

# The Thickness of the Renal Parenchyma Decreases with Age: A CT Study of 360 Patients

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Renal parenchymal thickness was estimated by using CT in 360 patients with no evidence of renal disease. In each patient, the measurements were normalized to the transverse diameter of the vertebral body and a reference table was formulated. The renal parenchymal thickness decreases about 10% per decade of increasing age in both men and women. These findings are consistent with previously reported findings based on autopsy material.

The proposed table may be useful as a criterion for assessing normal renal parenchyma on CT.

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Several studies have used pathologic material to describe the variation of kidney size and weight relative to sex, age, and body format [1-3]. Assessing kidney size in vivo with conventional radiologic techniques can be erroneous, because loss of renal parenchyma in the elderly is compensated for by an increase in peripelvic fat [4, 5]. CT, however, provides a reliable means of measuring the amount of renal parenchyma so that conclusions concerning changes in kidney size with age, sex, or body habitus can be accurately drawn.

In this study we correlated the amount of the normal renal parenchyma with the patient's age and sex and tried to establish an age-related reference table for both kidneys, to be used in the interpretation of renal CT scans.

## Materials and Methods

Our study comprised 360 men and women 20-80 years old. The sample population for each decade consisted of 60 patients, 30 men and 30 women. All patients were referred for a CT examination with an indication other than renal disease, had no record of renal disease, made no chronic use of potentially toxic drugs, and had no history of hypertension. Patients in whom normal renal variations were seen on CT, such as a double collecting system or fetal lobulation, or who had findings likely to cause morphologic alterations in the shape of the kidneys, were excluded from the study.

All examinations were performed on a Pfizer 0450 CT scanner with 9-mm slice thickness. For our study, we selected three sections through each kidney: one through the upper renal calix, one through the lower renal calix, and one at the level of the renal pelvis (Fig. 1). The thickness of renal parenchyma was measured by means of two perpendicular axes through fixed points in each kidney. One was drawn parallel to the axis of the renal vessels through the renal pelvis and the other through the middle of the pelvis (Fig. 2). Similar axes were used for both the upper and lower caliceal levels. Obviously, the direction of the axes differed according to the orientation of the kidneys in the body, which is the result of the different degree of rotation during fetal life. Measurements of parenchymal thickness were made as shown in Figure 2 at the anterior, posterior, internal, and external parts of the renal parenchyma and at three levels through each kidney. Additionally, for each patient and for each kidney, a reference measurement of the transverse diameter of the vertebral body was made, at a level through the middle of the body of the first lumbar vertebra. All measurements

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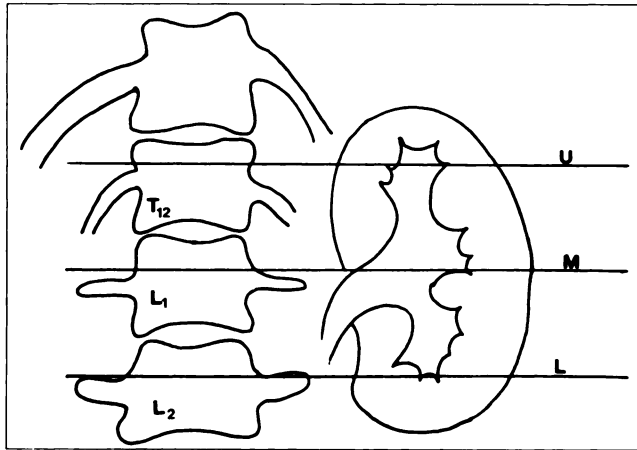


Fig. 1.—Schematic diagram of selected scans through each kidney used in estimation of amount of renal parenchyma. Three scans are selected: one through upper caliceal level (U), one through lower caliceal level (L), and one through renal pelvis (M).

of parenchymal thickness were normalized by dividing each one by the transverse diameter of the patient's vertebral body. This diameter is proportional to the patient's body format and it has been used for measuring the size of the normal pancreas on CT [6, 7].

Data were analyzed with a computer program. First, the sums of the measured parenchymal thicknesses ( $a + b + c + d$ ,  $a + c$ ,  $b + d$ , and  $[a + b] \times [c + d]$ ), indicative of the renal parenchymal volume, were calculated, thus totaling eight measured or computed parameters at each kidney level (i.e.,  $a$ ,  $b$ ,  $c$ ,  $d$ ,  $a + b + c + d$ ,  $[a + b] \times [c + d]$ ,  $a + c$ , and  $b + d$ ). Subsequently, data were divided into six groups according to age (20–29, 30–39, 40–49, 50–59, 60–69, 70–79), and the means and standard deviations for each age group and for each measurement were calculated. Finally, a correlation coefficient, revealing the degree of correlation between parenchymal thickness and age, was computed [8].

**Results**

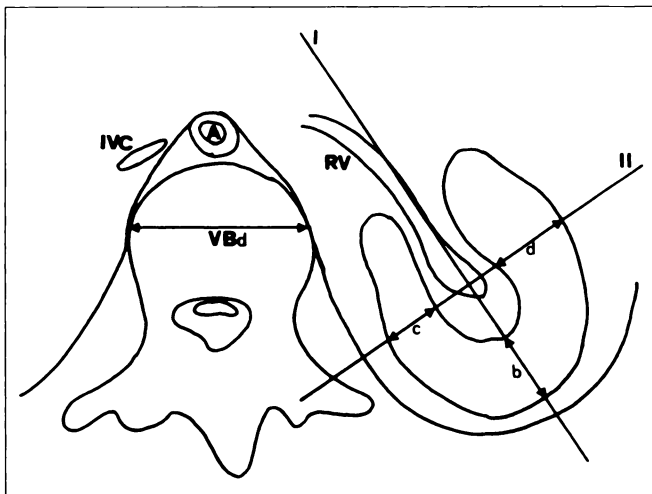
Statistical analysis showed that a good negative correlation exists between renal parenchymal volume and patient age for all measurements and for each level through each kidney. This correlation was found to be statistically significant at the 95% level for all measured parameters. In declining order, best correlation was achieved for the sums  $a + b + c + d$ ,  $[a + b] \times [c + d]$ ,  $b + d$ , and  $a + c$ , followed by the posterior parenchymal thickness,  $b$ , at the upper caliceal levels of both kidneys. For ease of use, the means and standard deviations of each measurement per decade are tabulated in Table 1.

A good assessment of the rate of renal parenchymal volume decrease with age can be obtained from the overall sum of the individual sums  $a + b + c + d$  (Fig. 3). The amount of renal parenchyma decreases about 10% per decade of advancing age for both kidneys, with a higher rate of decrease occurring between the sixth and the seventh decades. It is also evident that the right kidney is more massive than the left in all decades.

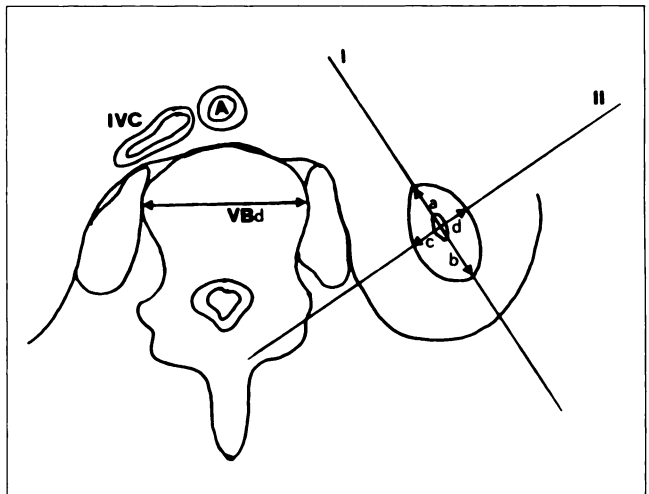
Differences in the amount of renal parenchyma between the sexes were tested by using the statistical *t* test. Results showed that for each decade there were no significant differences ( $p > .10$ ) between the two sexes, provided that all measurements were divided by the transverse diameter of the patient's vertebral body. When the vertebral diameter was not taken into account, significant differences were obtained, probably because of morphometric differences between the sexes.

**Discussion**

Assessing the amount of normal renal parenchyma by CT in living subjects and relating it to age, sex, and body habitus is of value in the study of morphologic changes of the kidneys



A



B

Fig. 2.—A and B, Schematic diagrams of CT scans through level of renal pelvis (A) and level of lower renal pole (B). Two perpendicular axes, I and II, are drawn to assist in measurement of renal parenchymal thickness in anterior (a), posterior (b), internal (c), and external (d) parts of kidney. IVC = inferior vena cava, A = aorta, RV = renal vein, VBd = vertebral body diameter.

**TABLE 1: Ratio of Parenchymal Thickness to Transverse Diameter of Vertebral Body**

Kidney Segment/Dimension	Ratio (mean $\pm$ SD) by Age					
	20-29	30-39	40-49	50-59	60-69	70-79
<b>Upper pole</b>						
Right kidney						
a	0.61 $\pm$ 0.10	0.50 $\pm$ 0.11	0.47 $\pm$ 0.08	0.43 $\pm$ 0.08	0.38 $\pm$ 0.07	0.32 $\pm$ 0.07
b	0.78 $\pm$ 0.10	0.76 $\pm$ 0.06	0.63 $\pm$ 0.10	0.55 $\pm$ 0.08	0.48 $\pm$ 0.08	0.39 $\pm$ 0.08
c	0.45 $\pm$ 0.07	0.37 $\pm$ 0.05	0.34 $\pm$ 0.06	0.34 $\pm$ 0.06	0.29 $\pm$ 0.06	0.24 $\pm$ 0.05
d	0.52 $\pm$ 0.08	0.48 $\pm$ 0.04	0.42 $\pm$ 0.07	0.38 $\pm$ 0.05	0.33 $\pm$ 0.06	0.27 $\pm$ 0.05
a + b + c + d	2.36 $\pm$ 0.28	2.11 $\pm$ 0.19	1.86 $\pm$ 0.25	1.70 $\pm$ 0.21	1.48 $\pm$ 0.22	1.22 $\pm$ 0.22
Left kidney						
a	0.59 $\pm$ 0.08	0.47 $\pm$ 0.07	0.44 $\pm$ 0.09	0.40 $\pm$ 0.08	0.35 $\pm$ 0.07	0.29 $\pm$ 0.06
b	0.70 $\pm$ 0.10	0.61 $\pm$ 0.10	0.57 $\pm$ 0.11	0.51 $\pm$ 0.08	0.40 $\pm$ 0.08	0.36 $\pm$ 0.07
c	0.44 $\pm$ 0.07	0.39 $\pm$ 0.06	0.35 $\pm$ 0.06	0.32 $\pm$ 0.05	0.27 $\pm$ 0.05	0.23 $\pm$ 0.05
d	0.52 $\pm$ 0.08	0.48 $\pm$ 0.12	0.40 $\pm$ 0.08	0.36 $\pm$ 0.07	0.30 $\pm$ 0.07	0.26 $\pm$ 0.06
a + b + c + d	2.25 $\pm$ 0.26	1.95 $\pm$ 0.28	1.76 $\pm$ 0.25	1.59 $\pm$ 0.21	1.32 $\pm$ 0.21	1.14 $\pm$ 0.19
<b>Middle level</b>						
Right kidney						
a	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
b	0.78 $\pm$ 0.10	0.72 $\pm$ 0.08	0.66 $\pm$ 0.08	0.59 $\pm$ 0.09	0.52 $\pm$ 0.09	0.43 $\pm$ 0.08
c	0.48 $\pm$ 0.09	0.39 $\pm$ 0.05	0.38 $\pm$ 0.05	0.35 $\pm$ 0.06	0.30 $\pm$ 0.05	0.27 $\pm$ 0.05
d	0.49 $\pm$ 0.06	0.47 $\pm$ 0.08	0.45 $\pm$ 0.07	0.38 $\pm$ 0.06	0.35 $\pm$ 0.06	0.32 $\pm$ 0.06
a + b + c + d	1.75 $\pm$ 0.18	1.58 $\pm$ 0.15	1.49 $\pm$ 0.15	1.32 $\pm$ 0.14	1.17 $\pm$ 0.16	1.02 $\pm$ 0.17
Left kidney						
a	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00
b	0.71 $\pm$ 0.10	0.61 $\pm$ 0.08	0.61 $\pm$ 0.11	0.53 $\pm$ 0.08	0.46 $\pm$ 0.07	0.41 $\pm$ 0.08
c	0.46 $\pm$ 0.08	0.42 $\pm$ 0.05	0.40 $\pm$ 0.06	0.35 $\pm$ 0.05	0.30 $\pm$ 0.06	0.26 $\pm$ 0.06
d	0.50 $\pm$ 0.10	0.48 $\pm$ 0.09	0.42 $\pm$ 0.09	0.36 $\pm$ 0.06	0.31 $\pm$ 0.06	0.28 $\pm$ 0.06
a + b + c + d	1.67 $\pm$ 0.22	1.51 $\pm$ 0.18	1.43 $\pm$ 0.22	1.24 $\pm$ 0.16	1.07 $\pm$ 0.16	0.95 $\pm$ 0.16
<b>Lower pole</b>						
Right kidney						
a	0.50 $\pm$ 0.11	0.44 $\pm$ 0.10	0.41 $\pm$ 0.10	0.38 $\pm$ 0.08	0.32 $\pm$ 0.06	0.27 $\pm$ 0.07
b	0.73 $\pm$ 0.10	0.68 $\pm$ 0.13	0.60 $\pm$ 0.09	0.54 $\pm$ 0.08	0.47 $\pm$ 0.09	0.39 $\pm$ 0.07
c	0.42 $\pm$ 0.08	0.45 $\pm$ 0.08	0.33 $\pm$ 0.06	0.31 $\pm$ 0.06	0.27 $\pm$ 0.06	0.23 $\pm$ 0.04
d	0.47 $\pm$ 0.09	0.42 $\pm$ 0.07	0.37 $\pm$ 0.07	0.33 $\pm$ 0.05	0.28 $\pm$ 0.05	0.26 $\pm$ 0.05
a + b + c + d	2.12 $\pm$ 0.27	1.99 $\pm$ 0.32	1.71 $\pm$ 0.26	1.56 $\pm$ 0.21	1.34 $\pm$ 0.20	1.15 $\pm$ 0.18
Left kidney						
a	0.42 $\pm$ 0.08	0.39 $\pm$ 0.07	0.36 $\pm$ 0.07	0.32 $\pm$ 0.08	0.28 $\pm$ 0.07	0.22 $\pm$ 0.05
b	0.66 $\pm$ 0.10	0.59 $\pm$ 0.07	0.56 $\pm$ 0.13	0.49 $\pm$ 0.07	0.43 $\pm$ 0.08	0.36 $\pm$ 0.08
c	0.42 $\pm$ 0.07	0.40 $\pm$ 0.07	0.33 $\pm$ 0.06	0.31 $\pm$ 0.05	0.27 $\pm$ 0.05	0.25 $\pm$ 0.05
d	0.44 $\pm$ 0.08	0.42 $\pm$ 0.09	0.35 $\pm$ 0.07	0.32 $\pm$ 0.05	0.27 $\pm$ 0.05	0.24 $\pm$ 0.06
a + b + c + d	1.94 $\pm$ 0.25	1.80 $\pm$ 0.22	1.60 $\pm$ 0.23	1.44 $\pm$ 0.21	1.25 $\pm$ 0.20	1.07 $\pm$ 0.19

Note.—Renal parenchymal thickness was measured at the anterior (a), posterior (b), internal (c), and external (d) parts of the kidney.

caused by various diseases. Measurements of the renal parenchymal thickness may also be of value as reference criteria for assessing the normal kidney on CT. Several reports have examined age- or sex-related changes of kidney length or weight, based mainly on anatomic findings [1, 5]. However, to our knowledge, no reports have been published on CT measurements of renal parenchymal thickness during life.

Reports based on autopsy material reveal that kidney weight varies considerably among normal adults [1, 2], and men have larger kidneys than women [2]. In our study, no differences were seen in the amount of renal parenchyma between the two sexes, because the patient's body build was taken into account in all measurements. Our findings are in

agreement with the anatomic findings of Kasiske and Umen [1]—that kidney weight in normal adults depends on body habitus and not on the patient's sex.

Decrease of kidney size with age is known from the anatomic findings of several workers [3, 5]. Loss of renal mass is primarily cortical [3] and can reach up to 40% in patients in their eighties [5]. Similarly, glomeruli can sustain a 30% hyalinization. Between the fourth and ninth decades, renal blood flow is reduced by 50% [9], and glomerular filtration is depressed to 30–50% of normal in the eighth decade as compared with the third decade [10]. Our findings show that the renal parenchymal thickness is also progressively reduced with advancing age. Indeed, the ratio of renal parenchymal

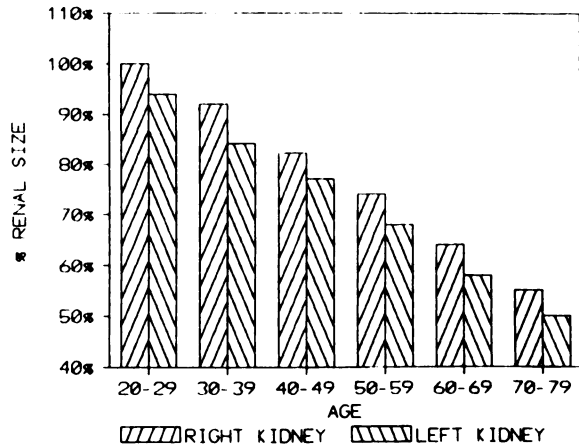


Fig. 3.—Progressive percent reduction of amount of renal parenchyma with advancing age. Amount of renal parenchyma is calculated as overall sum of individual sums (a + b + c + d) at each caliceal level. Data are normalized to 100% for right kidney at 20–29 years of age.

thickness to the transverse diameter of the vertebral body decreases by 10% per decade.

It is evident from our results that the amount of renal parenchyma is assessed best by the sum of parenchymal thicknesses divided by the vertebral diameter, that is,  $[a + b + c + d]/\text{vertebral diameter}$ . However, a simpler ratio, that of the thickness of the posterior part of renal parenchyma over the vertebral diameter, also shows a good degree of

correlation with age, that is,  $b/\text{vertebral diameter}$ . We believe that this ratio can be used reliably in everyday practice, because it represents adequately the amount of renal parenchyma present.

The proposed reference table (Table 1) can be of value in the interpretation of normal or abnormal renal parenchymal thickness. Further investigation of the way that the amount of renal parenchyma, as shown on CT, changes with progressive chronic renal disease may be of value also.

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