Urol Res (1993) 21:371–374

Urological Research

Original articles

Proportional analysis of the kidney arterial segments

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Received: 8 April 1993 / Accepted: 16 July 1993

Summary. The proportional area of each renal arterial segment was analyzed in 49 polyester resin corrosion endocasts of the renal vasculature. We defined a segmental artery as a primary or secondary branch of the renal artery that could be isolated outside the hilum. We found kidneys with five arterial segments in 30 of 49 casts (61.2% of cases) and kidneys with four arterial segments in 19 of 49 casts (38.8%). To enable the evaluation of the proportional areas of the autonomous segments (by using the "point-counting planimetry method"), each arterial segmental branch was injected with different-colored resin. The superior segment (apical) was present in 36 of 49 casts (73.5% of cases) and had a median proportional area of 13.02%. The anterosuperior and anteroinferior segments were present in 30 of 40 casts (61.2% of cases) and had median proportional areas of 21.36% and 17.18%, respectively. The anterior segment was present in 19 of 49 casts (38.8% of cases; when the mid-kidney anterior surface received only one segmental artery) and had a median proportional area of 28.44%. The inferior segment was present in 100% of cases and had a median proportional area of 22.65%. The posterior segment was also present in 100% of cases and was the segment with the greatest median proportional area (33.76%).

Key words: Anatomy – Kidney – Kidney segments – Radiology – Renal artery

Some 40 years ago a reasonably constant pattern of intrarenal artery distribution was described and popularized, which divided the renal parenchyma into specific anatomic segments [4]. Several articles followed, describing different types of arterial segmentation and nomenclature for the segments [1–3, 5, 9, 18, 19].

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Although some studies are available on renal arterial segmentation, none of them presents an analysis regarding the proportional areas of the segments. The aim of this study was to provide an analysis of the proportional surface area of each segment as measured on polyester resin endocasts of the kidney arterial vasculature.

Materials and methods

We studied 49 three-dimensional endocasts of the intrarenal arterial tree obtained from 33 fresh cadavers of both sexes (cause of death not related to the urinary tract). In 16 subjects the kidneys were studied bilaterally and in 17 subjects we studied only one kidney. For this work we considered only kidneys having a single renal artery.

We defined a segmental artery as a primary or secondary branch of the main renal artery that can be identified and isolated outside the renal hilum [1, 12]. We considered as a posterior segmental artery (retropelvic artery) the posterior branch of the renal artery; we did not consider its sub-branches inside the renal parenchyma as segmental arteries [11].

Polyester resin was injected into each segmental branch. The injections and the specimen preparation were performed according to the technique described in previous papers [11, 13–15, 17]. The segments were injected with resins of different colors as follows: posterior segment, red; superior (apical) segment, brown; anterosuperior segment, blue; anteroinferior segment, white; inferior segment, yellow. The terminology of the segments was based on that of the International Anatomic Nomenclature Committee [6]. Two other possibilities existed. First, when the main artery to the apex of the kindey (superior segment) was a branch of the posterior segmental artery (retropelvic artery), this branch arose inside the renal parenchyma and, was therefore, injected with the same color as the posterior segment (red), because in these cases the arterial supply of the kidney apex is dependent both anatomically and functionally on the posterior segmental artery. Second, when the mid-kidney had only one segmental artery, the anterosuperior and the anteroinferior segments were fused in the anterior segment (this segment was injected with blue resin). The possibilities for segmental arrangement are shown in Figs. 1 and 2.

After the endocasts had been obtained they were positioned horizontally and their anterior and posterior sides were photographed. Over the photographs, we placed a B-100 translucent Weibel grid [20], in order to evaluate the surface area of each segment by using the "point-counting planimetry method" (Fig. 3). The B-100 grid contains 100 points, each point being the geometric

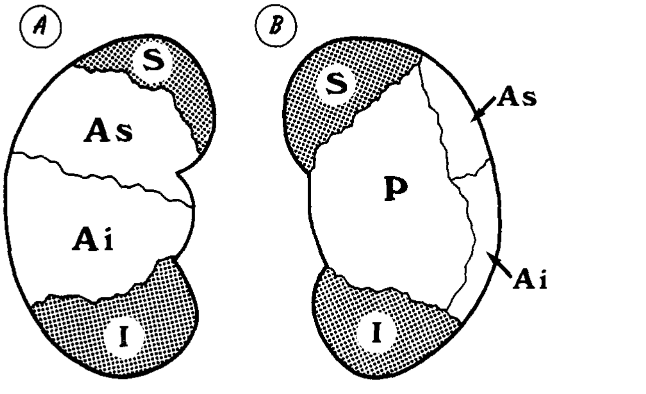

Fig. 1 a, b. Schematic drawings of a kidney with five arterial segments. There are two arteries to the mid-kidney anterior surface: the anterosuperior and the anteroinferior segmental arteries. **a** Anterior view; **b** posterior view. *S*, Superior segment; *As*, anterosuperior segment; *Ai*, anteroinferior segment; *I*, inferior segment; *P*, posterior segment

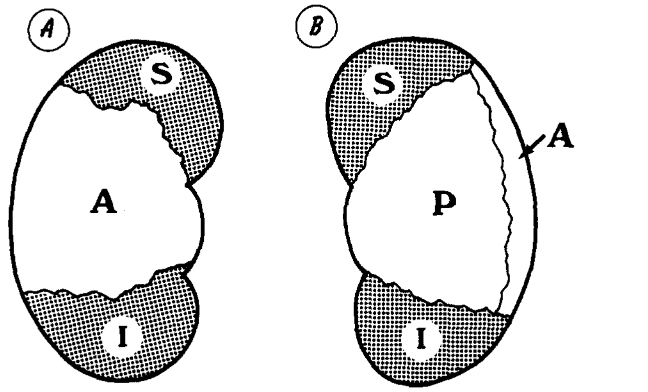

Fig. 2 a, b. Schematic drawings of a kidney with four arterial segments. There is only one artery to the mid-kidney anterior surface: the anterior segmental artery. **a** Anterior view; **b** posterior view. *S*, Superior segment; *A*, anterior segment; *I*, inferior segment; *P*, posterior segment

center of a square. If a B-100 translucent grid is superimposed on a photograph of a cast, it is possible to evaluate the number of points that correspond to one surface of the cast (Fig. 3). Since individual segments had been injected with different colors, it was also possible to evaluate the number of points that corresponded to each segment. Performing this technique for both sides and summing the results leads to an estimate of the proportional area that each arterial segment represents in the whole kidney.

For these calculation we used the absolute percentage values, that is, we evaluated the number of points on each side of the cast (anterior and posterior) and, after summing these results, obtained the number of points that represents the whole kidney (100%). We then evaluated the number of points for each segment on both sides, and by using a single "rule of 3" determined the proportional area of each segment. For example, let us assume the whole kidney (anterior and posterior surfaces) corresponds to 85 points and the inferior segment (anterior and posterior surfaces) to 27 points. Thus:

85 points (whole kidney) = 100%
27 points (inferior segment) = x

$$x = \frac{100 \times 27}{85}$$

x (inferior segment) = 31.8%.

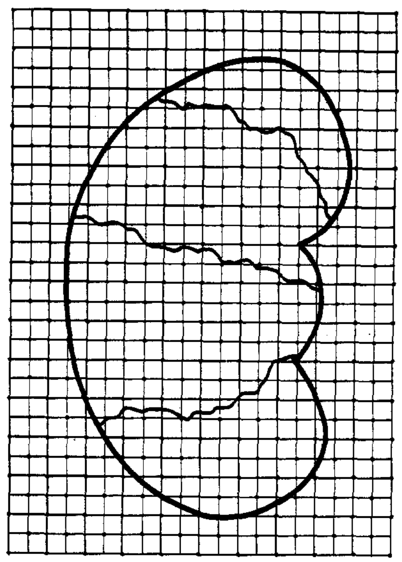

Fig. 3. Schematic drawing of a B-100 planimetry grid placed over the anterior aspect of a right kidney, illustrating the evaluation of the segmental surface area by the point-counting planimetry method

Results

The bifurcation of the main renal artery into an anterior and a posterior branch was found in all cases of kidneys with a single artery.

In 30 of 49 casts (61.2% of cases) we found kidneys with five arterial segments (Fig. 1) and in 19 of 49 casts (38.8%) we found kidneys with four arterial segments (Fig. 2).

Superior (apical) segment

The superior segmental artery usually had an extra-hilar origin. In 36 of 49 casts (73.5%) this artery arose from the anterior division of the main renal artery and in 13 of 49 casts (26.5%) from its posterior division (posterior segmental artery). When the main artery to the apex of the kidney (superior segment) was a branch of the posterior segmental artery (retropelvic artery), we did not consider the superior segment as independent and it was included with the posterior segment. When the superior segment existed independently (Figs. 1, 2) its area varied from 1.84% to 27.02% of the total kidney area (mean 13.02%).

Anterosuperior segment

In 30 of 49 casts (61.2%) we found an anterosuperior segment (Fig. 1). Its area varied from 5.17% to 34.22% of the total kidney area (mean 21.36%).

Table 1. Results of the arterial segment proportional analysis

	n	A_{min} [%]	A_{max} [%]	A_{med} [%]	CV [%]
Superior (apical)	36	1.84	27.02	13.02	39.09
Anterosuperior	30	5.17	34.22	21.36	31.88
Anteroinferior	30	1.29	25.80	17.18	32.36
Anterior	19	16.57	42.95	28.44	24.29
Inferior	49	7.42	38.18	22.65	27.99
Posterior	49	14.57	52.93	33.76	27.16

n, Number of cases; A_{min}, minimum area; A_{max}, maximum area; A_{med}, median area; *CV*, coefficient of variation

Anteroinferior segment

The anteroinferior segment (Fig. 1) was also found in 30 of 49 casts (61.2%) and its area varied from 1.29% to 25.8% of the total kidney area (mean 17.18%).

Anterior segment

In 19 of 49 casts (38.8%) there was only one segmental artery to the mid-kidney, this being the anterosuperior and the anteroinferior segments fused as the anterior segment (Fig. 2). When the anterior segment existed, its area varied from 16.57% to 42.95% of the total kidney area (mean 28.44%).

Inferior segment

The inferior segment was found in 100% of cases (Figs. 1, 2). Its area varied from 7.42% to 38.18% of the total kidney area (mean 22.65%).

Posterior segment

The posterior segment, was also found in 100% of the specimens studied (Figs. 1, 2). Its area varied from 14.57% to 52.93% of the total kidney area (mean 33.76%).

Table 1 shows a summary of the proportional analysis of the arterial segments.

Discussion

The superior (apical) segment presented the lowest *median value* of proportional area (13.02%) and also was the most varied segment regarding its area (coefficient of variation 39.09%). In 13 cases (26.5%) the superior segment was not considered independent because the arterial supply to the apex of the kidney originated from the posterior segmental artery (retropelvic artery).

When the mid-kidney anterior surface received two segmental arteries (61.2%; 30/49 casts), the anterosuperior and the anteroinferior segments existed separately (Fig. 1). In these cases, the anterosuperior segment presented greater *median values* of proportional area than those of the anteroinferior segment. In the remaining 38.8% of the cases (19/49 casts), the mid-kidney anterior surface received only one segmental artery for the anterior segment (Fig. 2). In this situation, the anterior segment presented greater *median values* of proportional area than those of the anterosuperior or of the anteroinferior segments separately.

The inferior segment was present in 100% of cases and always included the anterior and posterior surfaces of the kidney (Figs. 1, 2).

The posterior segment was also present in 100% of cases. This segment was supplied by the posterior segmental artery (often known as the retropelvic artery) and had the greatest *median value* of proportional area (33.76%) and also the greatest *maximum value* of proportional area, accounting for to 52.93% of the total kidney area. This fact is important because it demonstrates the significance of the posterior segmental artery. An injury to this vessel may occur during various interventions on the kidney (renal transplantation [16], intrarenal access [17], intrarenal endourologic surgery [10], nephron-sparing surgery for renal cell carcinoma [11], etc.) and may be associated with destruction of a large area of the renal parenchyma. Therefore, besides severe hemorrhage, a lesion to the posterior segmental artery may cause an important deficit in renal function [12] and even loss of the allograft in the case of renal transplantation.

Although the "point-counting planimetry method" is not ideal for measuring the area of three-dimensional specimens, it is simple, reproducible, and may be used in medical practice. Also, to our knowledge, this is the first report that presents an analysis of the proportional areas of the kidney arterial segments. Moreover, since this technique is morphometric it represents an objective way of evaluating the dimensions of the segments, in contrast to the personal and subjective perception of the physician [7, 8]. In some cases, as a comparative assay, after determining the area of the segments by this indirect method we determined the relative sizes of each segment in the kidney by a direct method. In the direct method the entire endocast was weighted, and that weight taken to represent 100%. Subsequently, the endocast was separated into the injected segments and each segment weighted individually. Then, by using the "rule of 3" explained above, the percentage accounted for by each segment in the whole kidney was determined. By comparing the results obtained by these two methods (Fisher's test) we verified that they are similar. Therefore, the "point-counting planimetry method" is a reasonable technique for quantifying the renal segments, and would be useful because it would allow the practitioner to evaluate the total kidney area and also the area of each arterial segment by using a planimetry grid superimposed over the results of imaging studies (angiography, computed tomography and magnetic resonance imaging, for example). This type of analysis would be of value in many clinical situations, such as an estimation of the renal parenchyma area that will be sacrificed as a consequence of embolization of an intrarenal arterial branch, estimation of the renal parenchyma area that will be sacrificed or preserved after a nephron-sparing operation, evaluation of the percentage of tumor atrophy after embolization, or evaluation of the area of parenchymal ischemia after an arterial branch lesion.

Acknowledgements. Supported by grant 50.1342/91-5/BM-FV from the National Council of Scientific and Technological Development (CNPq-Brazil). We are grateful to Ms. Marta Cardoso Leão for her excellent technical assistance.

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