THE ULTRASONIC VISUALIZATION OF CARCINOMA OF THE BREAST AND OTHER SOFT-TISSUE STRUCTURES

DOUGLASS H. HOWRY, M.D., DOROTHY A. STOTT, M.D., AND W. RODERIC BLISS, B.S.

WE HAVE PREVIOUSLY REPORTED[10, 11] on the development of an original ultrasonic instrument that makes possible the visualization of numerous soft-tissue structures and foreign bodies that cannot be demonstrated by usual roentgenographic methods. Our purpose now is to report on the in vitro application of this instrument for the visualization of benign and malignant tumors, the determination of the extent of tumor involvement in relation to other structures, and the localization of metastases in distant sites.

METHOD AND RESULTS

Figure 1 shows a blocked diagram of our equipment, which is called a "somascope." The general method by which this visualization is accomplished closely parallels the system of underwater sound navigation called "sonar." A high voltage, short, alternating current is produced in the pulse generator. This passes to an ultrasonic crystal that, under the influence of the alternating voltage, is caused to expand and contract violently for a short period of time, thus producing a mechanical wave. By the use of ultrasonic lenses, this wave is confined to a narrow beam. The sound beam travels through a tank of liquid until it strikes some discontinuity, such as the kidney cyst shown in the diagram. At the surface of the cyst a small echo is produced that progresses back through the tank until it again strikes the crystal. At this point, the mechanical pulse of sound is transferred into an electrical signal that is amplified and presented as a single spot on the cathode-ray tube of an oscilloscope. In the meantime, the unreflected portion of the beam progresses through the cyst fluid and strikes the far wall and other deeper structures within the kidney or other tissues that lie in the path of the beam. Each of these structures produces an echo that similarly becomes a single spot on the oscilloscope. Thus a line of spots, representing reflecting surfaces, is formed on the oscilloscope. The distance between these spots corresponds to the distance between sound-reflecting surfaces in the subject studied. As soon as the echoes have all returned from the initial pulse, a new pulse is generated and is caused to travel in a slightly different path, thus passing adjacent to the previous pulse. This sound pulse produces a new line of spots on the cathode-ray oscilloscope, adjacent to the old line. Thousands of sound pulses are formed in this manner each second, each passing in a slightly different direction through the specimen studied. In effect, the beam is swept back and forth through the tissue rapidly, while single pulses draw lines of spots. Because of the rapidity of this operation it is possible to form a visually continuous picture on the oscilloscope in a manner that is very similar to television. It should be emphasized that, since the beam sweeps back and forth through a two-dimensional plane in the specimen, the picture that is presented is that of a cross section of the object.

Figure 2 shows a kidney cyst, such as the one diagrammed previously. The ultrasound picture, somagram, that was produced on the cathode-ray oscilloscope with this specimen is shown in Fig. 3. In this somagram the outline of the smooth cyst wall is seen along with the general contour of the kidney and several of the calyxes and blood vessels. The complete absence of echoes from within the cyst is of considerable interest, since we have shown in other studies that such nonhomogenous fluids as those containing pus or cellular debris present a ragged, broken picture.

The application of the somascope to the

From the Medical Research Laboratory, Veterans Administration Hospital; and the Institute of Industrial Research, University of Denver, Denver, Colorado.

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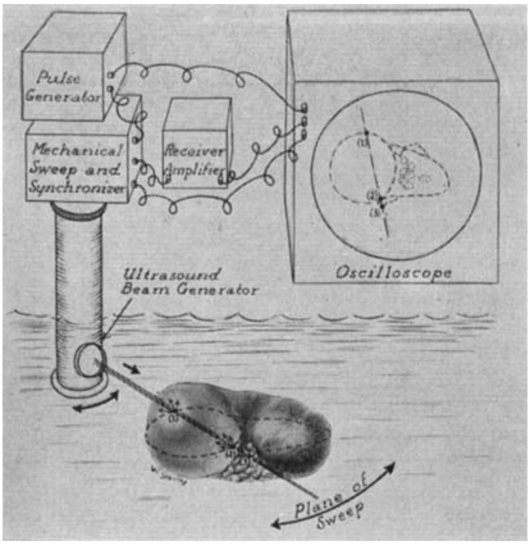

FIG. 1. Diagram of somascope scanning tissue specimen.

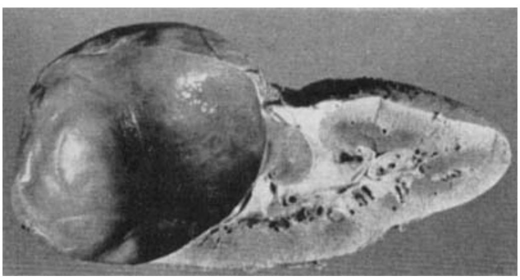

FIG. 2. Kidney with cyst; longitudinal section.

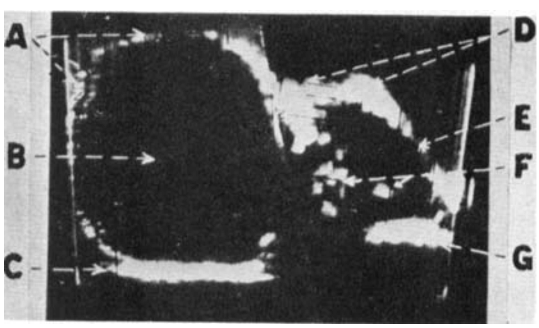

FIG. 3. Somagram of kidney specimen. A, Wall of cyst; B, homogeneous fluid; C, sonic reflector behind cyst; D, attached perirenal fat; E, kidney surface; F, calyxes and blood vessels; G, deep surface of kidney and perirenal fat.

visualization of carcinoma in the breast and other structures has, on a laboratory basis, proved quite successful. Figure 4,A is a photograph of a fresh breast specimen, free from the usual excision biopsy. Prior to pathological sectioning, the neoplastic mass was localized easily by the ultrasonic method, as is seen in Fig. 4,B. It should be noted that this tumor presents a jagged, irregular outline that corresponds quite well to the clawlike strands of this primary invading adenocarcinoma as seen in the gross pathological section. This can be compared with the smooth outline that was obtained from the simple serous cyst of the kidney in Fig. 1.

Figure 5 shows a fresh breast specimen from a 60-year-old woman. This patient had a cancer of the breast that was indicated only by many rock-hard axillary lymph nodes. Repeated examinations by competent observers failed to demonstrate any mass within the breast itself. A biopsy of one of the nodes in the anterior axillary chain revealed metastatic carcinoma. Somagrams of this fresh breast specimen were made in a serial fashion and are represented by the dotted lines A, B, C, D, and E in the upper left of Fig. 5. Cross sections of the breast were then made at the same levels and the comparative gross pathological sections and somagram photographs are shown. At levels A and B, through the biopsy wound, large metastatic lymph nodes were grossly demonstrated and these nodes were shown in the comparable sound pictures. At levels C

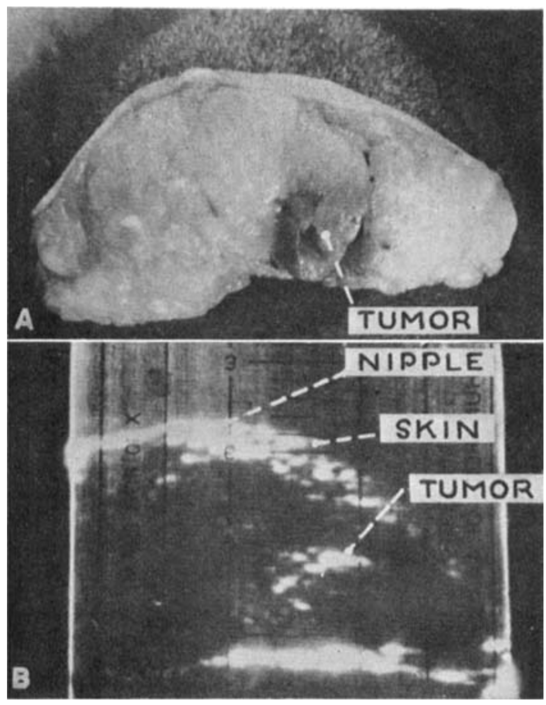

FIG. 4. Somagram produced in an adenocarcinoma of the breast. A, Gross specimen. B, Somagram demonstration of the adenocarcinomatous mass prior to pathological sectioning. (The straight black lines and numerals, which can be seen in portions of the somagrams, are calibration markings on the synchroscope tube and should be considered as removable artifacts.)

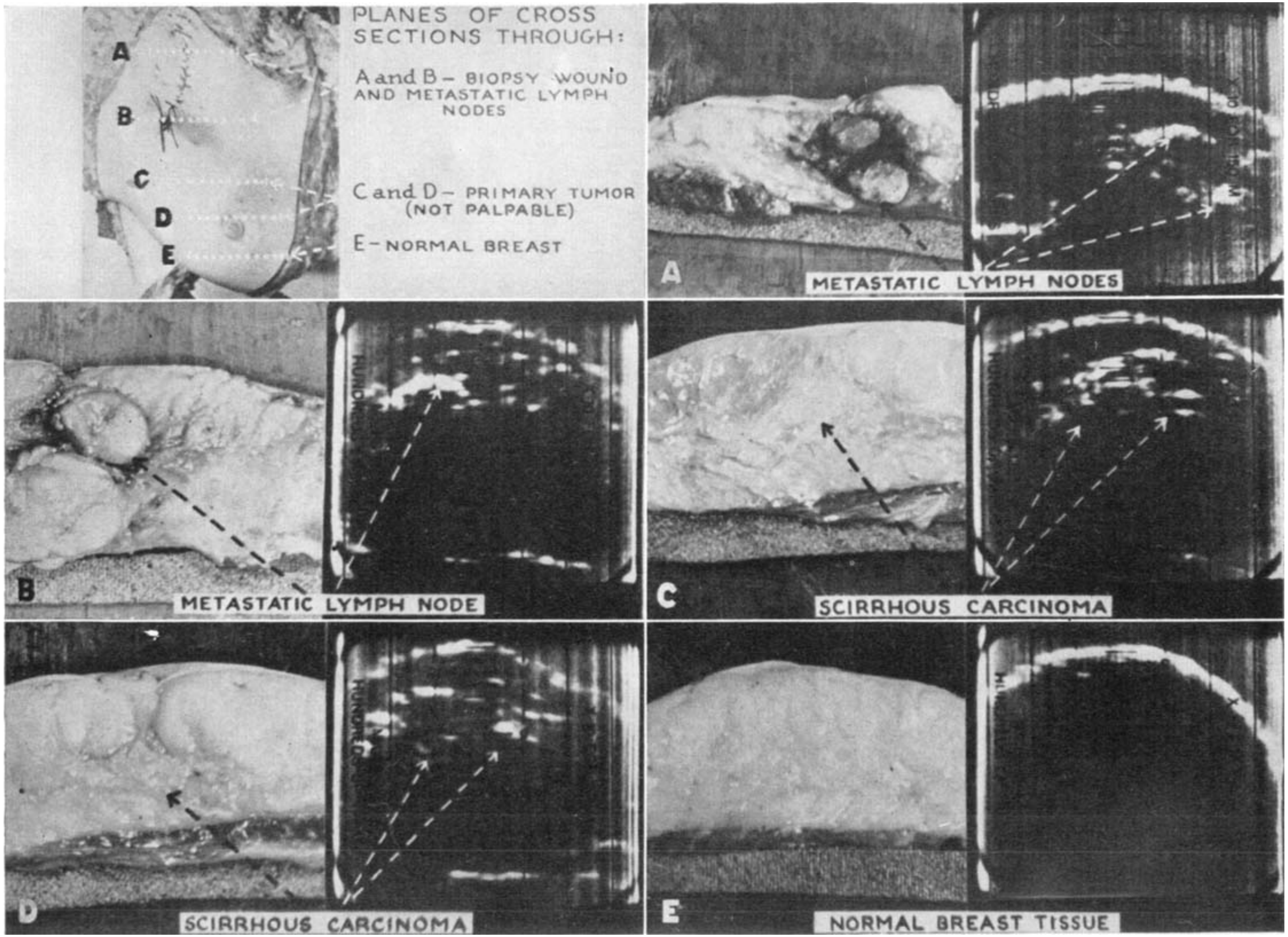

FIG. 5. Somagram demonstration of a nonpalpable scirrhous carcinoma of the breast. Levels of comparable somagrams and later pathological sections are represented by the dotted lines A, B, C, D, and E on the gross specimens.

and D, a diffuse, invasive scirrhous carcinoma was demonstrated and its general location was outlined in the ultrasound picture even though the tumor could not be palpated in the fresh specimen. At level E, which was pathologically proved to be outside the area of tumor involvement, relatively little structure was discernible within the breast by the somascope.

The ultimate use of this equipment would be in the living patient. Because of the temporary nature of the construction of this early experimental model, it is possible to examine only the extremities of living subjects. There is no sensation associated with its use and, in more than four and one-half years of constant association with this equipment, no injurious effects have been noted by any of the group.

Figures 6 and 7 show a cross-section diagram and comparable somagram of the mid-third of one of the investigator's arms. A large echo signal was obtained from the surface of the humerus, which lies deep within the sound picture. The lateral intermuscular septum is fairly well shown, as is the juncture between fat and muscle layers that extend around the anterior portion of the arm. The cephalic, brachial, and basilic veins and associated arteries are demonstrated. The ulnar and musculocutaneous nerves are also believed to be shown. Since little sound was reflected from within the bodies of the muscles themselves, the muscles show as black areas outlined in white in this study. It is anticipated that a space-occupying mass in this area could be detected either by direct visualization as was shown in Figs. 1 to 5 or indirectly by the displacement and distortion of the normal surrounding structures. The somascope has been tried on Hodgkin's disease and adenocarcinoma metastases in liver specimens and these were fairly well demonstrated, especially when some element of tumor necrosis was present.

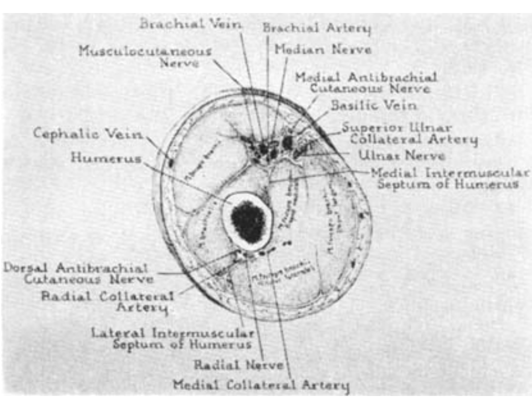

FIG. 6. Anatomical diagram of cross section through the mid-third of the right arm. (Adapted, with permission of the publisher, from Callander, C. L.: Surgical Anatomy, 2d ed. Philadelphia. W. B. Saunders Co. 1939; p. 588.)

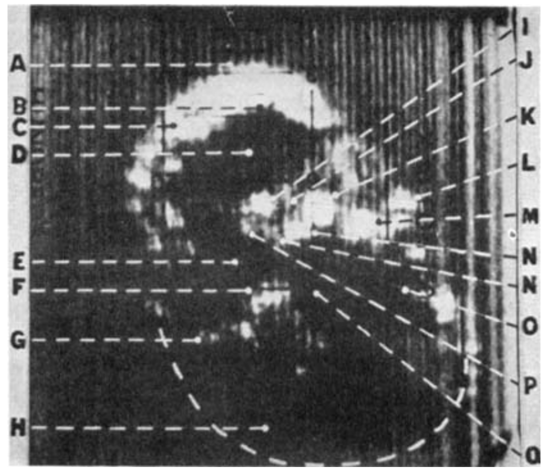

FIG. 7. Somagram through the mid-third of the right arm. A, Skin surface; B, fat-muscle juncture; C, cephalic vein; D, biceps brachii muscle; E, brachialis muscle; F, humerus; G, lateral intermuscular septum; H, triceps brachii muscle (lateral head); I, brachial vein; J, median nerve; K, basilic vein; L, skin surface; M, ulnar nerve and vessels; N,N, brachial artery and vein; O, triceps brachii muscle (long head); P, musculocutaneous nerve; Q, tri^eps brachii muscle (medial head).

DISCUSSION

The application of ultrasonics to the determination of body structures has been studied by several groups.[1-9, 19-20] Specific application to the study of malignant tissue of the breast has been discussed by Wild and Reed.[20] The method and equipment used by these authors differ from ours in several important respects: (1) we are using a much lower frequency sound beam and (2) considerably lower power, and (3) our sound pulses are confined to narrower dimensions by the use of focusing elements. These differences result in greater depth of penetration and improved picture detail.

Sound echoes are produced whenever a sound beam encounters a new substance that differs in either density or velocity of propagation from the medium in which the sound beam is traveling. The body abounds with numerous natural "contrast media" within normal and pathological structures; for example, the juncture between fat and glandular tissue produces strong echoes because of the difference in density between these tissues. The same is true for fluid accumulations versus their surrounding structures.

The early experimental model of the somascope had many deficiencies, the most important of which were its poor resolving power and low sensitivity. This has been largely corrected in a newly completed, clinical experimental instrument. With these improvements it is believed that the visualization of benign and malignant tumors in such areas as the neck, liver, and extremities will prove to be a fairly simple and reliable method of seeing gross pathological changes. It is of interest that the somascope operates to greatest advantage in those structures and regions in the body that are now only accessible to examination by palpation or direct surgical exploration, except under special conditions.

SUMMARY

Ultrasonic energy may be used to produce cross-section pictures, called "somagrams," of benign and malignant tumors in pathological specimens and to demonstrate nerves, vessels, tendons, and fascial planes in a living subject. Examples of such ultrasonic pictures are presented, along with a general description of the instrument that is called a "somascope." The somascope is an original development of this group and is an improvement over other ultrasonic instruments that have been used for diagnostic purposes.

These are the first known ultrasound pictures to have been produced by a pulse-echo method that show the interior construction of solid objects. The pictures were made in 1950 and 1951.

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