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Anatomic variation in the origin of the main renal arteries: spiral CTA evaluation

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Abstract. The aim of this study was to provide quantitative data on the origin and trajectory of the main renal arteries using spiral CT angiography and arteriography. Normal renal artery anatomy was assessed on spiral CT angiography (axial transverse sections and shaded-surface-display reconstructions) in 100 patients referred for renal arteriography who had no significant renal artery stenosis. Two hundred major renal arteries were studied. The vast majority of right (88 %) and left (87 %) renal arteries originated between the lower third of the first lumbar vertebra and the lower border of the second lumbar vertebra. In 50 patients both ostia were at the same level; in the remaining 50 patients, the right ostium was located above the left in 37 patients. On the right, the angle of origin varied from –10 to + 55 ° (mean + 24 °). On the left, the angle of origin varied from + 30 to –55 ° (mean –11 °). Spiral CT angiography provides additional anatomic data, notably regarding the angle of origin of the renal arteries, that is potentially useful for planning interventional procedures.

Key words: Renal artery – Spiral CTA – Anatomy

Introduction

The vast majority of published data on renal artery anatomy is based on observations at postmortem examination [1, 2, 3] or on arteriography [1, 4, 5 6]. The existence of anatomic variations of the origins of the renal arteries was first reported by Bartholin (1655–1738) [4]. Knowledge of the possible anatomic variations is of major importance for the radiologist who performs diagnostic renal arteriography. Furthermore, endovascular techniques, such as balloon angioplasty and stent implantation, are now commonplace in the treatment of renal artery pathology. The successful implantation of a renal stent requires precise knowledge of the orientation of the origin of the renal arteries from the aorta in order to position the stent perpendicular to the ostium of the artery to facilitate its introduction. Such information is difficult to obtain at postmortem studies where the anatomy may be distorted or from arteriographic studies where it is difficult to evaluate the transverse plane [1, 4, 5, 6].

Spiral CT angiography (spiral CTA) allows us to obtain precise anatomic information on the aorta and renal arteries using volumetric acquisition with multiplanar or three-dimensional reconstructions [7, 8]. Its role in the diagnosis of renal artery stenosis has been reported by several authors [9, 10, 11]. Only one study has been reported on the use of axial transverse cuts in the analysis of the origin of the renal arteries [12]. The object of the present study was to obtain quantitative data regarding the origin and the trajectory of the main renal arteries using spiral CTA.

Materials and methods

We identified 100 patients with suspected renovascular hypertension who underwent both spiral CTA and conventional arteriography between November 1996 and May 1997, and in whom no renal vascular pathology was detected by either technique.

The mean age of the population, 58 % of whom were men, was 64 ± 10 years; 24 % of them were diabetics; 82 % were smokers; 34 % had documented peripheral or coronary artery disease. The reasons for referral were hypertension that was difficult to control (56 %), recent aggravation of preexisting hypertension (36 %); newly diagnosed severe hypertension (19 %); onset of renal failure in patients prescribed angiotensin converting enzyme inhibitors (23 %).

The spiral CTA examinations were carried out with a Somatom Plus S scanner (Siemens, Erlangen, Germany). The acquisition protocol which was identical for

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Fig. 1. Axial transverse view of a spiral CTA demonstrating the angle of origin of the left renal artery *(arrows)*

each patient was not determined by patient weight. Before the spiral CTA, we systematically performed a sequential CT scan (360 mA, 137 kV), beginning at the level of the diaphragm and descending to the level of the aortic bifurcation. Continuous 5-mm-thick transverse axial sections to at least 6 cm below the origin of the superior mesenteric artery were obtained to visualize the adrenal glands and the origin of the renal arteries. The methodology for determining transit time and the protocol used for spiral CT acquisition have already been described in detail elsewhere [11]. Briefly, X-ray tube potential and current were set at 137 kV and 220 mA, respectively, which were the maximum settings allowed by the scanner for 20 rotations in the spiral mode. A total of 120 ml of contrast medium (meglumine iothalamate, 300 mg of iodine/ml) was injected with an automatic injector (Medrad, Agenor, France) at a flow rate of 4 ml/s. Collimation (3 mm) was matched with table speed (3 mm/s; pitch = 1). The length of the scan volume was 6 cm.

Data were first reconstructed with a 360° linear interpolation algorithm at 1-mm intervals to yield 55 transverse axial sections (window width 250–400 HU; window center 80–100 HU). Then, shaded-surface-display reconstructions were systematically performed with the Siemens software package (VRT, Siemens, France) after four- or fivefold magnification of all images.

Interpretation was performed from the data provided by axial transverse sections and shaded-surface-display reconstructions. Analyses concerned only main renal arteries. The origin of the renal arteries in relation to the vertebrae was evaluated on shaded-surface-display reconstructions. The distance between the origin of the right and left renal arteries, the distance between the origin of the superior mesenteric artery and the origin of the right and left renal arteries, the angle of origin of the renal arteries in relation to the transverse axis of the aorta, and the distance between the origin of renal arteries and the back of the patient (the plane of the examination table) were measured on axial transverse views. In order to define more precisely the level of origin of the renal arteries in relation to the vertebral column, the vertebrae were divided into three equal sections (proximal, middle, and distal). The intervertebral discs were considered to be equal in length to one of these divisions (i.e., one third the length of a vertebra). The angle of origin of the renal arteries was measured on the axial transverse cuts (Fig. 1). The angulation of the renal artery origin was considered positive when the vessel origin was anterolateral in the axial plane and negative when the origin was dorsally oriented.

RIGHT		LEFT
	T12 Lower	
1	Intervertebral Disc	1
1	L1 Upper Third	1
8	L1 Middle Third	6
22	L1 Lower Third	15
17	Intervertebral Disc	22
17	L2 Upper Third	18
18	L2 Middle Third	19
14	L2 Lower Third	13
2	Intervertebral Disc	3
	L3 Upper Third	1
	L3 Middle Third	1
	L3 Lower Third	

Fig. 2. Level of origin of the right ($n = 100$) and left ($n = 100$) renal arteries with respect to the vertebral column

Results

A total of 200 major renal arteries were studied on spiral CTA in 100 patients. All the examinations were of diagnostic quality with contrast enhancement greater than 200 HU in the aorta at the level of the renal arteries. No renal artery stenoses were demonstrated either by spiral CTA or by arteriography.

Origin of the main renal arteries in relation to the vertebrae

The origin of the renal arteries (Fig. 2) with respect to the vertebral column was situated between the intervertebral disc (between T12 and L1) and the upper third of the third lumbar vertebra. The most frequent site of origin of the right renal artery was at the level of the lower

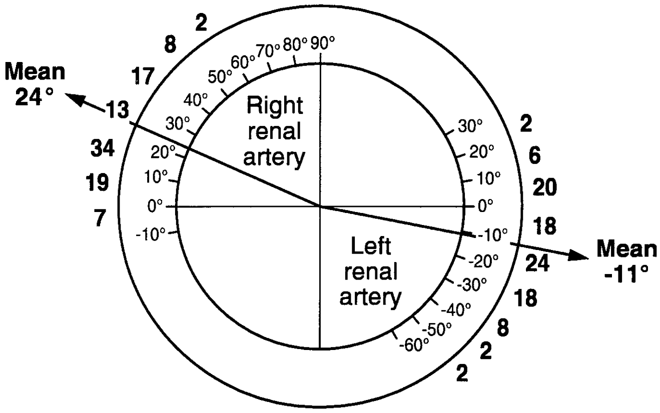

Fig. 3. Angle of origin of the right (n = 100) and left (n = 100) renal arteries from the aorta

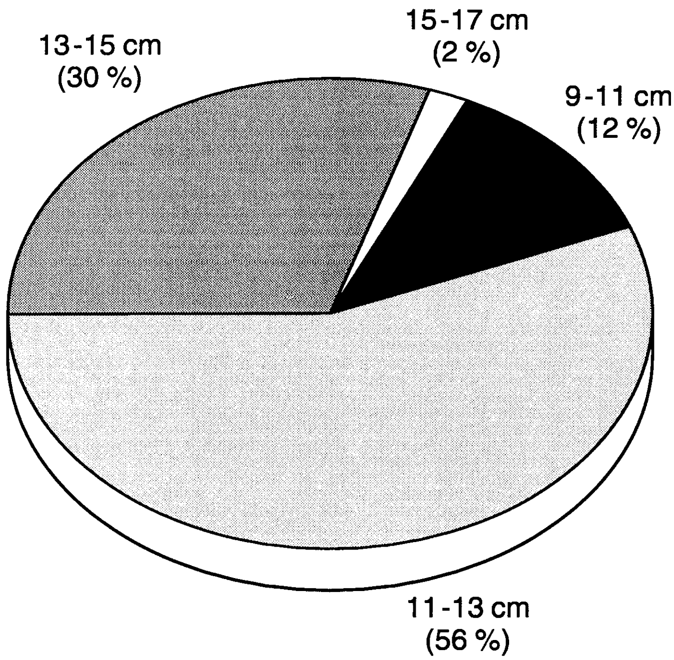

Fig. 4. Distance between the renal arteries and the plane of the examination table

border of the first lumbar vertebra, whereas the left renal artery had its origin most commonly at the level of the L1/L2 intervertebral disc. The vast majority of right (88 %) and left (87 %) renal arteries originated between the lower third of the first lumbar vertebra and the lower border of the second lumbar vertebra. Measurements on spiral CTA were confirmed by arteriography.

Distance between the origin of the right and left renal arteries

In 50 % of patients the right and left renal ostia were at the same level. In the remaining 50 patients the ostium of the right renal artery was located above the left renal artery in 37 patients. The longitudinal distance between the two ostia varied from one third of a vertebra to two vertebrae. The mean distance between the two ostia was 8 mm with a maximum of 54 mm.

Distance between the origin of the superior mesenteric artery and the renal arteries

The mean distance between the origin of the superior mesenteric artery and the origin of the right renal artery was 14.5 mm and ranged from 2 to 35 mm. For the left renal artery the mean distance was 18 mm and ranged from 4 to 50 mm.

Angle of origin of the renal arteries from the aorta

On the right, the angle of origin varied from –10 to + 55 ° (mean + 24 °) with the vast majority (83 %) between 0 and 40 °. On the left, the angle of origin varied from + 30 to –55 ° (mean –11 °) with the vast majority (80 %) between + 10 and –20 ° (Fig. 3).

Distance between the renal arteries and plane of the examination table

The distance between the plane of the table and the plane of origin of the renal arteries was between 9.5 and 17 cm (between 11 and 15 cm in 85 %) of cases). The mean distance was 12.5 cm (range 10.5–16 cm) in men and 11.5 cm (range 9.5–13.5 cm) in women (Fig. 4).

Discussion

Familiarity with the normal anatomy of the renal arteries and common anatomic variants is of major importance for the radiologist who performs diagnostic renal arteriography or therapeutic interventions such as angioplasty in the renal arteries. It is also critically important for the rapid and accurate performance of spiral CTA or angio-MR. The present study was designed to provide quantitative information on the relation of the renal arteries to the aorta, the vertebral column, and the plane of the examination table.

When performing non-selective renal arteriography, the catheter position is chosen to optimize visualization of the renal arteries and to avoid injection of contrast into the mesenteric arteries. When the catheter is positioned at the level of the upper border of the first lumbar vertebra, 99 % of the renal arteries are opacified. The catheter can also be positioned slightly lower, at the level of the mid portion of L1, as there is invariably a degree of retrograde opacification of the aorta (1–3 cm) due to the volume of contrast injected under pressure. The origin of the majority of the renal arteries at the origin of the L1/L2 intervertebral disc in the present study is concordant with the findings of previous studies [4].

However, the origin of the renal arteries is sometimes very close (2 mm) to the origin of the superior mesenteric artery which may result in overlapping of the ileal branches of the superior mesenteric and the main right renal artery or of the proximal superior mesenteric artery with the ostium of the right renal artery. The close relation of the origin of the superior mesenteric artery to the origin of the renal arteries is widely recognized [1, 2]; however, the present study shows the marked variability in this distance which may be up to 35 mm on the right and 50 mm on the left side.

The origin of the renal arteries was at the same level in 50 % of patients. This is in agreement with the findings of Aubert and Koumare [4] but differs from the results of Danek [13] in a much smaller series of patients who found that renal arteries originated at the same level in 80 % of patients. The fact that the origin of the right renal artery was proximal to that of the left renal artery in patients in whom the origin of both was not at the same level has already been reported [2, 3, 4].

The degree of leftward and rightward rotation used is also critical to adequately visualize the ostia. The marked variability in the angle of origin of both the right and left renal arteries makes it difficult to advise any particular degree of rotation. Furthermore, as the angle between the origin of the two renal arteries is not 180°, multiple views are needed. The present study confirms that the right renal artery generally arises from the anterolateral aorta, whereas the left renal artery generally arises from the posterolateral aorta. For the left renal artery, a 24° left anterior oblique projection will almost satisfactorily image the ostium in 47 % of cases. For the right renal artery, a 11° left anterior oblique projection will satisfactorily image the ostium in 42 % of cases. However, to adequately visualize the entire course of the right renal artery, a 20–25° right anterior oblique view is recommended due to the trajectory of the artery which passes dorsally and to the right behind the inferior vena cava. An anteroposterior view is less than ideal to visualize the ostia as it will only correctly visualize 26 % of right and 38 % of left renal ostia. These results are in broad agreement with some previously reported studies [12, 14, 15]. However, individual differences in the renal artery origin probably reflect the wide range of anatomic variations that exist in man.

Adequate visualization of the ostia of the renal arteries is important not only for the diagnosis of ostial stenoses, but also in their treatment by angioplasty or stent implantation [16].

An arteriogram in the frontal plane is nevertheless useful in assessing the severity of stenoses and the diameter of the main renal arteries in order to choose an appropriately sized balloon in patients scheduled for angioplasty. Quantitative angiography may be performed using the angiographic catheter as a scaling device; however, to perform accurate measurements, the catheter must be at least 6 F. Guidewires with radioopaque markers can also be used but are relatively expensive. External calibration can also be used, but the calibration device must be placed at the same distance from the tube and the amplifier as the renal arteries. A mean distance of 12 cm was observed in the present study for men and for women.

The arterial anatomy is also important when cross-sectional imaging techniques are used. In the present study, the renal arteries were located below the superior mesenteric artery (from 2 to 50 mm). Furthermore, the maximum distance between the two renal arteries was 54 mm. Thus, the volume explored should extend at least from the level of the superior mesenteric artery to 6 cm below this level. The greater the volume studied the greater the certainty that the renal arteries will fall within the scan volume, especially the accessory renal arteries which may originate low in the aorta and even from the common iliac arteries [17]. However, as the volume explored in the z axis increases, the spatial resolution in this axis and thus the sensitivity for the detection of renal artery stenosis diminishes. The spatial orientation of the renal arteries is of little importance where spiral CTA scanning is concerned.

Study limitations

The population we studied was highly selective; all were hypertensive with suspected renovascular disease. The findings thus may not apply in other populations such as potential renal donors. The scan protocol we used is not considered optimal by some authors [18]. The number of patients studied was limited and there were relatively few women, making comparisons between the genders impossible. However, previous studies found no significant difference in the origin of the renal arteries as a function of either the age of the patients studied or their gender [12, 19]. Finally, the accessory renal arteries were not studied.

Clinical implications

Renal arteriography may be performed either for diagnostic purposes or as a baseline before an interventional procedure. For diagnostic purposes, the catheter should be positioned at the level of the lower third of the first lumbar vertebra, and several different views should be obtained where possible. In general, a 24° left anterior oblique and an 11° left anterior oblique view should be performed first and other views chosen based on the findings. A rotational angiogram (from right anterior oblique 30° to left anterior oblique 60°) would ensure complete visualization of the renal ostia and the trajectory of the two main renal arteries. When performed as a prelude to a therapeutic intervention, the views required can be selected based on the results of the preliminary examinations such as spiral CT angiography or MRI angiography. Volumetric acquisition over a distance of at least 6 cm in the Z axis appears sufficient in everyday practice to ensure detection of the vast majority of major renal arteries.

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Book review

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Jager G.J., Barentsz J., Heerschap A.: Magnetic resonance in prostate cancer: clinical potentials. Berlin: Blackwell Science, 1998, 124 pages, 66 black and white and 19 colour figures, £ 45.00, ISBN 3-89412-336-2

This book is an overview of the latest developments in MR imaging of prostatic cancer described by the authors during the last 5 years. They have been pioneers in this field, as in modern MR imaging of bladder cancer. The book summarizes the state of the art of MR imaging of the prostate with, in the first part, a conventional morphological approach and, in the second, a personal and more modern functional approach.

The first part emphasizes the role of imaging in primary staging of prostatic carcinoma besides the pathological stage and prognostic factors such as the tumor volume, tumor stage and degree of neovascularity. The authors' experience in staging prostatic carcinoma with endorectal MR imaging is then presented, with emphasis on lack of sensitivity in identifying seminal vesicle invasion and capsular penetration. Using a Helmholtz-type coil and T1-weighted 3D imaging, MR also showed a low sensitivity (75 %) in detecting pelvic adenopathy, attesting the problem of identification of microscopic invasion in normal-sized nodes with conventional imaging. These insufficiencies, supported by concordant results in the literature, justify the development of new imaging techniques, which are presented in the second part. Dynamic turbo-FLASH subtraction technique for gadolinium-enhanced MR images has been proposed by the authors to improve the accuracy of endorectal imaging in staging and localizing prostate cancer. A computer program was developed to subtract the enhanced images and to calculate color-coded time, positive (wash-in) and negative (washout) slopes, and maximal intensity parametric images. The authors show how this technique can increase the conspicuity of prostatic carcinoma related to its hypervascularity and its relationship with the capsule.

The second development is in vivo localized proton spectroscopy of the gland with an endorectal coil. Several studies in the literature have recently shown a real interest in using this chemical information to detect prostatic carcinomas because the tumor demonstrates a higher content of choline and a lower content of citrate compared with normal prostatic tissue (low citrate/choline ratio). The authors were among the first to propose this approach. The spectroscopic technique is clearly presented as are the results in normal prostate and in prostatic carcinoma. Concordance between 2D spectroscopic and gadolinium-enhanced parametric images is highly convincing as being the new type of imaging of prostatic carcinoma. The last chapter is an appendix describing the latest developments in prostatic imaging: first, the combination of a phased-array pelvic coil with the endorectal coil to improve the signal-to-noise ratio and the delineation of the ventral aspect of the gland; second, a dynamic multislice acquisition to obtain perfusion information within the whole gland instead of in one slice.

In summary, this short book is a real state-of-the-art overview of MR imaging of prostatic carcinoma and should be a reference for residents, urologists and all radiologists involved in urogenital imaging.

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