Leading article

Intraoperative abdominal ultrasound

Although radiologists have been using ultrasound for 30 years it is only recently that surgeons have started to apply an ultrasound probe to the organs of the abdomen that are not so easily examined by conventional palpation. Intraoperative ultrasound provides the surgeon with interesting pictures but does it actually provide additional information? Does its use contribute to changes in patient management or even improve patient survival? Should its use be confined to a few centres and is it cost effective?

The resolution of detail by ultrasound depends on the tissue attenuation and the frequency of the transducer used.¹ Resolution can be improved by increasing the frequency of the ultrasound beam but at the expense of decreasing the image depth. A 5 mm cyst 4 cm deep within the liver might be missed by a 3.5 MHz transducer on the liver surface but seen with a 7 MHz transducer, whilst a 10 mm cyst 10 cm from the probe might be visualised by a 3.5 MHz transducer but missed by a 7 MHz transducer.

Intraoperative ultrasound can accurately localise renal calculi at surgery² and determine the extent of invasion of gastric cancers and therefore the degree of radical lymph node dissection necessary and the site of the stomach resection line at gastrectomy.³ The main use of intraoperative abdominal ultrasound, however, has been in imaging the pancreas, bile ducts, and liver.

The pancreas is a difficult organ to image preoperatively but at surgery, with good mobilisation, detection of any abnormality by palpation would seem to be straightforward. Plainfossé *et al* have shown that of 22 patients with suspected pancreatic carcinoma all masses were palpable but that intraoperative ultrasound provided supplementary diagnostic information in 18%.⁴ Rifkin and Weiss⁵ reported two examples of jaundice caused by impalpable pancreatic tumours which were visualised by intraoperative ultrasound.

Intraoperative ultrasound has also been recommended for investigation of patients with endocrine tumours of the pancreas. Klotter *et al* found that intraoperative ultrasound had a sensitivity for detecting these tumours of 89% compared with 83% for palpation.⁶ Angelini *et al* improved the detection rate of insulinomas from 74% for surgical palpation to 100% for intraoperative ultrasound.⁷ Cromack *et al* found that intraoperative ultrasound was not as accurate as palpation in detecting gastrinomas but it was able to assist in the diagnosis of suspicious palpable nodules.⁸ Intraoperative ultrasound has also been used during surgery for pancreatitis⁹ where it has been shown to be able to identify small impalpable pseudocysts and dilated ducts, although it is not known what benefit the patient gains from the detection of such abnormalities.

Palpation is unreliable for detecting stones within the common bile duct. Operative cholangiography is easy to perform but may lead to a high proportion of false positive examinations resulting in negative duct explorations.¹⁰ Intraoperative ultrasound of the common bile duct has been evaluated and compared with cholangiography in two large series.^{11,12} Of the patients who had common bile duct exploration both studies showed an accuracy for intraoperative ultrasound of over 90% and for cholangiography of less than 80%. Intraoperative ultrasound was said to be quick to perform (five to seven minutes), cheap but with a long

learning period. It is not invasive and does not require isolation and cannulation of the cystic duct. Air within the duodenum may degrade the image, however, air bubbles within the biliary tree may be mistaken for calculi and ultrasound cannot provide the surgeon with a view of the anatomy of the biliary tree nor show the passage of contrast into the duodenum.¹¹ In addition, the identification of stones within intrahepatic ducts is difficult.

Approximately 20 intraoperative ultrasound systems are now in operation in the United Kingdom and in most cases they have been purchased as an aid to liver resection and the detection of occult neoplastic lesions within the liver. Much of the credit for highlighting the value of intraoperative hepatic ultrasound must go to Bismuth and Castaing. They have described the technique of operative ultrasound of the liver and have shown how it may be of use in the identification of normal structures within the liver, for the recognition of anatomical anomalies and the identification of pathological lesions.¹³ Couinaud has described many variations in the anatomy of the veins within the liver¹⁴ and intraoperative ultrasound is the only method by which the surgeon can determine whether the anatomy conforms to a standard pattern. With a knowledge of the anatomy of the liver determined by ultrasound a lesion detected can be localised to one of the eight segments allowing a segmental resection rather than a hemihepatectomy to be performed. The portal vein branch feeding this segment can be imaged and cannulated with a fine needle.^{15,16} Injection of dye into the segment and occlusion of the feeding vein by a balloon at the tip of the cannula outlines the segment to be resected and occludes its blood flow so allowing the surgeon to carry out a bloodless resection as well as reduce the amount of liver that is resected. Bismuth *et al* have shown that the use of intraoperative ultrasound has altered their management in 26% of patients undergoing laparotomy for liver tumours.¹⁷ Makuuchi *et al* have described a large series of patients undergoing laparotomy for proposed liver resection. For the detection of hepatocellular carcinomas less than 5 cm in diameter intraoperative ultrasound had a sensitivity better than preoperative ultrasound, angiography or computed tomography. Intraoperative ultrasound was also more accurate at detecting intrahepatic metastases and tumour thrombi. Sixty five per cent of their patients with small hepatocellular carcinomas associated with cirrhosis had invisible and impalpable tumours which were only localised at surgery by intraoperative ultrasound.¹⁸

Up to 30% of patients undergoing an apparently curative resection of a carcinoma of the colon or rectum have occult liver metastases at the time of their bowel resection.¹⁹ Contact ultrasound of the liver performed at necropsy has the ability to detect liver metastases down to a diameter of 5 mm²⁰ and therefore intraoperative ultrasound should be able to detect a certain proportion of occult metastases which are impalpable at surgery either because they are too small to be felt or because they exist in an impalpable part of the liver.

Boldrini *et al* have examined the systematic use of intraoperative ultrasound during surgery for colorectal cancer.²¹ Of 86 patients scanned, metastases were diagnosed in 21 patients and intraoperative ultrasound detected metastases in two patients which were not detected by palpation, preopera-

tive ultrasound or computed tomography scan. Machi compared intraoperative ultrasound with palpation in patients with colorectal cancer and found occult metastases in five of 33 patients.²² We have also found occult metastases in approximately 10% of patients undergoing surgery for colorectal cancer,²³ and have detected metastases as small as 5 mm in diameter. Systematic examination of the liver by intraoperative ultrasound takes approximately 10 minutes and can be performed without mobilising its attachments. Biopsy of suspicious lesions may be carried out under intraoperative ultrasound control using a biopsy gun although there is a theoretical risk of seeding malignant cells within the needle tract.²⁴ At present the technique cannot be recommended for routine use during colorectal surgery until some form of treatment is available for patients who are harbouring occult metastases. In our hands, intraoperative ultrasound has not increased the number of patients suitable for resection. Should a locally ablative treatment for colorectal metastases such as cryotherapy^{25, 26} prove effective intraoperative ultrasound will be of value not only for detecting metastases but for monitoring treatment.

Who should be using intraoperative ultrasound and what type of equipment? The ability of intraoperative ultrasound to identify previously undetected lesions and to localise a lesion to a particular segment so that a lesser resection can be performed is valuable during hepatic resection and in this situation the use of intraoperative ultrasound can benefit patient management. Intraoperative ultrasound may prove useful during pancreatic surgery and its role in detecting common bile duct stones should be expanded further. As far as equipment is concerned either a linear array or a sector scanner may be used. A linear array scanner produces a more anatomical like image but usually with a narrow field of view whereas a sector scanner has the advantage of a wide field of view and may be applied to irregular aspects of the liver's surface such as the hilum or inferior surface. The cost effectiveness of intraoperative ultrasound is unknown but one advantage of the newer scanners is that the hepatobiliary surgeon and his urological or gynaecological colleagues can use the same scanner but with a different probe so that the cost is shared.

R M CHARNLEY
J D HARDCASTLE

Department of Surgery
University Hospital
Nottingham

Correspondence to: Professor J D Hardcastle,
Dept of Surgery, E Floor, West block,
University Hospital, Nottingham NG7 2UH.

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