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Assessment of Cirrhotic Liver Enhancement With Multiphasic Computed Tomography Using a Faster Injection Rate, Late Arterial Phase, and Weight-Based Contrast Dosing

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Abstract

Purpose: This study aimed to update our liver computed tomography (CT) protocol according to published guidelines, and to quantitatively evaluate the effect of these modifications.
Methods: The modified liver CT protocol employed a faster injection rate (5 vs 3 mL/s), later arterial phase (20-second vs 10-second postbolus trigger), and weight-based dosing of iodinated contrast (1.7 mL/kg vs 100 mL fixed dose). Liver and vascular attenuation values were measured on CTs of patients with cirrhosis from January to September 2015 (old protocol, n = 49) and from October to December 2015 (modified protocol, n = 31). CTs were considered adequate if liver enhancement exceeded 50 Hounsfield units (HU) in portal venous phase, or when the unenhanced phase was unavailable, if a minimum iodine concentration of 500 mg I/kg was achieved. Attenuations and iodine concentrations were compared using the *t* test and the number of suboptimal studies was compared with Fisher's exact test.
Results: CTs acquired with the modified protocol demonstrated higher aortic ($P = .001$) and portal vein ($P < .0001$) attenuations in the arterial phase as well as greater hepatic attenuation on all postcontrast phases ($P = .0006$, .002, and .003 for arterial, venous, and equilibrium phases, respectively). Hepatic enhancement in the portal venous phase (61 ± 15 HU vs 51 ± 16 HU; $P = .0282$) and iodine concentrations (595 ± 88 mg I/kg vs 456 ± 112 mg I/kg; $P < .0001$) were improved, and the number of suboptimal studies was reduced from 57% to 23% ($P = .01$).
Conclusions: A liver CT protocol with later arterial phase, faster injection rate, and weight-based dosing of intravenous contrast significantly improves liver enhancement and iodine concentrations in patients with cirrhosis, resulting in significantly fewer suboptimal studies.

Résumé

Objectif : L'étude visait à mettre à jour notre protocole de tomodensitométrie (TDM) du foie pour qu'il soit conforme aux lignes directrices publiées et pour évaluer de façon quantitative les effets de ces modifications.
Méthodes : Le protocole de TDM du foie modifié utilisait un débit d'injection plus rapide (5 mL/s contre 3 mL/s), retardait la phase artérielle (activation post bolus après 20 secondes contre 10 secondes) et dosait le contraste iodé selon le poids (1,7 mL/kg contre une dose fixe de 100 mL). Les valeurs d'atténuation pour le foie et le système vasculaire ont été mesurées à partir des TDM de patients souffrant de cirrhose de janvier à septembre 2015 (ancien protocole, n = 49) et d'octobre à décembre 2015 (protocole modifié, n = 31). Les TDM étaient jugées adéquates si l'injection de produit de contraste dans le foie excédait 50 unités Hounsfield (UH) à la phase de la veine porte hépatique ou, en l'absence de phase sans produit de contraste, si on atteignait une concentration minimale d'iode de 500 mg I/kg. Les atténuations et les concentrations d'iode ont été comparées à l'aide d'un test *t* et le nombre d'examens non optimaux a été comparé à la méthode exacte de Fisher.
Résultats : Les TDM effectuées à partir du protocole modifié ont entraîné des atténuations supérieures pour l'aorte ($P = 0{,}001$) et la veine porte hépatique ($P = 0{,}0001$) lors de la phase artérielle ainsi qu'une meilleure atténuation pour le foie pour toutes les phases post-contraste ($P = 0{,}0006$, 0,002, et 0,003 pour les phases artérielles, veineuses et d'équilibre, respectivement). Le rehaussement à la phase de veineuse portale (61 ± 15 UH contre 51 ± 16 UH; $P = 0{,}0282$) et les concentrations d'iode (595 ± 88 mg I/kg contre 456 ± 112 mg I/kg; $P < 0{,}0001$) ont été améliorées et le nombre d'examens non optimaux est passé de 57% à 23% ($P = 0{,}01$).

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Conclusion : Un protocole de TDM du foie avec une phase artérielle retardée, un débit d'injection plus rapide et le dosage du produit de contraste intraveineux selon le poids améliore grandement le rehaussement par le produit de contraste dans le foie et les concentrations d'iode chez les patients atteints de cirrhose, ce qui réduit considérablement le nombre d'examens non optimaux.
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Key Words: Cirrhosis; Iodinated contrast media; Liver imaging; Multidetector computed tomography

Hepatocellular carcinoma (HCC) is one of the leading causes of cancer related deaths worldwide [1]. In North America, the incidence of HCC has tripled over the past 30 years and is projected to continue rising due to increasing rates of chronic liver diseases such as steatosis and viral hepatitis [2].

Imaging with multiphasic computed tomography (CT) plays a primary role in the diagnosis, staging, and surgical planning of patients with HCC. According to the American Association for the Study of Liver Diseases, a >1 cm lesion arising in a cirrhotic liver that demonstrates arterial hyperenhancement and washout in a later phase on CT is diagnostic for HCC, and does not require biopsy prior to being managed with resection, liver transplantation, or other therapeutic strategies [3].

Good imaging technique is essential for detecting features of HCC, such as arterial enhancement, later-phase washout, an enhancing capsule, and venous invasion [4,5]. This is particularly true in cirrhotic livers where fibrotic and inflammatory changes can alter hepatic hemodynamics and decrease tumour conspicuity [4−9].

We recently observed poor liver enhancement in our fixed-dose liver CT examinations, and sought to update our protocol according to published guidelines. Both the Organ Procurement and Transplantation Network (OPTN) [5] and American College of Radiology Liver Imaging Reporting and Data System [10] recommend obtaining late arterial, portal venous and equilibrium phases, with the unenhanced phase being optional. The timing and ideal imaging appearance of these phases is well established in the literature [4−6,11−13].

The OPTN also recommends a rapid intravenous contrast injection rate of 4-6 mL/s and weight-based contrast dosing of 1.5 mL/kg. Multiple studies have shown that liver enhancement is improved by modifying contrast dose according to patient weight [4,11,14−17] or another surrogate for the extracellular space, such as lean body weight [18−22]. However, the vast majority of these studies were performed in Asian populations with adults weighing much less than the typical North American population [7,13,15,17−28].

In addition to updating our protocol, we sought to quantitatively evaluate the effect of our liver CT protocol modifications. Although liver CT protocol assessment criteria are not provided by the OPTN or Liver Imaging Reporting and Data System (LI-RADS) guidelines, an important benchmark recommended in the literature is that the liver should enhance by a minimum 50 Hounsfield units (HU) in the portal venous phase (PVP) [13,14,17]. Typically, an iodine concentration (IC) of 500-750 mg I/kg is required to achieve this [6,11,14,15,17,29], and this optimal concentration has been further verified in studies evaluating the detection of HCC [13,27,28].

The purpose of this audit was to compare the degree of liver and vascular attenuation and ICs achieved with our previous, fixed-dose liver CT protocol with a protocol modified by a late arterial phase, faster injection rate, and weight-based contrast dosing scheme. Because the majority of our liver CTs are performed for HCC evaluation in patients with chronic liver disease, and there is a relative paucity of literature on CT liver imaging quality in North American patients with cirrhosis, we targeted our audit to this population.

Materials and Methods

As a quality improvement study, the need for formal ethics approval and patient consent was waived by our Institutional Research Ethics Board. The study was conducted at a single, academic teaching hospital with subspecialty hepatobiliary surgery and liver transplantation service. Analysis of CT examinations was done retrospectively for the old protocol and prospectively for the modified protocol.

Patient Selection

Consecutive patients who underwent multiphasic CT imaging of the liver from January to September 2015 (old protocol, n = 49) and October to December 2015 (modified protocol, n = 31) were included. Only patients with documented liver cirrhosis, or imaging signs of cirrhosis such as parenchymal nodularity, lobar redistribution, and widened fissures, were included. A total of 4 studies were excluded due to pseudocirrhosis (n = 2) or an immeasurable, thrombosed portal vein (n = 2). For each patient, the age, gender, and body weight were recorded from the electronic health record. The clinical cirrhosis score (Model for End Stage Liver Disease [MELD]) was also recorded or calculated from the serum bilirubin, creatinine, and international normalized ratio.

CT Scanning Protocols

CT examinations were conducted on Sensation 64, Definition AS+, and Definition Flash scanners (Siemens Healthcare, Erlangen, Germany). Although protocols were designed to be similar across all 3 scanners, the Sensation 64 differs from the other scanners as it is not equipped with

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