Correlation of abdominal fat ratio with hepatic CT enhancement

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Abstract. The objective of the study was to evaluate the effect of abdominal fat proportion on hepatic computed tomography (CT) enhancement. CT data for 87 patients (47 men, mean age 55.09±13.27 years; 40 women, mean age 60.43±11.29 years) were analyzed by linear regression to assess the association of patient age and abdominal fat proportion with adjusted maximal hepatic enhancement (aMHE), calculated by dividing the maximal hepatic enhancement by the dose of iodine injected per kilogram of patient body weight, for each gender. The abdominal fat ratio (AFR) at the umbilical level, calculated as the volume of abdominal fat divided by the total abdominal volume, was used as a marker of abdominal fat proportion. It was found that aMHE was positively correlated with AFR for men (r=0.48, P<0.01) and women (r=0.46, P<0.01) but not with patient age (r=-0.09 and -0.14, respectively, both P>0.05). Therefore, it was concluded that determining an iodine dose on the basis of AFR might be an optimal way to maintain constant hepatic enhancement.

Introduction

In imaging using computed tomography (CT), optimal liver enhancement is crucial for detecting parenchymal liver lesions. Hepatic enhancement is affected by several radiologic factors, for example, the dose (1), concentration (2) and injection rate of iodinated contrast media (3,4) and the scan delay following the injection of contrast media (5,6). It is also affected by patient-related factors, including body weight (BW) (1,7) and cardiac output (8). BW is considered to be one of the most important factors. At many CT scan centers, patients undergoing abdominal CT receive a tailored dose of contrast media proportional to their BW while other factors are kept stable. Patients with increased body mass are often encountered in clinical practice. Fat tissue has much less blood perfusion than muscle tissue and parenchymal organs and contributes minimally to the extracellular volume, that is, the distribution volume of contrast media (9,10). Ho *et al* (11) reported that body fat proportion affected hepatic enhancement greatly and that calculations of contrast media dose on the basis of measured lean BW (BW without fat tissue) marginally increased patient-to-patient uniformity with respect to hepatic parenchyma and vascular enhancement. A tailored dose of contrast media proportional to BW alone may be insufficient and it is reasonable to measure the body fat proportion prior to hepatic enhancement. Lean BW can be quantified by bioimpedance, which is inconvenient in daily practice in the CT suite. In the present study, abdominal fat ratio (AFR) at the umbilical level was used as a marker of body fat proportion to evaluate its association with hepatic CT enhancement. Other patient factors for both genders were also analyzed.

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Patients and methods

Patients. The review committee of Affiliated Hospital of Shandong Academy of Medical Sciences (Jinan, China) approved this study and that patient written informed consent could be waived if patient privacy was strictly protected considering the retrospective nature of this study. An electronic database of the Department of Radiology of the Affiliated Hospital of Shandong Academy of Medical Sciences was searched to identify all patients who underwent a test bolus CT scan as part of their routine abdominal CT imaging from June 2008 to June 2012. Patients included were those who had undergone abdominal CT imaging for suspicious abdominal disease, and had negative results or only slight abnormalities such as small hemangiomas, hepatic cysts or adrenal adenomas, which were considered to have no or little effect on hepatic enhancement. These patients had no evidence of alcohol abuse, viral hepatitis/liver cirrhosis, other causes of chronic liver disease (for example, autoimmune conditions, metabolic disorders, drug use or cholangiopathy) or other factors influencing hepatic enhancement as identified by history taking, physical examination, laboratory testing or Doppler sonography of the liver.

Contrast media injection and scan protocols. Patients who had fasted overnight lay supine on a table for the test bolus CT scan with a 64-row multi-detector CT scanner (Sensation 64; Siemens AG, Munich, Germany). Prior to the scan, patients underwent an abdominal scan without contrast media while holding their breath at the end of expiration (120 kV; 250 mA; slice thickness, 5 mm; cycle time, 1 sec; standard reconstruction algorithm). A slice near the level of the hepatic hilus was selected. Then, 15 ml contrast media (Iohexol, 300 mg I/ml; Changfu Jiejing Pharmaceutical Co., Ltd., Shandong, China) was administered at 2.3 ml/sec via a 20-gauge intravenous catheter in the antecubital vein with a power injector (Medrad Stellant; Bayer Medical Care, Inc., Indianola, PA, USA). To record the hepatic enhancement change over time, test bolus scans involved multiple-slice dynamic sequences lasting 96 sec at the selected level 10 sec after injection of the contrast media. The test bolus protocol involved 24 low-dose serial scans, for 96 images (120 kVp; 250 mA; slice thickness, 10 mm; scan time, 0.36 sec; circle time, 4 sec). The patients breathed normally during the test bolus scan. Diagnostic scans were then performed according to the hepatic enhancement characteristics acquired from test bolus scans.

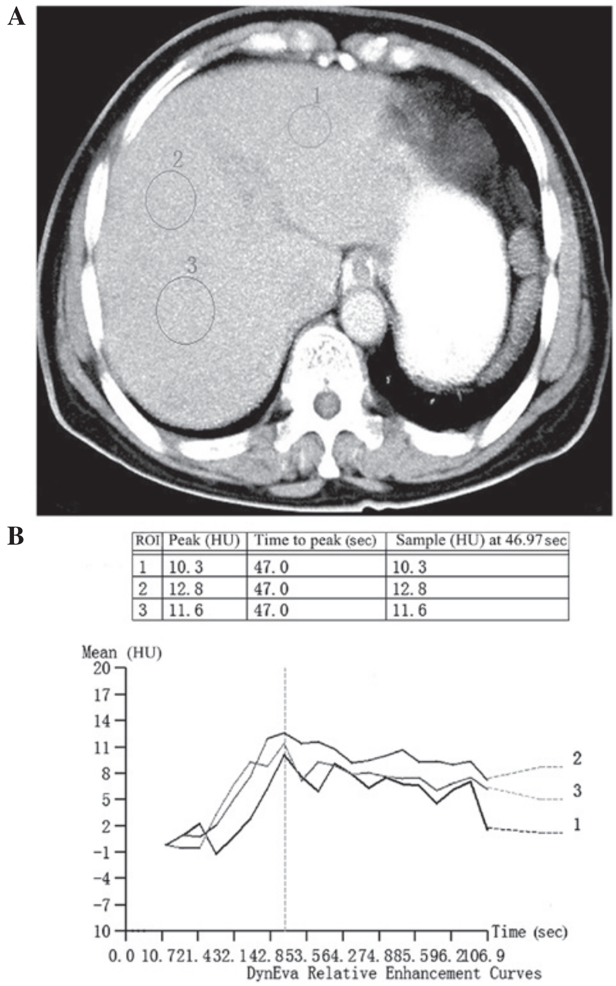
Quantitative image analysis. After image acquisition, the data were transferred to an image processing workstation (Syngo MMWP; Siemens AG). A 5-mm slice at the umbilical level on the unenhanced transverse series was selected, and the software integrated with the workstation was used to measure the volume of total abdomen and fat tissue by a semi-automatic segmentation technique, as previously described and validated (12). A freehand region of interest was manually traced outside the abdominal wall. Abdominal fat tissue and total volume were defined as pixels within a window of -190 to -30 and -190 to 1,000 Hounsfield units (HU), respectively. AFR, calculated as the volume of abdominal fat divided by the total abdominal volume, was used as a marker of body fat.

The software DynEva integrated with the workstation was used to assess features of hepatic enhancement with the test bolus series. One circular region of interest was set on the hepatic parenchyma, avoiding blood vessels, liver margins and possible lesions. The time-density curve of the region of interest was then automatically generated, and the maximal hepatic enhancement (MHE) was calculated by subtracting CT values on an unenhanced image from peak CT values in HU (Fig. 1). The mean of 3 measurements was used. Images with serious artifacts were excluded from assessment. The parameter of adjusted MHE (aMHE) proposed by Heiken *et al* (7) was calculated: aMHE = MHE/(I/BW), where I/BW is the dose of iodine in g/kg BW. aMHE was then analyzed by patient age and AFR.

Statistical analysis. All data analyses were conducted separately for men and women. Data are expressed as mean ± standard deviation. Patient AFR was correlated with BW via Pearson correlation coefficient. Linear regression test was used to assess the association of patient age and AFR with aMHE. P<0.05 was considered to indicate a statistically significant difference. Data analysis was conducted using SPSS software, version 16.0 (SPSS Inc., Chicago, IL, USA).

Results

Patient information. The study included 87 patients: 47 men (mean age, 55.09±13.27 years; range, 34-78 years) and 40 women (mean age, 60.43±11.29 years; range, 37-77 years).



ROI	Peak (HU)	Time to peak (sec)	Sample (HU) at 46.97 sec
1	10. 3	47. 0	10. 3
2	12. 8	47. 0	12. 8
3	11. 6	47. 0	11. 6

Figure 1. Measurement of maximal hepatic enhancement. (A) Three circular regions of interest (ROIs) set on the hepatic parenchyma and (B) time-density curves generated for calculating maximal hepatic enhancement.

Correlation of patient age and AFR with aMHE. The mean AFR, BW and aMHE were 40.26±7.45% (range, 26.00-54.09%), 63.64±10.90 kg (range, 42.90-94.70 kg) and 97.88±10.75 HU (range, 81.07-119.48 HU), respectively, for men and 38.97±9.80% (range, 20.50-60.40%), 60.60±8.79 kg (range, 41.50-74.80 kg) and 100.76±13.34 HU (range, 83.11-124.97 HU), respectively, for women. AFR was not correlated with BW for men (r=0.09, P>0.05) or women (r=0.08, P>0.05). aMHE was positively correlated with AFR for men (r=0.48, P<0.01; relational expression aMHE = 70.25 + 0.69 x AFR) and women (r=0.46, P<0.01; relational expression aMHE = 76.26 + 0.63 x AFR) but not patient age for men or women (r=-0.09 and -0.14, respectively, both P>0.05).

Discussion

In this study, the association of AFR at the umbilical level and other patient factors with hepatic enhancement features on CT were evaluated. AFR at the umbilical level was found to positively correlate with aMHE.

Fat tissue has much less blood perfusion than muscle tissue and parenchymal organs. For example, the blood flow in a 70 kg resting human has been estimated to be 260 ml/min in fat tissue, 750 ml/min in muscles, and 1,450 ml/min in the liver (9). In addition, adipose tissue contributes minimally to the extracellular volume, that is, the distribution volume of contrast media (10). According to our understanding, if the same volume of contrast media is administered to patients with the same BW but different amounts of body fat tissue, the use of contrast media per kilogram of lean BW will be relatively higher and thus greater hepatic enhancement will be achieved in patients with more body fat. Therefore, obese patients have a tendency to receive unnecessarily high doses of contrast media while muscular patients may receive doses that are too low. The observation of an association between abdominal fat and hepatic enhancement in the present study is consistent with some previous observations (11,13). Ho *et al* (11) reported that body fat proportion affected hepatic enhancement greatly, and that calculations of contrast media dose on the basis of measured lean BW marginally increased patient-to-patient uniformity with respect to hepatic parenchyma and vascular enhancement. Another study (14) revealed that hepatic enhancement was affected significantly by patient age; however, this trend was not observed in the present study, perhaps because of the small sample size.

The relational expressions between AFR and aMHE in men and women were substituted into the formula of Heiken *et al* (7): [aMHE = MHE/(I/BW)], and two relational expressions were obtained: I/BW (men) = MHE/(70.25 + 0.69 x AFR) and I/BW (women) = MHE/(76.26 + 0.63 x AFR). With these expressions, it is easy to determine the iodine dose needed per kilogram of BW to produce a desired level of hepatic enhancement in a patient of known BW and AFR. For example, the dose of iodine required for desired enhancement levels of 50 HU in a man with an AFR of 20% is ~0.59 g/kg, whereas that in a man with BFP of 40% is ~0.51 g/kg. These results indicate that determining an iodine dose by proportion of fat in the human body is an optimal method for maintaining a constant intensity of hepatic and vascular enhancement constant and to reduce the intersubject variability in enhancement intensity. The observation that the aMHE was higher in patients with greater AFR suggests that less contrast media should be administered to patients with the same BW but more body fat, to increase patient-to-patient uniformity of hepatic enhancement. The advantages of reducing the contrast media include a potential reduction in nephrotoxicity, particularly in patients with preexisting renal insufficiency or other risk factors associated with obesity (15,16), and cost reduction.

There are several markers of the proportion of body fat. Although anthropometric markers such as waist circumstance and body mass index are conveniently measured, they are estimates and are not accurate. Kondo *et al* (13) used body fat percentage to evaluate the association between body fat and hepatic enhancement, and their results indicated that the correlation with hepatic enhancement was higher for body fat percentage than for other anthropometric markers. However, the measurement of body fat percentage requires a special instrument that is not always available. Fat measurement is a basic and accurate function in almost every modern CT scanner, and the measurement method is convenient and can be performed in several minutes. Therefore, AFR was selected for assessment of its association with hepatic enhancement in the present study.

To assess the characteristics of hepatic enhancement, two imaging protocols, test bolus and bolus tracking, are commonly used. The bolus tracking protocol monitors in real time the enhancement of a preselected region of interest with repetitive low-dose test scans following the injection of a contrast medium; the diagnostic scan then automatically starts when the enhancement of the region of interest reaches the preset threshold. The test bolus protocol requires an additional test injection of a small amount of contrast media prior to the diagnostic scan, and then a series of repetitive low-dose scans at a preselected level are performed to record the degree of hepatic enhancement over time. A time-density curve is then generated to guide the later diagnostic scans. As compared with the bolus tracking protocol, the test bolus scans provide more accurate data of hepatic enhancement features and have been performed routinely in the Department of Radiology of Affiliated Hospital of Shandong Academy of Medical Sciences. Therefore, data for patients who underwent a test bolus scan as part of their abdominal CT imaging were selected for analysis. However, the test bolus protocol requires more contrast media and time; moreover, it impairs the quality of subsequent diagnostic scans because the level of enhancement masks parenchymal lesions. Therefore, it is seldom performed now in clinical practice.

The present study has certain limitations. First, some important factors influencing hepatic enhancement such as heart rate and cardiac output were not investigated because these data were not available for these patients. Second, since the correlation coefficient between aMHE and AFR was as low as ~0.5, the association between abdominal fat and hepatic enhancement requires verification in further studies. Finally, the sample size was relatively small.

Despite these limitations, the study revealed that AFR was positively correlated with aMHE in test bolus CT scans. It may be concluded that determining an iodine dose on the basis of abdominal fat ratio might be a optimal way to maintain a constant intensity of hepatic enhancement constant and to reduce the intersubject variability when designing an abdominal CT protocol.

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