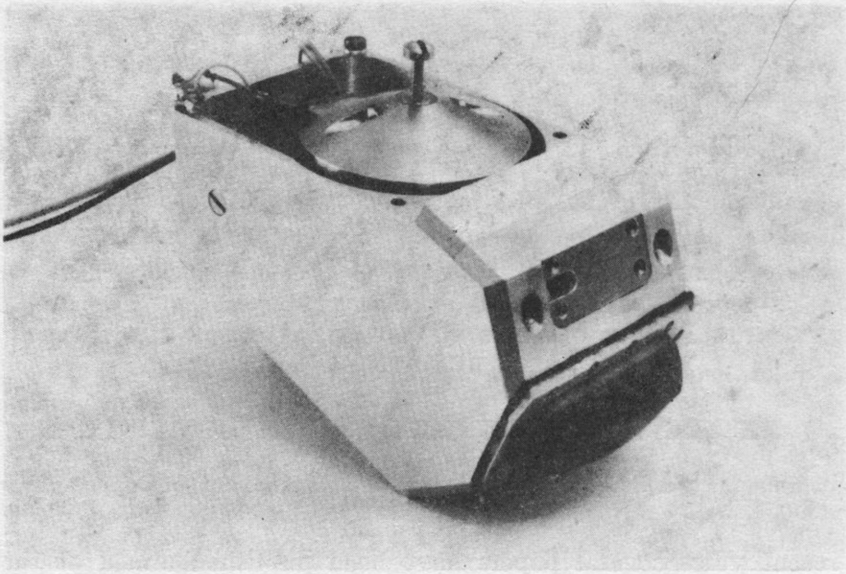

Fig. 2. Ultrasonic scanner (overall dimensions 130 × 80 × 75 mm) with a revolving reflector as shown in Fig. 1, *III*

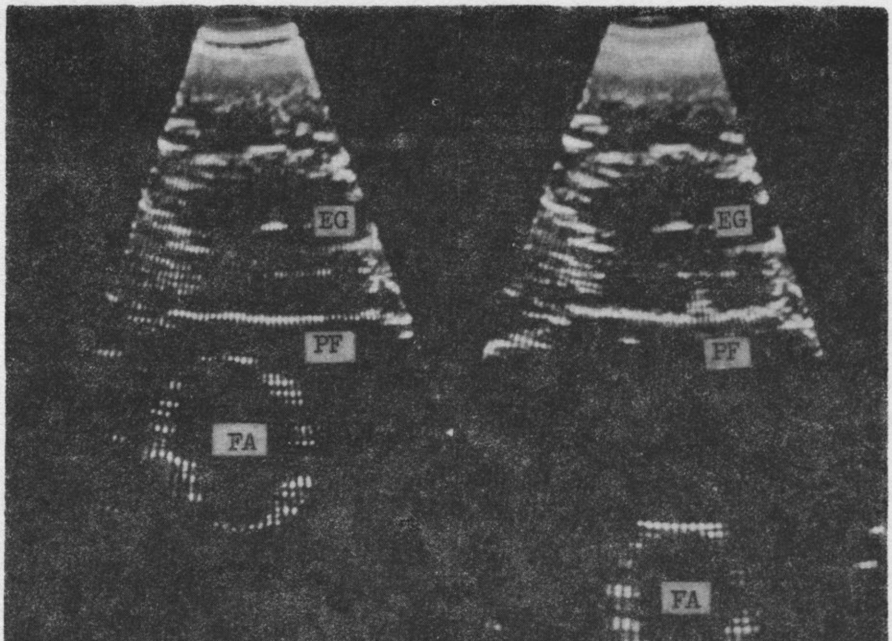

Fig. 3. Results of experimental investigations with an aorta phantom (*FA*) in various positions immersed in a tank containing water obtained with the system shown in Fig. 1, *III*

in which all transducers were excited simultaneously with voltages of variable phase.

A further improvement of such a system is that of THURSTONE [7], in which a multielement transducer array is controlled digitally by means of a special programme.

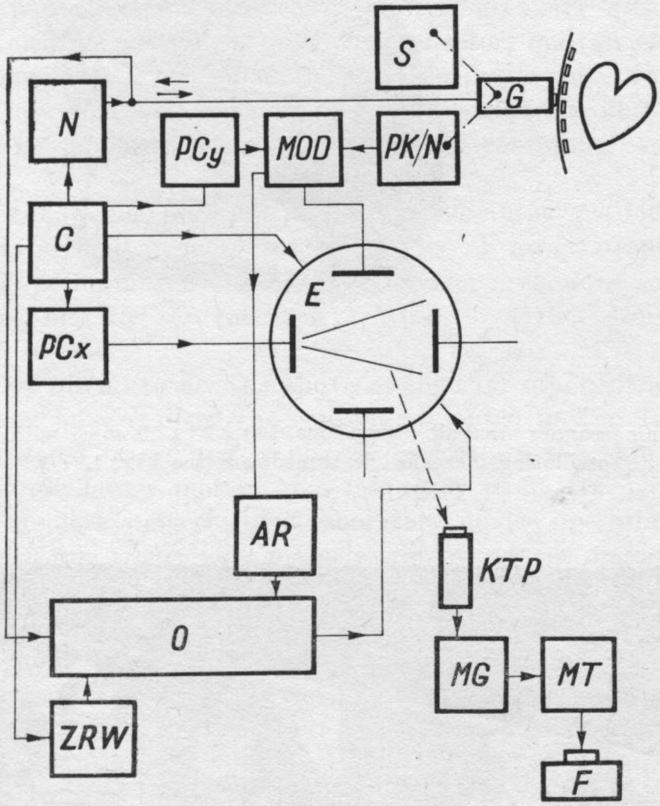

Fig. 4. Simplified block diagram of laboratory system for ultrasonic heart visualization in real time

C – timer, *PCx* – horizontal time base, *N* – transmitter, *G* – scanner with ultrasonic transducer, *S* – motor with transmission gear, *PK/N* – angle/voltage transducer, *O* – electronic receiver, *E* – oscilloscope screen, *PCy* – vertical time base, *MOD* – modulator, *AR* – automatic brightness system, *ZRW* – sensitivity-time control (swept gain), *KTP* – industrial TV-camera, *MG* – video-recorder, *MT* – TV-monitor, *F* – photographic apparatus

A different concept was proposed by GRIFFITH and HENRY [4] (Fig. 1, II) and EGGLETON et al. [2] with a single mechanically oscillating transducer. A similar concept has recently been realized by WHEATLEY [8].

In the Department of Ultrasonics of the Institute of Fundamental Technological Research of the Polish Academy of Sciences a method of ultrasonic

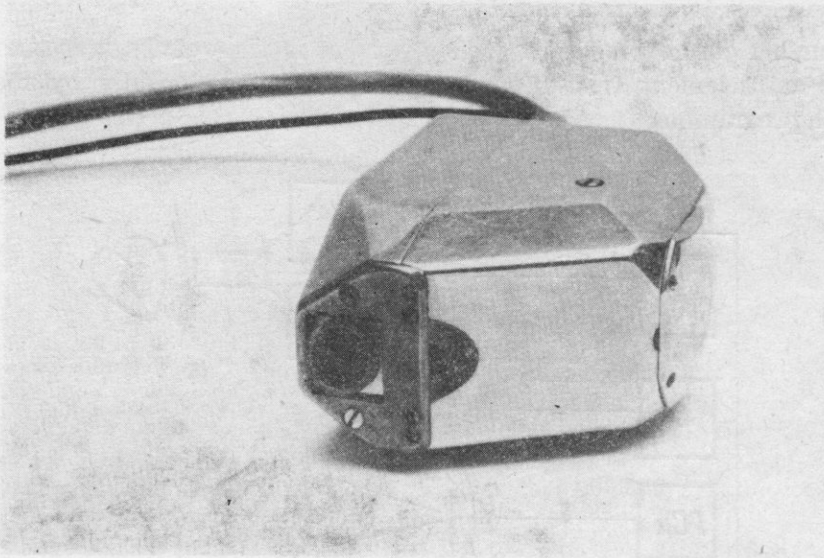

Fig. 5. Ultrasonic scanner (overall dimensions 100 × 75 × 50 mm) with a mechanically oscillating piezoelectric transducer (see Fig. 1, *II*)

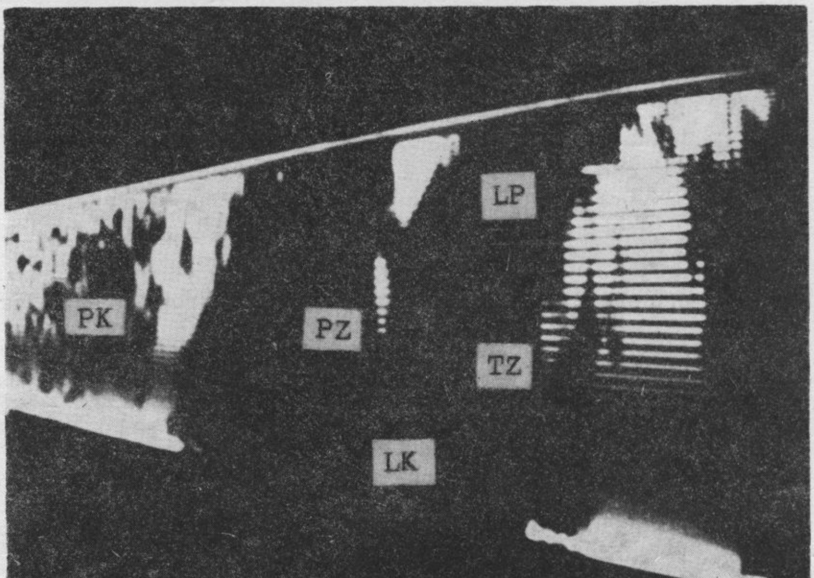

Fig. 6. Ultrasonogram of the heart obtained in real time

PK – right ventricle, *LK* – left ventricle, *LP* – left atrium, *PZ* – anterior leaflet of the mitral valve, *TZ* – posterior leaflet of the mitral valve visualization has been proposed (Fig. 1, III), in which the ultrasonic beam makes unidirectional angular sweeps at a constant angular speed. This is achieved by using a reflector in the form of a prism with a regular hexagonal base revolving at a constant speed of about 5 revolutions per second. The reflector is immersed in a liquid container the bottom of which is a thin foil for coupling to the patient's body. The ultrasonic scanner is presented in Fig. 2. The scanner incorporates a piezoelectric transducer 10 mm in diameter with a frequency of 3 MHz, an electric motor, the revolving reflector, and an electrical pulse generating system which synchronizes the other electronic units of the apparatus. The results of investigations using this system (carried out on a model made of thin rubber to simulate the aorta) in a vessel containing water is shown in Fig. 3.

The system, however, does not seem to be advantageous for cardiological uses, because of the small angle interrogated by the ultrasonic beam — about 15° (Fig. 1, III). This limitation is caused by ultrasonic shadows of ribs for the frequencies used and by the (necessary) distance of the resolving reflector from the body surface.

Therefore we intend to use the above method for other ultrasonic diagnostic purposes and have realized the concept presented in Fig. 1, II [2, 4], in which the ultrasonic transducer is placed directly on the skin between the ribs and makes oscillatory motion at a frequency of 25 Hz.

A simplified block diagram of a laboratory device operating in a pulse--echo mode, with one tranceiving piezoelectric transducer operating at a frequency of 3 MHz and with a repetition frequency of 2 kHz, is presented in Fig. 4. Fig. 5 shows the ultrasonic scanner with the piezoelectric transducer visible. Fig. 6 shows the first result of heart examination. The right ventricle, the left atrium and ventricle and the posterior and anterior leaflets of the mitral valve can be seen.

In order to obtain full investigational results it is necessary to record the heart structure in motion. This has been done with an industrial TV-camera and a video-recorder permitting repeated observation of the heart structure in motion on a TV-monitor in addition to classical photographic documentation.

The report should be viewed as a preliminary one. Further work will necessarily involve the determination of the resolution of the method, the fidelity of reproduction of the anatomical structures, the optimization of these parameters, the investigation of the range of application of this method and the development of a method of synchronizing photographic documentation with electrocardiographic recording as this is necessary for clinical tests.

Nevertheless, the results obtained imply the conclusion that ultrasonic heart visualization in real time will soon become a clinical tool of great diagnostic significance in cardiology.

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