Gastrointest Radiol 16:159–163 (1991)

Gastrointestinal Radiology

Hepatic Metastases: CT Versus MR Imaging at 1.5T

Venetia G. Vassiliades,[1] W. Dennis Foley,[2] John Alarcon,[1] Thomas Lawson,[2] Scott Erickson,[2] J. Bruce Kneeland,[2] Harvey V. Steinberg,[1] and Michael E. Bernardino[1]

[1] Emory University School of Medicine, Atlanta, Georgia, USA; and [2] Medical College of Wisconsin, Milwaukee, Wisconsin, USA

Abstract. A prospective multi-institutional study was performed to compare the sensitivity of computed tomography (CT) and high-field magnetic resonance (MR) imaging (1.5T) in the detection of hepatic metastases. T_1-weighted and T_2-weighted spin-echo (SE) MR images were compared with noncontrast, dynamic, and delayed CT. Sixty-nine oncology patients were studied. Noncontrast CT showed an overall sensitivity of 57%, dynamic CT 71%, delayed CT 72%, T_1-weighted SE MR 47%, and T_2-weighted SE MR 78%. Although there was no statistically significant ($p < 0.05$) difference among dynamic CT, delayed CT, and T_2-weighted SE MR, these three methods were significantly more sensitive ($p < 0.005$) than noncontrast CT or T_1-weighted SE MR. T_2-weighted SE MR was significantly more sensitive ($p < 0.006$) than CT or T_1-weighted SE MR in the detection of small (<1 cm) lesions. CT was more sensitive in the detection of extrahepatic disease. These data confirm the superiority of T_2-weighted SE over T_1-weighted SE pulse sequences at 1.5T.

Key words: Hepatic masses, CT and MRI.

There has been much controversy regarding which imaging modality, computed tomography (CT) or magnetic resonance (MR), is more effective in the detection of focal hepatic lesions. Most studies have compared CT with low- or medium-field-strength MR. The purpose of our multi-institutional study was to prospectively compare state-of-the-art CT with high-field-strength (1.5T) MR in the detection of hepatic metastases in oncology patients.

Address offprint requests to: Michael E. Bernardino, M.D., Department of Radiology, Emory University School of Medicine, 1364 Clifton Road, NE, Atlanta, GA 30322, USA

Materials and Methods

Sixty-nine patients with known malignancy were randomly selected from those patients referred for CT evaluation of suspected metastatic disease. Thirty-six of these patients were men and 33 were women with an age range of 22–86 years (median, 60 years). These patients were representative of oncology patients seen in tertiary care medical centers. The size and distribution of focal lesions were typical for this patient group.

Final diagnoses included several primary malignancies: breast carcinoma (N=17), colon carcinoma (N=16), lung carcinoma (N=8), hepatoma (N=6), melanoma (N=4), lymphoma (N=3), renal carcinoma (N=3), ovarian carcinoma (N=2), pancreas carcinoma (N=2), carcinoid (N=2), gastric carcinoma (N=1), cervical carcinoma (N=1), adrenal carcinoma (N=1), bladder carcinoma (N=1), esophageal carcinoma (N=1), and unknown primary (N=1).

Noncontrast CT, dynamic sequential bolus contrast CT, and delayed CT were compared with T_1- and T_2-weighted spin-echo (SE) sequences. Two hundred fifty-nine imaging studies were performed on these patients. Forty-one of the patients had positive examinations and in 28 patients the imaging studies were negative.

Thirty-four of the 69 patients had noncontrast CT performed on a GE 9800 with hi-lite detector, Siemens DR3, or Philips LX scanner. Contiguous 8- or 10-mm axial sections were obtained through the liver.

Sixty-eight of the 69 patients had dynamic incremental contrast scans obtained during the intravenous injection of 150–180 ml iodinated contrast by power injector at a rate of 2–3 ml/s continuously, or in a biphase mode of 5 ml/s for 10 s, then 1 ml/s. Scan repetition rate varied between 7–10 scans/min with the scan sequence beginning 30–45 s after the beginning of the injection.

Twenty-five of the 69 patients had delayed CT imaging performed. These patients received a total of 60 g iodine and were imaged 4–6 h following injection. Again, 8- or 10-mm thick sections were obtained through the liver.

The MR sequences were performed on either a GE or Philips 1.5T MR imaging unit. For the 65 patients undergoing T_1-weighted SE sequences, the following parameters were used. All patients were imaged with 8- to 10-mm thick sections obtained with a 2.0-mm section gap. The images were obtained

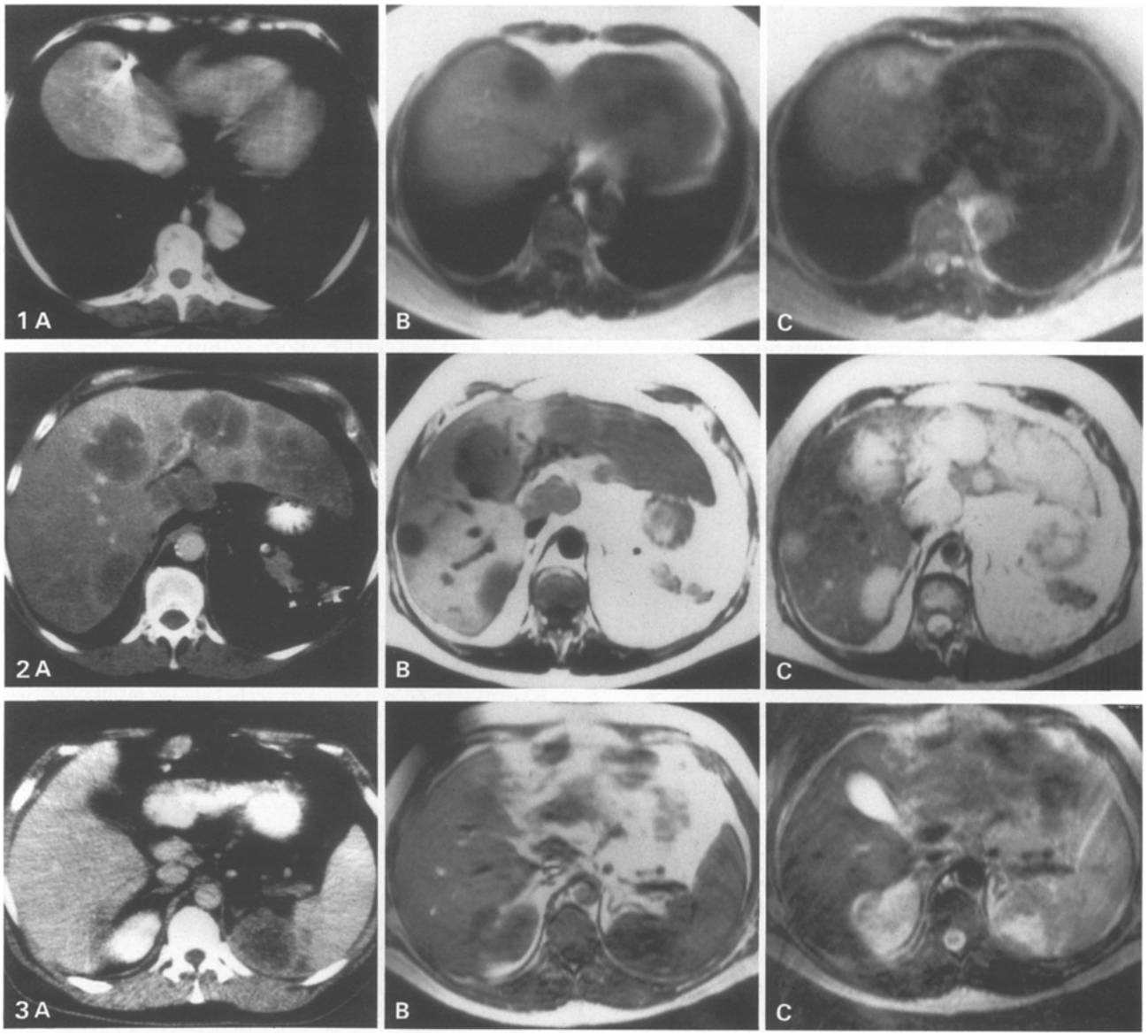

Fig. 1. A Dynamic sequential bolus-contrast CT section demonstrates a hypodense lesion in the dome of the liver, which is partially obscured by metallic clip artifact. **B** T_1-weighted SE MR more easily demonstrates the lesion. **C** T_2-weighted SE MR examination also easily demonstrates the lesion.

Fig. 2. A Contrast-enhanced CT examination demonstrates multiple lesions with the liver. **B** T_1-weighted SE sequence demonstrates more lesions than the contrast-enhanced CT. **C** T_2-weighted SE sequence again demonstrates more lesions than the contrast-enhanced CT examination.

Fig. 3. A CT section demonstrates necrotic mass in the left renal bed. **B** T_1-weighted SE examination shows the lesion, but it is difficult to separate from the spleen. The lesion was not prospectively identified. **C** T_2-weighted SE examination demonstrates an ill-defined area of increased signal within the mass, suggesting pathologic process. Again, this is difficult to separate from the retroperitoneal fat in spleen. It also was not prospectively identified.

with a TR of 250–300 ms, a TE of 20 ms, and 6–8 data acquisitions.

For the 67 patients undergoing T_2-weighted SE sequences, a TR of 2000 ms and a TE of 80–100 ms were used. Two to 4 data acquisitions were obtained. Flow compensation (gradient-moment nulling) was performed on 32 studies. Twenty-three of these 32 studies were repeated using respiratory compensation alone (respiratory-sorted phase encoding). The remaining 35 T_2-weighted studies were performed without flow or respiratory compensation.

For scan interpretation, the individual cases were pooled and randomized. Interpreters were blinded to patient name, clinical information, pulse sequence or contrast method, and results of other imaging examinations. Examinations from one institution were then read by radiologists from the other institution and vice versa. Consensus reading of all CT and MR cases by the home institution (with surgical and follow-up clinical knowledge) determined the "gold-standard" for each case.

If lesions were determined to be present, the size and location of each lesion was recorded with a maximum of five lesions

Table 1. Lesion detection

Confidence level	CT			SE	
	Noncontrast (N=138) (%)	Dynamic (N=262) (%)	Delayed (N=129) (%)	T_1 (N=243) (%)	T_2 (N=265) (%)
3	51	70	71	47	77
2 and 3	57	71	72	47	78

Table 2. Lesion detection for lesions ≥1 cm

Confidence level	CT			SE	
	Noncontrast (N=118) (%)	Dynamic (N=214) (%)	Delayed (N=97) (%)	T_1 (N=215) (%)	T_2 (N=217) (%)
3	59	80	84	51	81
2 and 3	61	80	88	51	81

Table 3. Lesion detection for lesions <1 cm

Confidence level	CT			SE	
	Noncontrast (N=20) (%)	Dynamic (N=48) (%)	Delayed (N=32) (%)	T_1 (N=28) (%)	T_2 (N=48) (%)
3	5	27	31	18	63
2 and 3	30	20	31	18	63

noted per hepatic segment [1]. In addition, each lesion was assigned a confidence level on a scale of 1 to 3. One represented a possible lesion, 2 a probable lesion, and 3 a definite lesion. No attempt was made to categorize lesions as metastases, hemangiomas, or cysts. (In reality, class 1 lesions were so few they were not analyzed.) The presence and location of extrahepatic disease were recorded.

The suspected lesions were confirmed by surgical exploration in five cases, percutaneous biopsy in 18 cases, and imaging and/or clinical follow-up in 46 cases. Of these 46 cases, 18 were positive and 28 were negative. Forty-three of the 46 cases had clinical or imaging follow-up over at least 6 months. Three patients died within 3 months of the initial imaging study. The number of focal lesions varied between one and an arbitrary maximum of 20. Size varied between 0.5 and 15 cm.

Results

The sensitivity of each technique for individual lesion detection is presented in Table 1. Dynamic CT, delayed CT, and T_2-weighted SE MR proved to be more sensitive than either noncontrast CT or T_1-weighted SE MR. No statistically significant difference could be found among dynamic CT, delayed CT, and T_1-weighted SE MR, and the relative sensitivities of each method did not change when readings at the two highest confidence levels were combined (Fig. 1 and 2).

When lesions were categorized as to size, dynamic CT, delayed CT, and T_2-weighted SE remained the most sensitive methods for detection of lesions ≥1 cm (Table 2), and no significant difference could be found among these three methods. However, in the detection of small lesions, T_2-weighted SE MR was significantly more sensitive ($p<0.006$) than the other four methods (Table 3).

The overall sensitivity for detection of patients with disease was 89% with dynamic CT versus 86% with T_2-weighted SE MR. There were six cases where CT diagnosed disease and MR did not, and two cases where MR diagnosed disease and CT did not.

To assess the specificity of the techniques we looked at patients with evidence of disease. Each method misdiagnosed at least one patient. When the two highest confidence levels were combined, dynamic CT misdiagnosed the largest number of patients, four (6%) of the patient population. These misdiagnoses were apparently secondary to focal fat, artifact, and peritoneal metastases. False-

positive MR diagnoses were secondary to severe cirrhotic changes and bowel adjacent to liver.

CT was superior to MR in the detection of extrahepatic disease (Fig. 3). In seven patients significant extrahepatic disease was prospectively identified on CT alone. These included five cases of retroperitoneal mass/lymph nodes and two cases of basilar lung nodules. Of these seven cases, three could be identified in retrospective review of the MR scans. In three patients, MR identified adrenal masses that CT did not. Two of these three masses could be seen in retrospective review.

Discussion

Most previous reports comparing CT with MR have been performed at low- to mid-field strengths [2–4]. The results of these studies have been variable. In some reports, CT showed slight superiority over MR in the detection of focal hepatic lesions, whereas in others, MR was the preferred modality. However, few demonstrated a statistically significant difference between CT and MR in lesion detection. Also, the scanning techniques used by the various investigators was different, depending upon the CT scanner or MR unit used. What has become clear is that with low- to mid-field strength, T_1-weighted imaging, either SE or inversion recovery, is clearly superior to T_2-weighted SE imaging for focal hepatic lesion detection.

Previous studies have demonstrated the superior sensitivity of T_2-weighted SE (TE/TR/no. excitations = 70–100/2000/2) over T_1-weighted SE sequences (TE/TR/no. excitations = 20/300/16) at 1.5T [5–6]. However, some authors have shown that heavily T_1-weighted inversion recovery or STIR, in which T_1- and T_2-dependent contrast are additive, are equivalent or slightly superior to T_2-weighted pulse sequences over T_1-weighted SE pulse sequences for hepatic MR imaging at 1.5T [7–8]. We were not able to perform STIR due to equipment limitations. Our report demonstrated a clear superiority of T_2-weighted over T_1-weighted SE pulse sequences for hepatic MR imaging at 1.5T, which is in agreement with other previously published studies. Thus, SE T_2 techniques at high-field strength are mandatory and should represent at least one sequence for the detection of focal hepatic lesions at high-field strength.

In the only other multi-institutional series comparing dynamic sequential bolus-enhanced CT with MR (performed at 0.5T), the accuracy of CT and MR in detecting focal hepatic lesions was equivalent [1]. Our study, modeled after the initial study of Chezmar et al. [1], produced equivalent overall results. As expected, MR lesion detectability at 0.5T and 1.5T was dependent upon the choice of pulse sequences, T_1-weighted being best at 0.5T and T_2-weighted being best at 1.5T. Dynamic sequential bolus CT, delayed iodine CT, and T_2-weighted SE MR were not statistically different in their detection of focal hepatic lesions. However, these three techniques were clearly superior to noncontrast CT or T_1-weighted SE imaging. There was practically no difference in high-field MR and CT for lesions 1 cm or greater in size. Thus, the choice of imaging modality used for screening might be determined by the availability of the modality and/or its cost.

When lesions less than 1 cm in size are considered, T_2-weighted SE imaging at the high-field strength appeared to be preferable to CT imaging. This was a most interesting and unexpected finding. The detection of these small lesions has become more and more important with the advent of more aggressive surgical and chemotherapeutic techniques. However, one problem with this study, as with most studies of this nature, was the fact that some of these newly detected lesions may not be malignant. It is difficult to determine the histologic cell type of all newly detected lesions without having the entire liver available for pathologic section. Thus, a major drawback in this study, as in most studies of this nature, was the fact that histologic proof was not available on all lesions counted in this study. No attempt was made to tissue characterize these lesions, and all lesions were considered to be malignant for the purposes of this study.

The majority of MR examinations were performed without respiratory compensation. Both institutions at the present time have noted significant improvement in their hepatic 1.5T MR images, using such mechanisms as first- and second-order flow compensation, presaturation, and respiratory-ordered phase encoding. Thus, the data presented herein is felt to be a worst case scenario for MR imaging, which could only be improved upon if the study was to be repeated at the present time. How much of an improvement remains to be determined in a future study. Also, the use of hepatic MR with newer hepatic-specific contrast agents could close the gap in sensitivity between MR and invasive techniques, such as CT portography, which is considered the "gold standard" prior to hepatic resection by many institutions. However, a recent study by Marchal et al. demonstrated no significant difference between T_2-weighted MR at 1.5T and ferrite-enhanced MR in the detection of focal hepatic lesions [9]. Also, a recent study

by Edelman et al. did not demonstrate any significant difference in lesion detectability when using gadolinium-enhanced fast-scan MR imaging in an "incremental dynamic mode" as compared to noncontrast MR [10]. Contrast agents, although known to increase lesion to liver contrast, have not been demonstrated to improve lesion detectability on hepatic MR at 1.5T.

As in the previous study by Chezmar et al. [1], CT proved to be superior for detecting extrahepatic disease. However, the discrepancy between the two modalities in extrahepatic detection was not as great as in the earlier article. This difference between the two studies could be secondary to the fact that two different patient populations with different extrahepatic pathology were studied. Another possibility is that MR may be improving in extrahepatic lesion detection, either because of equipment improvements or because of gaining of experience by the reader in detecting extrahepatic lesions with the modality.

In summary, dynamic sequential bolus CT, delayed CT, and T_2-weighted SE MR were statistically superior to noncontrast CT and T_1-weighted SE MR at 1.5T for focal hepatic lesion detection. T_2-weighted SE sequences were superior to the other techniques for detecting lesions less than 1 cm in size. It is felt that with improvements in motion artifact-reduction techniques that the sensitivity of MR should improve in the future and possibly surpass that of CT. Extrahepatic metastatic disease is still more reliably detected with CT. However, MR may improve in this area with the use of both oral and intravenous contrast agents.

References

1. Chezmar JL, Rumancik WM, Megibow AJ, et al. Liver and abdominal screening in patients with cancer: CT versus MR imaging. *Radiology* 1988; 168:43–47
2. Glazer GM, Aisen AM, Francis IR, et al. Evaluation of focal hepatic masses: a comparative study of MRI and CT. *Gastointest Radiol* 1986; 11:263–268
3. Stark DD, Wittenberg J, Bulch RJ, Ferrucci JT. Hepatic metastases: randomized, controlled comparison of detection with MR imaging and CT. *Radiology* 1987; 165:399–406
4. Reinig JW, Dwyer AJ, Miller DL, et al. Liver metastasis detection: comparative sensitivities of MR imaging and CT scanning. *Radiology* 1987; 162:43–47
5. Henkelman RM, Hardy P, Poon PY, Bronskill MJ. Optimal pulse sequence for imaging hepatic metastases. *Radiology* 1986; 101:727–734
6. Foley WD, Kneeland JB, Cates JD, et al. Contrast optimization for the detection of focal hepatic lesions by MR imaging at 1.5T. *AJR* 1987; 149:1155–1160
7. Reinig JW, Dwyer AJ, Miller DL, et al. Liver metastases: detection with MR imaging at 0.5 and 1.5T. *Radiology* 1989; 170:149–153
8. Shuman WP, Baron RL, Peters MJ, Tazioli PK. Comparison of STIR and spin-echo MR imaging at 1.5T in 90 lesions of the chest, liver, and pelvis. *AJR* 1989; 152:853–859
9. Marchal G, Van Hecke P, Demaerel P, et al. Detection of liver metastases with superparamagnetic iron oxide in 15 patients: results of MR imaging at 1.5T. *AJR* 1989; 152:771–775
10. Edelman RR, Sagel JB, Singer A, et al. Dynamic MR imaging of the liver with Gd-DTPA: initial clinical results. *AJR* 1989; 153:1213–1219

Received: May 14, 1990; accepted: June 28, 1990