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Urogenital Vascular Anomaly: A Cadaveric Case Study

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Abstract

Introduction: The kidneys are bilateral filtration organs that are perfused by the right and left renal artery. The presence of multiple renal arteries are anatomical variations, with varying health implications and outcomes. The current literature varies in classification methods, with no classification method fully encompassing all variations. This makes it necessary to utilize multiple classification systems. This report utilizes the Cases et al. classification system to classify the renal artery variations. To classify the testicular artery variations, the Machnicki and Notkovitch classifications were used.

Materials and Methods: A cadaveric dissection at Noorda College of Osteopathic Medicine presented with abnormal urogenital vascular findings. A standard ruler was used to measure the length and width of each artery in situ. All measurements were recorded in centimeters by three observers. A camera was utilized to document findings. The renal artery data was classified by the Cases system, which separates renal arteries by origin and insertion points, and the number of renal accessory arteries (RAA) present. The testicular artery data was classified by the Machnicki and Notkovitch systems which identifies variations based on origination and course.

Results: Upon dissection, a 67-year-old male donor presented with five renal arteries, and two testicular artery variations. There was one RAA on the right and two RAAs on the left. The right and left renal arteries originated from the abdominal aorta at the L2 level and inserted at the renal hilum. The right RAA originated 3 cm superior to the abdominal aortic bifurcation and inserted at the inferior pole of the right kidney. One of the left RAAs originated from the left renal artery and inserted into the superior pole of the left kidney and the other left RAA originated at the abdominal aorta, 4.4 cm superior to the abdominal aortic bifurcation and inserted into the inferior pole of the left kidney. An early bifurcation of the renal arteries was noted bilaterally. The right testicular artery originated from the right renal artery and bifurcated 3.8 cm below the origin. The left testicular artery originated from the aorta, above the renal vein.

Conclusion: Multiple urogenital vascular anomalies were discovered in a cadaver during a dissection lab at Noorda College of Osteopathic Medicine. According to the Cases system, the right kidney had a Type D, Pattern II classification. The left kidney had Type B and D, Pattern III classifications. According to the Machnicki classification system, the right testicular artery is Type B. According to the Notkovitch classification system, the left testicular artery is Type II.

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Introduction

The crucial homeostatic maintenance organs of the body are the bilateral filtration organs located in the retroperitoneum, known as the kidneys. They receive their blood supply primarily through the right and left renal arteries. These arteries play a fundamental role in renal perfusion, facilitating the filtration of metabolic waste products and regulation of electrolyte balance. However, the anatomy of renal arteries is not always uniform and concrete. In 70% of cases, bilateral renal arteries arise directly from the abdominal aorta, typically observed between the vertebral levels of L1-L2, establishing connections with the renal hilum. Conversely, in the remaining 30% of instances, variations in the number, origin, and course of renal arteries have been observed [1]. Variations can also occur in the gonadal arteries, which function to provide blood supply to the testes and ovaries, respectively. The testicular arteries more frequently branch bilaterally from the abdominal aorta at approximately the L2 spinal level. In 5% to 20% of cases, it was found to branch above this level. Another 5% to 6% of cases demonstrated the testicular arteries directly branching from the renal artery [2]. These variations can impact renal and gonadal blood flow and ultimately the functioning of the organs they supply.

Although the etiology of anatomical variations is not well understood, many researchers have hypothesized the role of embryologic errors in the formation of anatomic variations. Around the

fourth week of development, the intermediate mesoderm undergoes differentiation into the metanephros, forming a segmented structure. This process requires nine pairs of lateral mesonephric arterial branches to emerge from the dorsal aorta [3]. By the ninth week, the kidneys migrate from the sacral to the lumbar region. Arterial branches from the abdominal aorta establish connections with the kidneys, typically causing the earlier sacral arteries to degenerate [4]. It's been suggested that the persistence of these initial arterial branches in the sacral region might contribute to renal variations. Factors contributing to this phenomenon could include morphological aspects like the ascent of the kidneys to the lumbar region, fetal curvature, and the growth patterns of the lumbar and sacral regions [5].

A recurring theme in literature emphasizes the importance of thoroughly investigating and understanding the numerous variations that exist. This expanded knowledge base has the potential to greatly benefit medical specialists, including surgeons, nephrologists, radiologists, and urologists, in navigating the complexities of diagnostic and therapeutic interventions. By providing insights into these variations, it enables specialists to proactively mitigate potential errors, optimize treatment approaches, and enhance patient outcomes. Ultimately, this comprehensive understanding can minimize healthcare complications and costs and foster advancements in medical practice and patient care [6].

The complexity of renal and testicular artery anatomy requires a multidimensional approach towards classification of the different presentations. Given the intricate variations in vascular structures and interrelationship between these arteries, a single classification system may not capture the full spectrum of anatomical diversity. Therefore, integrating multiple classification systems becomes essential to achieve a comprehensive understanding of urogenital vascular anomalies. This approach allows for a more nuanced analysis, accommodating the variability in artery morphology and their clinical implications. By employing such a holistic method, researchers and clinicians can better identify, categorize, and address these anomalies to improve diagnostic accuracy and patient outcomes.

Materials and Methods

During cadaveric dissection at Noorda College of Osteopathic Medicine, a 67-year-old male donor presented with five renal arteries, and two testicular artery variations. One right renal accessory artery (RAA) and two left RAAs were observed. Bilateral early bifurcation of the renal arteries was noted. The right testicular artery originated from the right renal artery, while the left testicular artery originated directly from the aorta above the renal vein. The renal artery data was classified by the Cases system, which separates renal arteries by origin and insertion points, and the number of renal accessory arteries (RAA) present. The testicular artery data was classified by the Machnicki and Notkovitch systems which identifies variations based on origination and course.

The Cases classification system was selected for its comprehensive approach to characterizing renal arterial variations by addressing two key aspects. The system categorizes variations into distinct "Patterns" denoting the number of renal arteries entering each kidney and "Types" distinguishing the specific origin and insertion points of each artery [7].

Within this classification framework, arterial variations are further delineated based on their anatomical characteristics. Arteries falling under: Type "a" variants originate conventionally from the abdominal aorta and insert at the hilum of the kidney, designated by the acronym "ha" for hilar artery. The Type "b" variant encompasses accessory arteries arising from the hilar renal artery and inserting at the upper pole of the kidney, labeled as "hup" for hilar upper polar artery. The Type "c" variant includes arteries originating from the aorta and inserting at the upper renal pole, referred to as "aup" for aortic upper polar artery. Type "d" identifies arteries originating from the aorta and inserting at the lower renal pole, labeled as "alp" for aortic lower pole renal artery. Lastly, type "e" comprises arteries originating from the hilar artery and inserting at the lower renal pole, designated as "hlp" for hilar lower polar renal artery [7].

The Notkovitch classification system was one of two systems used in the categorization of testicular artery variations [8]. This system sorts the variations by their “Origin” explaining where the accessory artery begins, and the “Course” which separates the arteries by their path in relation to the renal vein.

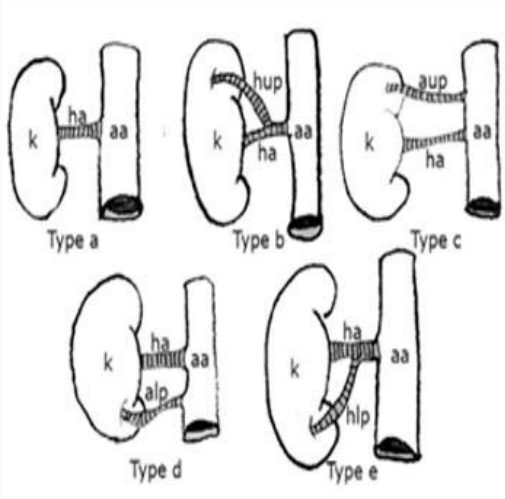
There are three types explained within the Notkovitch system, which are named Types I, II, and III. A Type “I” classification is used for a testicular artery that branches from the abdominal aorta and has a direct branching pattern, without contacting the renal vein. Type “II” classification describes a testicular artery that branches above the renal vein, and crosses in front of the renal vein as it travels toward its insertion. Type “III” classification is used for testicular arteries that originate below the renal vein and arch around the renal vein to reach the insertion point [8].

The Machnicki classification system was the other system used when trying to name the testicular artery variations seen in this study [9]. This system also sorts the testicular arteries using two characteristics, the “Origin(s)” of the testicular arteries, and the “Number” of testicular arteries found.

Within this system, the variations are categorized as follows. Type "A" describes one testicular artery that branches from the abdominal aorta. The Type “B” classification is used for one testicular artery that branches from the renal artery. A Type “C” classification describes the finding of two testicular arteries that both originate from the abdominal aorta. Finally, a Type “D” classification is used for the finding of two testicular arteries, with one branching from the abdominal aorta and the other from the renal artery (Figure 1).

Results

Upon dissection, a 67-year-old male donor presented with five renal arteries, and two testicular artery variations. There was one RAA on the right and two RAAs on the left. The right and left renal arteries originated from the abdominal aorta at the L2 level and inserted at the renal hilum. The right renal artery finding was classified as Cases: Type A Pattern II and the left renal artery was classified as Cases: Types A Pattern III [7]. The right RAA originated 3 cm superior to the abdominal aortic bifurcation and inserted at the inferior pole of the right kidney. This variant was classified as Cases: Type B Pattern III [7]. One of the left RAAs originated from the left renal artery and inserted into the superior pole of the left kidney and the other left RAA originated at the abdominal aorta, 4.4 cm superior to the abdominal aortic bifurcation and inserted into the inferior pole of the left kidney. The superior pole RAA was classified as Cases: Type B Pattern III and the inferior pole RAA was classified as Cases: Type D Pattern III [7]. An early bifurcation of the renal arteries was noted bilaterally. The right testicular artery originated from the right renal artery and bifurcated 3.8 cm below the origin. This was classified as



Classification Systems		
Cases et al, (2017) Classification System		
Type	**Origin**	**Renal Insertion**
A	Aorta	Hilum
B	Hilar Renal Artery	Upper Pole
C	Aorta	Upper Pole
D	Aorta	Lower Pole
E	Hilar Renal Artery	Lower Pole
Notkovitch et al, (1955) Classification System		
Type	**Origin**	**Course**
I	Abdominal Aorta	Direct; no contact with renal vein
II	Above Renal Vein	Crosses in front of renal vein
III	Below Renal Vein	Arches around renal vein
Machnicki et al, (1997) Classification System		
Type	**Origin**	**Testicular Arteries**
A	Aorta	I
B	Renal Artery	I
C	Aorta	II
D	Aorta, Renal Artery	II

Figure 1: Adapted from cases, et al. (2017) proposed classification system.

Machnicki: Type B [9]. The left testicular artery originated from the aorta, above the renal vein. This finding was classified as Notkovitch: Type II [8].

Discussion

The complexity of urogenital vascular anatomy, as demonstrated by the observed variations in this cadaveric case study, highlights the importance of accurate anatomical characterization in clinical practice. The Cases classification system, employed for renal artery variations, provided detailed insights into the anatomical variations encountered in the donor specimen. According to this system, the right kidney was classified as Type D, Pattern II, indicating a specific origin and course of the renal arteries [7]. Similarly, the left kidney exhibited Type B and D, Pattern III classification, indicating variations in both origin and insertion points of the renal arteries. These classifications offer valuable information for surgical planning and interventions involving the kidneys. Surgical procedures, such as partial or complete nephrectomy rely on appropriate ligation of the renal arteries to minimize complication [10]. With the addition of computed tomography, clinicians are able to anticipate potential vascular anomalies and tailor surgical approaches accordingly [11]. By elucidating the precise anatomical characteristics of renal artery variations, classification systems, like Cases et al. facilitate safer and more effective surgical interventions, minimizing the risk of iatrogenic injuries and improving patient outcomes [7].

In addition to renal artery variations, the Machnicki and Notkovitch classifications were employed to characterize testicular artery variations in this study. The identification of the right testicular artery as Type B and the left as Type II underscores the diverse anatomical variations encountered in the male reproductive system [1,9]. Knowledge of the common origins and courses of testicular arteries is essential for both minimally invasive and surgical procedures. Interventional radiologists performing minimally invasive procedures, like catheterization, need detailed knowledge of possible variations to ensure an appropriate location for embolization without complication [12]. Surgeries, such as orchidopexy and varicocelectomy, require detailed vascular knowledge where preservation of vascular integrity is paramount to maintaining fertility and sexual function [8]. By incorporating insights from these studies, clinicians can better anticipate and manage vascular anomalies in the male reproductive system, minimizing vascular complications to improve patient outcomes.

Conclusion

The intricate variations observed in urogenital vascular anatomy underscore the necessity for precise anatomical characterization in clinical practice. Through the utilization of classification systems such as Cases et al. for renal arteries and Machnicki and Notkovitch for testicular arteries, this study has provided valuable insights into the diverse anatomical variations encountered in the urogenital system. However, the absence of a universally accepted classification system highlights the need for standardization in anatomical classification, as discrepancies between classification methods may lead to inconsistencies in clinical practice.

Efforts should be directed towards establishing a standardized classification system that comprehensively encompasses all urogenital vascular variations. Such uniformity would facilitate clearer communication among healthcare professionals, enhance surgical planning, and minimize the risk of iatrogenic injuries during urogenital procedures. Collaborative initiatives involving anatomists, surgeons, and medical educators are essential in developing and implementing standardized classification systems for urogenital vascular anatomy.

Education on anatomical variations should be integrated into medical school curricula to ensure that future healthcare professionals possess a thorough understanding of the presence of anatomical variation. By fostering awareness of anatomical variations and their clinical implications early in medical training, medical students can develop the necessary skills to recognize and manage anatomic anomalies in clinical practice effectively.

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