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Original Article
Bangladesh Journal of Infectious Diseases
June 2024, Volume 11, Number 1, Page 59-64
ISSN (Online) 2411-670X
ISSN (Print) 2411-4820
DOI: https://doi.org/10.3329/bjid.v11i1.75563

Three-Dimensional Quantitative Analysis of Arterial Channels and Elements of the Renal Pelvis-Calyx System in Men

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Abstract

Background: The stereomorphology of renal arteries and their branches is crucial in nephrological and urological procedures, particularly in surgeries like percutaneous nephrolithotomy. Despite the clinical significance, the existing literature on the three-dimensional (3D) anatomical relationships between the renal arterial system and the renal pelvis-calyx complex remains limited and inconsistent. **Objective:** The objective of the study was to reveal the patterns of the three-dimensional quantitative organization of the branches of the renal artery in relation to the elements of the renal pelvis-calyx system in men. **Methodology:** A total of 58 corrosion specimens of male kidneys, obtained from individuals aged 22 to 75 years, were analyzed. The study employed quantitative morphological analysis to examine the extra- and intra-organ branches of the renal arteries and their relationship with the renal pelvis-calyx system. The analysis focused on the division patterns of the renal artery relative to the kidney's excretory sectors, using 3D projection models to visualize these relationships. **Results:** Results revealed various patterns of arterial branching across different age groups and sectors, identifying multiple excretory sectors with distinct arterial supply configurations. **Conclusion:** Conclusions highlighted the clinical significance of understanding these patterns for improving preoperative planning and reducing surgical complications in nephrolithotomy and other kidney surgeries. This detailed 3D anatomical knowledge assists in tailoring surgical approaches to individual anatomical variations. [*Bangladesh Journal of Infectious Diseases, June 2024;11(1):59-64*]

Keywords: Kidney; renal artery; pelvis; surgical planning; 3D anatomical analysis

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Introduction

The data concerning the variant stereomorphology of the renal artery and its branches are reflected in a small number of works. Moreover, they are quite few and contradictory[1-2]. However, the data on the features of the anatomy of extra- and intra-organ branches of the renal arteries according to the structure of the renal pelvis-calyx complex are of the greatest value to nephrologists and urologists, as they can contribute to an individual approach in the preparation and tactics of operations for the

removal of stones from the pelvis and calyces using methods such as percutaneous nephrolithotomy[3-4]. Thus, with the appearance of the first percutaneous nephroscopy, percutaneous surgery underwent maximum changes and became the gold standard for removing coral stones of the kidneys. Performing percutaneous access to the kidney is the most technically complex part of percutaneous nephrolithotomy[5,6]. According to several authors, there are two imaging methods for supporting the operation – radiographic television and ultrasound[7]. In that case, no differences in the effectiveness of both methods were identified. Thus, during surgery under X-ray control for access to the optimal calyx, the surgeon has to convert two-dimensional X-ray images into three-dimensional ones using mental skills[8-9]. However, even for an expert in the field of percutaneous nephrolithotomy, there are clinical cases such as a large stone volume, a complex anatomy of the renal cavity system, and their relationships with intra-organ vessels, where there is a probability of their damage and the occurrence of intraoperative bleeding, which unfortunately is not always taken into account due to the complexity of the structure of the intra-organ vascular bed and the vascular-pelvic relationships[10-11]. This has led to an increased need for additional and comprehensive information on the variants of the renal artery structure and its branches within the organ, as well as their relationship to the renal pelvis-calyx complex, especially in clinical practice and radiological diagnostics[12-13].

The emergence of modern research methods and new computer 3D technologies can contribute to the creation of algorithms for preoperative examination of the patient and planning of the proposed surgical intervention[14]. Improving the effectiveness of planning surgical interventions on the renal cavity system to remove stones by reducing the frequency of postoperative bleeding can be achieved with a 3D representation of the renal arterial vessels and the renal pelvis-calyx system with their topographic visualization on the organ surface[3,9]. The purpose of the study was to reveal the patterns of the three-dimensional quantitative organization of the branches of the renal artery in relation to the elements of the renal pelvis-calyx system in men.

Methodology

Study Settings and Population: The study was conducted on 58 corrosion specimens of the arterial system and the renal pelvis-calyx system of human kidneys, made from the kidneys of deceased male individuals aged 22 to 75 years who died from diseases unrelated to kidney pathology.

Research Algorithm: On the corrosion specimens of the arterial vessels of the kidneys and the renal pelvis-calyx system, the extra-organ branches of the renal arteries (RA) were determined with a study of their quantitative characteristics at the kidney gates, and variants of their division. The three-dimensional (3D) projection of the renal arterial vessels was studied relative to the frontal, horizontal, and sagittal planes; topographic anatomical relationships of the renal arteries and pelvis were also analyzed. On the corrosion specimens of the arterial vessels of the kidneys and the renal pelvis-calyx system, a quantitative morphological analysis of the intra-organ arteries of the renal artery was conducted concerning the sectors of the renal pelvis-calyx system: Quantitative morphological analysis of the branches of the renal artery in the kidney parenchyma with two sectors; Quantitative morphological analysis of the branches of the renal artery in the kidney parenchyma with three sectors; Quantitative morphological analysis of the branches of the renal artery in the kidney parenchyma with four sectors.

Statistical Analysis: All digital data and images obtained from the morphological and 3D analyses were processed using variation statistics methods with a workstation featuring an Intel Core2Duo T5250 1.5 GHz processor, RAM up to 2 GB on the Windows 7 platform. During the work, the Excel application package from Microsoft Office 2007 was used. The results were statistically analyzed to determine the significance of differences in arterial branching patterns across different age groups and renal sectors

Ethical Clearance: research activities were carried out in accordance with the Declaration of Helsinki and national regulations governing the use of human tissues in research. The study did not involve any direct contact with patients or the collection of new biological samples from living individuals, thereby minimizing ethical concerns.

Results

Depending on the division variants of the main renal artery - "A. renalis" (I) at the kidney gates relative to the frontal, sagittal, and horizontal planes into second-order vessels, that is, zonal arteries - "A. (zonal)" (II), where they have their specific arterial basins in the kidneys, corresponding groups were identified in different age periods.

It was established that in the first period of mature age, the division of the renal artery - "A. renalis" into 2 branches was found in 11 cases, which constituted 18.97%. In the second period of mature age, this variant of the renal artery division was found in 13 observations, which constituted 22.41% of cases. In the elderly, this variant of division was also found in 13 specimens, which also constituted 22.41% of cases. In the senile age period, this variant of the renal artery division was found in 12 corrosion specimens, which constituted 20.69% of cases.

Further research established that the division of the renal artery - "A. renalis" into 3 branches in the first period of mature age was found in 2 specimens, which constituted 3.45% of cases. In the second period of mature age, this variant of the division was found in 3 corrosion specimens, which constituted 5.17% of cases. In the elderly, this variant of division was also found in 2 specimens, which also constituted 3.45%. In the senile age period, this variant of the renal artery division was found in 2 specimens, which constituted 3.45% of cases (Figure I)).

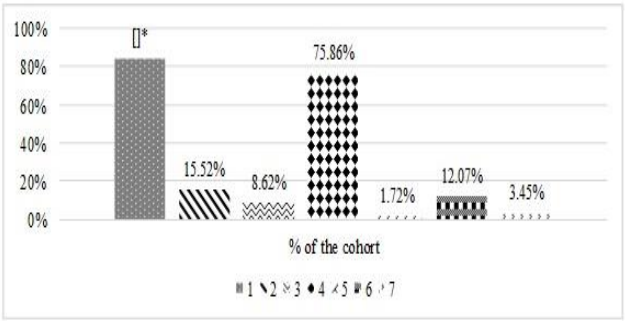

Figure I: Comparative characteristics of the variant anatomy of the extra-organ segment of the renal arteries in the area of the hilum based on corrosion specimens of the right and left kidneys in men of mature, elderly, and senile age*

Notes:

1. 2 branches of the renal artery (RA);
2. 3 branches of the RA;
3. Upper and lower branches of the RA;
4. Anterior and posterior pelvic branches of the RA;
5. 2 anterior and 1 posterior branches of the RA;
6. Upper, anterior, and posterior branches of the RA;
7. Anterior, posterior, and lower branches of the RA.

**p < 0.05 - significance of the difference between groups.

Furthermore, from this quantity, it was established that the division of the RA - "A. renalis" into upper and lower branches in the first period of mature age was identified in one specimen, which constituted 1.72% of cases. In the second period of mature age, this division variant was found in two specimens, which constituted 3.45% of cases. In the elderly and senile periods, these division variants were found once each, which constituted 1.72% of cases, respectively.

Further research established that the division of the RA - "A. renalis" into anterior and posterior pelvic branches in the first period of mature age was found in 10 specimens, which constituted 17.24% of cases. In the second period of mature age, this variant was found in 11 specimens, which constituted 18.97% of cases. In the elderly, this variant was found in 12 specimens, which constituted 20.68% of cases, and in the senile period, this variant was found in 11 specimens, which also constituted 18.97% of cases.

Further research established that the division of the RA - "A. renalis" into 2 anterior and 1 posterior branch was found in one specimen only in the second period of mature age, which constituted 1.72% of cases.

Next, the division of the RA - "A. renalis" into upper, anterior, and posterior branches was found equally in both the first and second periods of mature age, which was found in four specimens, constituting 3.45% of cases each. In the elderly, this variant was found in one specimen, which constituted 1.75% of cases. In the senile period, this variant of the RA division was found in two specimens, which constituted 3.45% of cases.

The next variant of the RA division into anterior, posterior, and lower branches was not found in the first period of mature age and the senile period. However, in the second period of mature age and the elderly, this variant was found once in specimens, which constituted 1.72% of cases, respectively.

Next, a three-dimensional quantitative analysis of the variants of renal artery division relative to the excretory sectors of the renal pelvis-calyx system was conducted separately for the left and right kidneys in men.

Discussion

Thus, the research revealed that among 9 left two-sector kidneys, in six specimens, the RA - "A. renalis" divided into anterior and posterior branches, which constituted 75.0% of cases. In two corrosion specimens, the RA divided into upper and lower branches, which constituted 25.0% of cases. And in one two-sector kidney specimen, the RA divided into three branches, which constituted 3.7% of cases.

Further, it was found that among 8 three-sector corrosion specimens of kidneys, in 5 specimens, the RA divided into anterior and posterior branches, which constituted 83.33% of cases. In one case, the division of the RA into upper and lower branches was identified, which constituted 16.67% of cases. In two three-sector kidney specimens, the RA divided into three branches, which constituted 92.6% of cases.

The analysis of 10 four-sector left corrosion kidney specimens established that in 7 specimens, the RA - "A. renalis" divided into anterior and posterior branches, which constituted 77.78% of cases. In two specimens, the RA divided into upper and lower branches, which constituted 22.22% of cases, and in one four-sector kidney specimen, the RA divided into three branches, which constituted 3.7% of cases.

Three-dimensional quantitative analysis of the variants of renal artery division relative to the excretory sectors of the renal pelvis-calyx system of the right kidneys in men showed that among 10 right two-sector kidneys, in eight specimens, the RA - "A. renalis" divided into anterior and posterior branches, which was found in 88.89% of cases. In one corrosion specimen, the RA divided into upper and lower branches, which was found in 11.11% of cases. And in one two-sector kidney specimen, the RA divided into three branches, which was found in 3.23% of cases.

Further, it was found that among 8 three-sector kidney specimens, in 4 specimens, the RA - "A. renalis" divided into anterior and posterior branches, which was found in 80.00% of cases. In one case, the division of the RA into upper and lower branches was identified, which was found in 20.00% of cases.

In three-sector kidney specimens, the RA divided into three branches, which was found in 93.54% of cases.

The analysis of 13 four-sector right corrosion kidney specimens established that in 11 specimens, the RA - "A. renalis" divided into anterior and posterior branches, which was found in 91.67% of cases. In one corrosion specimen, the RA divided into upper and lower branches, which was found in 8.33% of cases, and in one four-sector kidney specimen, the RA divided into three branches, which was found in 3.23% of cases.

We studied corrosion specimens of the arterial vessels of the kidneys and the renal pelvis-calyx system, where the specimens were divided into three groups based on the number of excretory sectors with different variants of arterial vessel division[15].

The analysis of the distribution of specimens of right kidneys in men by the number of excretory sectors and the number of branches of the renal artery participating in their blood supply indicates that two excretory sectors were found in 10 specimens: 9 specimens with two supplying arteries: 8 specimens with anterior and posterior arteries, 1 specimen with upper and lower arteries, and 1 specimen with three renal arteries. Three excretory sectors were found in 8 specimens of right kidneys: 5 specimens with two supplying arteries: 4 specimens with anterior and posterior arteries, 1 specimen with upper and lower arteries, and 3 specimens with three renal arteries. Four excretory sectors were found in 13 specimens: 12 specimens with two supplying arteries (11 specimens with anterior and posterior branches of the renal artery and 1 with upper and lower branches of the renal artery) and 1 specimen with three renal arteries.

The analysis of the distribution of specimens of left kidneys in men by the number of excretory sectors and the number of branches of the renal artery participating in their blood supply indicates that two excretory sectors were found in 9 kidney specimens: 8 specimens with two branches of the renal artery (6 specimens with anterior and posterior branches; 2 specimens with upper and lower branches) and 1 specimen with three branches of the renal artery. Three excretory sectors were found in 8 kidney specimens: 6 specimens with two branches of the renal artery (5 specimens with anterior and posterior branches; 1 specimen with upper and lower branches) and 2 specimens with three branches of the renal artery. Four excretory sectors were found in 10 specimens: 9 specimens with two branches of the renal artery (7 specimens with anterior and posterior branches; 2

specimens with upper and lower branches) and 1 specimen with three branches of the renal artery.

Conclusions

The conducted study is based on a 3D analysis of the division variants of the main branches of the renal arteries. The research included the study of topographic-anatomical features of the structure of the renal arterial vessels in relation to the excretory sectors. It should be noted that possessing information about the three-dimensional (3D) anatomy of the intra-organ branches of the renal artery in humans, depending on the variants of the structure of the renal pelvis-calyx system and the number of renal calyces in each of the excretory sectors, as well as their 3D visualization during life, allows predicting difficulties during kidney surgery when performing nephrolithotomy or organ-preserving operations, where it is necessary to take into account the individual features of the renal arterial bed structure and its segments. The evaluation of the obtained 3D results of the individual structure of the renal arterial bed and elements of the renal pelvis-calyx system is of great importance at the stage of preoperative preparation, helping the surgeon in choosing the optimal tactics for conducting the operation with the least number of postoperative complications and the development of unforeseen situations.

Acknowledgments
None

Conflict of Interest
The authors have no relevant conflicts of interest to declare.

Financial Disclosure
The study was conducted as part of the implementation of a grant from the Russian Foundation for Basic Research No. 18-29-09118 from 2018.

Contribution to authors:
Kafarov E, Akbaev S: Conception and design, or design of the research; Akbaev S, Vagabov I: the acquisition, analysis, or interpretation of data; conceptualized and designed the overall study; Kafarov E: involved in data collection; Akbaev S: Drafting the manuscript or revising it critically for important intellectual content; Kafarov E: conducted data analysis; Vagabov I: drafted the manuscript. All authors reviewed and approved the final manuscript.

Data Availability
Any questions regarding the availability of the study's supporti ng data should be addressed to the corresponding author, who can provide it upon justifiable request.

Ethics Approval and Consent to Participate
The Institutional Review Board granted the study ethical approval. Since this was a prospective study, every study participant provided formal informed consent. Each method followed the appropriate rules and regulations.

How to cite this article: Kafarov E, Akbaev S, Vagabov I. Three-Dimensional Quantitative Analysis of Arterial Channels and Elements of the Renal Pelvis-Calyx System in Men. Bangladesh J Infect Dis 2024;11(1):59-64

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Article Info
Received on: 17 April 2024
Accepted on: 2 May 2024
Published on: 3 June 2024

References

1. Song WH, Baik J, Choi EK, Lee HY, Kim HH, Park SM, et al. Quantitative analysis of renal arterial variations affecting the eligibility of catheter-based renal denervation using multi-detector computed tomography angiography. Sci Rep. 2020;10(1):19720
2. Lechiev Z, Delalov Y, Kafarov E. 3D analysis of the renal vascular system in a dichotomous variant of renal artery division. Int J Chem Biochem Sci. 2023;24(6):500-6.
3. Murushidi MY. Trekhmernoye anatomicheskoye modelirovaniye pochechnykh arteriy pri planirovanii perkutannogo dostupa k pochke [Three-dimensional anatomical modeling of renal arteries in planning percutaneous access to the kidney] [Abstract of PhD Thesis: 3.3.1]. Tyumen (Russia): Tyumen State Medical University; 2023.
4. Metleva AS. Diagnostic significance of C-reactive protein in acute and chronic pelvic inflammation in animals (review). Rev Electron de Vet. 2022;23(2):24-9.
5. Kafarov ES, Udochkina LA, Bataev KM, Fedorov SV. Sources and options for the formation of renal human veins. Int J Eng Adv Technol. 2019;8(4): 1009-12.
6. Kafarov E, Avduev I, Lechiev Z. Segmental structure of the human kidney: an innovative research algorithm. Adv. Life Sci. 2023;10(4):549-54.
7. Tukeshov SK, Baysekeev TA, Choi ED, Kulushova GA, Nazir MI, Jaxymbayev NB, et al. Osteosynthesis of complex comminuted hand bone fractures by applying the lacing method (a clinical case study). Georgian Med News. 2024;3(348):40-3.
8. Chigidinova DS, Gavrilova NE, Rudenko BA, Shanoyan AS, Mazaev VP, Shukurov FB. Endovascular treatment of renal artery stenosis caused by fibromuscular dysplasia. A clinical case report. Creat Surg Oncol. 2019;9(3):223-8
9. Vagabov IU. Trekhmernaya (3D) anatomiya arterial'nogo rusla pochki i yeye segmentov [Three-dimensional (3D) Anatomy of the renal arterial system and its segments] [Abstract of PhD Thesis: 3.3.1]. Ufa (Russia): Bashkir State Medical University; 2022.
10. Nametov A, Yertleuova B, Orynkhanov K, Semenenko MP, Sidikhov B, Murzabayev K, et al. Evaluation of the antibacterial effect of Artemisia lerchiana compared with various medicines. Braz J Biol. 2023;83:e277641

11. Al-Rubaiawi HK, Mohamed RJ, Alhelfy SH. Study of serum midkine as a dynamic prognostic factor and comparison with fineneedle aspiration in detection for thyroid cancer. Adv Life Sci. 2024;11(2):425-9.
12. Çiçek R, Dündar G, Gökçen K, Gökçe G, Gültekin EY. The evaluation of morphology of renal pelvicalyceal system's and infundibulopelvic anatomy of kidney's lower pole in post-mortem series. Folia Morphol. 2022;81(2):350-8
13. Suchshikh V, Karimov A, Yussupov M, Aitzhanov B, Abutalip A, Mussayeva A, et al. Effectiveness of different means of disinfection against soil foci of anthrax (*Bacillus anthracis*) burials at a depth of up to 3.5 m: an experimental study. Casp J Environ Sci. 2023;21:893-902
14. Kolsanov AV, Ivanova VD, Gelashvili OA, Nazaryan AK. Klinicheskaya anatomiya pochechnykh arteriy po dannym komp'yuternogo modelirovaniya [Clinical anatomy of renal arteries based on computer modeling data]. Morfologia. 2019;155(3):28-32.
15. Arif MA, Rasheed MK, Ismaeel AA. Association between vitamin D levels and insulin resistance in patients with type 2 diabetes mellitus. Adv Life Sci. 2024;11(2):419-24.