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Clinical Application of Ultrasonics for the Diagnosis of Malignant Tumors in the Abdomen–Especially for Hepatic and Pancreatic Carcinomas*

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INTRODUCTION

A dramatic advance in the application of ultrasonics to medical diagnosis has taken place in the last 10 years.

Pathological states which could formerly be proved only by complicated or potentially dangerous procedures can now be readily diagnosed by the imaging techniques of echography.

Thus, ultrasound is now well established as a valuable diagnostic tool, complementary to other diagnostic procedures, particulary radiology and isotope scanning.

Ultrasonic examination of the abdomen was originally directed towards obstetrics and gynecology. Rapid progress took place after the introduction of direct contact scanning. More recently, interest has spread to the examination of the entire abdominal areas and, with improved techinques and greater experience, the diagnostic range has been increased. In this paper, clinical application of ultrasonics for the diagnosis of malignant tumors of the upper abdominal organs are described.

THE NATURE OF ULTRASOUND

Ultrasound is a mechanical, vibrational energy generated at a frequency above the sensitivity range of the human ear (over approximately 20,000 cycles per second). The use of ultrasound in medical diagnosis was developed from the echosounding techniques employed for the detection of submarines. Similar methods are now used to study the configuration of the seabed and to locate shoals of fish, which has led to the technique sometimes referred to as sonar.

In practice, an ultrasonic beam is usually generated by applying an alternating voltage to a disc of piezo-electric material, causing a rapid change in shape. This vibrating movement of the surface generates a pressure

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wave of ultrasonic energy. Conversely, the transducer will react to reflected pressure waves and electric signal voltage appears across it.

The frequency of the oscillation of the transducer is a characteristic of each individual crystal and controls the resolution of the method and the penetration of the ultransonic beam. For most diagnostic purposes frequencies between 0.5 and 20 million cycles per second are used. Ultrasonic energy travels through a medium, as does audible sound, in the form of a wave. As it passes through the tissues of the body, the intensity of the wave is attenuated by divergence and scattering of the beam or by absorption, the energy then being converted into heat. When ultrasound strikes an interface, it may be reflected or refracted, or propagated without deviation. The degree of reflection and refraction depends on the difference in the characteristic acoustic impedance of the tissues on each side of the interface.

Ultrasonic power is measured in watt, and intensity in watts per square centimetre. However, it is more convenient to measure the ratios between two intensities, thus avoiding absolute measurements.

Because ultrasound is usually generated and detected electrically, the intensity can be expressed as a ratio of voltages. To simplify calculations and the expression of high numbers, namely a logarithmic unit, decibel (dB), is used. It is most important to note that when considering an absolute value of ultrasonic power it is meaningless to use such a unit as dB unless a reference level is known.

METHODS USED IN DIAGNOSIS

Generally diagnostic techniques are based on the identification of echoes reflected from tissue interfaces. This is a pulse-echo technique which is widely used as A, B and M mode. These echoes are of a very small amplitude, but can be electronically detected and amplified. Because ultrasound is almost totally reflected by gas, it is necessary to exclude air from between the transducer and the patient's skin by using some form of coupling agent. In direct contact scanning, an oil or acoustic jelly is used. As an alternative, a water bath is sometimes employed.

1. *The A scan* (*Amplified modulated display*)

In this type of presentation as shown in Fig. 1, the reflected signals are amplified and applied to the vertical deflection plates of the cathode ray tube. They are recorded as vertical deflections on the horizontal time base, the height of each deflection being a measure of the strength of the echo. The distance of the vertical deflection from the propagating source gives a measure of the distance of the reflecting interface. In medical abdominal

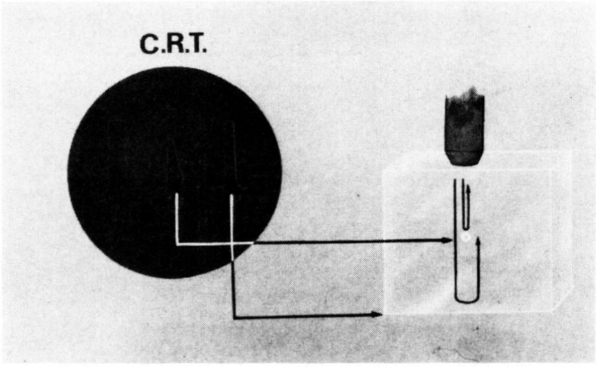


Fig. 1. A scope presentation
C.R.T.: cathode ray tube

work, the A scan is mainly used to measure the depth of an interface from the skin surface or the size of a structure and to assess the consistency of a mass.

2. The B scan (Brightness modulated display)

As shown in Fig. 2, the signals are applied to the grid of the cathode ray tube and the echo information is presented as dots of light, the intensity of which may be modulated according to the strength of the echo. The B-scan is the basis of several important diagnostic system. With the two-dimensional B-scope the probe is mounted on a mechanical scanner which allows for movement in several planes. The direction and position of the time base on the cathode ray tube is linked to the position of the ultrasonic beam within the patient and the position of the echoes on the oscilloscope is geometrically proportional to the corresponding interfaces within the body.

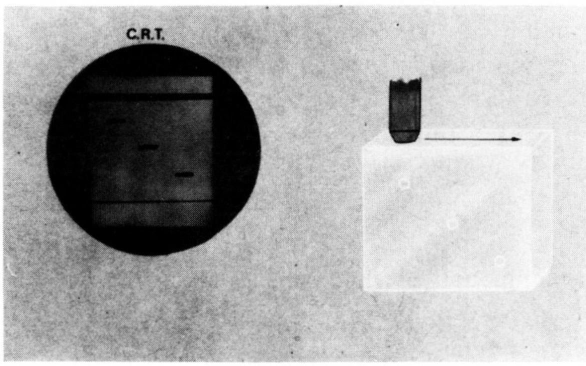


Fig. 2. B scope presentation
C.R.T.: cathode ray tube

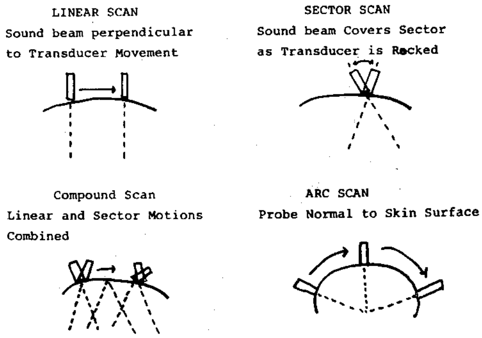


Fig. 3. The variation of scanning in B scope.

The resulting display produces a cross-sectional picture in the plane of the scan. The exact presentation depending on the manner in which the probe is moved; this is shown in Fig. 3. As the scan is only about one centimetre thick, the technique resembles radiographic axial tomography and is sometimes called "Echotomography". In a linear scan the probe is moved in a straight line over the surface of the body. This method is useful for rapid searching and tends to be used more often in conjunction with storage tubes. With an arc scan the probe is always normal to the surface of the skin and rotates round a central point. A sector scan is produced when the transducer is rocked from side to side over one position of the body surface.

This is useful when identifying acoustic shadowing. The compound sector scan is a combination of linear, arc and sector scanning.

It gives more echo information and is the type of scanning most frequently used when recording from a short persistence tube.

3. The M scan or Time position scan

This is variation of the B mode display, and is one of the methods used for studying moving structure. Its main use is in echocardiography. The echopulses are displayed as bright spots and the movement is usually recorded by moving the time base across the face of the cathode ray tube, the trace being photographed by time exposure.

ULTRASONIC EXAMINATION OF THE ABDOMEN

Ultrasonic examination of the abdomen was originally directed towards Obstetrics and Gynecology. Rapid process took place after the introduction of direct contact scanning. More recently, interest has spread to the examination of the entire abdomen.

Although the evaluation of the echography reported has proved its usefulness for differential diagnosis of tumor in the abdomen, at the present stage of development, the outline of the abdominal organs is usually displayed with only limited information in internal echo detail. Moreover, a considerable amount of experience is said to be needed to diagnose cases of intra-abdominal malignant tumors correctly, because it is often hampered by a lack of quantitative data, inconsistency of echograms by a number of erratic factors such as respiratory movements of the organs, variable characteristics of certain pathological changes and gas echo artifacts. To overcome these difficulties, recently two improved techniques have been introduced by K. Kikuchi and G. Kosoff.

Kikuchi and Fukuda have proposed the use of "Sensitivity Graded Tomogram Pairs" (SGTP) setting forth a set of four tomograms for a single pathological region at 6 dB steps which may be considered to be optimal in most diagnostic apparatus. They reported that it enabled a comparison of the echo intensities of the abnormalities with about a 3 dB accuracy by interpolation of a sorts. The other technique is a grey scale method which has been recently developed.

1. Senitivity graded tomography pairs

The units of equipment used are an Aloka SSD-10 Ultrasonograph, a MSU 6 scanner, an attenuator and a scan converter display system, Aloka UIR-2 is as shown in Photo. 1. Manual contact scanning by a 10 mm flat probe was used throughout. SGTP were obtained essentially as proposed by Kikuchi by recording ultrasonotomogram pairs at 3 or 6 dB steps covering a 30 dB range. Zero dB of the relative sensitivity was set arbitrarily at the sensitivity level of the equipment without attenuation.

Echo levels were compared between normal and pathological structures

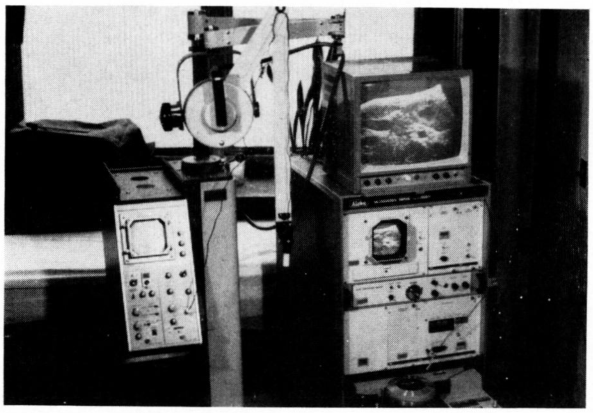


Photo. 1. A scan converter display system, Aloka UIR-2.

and were expressed as sensitivity grade values which denotes the dB of attenuation requited to cause the disappearance of abdomial echoes after the disappearance of echoes of normal parenchyma, preferably situated at the same distance from the transducer.

To examine entire regions of the upper abdomen by the SGTP method, paired echograms were taken on each of 5 parallel sagittal scan planes, an oblique scan was made along the right subcostal margin and the traverse and oblique planes are as shown in Fig. 4.

All scannings were made essentially by the single sweep scan method, in which the scanning speed was fixed at approximately 5 cm/sec., while the examinee held his breath at the deepest abdominal inspiration.

Recording was done by taking photographs or by direct taping into a VTR attached to the scan converter display system.

The entire procedure took approximately 20 minutes for each individual tested.

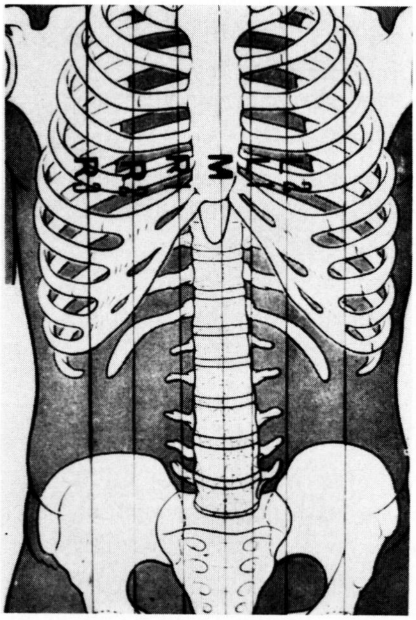


Fig. 4. The five sagittal scan planes.

1) Echo levels and patterns of the upper abdominal region of normal individuals.

The crosssectional anatomy demonstrated on sagittal scans of the upper adbomen allowed for identification of the liver, pancreas, gallbladder, right kidney, abdominal aorta, caval and portal veins based upon boundary and internal echoes of these structures.

As shown in Fig. 5, R-3 taken in rt. ventral axillary line shows a remarkable pattern of liver at −6 and −12 dB steps.

R-2 taken in rt. mammary line shows a definite pattern of the liver at −6 and −12 dB steps. R-1 taken in rt. parasternal line also showed the patterns of the liver at 0, −6 and −12 dB steps.

It also shows the echo patterns of the aorta, inferior caval vein and portal vein at −6, −12 and −18 dB steps. MED, taken in median line shows the patterns of the liver and inferior caval vein and a part of the heart. L-1 taken in 1t. parasternalline shows the pattern of the liver and remarkable vein at −6, −12 and −18 dB steps.

The level of sensitivity at which the internal echoes disappeared was taken as the standard value for comparison, instead of bottom echoes, due primarily to the consistency of the aorta.

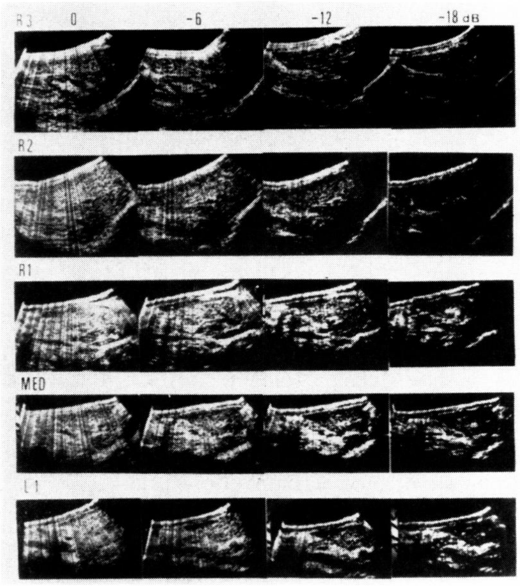


Fig. 5. Sagittal scans of upper abdomen by sensitivity graded tomogram pairs. They are taken from the upper abdomen of a normal individual on five parallel sagittal planes at 6 dB steps. From top to bottom; R_3, rt ventral axillary line, R_2, rt mammary line, R_1, rt parasternal line, MED, median line and L_1., lt, parasternal line, respectively. Internal echoes of the liver disappeared following attenuation of -18 dB of the equipment sensitivity

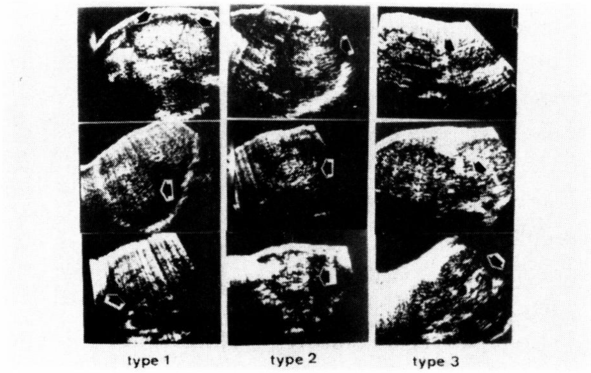


Fig. 6. Echo-patterns of primary hepatomas. Vertical rows from left to right, type 1, 2 and 3, respectively. Arrows indicate localization of individual tumor nodules or mass.

Also caution was paid to avoid artifacts caused by inconsistent contact of the transducer or uneven scanning both of which not infrequently lead to the production of errative echograms.

Lateral and axial resolution were generally improved slightly following sequential attenuation indicating presence of an apparent focusing effect even in a flat probe.

2) Patterns of primary hepatomas.

The primary hepatomas may be classified into 3 types based solely upon echo levels and echo patterns as shown in Fig. 6.

The first one is a circumscribed nodular pattern, in which a round tumor mass is surrounded by a sonolucent halo ; the latter becomes prominent on sequential attenuation. The levels and distribution of echoes of the mass showed a close resemblance to those of normal parenchyma, the maximum echo difference being only 6 to 9 dB higher than the normal liver tissue. The second one is a nodular pattern in which irregular contours of the surrounding halo was less prominent and the contours of the tumor mass were rather irregular ; the echo levels of the tumors frequently exceeded 12 dB or more of those of normal parenchyma.

The last one is a diffuse, irregular-spotted pattern with lowered ech levels, the latter being 6 dB or more lower than those of normal tissue and the tumor masses are sharply separated from the normal tissue. Eighty-five per cent of primary hepatomas were classified into type 1 or 2, indicating a preponderance of single nodular types.

3) Metastatic carcinoma of the liver.

Metastatic carcinoma of the liver generally disclosed a number of scattered nodular masses of elevated echo levels as shown in Fig. 7. In a small number of cases, lowering of echo levels was noted. Irregularly shaped strand echo of elevated echo levels extending from the hilar portion to the periphery of the liver were also relatively common. A round nodular mass with a surrounding halo resembling those of primary hepatoma may be obtained in cases with

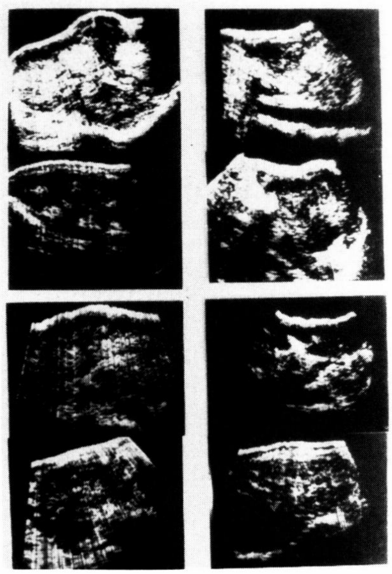


Fig. 7. Echo-patterns of metastatic carcinoma of the liver. Sensitivity graded tomogram pairs were obtained by parallel sagittal scanning.

metastatic carcinoma, however, parallel sagittal scanning invariably disclosed the presence of a number of metastatic foci with similar echo patterns.

2. Grey scale echography.

George Kosoff, Australia succeeded in developing the grey scale technique by means of which it is now possible not only to display high amplitude echoes from the surface of internal organs but also, at the same time, to display the low amplitude echoes denoting the tissue characteristics of the solid parenchyma of an organ. As a result of this development ultrasonic imaging has taken a tremendous stride foward and has become an increasingly valuable tool for medical diagnosis.

A new equipment for grey scale echography is shown in Photo. 2. It contains a focused probe, logarithmic

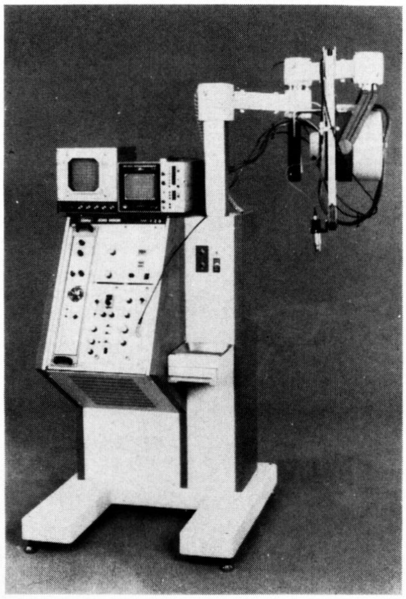
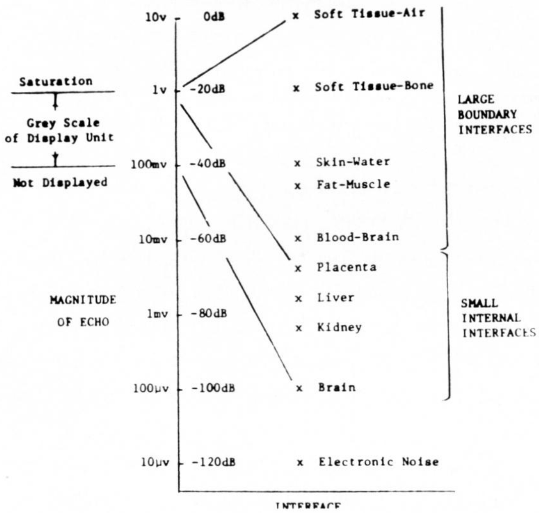


Photo. 2. a new equipment for grey scale echography.

Table 1. *Logarithmic amplifier of grey scale echography. Range of magnitudes of echoes from biological interfaces aud selection of internal echoes to be displayed over a major portion of the grey scale of the display unit*



amplifier and scan converter system. Logarithmic amplifiers may be capable of compressing the 60 dB signal into 20 dB in a continuum of grey shades as shown in Table 1. A scan converter may be used to store the information received during the scan and the echogram read-out on a T.V. receiver. The memory storage of a computer also may be used for this purpose. It allows for the storage of the widest range of magnitude of echoes and permits a number of different processes to be used in the read-out of the stored information.

1) Pattern of normal pancrease.

The normal pancreas could be visualized by sagittal and transverse scanning in over 90% of patients having no pancreatic disorders. Landmarks such as large vessels, the liver, gallbladder and the vertebral body may be used effectively as shown in Fig. 8.

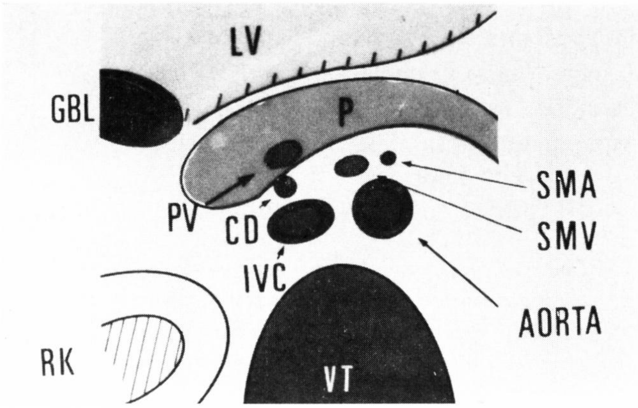


Fig. 8. Landmarks in Greyscale echograms.
LV; liver, GBL; gall bladder, P; pancreas, PV; portal vein, SMA; small mesenetric artery, SMV; small mesenteric vein, IVC; inferior caval vein RK; right kidney, VT; vertebral body, CD; choleducus

2) Grey scale echograms of the liver.

As shown in Fig. 9, in serial rt. subcostal scan RSC-1 shows a massive liver echo in which echoes of the inferior caval vein, hepatic vein and aorta are clearly detected. Immediately beneath the liver echo, a massive shadow due to pleural effusion is seen. The echo of the heart is shown in the right upper portion. RSC-2 also shows a massive liver echo. In RSC-3, remarkable echoes of the inferior caval vein and aorta are seen in the large liver echo.

RSC-4 and -5 show a sagittal shadow of the portal vein in the upper portion of the inferior caval vein and aorta. In RSC-6, the echo of the

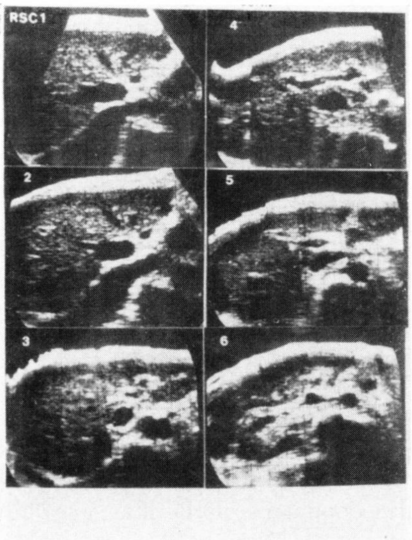


Fig. 9. Greyscale echograms of the liver (serial RT. subcostal scan)

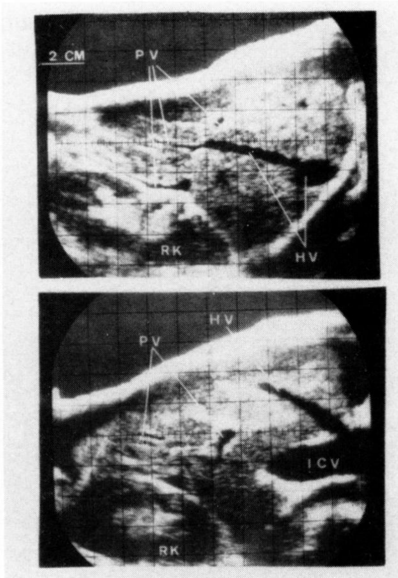


Fig. 10. Greyscale echograms of the liver (parallel oblique scans)

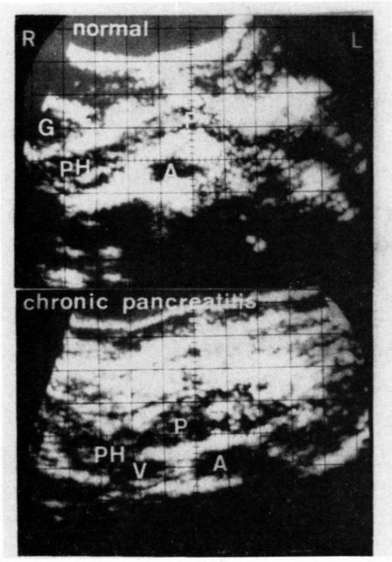


Fig. 11. Grey scale echograms of the pancreas Typical echogram obtained from a case of chronic pancreatitis.

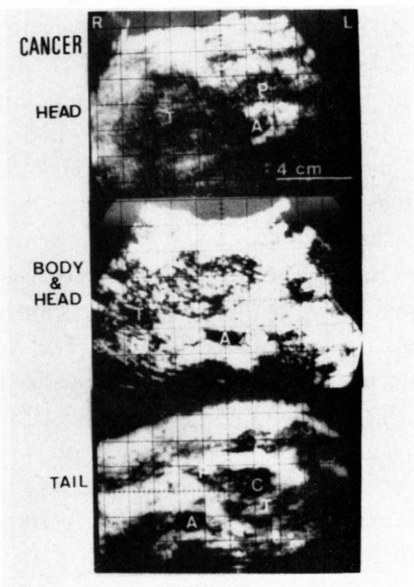


Fig. 12. Grey scale echograms of pancreatic carcinomas (transverse scanning). From top to bottm; pancreatic carcinoma of the head, body and tail, respectively.

Table 2. *Characteristics of echograms of pancreatic carcinomas*

Localization	Swelling	Contours	Echo level	Posterior wall Defect by Atten.
Head 13	localized 31 (81.6%)	irregular 28 (73.7%)	lower than normal 16 (42.1%)	defect (+) 22 (57.9%)
Body 9	—	—	low echo level with centiral echo cluster 12 (31.6%)	—
Head & Body 5	diffuse 5 (13.2%)	—	—	—
Tail 1	no swelling 2 (5.3%)	smooth 4 (1.05%)	higher than normal 8 (21.1%)	defect (−) 15 (39.5%)

right kidney is seen. In Fig. 10, grey scale echograms of the liver are shown in parallel oblique scans. The upper photograph shows a large portion of the liver echo which definitely includes the portal vein and hepatic vein. The lower photograph also shows the patterns of the liver and kidney echoes.

3) Grey scale echograms of the pancreas.

As shown in Fig. 11, normal pancrease is clearly seen immediately in front of the vertebral body and aorta in the transverse scan.

In chronic pancreatitis, which has diagnostic problems, the swelling of the pancreas is rather uniform and the level and distribution of the internal echoes are within normal ranges with the exception of when it is complicated by pancreastolithiasis.

In Fig. 12, a representative case of pancreatic carcinoma is shown. As summarized in Table 2, the abnormal findings obtained in 38 cases of pancreatic carcinoma. Findings which may be used as criteria for distinguishing pancreatic carcinoma are; localized enlargement of the organ, irregularity of the contours, levels and distribution of the internal echoes, and disappearance of the posterior wall echo following sequential attenuation. The overall diagnostic rate by the grey scale method was 84% as judged from preoperative interpretation. A retrospective study disclosed the presence of pathological findings in 95% of cases. The smallest tumors identified were 1.5×1.2 cm carcinomas located at the head of the pancrease immediately behind the main pancreatic duct.

This tumor was diagnosed when small echo clusters with elevated echo levels were reveal led.

CONCLUSION

In conclusion, the B-scan ultrasound, especially sensitivity graded tomogram pairs and grey scale echography are the most useful for the diagnosis of malignant tumors in the abdomen because of its accuracy and lack of biomedical hazards which are sometimes entailed in other diagnostic techniques.

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