Progress report
Ultrasound and gastroenterology

Technical considerations

The recent technical advances in ultrasonic imaging have opened up new diagnostic possibilities for the gastroenterologist. The delight of ultrasonic scanning must lie in its non-invasiveness. For the patient an ultrasound scan requires no preparation. To perform the examination the patient lies on a couch and arachis oil is massaged on to the skin of his abdomen to ensure good contact and permit transmission and collection of sound waves. No further preparation is required and no injections, potentially hazardous ionising radiation, or other invasive procedures are necessary.

While it is of no use to the clinician to know the more esoteric scientific technology, nevertheless there are some technical points which are of importance in understanding what anatomy and pathology can or cannot be seen by ultrasonics.

The most important principle of ultrasonic examination of tissue is that, at certain frequencies, sound is reflected when passing between two tissues of unequal acoustic density. In particular, an interface, such as that between liver and diaphragm, reflects much sound. Fluid—for example, a cyst’s contents or bile within the gall bladder—reflects virtually no sound.

By way of contrast, gas totally disperses and partly reflects the sound and any organ lying behind a gas-filled structure is totally ‘invisible’ to sound waves. Thus the pancreas is often hard to visualise, lying as it does behind the colon. Barium sulphate is also particularly reflective of sound waves. Sound waves are broken up by thick scar tissue.

The sound used is usually transmitted at a frequency of 2.5 million cycles per second for examination of the abdomen, although frequencies between 1.5 and 5 million cycles are used occasionally. Sound at this high frequency is produced by a transducer, a device capable of producing high frequency pulsations when an electrical stimulus is applied to it. It is also able to act in reverse and produce a small voltage charge when ultrasonic reflections strike it. These voltage charges are converted into a two-dimensional image on the screen by electronic processing. This is the B-scan. Recently, a considerable technical advance has meant that various different levels of sound can be portrayed on the screen in varying shades of grey, between black and white, with the ‘loudest’ sounds being the most white. In contrast, the simple B-scan is able to portray only a black and white picture. This advance has meant that tissues of relatively similar, but different, acoustic textures can be portrayed as different shades of grey. Thus it has become possible to differentiate such tissues as a solid hepatic metastasis from normal liver tissue.

That there is absolute safety at the frequencies used for diagnostic purposes is firmly established. The only reports of damage were the chromosome breakages in insonated peripheral blood lymphocytes reported by MacIntosh and Davey. Many authors have since attempted to reproduce these results.
but were unsuccessful. MacIntosh recently repeated his work and was unable to replicate his original results. In no case has there been human tissue damage attributed to ultrasound, among thousands of examinations of all parts of the body, including such potentially sensitive structures as the eye. Ultrasonic examination of an organ is performed by sweeping the transducer in contact with the skin over the organ. The picture produced by each sweep of the transducer is of necessity a section of the structure lying beneath it. A number of these sections are taken at intervals to build up a three-dimensional view of the underlying structures.

**Liver imaging**

Examination of the liver is performed initially by scanning in the right hypochondrium. The patient takes a deep inspiration and a parasagittal sweep is performed under the costal margin. The deep inspiration displaces the gut downwards and permits good examination of the liver in 90% of patients. In about 10% of patients satisfactory views of the liver are not obtainable. A number of factors may be responsible for this. Fat, which is a poor transmitter of sound, may cause dispersion of the sound beam and the obese patient may be unscannable. If the colon is closely applied to a small liver, even a deep inspiration may be insufficient to permit a satisfactory scanning. A thick cholecystectomy or other right hypochondrial scar may prevent visualisation of liver tissue.

Scans are taken at 1 cm intervals from the left to the right extremities of liver tissue. Transverse or oblique abdominal scans are also often made to build up a complete picture of the liver and confirm the findings of the parasagittal scanning (Fig. 1).

Investigation of the liver may pose a difficult problem for the clinician. There is no radiological technique for the investigation of the liver comparable with the chest radiograph for demonstration of the lungs or the barium meal.
for gastric pathology. The development of ultrasonic liver imaging has undoubtedly been stimulated by this fact.

Jaundice and the biliary system

The ability to differentiate between extrahepatic biliary obstruction and other causes of jaundice is important to the clinician. A serum bilirubin of 30 μmol/l or over makes visualisation of the biliary tree by conventional oral or intravenous use of radio-opaque dyes difficult, and a number of attempts have been made to circumvent this problem. Various other techniques have been used to distinguish between obstructive and non-obstructive jaundice. An alkaline phosphatase level of over 30 King Armstrong units suggests biliary obstruction. Computer analysis of data has been used to help in the differential diagnosis of jaundice. Endoscopic retrograde cannulation of the biliary system has been used to verify the presence or absence of an obstruction with good results in expert hands. A thin needle technique for cholangiography has been described by Okuda and his colleagues from Chiba University. The high success rate and relative safety of this technique are now well recognised.

The original description of the ultrasonic anatomy and pathology in the biliary system was made by Taylor and Carpenter. In obstructive jaundice, the earliest change noted in the gall bladder is an alteration in shape; the normal gall bladder having a semilunar outline, whereas the obstructed gall bladder has a biconvex distended appearance. At the same time, the characteristic ultrasonic appearance on echograms of a dilated biliary tree was noted (Fig. 2).

With the use of a real-time scanner, regular visualisation of a dilated common bile duct may be possible. Accurate demonstration of structures in the porta hepatis can also be carried out with clear separation of portal vein and common bile duct.

The accuracy of ultrasound in differentiating obstruction from non-obstruction is important to the clinician. Originally small series were reported

Fig. 2 Parasagittal scan showing skin (S), liver (L), dilated biliary ducts (BD), and large gall bladder (GB) in a patient with carcinoma of the pancreas.
which indicated a high degree of accuracy. Recently, accuracies of over 90% have been obtained in larger series with clinical and operative information to substantiate the figures. As this figure is considerably better than any other diagnostic technique in use at present, it appears that ultrasonic scanning should now be considered as a prime diagnostic tool in the evaluation of the jaundiced patient.

In the non-jaundiced patient, a frequent clinical problem is the patient with right hypochondrial pain and in whom the oral cholecystogram or intravenous cholangiogram fail to opacify the gall bladder. The ease with which ultrasound can often visualise the gall bladder suggests its use in this problem.

Gall stones in the gall bladder reflect a considerable proportion of sound waves and are seen ultrasonically as sharp outlines (Fig. 3). As they reflect so much sound, they cast a shadow behind them. In general, calcified gall stones are more acoustically reflective than non-calcified stones. A gall stone will therefore usually be easily recognisable when in the gall bladder by the production of echoes within the silent lumen of the gall bladder and the shadows they cause. If in doubt, the position of the patient can be altered and it may be possible to demonstrate the movement of the stone. Occasional confusion may be caused by the spiral valve of the cystic duct which is capable of producing a shadow similar to those seen behind gall stones.

In a series of 43 patients, 27 gall bladders were considered to be ultrasonically normal and 26 eventually proved to have no gall bladder disease. Irregularity of the gall bladder wall ultrasonically was a regular feature in gall bladders diseased by chronic inflammation. This range of accuracy has been shown by other authors. Ultrasonic scanning is therefore indicated in patients with radiologically non-functioning gall bladders in whom useful clinical information may often be obtained.

**Liver tumours**

The diagnosis of primary or secondary liver tumours is not a simple matter.

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Fig. 3* Parasagittal scan showing gallstones (GS), in the gall bladder (GB). Skin (S), liver (L), diaphragm (D), and right kidney (K) are also indicated.*
using ultrasound. On theoretical grounds tumours might be thought to be picked up with some ease, as ultrasound displays interfaces between tissues. In practice, the difference in acoustic attenuation between two solids such as the normal liver and a secondary tumour is extremely small and only the most modern machines with grey-scaling have the capacity for detecting these small differences. Even then, the differences in attenuation may be picked up only by appreciating differences in patterns reflected from a slice of liver tissue at different intensities of acoustic input.

A liver tumour may be more acoustically reflective or less reflective than normal liver tissue\textsuperscript{26}. With transonic areas it may be difficult to be certain whether there is a tumour present or whether a combination of shadowing from reflective structures and the normal attenuation of sound by liver tissue is occurring. Only experience and patience on behalf of the scanner will resolve this issue (Fig. 4).

The size of tumour detected is dependent on a number of factors. Certain areas of the liver are easier to scan than others. In particular, the right lobe of the liver lateral to the porta hepatis is ultrasonically a highly homogeneous tissue. A tumour in this area is much more likely to be detected than one in the region of the porta where large vessels may make interpretation difficult. Another important factor is the difference in attenuation between the normal liver and the tumour. A big difference in attenuation created, for instance, by central necrosis in a tumour, showing up as a highly transonic region or a highly vascular tumour showing up as a highly reflective region, will ensure that small tumours of the order of 2 cm diameter may be seen\textsuperscript{27}. Conversely, tumours of 3 or 4 cm may be missed if their attenuation is similar to that of the liver, and especially if they are in an area of liver which is not easy to scan. There is some suggestion also that the primary site of the malignancy may determine liver patterns seen ultrasonically. Two independent sources reported that metastases from colonic carcinoma have a strongly echoing appearance when scanned ultrasonically\textsuperscript{28,29} (Fig. 5).

In spite of these points, it is clear that ultrasound has an important role to
Fig. 5 An enormous hepatic metastasis (M) in the liver (L) from an unknown primary.

play in the diagnosis of liver tumours. It is often difficult in performing studies on livers suspected of being involved in metastatic disease to obtain histological proof of presence or absence of disease, and some studies are therefore not wholly satisfactory. Smith and Taylor\textsuperscript{30} studied 70 patients with breast carcinoma. Fifteen of these had established metastases, either histologically (10 patients) or on clinical evidence of progressive hepatomegaly with an irregular liver edge (five patients). Ultrasound correctly identified metastases in 14 of the 15 (93\%), while alkaline phosphatase was raised in 13 of the 15, and isotope scanning detected seven of only nine patients imaged. Ultrasound gave false positives in three of 55 (5\%), serum alkaline phosphatase four of 55 (7\%), and radio-isotope scanning eight of 35 patients imaged (23\%). The obvious suggestion is that ultrasound can be considerably more accurate in metastases from breast carcinoma than radio-isotope scanning, but point also to the fact that alkaline phosphatase in their laboratory and others\textsuperscript{31}, remains the best and most accurate single method for the diagnosis of suspected hepatic tumours. Difficulties in the interpretation of radio-isotope liver scans and consequent false positive and false negative reports have been noted previously\textsuperscript{32,33}. Those with less experience at hepatic ultrasound scanning have had less accuracy. One group had an 80\% accuracy in 21 patients with proven metastases\textsuperscript{33,34}. Laparoscopy with its ability to biopsy a specific hepatic lesion has been shown to be most useful in the diagnosis of hepatic tumours\textsuperscript{34}.

Primary hepatomas may be hard to detect ultrasonically, especially when there are multiple small abnormal areas\textsuperscript{36}. Various diagnostic features have been recently noted and, using these, 62\% of primary hepatomas have been detected by an experienced group\textsuperscript{37}.

In summing up, ultrasound obviously has a part to play in the detection of suspected intrahepatic tumours. It is only likely to be the most accurate diagnostic tool available to the clinician if the ultrasound unit to which he sends his patient has considerable experience in grey-scale liver scanning.
Hepatic and abdominal abscesses

Until recently there has been no reliable technique for demonstrating liver abscesses. Even as recently as 1976 a Lancet editorial was written on the difficulty of diagnosing and managing liver abscesses. Radio-isotope scanning does not always have a high rate of pick-up, although a 95% pick-up has been reported.

The special properties of ultrasound permit comparatively easy diagnosis of liver abscess. One hundred per cent accuracy is now achieved in the diagnosis of amoebic liver abscesses by ultrasound in some centres, and there seems good reason to believe that ultrasound is now the method of choice in diagnosing intrahepatic abscesses. Ultrasound is the definitive means of investigating patients suspected of having an intra-abdominal abscess. Radiological techniques for the diagnosis of abdominal abscesses are dependent on the displacement of an intra-abdominal organ—for example, stomach, kidney—to be radiologically abnormal, or on the presence of gas in the cavity. Isotope scanning using radioactive Gallium is not the reliable method that was hoped for originally. A uniformly high accuracy has been noted in the use of ultrasound to detect abdominal abscesses. Errors may occur when the abscess is overlaid with gas-containing bowel. Subphrenic abscesses are sharp edged and crescentic in shape and are easily seen on the right between the liver and diaphragm. The left subphrenic region is hard to visualise, ultrasonically hidden as it is behind the stomach and colon. Abnormalities of the spleen may be mistaken for an abscess compounding the problems on the left side.

In performing an ultrasound scan, accurate anatomical localisation of hepatic or intra-abdominal abscesses is possible, which is of use in needle aspiration. Ultrasound can locate the centre and edges of an abscess and measure the depth of the abscess below the skin surface giving the angle at which to aspirate and depth to insert the needle. Alternatively, a commercially produced transducer is available with a hole drilled through its centre. The abscess can be lined up with this transducer and a needle inserted into the cavity under ultrasonic control through the hole in the centre of the transducer.

Hepatic cysts

Until recently the diagnosis of intrahepatic cysts was often made only at laparotomy. The visualisation of hepatic and intra-abdominal cysts was one of the earliest uses of ultrasound in the days when machines were comparatively primitive.

A recent study using modern ultrasonic machines has shown 100% accuracy in the diagnosis of 23 hydatid cysts, 20 of which were proven at laparotomy and three confirmed by other means. Another series revealed 100% accuracy in 13 patients with one false positive.

Liver volumes

Routine clinical examination involves an estimation of liver size by means of palpation and percussion. Ultrasound is particularly suited for the evaluation
of the edge and the size of an organ, Agreement between ultrasonic and clinical assessment of the position of the liver edge relative to the costal margin may be only 50%. However, measurement of liver volume can be performed with a good degree of reproducibility (within 5%)\(^{51,52}\). Liver volumes measured before and after portal decompression surgery showed a decrease of 30%\(^{53}\).

**Vinyl chloride liver disease**

Portal fibrosis and the development of angiosarcoma is a recently described complication of vinyl chloride monomer toxicity after industrial exposure\(^{64}\). In experienced hands, a study of 19 exposed workers showed good correlation between ultrasonic findings and clinical and pathological abnormalities\(^{65}\).

**Pancreas**

The pancreas is technically difficult to recognise ultrasonically, and only recently have the normal and abnormal ultrasonic appearances been described satisfactorily.

The description of a method for the ultrasonic localisation of the superior mesenteric and splenic veins\(^{19}\) has been a major advance in locating the position in the abdomen of this elusive organ for which there is no satisfactory surface marking. Scanning of the pancreas is aided technically if the liver extends below the costal margin, as this permits satisfactory transmission of sound\(^{58}\). Often the colon or stomach lie over the pancreas and these air-containing organs may interfere with sound transmission and prevent satisfactory pictures being taken.

The frequency of detection of the normal pancreas varies considerably\(^{23,55,56}\). It is often easier to detect an abnormal pancreas as the increase in size will make localisation easier. The use of a real-time scanning machine is likely to make localisation of the pancreas more common. These machines permit rapid alteration of the scanning plane and thus permit a rapid overall scan of the abdomen. The scanner is thus able to locate intra-abdominal organs such as the pancreas which may be tedious to locate by conventional B-scanning.

**Diseases of pancreas**

Pancreatic carcinoma appears as a localised solid mass lying either over the great vessels or behind the stomach\(^{59}\). Detection rates for carcinoma of the pancreas by ultrasonic scanning vary considerably. Some authors claim up to 85% accuracy\(^{59,60}\). This accuracy is better than nuclear pancreatic scans\(^{61}\) and similar to that obtained in experienced hands using endoscopic retrograde cannulation of the pancreas\(^{60,62}\) (Fig. 6).

In chronic pancreatitis the appearance is characterised by total or partial enlargement of the gland and areas of low and high echoes alternating irregularly\(^{57}\). Unfortunately, these features are not present in all glands. A 65% accuracy of diagnosis of pancreatitis is all that can be expected by conventional scanning\(^{64}\), although Weill and his colleagues using a real-time scanner reported a figure of 94% accuracy for chronic pancreatitis\(^{64}\). The ultra-
Fig. 6 A large pancreatic tumour (T) displacing the normal pancreas forwards. Liver (L) and skin (S) are also seen in this parasagittal scan.

Fig. 7 A small pancreatic cyst (C) over the pancreas (P) in a patient with recurrent pancreatitis.

The sonographic appearance of carcinoma of the pancreas may however be identical with that seen in chronic pancreatitis.

Ultrasound is the best method of diagnosing pancreatic cysts. The only difficulty that may occur is if a cyst is very large. In that case, it is not possible to be certain of the origin of the cyst and a mesenteric or occasionally hepatic cyst on the edge of the liver may be mistaken for a pancreatic cyst. Although most pancreatic cysts are empty of echoes, this is not always the case, and if there is a mass within the cyst, it is not possible to be certain whether the pathology present is just a simple cyst or a cystadenocarcinoma of the pancreas (Fig. 7).

Which patients should the clinician send to the ultrasound clinic? Certainly those with recurrent abdominal pain of suspected pancreatic origin or a palpable pancreatic tumour, although, in spite of many suggestions for ultra-
sonic differentiation of these pathologies, most authors agree that accurate distinction is not always possible. The more patients that the clinician sees, the better it will be able to help the clinician for whom the pancreas is a difficult diagnostic problem.

Abdominal masses

The gastroenterologist is often faced with the problem of being able to palpate a mass in the abdomen, and yet being unsure of its origin or nature. Ultrasound examination can usually determine for the clinician whether a mass lies within the liver or outside it. An enlarged kidney or dilated gall bladder can also be delineated.

The performance and interpretation of ultrasound scans is not something that is learnt overnight. Scanning of the liver in particular is, like many techniques, something of a 'knack' and learnt only by much practice.

Although centres with experience will be able to produce results comparable with many of the series quoted above, the novice scanner will find great difficulty at first in obtaining pictures which he and his clinical colleagues can interpret. It is similarly important for the gastroenterologist to appreciate that the purchase of a good ultrasound machine will not automatically mean that their diagnostic dilemmas in certain areas are over. Much time and patience will be needed before reliable results are obtained.

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