Spiral Biphasic Contrast-Enhanced Computerized Tomography in the Diagnosis of Hepatocellular Carcinoma

Chin-Ming Jeng, Ching-Huei Kung, Yung-Chen Wang, Chau-Ying Wu, Wen-Yu Lee, Chin-Kai Fan, and Yong-Chien Huang

Abstract: Advances in spiral computerized tomography (CT) have made rapid biphasic contrast-enhanced CT possible. This study evaluated the capability of biphasic contrast-enhanced spiral CT to detect hepatocellular carcinoma (HCC). A total of 125 patients (68 men and 57 women) with proven HCC underwent preliminary noncontrast (NC) scanning, followed by hepatic arterial phase (HAP) and portal venous phase (PVP) imaging. Contrast medium (80 mL, 300 mgI/mL) was administered routinely at a rate of 2 mL/second using an automated contrast injector under guidance software monitoring. Study of NC and PVP images without concurrent study of HAP images detected 131/171 (76.6%) cases of HCC. In contrast, combined study of NC, PVP, and HAP images detected 153/171 (89.5%) cases of HCC. Thus, combined study of NC and biphasic images was able to detect an additional 12.9% of HCC cases in comparison with conventional study of NC and PVP images only. All HCCs that were detectable only on HAP imaging were enhanced homogeneously with contrast medium during the arterial phase.

Materials and Methods

From January 1998 through June 2000, 125 patients (68 men and 57 women aged 33–78 yr; mean age, 62 yr) with HCC referred for transarterial embolization (TAE) at our department were enrolled in this study. All underwent biphasic spiral CT studies of the liver prior to TAE.

HCC was histologically proven by percutaneous needle biopsy in 38 of these patients. Twenty-three patients had recurrent HCC after previous surgery or TAE. Diagnosis of HCC in the other 64 patients was made without direct histologic proof and was based on increased serum α-fetoprotein (AFP), changes in tumor size after TAE as observed on CT, and positive response to TAE with reduction
of serum AFP. The results of CT were also correlated with the findings of hepatic angiograms and/or CT during arterial portography (CTAP) prior to TAE.

All CT studies were performed using a spiral CT scanner (CTi, GE Medical Systems, Milwaukie, WI, USA). A series of noncontrast (NC) images was obtained in the craniocaudal direction as a control. Contiguous 10-mm-thick axial sections were reconstructed from the volumetric data. All HAP imaging was performed using similar parameters.

Eighty milliliters of a 300 mgI/mL nonionic iodinated contrast medium (Ultravist 300, Schering AG, Berlin, Germany) was injected at a rate of 2 mL/second using an automated power injector (EnVision-CT, Medrad, Pittsburgh, PA, USA) through a 21-gauge indwelling venous catheter in the antecubital vein. Contrast medium was injected under proper monitoring by SmartPrep injection guidance software installed in the scanner. The time to start scanning in the HAP was decided by the peak time of the contrast density curve with the region of interest fixed over the abdominal aorta at the hepatic level, usually about 21 to 26 seconds after the start of injection and depending on the physiologic status of the patient. PVP images were obtained in a caudocranial direction beginning about 30 seconds after completion of HAP studies.

Each hard-copy set of NC and PVP images with and without the corresponding HAP images was analyzed separately by two of the authors (CMJ and CHK) experienced in abdominal imaging in a blinded fashion without knowing the results from any other imaging modalities. On HAP and PVP images, tumors were judged on the basis of visual assessment to be hyperattenuating when they enhanced homogeneously, hypoattenuating when their attenuation was lower than the surrounding normal liver parenchyma, and isoattenuating when they could not be identified.

The chi-square test was used to compare the detectability of the lesion. A p value of less than 0.05 was considered statistically significant.

Results

The number of lesions detected using combinations of the three imaging techniques are listed in Table 1. Imaging results of a representative patient are shown in Figure 1. The number of tumors detected by NC and PVP imaging without and with HAP imaging are listed in Table 2 (Fig. 2). As shown in Tables 1 and 2, 131 tumors (76.6%) of 171 foci in 125 patients were detected by NC and PVP imaging, but 40 tumors (23.4%) were not found with this technique. Among these 40 tumors, 22 were only demonstrated on HAP imaging, and 18 (10.5%) were not found by combined reading (Table 2). All lesions detected on NC and PVP images appeared as hypoattenuating foci in contrast to surrounding hepatic parenchyma. In contrast, all lesions found on HAP images appeared as hyperattenuating foci.

The number of lesions detected by concurrent reading of NC, HAP and PVP images (89.5%) was significantly higher than the number of lesions detected without HAP imaging (76.6%; p < 0.002) (Table 2).

Eighteen tumors not detected on parallel HAP, NC and PVP images were confirmed by hepatic angiogram and/or CTAP.

Discussion

Several studies have shown that combined use of HAP and PVP images increases the rate of detection of hypervascular liver tumors [3–5]. This study compared the value of biphasic imaging with a modified contrast enhancement technique versus conventional CT in the detection of HCC.

NC images were obtained routinely as control scans prior to contrast enhancement in this study. As shown in Table 1, NC scanning led to detection of an additional six tumors (3.5%) in combination with HAP images in our series.

An intravenous bolus of contrast material is initially transported to the liver by the hepatic artery, approximately 20 seconds before opacification of the portal vein is achieved [1]. Hepatic dynamic scanning demonstrates hypervascular HCC supplied by hepatic arterial branches as hyperattenuating lesions during the hepatic arterial dominant phase after rapid injection of contrast medium, and then frequently demonstrates isoattenuating or hypoattenuating lesions on CT scans obtained during the subsequent portal venous dominant phase [7]. Our study found that HAP images were helpful in the detection of an additional 12.9% of lesions that were hyperattenuating on HAP images, but isoattenuating on NC and PVP images.

There are no definite rules on the optimal rate of injection for imaging the liver during the arterial phase. Theoretically, with a higher rate of injection, the dilution of the bolus of contrast material is minimized and the degree of enhancement of the hepatic artery is potentially increased. In previous studies, the rate of injection varied from 2 to 6 mL/second [3, 8–12]. Chambers et al indicated that the enhancing effects were not increased in response to the intravenous injection rate [9]. The rate of contrast injection might not be the only factor that influences the degree of enhancement.

Table 1. Number of tumors detected and not detected using the three imaging techniques

<table>
<thead>
<tr>
<th>Imaging technique</th>
<th>No. of tumors detected</th>
</tr>
</thead>
<tbody>
<tr>
<td>NC + HAP + PVP</td>
<td>69</td>
</tr>
<tr>
<td>NC + HAP</td>
<td>6</td>
</tr>
<tr>
<td>NC + PVP</td>
<td>23</td>
</tr>
<tr>
<td>HAP + PVP</td>
<td>24</td>
</tr>
<tr>
<td>PVP alone</td>
<td>9</td>
</tr>
<tr>
<td>HAP alone</td>
<td>22</td>
</tr>
<tr>
<td>No. of tumors not detected by any of the imaging techniques</td>
<td>18</td>
</tr>
<tr>
<td>Total no. of foci</td>
<td>171</td>
</tr>
</tbody>
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NC = noncontrast; HAP = hepatic arterial phase; PVP = portal venous phase.
Fig. 1. A 70-year-old female with a 3-cm hepatoma at the lateral aspect of segment 6/7 (white arrowhead) and another 3-cm hepatoma at segment 5 (black arrowhead). A, B) Noncontrast images show that both lesions were hypodense to hepatic parenchyma. C, D) Hepatic arterial phase images show similar hyperdense enhancement of both lesions. The aorta was enhanced strongly in both upper and lower images (black arrow). E) Portal venous phase (PVP) image shows that the lesion was mildly hypodense to hepatic parenchyma of the upper lesion (white arrowhead). F) PVP image shows that the lower lesion was isodense to hepatic parenchyma (black arrowhead). The portal venous system was enhanced homogeneously in both the upper and lower images during the PVP (white arrow).
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Fig. 2. A 64-year-old male with cirrhosis of the liver and a 2-cm hepatoma at the central portion of segment 4 (black arrowhead). A) Noncontrast image shows that the lesion was mildly hypodense to liver parenchyma. B) Hepatic arterial phase image shows that the lesion was isodense to liver parenchyma. C) Portal venous phase image shows that the lesion was markedly hypodense to liver parenchyma. Marked enlargement of the lateral segment of the left lobe with obvious lateral extension into left subphrenic space is noted (white arrowhead in A).

Table 2. Number of tumors detected by noncontrast (NC) and portal venous phase (PVP) imaging with and without hepatic arterial phase (HAP) imaging

<table>
<thead>
<tr>
<th>Type of image</th>
<th>No. of tumors</th>
<th>Analyses</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Undetected</td>
<td>Detected</td>
<td>Detection rate (%)</td>
<td>*p value</td>
</tr>
<tr>
<td>NC + PVP</td>
<td>40</td>
<td>131</td>
<td>76.6</td>
<td>&lt; 0.002</td>
</tr>
<tr>
<td>NC + HAP + PVP</td>
<td>18</td>
<td>153</td>
<td>89.5</td>
<td></td>
</tr>
</tbody>
</table>

*Chi-square test.

In our series, a 21-gauge indwelling venous catheter was used to inject 80 mL of 300 mg/mL contrast medium at a rate of 2 mL/second with an automated power injector. With this low rate of contrast medium injection in biphasic spiral scanning of the liver, we were able to detect an additional 12.9% of lesions from HAP images. This is higher than the detection rate of 8% obtained by Bonaldi et al, who used a rate of 6 mL/second [3].

The injection rate was limited to 2 mL/second in our patients because, in our experience, a rate of 3 mL/second almost always resulted in congestive bulging of the venous tract close to the intravenous catheter. Use of a higher injection rate poses the risk of contrast extravasation, which is harmful to the patient and will disturb the study procedures. Instead of using a higher injection rate to achieve a better attenuating effect of contrast medium as described in previous reports [1, 8, 10], we used an automated contrast guidance software program, SmartPrep, installed in the scanner to monitor the peak time of maximal arterial phase enhancement. The optimal delay from the time of injection to the onset of scanning is difficult to establish, and there can be
marked variability in the enhancement of the liver or tumors from patient to patient according to their size, sex, weight, cardiac output, metabolic status and degree of hydration [13]. The SmartPrep monitoring program indicated the exact timing of the start of HAP scanning. Using this automated monitoring method, the imaging techniques were individualized for each patient in our study. Therefore, we were able to achieve peak enhancement of the liver using an injection rate of 2 mL/second during HAP and PVP scanning.

The volume of contrast material injected is probably another meaningful parameter in hepatic enhancement in addition to the rate of injection and individual patient factors [3]. The previously reported dosage varied from 125 to 180 mL of 60% contrast medium [3, 4, 11–13]. We used 80 mL of contrast medium with similar concentrations in all patients — much less than used in previous reports. Nevertheless, a detection rate of 89.5% was achieved, a result that is similar to previous reports. This finding suggests that use of a higher dosage and injection rate of contrast medium might not be necessary under guidance with monitoring software, and that the cost of contrast medium can thus be reduced.

The results of this study suggest that biphasic contrast-enhanced CT of the liver with lower dosage and injection rate of iodinated contrast medium is suitable for routine detection of HCC in patients with known or suspected hepatic neoplasia, especially in hepatitis B or C carriers.

**References**


