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ORIGINAL ARTICLE

Evaluation of Normal Adrenal Gland Volume by 64-slice CT

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Objective To measure volume and other parameters of normal adrenal glands in Chinese adults with 64-slice multidetector CT, to evaluate the relationship of volume result with age, sex and body size, and to explore the correlations between adrenal volume and other measurements.

Methods This study was based on 125 acquired contrast-enhanced upper abdominal CT scans performed with a 64-slice CT. The final study group consisted of 81 patients (49 males, 32 females). Portal venous phase images were studied for the measurements. Both the reconstruction interval and thickness were 1.5 mm. Each adrenal gland was outlined manually with computer-assistant technology to calculate its volume. The maximal sectional area, length, width and thickness of each adrenal gland were also measured.

Results The mean age of total population was 47.9 ± 13.0 (range: 20-76) years. The left, right, and total adrenal gland volumes were 4.23 ± 0.74 (range: 2.85-5.83) cm^3 , 4.26 ± 0.86 (2.59-6.56) cm^3 , and 8.50 ± 1.40 (5.80-11.39) cm^3 , respectively. These volumes increased with weight ($r=0.381$, 0.389 , and 0.437 respectively, all $P<0.001$), height ($r=0.386$, $P<0.001$; $r=0.297$, $P=0.007$; $r=0.384$, $P<0.001$) and body surface area ($r=0.406$, 0.392 , and 0.452 , all $P<0.001$). There was no significant difference in left, right or total adrenal volume with regard to sex after applying General Linear Model procedure to reduce the impact of weight ($F=1.304$, 0.064 , and 0.597 , all $P>0.05$), nor did volume change significantly with age ($r=-0.033$, -0.014 , and -0.026 , all $P>0.05$). Nearly all descriptors of bilateral adrenal glands correlated with ipsilateral volume except thickness ($r=-0.027$, $P=0.814$) and width ($r=0.166$, $P=0.138$) in the left side. Among these parameters, length had a stronger correlation with volume than others in the both left ($r=0.412$, $P<0.001$) and right ($r=0.516$, $P<0.001$) adrenal glands.

Conclusion Our study has defined the volume distribution and other parameters of normal adrenal glands in Chinese adults, which provide a baseline for future studies.

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ANATOMICALLY, adrenal glands are tiny structures that are situated in the extraperitoneal perirenal space bilaterally.¹ Each one is surrounded by an adipose capsule and renal fascia. Functionally, adrenal glands are vital endocrine glands despite their small size. They secrete hormones directly into the bloodstream and play a crucial role in many metabolic processes, and also help human body in dealing with physical and mental stress.

There are wide varieties of the adrenal diseases that lead morphologic changes in adrenal glands.² The volume of the adrenal glands can also be modified by several systematic pathological conditions including depression and septic shock.³⁻⁵ With the development of multidetector spiral computed tomography, the determination of adrenal volume has become possible since recent years.⁵⁻⁷ However, adrenal thickness, instead of the volume, is still considered as a useful parameter for evaluating suspected adrenal pathology.⁸⁻¹⁰

To date, only limited studies have reported *in vivo* quantitation of adrenal gland volume, most based on single thick slice acquisition of 3 mm, and all the subjects were from western population.^{3, 5-7} Besides, the relationships between volume and other measurements of normal adrenal glands have not been fully explored. The purpose of this study was to measure volume and other parameters of normal adrenal glands in Chinese adults with 64-slice multidetector CT, to evaluate relationship of volume result with age, sex and body size, and to explore the correlations between adrenal volume and other parameters.

PATIENTS AND METHODS

Patients

This retrospective study was based on 125 consecutive contrast-enhanced upper abdominal CT scans performed from July to September of 2008 in our hospital. All patients were referred to radiology department for routine clinical evaluation. Cases with focal adrenal enlargement suggesting a mass were not included. Patients with a history of hypertension, endocrinopathy or chronic steroid use were also excluded to decrease the selection bias. The final study group consisted of 81 patients (49 males, 32 females).

This was a retrospective single-institution study, and the requirement for informed consent of the individual patients was waived in that situation at our facility.

CT scan protocol

All examinations were performed with a 64-slice CT scan-

ner (Somatom Sensation 64, Siemens Medical Solutions, Forchheim, Germany) with a detector collimation of 64×0.6 mm and a pitch of 1.2. Rotation time was 0.33 second. Reference tube current was 220 mA and the tube voltage was 120 kVp. For contrast enhancement, 90 mL of contrast media (iopromide, Ultravist, 370 mg/mL, Bayer Schering Pharma, Berlin, Germany; Iohexol, Omnipaque, 350 mgI/mL, GE Healthcare Limited, Buckinghamshire, UK) was injected *via* an 18-G catheter placed in an antecubital vein with a flow rate of 4 mL/s. Automated detection of peak enhancement in the abdominal aorta was used for timing of the bolus. Triple-phase enhanced CT scans were performed. Portal venous phase images were used for the measurements which were obtained 35-40 seconds after the onset of arterial scan. Both the reconstruction interval and thickness were 1.5 mm (without overlaps).

Measurements

The adrenal volume was estimated quantitatively using commercially available software (syngo Volume, Siemens). The adrenal contour was manually defined by a single investigator. Threshold values were established to exclude adjacent fat from the volume calculated. Only tissue with attenuation values of 0 to 200 Hounsfield units within the region of interest was included.

The width and thickness of each gland were determined on the axial section in which the adrenal gland appeared largest during the examination (Fig. 1).¹ The width of the adrenal gland was the greatest linear dimension. The thickness was defined as its dimension perpendicular to the long axis of the gland. The contour of adrenal gland on that axial image was defined to obtain maximal sectional area. The length (also named as height) of the gland was defined as its cephalocaudal dimension. It can also be estimated by counting the number of transverse cross sections on which each gland was visualized.

Statistical analysis

Statistical analysis was performed by using commercially available software (SPSS, version 16.0 for Windows, Chicago, USA). Data were reported as means±SD. *Pearson* correlation was used to analyze the correlation between adrenal volume and other adrenal parameters (length, width, thickness and maximal sectional area), patient age or anthropometric measurements [weight, height and body surface area (BSA)], separately. The analysis of covariance model was specified with body weight, height or BSA as a covariate and sex as classification variable. $P < 0.05$ was considered to represent a statistically significant result.

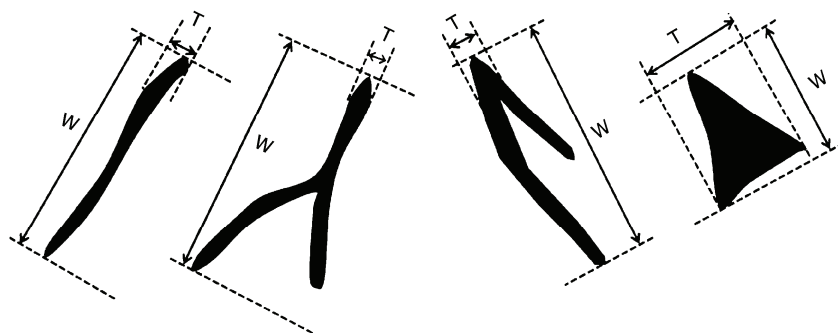


Figure 1. A schematic diagram showed measurements of the width (W) and the thickness (T) of normal adrenal glands.

RESULTS

Descriptive statistics of whole subjects

The mean age of total population was 47.9 ± 13.0 (range: 20-76) years. The mean weight, height and BSA were 70.7 ± 12.7 (41-100) kg, 168.3 ± 7.4 (151-185) cm and 1.81 ± 0.19 (1.35-2.24) m^2 , respectively. The average measurements for the left adrenal gland were: mean volume 4.23 ± 0.74 (2.85-5.83) cm^3 ; maximal sectional area 1.86 ± 0.53 (0.93-3.13) cm^2 , length 3.93 ± 0.67 (2.25-5.55) cm, width 2.52 ± 0.73 (1.27-4.60) cm and thickness 0.97 ± 0.23 (0.30-1.42) cm. The average measurements for the right adrenal gland were: mean volume 4.26 ± 0.86 (2.59-6.56) cm^3 ; maximal sectional area 2.22 ± 0.66 (0.56-4.09) cm^2 , length 3.76 ± 0.57 (2.55-5.25) cm, width 3.33 ± 0.68 (1.45-4.54) cm and thickness 0.76 ± 0.18 (0.30-1.42) cm. Mean total volume was 8.50 ± 1.40 (5.80-11.39) cm^3 .

Evaluation of relationship of adrenal volume with age, sex and body habitus

Left, right and total adrenal gland volumes increased with weight ($r=0.381$, 0.389 and 0.437 respectively, all $P<0.001$), height ($r=0.386$, $P<0.001$; $r=0.297$, $P=0.007$; $r=0.384$, $P<0.001$) and BSA ($r=0.406$, 0.392 and 0.452 , all $P<0.001$), especially weight and BSA (Fig. 2). There was no significant difference in left, right or total adrenal volume with regard to sex after applying General Linear Model procedure to reduce the impact of weight ($F=1.304$, 0.064 , and 0.597 , all $P>0.05$), nor did volume change significantly with age ($r=-0.033$, -0.014 , and -0.026 , all $P>0.05$).

Correlation between adrenal volume and measurement parameters

Nearly all descriptors of bilateral adrenal glands correlated with ipsilateral volume except thickness and width in the left side (Table 1). Among these parameters, length had a

stronger correlation with volume than others in the both left ($r=0.412$, $P<0.001$) and right adrenal glands ($r=0.516$, $P<0.001$; Fig. 3). The left adrenal volume correlated with the right adrenal volume ($r=0.554$, $P<0.001$).

DISCUSSION

The change of adrenal volume has significant clinical importance in several crucial conditions.³⁻⁵ For example, it was an independent prognostic factor for 28-day mortality of patients with septic shock.⁴ Thus, the knowledge of normal adrenal volume distribution is of great importance. However, there were wide varieties of results reported by different investigators, with the mean value ranging from 3.5 to 11.4 cm^3 . Besides, to the best of our knowledge, all previous *in vivo* studies were of the western population.^{3, 5-7} This study was performed to determine the range of normal adrenal volume in Chinese adult subjects, in order to provide a reference for future analyses of pathologic conditions. The mean total volume of this study was 8.50 ± 1.40 cm^3 , which was in accordance with the results of previous studies.^{5, 7} The wide difference of previous results is mainly explained by the technological advances in CT imaging, since multidetector scanner allows thin slice imaging with greater accuracy and less partial volume error.

Similar to previous researches,^{5, 6} our results revealed a positive correlation between total adrenal gland volume and body weight, height and BSA, while the correlation strength is weaker than that reported by Nougaret *et al.*⁵ In contrast, the relative contribution of sex to adrenal volume was not significant, which was different from the result of Rubin and Phillips.⁶ There was also no consistent correlation between adrenal volume and age. Further studies might be required to determine the impact of sex. Nevertheless, it is essential to control these variables, especially body size in comparative studies of the adrenal gland volume in the future.

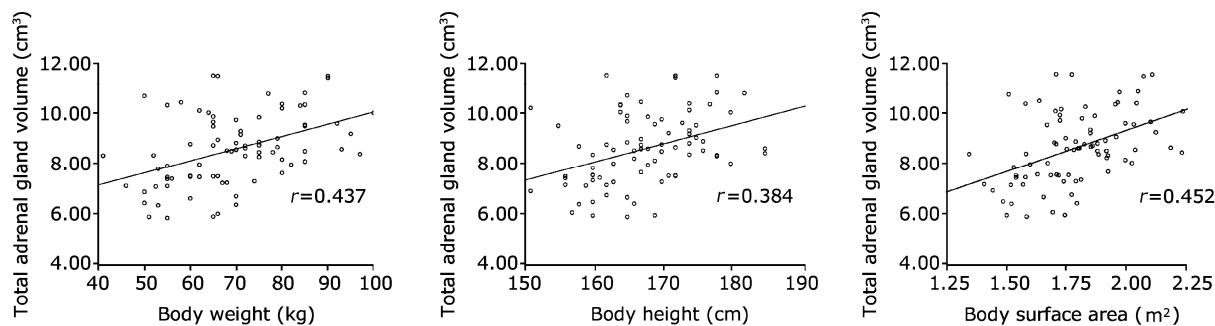


Figure 2. Scatterplots showing the results of regression analysis of adrenal gland volume and patients’ weight, height and body surface area. (n=81)

Table 1. Correlation between volume and length, maximal sectional area, thickness and width in bilateral adrenal glands (n=81)

Descriptor	Ipsilateral adrenal gland volume	
	r value	P value
Left length	0.412	<0.001
Left sectional area	0.365	0.001
Left thickness	-0.027	0.814
Left width	0.166	0.138
Right length	0.516	<0.001
Right sectional area	0.423	<0.001
Right thickness	0.371	0.001
Right width	0.371	0.001

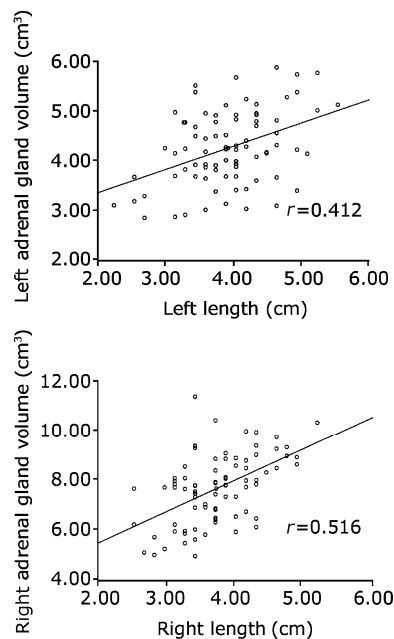


Figure 3. Scatterplots showing the results of regression analysis of adrenal gland volume and length in the left and right side. (n=81)

The results of length, width, thickness and maximum sectional area of left and right adrenal glands in this study correlate well with previous CT studies.^{1, 9, 10} Despite that all measurements have moderate correlations to the

volume in the right adrenal gland, the correlations are less obvious on the left side. There are several possible explanations. First, the location of right adrenal gland is confined between the liver and the diaphragm, so it is always presenting a linear or slightly bent linear morphology, which reduce the variety of dimensional values.¹⁰ Second, physiologic characteristics of the left and right adrenal glands are different: the left adrenal vein blood supply drains into the left renal vein, while the right adrenal vein drains directly into the inferior vena cava. So increased pressure might be transmitted to the left adrenal gland,¹¹ resulting in an increased susceptibility to hyperplasia or adenomatous change. Previous study also showed that the adrenal gland nodularity was commoner on the left side.¹² Nevertheless, linear measurements are affected by the variety of configurations of the adrenal gland. Assessing adrenal volume is an accurate way which overcomes the effect of gland morphology on measurement.

This study has several limitations. One is selection bias because of its retrospective nature. Although strict exclusion criteria were established to minimize this influence, our patient population was not screened for biochemical evidence of endocrinopathy. Second, the calculation of adrenal volume is time consuming because the contours were defined by manual-drawing. Nowadays, with the development of recent semiautomated organ segmentation techniques, imaging-based volumetry has become an easy and fast procedure which can be applied in routine practice.^{5, 13, 14}

In conclusion, our study has defined the volume distribution and other parameters of normal adrenal glands in Chinese adults. These measurements provide a baseline for establishing adrenal normality or enlargement on CT examination of the adrenal glands, which are useful to facilitate accurate diagnosis in clinical or research setting. Besides, we have found that length has a stronger correlation with volume than other parameters in both adrenal glands.

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