Measurement of the Surface Area of the Renal Sinus Fat Using MDCT: Correlation with Presence and Severity of Essential Hypertension and Body Mass Index

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ABSTRACT

Objectives: Essential hypertension remains a major modifiable risk factor for cardiovascular disease. Excess visceral adipose tissue is associated with the presence of adverse metabolic risk factors. Our study aims to measure the surface area of the renal sinus fat using MDCT and correlate the renal sinus surface area with the presence and grading of essential hypertension as well as body mass index.

Materials and Methods: This cross-sectional study included two groups; the patients’ group including 40 cases presented with a history of primary essential hypertension and the control group including 40 cases. The average of the surface area of the two kidneys as well as the average of the surface area of sinus fat was measured in the control and patient subgroups and was correlated with the presence and grading of essential hypertension as well as body mass index.

Results: There was a significant correlation between the presence and grading of essential hypertension with prominent renal sinus fat. There was a significant correlation between the average surface area of kidneys and surface area of sinus fat in overweight and obese groups than in the control group (P < 0.01).

Conclusion: Obesity is now recognized as a risk factor for the development of renal dysfunction. There was a significant correlation between the surface area of renal sinus fat measured using MDCT and the presence as well as grading of essential hypertension, suggesting that renal sinus fat may promote cardiovascular events.

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KEYWORDS:
Chronic kidney disease (CKD); cardiovascular disease (CVD); renal sinus fat area (RSFA)

TO CITE THIS ARTICLE:
Abdeldayem EH, Mansour MG, Mosaad BMR. Measurement of the Surface Area of the Renal Sinus Fat Using MDCT: Correlation with Presence and Severity of Essential Hypertension and Body Mass Index. Journal of the Belgian Society of Radiology. 2022; 106(1): 91, 1–8. DOI: https://doi.org/10.5334/jbsr.2776
INTRODUCTION

Essential hypertension remains a major modifiable risk factor for cardiovascular disease (CVD) despite important advances in our understanding of its pathophysiology and the availability of effective treatment strategies [1]. Adipose tissue modifies the development of cardiovascular disease in a complex manner [2, 3], thus understanding the mechanisms by which visceral fat promotes cardiovascular events, would enable practitioners to target therapies to reduce cardiovascular events in individuals with high intra-peritoneal fat [4, 5].

Renal sinus lipomatosis, which is a particular depot of visceral fat, involves prominent fat proliferation that leads to mass effect on the intrarenal collecting system. Computed Tomography and Magnetic Resonance imaging directly reveal the fatty nature of sinus lipomatosis [6–8].

The increased adipose tissue was associated with various metabolic abnormalities as well as the adverse cardiorenal outcome. For renal sinus fat (RSF), it was demonstrated that increased fat at this anatomical location is associated with hypertension as well as lower GFR, statistically independent of fat accumulation in other compartments [9].

Our study aims to measure the surface area of the renal sinus fat using MDCT and correlate the renal sinus surface area with the presence and grading of essential hypertension as well as body mass index.

2. MATERIALS AND METHODS

2.1. PATIENTS

This cross-sectional study included 40 patients from March 2019 to June 2021 who were recruited from the attendants of the cardiology clinic, at a multi-disciplinary private hospital. Participation in the study was voluntary after receiving informed consent. The study was approved by the institutional regulatory board of the Hospital. All procedures performed were under the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

2.2. INCLUSION CRITERIA

- Recent diagnosis of primary hypertension, which was defined as the average of 2 or more diastolic BP measurements on at least 2 subsequent visits, was ≥90 mm Hg or when the average of multiple systolic BP readings on 2 or more subsequent visits was consistent ≥140 mm Hg [10].

2.3. EXCLUSION CRITERIA

- Secondary causes of hypertension such as renovascular disease.
- Diabetes Mellitus.
- Other risk factor for hypertension as smoking.
- Family history of hypertension.

As the renal sinus surface area is variable with age, sex, race, body mass index, and visceral-adipose-tissue changes we were limited by the lack of standard normal reference value of renal sinus fat area (RSFA), as reported in Huang et al. [11], so a control group of another 40 patients was selected.

The control group patients were normotensive and were selected from the same medical institute. They underwent a computed tomography (CT) scan of the pelvi-abdomen for other diagnostic purposes to standardize the reference range. All the control group patients had a medical history free of any renal troubles and had normal size and CT appearance of both kidneys. The body mass index (height/weight) was within the normal range between 18.5 and 24.9.

2.4. TECHNIQUE OF NON-CONTRAST CT EXAMINATION OF THE KIDNEYS

- Patient position: supine position with arms elevated.
- CT machine: High speed 64 slice CT machine – Philips.
- Technique: Scan direction was craniocaudal in all patients. Scout was taken starting from the 10th thoracic rib or the shadow of the diaphragmatic copula down to the iliac crest.
- Patient preparation: no specific preparations were needed.
- CT parameters: we used 1.25 mm thickness, 0.625 mm interval, and 512 × 512 matrix size with a 1.75:1 pitch number. The rotation time used was 0.5 seconds with a tube speed of 35 mm/rotation. The Kv was 120 while the mA was ranging from 120 to 400 according to the body weight.

2.5. POST-PROCESSING MEASUREMENTS

- The slices at the mid-polar region of each kidney containing the largest amount of sinus fat based, on just visual inspection only, were determined.
- We have selected the slice at the mid renal zone: if the range included an odd number of slices, then the middle slice of the range was traced. If the range included an even number of slices, then the anatomically more cranial of the two middle slices were traced.
- Then, the sinus fat surface area was traced manually and identified by its low-density fatty content with a negative Hounsfield unit (HU).
- Then, the surface area of each kidney was traced along the renal tissue being demarcated by the surrounding retroperitoneal fat.
• The mean of the renal sinus fat surface area was calculated by summation of RSFA on both sides and divided by 2 to get the average of RSFA of every individual. The same steps were performed for the calculation of the mean of the surface area of the kidneys (Figures 1 and 2).

2.6. DATA MANAGEMENT AND ANALYSIS

The collected data was revised, coded, tabulated, and introduced to a PC using a statistical package for social sciences (IBM SPSS 20.0). Data were presented and suitable analysis was done according to the type of data obtained for each parameter. Descriptive Statistics

• Mean, Standard deviation (+ SD), and range for parametric numerical data, while Median and Interquartile range (IQR) for non-parametric data.

Analytical Statistics

• An Independent sample t-test was used to assess the statistical significance of the difference of a parametric variable between two independent means of two study groups,
• ANOVA was used to assess the statistical significance of the difference of a parametric variable between means of more than two study groups.

3. RESULTS

The patients' group included 40 cases (42.2 ± 9.79 years of age), who presented with a history of primary essential hypertension and the second group was the control group including 40 patients (50.53 ± 13.65 years of age) (Table 1).

The average surface area of both kidneys in the patient and control groups was 3110.17 ± 826.98 and 2499.72 ± 478.86 mm respectively, while the average surface area of sinus fat was 392.50 ± 374.25 and 265.30 ± 114.77 mm respectively.

A comparative study was performed between the patient and control groups regarding the age, waist circumference, weight, and body mass index with demographic data in (Table 2).

| VARIABLE                        | TYPE           | CONTROLS          | CASES           | CHI-SQUARE       | P-VALUE       |
|---------------------------------|----------------|-------------------|-----------------|------------------|---------------|
| Sex                             | Male           | 40 100.0%         | 40 100.0%       |                  |               |
| Sex                             | Female         |                   |                 |                  |               |

| VARIABLE                        | TYPE             | CONTROLS          | CASES          | INDEPENDENT     | P-VALUE       |
|---------------------------------|------------------|-------------------|----------------|----------------|---------------|
| Age in years                    | MEAN + SD        | 50.53 ± 13.65     | 42.20 ± 9.79   | 3.134           | 0.003**       |
| Height in cm                    | MEAN + SD        | 175.38 ± 6.61     | 171.05 ± 8.07  | 2.623           | 0.010*        |
| Waist circumference             | MEAN + SD        | 91.73 ± 5.84      | 100.47 ± 10.89 | -4.477          | 0.000**       |
| Weight                          | MEAN + SD        | 72.15 ± 6.58      | 80.20 ± 15.70  | -2.991          | 0.004**       |
| Body mass index                 | MEAN + SD        | 23.40 ± 7.1       | 27.27 ± 4.3    | -5.503          | 0.000**       |

Table 1 Comparison between hypertensive patients and control group as regards demographic data.

| VARIABLE                                         | TYPE             | CONTROLS          | CASES          | CHI-SQUARE       | P-VALUE       |
|--------------------------------------------------|------------------|-------------------|----------------|------------------|---------------|
| Average of the surface area of both kidneys      | MEAN + SD        | 2499.72 ± 478.86  | 3110.17 ± 826.98 | -4.040          | 0.000**       |
| Variables                                       | MEDIAN IQR       | 265.30 ± 114.77   | 392.50 ± 374.25 | 426.000          | 0.000**       |
| Average of RSFA in mm² of both kidneys           | MEDIAN IQR       | 10.10 ± 3.63      | 13.00 ± 13.00  | 613.000          | 0.072         |

Table 2 Comparison between cases and controls as regards the average surface areas of both kidneys and RSFA.

* Significant correlation.
The average surface area of both kidney as well as sinus fat was compared between the patient and control groups and found that both were significantly higher in the patient group than in the control group. The average of the surface area of the two kidneys as well as the average of the surface area of sinus fat was measured in the control and patient subgroups according to blood pressure (grade I, II, and III) and there was a significant correlation between the presence and grading of hypertension with prominent renal sinus fat (Table 3).

There was a significant correlation between the average surface area of kidneys and surface area of sinus fat in overweight and obese groups than in the control group (P < 0.01), suggesting obesity is more likely to be correlated with renal sinus lipomatosis, and thus increase the risk of essential hypertension (Table 4).

| VARIABLES                                      | TYPE                  | ANOVA | P-VALUE |
|------------------------------------------------|-----------------------|-------|---------|
|                                                 | CONTROLS              |       |         |
| Average of the surface area of both kidneys     | MEAN + SD             |       |         |
|                                                 | 2499.72 478.86        |       |         |
|                                                 | 2774.98 483.12        |       |         |
|                                                 | 2956.13 837.09        |       |         |
|                                                 | 3538.56 893.01        |       |         |
|                                                 | 9.354                 |       | 0.000** |
|                                                 | **                   |       |         |
| VARIABLES                                       | MEDIAN IQR            |       |         |
| Average of the surface area of sinus fat in mm² of both kidneys | 265.30 114.77 | 272.00 395.00 | 415.00 360.00 | 544.20 316.00 | 17.958 | 0.000** |
| The ratio between the average RSFA and the average surface area of both kidneys. | 10.10 3.63 | 9.00 10.00 | 14.00 13.00 | 13.00 10.75 | 6.201 | 0.102 |

Table 3 Comparison of the average RSFA and average surface area of both kidneys between controls and patient subgroups according to blood pressure (grade I, II, and III).

* Significant correlation

| VARIABLES                                      | TYPE                  | ANOVA | P-VALUE |
|------------------------------------------------|-----------------------|-------|---------|
|                                                 | CONTROLS              |       |         |
| Average of the surface area of both kidneys     | MEAN + SD             |       |         |
|                                                 | 2499.72 478.86        |       |         |
|                                                 | 2471.38 469.72        |       |         |
|                                                 | 3429.49 837.44        |       |         |
|                                                 | 3405.07 766.20        |       |         |
|                                                 | 13.981                |       | 0.000** |

| VARIABLES                                      | MEDIAN IQR            |       |         |
| Average of RSFA in mm² of both kidneys         | 265.30 114.77         | 368.00 375.50 | 440.00 553.75 | 415.00 337.50 | 13.648 | 0.003** |
| The ratio between the average RSFA and average surface area of both kidneys. | 10.10 3.63 | 14.00 15.50 | 12.50 13.25 | 11.00 11.50 | 3.772 | 0.287 |

Table 4 Comparison of the average RSFA and average surface area of both kidneys between controls and overweight groups.

* Significant correlation.
Figure 1 A 51-year-old male patient, with a recent history of essential hypertension. A) and B) The RSFA on the right side was 366.07 mm² and on the left side was 327.28 mm². C) and D) The surface area of the right kidney and left kidney was 2313.51 and 2339.60 mm² respectively.

Figure 2 A control 57-year-old male patient, performed CT pelvi-abdominal examination with a history suggestive of appendicitis. A) and B) The RSFA on the right side was 255.83 mm² and on the left side was 302.04 mm². C) and D) The surface area of the right kidney and left kidney was 2396.9 and 2903.87 mm² respectively.
4. DISCUSSION

We have selected the surface area as a simple and available post-processing tool for the calculation of the sinus fat area as well as the surface area of the kidneys. The control of our study was selected for the setting of the reference range of renal sinus fat surface area and was from almost the same range of age.

Foster et al. [12] studied the volumetric renal sinus fat within the right and left kidneys separately and correlated their results with the renal sinus fat area within a single MDCT scan slice in the right kidney. They found a high correlation between volumetric and single-slice renal sinus fat in the right with p < 0.0001.

In animal models, excessive accumulation of fat within the renal sinus displaces and compresses the low-pressure renal lymphatics and veins as well as the ureters [13, 14]. Also, renal sinus fat may exert an influence on hypertension and CV risk through one of several mechanisms. Sinus lipomatosis may compress the blood and lymph vessels in the renal sinus with a consequent increase in the intrarenal hydrostatic pressure. This observation has been previously shown in animal studies in which obese rabbits exhibited larger kidneys with larger fat deposits within the renal sinus. This occurred due to renal lymphatic compression, despite an absence of detectable fat accumulation within the renal parenchyma [15, 16].

Various hypotheses emerged to explain how additional risk factors for hypertension as DM would affect the amount of RS fat. One of these hypotheses was an ectopic deposition of lipids into nonadipose tissues, such as the kidney. This can lead to the accumulation of toxic metabolites, derived from the metabolism of fatty acids. These metabolites may lead to mitochondrial dysfunction, apoptosis, and eventually renal injury [17].

Many classifications have been proposed for the subdivision of body fat into different compartments; most commonly, abdominal fat depots are classified into intra-peritoneal or visceral (IP) and subcutaneous (SC) fat compartments. Unlike SC fat, IP fat is associated with adverse cardiovascular (CV) events, including myocardial infarction and higher incidences of obesity-related hypertension.

In this study, we thought to address the association between renal sinus (RS) fat and hypertension for the following reasons: (1) those with higher amounts of IP fat also exhibit more body mass index; (2) increased amounts of RS fat have been associated with larger kidney size, (3) prominent RS fat is associated with the presence and grading of hypertension. Further studies are warranted to determine whether increased RS fat causes or contributes to poor control of hypertension.

5. CONCLUSION

Excess visceral adipose tissue is associated with the presence of adverse metabolic risk factors and cardiovascular disease. There was a significant correlation between the surface area of renal sinus fat measured using MDCT and the presence as well as grading of essential hypertension. Thus, RSF is an imaging feature that may suggest likelihood of essential hypertension.

6. STUDY LIMITATIONS

Segmentation of the renal sinus fat area can be possible based on artificial intelligence. Together with volumetric calculation, an additional quantitative value to the radiology report can be performed, thus it may be used as a ‘screening tool’ for essential hypertension.

DATA ACCESSIBILITY STATEMENTS

All the datasets used and analyzed in this study are available with the corresponding author on reasonable request.

ABBREVIATIONS

RS: renal sinus.
IP: intraperitoneal.
SC: Subcutaneous fat.
RSFA: renal sinus fat area.
CKD: Chronic kidney disease.
CVD: cardiovascular disease.
CV: cardiovascular.
GFR: glomerular filtration rate.

ETHICS AND CONSENT

Written informed consent was signed by all patients before the examination. The study was done at a private hospital and was approved by the Research Ethics Committee (REC) of the hospital. The protocol of the study was carefully revised by the regulating staff responsible for medical research in the hospital. All ethical approval and consents for the study were archived in a file and marked by the title of the study. The ethical number was not applicable.

Consent for publication: All patients included in this research were fully conscious and older than 16-year-old and gave written informed consent to publish the data contained within this study.
ACKNOWLEDGEMENTS

We would like to thank the cardiology department for so much co-operation throughout this study.

COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHORS CONTRIBUTIONS

- E.H.A editor of the manuscript, image interpretation and performed the statistical analysis.
- M.G.A participated in the design of the study, image interpretation and data collection.
- B.M.M. put the idea of research and shared in the design of the study, image interpretation and data collection.
- All authors read and approved the final manuscript.

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