The Value of Nonenhanced Single-Source Dual-Energy CT for Differentiating Metastases From Adenoma in Adrenal Glands

Ye Ju, MM, Ailian Liu, MD, Yue Dong, MD, Yijun Liu, MD, Heqing Wang, MD, Meiyu Sun, MD, Renwang Pu, MM, Anliang Chen, MM

Rationale and Objectives: To evaluate the value of the nonenhanced single-source dual-energy computed tomography (ssDECT) in differentiating metastases from adenomas in adrenal glands.

Materials and Methods: This retrospective study was approved by our Institutional Review Board, and written informed consent was waived. One hundred twelve patients (66 men:46 women; mean age, 58 years) with 63 adrenal metastases (AMs) and 64 adrenal adenomas (AAs) underwent a plain dual-energy spectral CT imaging from August 2011 to December 2013 were included. The fat (water) density (DFa [Wa]) from the material decomposition (MD) images and CT number and effective atomic number (eff-Z) from the virtual monochromatic spectral (VMS) image sets were measured for the AMs and AAs. The spectral Hounsfield unit (HU) curve (CT number as a function of photon energy from 40 to 140 keV) was generated, and its slope (K) was calculated. The difference of these parameters between AMs and AAs was statistically compared by the Wilcoxon rank sum test. Receiver operating characteristic curve (ROC) curves were used to compare the diagnostic efficacies of these measures in the identification of AAs and AMs. The distribution of spectral HU curve was analyzed using the chi-square test in terms of its slope K: ascending ($K > 0.1$), straight ($-0.1 \le K \le 0.1$), and descending ($K < -0.1$).

Results: 1) The CT number (medium, range) of metastases (50.47, 29.93 HU at 40 keV and 29.00, 9.36 HU at 140 keV) was significantly higher than that of adenomas (−0.76, 33.04 to 13.73, 18.96 HU) at each energy level from 40 to 140 keV ($P < .05$). 2) The fat concentration of metastases (−177.37, 296.38 mg/mL) was statistically lower than that of adenomas (126.73, 328.07 mg/mL; $P < .05$). 3) The eff-Z of metastases (7.76, 0.23) was significantly higher than that of adenomas (7.42, 0.32; $P < .05$). 4) With CT number of VMS image at 40 keV of 21.78 HU as a threshold, the sensitivity and specificity for differentiating metastases from adenomas was 92.1% and 76.6%, respectively, and the area under the ROC curve was 0.90. 5) The spectral curve types included 3.2% (2 of 63) ascending, 20.6% (13 of 63) straight, and 76.2% (48 of 63) descending for the metastases, whereas the corresponding numbers were 60.9% (39 of 64), 21.9% (14 of 64), and 17.2% (11 of 64) for the adenomas. The difference was statistically significant ($X^2 = 56.63$; $P < .05$).

Conclusions: The nonenhanced ssDECT enables a multiparametric approach to provide an excellent sensitivity for identifying AMs from AAs.

Key Words: Adrenal neoplasm; spectral imaging; x-ray computed tomography; quantification; differential diagnosis.

The differentiation of metastases from adenomas in adrenal glands continues to be a challenge, primarily because an adrenal mass is found so often. The prevalence of adrenal adenomas (AAs) in the general population has been reported to be closer to 5% (1). And even for patients with extra-adrenal malignancy, most adrenal mass are adenomas (2).

It has been reported that unenhanced computed tomographic (CT) scans have a sensitivity of 71% and a specificity of 98% in the diagnosis of AA (3). There are many reports about the magnetic resonance (MR) imaging (MRI) in the differentiation between benign and malignant adrenal tumors (4–6). It is worth mentioning that combined analysis (chemical-shift imaging and early dynamic serial imaging) has a sensitivity of 94% and a specificity of 98% for diagnosing nonadenomas (4). However, about 10%–40% of adenomas are lipid poor, which reduces the sensitivity for characterization of adenomas on those scans (7,8).

Ultrasonography is of great value in diagnosing adrenal tumors because it is easily accessible and relatively cheaper. But ultrasonography often misses small neoplasms. Positron emission tomography–computed tomography (PET/CT)

Acad Radiol 2015; 22:834–839

From the Department of Radiology, The First Affiliated Hospital of Dalian Medical University, No. 222 Zhongshan Road, Dalian, Liaoning 0086-116011, China (Y.J., A.L., Y.D., Y.L., H.W., M.S., R.P., A.C.). Received August 24, 2014; accepted March 2, 2015. **Address correspondence to:** A.L. e-mail: dmu_liuailian@126.com

http://dx.doi.org/10.1016/j.acra.2015.03.004

also has been shown to be valuable in the differentiation of benign and malignant lesions with high sensitivity and specificity (9). Metastasis detection at PET/CT, however, depends on the primary tumor, metastasis size, and differentiation. Hemorrhage and necrosis are also known to cause false-negative results in 2-[fluorine-18]fluoro-2-deoxy-D-glucose (FDG) PET (10).

Recently, several publications have shown that dual-energy CT (DECT) can be used to evaluate adrenal masses (11–15). One of the studies has suggested that dual-source DECT (dsDECT) can be used to distinguish AA from adrenal metastasis (AM) (11). But, to our knowledge, the differentiation of adrenal mass with unenhanced single-source DECT (ssDECT) has not been investigated. The purpose of this study was to assess the clinical value of the unenhanced ssDECT in differentiating AMs from AMs by using comprehensive analysis tools.

MATERIALS AND METHODS

Patients

This study was a retrospective validation study of diagnostic test, and it was approved by the Institutional Review Board of our hospital, and written informed consent was waived. Abdominal patients from August 2011 through December 2013 in our hospital who met the following criteria were included in this study: 1) underwent nonenhanced abdominal CT using single-source dual-energy spectral imaging mode; 2) had localized nodules within the adrenal glands; 3) had either MR or >6-month follow-up CT on the adrenal glands. Finally, a total of 112 patients (66 men:46 women; mean age, 58 ± 11 years; age range, 24.0–84.0 years) were included in our study (Table 1). The size of the nodules was 2.18 ± 1.10 cm in diameter with range from 0.88 to 7.16 cm. There were 127 total adrenal nodules including 63 metastases and 64 adenomas in the 112 patients. Ninety-seven of the 112 patients had a single adrenal nodule (57 on the left and 40 on the right); 15 patients had two adrenal nodules (15 on the left and 15 on the right). All the adenomas had histologic proof and was obtained at surgery or percutaneous biopsy; adrenal nodules were regarded as metastatic if they had a ≥30% increase in size during the 6 months of a subsequent CT or MR examination and occurred in patients with a history of malignancy: lung cancer (26 patients), gastric cancer (5 patients), colon carcinoma (9 patients), esophageal carcinoma (2 patients), pancreatic cancer (2 patients), renal cell carcinoma (3 patients), bladder cancer (one patient), breast cancer (one patient), and no clear pathologic type (3 patients).

Imaging

All patients underwent the nonenhanced abdominal CT scanning on a GE Discovery CT750 HD scanner (GE Healthcare, Milwaukee, WI) using the ssDECT imaging scan mode with the fast tube voltage switching between 80 and 140 kVp within each detection angular view during a single rotation. The spectral imaging acquisition protocol was as follows: 0.625 mm × 64; 550 mA; pitch, 1.375:1; rotation time, 0.8 s per rotation, resulting in an average volumetric CT dose index of 18.28 mGy. From single-spectral CT scan, a set of virtual monochromatic spectral (VMS) images with photon energy levels from 40 to 140 keV were reconstructed. In addition, material decomposition images with the fat and water as basis material pairs were also reconstructed. The reconstructed images had slice thickness and spacing of 2.5 mm.

Image Analysis

Both the VMS image sets from 40 to 140 keV and material decomposition images using fat and water as basis material pairs were transferred to an advanced workstation for measurement and image analysis. For each adrenal mass detected with CT, 1 observer (Y.J.) who has 3 years of experience in imaging did the measurement and quantitative analysis under the direction of a radiologist (H.W.) who has 10 years of experience in abdominal imaging, and both of them did not know the final diagnosis. All measurements were performed on an advanced workstation AW4.5 (GE Healthcare, Waukesha, WI) using the Gemstone Spectral Imaging (GSI) viewer software on the workstation. Initially, the 70-keV monochromatic image was used to locate the lesion and place a region of interest (ROI) for measurement, and the GSI viewer would propagate the measurement to all energy levels from 40 to 140 keV. Circular or elliptical ROI (area of the ROI was about half of the lesion) was placed in the lesion, avoiding necrosis, hemorrhage, calcification, and the edge of the lesion. The CT number from the monochromatic image as a function of photon energy from 40 to 140 keV and fat concentration from the fat-based material decomposition image were measured for the AMs and AAs. The spectral Hounsfield unit (HU) curve (CT number as function of photon energy from 40 to 140 keV) was generated; its slope and effective atomic number (eff-Z) were calculated. The slope (K) of the spectral HU curve was defined as the difference of the CT numbers at 40 and 140 keV divided by the energy difference of 100. The spectral curve was divided into the following three types based on the measured slope: ascending ($K > 0.1$), straight ($-0.1 \le K \le 0.1$), and descending ($K < -0.1$).

Statistical Analysis

Software (SPSS, version 17; SPSS) was used for statistical analysis. A value of $P < .05$ was considered statistically significant. The CT number from the monochromatic images (40–140 keV), fat concentration, and eff-Z between AMs and AAs were compared statistically by using the Wilcoxon rank sum test (they were not followed with normal distribution.) Sensitivity, specificity, and area under the receiver operating characteristic curve (ROC) curve (AUC) for diagnosing