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Intraoperative Sonography of Hepatocellular Carcinoma: Detection of Lesions and Validity in Surgical Resection

Byung Ihn Choi,[1] Joon Koo Han,[1] In Sup Song,[1] Chu-Wan Kim,[1] Man Chung Han,[1] Soo Tae Kim,[2] Hyo Suk Lee,[3] Chung Yong Kim,[3] and Yong Il Kim[4]

Departments of [1]Radiology, [2]Surgery, [3]Internal Medicine, and [4]Pathology, Seoul National University College of Medicine, Seoul, Korea

Abstract. Eighty-six hepatocellular carcinomas (HCCs) in 67 patients were examined by intraoperative sonography. Sensitivity for detecting tumors with intraoperative sonography was compared with sonography, computed tomography (CT), hepatic angiography, and CT after intraarterial injection of iodized poppy-seed oil (Lipiodol-CT). The overall sensitivities were 76% with sonography, 86% with CT, 89% with angiography, 96% with Lipiodol-CT, and 98% with intraoperative sonography. The differences in sensitivity between intraoperative sonography and sonography ($p < 0.01$), CT ($p < 0.01$), and angiography ($p < 0.05$) were significant. In 35 lesions smaller than 2 cm, the sensitivities of Lipiodol-CT and intraoperative sonography were high (91 and 94%, respectively). In operating field, tumors were invisible in 36 (42%) and nonpalpable in 31 of 86 cases (36%). In 35 tumors smaller than 2 cm, invisible tumors were 66% and nonpalpable tumors were 63%. However, 84 of 86 cases (98%) could be localized with intraoperative sonography.

These results suggest that intraoperative sonography is the final diagnostic imaging procedure before surgical resection of tumors and in cases of invisible and nonpalpable tumors in the operating field, this procedure is mandatory to improve surgical results.

Key words: Liver neoplasms—Liver neoplasms, diagnosis—Liver neoplasms, computed tomography—Liver neoplasms, ultrasound—Liver neoplasms, angiography.

Address offprint requests to: Byung Ihn Choi, M.D., Department of Radiology, Seoul National University Hospital, 28 Yongon-dong Chongono-gu, Seoul 110-744, Korea

Hepatocellular carcinoma (HCC) is the most common primary liver malignancy in southeast Asia and sub-Saharan Africa, and the prognosis is extremely poor because of the difficulty in early detection and its frequent association with cirrhosis [1]. Although transhepatic arterial embolization using iodized poppy-seed oil (Lipiodol, Guerbet) mixed with anticancer drugs and percutaneous ethanol injection have been introduced in the treatment of HCC [2–5], surgical resection is the most effective treatment of HCC, particularly small lesions [6].

Fortunately, recent advances in liver imaging techniques, such as sonography, computed tomography (CT), angiography, and CT after intraarterial injection of Lipiodol (Lipiodol-CT), make it possible to detect small HCCs. However, these techniques have their own limitations and pitfalls in detecting small tumors [7]. Furthermore, small HCCs may not be seen or palpated from the surface of the liver in operating procedure. Therefore, additional diagnostic procedures are necessary to determine operability and the best operative method. Intraoperative sonography is useful in this setting and has been used by Japanese physicians [8–10]. However, to our knowledge, the validity of intraoperative sonography in the surgical resection of HCCs has not yet been reported in the English literature.

We performed intraoperative sonography before hepatectomy to evaluate the diagnostic accuracy and limitation with comparison of sonography, CT, angiography, and Lipiodol-CT, and studied its contribution to operative procedures.

Materials and Methods

During a recent 22-month period, liver surgery with intraoperative sonography was performed on 81 patients.

Table 1. Detectability of HCC by five imaging techniques

Tumor size (cm)	Number of tumors	Sonography (%)	CT (%)	Angiography (%)	Lipiodol-CT (%)	Intraoperative sonography (%)
≤ 2	35	19/31 (61)	24/35 (69)	26/35 (74)	29/32 (91)	33/35 (94)
≤ 5	30	19/23 (83)	28/29 (97)	29/29(100)	24/24(100)	30/30(100)
> 5	21	17/18 (98)	21/21(100)	20/20(100)	16/16(100)	21/21(100)
Total	86 (100)	55/72 (76)	73/85 (86)	75/84 (89)	69/72 (96)	84/86 (98)

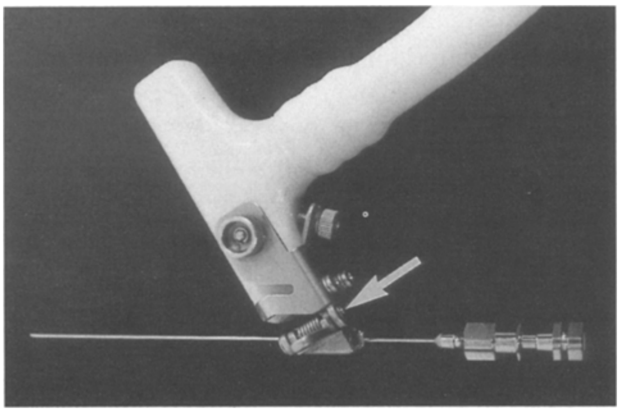


Fig. 1. TU-type transducer used in intraoperative sonography. An adapter (*arrow*) is attached to the transducer and needle for guided punctures.

Of these, 67 patients with 86 HCCs were selected for this study. The group comprised 65 men and two women, 24–71 years of age (mean age, 52 years). Clinical and laboratory data were reviewed in all patients. Most had chronic liver disease. Hepatitis-B surface antigen (HBsAg) was positive in 47 patients (70.1%). Fifteen patients (22.4%) had a normal serum alpha-fetoprotein (AFP) level (< 20 ng/ml) and 27 (40.3%) had an AFP level of 20–400 ng/ml. In 25 (37.3%), serum AFP levels were above 400 ng/ml. Liver cirrhosis was found in 51 patients (76.1%).

For intraoperative sonography we used an Aloka 630 (Aloka, Tokyo, Japan) linear electronic scanner and T-type transducers of 5 and 7.5 MHz, TU- and I-type of 7.5 MHz. For sonographically guided puncture, a T- or TU-type transducer with a special adapter and 22-gauge needle were employed (Fig. 1). The transducers were sterilized with EO gas. Sonography was performed immediately after laparotomy and scans were generally performed across the entire liver in both transverse and sagittal planes. In 24 patients, puncture of the portal venous branch which supplied the tumor nodule and injection of 5 ml of indigo carmine dye were done for systematic subsegmentectomy of the liver (Fig. 2), according to the method of Makuuchi et al. [11]. Sonography, CT, angiography, and Lipiodol-CT were performed in 58, 66, 65, and 56 patients, respectively. Technique of each study has been described in the literature [7]. All of these studies were done within 1 month. The interval between these studies and surgery ranged from 0.5 to 2 months.

The detectability of tumor nodules by intraoperative sonography was evaluated on the basis of intraoperative and pathologic findings and was compared with those of conventional sonography, CT, angiography, and Lipiodol-CT. Validity of intraoperative sonography in determining tumor size and location during the surgical procedure was compared with the surgeon's vision and palpation.

Results

Of the 67 patients with HCCs, 52 had one tumor, 11 had two tumors, and four had three tumors. The diameters of the tumors were as follows: ≤ 20 mm (35), 21–50 mm (30), and > 50 mm (21). The tumor was located in the anterior segment of the right hepatic lobe in 36 cases, the posterior segment of the right hepatic lobe in 40, the medial segment of the left hepatic lobe in five, and the lateral segment of the left hepatic lobe in five cases.

The overall detection rates of HCCs by sonography, CT, angiography, Lipiodol-CT, and intraoperative sonography are summarized in Table 1. In the conventional studies, sonography, CT, and angiography yielded detection rates of 76, 86, and 89%, respectively. The results obtained on screening studies showed sonography to be slightly less sensitive than screening CT but there was no statistically significant difference. However, Lipiodol-CT and intraoperative sonography were superior to sonography ($p < 0.01$) and CT ($p < 0.01$) in detecting HCCs. The detection rate of Lipiodol-CT was not significantly different from that of intraoperative sonography.

In 35 tumors smaller than 2 cm in diameter, the detection rate with each imaging procedure generally decreased. Statistically, there was a significant difference between intraoperative sonography and sonography ($p < 0.01$), CT ($p < 0.01$), and angiography ($p < 0.05$). Intraoperative sonography showed the best detection rate for lesions of any size (Fig. 3). Two small HCCs were not detected with intraoperative sonography. One of the undetected tumors was of small mass mimicking regenerating nodules of underlying liver cirrhosis. One of them was an isoechoic mass (Fig. 4).

In the operating field, tumors were invisible in 36 of 86 cases and nonpalpable in 31 of 86 cases (Fig. 5). In 35 tumors smaller than 2 cm in diameter, invisible tumors were 66% and nonpalpable tumors were 63% (Table 2).

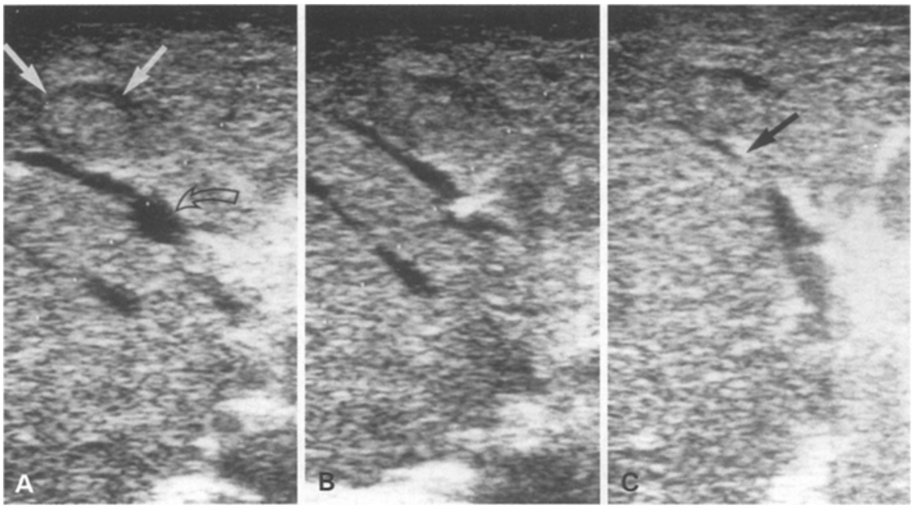
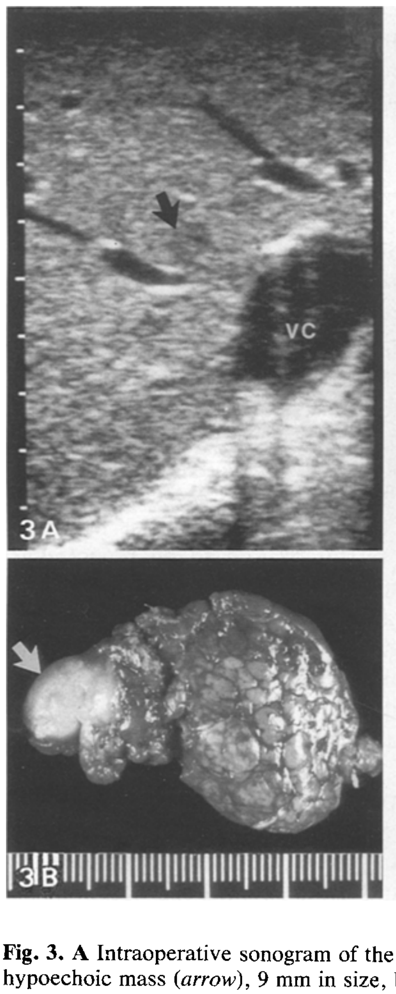
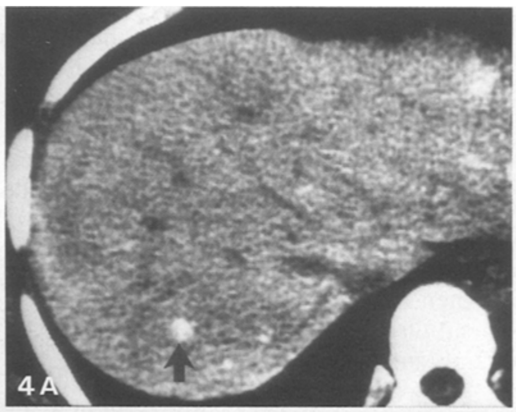
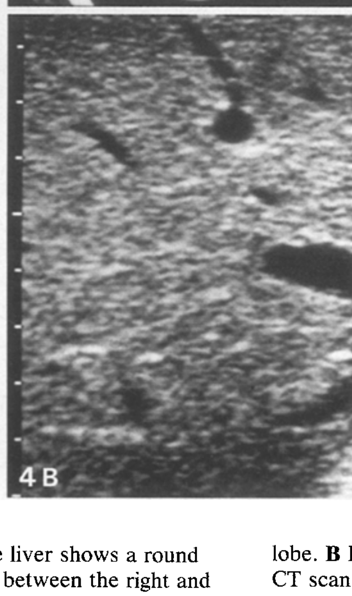


Fig. 2. Puncture of the portal venous branch and injection of dye. **A** A small HCC (*arrows*) and the feeding portal venous branch (*curved arrow*) of the right posterior portal vein are demonstrated. **B** This vein is punctured and the tip of the needle is clearly seen. **C** The injected dye demonstrates high echo (*arrow*) in the portal venous branch due to microbubbles in the dye.







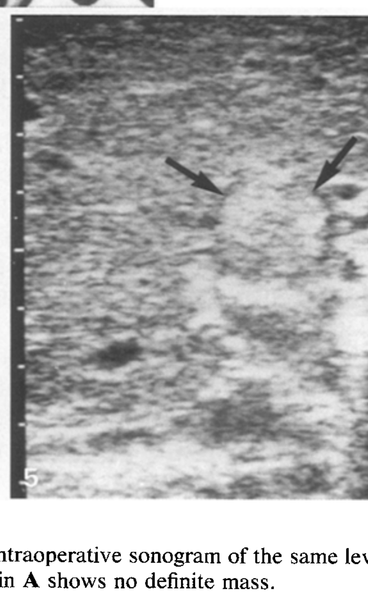


Fig. 3. **A** Intraoperative sonogram of the liver shows a round hypoechoic mass (*arrow*), 9 mm in size, between the right and middle hepatic vein. Other radio-logic modalities did not show this mass. *VC*, inferior vena cava. **B** Gross appearance of the resected specimen shows a tumor nodule (*arrow*) and macronodular cirrhosis.

Fig. 4. **A** Lipiodol-CT scan of the liver shows a round mass (*arrow*), 1 cm in size, in the posterior segment of the right hepatic lobe. **B** Intraoperative sonogram of the same level of the liver as CT scan in **A** shows no definite mass.

Fig. 5. Intraoperative sonogram of the liver shows a round hyperechoic mass, 2.0 cm in size, in the anterior segment of the right hepatic lobe. A thin hypoechoic capsule (*arrows*) is also seen. This mass was invisible and nonpalpable in the operating field.

Table 2. Deeply existing HCCs

Tumor size (cm)	Number of tumors	Invisible tumors (%)	Nonpalpable tumors (%)
≤ 2	35	23 (66)	22 (63)
≤ 5	30	9 (30)	6 (20)
> 5	21	4 (19)	3 (14)
Total (%)	86 (100)	36 (42)	31 (36)

Discussion

Although recent development of imaging techniques has made it possible to diagnose small, asymptomatic HCCs, each imaging technique has its own weakness and drawbacks. On sonography, one major difficulty is the detection of small lesions in the right hepatic lobe and tip of the left hepatic lobe immediately below the diaphragm where lung air interference is great. The other limitation of sonography is an isoechoic mass. The shortcomings of CT are partial volume effect caused by overlapping of surrounding structures and the blind area of the interslice gap. Another weakness of CT lies with isodense tumors. Pitfalls of angiography occur in the detection of small tumors and those of poor vascularity. Confusion can also occur when two masses are superimposed in the ventrodorsal direction. Lipiodol-CT has limitation in detecting small tumors with poor vascularity [7, 10].

On the contrary, intraoperative sonography rarely produces blind areas because scanning during an operation is not disturbed by the ribs, lung, or bowel and the distortion and weakening of sonographic beams caused by the abdominal wall can be avoided. Furthermore, a high-frequency transducer of 5.0 or 7.5 MHz is used and therefore the quality of images is excellent. In addition, sonography can demonstrate liver lesions and adjacent structures simultaneously and continuously from various directions, whereas CT or angiography cannot.

The detection rate of intraoperative sonography was 98% in our series. This finding is comparable with those of others [8–10]. Intraoperative sonography had the best accuracy of the various imaging procedures. In fact, intraoperative sonography is generally performed as a second, detailed study using information gathered from other methods. Therefore, bias may exist. Such a condition is inevitable, because thorough knowledge of the patient's condition is mandatory for surgery. However, the pitfalls of intraoperative sonography occur in detecting isoechoic small tumors. In addition, when associated liver cirrhosis was severe, the differentiation of small malignant nodules from regenerating cirrhotic nodules was extremely difficult with intraoperative sonography. In such cases, Lipiodol-CT is useful in differentiating small HCCs from regenerating nodules. On Lipiodol-CT, small HCCs can usually retain Lipiodol, whereas regenerating nodules do not [7,12]. Another method we can use preoperatively is a sonographically guided needle biopsy of the mass for the decision on the type of surgery.

Recently, intraoperative sonography-guided hepatectomy has largely replaced conventional hepatectomy for the treatment of tumors deep below the surface of the liver because detection rate of small tumors that cannot be seen or palpated from the liver surface increases. In our series, most of the tumors smaller than 2 cm in diameter were not visible (66%) and palpable (63%). In such cases, intraoperative sonography was useful in identifying tumors and visualizing spatial relationships between tumors and adjacent hepatic and portal veins, thus facilitating satisfactory hepatic resection of tumors.

Intraoperative sonography has additional benefit for sonographically guided puncture, which is a preliminary procedure for portal branch-oriented hepatectomy, also called systematic segmentectomy. In southeast Asia, HCCs frequently appear in association with cirrhosis of the liver and results of hepatectomy are poor. Foster [13] reported a 5-year survival rate after hepatic resection of 36% for non-Asians and 6% for Asians. Systematic segmentectomy or subsegmentectomy can avoid unnecessary wide hepatic resection that may lead to hepatic failure in cases of HCCs associated with liver cirrhosis. The application of intraoperative, sonographically guided puncture to hepatectomy is extremely useful. When cirrhosis of the liver makes major hepatectomy difficult, the portal branch to be resected is selectively punctured under sonographic guidance and 5 ml of indigo carmine is injected. The surface of the portal area of the liver containing the tumor is stained in blue color and the segment to be resected is clearly distinguishable from other segments through the liver surface [14].

On the basis of our experience, we believe that intraoperative sonography is the final diagnostic imaging procedure before surgical resection of tumors, and, in cases of invisible and nonpalpable tumors in the operating field, this procedures is mandatory to improve surgical results.

References

1. Sheu JC, Sung JL, Chen DS, et al. Early detection of hepatocellular carcinoma by real-time ultrasonography; a prospective study. *Cancer* 1985;56:660–666

2. Takayasu K, Shima Y, Muramatsu Y, et al. Hepatocellular carcinoma; treatment with intraarterial iodized oil with and without chemotherapeutic agents. *Radiology* 1987;162:345–351
3. Yamada R, Sato M, Kawabata M, Nakatsuka H, Nakamura K, Takashima S. Hepatic artery embolization in 120 patients with unresectable hepatoma. *Radiology* 1983;148:397–401
4. Livraghi T, Festi D, Mouti F, Salmi A, Vettori C. US-guided percutaneous alcohol injection of small hepatic and abdominal tumors. *Radiology* 1986;161:309–312
5. Shiina S, Yasuda H, Muto H, et al. Percutaneous ethanol injection in the treatment of liver neoplasms. *AJR* 1987;149:949–952
6. The Liver Cancer Study Group of Japan. Primary liver cancer in Japan. *Cancer* 1984;54:1747–1755
7. Choi BI, Park JH, Kim BH, Kim SH, Han MC, Kim CW. Small hepatocellular carcinoma; detection with sonography, computed tomography (CT), angiography and Lipiodol CT. *Br J Radiol* 1989;62:897–903
8. Igawa S, Sakai K, Kinoshita H, Hirohashi K. Intraoperative sonography; clinical usefulness in liver surgery. *Radiology* 1985;156:473–478
9. Hayashi N, Yamamoto K, Tamaki N, et al. Metastatic nodules of hepatocellular carcinoma; detection with angiography, CT, and US. *Radiology* 1987;165:61–63
10. Takayasu K, Moriyama N, Muramatsu Y, et al. The diagnosis of small hepatocellular carcinomas; efficacy of various imaging procedure in 100 patients. *AJR* 1990;155:49–54
11. Makuuchi M, Hasegawa H, Yamazaki S. Intraoperative ultrasonic examination for liver surgery and new concepts in partial hepatectomy. *Gekachiryo* 1981;44:579–586 [Japanese]
12. Yumoto Y, Jinno K, Tokuyama K, et al. Hepatocellular carcinoma detected by iodized oil. *Radiology* 1985;154:19–24
13. Foster JH. Survival after liver resection for cancer. *Cancer* 1970;26:493–502
14. Makuuchi M, Hasegawa H, Yamazaki S. Ultrasonically guided subsegmentectomy. *Surg Gynecol Obstet* 1985;161:346–350

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