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REVIEW

Multislice CT in imaging the liver

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Abstract

The objective of this paper is to address the dramatic impact of multislice CT (MSCT) in imaging the liver. Standard helical (spiral) CT has finally allowed for scanning the majority of the liver during the critical portal venous phase (PVP). This is often referred to as the 'optimal temporal window'. In general, it occurs following a 70 s scan delay and is coincidental with the maximal delivery of contrast via the portal vein that provides 80% of the hepatic blood supply. This yields maximal conspicuity between low-attenuation lesions and the dramatically enhanced normal liver parenchyma at routine injection rates of 2–3 ml/s. Most importantly, these scanners, when compared to single-slice scanners, avoid impinging on the 'equilibrium' phase where tumors can become isodense/invisible. The introduction of MSCT with four, eight and 16-detector systems has significantly increased imaging speed. Volumetric CT will continue to increase speed in the future. This provides a number of important gains that will be described.

Keywords: *Liver; metastases; contrast; multislice; multidetector CT.*

Introduction

The development of multislice CT (MSCT) technology represents a substantial technological advance in CT. The dramatic four- to eight-fold increase in imaging speed accomplishes several things. It (a) makes the examination more comfortable, (b) provides a higher quality examination, (c) provides more flexibility for scanning with thinner sections and (d) gives increased flexibility in scanning during multiple phases of hepatic enhancement; this includes the hepatic arterial phase (HAP), the PVP, retrospective reconstruction of thinning sections, and now the ability to perform exquisite 3D vascular imaging.

When conventional helical CT is used there is continuous data acquisition. This is related to the intrinsic technology of the scanner that consists of a detector made up of an array of rectangular channels. The collimation generally ranges from 1 to 10 mm slice thickness for these scanners. With the evolution to MSCT scanners, manufacturers have developed different arrays which, instead of being long and rectangular, are divided into matrices that generally fall into two different categories: one group has detector elements of equal width along the *z*-axis (matrix detectors) and the other group has detector elements of unequal width (adaptive array detectors). These scanners tend to be very fast (sub-second).

There are specific clinical advantages in assessing both primary and metastatic liver disease using MSCT. Two clinical applications are directly obvious. Firstly, increased coverage using the same thickness as with earlier scanners; secondly, the generation of much thinner sections with similar anatomical coverage. Hybrid approaches yield a combination of thinner sections and greater anatomic coverage.

The options and methods of scanning the liver are numerous, with no single approach being definitive; different approaches are often appropriate when specific

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disease entities are suspected. The two major phases of a liver study are the HAP and the PVP. Scans can also be performed pre-contrast and in the equilibrium phase (limited value, i.e. cholangiocarcinoma). For most protocols, a scan delay of 60–70 s after initiating contrast injection is appropriate, with newer scanners using conventional rates of contrast injection (2–4 ml/s). At faster rates, earlier scanning may be desired. One option is to use computer-assisted scanning technology (CAST) and begin scanning at a 50 HU threshold to optimise hitting the peak liver enhancement (SmartPrep® , GE, General Electric Medical Systems, Milwaukee, WI) and assure scanning at the optimal PVP.

In some cases, adequate hepatic enhancement has been reported with iodine doses that are 25% lower than conventional CT. This is especially important in certain economic climates. If a patient's weight is taken into account, an even more pronounced reduction in contrast of up to 40% can be achieved, resulting in significant cost savings (Figs 1–4).

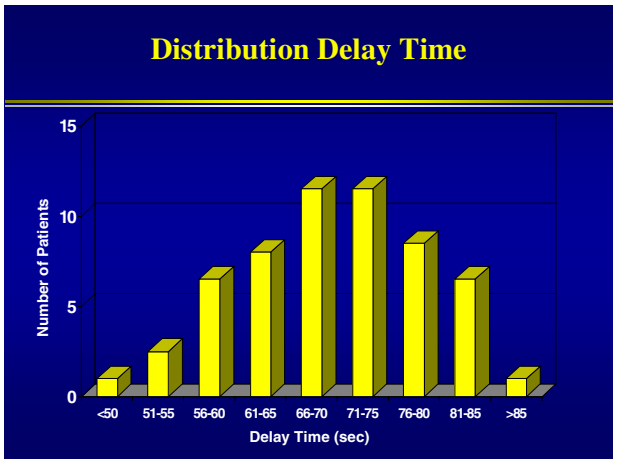

Figure 1 **Distribution of delay times for different patients because of different circulation times.**

Most pathology in metastatic disease is hypovascular. MSCT allows one to capture the peak of the portal venous phase (PVP) because of its short scan time relative to standard helical CT (Figs 5 and 6). When confronted with hypervascular lesions that are most commonly from metastatic islet cell tumors, melanoma, choriocarcinoma, renal cell carcinoma, thyroid carcinoma and, in some cases, breast carcinoma, a dual-phase study is recommended (Figs 7–9). The addition of the HAP component initiated at 15–20 s into the study can increase lesion detection by 8–13% compared to PVP imaging alone. Scans at 5 or 7.5 mm have become standard. Thinner collimations can detect more lesions, but these often remain indeterminate because of their extremely small size. In one series where images of the liver were reconstructed with overlapping collimation, 7% more lesions could be detected. An early arterial phase (AP) has the additional value of producing superb 3D imaging of the vascular system depicting hepatic arterial anatomy preoperatively. It is also of value in assessing patients who are candidates for intra-arterial chemotherapy. This flexibility of multislice scanning generally avoids more invasive techniques i.e. angiographic CT arterial portography (CTAP).

In cases where a CT angiogram (CTA) is desired, a triple rather than dual-phase study may be substituted. The true AP is performed 10 s after contrast initiation followed by the late arterial phase (LAP) and PVP phases. (HAP = 25 s, PVP = 65–70 s) after initiating the contrast bolus. Collimation of 5–7 mm and injection rates of 4–6 ml/s are used. The time saving is clearly evident with the use of multislice as seen in Fig. 5 by the decreased scanning time.

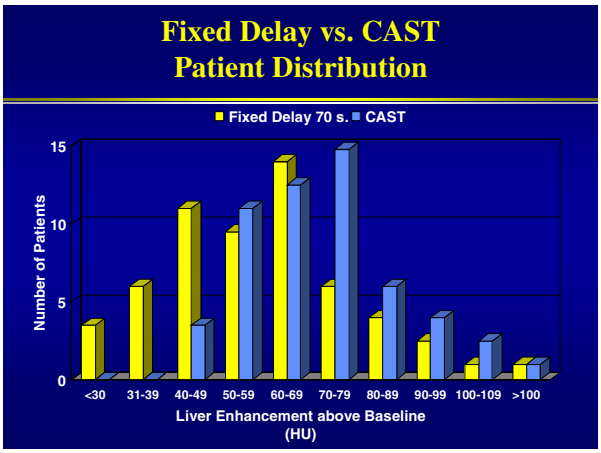

Figure 2 **Distribution of fixed delay time vs. CAST. This shows that when a bolus tracking program such as a computer automated scan time (CAST) is used, patients' scans have better contrast enhancement in the liver than with a fixed delay.**

In imaging the liver, disease entities may be divided into focal (metastases, focal fat) or diffuse (fatty infiltration, cirrhosis and hemachromatosis). Focal lesions can be either primary or metastatic in origin (Figs 7–9).

Primary lesions

Primary lesions consist of both benign and malignant lesions.

Hepatic hemangioma

Hepatic hemangioma is the most common benign tumor occurring more commonly in women and with multiplicity up to 10%. Often less than 3 cm, they can attain a considerable size. They have a typical imaging appearance on non-contrast scans of a low-attenuation mass with areas measuring blood density. On post-contrast enhancement there is peripheral clumping of enhancement that proceeds from the periphery towards the center of the

(a)

Individualized Scan Delay Approach

- Mechanism integrate Scanning/contrast
- Computer Automated Scan Technology (CAST)
  - Provides ability to directly observe effects of contrast enhancement
- Utilize information to change existing Approach to Scanning
- Standard Approach: Scan following "fixed delay" after contrast administration
- New Approach: Scan at optimal level enhancement

(b)

Computer Automated Scanning Technology (CAST)

- Rapid acquisition of series of low-radiation dose "monitoring images"
- Trace enhancement of specific structures (Liver, aorta) using cursors
- Generate time-density curves
- Establish a desired threshold of enhancement
- Transition from "monitoring" to "diagnostic" phase when threshold achieved
- Option to manually intervene

Figure 3 **(a) Benefits of an individualized delay approach to liver scanning. (b) Computer automated scan technology or bolus tracking benefits.**

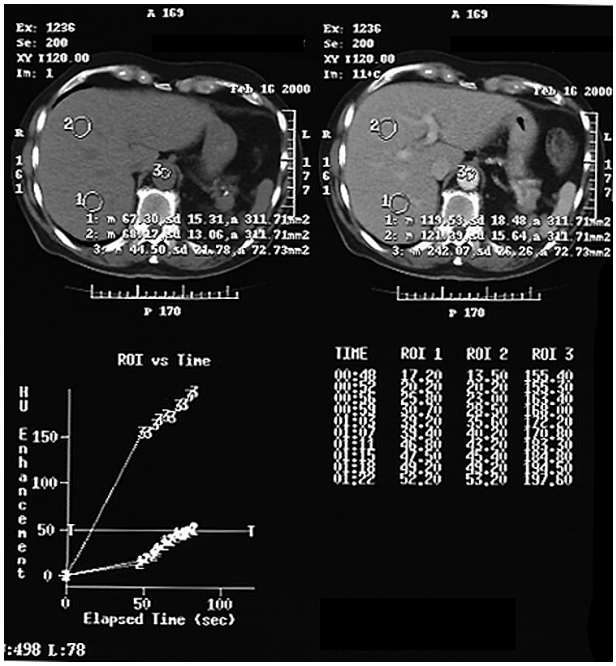

Figure 4 **Computer generated curves showing liver enhancement over time using CAST approach.**

(a)

Hypovascular Metastases (Single Slice)

Contrast: 150 ml @ 3 ml./sec.

Slice thickness: 7mm Pitch: 1.5

H. U.

Liver

Tumor

PVP

70

Time (sec.)

(b)

Hypovascular Metastases (Multislice)

Contrast: 150 ml. @ 3 ml./sec.

Slice thickness: 5 mm Pitch: 3

H.U.

Liver

Tumor

PVP

70

Time (sec.)

Figure 5 **(a) Hypovascular metastases time–density curve with single slice CT. (b) Hypovascular metastases time–density curve with multislice, multidetector CT.**

lesion. Complete fill-in is not required for accurate diagnosis since many may have fibrosis or thrombosis. Spontaneous hemorrhage is rare. Histologically they represent thin-wall endothelialline spaces fed by peripheral hepatic arterial branches. When there is a question as to diagnosis, a nuclear medicine RBC SPECT scan or MR can usually be definitive.

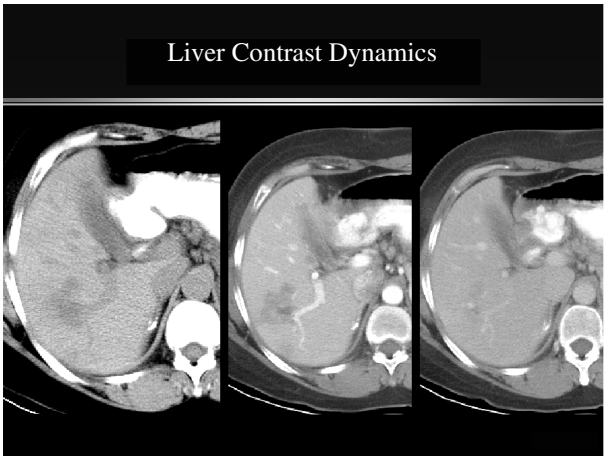

Figure 6 **Hypovascular metastases. L-R: Non-contrast shows liver metastasis in right lobe. Following contrast, lesion is better seen during PVP. Image on right shows lesion disappearing shortly after PVP.**

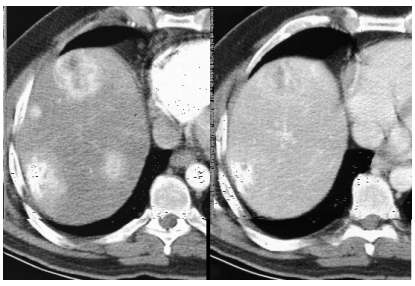

Figure 7 **Hypervascular metastasis. Using single slice helical CT, the early hepatic arterial dominant phase (HADP) shows the lesions well but they are less well seen during PVP in the image on the right.**

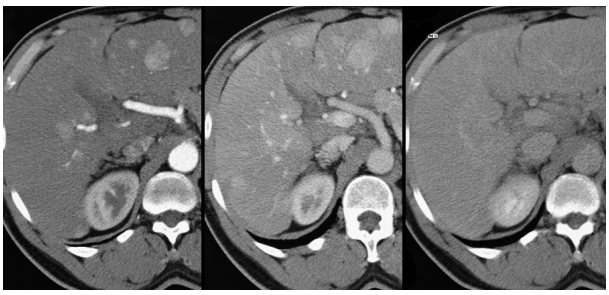

Figure 8 **Tri-phasic study, hypervascular metastasis. Hepatic arterial phase (HAP) on left shows early enhancement of tumors. The late arterial phase (LAP), center, shows lesions but the PVP on the right is inadequate.**

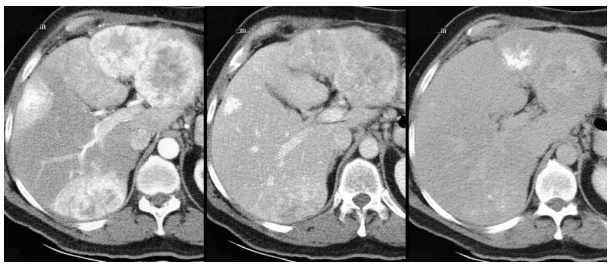

Figure 9 **Hypervascular metastasis. Hepatic arterial phase (HAP) on the left shows lesions optimally. Center image during later arterial phase (LAP) shows lesions poorly. Portal venous phase (PVP) is suboptimal for hypervascular tumor.**

Focal nodular hyperplasia (FNH)

FNH is the second most common benign hepatic tumor. These are multiple in up to 20% of cases, most common in women and generally asymptomatic. CT demonstrates these lesions to be homogeneously hyperdense during the AP and isodense during the PVP phase. Approximately half of the lesion's hepatocytes demonstrate a central low hypoattenuating scar. The lesions consist of hepatocytes, bile ducts, and Kupffer cells. They are thought to be the result of congenital vascular malfunctions which induced localised hyperplasia.

Hepatocellular adenoma (HCA)

HCA is a benign vascular neoplasm primarily occurring in young women with a strong association with oral contraceptive use. These tumors do have malignant potential and a tendency to undergo spontaneous hemorrhage. The CT appearance is of a slightly heterogeneous area of increased enhancement during the HAP, which becomes isodense during the PVP. Lesions may contain fat or have hemorrhage and be difficult to distinguish from hepatocellular carcinoma (HCC). They lack bile duct epithelium. MR imaging characteristics include hypointense to hyperintense on T1-weighted sequences depending on the presence of hemorrhage, which creates a mixed appearance. T2-weighted sequences are iso- to hyperintense and often heterogeneous. Surgical resection eliminates the possibility of spontaneous potentially life-threatening hemorrhage or the development of HCC.

HCC

HCC is the most common primary hepatic malignancy worldwide with approximately 70–80% having underlining cirrhosis (Fig. 10). It is especially common in Asia and Northern Africa, where there is an increased incidence of patients with hepatitis B and C. It is an

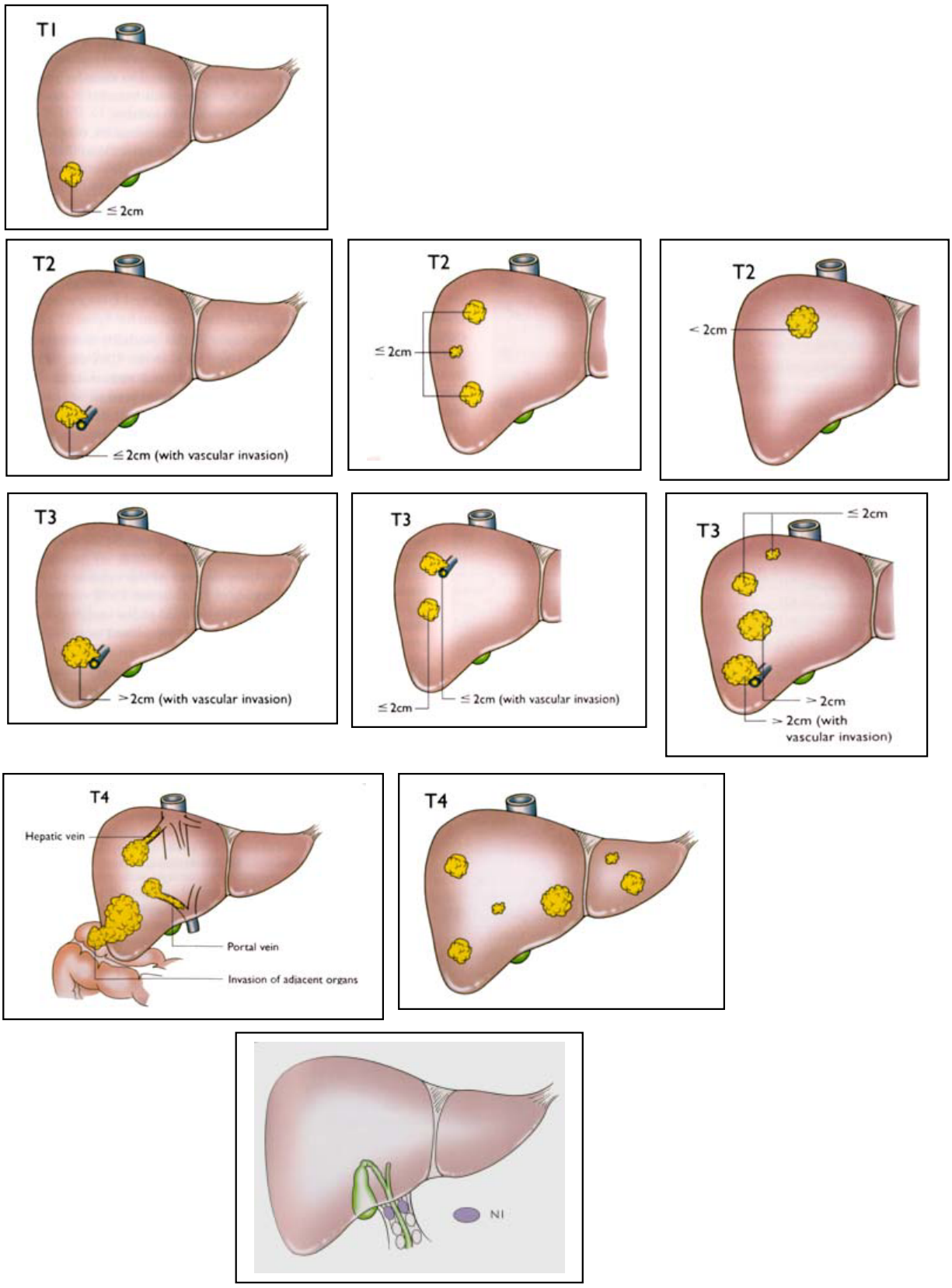

Figure 10 **Staging system for hepatocellular carcinoma.**

aggressive, vascular lesion, best appreciated in the late HAP portion of the CT. Small lesions may have a homogeneous enhancement which become heterogeneous as the lesions enlarge. These lesions have a tendency to invade portal and even hepatic veins and may have small amounts of fat. The staging of HCC is shown. The fibrolamellar HCC lesion is a less virulent variety that has a central scar.

Cholangiocarcinoma

Cholangiocarcinoma is a less common lesion of bile duct origin and is not common extrahepatically; it includes the *porta hepatis*, termed Klatskin tumors and less commonly seen as intrahepatic lesions. It tends to have lower attenuation on the HAP and PVP phases, but frequently delayed images (10–15 min) show a characteristically dense enhancement, unlike HCC central calcifications that are often seen (40%).

Epithelioid hemangioendothelioma (EHG)

EHG are malignant lesions in which calcifications may be observed. They are often seen better on unenhanced CT scans and demonstrate moderate contrast enhancement, but incomplete filling of the lesion on non-delayed images. When large, they may be associated with an abnormal hepatic contour related to capsular retraction and hypertrophy. They generally have a slow growth rate and compensatory hypertrophy may be seen in the unaffected liver. Histologically, these tumors have large areas of desmoplasia and fibrosis, accounting for the biliary ductal dilatation often seen peripheral to the tumor. When encasement of the portal venous system occurs, the result is lobar atrophy.

Secondary disease

Secondary disease (metastatic disease to the liver) overwhelmingly appears as low-density lesions in the liver during the PVP phase. Thus the HAP is not necessary. There may be an element of some peripheral enhancement to these lesions which is often irregular. Lesions are often multiple and may occur from a wide variety of sites although gastrointestinal primaries are one common etiology.

The select group of hypervascular lesions (e.g. melanoma, islet cell tumors, carcinoid, renal, thyroid, choriocarcinoma and in some cases breast carcinoma) require the minimum of a dual-phase study where multislice imaging is extremely effective. Triple-phase studies are valuable to provide an early AP for 3D image processing[10].

Conclusion

The introduction of multislice CT has from the beginning revolutionized the approach to imaging the liver, providing increased flexibility to improve diagnostic imaging.

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