Diagnostic Ultrasonography*

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It was the development of radar and sonar during the last World War which made the ultrasonic techniques I am going to talk about possible. Following the War, Dr. K. T. Dussik had the idea that, if one directed ultrasonic waves into the body, one might obtain echoes reflected from tissue surfaces in the same way that the Navy received echo information reflected from the submarine's hull. When he did this, he did get reflected echoes from within the body, and this opened the door for other investigators to demonstrate how this echo information could be made useful in diagnostic medicine. The next step was to display these echoes in a form which the physician could recognize and utilize diagnostically. The first part of this presentation will tell you about the various methods we can use to display this echo information, and the second part will give you examples of its diagnostic application in many different medical specialties. Ultrasound is applicable for visualization of soft tissue structures in all parts of the body.

The essential components of an ultrasonic diagnostic unit are a pulser, a transducer, a receiver, an amplifier, and a display system (oscilloscope). (Holmes and Howry, 1963; Holmes, Wright, and Howry, 1964) Originally, the pulser initiated a 1000 volt pulse, but later, with development of more sensitive equipment, this has been reduced to 300 volts. The ultrasonic waves are produced by pulsing a piezo electric crystal contained in the transducer specially constructed so the ultrasonic waves directed into the body come only from the face of the transducer. Ultrasound, like light, can be focussed; thus, by use of appropriate lenses, it is possible to narrow the ultrasonic beam and direct it to desired depths. When the ultrasonic waves strike a tissue interface of different density, they are reflected back to this same crystal, which acts as a receiver converting the ultrasonic energy into electrical energy which passes through the amplifier-receiver system and is displayed on an oscilloscope screen. The simplest display is that used in materials testing (time base). When the transducer is placed on a bar of aluminum, there is displayed an echo "pip" for the near side of the bar, a "pip" for the flaw in the aluminum bar, and a "pip" for the far side of the aluminum bar. By measuring the distance between the flaw echo in relation to the echoes representing the two sides of the bar of aluminum, one can locate the flaw rather precisely. This simple display is often called A-mode presentation. With early X-ray the medical profession really needed the technique, so they developed it and the engineers paid little attention to it. The reverse has occurred with ultrasound, since for the new rocket programs it became imperative to have better materials testing techniques.

The echoes can also be displayed on the screen as a bright dot representing each tissue interface. The

* Supported in part by USPHS Grants #HE 02115 and #HD 01669.

equipment sends and receives ultrasonic energy at the rate of 400 times per second. Thus, if the transducer is moved mechanically around the body, these bright dots will coalesce on the screen to trace the tissue outline, for example, the front edge of the liver or the spleen. To insure a proper relation between organ interfaces as the transducer's position is changed, one must incorporate into the system a position indication and deflection system. This insures that the information displayed on the scope screen reproduces exactly the anatomical pattern the transducer is looking at as it moves about the body. This system is called a B-mode presentation (intensity modulation), and the movement of the transducer is called scanning. To display irregular surfaces, a rocking motion of the transducer is coupled with the movement around the body. This is called compound scanning. The ultrasonic power level delivered to the tissues is .04 to .004 watts per square centimeter. In physical medicine for heat therapy they are using ultrasound at power levels of 1 to 3 watts per square centimeter without toxic effects in treating patients with rheumatoid arthritis. Thus, we feel that the power level used for diagnostic purposes is within safe limits. We have exposed pregnant rabbits at diagnostic doses of ultrasound for periods of five days and found no evidence of toxicity in mother or fetus.

The simple display described above is used clinically for echoencephalography. The transducer surface is covered with lubricating jelly and placed on the side of the head, and the picture obtained is similar to the one I described for the aluminum bar. There are echo "pips" representing the midline of the brain, the near side of the skull, and the far side of the skull. The picture has the appearance shown in Figure 1. (Holmes, 1964a) The transducer is then placed on the opposite side of the head and a similar but inverted picture obtained, which is displayed directly under the first picture, as shown in Figure 1. Finally, a receiving transducer is placed on the opposite side of the head from the sending transducer and a "pip" obtained for the midline position between the two transducers, as shown on the bottom line of Figure 1. The permanent record is obtained by photographing the oscilloscope screen with a Polaroid camera.

Interpretation depends on the relative position of the echo "pips". In the healthy individual the "pips" representing the midline of the brain should fall directly above each other, thus indicating an equidistance between the skull echoes and that of the midline of the brain. However, if there is an intracranial lesion which shifts the midline of the brain to one side, then the echo pattern, as presented on the right-hand side of Figure 1, will show the two "pips" representing the center of the brain displaced in opposite directions. In general, if the shift between the two midline "pips" is greater than 2 mm, it is probably clinically significant. (Jeppsson, 1961) Difficulties in interpretation by the inexperienced operator result from the fact that other structures within the brain may produce echoes as, for example, the interface between the ventricle and brain. Whenever this echo is mistaken for the one representing the midline of the brain, there will always be a shift. There are several tricks in helping to identify the midline echo. Usually, the midline echo

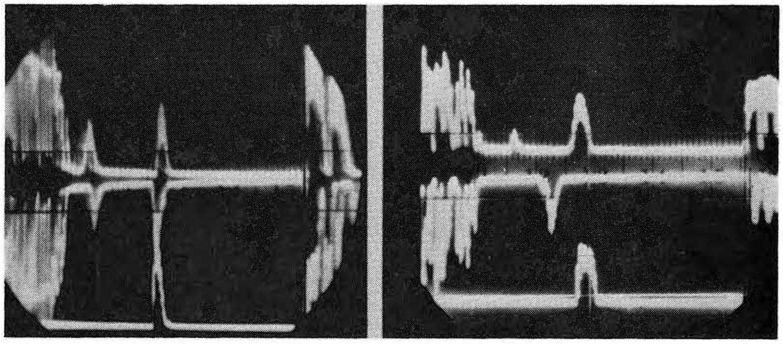

Fig. 1—Shows on the left an echoencephalogram in a healthy normal individual, and on the right an echoencephalogram from a patient with intracranial tumor which produced a shift in the position of the midline echo. Reprinted from *Digest* (Otago Univ. Med. Students Assoc. Dunedin, New Zealand) 6: 27, 1964.

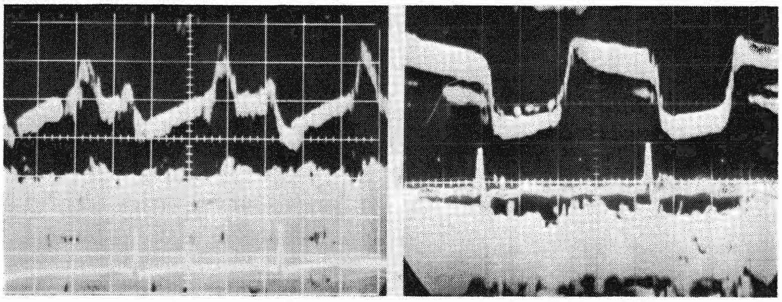

Fig. 2—Picture on the left shows the wave motion pattern of the anterior leaflet of the mitral valve in a healthy individual, and on the right a patient with mitral stenosis. Reprinted from *Digest* (Otago Univ. Med. Students Assoc. Dunedin, New Zealand) 6: 27, 1964.

has an M-shaped appearance. In addition, the midline echo should move back and forth due to vascular pulsations. Finally, in a true shift, the two echoes representing the brain midline must fall on either side of the bottom echo representing instrument midline. As the operator becomes skilled in this technique, he will learn to recognize the midline echo readily, and very few mistakes will be made. (White, 1966)

In approximately 1000 cases examined by Ford and Ambrose in England, the accuracy of this technique in detecting midline shift range from 90% to 95%. (Ford and Ambrose, 1963) Similar series have been reported by other investigators. (Jeppsson, 1961) The echoes reflected from the brain ventricular interface have been used to determine the size of the third and lateral ventricles. (Ford and McRae, 1966)

Echoencephalography can be readily used in the Emergency Room of a large hospital as a screening procedure, since the equipment is simple and quite portable. Furthermore, in a head injury, serial pictures can be obtained, thus predicting a progressive shift. In many hospitals the echoencephalograph is housed in the EEG Department, and when the two techniques are used together, the information obtained is complementary. Thus, if the midline is shifted away from the side of increased electrical activity, it usually confirms the diagnosis of tumor. If shifted toward it, there may be cerebral atrophy.

The same equipment with slight modifications can be used for emergency-type examinations of the eye, as described by N. R. Bronson at the 1967 Miami meeting on ultrasound in medicine. One can obtain reflected echo "pips" from the cornea, the lens, the retina, (personal communication, N. R. Bronson) and from a foreign body in the eye. Thus, different echo patterns will be obtained in retinal detachment, tumor and anatomical displacement of the intraocular structures. Here again, ultrasound has a great advantage as a screening procedure.

The A-mode presentation is also used to measure the biparietal diameter of the baby's head in utero. (Taylor et al., 1964) After palpating the location of the head, the transducer is placed on either side of the baby's head and an echo pattern obtained similar to that noted in Figure 1. A midline echo must be obtained to confirm positioning of the transducer as truly biparietal. Measurements are then made between the echo patterns representing the two sides of the baby's skull. In our series, the measurements of the biparietal diameters of the fetal head were within 3 mm of the measured diameter at delivery in 95% of the babies. (Taylor et al., 1964) Thus, in the Labor Room it is possible to determine easily whether the baby's head is of normal size and will readily pass through the birth canal.

If the echo-producing structure has motion, then the dot will move back and forth on the screen. When the transducer is placed over the mitral valve, one obtains a characteristic motion pattern for the anterior leaflet of that valve. By using an electronic sweep, the dot's movement can be displayed in wave form, as shown on the left-hand side of Figure 2.

The normal wave pattern for the mitral valve shows a high peak in mid-diastole, followed by a steep slope (posterior motion), and then a second smaller peak which occurs at the time of a trial systole (Fig. 2). In the normal, the velocity of maximum posterior motion exceeds 80 mm/sec. The picture on the right side of Figure 2 is that of a stenosed mitral valve. The difference between the two patterns is quite apparent, even to the uninitiated eye. Furthermore, the velocity of posterior motion is always less than 45 mm/sec in those patients with stenosis of sufficient severity to require surgery. (Joyner, 1966)

In experienced hands other information can be deduced from this record. (Joyner, 1966; Edler, 1966) The slope of the line correlates fairly well with the degree of valve movement, and this correlates with the degree of stenosis. Judgment can be made of the thickness of the valve by the thickness of the echo pattern and its degree of motion. If mitral insufficiency is present, the echo pattern will be similar to that of the normal, except the amplitude may be greatly increased. After mitral valve commissurotomy, the motion pattern of the valve has the same appearance as prior to surgery, except for a much steeper slope. If the valve restenoses as the patient is followed postoperatively, then this slope approaches that obtained prior to surgery. Thus, by careful examination of mitral valve motion, it is possible to deduce the presence of mitral stenosis—often the degree of stenosis; estimate the thickness of the valve; and, after surgery,

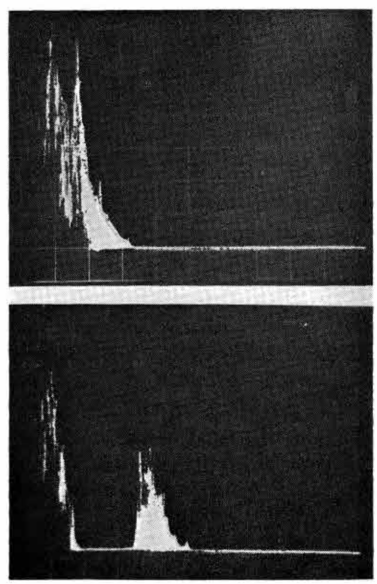

Fig. 3—Shows, above, the echo pattern obtained by A-mode technique of the lung in a healthy laboratory worker, and, below, the pattern obtained in a patient with pleural effusion.

detect the reappearance of stenosis. This has proved to be valuable information for the surgeon, since it can be obtained easily and serially on the same patient. As in all ultrasonic studies, the information obtained should be used to supplement other clinical information.

Another practical application for ultrasound is the detection of pericardial effusion. The anterior and posterior walls of the heart will have a definite motion pattern. Normally, these will be placed immediately adjacent to the echo patterns reflected from structures of the anterior and posterior walls of the chest. However, if there is pericardial effusion, since fluid transmits sound well, there will be a clear black area between the chest wall echoes and the motion patterns of the anterior or posterior wall of the heart. This clear black area will disappear after aspiration of the effusion. Again, in inexperienced hands, difficulties will be encountered in identifying the motion pattern representing ventricular wall and, thus, diagnostic errors will be made.

Recently, ultrasound was shown to be useful in detecting pleural effusion. Since air rapidly attenuates sound, the echo pattern of the normal lung shows a rapid decrease in amplitude of the echo pattern within one to three centimeters of the chest wall (upper picture of Figure 3). When there is pleural effusion, there will be a clear dark area representing good sound transmission between the chest wall echoes and those characteristic of normal lung (lower picture of Fig. 3). When there is consolidation of the lung due to any cause, the ultrasonic echo pattern will extend farther into the lung tissue when compared with Figure 3. Further work is needed to develop this technique for diagnostic application in the lung, but ultrasound does appear to be able to provide supplementary information which will help diagnostically.

As stated previously, compound scanning provides a cross-sectional, anatomical picture of the structures examined. The equipment necessary for obtaining these pictures is shown in Figure 4. In this particular scanner, the transducer moves in a sector scan, mechanically, 30° each side of the perpendicular, while the transducer carriage is simultaneously moved across the abdomen. (Holmes et al., 1965) This represents the double scanning motion previously described. We also have a scanner in which the double motion is provided entirely by the operator's hand. The coupling between transducer and skin surface is obtained by applying mineral oil to the skin. We also have a scanner in which the patient is placed against a plastic membrane while the transducer moves within a water bath which provides the ultrasonic coupling.

How do we know that we are obtaining a true outline of anatomical structures? Figure 5 shows, on the left, a sonogram through the liver region of a cat. (Holmes and Howry, 1963) At the top is the echo outline of the spine and the lumbodorsal muscle groups. The clear black area below and to the left represents the liver which

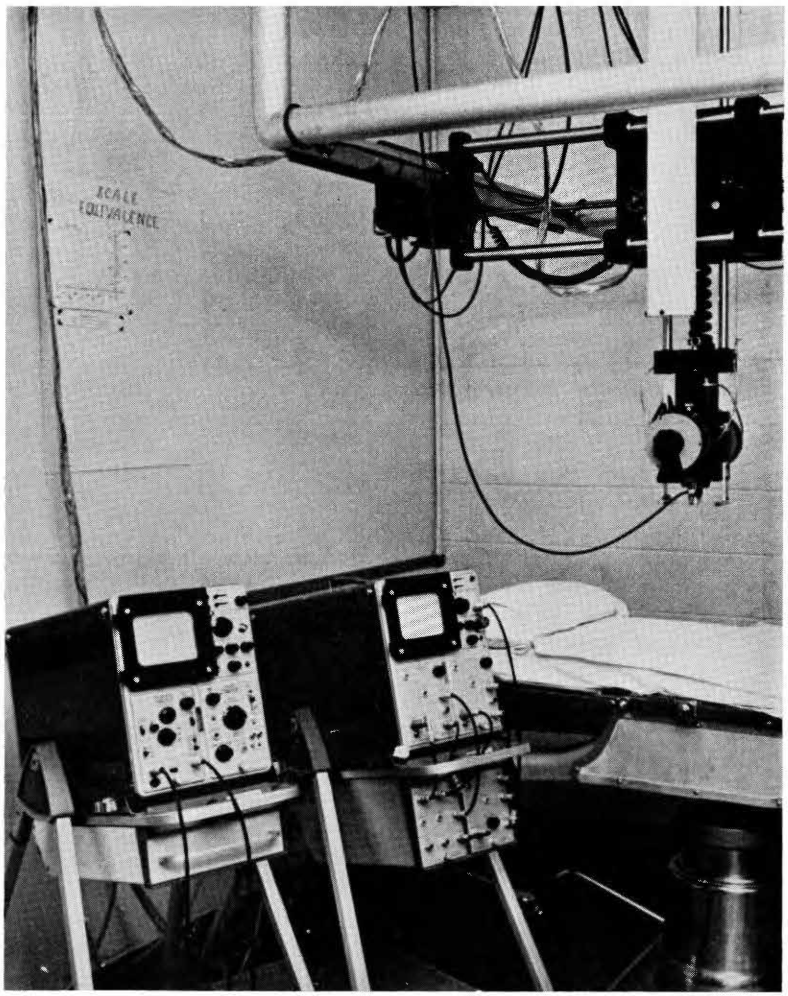

Fig. 4—The first compound contact scanner built at this institution, which has a mechanical sector scan moving 30° each side of the perpendicular, while the transducer carriage is simultaneously moved across the anatomical area being examined, thus achieving a compound scanning motion.

transmits sound well. The echo pattern below and to the right outlines the stomach. The picture on the right is the cross-sectional picture of the same animal at the same level as the sonogram so you can directly compare anatomical structures.

The next ultrasonic cross section is that of a dog at the level of the bladder (Fig. 6). The echo outlines of the spine and lumbodorsal muscle groups are seen above. The clear black area surrounded by an echo pattern represents the full bladder, and there is a smaller echo pattern, just above and to the left, representing a loop of the intestine. The echo in the center of the urine-filled bladder is the catheter. Lower in the picture one sees the flank folds and the echo pattern of the penis.

In a separate study, echo patterns of the cat were obtained as shown in Figure 5. Then an experimental liver abscess was produced by injection of E-coli and turpentine. A definite nest of echo patterns appeared at the site of the abscess. Pathological specimens of a normal liver and a cirrhotic liver were scanned. (Holmes and Howry, 1963) The normal liver appeared as a clear black area, while the cirrhotic liver had multiple echo patterns within the liver area. Now we are ready to examine clinical material.

Figure 7 shows, below, a scan through the liver region of a normal person, and, above, a similar type scan through the liver region of a patient with alcoholic cirrhosis. The normal liver, as in the animal pictures, transmits sound well and appears as clear black area with echoes outlining the anterior and posterior surfaces. In contrast, the picture in the cirrhotic patient shows multiple echo patterns within the liver. These are scattered in a somewhat indiscriminate pattern. The numbers of echoes seen within the cirrhotic liver do appear to have some correlation with the degree of cirrhosis.

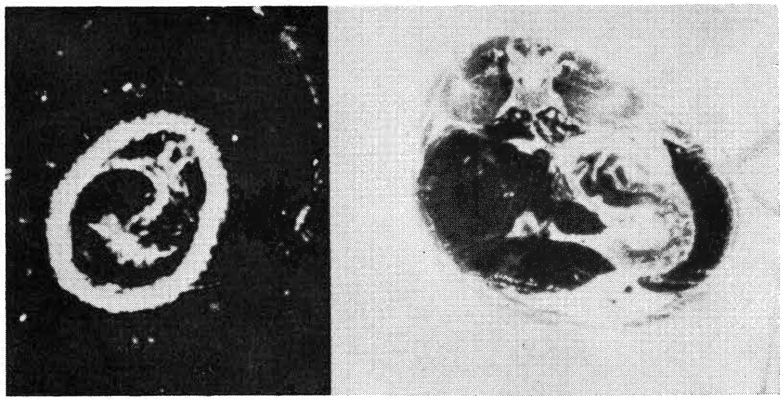

Fig. 5—On the left is a sonogram through the liver region of a cat, while on the right is shown the corresponding anatomical cross section, so that structural comparisons can be made. Reprinted from *Am. J. Digest. Diseases* 8: 12, 1963.

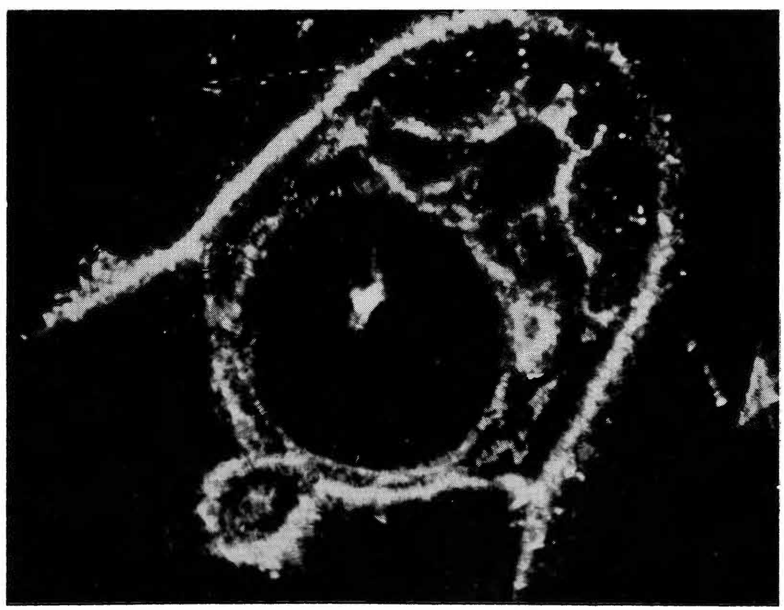

Fig. 6—Sonogram of a dog through the bladder region. A catheter was inserted and the bladder filled with fluid to simulate the urine-filled bladder. Reprinted from *Am. J. Digest. Diseases* 8: 12, 1963.

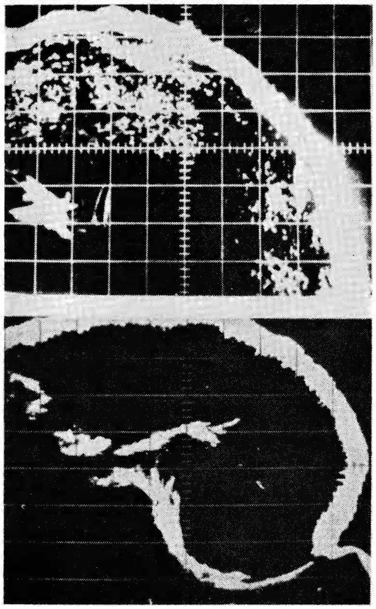

Fig. 7—The lower sonogram is the liver region in a healthy laboratory worker, and the upper sonogram the corresponding liver area in a patient with alcoholic cirrhosis. Reprinted from *Biomedical Science Instrumentation*. Vol. 2. New York: Plenum Press, 1964, p. 11.

Liver abscess either in humans, or experimentally produced in animals, shows a defined nest of echo patterns within the liver. Figure 8 shows the liver sonogram in a patient with metastatic carcinoma of the liver. There are scattered nests of echoes within the usual clear black area representing liver. With carcinoma of the liver or other organs, we can find an abnormal echo pattern in 90% of the cases. This is confirmed by autopsy, biopsy, or surgical examination. However, the echo pattern for tumor is variable. (Holmes, 1966a; Holmes, 1967a) Sometimes it has the scattered pattern of a cirrhosis; at other times it will have the echo nests seen above. In some patients it may appear as a dense echo pattern surrounding a clear black area which is the usual pattern for cysts. This particular tumor will reflect sound exceedingly well from its surface and does not permit it to penetrate to the center of the tumor. Thus, we demonstrate cancer or tumor in areas like the liver, but can we do even more by predicting the type of cancer from the type of echo pattern obtained? If so, we might provide a great deal of diagnostic help for the clinician.

Another anatomical area where ultrasound can be helpful is the examination of a fluid-filled organ such as the bladder. (Holmes, 1966b) The upper picture in Figure 9 shows an outline of the urine-filled bladder taken with the water path scanner. The lower picture shows the scan after removal by catheter of 500 cc of urine. The clear black area has entirely disappeared.

Figure 10 indicates the use of this technique to demonstrate residual urine without catheterization. The upper picture shows the bladder of a woman prior to voiding. She voided 250 cc, and the lower picture shows her bladder after voiding. There is still a significant amount of urine in the bladder. This technique has been most valuable in detecting the presence of residual urine in patients we don't want to catheterize, and we have been able to calculate the amount of urine within a 10% error. Ultrasound has helped us in determining whether the prescription of a triple voiding technique is going to be effective in treating a patient. We have used ultrasound in our anuric patients to visualize bladder urine when we don't want to introduce a catheter in a patient because he has an intrinsic renal lesion. We look at the bladder, and if the bladder is full, then we can proceed with a GU evaluation.

We can outline the kidney in most patients, but we can't obtain a very distinct outline of calyceal structures. Thus, with ultrasound we can estimate renal size and also estimate the depth at which one should introduce a biopsy needle. Figure 11 is a sonogram of a kidney, in this instance a transplanted kidney located in the groin area. I chose this picture because it shows very well what we visual-

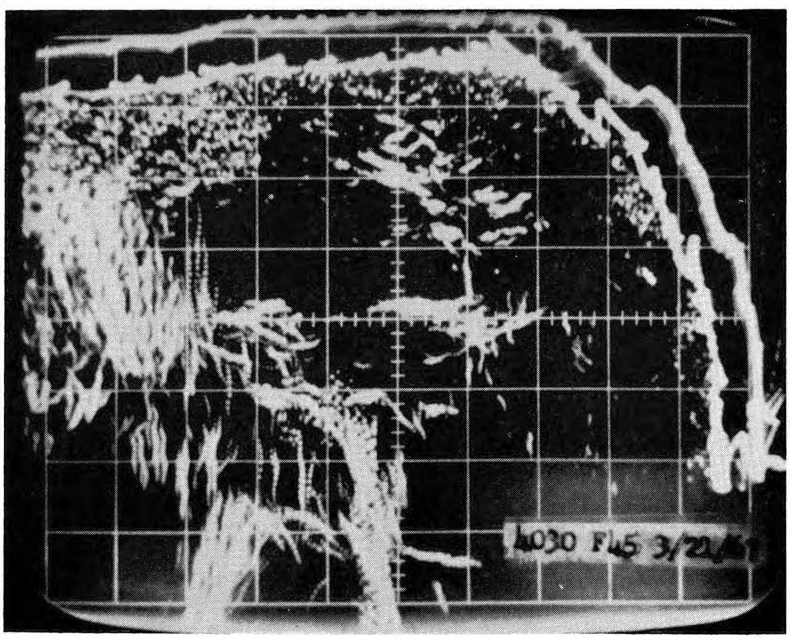

Fig. 8—Shows the scattered echo pattern of the liver sonogram of a woman with metastatic carcinoma of the liver confirmed at autopsy.

ize in the kidney at the present time, i.e., a good renal outline (on the right), but only an undifferentiated "echo" nest representing the calyces and pelvis. However, polycystic kidney produces a characteristic echo pattern, i.e., clear black areas with interlacing echo lines, presumably representing each cyst wall. (Holmes, 1967c) In addition, the size of the kidney outline is significantly enlarged. In patients with polycystic kidney, we have often been able to demonstrate the lesion at a much earlier date than we observed X-ray changes based on the intravenous pyelogram. Single cysts of the kidney also have a characteristic appearance in the sonogram. (Holmes, 1967c)

In thin individuals we can obtain a complete picture of the intra-abdominal structures (Fig. 12). Below is the echo outline of the spine, and the major vessels above. At the top right is the liver area, and, to the left, scattered echoes probably representing stomach filled with food; if it were filled with water, its appearance would be similar to the bladder. One can see the pancreatic area. In two cases of proven pancreatic tumor there were dense echo patterns in this area. We can also visualize the spleen and determine splenic size, which may be of diagnostic value. This picture suggests the diagnostic potential of ultrasound, especially for diagnosis in diseases involving the two major blood vessels or the pancreatic area.

In contrast to Figure 12, the next sonogram (Fig. 13) shows the entire anterior portion of the abdomen displayed as a dense echo pattern. At autopsy, the anterior abdomen was filled with metastatic carcinoma. However, another patient with a similarly palpable mass of the abdomen, when scanned with ultrasound, was found to have a clear black area surrounded by the dense echo pattern typical of cyst. In patients with ascitic fluid,

Fig. 9—At top, sonogram of a full bladder containing 500 cc of urine, taken with a water-path scanner. The lower picture shows the scan of the bladder region after removal of the urine by catheter. Reprinted from *Am. J. Digest. Diseases* 8: 12, 1963.

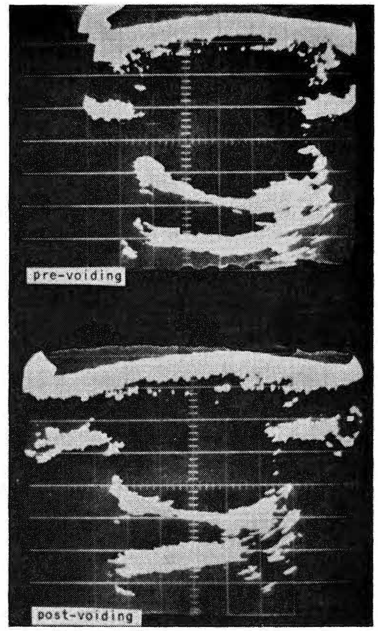

Fig. 10—Shows cross section of the bladder area pre-voiding in the upper picture, while the lower picture shows the same bladder area after the patient voided 250 cc and illustrates the use of ultrasound for diagnosis of bladder retention without catheterization. Reprinted from *J. Urol.* 97: 654, 1967.

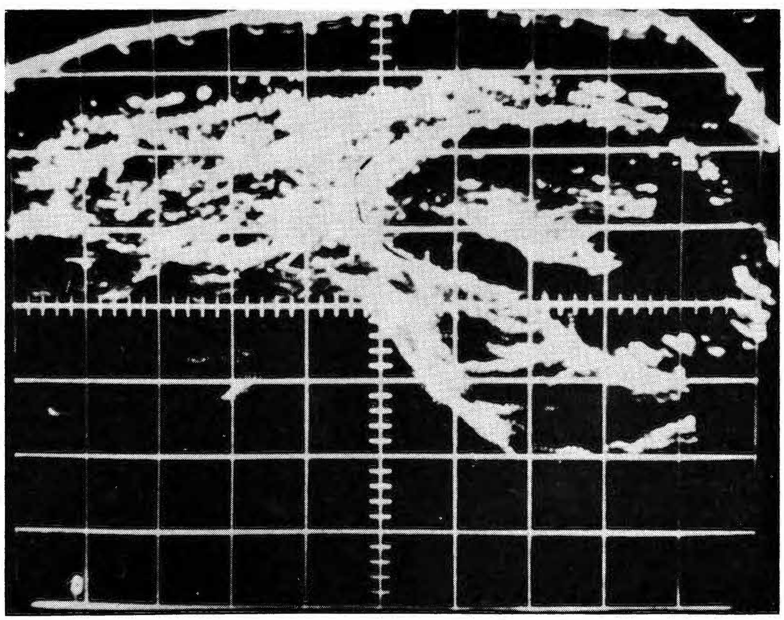

Fig. 11—Sonogram of a transplanted kidney located in the right groin to illustrate the ultrasonic technique in outlining the kidney. The nest of echoes within represent calyceal structures but lack characteristic definition. Reprinted from *Diagnostic Ultrasound: Proceedings 1st International Conference.* C. C. Grossman et al. (eds.). New York: Plenum Press, 1966, p. 249.

clear black areas will appear diffusely throughout the abdomen, with the echo pattern representing intestine and stomach pushed together, sometimes anteriorly, sometimes posteriorly. When peritoneal dialysis encounters difficulty or unsatisfactory results, a scan of the abdomen ultrasonically may reveal what has happened and demonstrate the areas of fluid distribution. Occasionally, a swollen abdomen thought to be ascites will have the outline of a circumscribed cyst with the fluid limited to one specific area. Our resident staff feel that ultrasound has contributed most significantly in the differential diagnosis of abdominal masses. (Holmes, 1967c)

Pregnancy has presented an ideal anatomical situation for the contact scanner. Because of the rounded abdomen, we have the most effective scanning path for the transducer. Furthermore, since the uterus is fluid-filled, it will accentuate visualization of the fetal structures. Figure 14 presents a cross-sectional picture of a pregnant uterus with the fetal chest displayed at the top of the uterus. The fetal spine is seen at the top of the fetal chest, and, to the left are echoes representing the fetal limbs. This was taken in the eighth month of gestation. This type of scan permits us also to determine fetal position. Furthermore, from pictures of this type taken at different stages of pregnancy, one can estimate fetal development. The present measurements we are using for estimating fetal development include the biparietal diameter of the head and the circumference of the thorax. (Thompson et al., 1965)

If there is a multiple pregnancy, then we will see two thoraces and two fetal heads, usually a head near the fundus and a head in the pelvis. In the left-hand picture of Figure 15 are shown the thoraces of two babies, while, in the upper right, is the outline of the fetal head of the lower twin. The lower picture shows the X-ray, depicting by

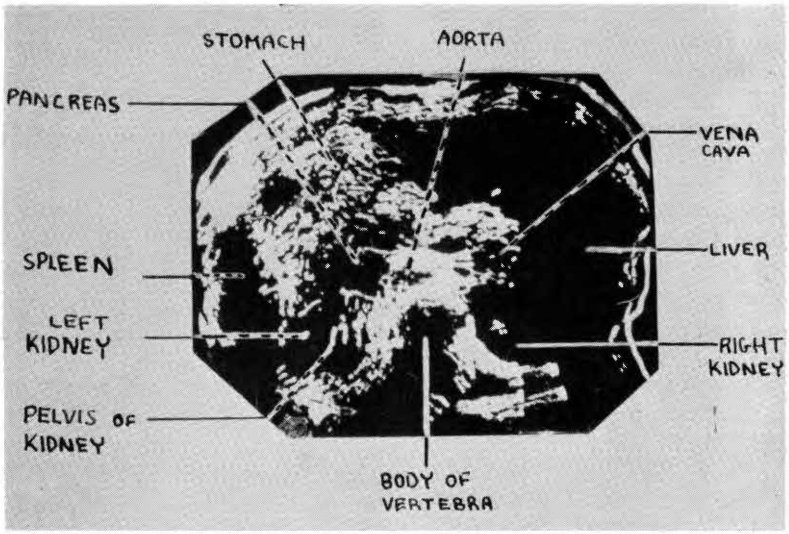

Fig. 12—Sonogram through the abdomen of a 10-year-old boy at the liver area to illustrate the various intra-abdominal structures which can be seen, including the echo outline of the spine and the major blood vessels. Reprinted from *Proceedings Third Annual Rocky Mountain Bioengineering Symposium.* New York: Institute of Electrical and Electronics Engineers, 1966, p. 78.

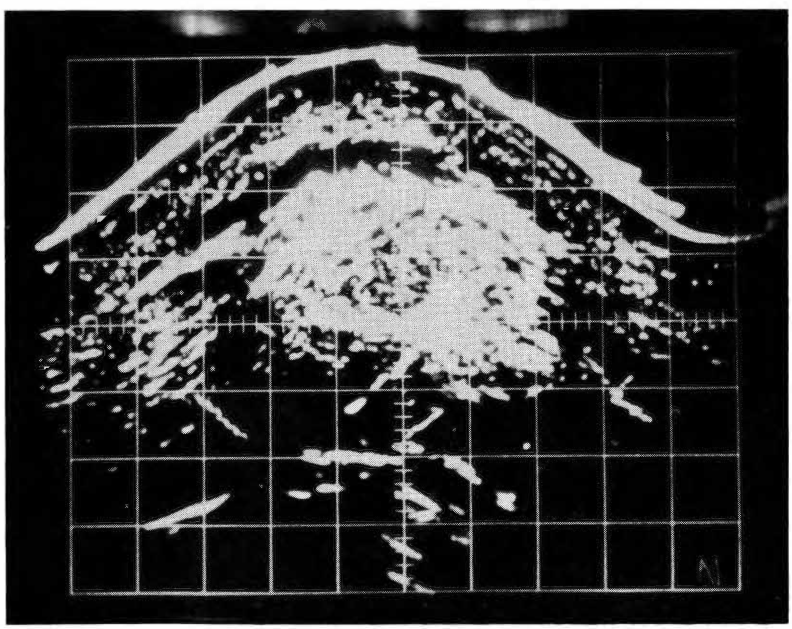

Fig. 13—Sonogram of anterior abdomen in a patient with metastatic carcinoma throughout the anterior abdomen confirmed by autopsy. The dense echo pattern obtained can be contrasted with the echo pattern of the previous Figure. Presented at Miami meeting, American Institute for Ultrasound in Medicine, Miami, 1967.

white lines the levels at which the sonograms were taken. Often we can help the obstetrician further by telling him which baby, the larger or the smaller, is presenting first. If there is an increased amount of fluid in the uterine cavity, this is easy to demonstrate. We find the most frequent requests for ultrasonic examination involve the pregnant woman with a uterus either too big or too small for the calculated time of gestation. In this type of case we can determine whether the fetus is developing normally or whether some other defect such as a hydatid mole is present.

We can also visualize the placenta as an area of diffuse dots (Fig. 16). In 112 patients in which the placental position was confirmed, either by manual removal or Caesarian section, the position was correctly determined by ultrasound in 97%. (Gottesfeld et al., 1966) Placental visualization has had clinical use in suspected cases of placenta previa and whenever the physician desires to do an amniocentesis. In anteriorly placed placentas, one can map the exact location and size of the placenta by serial ultrasonic sections. This may have future diagnostic potential.

In the diagnosis of hydatid mole, ultrasound has achieved almost 100% accuracy. (Gottesfeld et al., 1967) A typical pattern of hydatidiform mole is shown in Figure 17. The very character of the hydatidiform mole means that it will provide a scattered diffuse echo pattern which is entirely different from the organized form of echo patterns previously presented for the developing fetus. In some instances it is necessary to examine the patient one or more times before arriving at a final diagnosis of hydatidiform mole.

When fetal death occurs, the fetal echo pattern begins to change shortly after death. Our residents have given this the nickname "brush border" appearance. The echo pattern becomes broad-

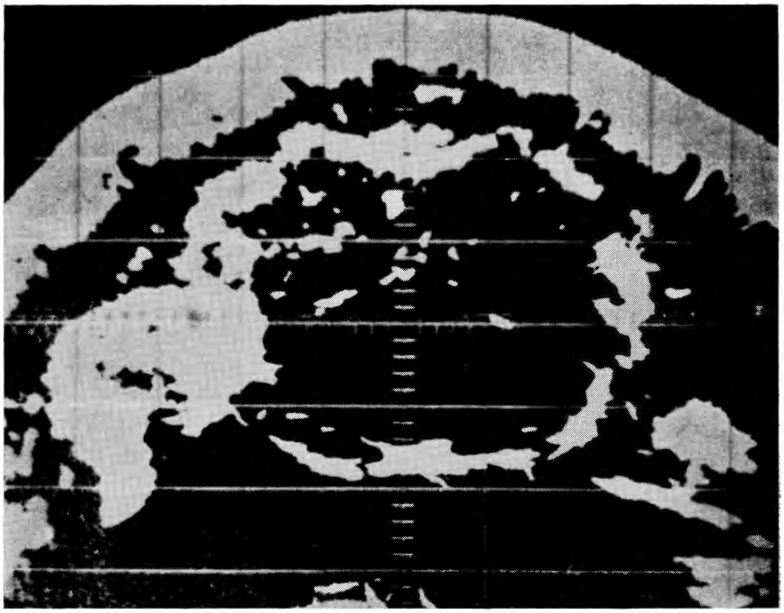

Fig. 14—Sonogram of a pregnant woman at 34 weeks gestation. At the top is the outline of the fetal thorax with the fetal spine delineated; on the left are echo patterns probably from a fetal extremity. Reprinted from *Am. J. Obstet. Gynec.* 92: 44, 1965.

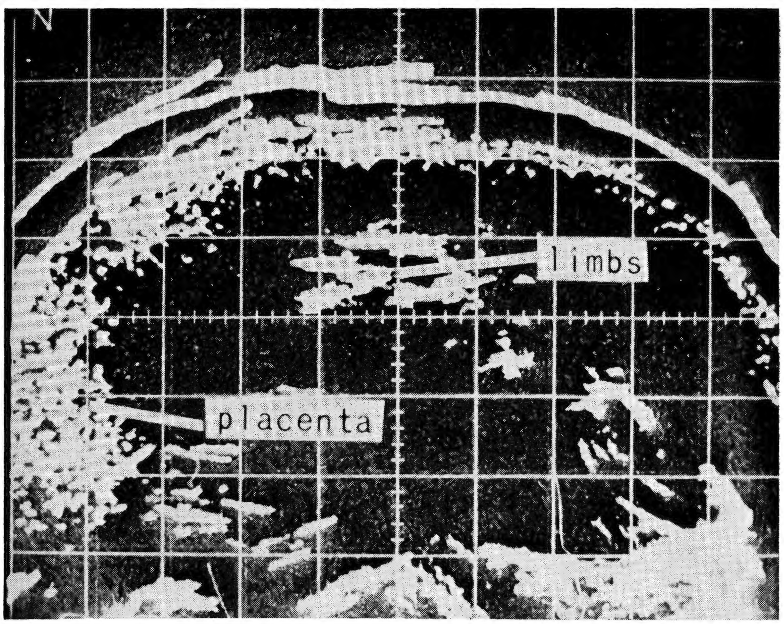

Fig. 15—Illustrates the stippled echo pattern characteristic of the placenta in a woman at 8th month of gestation. The fetal echo patterns in the center of the uterus represent echoes from the fetal extremities.

stroked, rather than fine-stroked. Furthermore, as time from death increases, the organized appearance of the fetal echo pattern begins to disintegrate, and the fetal head outline, for example, becomes less distinct. On an empiric basis we have been able to predict fetal death in a number of instances when it was important to have this information. It is interesting that this same type of echo pattern has been observed in babies of Rh negative and severely diabetic mothers. We have no good explanation for the change in echo pattern configuration with fetal death. We have been doing some experimental work by changing fluid balance in rabbits, and it would appear that the echo pattern difference between a dehydrated and overhydrated animal has some of the same characteristics we note in association with fetal death or in the fetus of a diabetic mother. Further work needs to be done in this area.

Ultrasound has been diagnostically useful in a number of gynecological lesions, particularly in the differentiation between solid and cystic tumor of the pelvis. (Thompson et al., 1967) Figure 18 shows the ultrasonic picture of a pseudomucinous ovarian cyst. There is a clear black area well outlined by echoes. The presence of echoes within the cyst is suggestive of malignancy, and this patient did have metastases to omentum and peritoneum. The appearance of the tumor at surgery is shown in the upper pictures of Figure 18.

Figure 19 illustrates how ultrasound may have diagnostic potential in muscular areas like the leg. (Holmes and Howry, 1958) The picture on the left shows a sonogram with the muscle fascia and the outline of the two leg bones clearly seen as compared with the corresponding anatomical cross section on the right. This was an amputated leg. The muscle area in the normal apparently has a characteristic echo pattern, while in two

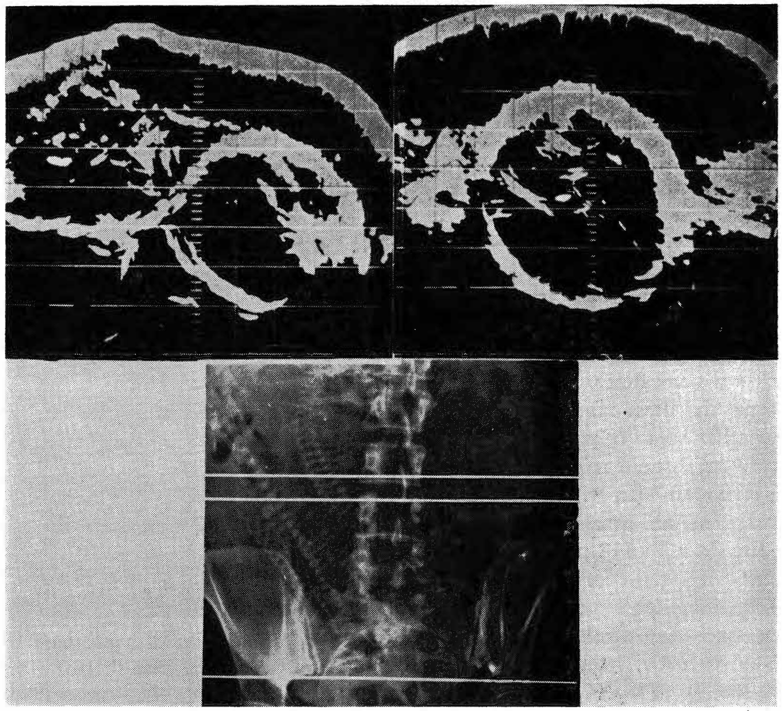

Fig. 16—Sonogram of a multiple pregnancy showing, in the upper left, the outline of the fetal thorax in each of the twins. The head of the lower twin is outlined on the right. The corresponding X-ray showing the cross-sectional levels of the sonograms is shown below. Reprinted from *Am. J. Obstet. Gynec.* 90: 655, 1964 (C. V. Mosby).

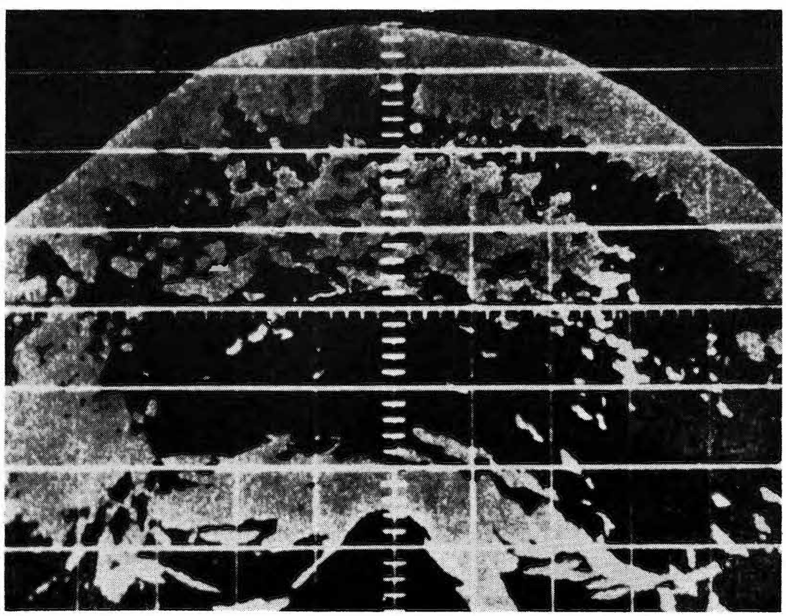

Fig. 17—Sonogram in a patient at 16 weeks of gestation who had a proven hydatidiform mole. This characteristic echo pattern is quite different from that seen in previous pictures of the well-organized outline of fetal parts. Reprinted from *Am. J. Obstet. Gynec.* 90: 655, 1964. (C. V. Mosby)

cases with muscular disease, the pattern was quite different. In the leg with edema, clear black areas appear under the skin. Thus, ultrasound may have diagnostic potential in orthopedics, for example, in athletic injuries where the X-ray is negative.

While the sonograms I have shown look pretty good, they do not tell the entire story. At the present time, we still find about 15% of the examinations are unsatisfactory and we can make no interpretation. This relates to equipment deficiencies, difficulty in calibrating equipment, inadequate examining techniques, and problems in training technicians. When we get a good picture with ultrasound, as you have seen from the examples shown, then it has significant diagnostic value. How do we solve this problem of obtaining a good sonogram with every examination and being able to obtain a good picture in repeat examinations from day to day? We have set up a daily standardization technique for our equipment, but it is still insufficient in calibrating all variables of the equipment. Furthermore, each technician scans in a different manner, which makes comparison difficult unless the same technician makes successive examinations. Improved training can eliminate these differences, and we have devised scanning tanks and other training equipment to help eliminate this variable. At the present time there are five different companies selling equipment and, if one chose a piece of equipment from each, one would have to learn to operate each piece of equipment separately, because each has different characteristics. Eventually, we should achieve standards for equipment so that a technician could operate readily any standard piece of equipment designed for diagnostic ultrasound.

Diagnostically ultrasound can examine certain areas more easily and with less patient hazard and preparation than is required by

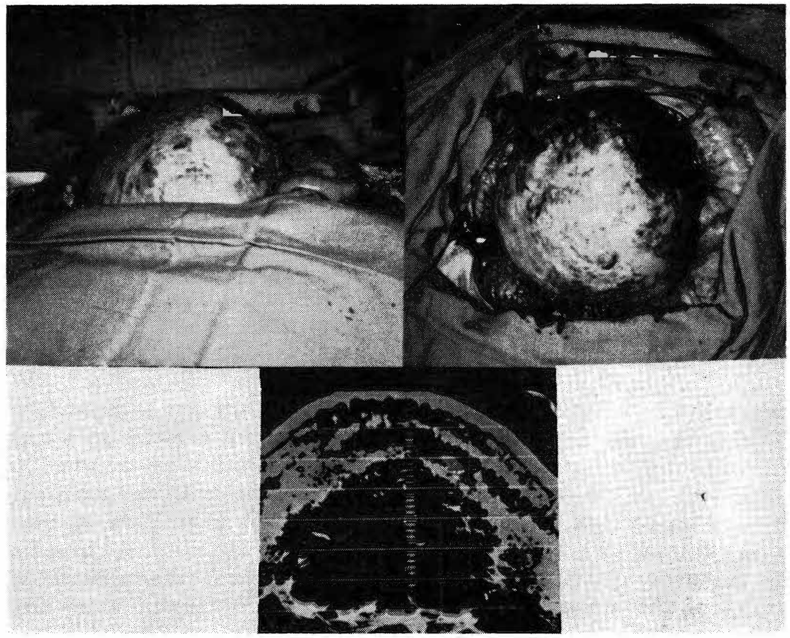

Fig. 18—Sonogram on the bottom shows a clear black area surrounded by dense echo pattern characteristic of a pseudomucinous ovarian cyst. The appearance of the tumor at surgery is shown in the upper two pictures. Reprinted from *Am. J. Obstet. Gynec.* 90: 655, 1964. (C. V. Mosby)

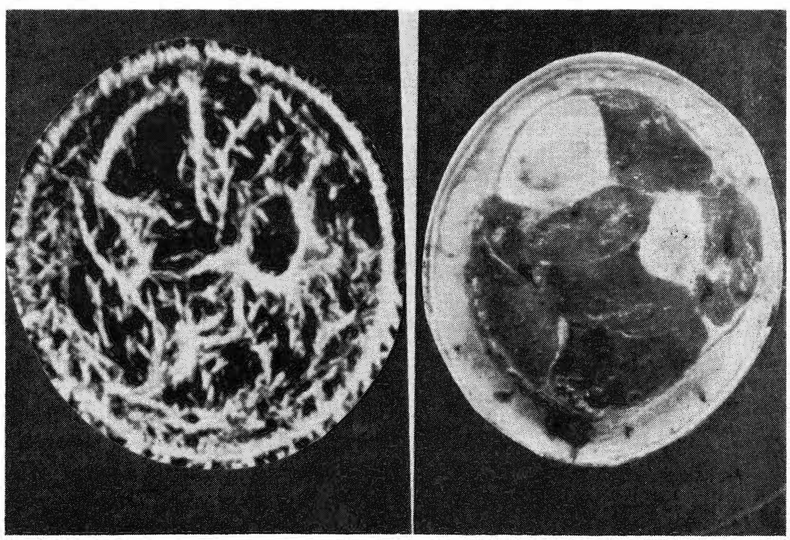

Fig. 19—On the left is a sonogram of an amputated leg to illustrate the characteristic echo pattern of the leg bones and the muscle area. The picture on the right shows the corresponding anatomical cross section for structural comparison. Reprinted from *Trans. Am. Clin. Climat. Assoc.* 70: 225, 1958.

other techniques. For example, ultrasound can visualize certain anatomical structures without the use of contrast media. This may be very helpful for visualizing a gallbladder which does not take up dye or in determining renal size in the uremic patient.

The best contrast media we have for ultrasound is 0.9% NaCl. In our animal studies I can improve visualization by injecting 0.9% saline into the anatomical area of study. Perhaps 0.9% saline, properly injected under sterile conditions, can be used in man. We have shown that, with ascites, ultrasonic visualization of the peritoneal cavity and its contents is improved. In the stomach all one has to do is ingest water to obtain good visualization of the stomach wall.

Pregnancy has proved the most practical and routine diagnostic use for ultrasound at the present time. Using this technique, we can visualize the fetus from about the fifth or sixth week up to term. The fetal head is demonstrated at about twelve to thirteen weeks, and the fetal thorax at about sixteen weeks. Thus, we have the potential of following fetal development and being able to tell the obstetrician whether it is proceeding normally. From measurement of the biparietal diameter of the fetal head and the circumference of the fetal thorax, we have been able to estimate fetal weight within 400 gms in over 95% of babies. However, converting fetal measurement to an estimation of weight in order to predict fetal development seems like an indirect approach fraught with many inaccuracies. With further study we should establish direct measurements of fetal parts at each stage of gestation and be able to predict more precisely fetal development. This would be useful in predicting the best time for section, in eliminating complications of delivery, and in evaluating babies of Rh negative and diabetic mothers.

Equipment is cheaper than X-ray equipment. The less complicated A-mode unit costs between $3000 and $7000; with time motion incorporated, the cost increases to $7000 to $8000. The compound scanner costs about $16,000. I have described what each will do diagnostically.

There are still many problems to be solved. We are in a stage of development of ultrasonic techniques where we still have to learn many of the applications that can be made with it diagnostically. We also must learn how to standardize the equipment (developing proper standards) so that we are sure it is operating the same way from day to day. We must learn to train technicians effectively. We have the problem of what department should operate the equipment in any hospital. We have found that everyone wants to use ultrasound in his own specialty, and that brings up the problem of whether the equipment should be located in a service division, like the X-ray department.

There is a very simple technique (Doppler) that has just come out using ultrasound. This utilizes a transducer placed directly over a blood vessel or fetal heart, and the equipment produces a sound which varies in pitch according to the rate of flow in the vessel. It also picks up more easily than fetal EKG the fetal heart beat so that, ever since we bought our first instrument, our obstetricians have been using it almost constantly to determine viable fetuses. The tone is also different if the transducer is placed over the placental vessels, so that one can tell with about 90% accuracy where the placental vessels are located in the uterus. This represents a simple technique for locating the placenta. The technique also has potential application for detecting obstruction of peripheral vessels, and we have been using it in situations like an A-V anastamosis in chronic dialysis patients to tell how much flow is going through the venous side of the A-V anastamosis. This is the most recent development in the ultrasonic diagnostic field.

I would be happy to answer questions. Although I am prejudiced, I think that within four or five years ultrasound will be utilized in most hospitals for routine diagnostic purposes. It has diagnostic applications which are not possible with other techniques. Although the word "scan" is used in ultrasound, let me point out that it is supplying different diagnostic information than isotopic scans. If you use the two techniques together, the isotope measures the changes in cellular activity and uptake, while ultrasound demonstrates changes in tissue density. Thus, the two techniques used together provide more information than either one alone.

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