because of the absence of gamma activity and because of the association of Sr with Ca. Beta-counting of the Y^{90} daughter of the Sr^{90} gave 16 disintegrations per minute per gram of shell material, and the decay rate was appropriate for Y^{90}. Thus, although there were undoubtedly other radionuclides in the shell shortly after the detonations, physical decay left detectable amounts of only Sr^{90}.

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13. Work done under contract AT(45-1)1385 with the AEC. I thank also Mr. Egil Oas for preparing the thick and thin sections of the shell, Miss Lorna Matson for the radioautographs, and Dr. Grant Gross for identification by x-ray diffraction of aragonite in the shell.

7 June 1965

Ultrasonic Scanning of Biologic Tissue by a New Technique

Abstract. *The size of the ultrasonic beam and beam dispersion severely limit resolution by two-dimensional scanning systems. Resolution and tissue penetration are improved by using a highly focused, ultrasonic transducer array in conjunction with an electronic timing system for the selection of particular echo information.*

Pulsed ultrasonic energy has been used in echo-ranging systems in biologic tissue for years; Gordon has published a comprehensive review of techniques used in this field (*1*). Several ultrasonic scanning systems have been devised which generate a two-dimensional image corresponding to the cross-section of the acoustic interfaces in tissue. Unfortunately, present scanning systems do not have fine resolution, yielding data that are difficult to interpret. Our current work to improve resolution may provide a new and versatile tool for research and diagnosis.

Ultrasonic scanning systems that generate a two-dimensional image have hitherto produced the image by displaying the echoes received after an ultrasonic pulse had been transmitted along a line corresponding to the path of propagation of the pulse in the subject tissue. The transducer was then moved about the subject in some manner, and the two-dimensional image was generated by summation of these individual line elements. Because the duration of the ultrasonic pulse may be very short (less than 1 μsec), it was possible to obtain excellent resolution in the depth direction or along the path of propagation of the ultrasonic beam. However, since the transducers required were operating primarily in the Fresnel region, the extent of the ultrasonic beam in directions normal to the path of propagation prevented good resolution in lateral directions. A focused transducer could be used to improve resolution in lateral directions at depths near the focal length of the transducer (*2*), but this improvement entailed the sacrifice of resolution at distances removed from the focal region.

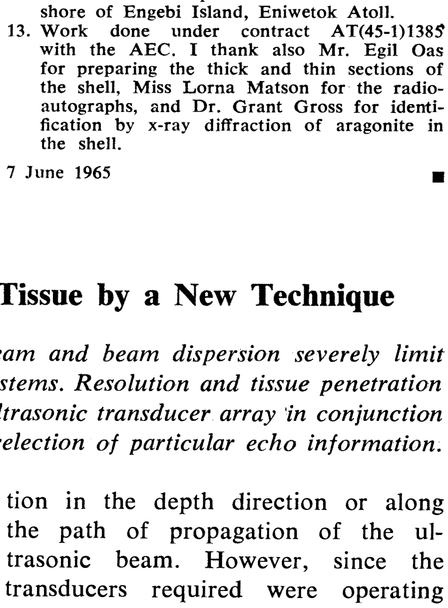

Fig. 1. Diagrammatic cross-sectional view of a multireflector, ultrasonic transducer array.

A technique has been developed that utilizes only the echoes that return from the region of minimum beam size, that is, the focal point of a focused transducer. This system generates a two-dimensional image by scanning the transducer in two dimensions and generating the image point by point. Echoes returning from the focal point are selected on the basis of a known, discrete time of return to the transmitting transducer. Thus, one restriction on the focusing system for the transducer array is that the length of the path of propagation from any point on the transducer surface to the target area must be constant. Fortunately the velocity of ultrasonic propagation in tissue is so close to its velocity in water that water can be used as the coupling medium between the transducer array and the tissue without affecting the focusing characteristics of the array.

Several possible systems could be employed for such a focused transducer-array system, including use of multiple transducers or of a single transducer with a concave face to provide a focused beam. The former system would be limited by the probable necessity for summation of the detected video signals rather than use of the video signals themselves; a difficulty inherent in the latter system would be development of a transducer large enough to produce a large solid angle of incidence convergent on the target area. A large solid angle is desirable so that target interfaces can be detected even when situated behind a strong reflecting surface or when oriented otherwise than normal to the transducer. The use of a sonic lens, which would cause the beam to converge by refraction, has the inherent limitation that the duration of the tone burst is lengthened by the reverberations within the lens itself. Because resolution by the system in a depth direction is limited by the timing accuracy and by the duration of the transmitted pulse, any reverberations within the focusing system must be avoided. These considerations then dic-

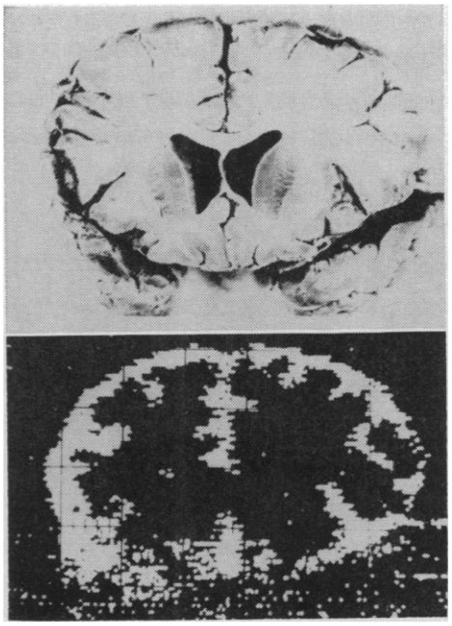

Fig. 2. Coronal section of brain (top) and an ultrasonic scan thereof by the new scanning system.

tate the use of a reflecting system to focus the ultrasonic energy.

A multireflector transducer-array system has been developed, of which Fig. 1 is a diagrammatic cross-section. The basic reflecting surface is a section of a prolate spheroid yielding an elliptic section in two dimensions. Energy from the first focal point of the spheroid is reflected to the second focal point. The spheroidal reflector is illuminated by a paraboloidal reflector whose focal point coincides with the focal point of the spheroid. An unfocused transducer that generates a plane wave front is directed along the major axis of the spheroid. The paraboloid converts the plane wave front into a spherical wave front diverging from the focal point of the spheroid. The spheroidal section reflects this energy to the target focal point which can be at a depth in tissue approximately equal to the separation between the foci of the spheroid. By reciprocity, echoes are returned along similar propagation paths. This focusing system accomplishes the objects of focusing a plane wave to a point, maintaining a constant length of propagation path to the target and return, and converging the energy to the target point through a large solid angle.

Initial results with such a system in prototype indicate a considerable improvement in image resolution. A spheroidal reflector 25 cm in diameter and with a spacing of 20 cm between foci has been excited with pulsed ultrasound at a frequency of 2.25 Mcy/sec. The ultrasonic receiver has been electronically time-gated to pass only echoes returning within 0.5 μsec of those returning from the target focal point; this provides a target volume 0.75 mm in diameter. The transducer is transported in two dimensions, and position information is taken from linear-motion potentiometers to the oscilloscope used for image display. The presence of an echo from the target volume is used to intensify the oscilloscope beam, and the image is generated by the storage-type oscilloscope. With this system resolution within 1 mm has been obtained in each of three dimensions; a relatively thin sectional image can thus be developed with improved image resolution.

A two-dimensional image obtained with an early prototype of the new scanning system appears in Fig. 2; resolution is clearly improved in this scan of a coronal section of brain, and gyri and sulci are plainly shown. Resolution in this image was limited to some degree by the resolution capability of the storage oscilloscope used to display it. Time spent in producing this image was 8 to 10 minutes, which was determined mainly by the mechanical transport system used rather than by limitations in the actual scanning.

Figure 2 also illustrates a problem presented by this scanning technique. In this scan, echoes returning from considerable depth in tissue were much lower in amplitude than those returning from near the surface; thus the lateral ventricles are not clearly outlined. Yet the wide angle of incidence from the transducer array permitted presentation of images from both sides of the brain fairly readily. Since the echoes used to generate the image display return to the transducer all at the same time following a transmitted pulse, the usual technique for controlling the gain of the ultrasonic receiver as a function of time, in order to provide increased gain at increased depth in tissue, cannot be used with this system.

Underway is an attempt to develop a method of controlling the echo amplitude so that the images developed will have more uniform illumination. Techniques under study include automatic control of receiver gain and control of the amplitude of the transmitted pulse; the control information is being taken from the echo amplitudes that return from the region of the target focal point.

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21 April 1965

Double Beta-Lipoprotein: A New Genetic Variant in Man

Abstract. *A β-lipoprotein variant, in which two bands appear after electrophoresis, has been found in three generations of a family. The variant, immunologically also a β-lipoprotein, differs in molecular size, density, and charge from normal β-lipoprotein. Individuals showing the variant appear to be heterozygous for an uncommon mutant gene.*

Genetically determined variations have been detected in many proteins of normal human serum. Some variations, such as those in haptoglobins, transferrins, and γ-globulins, represent common polymorphisms (*1*); others, such as double albumin, in which two electrophoretically separable albumins occur in the same serum (*2*), are rare. Inherited variations in serum lipoproteins, for which differences in the protein moieties may be responsible, include antigenic polymorphism (see *3*), a-β-lipoproteinemia (*4*), and absence of high-density lipoprotein (*5*). Variations in mobility and staining characteristics of lipoprotein bands detected by pa-

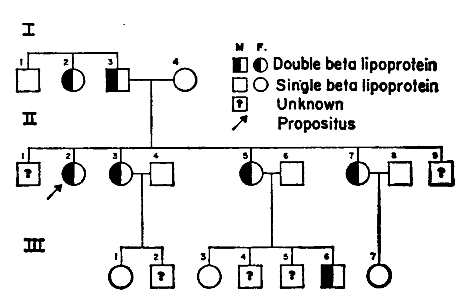

Fig. 1. Pedigree.