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► **To cite this version:**

Shahed Borojeni, Antoinette Borojeni, Paul Panayotopoulos, Antoine Bouvier, Christophe Aubé, et al.. Study of Renal and Kidney Tumor Vascularization Using Data from Preoperative Three-dimensional Arteriography Prior to Partial Nephrectomy. *European Urology Focus*, 2020, 6 (1), pp.112-121. 10.1016/j.euf.2018.07.028 . hal-03292782

HAL Id: hal-03292782

<https://univ-angers.hal.science/hal-03292782>

Submitted on 21 Jul 2022

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Study of Renal and Kidney Tumor Vascularization Using Data from Preoperative Three-dimensional Arteriography Prior to Partial Nephrectomy

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Abstract

Background: In a cadaveric model with healthy kidneys, it has recently been highlighted that a single renal segment could be supplied by one or more arterial branches originating from an artery supplying another segment.

Objective: To demonstrate occurrences of anatomical variations of renal vascularization and to analyze vascularization of renal tumors.

Design, setting, and participants: This prospective monocentric study included all patients treated for a renal tumor between May 2015 and June 2017 by laparoscopic partial nephrectomy after superselective tumor embolization in a hybrid operating room.

Intervention: Three-dimensional renal and tumoral arteriography with cone-beam computed tomography scan was performed, coupled with preoperative cross-sectional imaging. This procedure provided an accurate vascular anatomical mapping of the kidney and allowed further analysis of tumor vascularization.

Outcome measurements and statistical analysis: Relation between anatomical variations of the vascularization and perioperative data was assessed. A χ^2 test or Fisher's test was used for qualitative variables, and a Student *t* test was used for quantitative variables.

Results and limitations: Out of the 60 patients included, only 25 (42%) presented a standard vascular subdivision. In 26 patients (43%), tumors were supplied by more than one branch and in 20 patients (33%), there was a branch supplying the tumor from another segment. In these cases of multiple or multi-segmental tumor vascularization, tumor size, operative duration, and duration of embolization were significantly higher than in the case of standard vascularization. These complex tumors were more often located at the upper pole of the kidney or at the junction of the anterior and posterior vascular territories of the kidney. Limitations of this study include the low number of patients and its monocentricity.

Conclusions: This study confirms that renal vascularization frequently differs from Graves' reference model and that tumor vascularization can depend on several segmental branches.

This vascular complexity explains surgical difficulties and must be taken into consideration when segmental arterial clamping is considered during partial nephrectomy.

Patient summary: We studied renal and tumor vascularization using three-dimensional preoperative arteriography data on tumor kidneys. We have shown that there is great variability in renal vascularization and that tumors can be vascularized branches that originate from an artery leading to another segment. This vascular complexity explains surgical difficulties and must be taken into consideration when segmental arterial clamping is considered during partial nephrectomy.

Keywords: Angiography; Hybrid operating room; Laparoscopy; Nephron-sparing surgery; Renal cell carcinoma; Segmental arterial clamping; Super-selective renal embolization

1. Introduction

In 1744, Bertin hypothesized the renal vascular segmentation. This hypothesis was later confirmed by Hyrtl in 1882 [1] who described the renal arteries as end vessels, making the kidney particularly sensitive to ischemia. The main renal artery is divided into two branches, one anterior and the other posterior to the renal pelvis. It defines two unequal territories with most of the blood supply carried anteriorly, separated by an “avascular” frontal plane, without anastomosis between the different sectors [1]. In 1901, Brödel [2] described this plan as passing through the row of minor posterior calyces and as being

particularly useful for nephrotomy to approach the pelvis without damaging the important arterial branches.

In 1954, Graves [3] described the first segmental renal classification (Fig. 1), which is considered as the reference anatomical description. It divides the renal parenchyma into five segments: four anterior (apical, superior, middle, and inferior) and one posterior, each segment supplied by its own arterial branch.

A good understanding of renal vascularization determines the success of partial nephrectomy, as Dufour [4] pointed out in 1951 in his report to the congress of the French Association of Urology.

Partial nephrectomy is considered as the reference treatment in localized renal tumors of <7 cm [5]. Indeed, it allows a similar disease control as complete nephrectomy, while preserving renal function [6]. Nevertheless, this procedure requires clamping of the main renal artery to minimize blood loss leading to renal ischemia which, if prolonged, can damage renal function [7–9].

To minimize renal ischemia, some authors proposed clamping of the segmental artery which irrigated the tumor [10,11]; however, a study using near-infrared fluorescence (NIRF) imaging during robot-assisted partial nephrectomies showed that this technique did not provide complete ischemia of the tumor area [12].

A more recent study conducted by Macchi et al [13] on cadaveric normal kidneys demonstrated that a single renal segment could receive one or more branches that originate from an artery leading to another segment. This shows that human renal arterial vascularization is frequently different from Graves' description. The hypothesis is therefore that, like renal segments, tumors can also be vascularized by branches that originate from an artery leading to another segment. It could explain the failure of selective clamping of a segmental artery to obtain complete ischemia of the tumor area.

The hybrid operating rooms, coupling an interventional radiology room and a classical operating theater, allowed the development of preoperative superselective tumor embolization, making clampless partial nephrectomy possible [14]. This procedure is technically safe, carcinologically efficient, and a mini-invasive alternative for the management of localized renal tumors [15].

To perform tumor embolization, three-dimensional (3D) arteriography was performed, allowing a fine analysis of the renal vascularization and of the tumor vascularization.

The primary objective of this study is to demonstrate regular occurrences of anatomical kidney arterial vascularization variations and to analyze the vascularization of renal tumors.

The secondary objective is to assess the criteria of vascular complexity found on the arteriography and to evaluate their association with a more complex procedure.

2. Materials and methods

This study was approved by an ethics committee, and all patients gave their consent for the procedure and their inclusion in the prospective Uro-CCR database.

2.1. Population

We performed a prospective monocentric study between May 2015 and June 2017 and consecutively included 60 patients treated by laparoscopic partial nephrectomy after selective arterial embolization in our urology department (Angers, France).

The inclusion criteria were a localized kidney tumor and indication of partial nephrectomy and validated by the uro-oncologic multidisciplinary board.

2.2. Procedure

The procedure was performed in the hybrid room (Discovery IGS 730, GE Healthcare, Waukesha, WI) of our establishment [14,15].

Each patient was placed in standard supine position under general anesthesia. Initially, the interventional radiologist performed a puncture of the femoral artery and inserted a 4-F introducer to allow for the catheterization of the renal artery. Next, a 3D renal arteriography (Fig. 2) with cone-beam computed tomography scan (CBCT) was performed to study global renal vascularization and tumor vascularization. The rotational angiography over 200° was performed at 40° per second rotation speed during 5 s with breath-holding. X-ray acquisition started 2 s after intra-arterial administration of 3 ml/s of a nonionic contrast agent (Visipaque 320 mgI/mL; GE Healthcare) through the 4-F catheter placed into the renal artery (total volume of 27 ml).

In order to identify the vessels irrigating the tumor, the Vessel Assist software (GE Healthcare) was used.

The segmental arteries vascularizing the tumor were catheterized with a coaxial microcatheter (Progreat hydrophilic coated micro catheter 2.7F, Terumo Europe, Leuven, Belgium), allowing superselective embolization of tumor vessels using either Embozene microspheres (CeloNova Bioscience Inc., San Antonio, Texas) or micro coils (Vortex, 2 and 3 mm diameter, Boston Scientific, MA, USA), or glue N-butyl-2-cyanoacrylate Glubran 2 (GEM Srl, Viareggio, Italy) diluted with Lipiodol (Guerbet, Paris, France).

We also performed a final CBCT to control the devascularization of the tumor and preservation of the renal parenchyma.

Once the hyperselective embolization of the tumor was performed, the patient was positioned in a lateral position and partial nephrectomy was performed by laparoscopy, always by the same surgeon.

2.3. Pathology

All tumors were analyzed by our pathology department. Histological subtypes were recorded according to the 2015 World Health Organization classification of kidney tumors [16].

Fuhrman or International Society of Urological Pathology grade for clear-cell renal cell carcinomas and surgical margins were systematically analyzed [17].

2.4 Arteriography data

Two independent reviews of the data of 3D renal and tumoral arteriography (Fig. 2) were performed and compared by a urologist and radiologist, in addition to preoperative cross-sectional imaging if necessary.

To establish accurate vascular anatomical mapping of the kidney, the following data were collected by both reviewers: number of primary renal arteries, existence and origin of a polar artery, number of anterior and posterior renal arteries, and number of segmental artery from the anterior artery.

In order to analyze the tumor vascularization, the following data were collected by the two reviewers: tumor localization, number of tumor arteries, and segmental origin of each one. The aspect of tumor vascularization (hypovascularization, moderate vascularization, or hypervascularization) was assessed by comparing the tumor and parenchymal vascular enhancement, according to the expertise of the interventional radiologist at the time of arteriography.

2.5 Data and statistical analysis

The following data were collected and anonymized via the National Prospective Kidney Cancer Database (Uro-CCR): age, sex, body mass index (BMI), tumor size, and tumor complexity data according to the R.E.N.A.L. (Radius, Exophytic/Endophytic properties, Nearness of tumor to the collecting system or sinus in millimeters, Anterior/Posterior, Location relative to polar lines) score [18].

We evaluated the relationship between anatomical variations in vascularization and intraoperative data by collecting: number of arterial branch vascularizing the tumor, number of embolized arteries, appearance of global tumor vascularization (hypovascularization, moderate vascularization, or hypervascularization), operative time, embolization duration, and blood loss.

After the two independent reviews of the arteriography, the data of the anatomical kidney vascular pattern and tumor vascularization were collected for each patient.

Qualitative variables are described with percentages. Quantitative variables are described with medians (interquartile range: 25th percentile–75th percentile).

For comparison of groups, the χ^2 test or Fisher's test (in case of small numbers) was used for qualitative variables, and Student's *t* test was used for quantitative variables. The results were significant if $p < 0.05$.

The analyses were performed using SPSS version 15.0 software (IBM Analytics, USA).

3. Results

3.1 Population

This study included 60 patients (Table 1); of this, 26 (43%) were women and 34 (57%) were men. The median age of patients at diagnosis was 62 yr (52–68.75). Of 60 patients, 12 (20%) were aged <50 yr, 36 (60%) were aged between 50 and 70 yr, and 12 (20%) were >70 yr.

The median BMI of patients was 27.6 kg/m² (24.28–30.76 kg/m²).

3.2 Tumor characteristics

The median tumor size was 2.85 cm (2.23–3.78 cm). Furthermore, 29 (48%) tumors were lateralized on the right and 31 (52%) on the left.

The R.E.N.A.L. median score was 7: nine (15%) were of high complexity, 31 (52%) of medium complexity, and 20 (33%) of low complexity.

Of the 60 tumors (Table 2), 47 (78%) were renal cell carcinomas including 37 (62%) with clear-cell renal cell carcinoma, five (8%) with papillary renal cell carcinoma, four (6%) with chromophobe renal cell carcinoma, and one (2%) of the collecting ducts carcinoma (Bellini tumor). Thirteen (22%) of the tumors were benign: six (10%) were oncocytomas, five (8%) were angiomyolipomas, one was a benign cyst, and one was a metanephric adenoma.

3.3 Arteriography data on renal and tumor vascularization

The median duration of tumor arterial embolization was 44.5 min (32–55.75 min). The median irradiation was 71 Gy.cm².

Analysis of renal vascularization (Table 3) showed an anatomical variant for 35 (58%) of the kidneys studied.

In 15 cases (25%), the primary renal artery was not unique. There were two main renal arteries (originating from the aorta and traveling towards the hilum) in two cases (3%). In 13

cases (22%), there was a polar renal artery (leading directly to a renal pole without traveling through the hilum): six were superior polar arteries (four of which originated from the main renal artery and two from the aorta) and seven lower polar arteries (all originating from the aorta).

In nine cases (15%) there was a first-order variant, which means that the main renal artery divided itself into more than one anterior and posterior artery.

Regarding secondary segmental vascular distribution, 26 cases (43%) had a different distribution than that described by Graves.

Thirty-four (57%) tumors were vascularized by a single artery, 16 (27%) by two arteries, nine (15%) by three arteries, and one (2%) was vascularized by four arteries (Table 4).

Twenty tumors (33%) were vascularized by arterial branches from different segmental arteries (Table 4; Fig. 3).

3.4 Anatomy and tumor vascularization

The mean tumor size was higher for tumors vascularized by multiple arteries (3.6 vs 2.4 cm; $p = 0.015$) and for tumors vascularized by arterial branches from different segmental arteries (3.7 vs 2.5 cm; $p = 0.014$; Table 5; Fig. 4).

Tumors vascularized by multiple arteries or branches coming from different segmental arteries were preferentially located at the upper pole of the kidney ($p = 0.015$ and 0.031) and/or at the junction between the anterior and posterior areas of the kidney ($p = 0.014$ and 0.012 ; Table 5).

3.5 Difficulty of surgery and tumor vascularization

The median blood loss was 100 ml (50–287.5 ml). Blood loss was not significantly superior in the case of a tumor vascularized by multiple arteries (145 vs 50 ml; $p = 0.509$) or

branches from different segmental arteries (120 vs 100 ml; $p = 0.46$; Table 5). There was no significant difference in blood loss, depending on the hypovascular or hypervascular aspect of tumors on the arteriography ($p = 0.60$).

The median operating time was 83.5 min (60–105 min). The duration of surgery was higher in the case of a vascularized tumor vascularized by multiple arteries (90 vs 75 min; $p = 0.049$) or branches from different segmental arteries (97.5 vs 72.5 min; $p = 0.014$; Fig. 5).

3.6 Difficulty of embolization and tumor vascularization

The duration of embolization was higher in the case of a tumor vascularized by multiple arteries (49 vs 38.5 min; $p = 0.003$) or branches from different segmental arteries (49 vs 40 min; $p = 0.003$; Fig. 6). In four cases, embolization was described as difficult. The difficulty was attributed to an already operated patient, a patient already embolized, an ostial stenosis, or an arterial spasm.

3.7 Histological subtype and tumor vascularization

Except for clear-cell renal carcinomas, which are more often hypervascularized ($p = 0.0326$), vascularization aspect on the arteriography was not correlated to histological subtype of the tumor (Table 6).

4. Discussion

The increase of conservative surgery of the kidney has led to the development of novel techniques to avoid renal ischemia caused by the clamping of the renal artery necessary for the control of blood loss during this procedure. Techniques such as selective arterial clamping [10,11] or selective tumor arterial embolization [14,19,20] require a good knowledge of not only renal vascularization but also tumor vascularization, as pointed out by Shao et al [21],

who recommended precise analysis of renal and tumor vascular mapping before this type of procedure.

Our study confirms the great variability of renal vascularization, as highlighted by Macchi et al [13], since only 42% of the kidneys studied have a vascularization conforming to Graves' description. As shown in their study, the most frequent anatomical variant concerned the segmental division of the anterior renal artery: in 43% cases, it was divided into more or less four segmental arteries.

In our study, the main renal artery was unique in 75% of the cases: there was a polar artery in 22% of cases and two primary renal arteries in 3%, which is consistent with data from the literature reporting a single major renal artery in 72–76% cases and two major arteries in 17–23% cases [22–26].

Macchi et al [13], in their anatomical study of renal arterial vascularization on cadaveric kidneys, showed that a single renal segment can be vascularized by one or more branches from an artery destined for another segment, raising the possibility that it could be the same for tumors, thereby explaining the frequent failure of selective clamping of a segmental artery to obtain complete ischemia of the tumor area. This possibility is confirmed by our study since 33% of tumors were vascularized by arteries intended for different segments, which is consistent with the study by Shao et al of 2012 [21] that reports the need for selective clamping of a segmental artery in 52% of cases to obtain satisfactory tumor ischemia.

Furthermore, in the study by Bjurlin et al [12] using NIRF during robot-assisted partial nephrectomy, 35% of cases required clamping of the main renal artery due to the persistence of tumor perfusion despite selective clamping, which may be related to multi-segmental tumor vascularization.

Moreover, in our study, there was more than one artery for tumoral irrigation in 43% of the cases (two to four arteries). This complexity of tumor vascularization appears to be

correlated with the tumor size, which was higher in the case of a tumor vascularized by multiple arteries ($p = 0.015$) or from different segmental arteries ($p = 0.014$). This can be explained both anatomically and by tumor-induced neoangiogenesis.

The mean embolization duration increased significantly in the case of multiple tumor vascularization ($p = 0.003$) and also in the case of “multi-segmental” tumor vascularization ($p = 0.003$); this required the catheterization of several arteries.

The duration of surgery was also significantly increased in cases of vascularized tumors by multiple arteries ($p = 0.049$), or by branches from different segmental arteries ($p = 0.014$), underlining the operative difficulty in performing on these tumors.

These complex tumors were mostly located at the upper pole of the kidney (60%, $p = 0.031$) or at the junction of the anterior and posterior kidney areas (65%, $p = 0.012$). These results are consistent with the study by Shao et al [21], which reports that tumors requiring clamping of several segmental arteries were mostly located at the junction of the anterior and posterior kidney areas (80%, $p = 0.011$).

Furthermore, Kabore et al [27], in their study on the accessibility of segmental renal arteries to selective clamping, showed that upper and middle segmental arteries were the least accessible. Tumor localization could, therefore, be taken into account in the future when selective clamping is considered during partial nephrectomy.

In our study, we did not find any significant difference in blood loss between patients with multiple tumor vascularization ($p = 0.509$) or with multi-segmental tumor vascularization ($p = 0.46$). This could be explained by the small size of our study or by the fact that the tumor arteries were embolized, thus limiting arterial bleeding.

The overall vascular aspect of renal tumors in arteriography (hypovascularized, moderately vascularized, or hypervascularized) was not correlated with intraoperative blood loss or tumor histology, apart from clear-cell carcinomas more often hypervascularized (68%, $p = 0.033$). These results are in agreement with studies showing the limits of arteriography,

which is not a good diagnostic test for the etiologic orientation of the renal masses compared with the CT scan or magnetic resonance imaging. Indeed, CT-angiography brings more information about the tumor: precise size, composition (tissue or cystic, fat component, calcifications, necrosis, central scar), the kinetics of enhancement, the analysis of the system venous invasion, and loco regional invasion. Nevertheless, CT-angiography does not allow a characterization of the renal arterial vascularization and the tumor vascular complexity as precise as the arteriography does, visualizing the arteries only to the segmental level.

The limitations of our study were the low number of patients and its monocentricity. Further studies on the relationship between tumor-induced neoangiogenesis, hypervascularization, and multiple or multi-segmental tumor vascularization are needed.

Our study has the advantage of finely analyzing the vascularization of kidney tumors through 3D arteriographies and opens the perspective to further studies that are necessary to confirm these results.

5. Conclusions

Good knowledge of renal and tumor vascularization is the key to the success of techniques to control renal ischemia during partial nephrectomy, such as segmental arterial clamping or superselective tumor arterial embolization. In the majority of cases, the renal vascular distribution is different from Graves' description, confirming the anatomical variability of the renal arterial vascularization, whether at the level of the main renal artery or its segmental arteries.

Renal tumors are often vascularized by several arteries and sometimes even by arteries intended for different segments, which seems to increase surgical difficulty. These results should be taken into account in future studies when segmental arterial clamping is envisaged during a partial nephrectomy, as more than one segmental artery should be clamped when the tumor arterial branches originate from different segmental arteries.

These complex tumors appear to be predominantly situated at the upper pole of the kidney or at the junction of the anterior and posterior territories of the kidney.

As it involves performing an arteriography, the technique of selective tumor embolization has the advantage of providing a precise cartography of the tumor vascularization, allowing to target the embolization gesture and thus to obtain a complete devascularization of the tumor.

Author contributions: Pierre Bigot had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: S. Borojeni, A. Borojeni, Bigot.

Acquisition of data: S. Borojeni, Panayotopoulos.

Analysis and interpretation of data: S. Borojeni, A. Borojeni.

Drafting of the manuscript: S. Borojeni.

Critical revision of the manuscript for important intellectual content: Bigot, Bouvier, A. Borojeni, Panayotopoulos.

Statistical analysis: S. Borojeni, A. Borojeni.

Obtaining funding: None.

Administrative, technical, or material support: None.

Supervision: Bigot, Azzouzi, Aubé.

Other: None.

Financial disclosures: Pierre Bigot certifies that all conflicts of interest, including specific financial interests and relationships and affiliations relevant to the subject matter or materials

discussed in the manuscript (eg, employment/affiliation, grants or funding, consultancies, honoraria, stock ownership or options, expert testimony, royalties, or patents filed, received, or pending), are the following: None.

Funding/Support and role of the sponsor: None.

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Fig. 1 – Renal vascular segmentation by Graves (right kidney). Pattern of arterial distribution: (A) anterior view; (B) three-quarter view; (C) lateral view; and (D) posterior view. Segmentation: 1 = apical segment; 2 = superior segment; 3 = middle segment; 4 = inferior segment; and 5 = posterior segment.

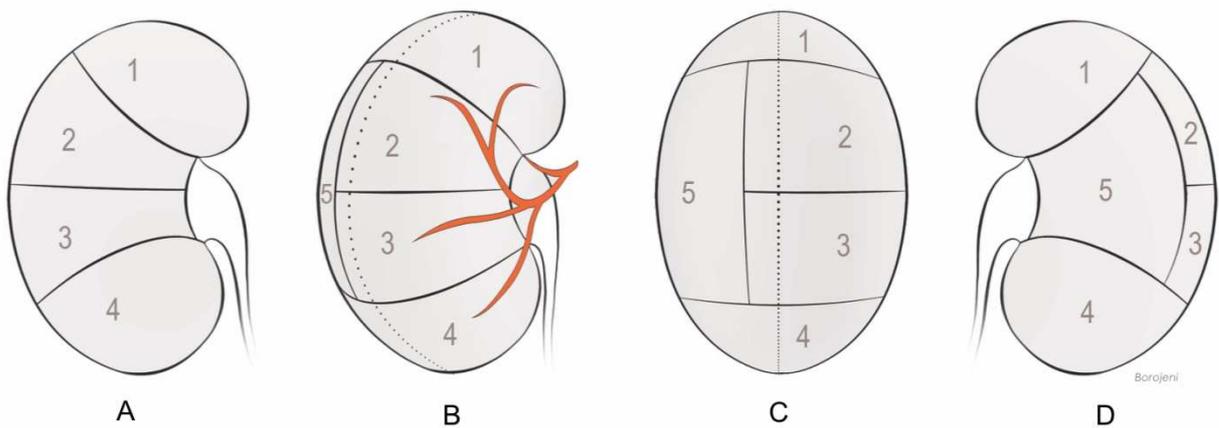


Fig. 2 – Three-dimensional arteriography of a left kidney. Standard arterial distribution: (A) medial, (B) anteromedial, (C) anterior, (D) three-quarter, (E) lateral, and (F) posterior view. Hypervascularized upper polar tumor.

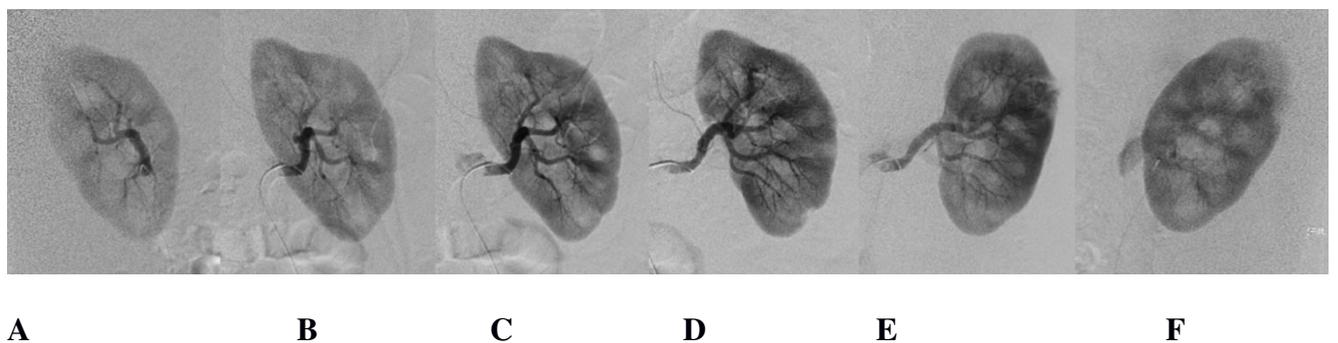


Fig. 3 – Upper polar tumor of the right kidney. (A) Cone-beam computed tomography view: coronal cross-section showing hypervascularized upper polar tumor; (B)

preoperative arteriography; (C) post-embolization arteriography; (D) tumor feeding vessels; (E) vessel assist reconstruction: tumor requires catheterization of three arterial branches from different segmental arteries.

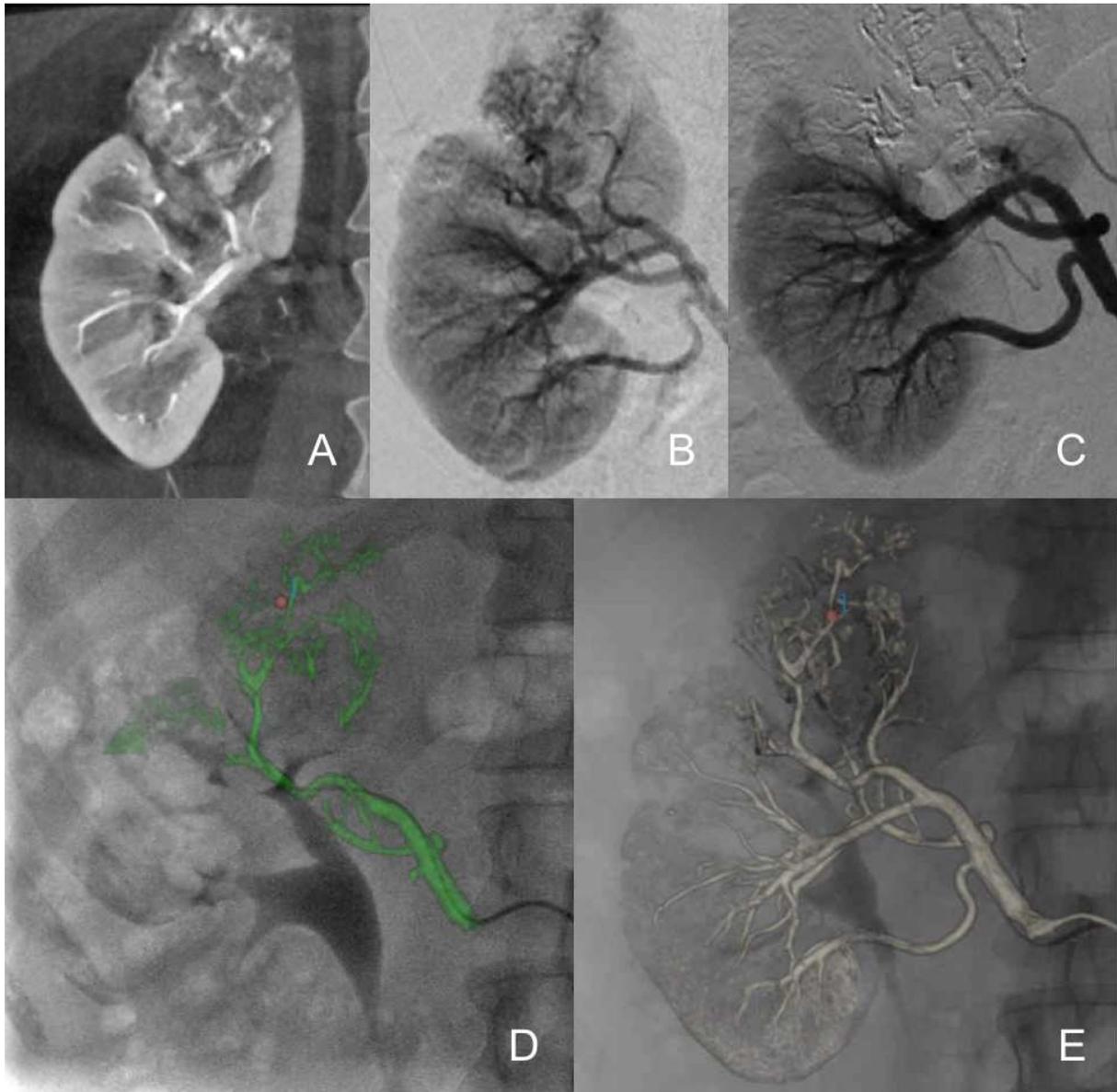


Fig. 4 – Box plot of the tumor size according to the number of tumor arteries and their origin.

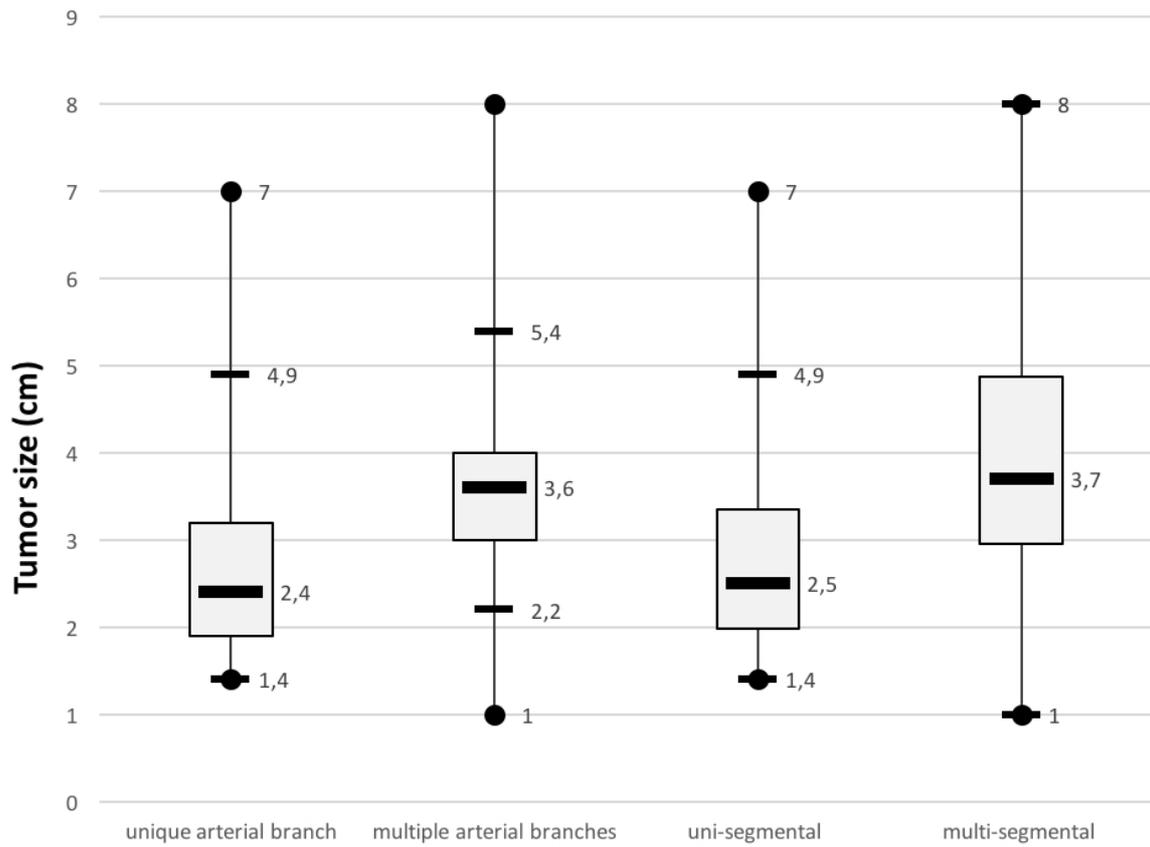


Fig. 5 – Box plot of the operative duration depending on the number of tumor arteries and their origin.

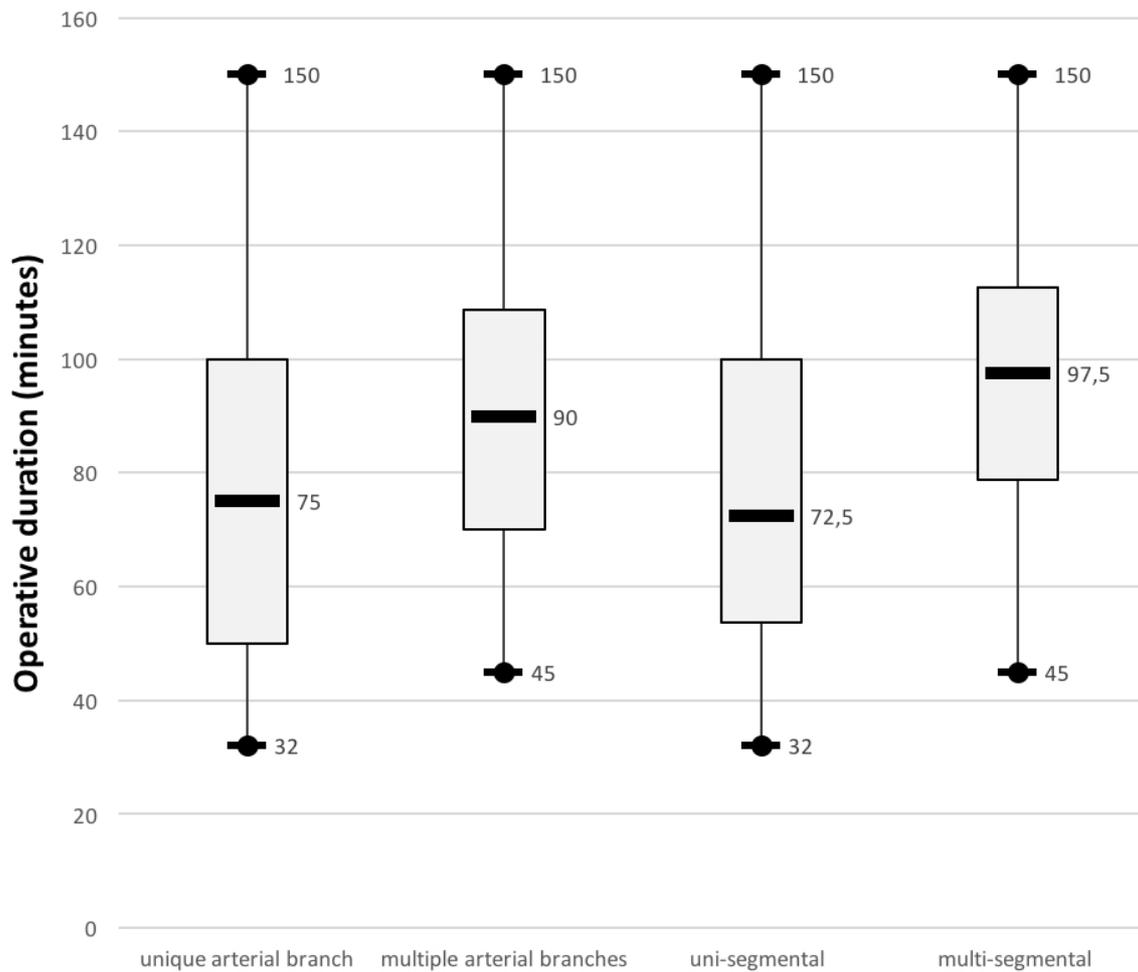


Fig. 6 – Box plot of the duration of embolization depending on the number of tumor arteries and their origin.

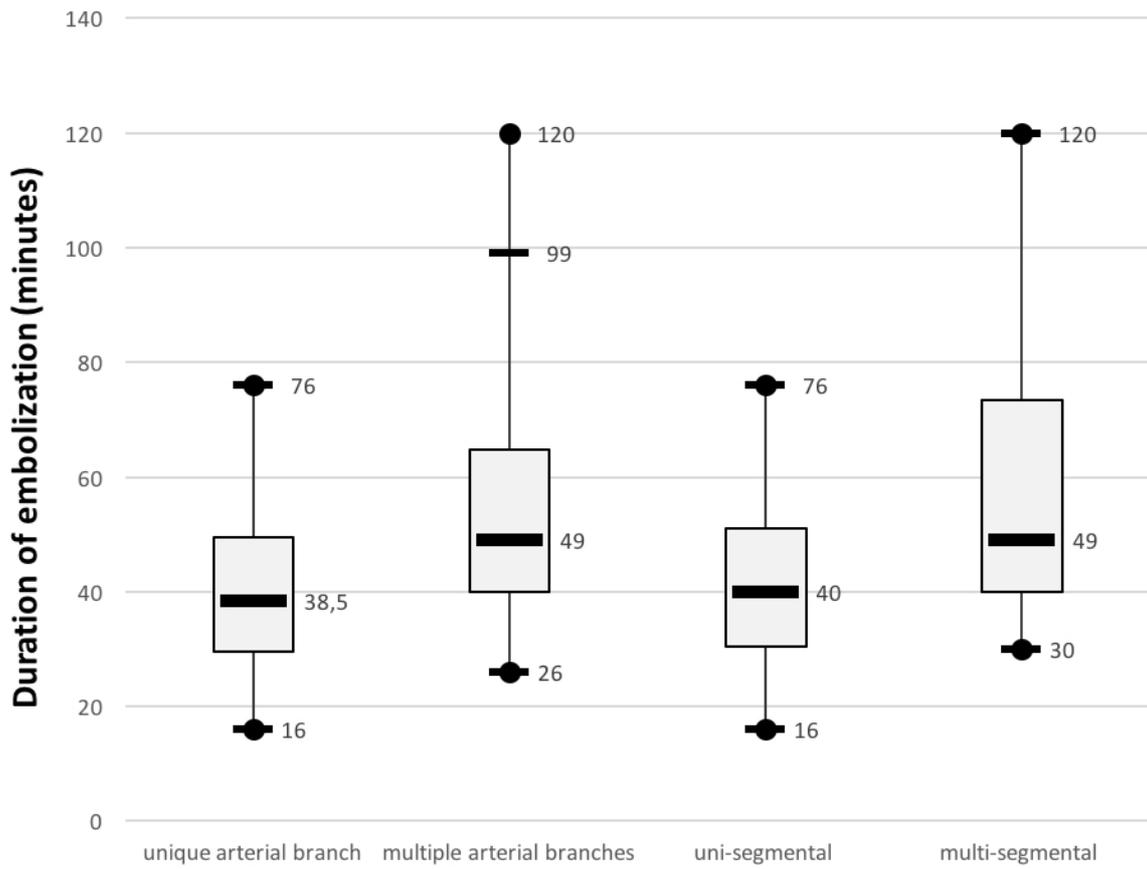


Table 1 – Age, sex, and BMI of the study population.

| Patients, <i>n</i> = 60 | |
|---------------------------------|--------------------|
| Median age (yr) | 62 (52.00–68.75) |
| <50, <i>n</i> (%) | 12 (20) |
| 50–70, <i>n</i> (%) | 36 (60) |
| >70, <i>n</i> (%) | 12 (20) |
| Sex, <i>n</i> (%) | |
| Female | 26 (43) |
| Male | 34 (57) |
| Median BMI (kg/m ²) | 27.6 (24.28–30.76) |

BMI = body mass index.

Table 2 – Tumor characteristics

| | |
|------------------------------|------------------|
| Side, <i>n</i> (%) | |
| Right | 29 (48) |
| Left | 31 (52) |
| Median tumor size, cm (IQR) | 2.85 (2.23–3.75) |
| Growth pattern, <i>n</i> (%) | |
| Exophytic | 24 (40) |
| Mesophytic | 25 (42) |

| | |
|---------------------------------------|-----------|
| Endophytic | 11 (18) |
| <hr/> | |
| Median R.E.N.A.L. score, <i>n</i> (%) | 7 (6–8) |
| High | 9 (15) |
| Medium | 31 (52) |
| Low | 20 (33) |
| <hr/> | |
| Histologic subtype, <i>n</i> (%) | |
| Renal cell carcinoma | 47 (78) |
| Clear-cell renal cell carcinoma | 37 (62) |
| Collecting duct carcinoma | 1 (2) |
| Papillary renal cell carcinoma | 5 (8) |
| Chromophobe renal cell carcinoma | 4 (6) |
| Oncocytoma | 6 (10) |
| Angiomyolipoma | 5 (8) |
| Other benign tumors | 2 (3) |
| <hr/> | |
| Grade, <i>n</i> (%) | |
| Fuhrman 1 | 6 (12.8) |
| Fuhrman 2 | 28 (59.6) |
| Fuhrman 3 | 13 (27.7) |
| <hr/> | |

IQR = interquartile range; R.E.N.A.L. = Radius, Exophytic/Endophytic properties, Nearness of tumor to the collecting system or sinus in millimeters, Anterior/Posterior, Location relative to polar lines.

Table 3 – Renal vascularization at arteriography

| | |
|--|---------|
| Anatomic variations, <i>n</i> (%) | 35 (58) |
| Main renal artery variant | 15 (25) |
| ○ Two main renal arteries | 2 (3) |
| ○ Polar renal artery | 13 (22) |
| First-order variant | 9 (15) |
| ○ More than one anterior artery | 7 (12) |
| ○ More than one posterior artery | 2 (3) |
| Segmental variant | 26 (43) |
| ○ Less than four branches from the anterior artery | 14 (23) |
| ○ More than four branches from the anterior artery | 12(20) |

Table 4 – Tumoral vascularization at arteriography

| |
|-------------------------------------|
| Tumor vascularization, <i>n</i> (%) |
|-------------------------------------|

| | |
|--|--------------------|
| Hypervascularized | 37 (62) |
| Moderately vascularized | 5 (8) |
| Hypovascularized | 18 (3) |
| <hr/> | |
| Number of arterial branch vascularizing the tumor, median; mean, <i>n</i> (%) | 1 (1–2); 1.6 (1–4) |
| 1 | 34 (56.7) |
| 2 | 16 (26.7) |
| 3 | 9 (15) |
| 4 | 1 (1.7) |
| <hr/> | |
| Tumors vascularized by arterial branches from different segmental arteries, <i>n</i> (%) | 20 (33) |
| Number of embolized arteries, median; mean | 1 (1–2); 1.5 (1–4) |
| Median embolization duration, min | 44.5 (32–55.75) |
| Median operating time, min | 83.5 (60–105) |

Table 5 – Size, location, blood loss, and operative and embolization duration depending on the number of tumor arteries and their origin

| | Unique tumoral arterial branch (<i>n</i> = 34) | Multiple tumoral arterial branches (<i>n</i> = 26) | <i>p</i> value | Tumoral arterial branch from a unique segment (<i>n</i> = 40) | Tumoral arterial branches from different segmental arteries (<i>n</i> = 20) | <i>p</i> value |
|--------------------------------|---|---|-------------------|---|--|-------------------|
| Median tumor size, cm | 2.4 (1.9– 3.35) | 3.6 (2.95– 4.18) | 0.015 | 2.5 (1.93– 3.45) | 3.7 (2.85–5.25) | 0.014 |
| Endophytic, <i>n</i> (%) | 5 (14.7) | 6 (23.0) | 0.507 | 7 (17.5) | 4 (20) | >0.99 |
| Mesophytic, <i>n</i> (%) | 15 (44.1) | 10 (38.5) | 0.660 | 17 (42.5) | 8 (40) | >0.99 |
| Exophytic, <i>n</i> (%) | 14 (41.2) | 10 (38.5) | 0.831 | 16 (40) | 8 (40) | >0.99 |
| Superior pole, <i>n</i> (%) | 8 (23.5) | 15 (57.7) | 0.015 | 11 (27.5) | 12 (60) | 0.031 |
| Middle pole, <i>n</i> (%) | 14 (41.2) | 4 (15.4) | 0.046 | 17 (42.5) | 1 (5) | 0.003 |
| Inferior pole, <i>n</i> (%) | 12 (35.3) | 7 (26.9) | 0.681 | 12 (30) | 7 (35) | 0.922 |

| | | | | | | |
|------------------------------------|-----------------|------------------|-------|------------------|--------------------|-------|
| Striding location, <i>n</i> (%) | 9 (26.4) | 15 (57.7) | 0.014 | 11 (27.5) | 13 (65) | 0.012 |
| Median blood loss (ml) | 50 (17.5–300) | 145 (87.5–225) | 0.509 | 100 (50–287.5) | 120 (50–275) | 0.460 |
| Median operative duration (min) | 75 (50–100) | 90 (67.5–112.5) | 0.049 | 72.5 (51.25–100) | 97.5 (76.25–117.5) | 0.014 |
| Median embolization duration (min) | 38.5 (28.25–50) | 49 (39.75–67.75) | 0.003 | 40 (29.5–53) | 49 (40–74.5) | 0.003 |

Table 6 – Characteristics of tumor vascularization according to histologic subtype

| Histologic types | Tumor vascularization in arteriography | | |
|--|--|---------------------------------------|---------------------------------|
| | Hypovascularized, <i>n</i> (%) | Moderately vascularized, <i>n</i> (%) | Hypervascularized, <i>n</i> (%) |
| Clear-cell renal cell carcinoma, <i>n</i> = 37 | 10 (27.0) | 2 (5.4) | 25 (67.6) |
| Collecting duct carcinoma, <i>n</i> = 1 | 1 (100) | | |

| | | | |
|---|----------|--------|----------|
| Papillary renal cell carcinoma, <i>n</i> = 5 | 2 (40) | 1 (20) | 2 (40) |
| Chromophobe renal cell carcinoma, <i>n</i> = 4 | 1 (25) | 1 (25) | 2 (50) |
| Oncocytoma, <i>n</i> = 6 | 2 (33.3) | | 4 (66.7) |
| Angiomyolipoma, <i>n</i> = 5 | 2 (40) | 1 (20) | 2 (40) |
