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Non-invasive techniques in the diagnosis of jaundice—ultrasound and computer

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SUMMARY This study describes the use of ultrasound in 84 consecutive patients to distinguish between medical (intrahepatic) and surgical (extrahepatic) types of jaundice. Accuracy rates in the 84 patients investigated were compared with those found in 169 patients using the computer-aided diagnostic model for jaundice. In 50 patients in whom both techniques were carried out direct comparison was possible. Ultrasound failed to give adequate visualisation for technical reasons in two patients, but 75 of the remaining 82 (91·5%) were correctly separated into medical and surgical categories. A similar percentage (90%, 152 of 169 patients) were correctly classified by the computer-assisted model, and in the 50 patients assessed by both techniques correct diagnostic separation was achieved in 43 (86%) by ultrasound and in 42 (84%) by computer. However, in this latter group two of the errors with computer diagnosis were falsely positive for a surgical jaundice (extrahepatic obstruction), and a surgical exploration performed on the basis of this test could have been unnecessary. This was not found with ultrasound in these same patients, all the errors being false negatives. A high degree of confidence can therefore be attached to the demonstration by ultrasound of a dilated biliary tree.

One of the most important problems in the management of jaundiced patients is the correct differentiation between those with extrahepatic biliary obstruction for whom surgical intervention is needed, and those patients with cholestatic jaundice from an intrahepatic cause for whom surgery is best avoided because of the dangers of precipitating hepatic decompensation. In this differentiation a clinical diagnosis on history, physical examination, and liver function tests has been shown to be correct in a number of studies in approximately 80-85% of patients (Martin *et al.*, 1960; Schenker *et al.*, 1962).

In the remaining proportion, in whom the diagnosis still appears uncertain, further diagnostic measures must be used, and in particular some form of visualisation of the biliary tree becomes essential. In the presence of jaundice, this can be by percutaneous transhepatic cholangiography (PTC) or endoscopic retrograde cholangiography (ERCP). The former is more successful where dilated ducts are suspected, and *vice-versa* (Elias *et al.*, 1976) but both techniques are invasive with a percentage, albeit small, of serious side-effects, and with a failure rate of 5-20%. ERCP is also expensive in terms of time and equipment. A simpler, less invasive, and cheaper technique could be used more readily to overcome the margin of error in the difficult cases of jaundice, as well as for worthwhile confirmation of those in whom a provisional diagnosis has been made on the basis of clinical and laboratory findings. Grey-scale ultrasonography would appear to fit these criteria (Taylor *et al.*, 1974; Perlmutter and Goldberg, 1976; Taylor and Rosenfield, 1977; Vicary *et al.*, 1977; Rubio *et al.*, 1978; Vallon *et al.*, 1978), and in this paper we report our experience of diagnostic ultrasound in a group of 83 consecutive cases of jaundice referred for this investigation because a surgical cause for the jaundice could not readily be excluded clinically. These results are compared with those obtained using the computer-based diagnostic model which has been developed in this Unit over recent years and by which consistently accurate predictions of the likely diagnosis are possible from basic clinical and laboratory data.

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Methods

PATIENTS

The cause of jaundice in these 84 patients was almost equally divided between medical and surgical (Table 1). Fifty-four of the 84 patients had been referred from hospitals outside the district for further evaluation of their jaundice and as such formed a selected series of the more difficult diagnostic problems. Patients with fulminant hepatic failure, alcoholic cirrhosis, and active chronic hepatitis tended to be excluded from such investigations because the aetiology was readily diagnosed on clinical grounds. The correct final diagnosis was established in all patients by prolonged clinical follow-up and histology in those without, and by laparotomy or necropsy in those with, extrahepatic biliary obstruction. Cholangiography was carried out in 46 of the 84 patients, being routinely performed in most cases going to surgery to ascertain the site of obstruction, or for clarification in those patients where other investigations had given conflicting results. Cholangiography was by the fine needle percutaneous technique in 31, the endoscopic retrograde technique in 10, and both in five.

Grey-scale ultrasonography was carried out by one observer (R.P.) using a Nuclear Enterprises Diasonograph 4200 with grey-scale modification and accepted ultrasound scanning technique (Taylor and Hill, 1975). All patients were categorised as surgical or medical only, based on the final conclusion as to the presence or absence of dilated bile ducts, other features being recorded but not allowed to influence this categorisation. Patients did not undergo any special preparation, and only very few had undergone previous surgery, which can sometimes impede ultrasound effectiveness.

The clinical data on 50 of the 84 patients were also assessed by the computer-based diagnostic model, the validity of this relatively small sample being determined by comparison with the results obtained in a total series of 169 patients seen prospectively (A.T.) and investigated by the computer over the same period of time. The computer model calculates the probability of the occurrence of each of 11 possible disease groups, nine medical and two surgical. These calculations are based on Bayes' theorem and use up to 66 defined items (indicants) of clinical and biochemical information, all of which are obtainable within the first 48 hours of the patient's admission. Over half of these are based on the history and include factors such as age, sex, duration of jaundice, presenting symptom, presence of pain, pruritus, pale stools, and weight loss. The remainder include features found on physical examination, such as the presence or absence of signs of chronic liver disease, an abdominal mass, a tender or enlarged liver, and splenomegaly. In addition, basic haematology and liver function tests and a plain abdominal radiograph may be included.

Bayes' theorem, in the medical context, enables the known frequency of indicants occurring in a particular disease to be used to calculate the probability of that disease occurring in a new patient who has particular test results (Knill-Jones, 1977). In practice, the clinical and biochemical features of the patient under investigation are compared with those obtained from 390 jaundiced patients with a final diagnosis, who form the current basis of the computer's data bank. The two surgical groups within the 11 recognised diagnostic classes comprise those with biliary obstruction by tumour and by gallstones. If the added probabilities of these two is 0·5 or greater, then the case is classified as 'surgical'; if less, it is classified as 'medical'.

Table 1 *Final diagnosis in 84 patients undergoing ultrasound examination for cholestatic jaundice and 169 patients undergoing computer diagnosis*

	Intrahepatic cause			*Extrahepatic cause*	
	Ultrasound	*Computer*		*Ultrasound*	*Computer*
Cholestatic acute hepatitis	7	25	Common duct stones	13	16
Cryptogenic cirrhosis	4	12	Carcinoma of pancreas	16	28
Primary biliary cirrhosis	2	12	Cholangiocarcinoma or tumour mass at porta hepatis	10	9
Wilson's disease	1	2			
Acute alcoholic hepatitis	3	18	Benign common bile duct stricture	4	2
Hodgkin's disease	4	6	Chronic pancreatitis	1	2
Active chronic hepatitis	2	12			
Biliary atresia	7	—			
Chronic cholangitis from inflammatory bowel disease	2	4			
Primary sclerosing cholangitis	1	1			
Benign recurrent intrahepatic cholestasis	1	2			
Drugs	1	8			
Miscellaneous	5	10			

Results

In two of the 84 patients, adequate visualisation by ultrasound could not be obtained due to excessive intra-abdominal gas. Seventy-five (91·5%) of the remaining patients were correctly separated by ultrasound into medical and surgical categories. Of the seven patients incorrectly classified, six (7%) were subsequently shown to have an extrahepatic obstruction and were therefore false negative for a 'surgical' jaundice, ultrasound having failed to detect dilated ducts, whereas in only one case was a false positive diagnosis recorded (Table 2).

Table 2 *Correct and incorrect results of ultrasound scanning in 84 patients with cholestatic jaundice, and of computer diagnosis in 169 similar patients*

Predicted diagnosis (ultrasound or computer)	*Ultrasound*	*Computer*
Surgical (dilated ducts)		
Correct	37	49
Incorrect	1	8
Medical (non-dilated ducts)		
Correct	38	103
Incorrect	6	9
Total		
Correct	75	152
Incorrect	7	17
Technical failures	2	0

Of the false negative results, only one patient had been jaundiced for as little as one week before investigation, the remainder for longer than three weeks.

In the 50 of these 84 patients in whom a diagnosis was also obtained by the computer-based model, a correct diagnostic separation was achieved in 43 patients (86%) by ultrasound and in 42 patients (84%) by computer, the difference between the two being statistically insignificant. This group of patients included the two ultrasound technical failures, both being correctly identified by the computer. Furthermore, in all cases the computer's accuracy was similar whether the calculated probabilities were high or low. Six of the computer diagnoses were false negatives, missing a surgical diagnosis, and two were false positive. All the errors for ultrasound represented false negatives (failure to detect dilated ducts), however, there being no false positive diagnosis of extrahepatic obstruction in the presence of a medical jaundice in this subgroup of patients. If the diagnosis obtained by both investigations are considered together, there is a 95% chance of an agreed diagnosis being correct (Table 3).

When the computer results in this subgroup were compared with those obtained in the total series of 169 jaundiced patients who had been examined in this way, over the same period of time, 152 (90%) of the latter group were correctly separated into medical and surgical categories, representing a slightly higher percentage accuracy than in the smaller group of 50 patients. The patients incorrectly diagnosed were evenly divided between false positive and false negative diagnoses.

Table 3 *Forty-eight patients with both successful ultrasound and computer calculated diagnosis available: combined accuracy of both techniques compared with final diagnosis*

Ultrasound and computer	*Comparison with final diagnosis*	
	Correct	*Incorrect*
Agree—39 patients		
'Medical'	20	2
'Surgical'	17	0
Total	37 (95%)	2 (5%)
Disagree—9 patients	Ultrasound correct in 6 Computer correct in 3	

Discussion

Our overall diagnostic accuracy rate of 80% for ultrasound is less than that of some series—97% of 150 patients (Taylor and Rosenfield, 1977) and 95% of 40 patients (Isikoff and Diaconis, 1977)—but compares favourably with others—86% of 35 patients (Malini and Sabel, 1977) and 88% of 26 patients (Vicary *et al.*, 1977)—particularly when the high proportion of complicated referred cases is considered. The number of technical failures is less than that of approximately 8% reported in some series (Vicary *et al.*, 1977).

The great majority of errors on ultrasound in our series represented a failure to diagnose the presence of a dilated biliary tree. Although four of the six false negative results were in patients with choledocholithiasis, we were unable to attribute these failures to carrying out the ultrasound examination too early for adequate dilatation of the biliary tree to have occurred, as has been suggested by others (Taylor and Rosenfield, 1977). Despite the lack of ultrasonic demonstration of dilated ducts in these patients, they were shown to be present by percutaneous cholangiography in three, endoscopic retrograde cholangiography in two, and at operative cholangiography in one.

The finding of dilated ducts by ultrasound was, in our experience, virtually diagnostic of extrahepatic biliary obstruction, the only false positive result being in a 6 month old child with biliary atresia thought to have dilated intrahepatic ducts on ultrasound, but shown to have narrow, atretic ducts at laparotomy and operative cholangiography. Seven of our patients were children with biliary atresia and the presence of intrahepatic ducts that

are smaller than usual was demonstrated by fine needle percutaneous cholangiography in all of them. However, the level of confidence for this apparently high accuracy of ultrasound in the case of a positive diagnosis of extrahepatic obstruction, must be directly related to the technical expertise available. The present results represent the working of an experienced operator and in this situation the ultrasound findings might be taken as sufficient evidence to proceed to immediate surgery without the need for cholangiography. Percutaneous transhepatic cholangiography by the fine needle technique may still be worth carrying out in cases going to surgery in order to demonstrate the site, as well as the likely nature, of the obstruction. In a proportion of cases, ultrasound can be of additional help in this respect (Taylor and Rosenfield, 1977) by directly demonstrating lesions such as biliary calculi or a mass in the pancreas, but we have deliberately excluded data on this for a clearer assessment of the accuracy of ultrasound in the straightforward differentiation of 'surgical' from 'medical' jaundice. In our experience, the absence of dilated ducts on ultrasound cannot necessarily be taken to indicate a 'medical' jaundice, although it does so in the majority of cases. Further investigations by ERCP and liver biopsy should always be performed where there is clinical or laboratory uncertainty that the cause of the jaundice is intrahepatic.

The present study shows that ultrasound can give a detection rate for surgical cholestasis that is as good as the best interpretation of all clinical information using the computer-based diagnostic model, including routine liver function tests. This demonstrates its value as an initial non-invasive screening test. The computer, however, though possibly little greater in accuracy than the clinical opinion of an expert specialist physician, provides an answer based on simple tests that is more reproducible and consistent than is available at a more general level (Stern *et al.*, 1974). At present its application involves the clinical discipline of recording carefully defined and coded information and relaying the data over a telephone to a distant computer for analysis, as well as periodical upgrading of the data bank. However, the development of cheap microcomputers and hand calculators capable of storing the data and making the necessary calculations will gradually allow the use of calculated probabilities to become more acceptable and available to clinicians. Ultrasound may be more practicable at present as it is reasonably inexpensive and could be generally available in non-specialised centres requiring its use for other areas of diagnostic endeavour, such as obstetrics. Its disadvantage is the degree of observer variation that exists particularly among the inexpert, and the high level of training and experience required. In this paper we have not attempted to estimate confidence levels for ultrasound observations, although studies of observer variability will be needed for this technique, just as they are for others, for more complete assessment of its future value. Such difficulties will be minimised and accuracy improved with the advent of more precise and versatile technical developments such as real-time ultrasound scanning, already in use in the obstetric field, or computer analysis of standard ultrasound data.

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