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Original Research

# Evaluation of Normal Adrenal Gland Volume and Morphometry and Relationship with Waist Circumference in an Adult Population Using Multidetector Computed Tomography

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## Abstract

**Objectives:** This study aims to determine the normal range of values of the right, left, and total volume and shape of the adrenal gland (AG) and to evaluate its relationship with gender, age, height, weight, body mass index (BMI), and waist circumference (WC) in multidetector computed tomography (MDCT) images.

**Methods:** The study included 115 MDCT scans, of which 56 were men and 59 were women. For volume measurement, the outlines of the AG were drawn semi-automatically for all patients. Then, collecting the area in each slice, the volumes were automatically measured. The intraclass correlation coefficient (ICC) test was used to analyze intraobserver reliability for repeated measurements with a 95% confidence interval. Participant's age, gender, weight, height, BMI, and WC were obtained. $p<0.05$ was considered statistically significant.

**Results:** The mean age of participants was 49.5±17.7 (19–81). The average right AGV (RAGV), left AGV (LAGV), and total AGV were 3.47±1.33, 4.77±1.33, and 8.25±2.74, respectively. The ICC values for all measurements were >0.80–0.90, indicating good and excellent agreement. LAGV was measured as higher than the RAGV. A positive moderate correlation of the AGVs with BMI and WC was observed.

**Conclusion:** The increase in BMI and WC, which are indicators of obesity, correlates with the increase in AGV, we think that the findings will be valuable in evaluating the pathophysiology of the hypothalamic-pituitary-adrenal axis.

**Keywords**: Adrenal glands; computed tomography, reference value; volumetry; waist circumference.

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## Introduction

Adrenal glands (AGs), also known as suprarenal glands, are anatomically located extra peritoneal double organs with endocrine secretory function.[1] The methods commonly used in the AG evaluation and size measurements are ultrasonography, magnetic resonance imaging, and multidetector computed tomography(MDCT).[2-4] Due to its fast, widely accessible, and high spatial resolution, MDCT is the primary method of choice for the assessment of the AGs.[5]

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In clinical and radiological practice, adrenal thickness measurements are still frequently used.[6,7] However, thanks to the advancements in MDCT technology, semi-automatic volume measurements of organs such as the AG and body parts have become possible.[8,9]

In various conditions, such as malignant or benign mass, bleeding, and endocrine disorders, the volume of the AGs may be affected. Moreover, AG volume (AGV) is a predictive value in septic shock.[10]

Due to the variability of AG morphology, thickness measurements may not be accurate. However, volumetric analysis can provide more standardized evaluations due to advances in MDCT software technology. Therefore, it should be used with increasing frequency in practical applications.

This study aims to determine the normal range of values of the right, left, and total volume and shape of the AG and evaluate its relationship with gender, age, height, weight, body mass index (BMI), and waist circumference (WC) in MDCT images.

## Methods

This study was approved by the local ethics committee (2021–451) and complies with the Helsinki Declaration. The informed consent was waived due to the retrospective nature of the study and the assessment utilized anonymous research findings. This study was conducted over 12 months from January 2020 to December 2020. The study included 115 MDCT scans, of which 56 were men and 59 were women. All patients were referred to the radiology department for routine clinical evaluation such as various clinical symptoms related to the upper abdomen. Cases that indicate a mass of focal adrenal thickening, adrenal calcification, the thickness of adrenal body >10 mm, patients with a history of hypertension, adrenal insufficiency or bleeding, oral contraceptive medical therapy, depression, surgery, endocrine diseases, or chronic steroid use were excluded from this study.

All of the MDCT studies were performed using a multidetector 16-row helical CT scanner (Alexion, Toshiba Medical Systems, Nasu, Japan). The following parameters for scanning were applied: Tube voltage was 120 Kv, beam collimation was 1 × 16 mm, gantry rotation time was 0.75 s, and the pitch was 1. Thin section CT data were reconstructed at a slice thickness of 1 mm with 0.8mm intervals. The image matrix was 512 × 512. We used automatic tube current modulation at a maximum of 225 m. As for exposure dose reduction. Images were acquired in the supine position 60 s after injection (Iohexol, Kopaq, Koçsel, 370 mg/mL, 1.5 mL/kg).

The volume of the AGs was analyzed using a workstation Vitrea (Canon Medical Systems Corporation, Otawara, Japan) by only one radiologist (E.G.) with 7 years of experience in abdominal radiology.

For volume measurement, AG contour was manually evaluated by the examiner for all patients (Figure 1). Then, collecting the area in each slice, the volumes were automatically measured using Vitrea post-processing imaging software (Canon Medical Systems Corporation, Otawara, Japan). Eventually, the volume was measured by the software, and three-dimensional reconstruction of the organ was produced (Fig. 2a and b). The AGV was measured in ml. The bilateral AGV was reevaluated 1 week after the initial evaluation to assess the reproducibility of the same observer.

AG shape was evaluated in four groups as linear, "v" shape, "y" shape, and triangular shape according to the previous study.[11]

WC was evaluated in the last MDCT image where the iliac bone was not visible just above the iliac crest (Fig. 3).

### Statistical Analysis

Statistical analysis was performed through the SPSS v.22 package program (IBM SPSS Statistics, Chicago, IL, USA). Participant age, gender, weight, height, BMI, and WC were obtained. Descriptive statistics were expressed as a mean± standard deviation. The distribution of data was analyzed through the Kolmogorov–Smirnov test. The relationship of

**Figure 1.** Contrast-enhanced CT image of the upper abdomen in the axial plane showing adrenal glands.

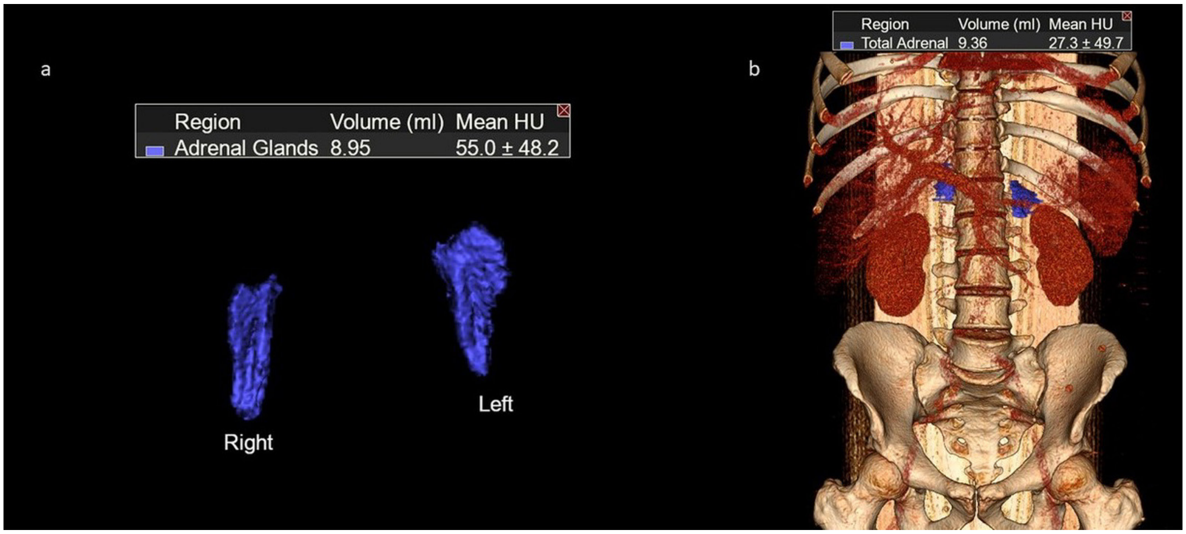


**Figure 2.** (a and b) Calculation of adrenal glands volume and three-dimensional reconstructed CT image of its.

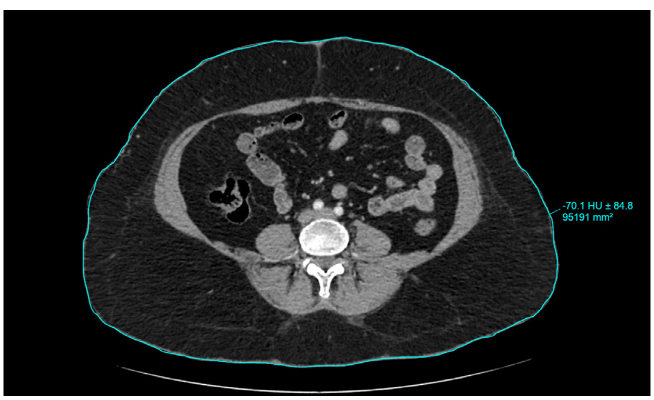


**Figure 3**. Evaluation of the waist circumference on a CT image, using both a line to approximate the skin contour and calculating in mm$^2$.

AGV to gender and between the two sides was evaluated using the Mann–Whitney U-test. The relationship between the bilateral AGVs versus age, weight, height, BMI, and WC was calculated through the "Pearson's correlation coefficient test." The intraclass correlation coefficient (ICC) test was used to analyze intraobserver reliability for repeated measurements with a 95% confidence interval. ICC was interpreted as follows: Below 0.50: Poor; between 0.50 and 0.75: Moderate; between 0.75 and 0.90: Good; and above 0.90: Excellent. A $p$=0.05 was considered statistically significant.

## Results

The demographic data of the 115 subjects (230 AG) are presented in Table 1. Nine patients were excluded from the study due to the history of surgery, chronic steroid usage, hypertension, and endocrine diseases such as diabetes. Furthermore, 24 patients were excluded from the study because of the focal adrenal thickening or mass.

The most common shape in both the right AG (RAG) and the left AG (LAG) was found to be the "Y" shape. AG shapes and their frequency (in percentage) are shown in Table 2.

**Table 1**. Descriptive statistics for age, height, body mass index, waist circumference, and gender distributions of all cases

| Clinical characteristic | Total (*n*=60) |
|---|---|
| Age (years old) | 49.5±17.7 (19–81) |
| Weight (kg) | 73.24±12.93 |
| Height (cm) | 169.14±7.11 (150–185) |
| BMI (kg/m$^2$) | 27.16±3.86 (21.48–34.30) |
| WC (mm$^2$) | 71248.39±18909.96 |
| Gender (M/F) | 56/59 |

Data are expressed as n (number) or the mean±standard deviation (range). F: Female; M: Male; BMI: Body mass index; WC: Waist circumference.

**Table 2.** The shape of the adrenal glands

| The shape of AG | RAG | | LAG | |
|---|---|---|---|---|
| | *n* | % | *n* | % |
| Linear type | 6 | 5.21 | 1 | 0.86 |
| Y type | 106 | 92.17 | 104 | 90.43 |
| V type | 1 | 0.86 | 1 | 0.86 |
| Triangular | 2 | 1.73 | 9 | 7.82 |

AG: Adrenal gland; RAG: Right adrenal gland; LAG: Left adrenal gland.

**Table 3.** Adrenal gland volume values

| Volume | *n* | Mean | Standard deviation | Median | Minimum | Maximum |
|---|---|---|---|---|---|---|
| RAG | 115 | 3.47 | 1.33 | 3.01 | 1.41 | 6.59 |
| LAG | 115 | 4.77 | 1.69 | 4.25 | 2.06 | 8.82 |
| TAG | 115 | 8.25 | 2.74 | 7.92 | 3.47 | 15.41 |

RAG: Right adrenal gland; LAG: Left adrenal gland; TAG:Total adrenal gland

**Table 4.** Pearson's correlation of age, weight, height, body mass index, and waist circumference of the adrenal glands

| | LAG | LAG | TAG |
|---|---|---|---|
| Age | | | |
| Pearson correlation | 0.222 | 0.247 | 0.260 |
| *P*-value | 0.017 | 0.008 | 0.005 |
| Weight | | | |
| Pearson correlation | 0.165 | 0.248 | 0.233 |
| *p*-value | 0.048 | 0.008 | 0.012 |
| Height | | | |
| Pearson correlation | 0.112 | 0.223 | 0.192 |
| *P*-value | 0.235 | 0.067 | 0.060 |
| BMI | | | |
| Pearson correlation | 0.425 | 0.429 | 0.442 |
| *P*-value | 0.005 | 0.001 | 0.001 |
| WC | | | |
| Pearson correlation | 439 | 472 | 442 |
| *P*-value | 0.001 | 0.001 | 0.001 |

**Correlation is significant at the 0.01 level (two tailed). RAG: Right adrenal gland; LAG: Left adrenal gland; TAG: Total adrenal gland; BMI: Body mass index; WC: Waist circumference

The mean right AGV (RAGV), left AGV (LAGV), and total AGV (TAGV) were 3.47±1.33, 4.77±1.33, and 8.25±2.74, respectively (Table 3).

There was no statistically significant relationship between gender and mean RAGV, LAGV, and TAGV ($P < 0.05$). We also evaluated the mean AGV on the right and left sides of each subject and LAGV was measured higher than the RAGV ($P<0.001$).

A positive weak correlation between the AGVs and age as well as weight was observed. A positive moderate correlation between the AGVs and BMI as well as WC was observed. There was no statistically significant relationship between the AGVs and the height of the patients ($P>0.05$) (Table 4).

The ICC values for all measurements were >0.80–0.90, indicating good and excellent agreement (Table 5).

**Table 5.** Intraclass correlation coefficient for intraobserver measurement of right, left, and total adrenal gland volume

| | ICC value | %95 CI | *p*-value |
|---|---|---|---|
| RAG | 0.926 | (0.908–0.938) | <0.001* |
| LAG | 0.908 | (0.876–0.927) | <0.001* |
| TAG | 0.917 | (0.885–0.936) | <0.001* |

**P*-value significant at 0.05. RAG: Right adrenal gland; LAG: Left adrenal gland; TAG: Total adrenal gland; ICC: Intraclass correlation coefficient; CI: Confidence interval.

## Discussion

Glucocorticoid, mineralocorticoid, and androgenic hormones are the hormones secreted by AG. AG medulla cells secrete epinephrine and norepinephrine hormones. AGV change, which is an independent prognostic factor for mortality in patients with septic shock, is quite important in some cases.[10,12] To more objectively and accurately assess patients with suspected adrenal pathology, it is necessary to know the normal sizes of the AGs.

Bilateral atrophic AGs are generally seen in patients with Addison's disease or a history of chronic steroid usage,[13] while unilateral or bilateral adrenal enlargement may be seen in the presence of an underlying lesion, hypo-or hyperfunction.[14,15] Thus, the knowledge of normal AGV value is of high significance.

AG shapes can differ. In an MDCT study conducted by Akın *et al*.[16] with 420 patients with a mean age of 63 years, the most common AG shape in men and women was reported as "Y" and the second most common was the "triangular" shape. In a study conducted by Montagne *et al*.[11] with 60 patients using MDCT images, RAG was often reported as "linear" and LAG as "Y" or "V." In our study, both RAG and LAG were reported in accordance with the literature. "Y" shape was the most common form of AG in both men and women. Similarly, "linear" was the second most common shape in RAG, while the second most common shape in LAG was found to be "triangle."

In a retrospective study conducted by Schneller *et al.*[17] with 105 participants, the mean AGV was reported as 4.84±1.67 $cm^3$ for the left and 3.62±1.23 $cm^3$ for the right. In the same study, TAGV was positively correlated with weight and was higher in males compared to females. In the CT study carried out by Carsin-Vu *et al.*[9] with 154 patients (65 males and 89 females), the mean RAGV was reported as 3.8±1.3 $cm^3$ (1.5–8.7 $cm^3$) and the mean LAGV as 4.5±1.6 $cm^3$ (1.5–10.3 $cm^3$). The LAGV was found higher than the RAGV. Besides, a weak positive correlation was found between age and mean AGV. The AGV was statistically significantly higher in men compared to women. In accordance with our study, the LAGV was found to be higher than the RAGV. In addition, a weak positive correlation was found between age and AGV. However, there was no statistically significant correlation between AGVs and gender. Furthermore, there was no statistically significant correlation between AGVs and height in our study.

Wang *et al.*,[18] in the study that included 81 participants (49 males and32 females) with 64-slice MDCT, RAGV, LAGV, and TAGV, were found to be 4.26±0.86 $cm^3$, 4.23±0.74 $cm^3$, and 8.50±1.40 $cm^3$, respectively. In this study, a weak positive correlation was reported between weight and all volume measurement values, and there was no significant difference between age and gender and volume values. In the literature, in another CT study performed in 420 patients (220 males and 200 females) over 50 years old; there was no significant relationship between age and height, and AGVs.[16] In their study, AGVs were higher in women compared to men in all age groups. Again, a weak negative correlation between AGV and weight in men was reported in their study. Unlike the above study, our study included a wider age range, although there were fewer participants, so we think that it reflects the normal value ranges better.

In the CT study conducted by John *et al*. with 586 participants, the average AG thickness was found on the right; 7.2±1.8, 4.1±1.1, and 4.3±1.1 mm for the trunk, medial, and lateral legs, respectively; on the left, they reported 8.8±1.9, 4.7±1.1, and 4.9±1.3 mm. The total diameters were found to be 15.6±3.7 mm for the right and 18.4±3.8 mm for the left. Furthermore, in their study, the mean thickness of the LAG was higher than the RAG, and the AG thickness was higher in men than in women.[19] Carsin-Vu *et al.*[9] reported that MDCT-based volumetric measurements are more repeatable than linear measurements and that adrenal volume measurement is more reliable than linear measurements for normal values. Since our study provides volumetric data compared to linear measurements, we believe that the data are more reliable.

In the study of Liu *et al.*,[20] obese patients had higher RAGV, LAGV, and TAGV than non-obese patients. Compared to non-obese individuals, several studies have shown reduced sympathetic nervous system activity and lower plasma catecholamine levels in obese individuals.[21–23] In our study, a moderate positive significant correlation was found between WC and AGVs. Furthermore, a moderate positive significant correlation was found between BMI and AGVs. This may be explained by adrenal enlargement as a result of increased adrenal activity in response to decreased catecholamine levels.

Our study had several limitations. Our study included only a limited number of patients and is single centered. Future multicenter studies with higher patient numbers will provide more accurate information. Since the participants were not biochemically followed up for endocrinopathies, we could not exclude its effect on the volume and there were no data on the biochemical activity of the AGs. In addition, interobserver reliability could not be evaluated because the evaluations were carried out by a single radiologist. Finally, our measurements were only made *in vivo*, and the actual *ex vivo* volume was not evaluated.

## Conclusion

The volume value of normal AG in an adult population has been evaluated by our research. These measurements can provide reference data for determining adrenal normality or enlarged AG on MDCT scans, which are important for increasing objective diagnosis. Since, the increase in BMI and WC, which are indicators of obesity, correlates with the increase in AGV, we think that the findings will be valuable in evaluating the pathophysiology of the hypothalamic-pituitary-adrenal axis.

### Disclosures

**Ethics Committee Approval:** Hitit University Ethics Committee for Non-Interventional Studies (07.04.2021/2021-451).

**Peer-review:** Externally peer-reviewed.

**Conflict of Interest:** None declared.

**Authorship Contributions:** Concept – E.G., M.K., K.H.G.; Design – E.G.; Supervision – E.G., M.K., K.H.G.; Materials – E.G., K.H.G; Data collection &/or processing – E.G., M.K., K.H.G.; Analysis and/or interpretation – E.G.; Literature search – E.G., K.H.G; Writing – E.G., M.K., K.H.G.; Critical review – E.G., M.K., K.H.G.

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