Utility of Operative Ultrasound in the Surgical Management of Liver Tumors

In this study the utility of operative ultrasound in the surgical management of 98 consecutive patients with liver and gastrointestinal tumors was assessed. All patients had preoperative workup including ultrasound study of the liver as well as selective hepatic arteriography (50 patients) and computerized tomography of the liver (45 patients). At surgery, inspection and palpation of the liver as well as operative ultrasound examination were performed in all cases. Fifty-six patients were known to have liver tumors before operation, while 42 patients had their liver examined as part of the treatment of a primary gastrointestinal malignancy. A total of 126 liver tumors were found in 58 patients, all of whom were confirmed histologically. Eighteen nodules unsuspected before operation were found at surgery—nine by inspection and palpation of the liver, and nine others that were nonpalpable were found by operative ultrasound only. Eighteen lesions that were missed by all diagnostic modalities were found as secondary lesions on pathologic examination of the resected specimens. In addition to diagnostic applications, operative ultrasound was useful in localizing nodules and permitting guided biopsies deep in the hepatic parenchyma. In eight cases, segmental resections were performed with operative ultrasound to localize the plane of section and to catheterize the intrahepatic portal vein branch afferent to the tumor in order to perform balloon catheter occlusion of the vessel for control of bleeding.

Operative ultrasound was found to be important in the surgical management of 19 of 98 patients (19%).

The evolution of radiologic techniques—ultrasound, computed tomography (CT), and selective hepatic arteriography—has brought a large number of patients with potentially treatable liver lesions to the attention of the surgeon, often with an already established diagnosis. However, these techniques do not always provide the topographic precision necessary for the planning and execution of anatomic liver resections, which can be adapted to the size and location of the lesion and the condition of the underlying liver parenchyma.

Operative ultrasound promises to be a useful tool for the liver surgeon because the external landmarks of the liver provide only an incomplete guide to the "internal" vascular anatomy. In the surgical treatment of liver tumors, it is expected that the increased information brought by operative ultrasound will result in both diagnostic and technical advances.

Operative ultrasound has several advantages that are particularly important in hepatic surgery: (1) Since no energy is lost by the ultrasound signal by passage through the abdominal wall, higher frequency scanning (5 or 7.5 MHz) can be used, which permits greater resolution and the detection of smaller lesions; (2) the ultrasound study is performed with the probe in the surgeon's hand, and this the image obtained can be related directly to the external landmarks of the liver by the position of the probe; and (3) sophisticated maneuvers can be performed under ultrasound guidance, such as needle biopsy or cannulation of biliary or vascular elements.1

In this study, we have attempted to define the practical consequences of routine use of operative ultrasound in the surgery of both primary and secondary liver tumors.

Materials and Methods

In 1983 and 1984, operative ultrasound was used in the management of 98 consecutive patients with hepatic and gastrointestinal tumors. Fifty-six patients were known to have liver tumors before operation (25 hepatocellular carcinomas, or HCC, 25 secondary liver cancers, 6 benign

* Chief Resident in Surgery. Hopital Paul Brousse, Villejuif.
‡ Radiologist, Hopital Paul Brousse, Villejuif.
§ Professor in Surgery, Hopital Paul Brousse, Villejuif.
Reprint requests: Denis Castaing, M.D., Department of Surgery, Hopital Paul Brousse, 14 Avenue P.V. Couturier, 94800 Villejuif, Cedex, France.
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Fig. 1. This 60-year-old man had a liver tumor (T) in segment 8. Right. Echo-guided puncture of the segmental portal vein branch of 8. The tip of the needle (n) can be identified by injecting saline and the resulting microbubbles will appear as hyperechogenic shadows. Left. Placement of a balloon catheter (bc) into the portal branch of segment 8. Balloon occlusion permits intrahepatic vascular control to reduce blood loss. Note the reduction of the diameter of the portal branch.

tumors), while 42 patients without known liver tumors had their liver explored during the treatment of gastrointestinal (GI) primary malignancies.

All patients underwent preoperative hepatic ultrasonography performed by the same examiner. Real-time sector scanning with a 3.5 MHz probe (GEM, Sonoscope 390) (General Equipment Medical France, Arcueil, France) was used for all studies. Fifty patients had selective hepatic arteriography with delayed parenchymal and venous phases of the injection. Forty-five patients had abdominal CT scans with intravenous contrast. At operation, all patients had systematic ultrasound examination of the liver, as described previously.2,3 A sterilizable 5-MHz probe was used with either the Aloka model SSD

Fig. 2. In this 52-year-old man with posthepatitic cirrhosis, a 25 mm hypoechogenic tumor (T) of segment 5 was discovered by screening echography. This tumor was unresectable and an embolization using butyl acrylate (ba) of the portal branch was performed with unilateral ligation (l) of right branch of the hepatic artery (rha). mhv = middle hepatic vein; rbpv = right branch of the portal vein.
TABLE 1. Diagnosis of Liver Tumors, a Comparison of Imaging Techniques in the Identification of 126 Liver Tumors (in 98 Patients)*

<table>
<thead>
<tr>
<th>Diameter of Tumor</th>
<th>Arteriography ( % )</th>
<th>CT Scan ( % )</th>
<th>Preoperative Ultrasound ( % )</th>
<th>Surgical Exploration ( % )</th>
<th>Operative Ultrasound ( % )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greater than 30 mm</td>
<td>45/60 (75%)</td>
<td>16/20 (80%)</td>
<td>56/20 (93%)</td>
<td>56/60 (93%)</td>
<td>57/60 (95%)</td>
</tr>
<tr>
<td>Between 10 and 30 mm</td>
<td>3/21 (14%)</td>
<td>2/5 (40%)</td>
<td>20/26 (77%)</td>
<td>20/26 (77%)</td>
<td>21/26 (81%)</td>
</tr>
<tr>
<td>Less than 10 mm</td>
<td>3/35 (8%)</td>
<td>2/5 (40%)</td>
<td>10/40 (25%)</td>
<td>21/40 (52%)</td>
<td>21/40 (52%)</td>
</tr>
<tr>
<td>Total</td>
<td>51/126 (40%)</td>
<td>20/30 (67%)</td>
<td>86/126 (68%)</td>
<td>97/126 (77%)</td>
<td>99/126 (78.5%)</td>
</tr>
</tbody>
</table>

* Results expressed as ratio of lesions found by the test/lesions confirmed on histology in the patient having the test.

256 (AHS France, Cedex, France) or CGR Scanel 500 (CGR Ultrasonic, Cedex, France), both of which are real-time systems with a linear scanning array.

Intraoperative biopsy was performed to confirm the identity of all lesions found unless a tissue diagnosis had been obtained before operation. Lesions identified only by operative ultrasound were biopsied with a Menghini needle under ultrasound guidance. Histologic confirmation of all lesions was obtained either by biopsy or on examination of the resected specimen.

Ultrasound-guided cannulation of intrahepatic portal vein branches was performed in 5 of 26 hepatic resections; After puncture of the branch afferent to the tumor, the needle was used to inject methylene blue to mark the hepatic parenchyma of a specific portal territory. For difficult resections, a balloon catheter was placed into the portal vein branch using the Seldinger technique for the performance of an intrahepatic localized portal vein occlusion (Fig. 1).

In three unrespectable HCC, the intrahepatic portal catheter was used to perform embolization with butyl acrylate, which, combined with unilateral hepatic artery ligation, produced selective tumor ischemia2 (Fig. 2). Under echoguidance, a needle was placed in the portal branch of the tumor, and total obstruction of this vein was obtained by injections of butyl acrylate. A Silastic® sling was placed around the hepatic artery and its two extremities brough out through the abdominal incision to obtain, in the postoperative period, a temporary occlusion of the hepatic artery, and, as a result, a selective total ischemia of tumoral nodules.4 In addition, the occlusion of the portal branch of the tumor aims to avoid retrograde portal extension of the tumor by the intraportal tumoral clot, which is frequently present.

RESULTS

In this group of 98 patients (56 with liver tumors known before operation and, in the 42 patients without known liver tumors before operation, two with hepatic metastases discovered during operation and 40 without tumors), 126 tumoral nodules were found by a combination of the above techniques with surgical exploration and/or histology of the specimen.

The 25 patients with HCC had 49 tumoral nodules, and 27 patients with hepatic metastases were found to have a total of 71 tumoral nodules in the liver. In two of these patients, liver metastases unknown before operation and undetected by intraoperative palpation were found during operation only by ultrasound. In the first patient, with an apparently localized cancer of the head of the pancreas, hepatic ultrasound, CT scan, and selective arteriography showed no evidence of metastases. However, operative ultrasound demonstrated a 1.2-cm lesion that was confirmed by guided needle biopsy. In the second case, a nonpalpable liver metastasis from a sigmoid primary tumor was found by operative ultrasound despite negative preoperative ultrasound and CT.

The 40 remaining patients had treatment of gastrointestinal (GI) primary tumors with no evidence of liver lesions at the time of surgery.

In the six patients with known benign liver tumors, the tumors were found to be solitary at operation; three had hemangiomas, two had focal nodular hyperplasia, and one had hepatic adenoma.

DIAGNOSTIC EFFICACY OF IMAGING TECHNIQUE

The relationship between tumor size and successful detection by the different imaging techniques is summarized...
in Table 1. The sensitivity, specificity, and predictive value of the studies are presented in Table 2.

Using the preoperative studies, nearly all of the tumors greater than 3 cm were identified before operation (Table 1). A single false-positive result was noted in this group in which a segmental atrophy in a cirrhotic liver was mistaken for a hypervascular tumor on arteriography. One tumor was found by operative ultrasound alone. For tumors between 1 and 3 cm in diameter, preoperative studies were less sensitive: only 14% of the lesions were detected by arteriography. Preoperative ultrasound detected 77% of these tumors. Three additional lesions were found at surgery; all superficial lesions were evident on inspection of the liver. Preoperative studies were less reliable in tumors less than 1 cm in diameter. Nine of these were discovered by inspection and palpation of the liver, while nine others were nonpalpable and discovered by operative ultrasound only. Eighteen liver nodules not detected by a diagnostic test were found by a careful examination of the resected specimen.

In the imaging of liver tumors, positive studies have a high predictive value (Table 2). Operative ultrasound complements surgical palpation, since it detects more deeply placed lesions that are difficult to palpate, especially in abnormal hepatic parenchyma (Fig. 3).

**Topographic Precision in the Imaging of Liver Tumors**

As shown in Table 3, both preoperative ultrasound and CT provide accurate segmental localization of the tumor in most cases. Operative ultrasound permits the location of the tumor to be confirmed at surgery even when the tumor is not palpable (Fig. 4).

**Utility of Operative Ultrasound (Table 4)**

Of the 25 patients with HCC, 14 were found to have unresectable disease at laparotomy. In three patients, nonpalpable contralateral metastases were found by ultrasound, which led to a decision not to perform resection. Three of these 14 patients were treated with selective in-

<table>
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<tr>
<th>Tumor Diameter</th>
<th>Arteriography</th>
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<th>Preoperative Ultrasound</th>
<th>Surgical Exploration</th>
<th>Operative Ultrasound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greater than 30 mm</td>
<td>32/45 (71%)</td>
<td>13/16 (81%)</td>
<td>54/56 (96%)</td>
<td>53/56 (95%)</td>
<td>56/57 (98%)</td>
</tr>
<tr>
<td>Between 10 and 30 mm</td>
<td>2/3 (67%)</td>
<td>2/2 (100%)</td>
<td>19/20 (95%)</td>
<td>18/20 (90%)</td>
<td>21/21 (100%)</td>
</tr>
<tr>
<td>Less than 10 mm</td>
<td>2/3 (67%)</td>
<td>2/2 (100%)</td>
<td>7/10 (70%)</td>
<td>17/21 (81%)</td>
<td>21/21 (100%)</td>
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</tbody>
</table>

* Results presented as a ratio of tumors correctly localized/tumors diagnosed by that test in the patient having the test.
trahepatic portal embolization and delayed hepatic artery ligation. Of the 11 patients who underwent resection, three were noncirrhotic and eight were cirrhotic. Of the three patients without cirrhosis, one underwent orthotopic transplantation, the second extended right hepatectomy, and the third, who had had a left extended hepatectomy 1 year previously, underwent localized resection of a nonpalpable recurrence, which was performed under ultrasound guidance. In the eight cirrhotic patients, three (2

### Table 4. Influence of Operative Ultrasound on the Surgical Management of 98 Patients with Hepatic and Gastrointestinal Tumors

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Patients (N)</th>
<th>Effect of Operative Ultrasound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Patients</td>
</tr>
<tr>
<td>Hepatocellular cancer</td>
<td>25</td>
<td>11</td>
</tr>
<tr>
<td>Liver metastases</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>Benign liver tumors</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Nonhepatic GI tumors</td>
<td>42 (Primary resected in 41)</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>98</td>
<td>4</td>
</tr>
</tbody>
</table>

* Information obtained by operative ultrasound altered the surgical approach in 19 of 98 patients (19%).

With lesions in segment 8 and 1 with a lesion deep in segment 4) were treated with subsegmental resections, using balloon catheter control of portal venous bleeding, and five with more accessible tumors were treated with smaller resections that could have been performed without operative ultrasound. Operative ultrasound played a significant role in the treatment of seven of the 25 patients with HCC.

Of the 25 patients with liver metastases, ten had unresectable tumors. Two patients in this group had intraoperative discovery of nonpalpable contralateral lesions, which led to a decision not to resect the principal mass. In the 15 resected patients, ten formal anatomic resections were performed. Five patients were treated with segmental resections under ultrasound guidance, of which two were performed using intrahepatic portal vein occlusion to control bleeding. Operative ultrasound was important in nine of the 25 patients with metastatic liver disease.

As described earlier, operative ultrasound identified nonpalpable liver metastases in two of the 42 patients with nonhepatic GI malignancies that would not otherwise have been recognized.

Operative ultrasound was useful in one of the six patients with benign liver tumors. A nonpalpable liver tumor that had been identified by preoperative studies was biopsied during operation and found to be benign. Localized liver resection was performed.

In reviewing the entire series of patients, operative ultrasound improved the therapy of 19 of 98 (19%) patients

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*Information obtained by operative ultrasound altered the surgical approach in 19 of 98 patients (19%).

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*Fig. 4. This 68-year-old man had a liver metastasis (T) from a cancer of the rectum discovered 2 years after treatment of the primary. Ultrasound demonstrated clearly the location of the tumor in segment 6, permitting a segmental resection. rhv = right hepatic vein; rbpv = right branch of portal vein.*
with abdominal pathology and of 17 of 56 (30%) patients operated on for liver tumors.

Discussion

The findings of this review emphasize the utility of operative ultrasound in digestive surgery. It is most important in two situations: (1) when the detection of small lesions is important, such as mandatory in-screening for liver metastases, and (2) in the diagnosis and therapy of liver tumors in patients with abnormal hepatic parenchyma, such as in cirrhosis or in patients who had previous liver surgery. Although most patients can be managed successfully without these techniques, operative ultrasound is often helpful and sometimes necessary.

The diagnostic utility of operative ultrasound in the management of HCC in cirrhosis has been stressed by several authors.6-7 Sheu et al. have reported that 49.5% of HCC less than 3 cm in size were nonpalpable at surgery.6 A pessimistic attitude toward the treatment of small HCC in cirrhosis is not appropriate, since 5-year survivals of greater than 50% have been reported in two recent series.6,8

Operative ultrasound has been used to perform intraoperative maneuvers that have been introduced by several Japanese authors, in particular Makuuchi and Hasegawa.1-5 The intrahepatic cannulation of the portal vein has as its basis the observation that the intrahepatic dissemination of HCC often occurs by the mechanism of malignant portal vein thrombosis.1,10 As the thrombus progresses toward the hilus from the portal vein branch afferent to the tumor, emboli are showered distally at each portal vein bifurcation. The hepatic territory corresponding to the portal thrombosis is thus at risk for tumor spread. With ultrasound guidance and balloon catheter insertion when necessary, localized liver resections, which preserve liver parenchyma and provide adequate tumor margins, can be performed. These considerations are critical in the cirrhotic patient in whom the risk of postoperative hepatic insufficiency is important.11

Anatomic liver resections based on the segmental anatomy described by Couinaud12 were described and performed before the introduction of operative ultrasound.13 However, their planning and execution are made more precise by the reliable anatomic data provided by operative ultrasound. Adequate tumor margins can be obtained without the systematic performance of extended liver resections for all tumors.13

Although operative ultrasound permitted the diagnosis of two unsuspected liver metastases in a series of 42 patients with extrahepatic primary tumors, its role as a screening device is uncertain. It does not resolve the problem of micrometastasis, and, in the absence, of effective adjuvant therapy for GI malignancies, the therapeutic consequences of improved methods of detection must be the subject of further study.

In the surgery of benign tumors, the role of operative ultrasound is primarily in the performance of guided needle biopsy; thus, the identity of suspicious lesions can be established without resection. Blind radical resections for inaccessible lesions therefore can be avoided.

As greater experience is accumulated, the role of operative ultrasound in liver surgery will be better defined. Our initial experiences were highly favorable, and we have now adopted it as a routine practice. The anatomic precision that operative ultrasound provides permits greater confidence in the execution of surgical maneuvers in liver disease.

References