Liver metastases: optimizing detection with multislice CT (MSCT)

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Abstract

Conventional, single-slice helical computed tomography (CT) allows for scanning the majority of the liver during the critical portal venous phase. 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 enhanced normal liver parenchyma. This provides optimal imaging for the vast majority of hepatic metastases. Most importantly, these scanners, when compared to conventional non-helical scanners, avoid impinging upon the ‘equilibrium’ phase where tumors can become isodense/invisible. Helical CT also allows scanning during the arterial phase for detection of hypervascular lesions but was limited in its ability to scan effectively in multiple phases necessary for detection of hypervascular metastases. With the introduction of multislice CT, imaging speed has increased significantly especially with the introduction of 8- and 16-detector systems and will continue to increase in the future volumetric CT. This provides a number of important gains that are discussed in detail.

Introduction

The development of multislice computed tomography (MSCT) technology represents a substantial technological advance in computed tomography (CT). The dramatic four-, eight-, and sixteen-fold increase in imaging speed affords several benefits: (1) makes the examination more comfortable; (2) provides a higher quality of examination with improved liver lesion conspicuity; (3) provides scanning with thinner sections; (4) gives increased flexibility in scanning during multiple phases of hepatic enhancement; and (5) offers the ability to perform exquisite three-dimensional (3D) vascular imaging.

Discussion

When conventional single-slice helical CT (SSCT) 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. 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 have very fast (sub-second) acquisition of multiple slices.

There are specific clinical advantages in assessing both primary and metastatic liver disease using MSCT. Two clinical applications are directly obvious: first, to increase coverage using the same thickness as with earlier scanners and, second, to generate 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 one singular approach being definitive and often different approaches are appropriate when specific disease entities are suspected. In conventional (SSCT), the two major phases of a liver study are the hepatic arterial phase (HAP) and the portal venous phase (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 using conventional rates of contrast injection (2–4 ml/s). At faster rates, earlier scanning may be desired. One option to a fixed delay time is to use computer-assisted scanning technology (CAST) and begin scanning at a 50 HU threshold to optimize 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 using such technology. 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.

**Figure 1**

Distribution Delay Time

| Delay Time (sec) | Number of Patients |
|-----------------|-------------------|
| 0-20            | 5                 |
| 21-40           | 10                |
| 41-60           | 15                |
| 61-80           | 10                |
| 81-100          | 5                 |
| 101-120         | 0                 |

Fixed Delay vs. CAST Patient Distribution

| Liver Enhancement above Baseline (HU) | Number of Patients |
|--------------------------------------|--------------------|
| -50 to -20                           | 0                  |
| 21 to 50                             | 5                  |
| 51 to 80                             | 10                 |
| 81 to 110                            | 15                 |
| 111 to 140                           | 10                 |
| 141 to 170                           | 5                  |
| 171 to 200                           | 0                  |

**Figure 2**

**Contrast dynamics**

The liver, because of its unique dual blood supply, 20% from the hepatic artery and 80% from the portal venous system, remains just as much or more of a challenge for optimizing protocols in the current era of MSCT. The previously termed PVP for SSCT has now been more appropriately named the hepatic venous phase (HVP) on MSCT as this phase captures the opacification of these veins and maximal liver enhancement. This is the only phase necessary to image the vast majority of metastatic disease to the liver. It includes common neoplasms such as lung, colon, lymphoma, and genitourinary tumors. The main impact of MSCT has been on the ability to now examine an organ such as the liver in multiple phases of contrast dynamics with the hope of allowing increased detection of lesions as well as improved lesion characterization. The reason to image during an earlier phase of contrast is to improve the detectability of tumors which are hypervascular. This relates to the study of primary neoplasms, i.e. hepatocellular carcinoma (HCC), as well as metastatic disease. The most common hypervascular tumors that benefit from the more comprehensive examination include neuroendocrine tumors,

**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

**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
melanoma, sarcoma, carcinoid, renal cell, thyroid, and choriocarcinoma. Although breast carcinoma may be hypervascular, it generally has peripheral rather than dense focal enhancement and can effectively be seen during standard imaging. Optimizing protocols for multiphasic imaging includes arterial phase(s) to the HVP (i.e. dual phase imaging) and/or inclusion of a very early arterial phase for 3D imaging of the vascular system (i.e. triple-phase imaging). In contrast to SSCT, MSCT is able to define three rather than just two distinct phases of contrast enhancement. With SSCT, the two phases are the hepatic arterial dominant phase (HADP) and the PVP; with MSCT these phases have been termed the HAP, late arterial phase (LAP) or portal venous inflow phase (PVIP), and a HVP. The first two phases were incorporated in the HADP described with SSCT. The ability to rapidly scan with MSCT allows one to separate these and scan in two phases what could only be done in one phase previously. Hypervascular lesions, either primary or metastatic, are usually best seen in the LAP; however, some lesions are seen only in either the HAP or LAP phases. Hypervascular lesions have always presented a challenge to the radiologist. Failing to image hypervascular lesions during the HAP results in an insensitive examination similar to failing to image hypovascular lesions in the PVP. The HAP is best identified 10–20 s after the administration of contrast and is characterized by enhancement of the hepatic artery. The LAP is best identified 25–30 s after injection and shows enhancement of the hepatic artery and some enhancement of the portal venous structures. The HVP is marked by opacification of the hepatic veins at the dome of the liver. The speed results in one of the most important
challenges in developing optimized protocols for this new, robust technology. Although multiphasic studies could be performed with helical scanners, high-quality, whole organ imaging with multiple phases awaited the introduction of MSCT.

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. Thinner collimations (5, 3.75, and 2.5 mm) 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 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).

Higher concentration contrast in MSCT

Detection of liver lesions is not only dependent on scanning during the phase that optimally distinguishes normal from abnormal tissue as discussed. Optimized imaging requires using adequate amounts of contrast, i.e. grams of iodine. The grams of iodine have a direct impact on the difference in hepatic attenuation relative to lesion detection which defines the relative conspicuity of lesions [normal hepatic attenuation–liver lesion attenuation results in lesion conspicuity]. Most recently, with the rapid proliferation of MSCT technology, the concept of using higher concentrations of contrast material has begun to be explored. The impetus for this has been that the standard contrast concentrations of 300–320 mgI/ml have required volumes of the order of 150 ml to deliver adequate grams of iodine as the ‘drug’ necessary to effectively image the liver. This is in contrast to examining other areas of the body such as the chest where the dose and volume of iodinated contrast can be significantly reduced [i.e. 150 to 100 ml (helical CT) to 60–75 ml (MSCT)]. Imaging of liver lesions requires more precise protocols. Studies of the liver with less than optimal contrast enhancement result in compromised lesion detectability.

Fortunately, to date, prices of contrast material are not directly tied to grams of iodine within the product but are most closely linked with the volume of contrast. Thus, if we can use lower volumes and higher concentrations of contrast, it has the additional benefit of becoming highly cost effective. With SSCT and helical scanning, protocols for body CT required volumes of contrast in the range of 150 ml with 300 and 320 mgI/ml to be able to have optimal enhancement of the liver and also provide adequate enhancement of abdominal and pelvic structures. With MSCT this can be accomplished without requiring these large volumes since scans can be completed so rapidly. Thus, it becomes the challenge for radiologists to adopt new protocols to take advantage of this continually evolving technology. Higher concentrations of contrast, 350, 370, and even 400 mgI/ml, have been developed and are being employed clinically. If a target of 37–48 g of iodine is considered to image the liver, then this can be achieved by a number of different permutations of volume and concentration of contrast. Higher concentrations of contrast also allow contrast delivery of the same grams of iodine per second to the target organ at lower rates. For example, the administration of 150 ml of 300 mgI/ml at 5 ml/s delivers an iodine dose of 1.5 g/s whereas the administration of 100 ml of 370 mgI/ml at only 4 ml/s delivers essentially the same iodine dose of 1.48 g/s. The ability to decrease the total volume of contrast will result in overall substantial cost savings in a busy clinical CT service.

Conclusion

The introduction of MSCT has revolutionized the approach to imaging the liver by providing increased flexibility. In order to effectively utilize this technology, protocols designed for imaging hepatic metastatic disease must be carefully constructed.

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