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Volume of Polycystic Kidneys During Reduction of Renal Function

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Abstract. Total renal volume was measured by CT scanning in 43 patients with the adult form of polycystic kidney disease whose 24 h endogenous creatinine clearance ranged from 8 to 130 ml/min. The total volume of the 2 kidneys increased from 1,212 (SD ± 411) cm^3 in patients with normal renal function to 2,053 (SD ± 698) cm^3 in patients with severely decreased function, as compared to 497 (SD ± 58) cm^3 in persons without evidence of renal disease. Despite progression of the disease, the mean difference in size between the 2 kidneys remained constant and was significant only in patients with well-preserved renal function. In 23 of the 43 patients hepatic cysts and in 2 patients pancreatic cysts were demonstrable by CT scanning.

Key words: Age – Adult polycystic kidney disease – Renal volume – CT scanning – Endogenous creatinine clearance – Hepatic cysts

At our center patients with the adult form of polycystic kidney disease constitute 11% of all patients treated for terminal uremia by dialysis and/or renal transplantation [1].

The growth rate of polycystic kidneys during progressive renal failure and possible reduction in kidney size after institution of replacement therapy [2] are poorly elucidated. Especially when renal function is poor, neither nephrotomography nor renal angiography clearly delineates the outline of the enlarged kidneys [2–4]. The present study shows that computerized tomography (CT scanning) permits precise determination of kidney volume independently of renal function. Therefore we wanted to determine the size of polycystic kidneys in relation to deteriorating renal function before replacement therapy becomes mandatory.

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Material and Methods

Patients

The mean age of the 43 patients examined, 27 men and 16 women, was 43 (range 16–66) years. The presenting symptoms are shown in Table 1. The diagnosis was established by usual clinical criteria and intravenous urography.

Renal Function

This was determined by measuring the 24 h endogenous creatinine clearance the same month as CT scanning. Twenty-four hour endogenous creatinine clearance varied from 8 to 130 ml/min. The patients renal function was normal (> 90 ml/min), in 12 moderately considerably decreased, and severely decreased – according to the classification defined by Bröchner-Mortensen et al. [3]. In 11 patients renal function was normal (> 90 ml/min, in 12 moderately decreased (60–89 ml/min), in 8 considerably decreased (30–59 ml/min), and in 12 severely decreased (5–29 ml/min).

Table 1. Presenting symptoms in 43 patients[a] with adult polycystic kidney disease

Symptom	No. of patients
Pain in the lumbar area	19 (44%)
Hematuria	8 (19%)
Hypertension	5 (12%)
Bacteriuria, renal infection	4 (9%)
Urolithiasis	1 (2%)
No symptoms[b]	14 (33%)
Unknown	2 (5%)

[a] 8 patients had more than 1 symptom

[b] The disease was diagnosed in connection with routine examinations (6 patients) or in connection with evaluation of possible inheritance (8 patients)

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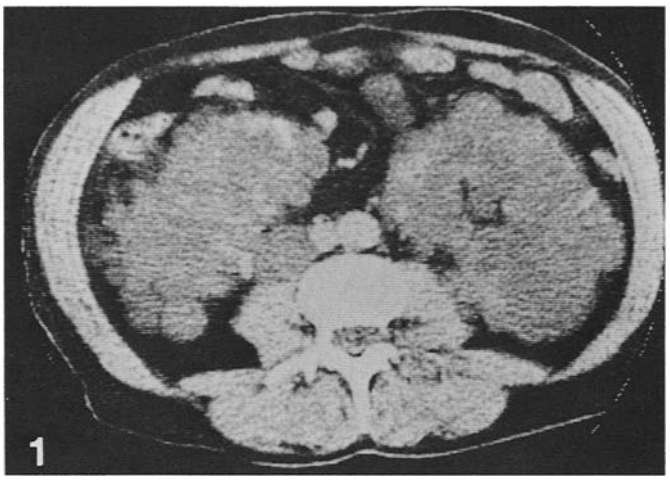


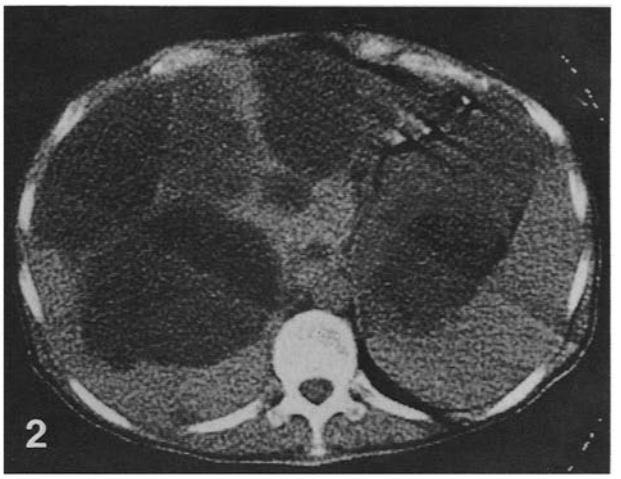


Fig. 1. CT image of polycystic kidneys from a patient with severely decreased renal function. The irregular "polycystic" surface is easily demarcated

Fig. 2. CT image of a liver with cysts from a patient with the adult form of polycystic kidney disease. The cysts must be > 1 cm in diameter to be clearly identifiable

Table 2. Mean age and mean endogenous creatinine clearance (±SD)

Renal function	No. of patients	Age (years)		ECC[a] (ml/min)	
		Mean	SD	Mean	SD
Normal	11	31	(± 7)	103	(±12)
Moderately decreased	12	40	(±11)	76	(± 8)
Considerably decreased	8	47	(±11)	44	(± 9)
Severely decreased	12	55	(± 8)	17	(± 6)

[a] ECC, endogenous creatinine clearance

Table 3. Mean total renal volume and mean difference in size between the 2 kidneys

Renal function	Total volume cm^3	Difference in size	
		cm^3	% of total volume
Normal	1,212	243[a]	20
Moderately decreased	1,446	188	13
Considerably decreased	1,915	155	8
Severely decreased	2,053	206	10

[a] $P < 0.05$, t test

Computerized Tomography

(CT scanning) of the abdomen – including kidneys, liver, spleen and pancreas – was performed with an EMI CT 5005 General Purpose Scanner. The scanning time was 18 s, the scan thickness 13 mm, and the mutual distance between the scans 20 mm. The reconstruction field was 13 inches (32 cm), and the matrix 320 × 320. CT image of polycystic kidneys is shown in Fig. 1, and that of hepatic cysts in Fig. 2.

In order to differentiate intestines from the other upper abdominal structures, we administered perorally 5% water-soluble contrast material, joxitalamate (Telebrix®) or amidotrizoate (Gastrografin®); 40–60 mg butylscopolamine (Buscopan®) was given intramuscularly in order to avoid artifacts from intestinal peristalsis.

The area of each renal cross section was determined planimetrically with a Haff planimeter (No. 315) and then multiplied by 20 mm to calculate cross-sectional volume. The sum of all cross-sectional volumes was taken to represent total renal volume.

Accuracy

The accuracy of the method was estimated using a dummy with irregular ("polycystic") surface, and a total volume of 1,500 cm^3 and a maximal variation of 5% was found by repeated measurements.

Normal Renal Volume

Normal renal volume was measured in 12 controls (mean age 35, range 27–45 years) with no clinical or laboratory evidence of renal disease and with normal intravenous urograms. The combined volume of 2 normal kidneys was found to be 497 (SD ± 58) cm^3, with an average difference between the 2 kidneys of 30.9 (SD ± 25.7) cm^3.

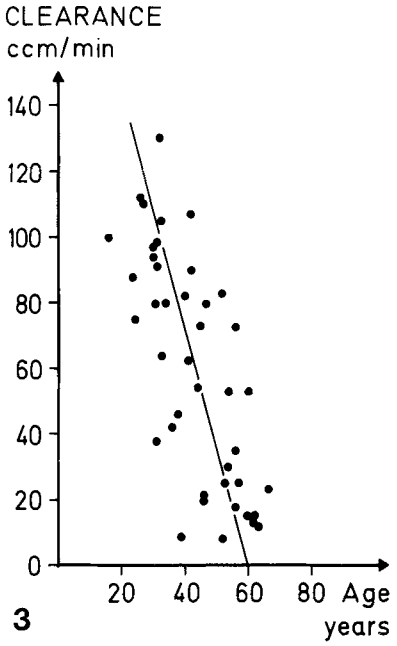
Results

Renal Function

We found that renal function deteriorates linearly with age beginning at the mean age of 40 (±11) years, and reaches lowest values at the mean age of 55 (±8) years (Table 2, Fig. 3).

Total Renal Volume

Volume increases progressively and linearly until renal function is severely reduced (Table 3, Fig. 4). The



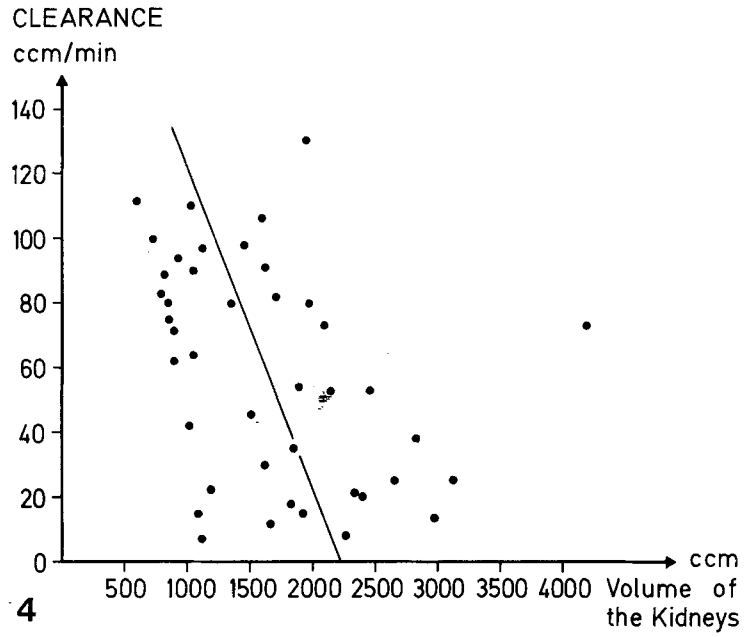


Fig. 3. Age of patients in relation to endogenous creatinine clearance. There is a significant linear correlation between age and renal function ($P < 0.001$, Spearman's rank test [6]) with a coefficient of correlation (R_s) of -0.706

Fig. 4. Total renal volume in relation to endogenous creatinine clearance. There is a significant linear correlation between total renal volume and creatinine clearance ($P < 0.001$, Spearman's rank test [6]) with a coefficient of correlation (R_s) of -0.473

difference in size between the 2 kidneys, however, remains relatively constant and is significant only in the group with the best renal function ($P < 0.05$, t test) (Table 3).

Complications

At the time of CT scanning 15 patients were receiving treatment for hypertension. The mean renal volume (1,952, SD $\pm$ 944 cm^3) in the treated group was significantly higher than the mean renal volume (1,477, SD $\pm$ 623 cm^3) in the nontreated group ($P < 0.05$, t test).

Cysts in Other Organs

Hepatic cysts were found in 23 patients (53%), pancreatic cysts in 2 patients (5%), and splenic cysts in no patients.

Table 4. Occurrence of hepatic cysts

Renal function	No. of patients with:	
	No cysts	Hepatic cysts
Normal	6	5
Moderately decreased	6	6
Considerably decreased	1	7
Severely decreased	7	5

In the 4 groups of patients (Table 4) there was no significant difference in the occurrence of demonstrable hepatic cysts. The total number of hepatic cysts and the volume of the cysts could not be determined.

Discussion

Renal Function

Impairment of renal function starts in the middle of the fourth decade, and terminal renal failure, necessitating dialysis or renal transplantation, is reached in the middle of the sixth decade (Table 2, Fig. 3). The intercept on the x-axis is 60 ($\pm$9) years, indicating that zero renal function is reached at the end of the sixth decade. This finding is in general agreement with those of a number of other investigations [4, 7].

Total Renal Volume

It is widely accepted that renal size generally increases before functional destruction is seen [8]. Our investigation shows that the increase starts before renal function is impaired. In fact, growth continues when renal function deteriorates, since total kidney volume is significantly lower in patients with normal renal function than in patients with severely decreased renal function ($P < 0.01$, t test).

Our study does not agree with previous studies [8, 9] which show that the size of polycystic kidneys is not correlated to renal function. The growth of polycystic kidneys may be due to growth of individual cysts or formation of new cysts. The latter does not correlate with the factors that potentially may influence the growth rate of cystic nephrons [7]. In fact, the combined kidney volume seems to increase linearly when it is determined in patients with progressive degrees of renal functional impairment (Table 3, Fig. 4).

Lalli and Poirier [9] studied 20 patients with adult polycystic kidney disease; in all patients urographic examinations were repeated at intervals from 2 to 21 years. They observed that increase in renal size was correlated with the severity of the disease and was an indicator of probable shortened life expectancy. They measured the renal size by the renal length on radiographs from the urographic examinations. No change in renal width or problems with delineation of renal outline were mentioned. When renal function is severely decreased, renal length (size) must be measured carefully on urograms because the outline of the enlarged kidneys is difficult to delineate [2–4]. Our study does not reject Lalli and Poirier's conclusion, which is in agreement with clinical observations [7]. We feel that consecutive determinations of the combined kidney volume in individual patients during progressive renal function impairment are necessary to verify their conclusion. Consecutive determinations may even modify our conclusion that total renal volume appears to increase linearly with progressive renal function impairment.

A significant difference in volume between the right and left kidneys in the early stages of the disease is apparent from Table 2. In many patients only 1 kidney is clearly palpable initially. The difference between the sizes of the 2 kidneys becomes insignificant with deteriorating renal function, as in the late stage of the disease when both kidneys are usually palpable.

Complications

The complications of adult polycystic kidney disease are a frequent cause for the establishment of the diagnosis. In our study the frequency was 63%, and the difference in the frequency of each symptom (Table 1) correlates well with that reported in other studies [7].

At the time of CT scanning 35% of the patients were receiving treatment for hypertension. This is in agreement with Dalgaard's study [8]. On the other hand, we found no correlation with deteriorating renal function. This disagrees with Dalgaard's study [8], in which hypertension appeared generally quite late in the course of disease. This seems to be the first study to point to a significant correlation between combined renal volume and the occurrence of hypertension. The material is, however, small.

No symptoms of hiatal hernia, which frequently develop when the kidneys enlarge to occupy a prominent place in the abdomen [7], were observed.

Cysts in Other Organs

The frequency of hepatic cysts in the present material is 51%. Patients had both single and multiple cysts. This is in general agreement with other clinical findings [3, 4, 7] and with autopsy materials [8]. In our patients there was no evidence of hepatic dysfunction or portal hypertension.

Conclusions

1. CT scanning permits determination of renal volume at all levels of renal function. In case of renal failure when origin can not be determined by ordinary clinical and urographic examination, CT scanning may be of diagnostic value. Most patients with terminal renal failure have maximally contracted kidneys, whereas patients with polycystic kidney disease have significantly increased renal volume.

2. In the initial stages of adult polycystic kidney disease the volume of the polycystic kidneys is often different on the 2 sides. This difference becomes insignificant with progressive renal failure.

3. The growth rate of polycystic kidneys seems to follow a linear course when determined in patients with variable degrees of renal function impairment. Consecutive studies of the combined kidney volume in individual patients during progressive renal failure have not, however, been performed.

4. Hepatic cysts, not detectable by palpation of the liver, may be demonstrated by CT scanning.

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