

Quality initiative: Quantifying and reducing dose in multiphase liver CT: Eliminating the nonenhanced study and using conscientious Z-creep

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The use of computed tomography (CT) for evaluation of liver disease has increased dramatically at our tertiary care center due to increased hepatology referrals. We sought to decrease the radiation dose associated with multiphase liver CT studies while maintaining a high degree of diagnostic accuracy. We found that by eliminating the nonenhanced acquisition and adjusting the imaging field of view to include the liver-containing abdomen only—simply by manipulation of patient-specific imaging parameters—we achieved a 30% reduction in dose.

Introduction

It is widely accepted that exposing patients to unnecessary ionizing radiation falls below the standard of care. It is our responsibility as radiologists to eliminate excessive radiation exposure and to protect our patients. The recent advances in multidetector computed tomography (MDCT) have allowed the development of numerous imaging protocols that were not available 10-15 years ago. Dedicated liver imaging is an area of radiology that has benefited from these advances. Many new liver imaging protocols have been established and deemed valuable in the radiologists' arsenal for increasing the sensitivity and specificity of their diagnosis. However, the value of including each new protocol for every patient raises many questions.

It is estimated that the median effective dose for a non-contrast and three-phasic liver CT exam is 31 millisievert

(mSv) (range, 21-43), with an absolute range of 6-90 mSv. 31 mSv is equivalent to 442 chest x-rays, 74 mammograms, or 15 years of background radiation exposure (1). Many of the patients undergoing liver-specific imaging require multiple followup studies, which further increase their radiation exposure.

We evaluated our current liver-specific CT protocols to reduce radiation dose while maintaining a high degree of diagnostic accuracy. Our study showed that a 30-40% dose reduction could be achieved by eliminating the nonenhanced acquisition and by employing conscientious "Z-creep" (tight scan window flanking the liver, to avoid scanning unnecessary parts of the abdomen) while maintaining a high degree of specificity and sensitivity.

The standard MDCT liver imaging protocol at the VA Puget Sound Healthcare System (VAPSHCS) includes four different acquisitions, a noncontrast scan, and three additional scans with the use of iodinated contrast. These acquisitions are obtained by scanning the patient from just above the diaphragm to the top of the iliac crests, as follows:

- 1 Nonenhanced scan without contrast
- 2 Enhanced arterial phase (20-30 seconds)
- 3 Portal-venous phase (60-70 seconds)
- 4 10-minute delay

By using these four separate acquisitions, the radiologist can achieve diagnostic sensitivity and specificity in the mid-to-upper-90th percentile for detection of liver masses (2).

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While improving diagnostic accuracy is optimal, the value of each acquisition has been called into question as we become more aware of the negative effects of ionizing radiation. We feel that the routine use of a nonenhanced acquisition is no longer necessary for all patients, and by eliminating this acquisition in the majority of our patients, we expect to reduce radiation exposure.

Situations where a nonenhanced acquisition would be added are as follows:

- The patient is new, and baseline nonenhanced liver imaging has not been already performed.
- The patient has undergone recent hepatic arterial chemoembolization or radiofrequency ablation (RFA), which can be difficult, as it involves evaluation of high-density embolization material or coagulation necrosis on contrast-enhanced acquisitions.

Additionally, by altering the scanning window from the standard “diaphragm to iliac crest” to include only the area of the abdomen occupied by the liver (also known as “conscientious Z-creep”), we can reduce radiation exposure to the patient. By changing the way we acquire the images for liver specific MDCTs, we can reduce radiation dose by 30-40%.

Methods

Prospective data was collected at the VAPSHCS on a total of nine patients who were referred for hepatic mass evaluation. This Health Insurance Portability and Accountability Act (HIPAA)-compliant study was approved by the departmental quality assurance/quality initiative (QA/QI) committee. The need to obtain informed consent was waived. All underwent multiphase liver-mass MDCT exams. A subset of three patients were imaged using the standard four-phase protocol established at our institution, with the field of view from the diaphragm to iliac crests. This subset included new patients, without prior liver CTs or recent chemo-embolization. A second subset of three patients underwent a four-phase MDCT for liver-mass evaluation; however, the field-of-view imaging parameters were manipulated to include only the liver area of the abdomen (to employ conscientious Z-creep). These patients were scanned from the diaphragm to inferior liver. A third subset of three patients underwent a three-phase MDCT without the nonenhanced acquisition, and the field of view was flanked to employ conscientious Z-creep. Treatment for this group of patients included followup exams, with prior nonenhanced liver CTs on record. Radiation-dose data was collected for each CT series acquisition, and the total effective dose was calculated for each patient. Total effective dose was calculated using the “K” factors supplied by the American Association of Physicists in Medicine (AAPM).

Results

Our study revealed a 30% dose reduction in patient groups that were subject to conscientious adjustment of Z-

creep, compared to the standard diaphragm-to-crest scanning window. A 30% dose reduction was also observed in the patient group who underwent a three-phase scan plus use of conscientious Z-creep. However, we did not see any significant dose reduction between the conscientious Z-creep-adjusted group and the three-phase-plus-Z-creep group (Table, Figs. 1, 2).

Table: Cumulative dose in multiphase liver CT performed on nine patients

Patient subset	Radiation (mSv)
4 phases: Diaphragm to iliac crest. n=3	31.9
4 phases: Diaphragm to lowest liver edge. n=3	22.3
3 phases: Diaphragm to lowest liver edge (noncontrast not performed). n=3	22.1

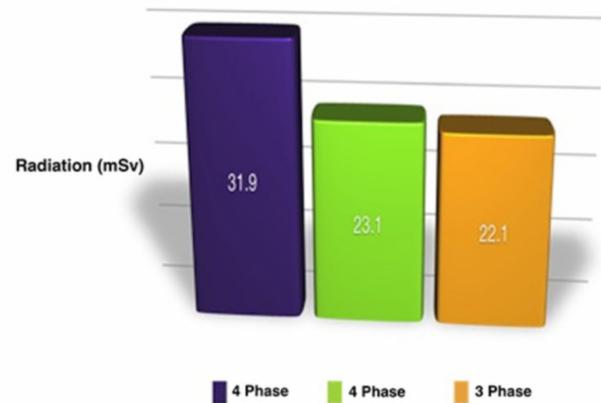


Figure 1. Dose reduction with flanking and eliminating the nonenhanced acquisition. A 30% radiation dose reduction was achieved between the standard 4-phase liver mass MDCT protocol (purple column) and the implementation of conscientious Z-creep (tight flanking of the field of view) (green column). Eliminating the nonenhanced acquisition plus implementing conscientious Z-creep also produced a 30% reduction in dose (gold column) when compared to the standard four-phase protocol.

Discussion

Thoughtful and specific protocoling can reduce the amount of radiation exposure for the patient and can improve efficiency within the radiology department. CT use has increased significantly over the past several decades,

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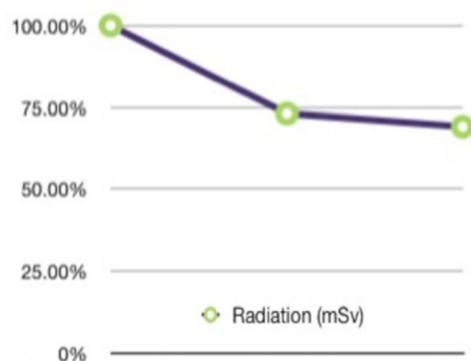


Figure 2. Percent decrease in total effective radiation dose. The total effective radiation dose was reduced between patient subsets through the adjustment of scan parameters and the use of patient-specific protocolling.

and it is important to limit the amount of radiation exposure to patients whenever possible (1).

In a study by Miller et al (2), 584 liver lesions were detected using dedicated liver imaging in 102 different patients. The authors evaluated the usefulness of the nonenhanced study and found that no lesions were visualized using only the nonenhanced study. Nonenhanced exams have decreased sensitivity for detection of small lesions, often due to difficulty in differentiation from unopacified vessels or biliary dilatation. The authors concluded that a nonenhanced study should not be routinely used for hepatocellular carcinoma or metastases evaluation. A second study by Oliver et al (3) had similar findings. In their population, they discovered that 3% (2/81) of patients had lesions that were detected on the nonenhanced acquisition only. The lesions that were not detected on the arterial or portal venous phases at the time of the study were nonenhancing and hypercellular. In both studies, delayed acquisitions were not acquired. The combination of all three phases yields the greatest diagnostic performance, particularly in small HCCs (smaller than 2 cm), which typically are more conspicuous on the delayed-phase images than on portal-venous-phase images (4). However, the routine use of a nonenhanced acquisition is unnecessary.

For our protocol, if the patient had previous nonenhanced imaging of the liver, a nonenhanced study was not repeated. An exception was if the patient had recently undergone chemo-embolization or RFA; in that case, they received a nonenhanced phase as well. The optimal study to evaluate postembolization patients is contrast-enhanced magnetic resonance imaging (MRI). If MRI is contraindicated in a patient, a four-phase CT is the next best option. Postembolization material and coagulation necrosis can be hyperdense on CT and lead to confusion differentiating between embolization material and true enhancement.

Our data revealed a 30% dose reduction in patients that were subject to conscientious Z-creep elimination, compared to the standard diaphragm-to-crest scanning window. While it is reasonable to conclude that dose reduction would occur by eliminating the scanning of non-liver-containing abdomen, it is curious that there was no difference between the patients who received a tightly flanked three- or four-phase study. This can be explained by the lack of power in our data and the variables of patient and/or liver size. In both patients who only had a three-phase acquisition study, the average Z-axis length was 32.3cm, but in the patients who had a nonenhanced study, the average Z-axis was 25cm. If we had a larger sample size, we are confident that difference in patient size would equal out and a significant difference in total effective dose would be accomplished.

A four-phase contrast-enhanced liver protocol MDCT is one of highest radiation-dosed studies in the radiology repertoire. Frequently, the patients receiving this study require multiple followup examinations, which can result in a very large cumulative exposure. Radiation dose reduction is a worthy goal, and by making two simple-to-implement changes, we can improve patient care and improve the efficiency of the radiology department.

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