ОРИГИНАЛЬНАЯ СТАТЬЯ

APPLICATION OF VOLUMETRIC DYNAMIC VOIDING COMPUTED CYSTURETROGRAPHY IN URETHRAL STRICTURE DIAGNOSIS BEFORE AND AFTER RECONSTRUCTIVE SURGERY

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Purpose. To determine the possibilities of volumetric dynamic voiding computed cystourethrography for assessment of the lower urinary tract in patients with urogenital pathology, which were treated with free revascularized microsurgical autografts.

Materials and methods. We performed volumetric dynamic voiding computed cystourethrography and X-ray voiding cystourethrography examinations in 56 patients (100%) with various pathologies of the urethra. The examinations were performed using wide detector computed tomography scanner. Detector is possible to cover 16 centimeters area of the interest per one rotation of the X-ray tube.

Results. Thirty two of fifty six examined patients underwent phallus and urethra reconstruction using free revascularized microsurgical autografts. The rest of the patients underwent only reconstruction of the urethra. According to the volumetric dynamic voiding computed cystourethrography data the average urine flow rate in patients with urethral strictures was 4.3±1.3 ml/s, after stricture the urine flow rate was 8.1±5.4 ml/s. Sensitivity, specificity and accuracy for urethral stricture detecting were 95,7 %, 94,1 %, 95,0% for volumetric dynamic voiding computed cystourethrography and 86,9%, 88,2%, 87.5% for voiding cystourethrography.

Conclusion. The obtained results demonstrate higher diagnostic efficiency rates of voiding dynamic computed cystourethrography in the assessment of urethral stricture, compared to the X-ray voiding cystoureterography. In addition this modern method provides additional information about the urine flow rate.

Keywords: CT, voiding cystourethrography, phalloplasty, urethral stricture, obliteration of the urethra.

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ПРИМЕНЕНИЕ ОБЪЕМНОЙ ДИНАМИЧЕСКОЙ КОМПЬЮТЕРНОЙ МИКЦИОННОЙ ЦИСТУРЕТРОГРАФИИ В ДИАГНОСТИКЕ СТРИКТУРЫ УРЕТРЫ ДО - И ПОСЛЕ РЕКОНСТРУКТИВНЫХ ОПЕРАЦИЙ

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Цель исследования. Определение возможностей объемной динамической микционной компьютерной цистоуретрографии для оценки состояния нижних мочевых путей у пациентов с патологией урогенитальной области, которые подвергались хирургическому лечению свободными реваскуляризированными микрохирургическими аутотрансплантатами.

Материалы и методы. Объемная динамическая микционная компьютерная цистоуретрография и рентгеновская цистоуретрография нижних мочевыводящих путей были выполнены для 56 пациентов с различной патологией урогенитальной области. Исследования проводились в объемном режиме с помощью широкодетектерного компьютерного томографа, позволяющего покрывать область исследования в 16 см за один оборот рентгеновской трубки.

Результаты. Тридцати двум из 56 обследованных пациентов провели реконструкцию полового члена и уретры с использованием свободного реваскуляризированного микрохирургического аутотрансплантата. Остальным пациентам была выполнена только реконструкция уретры. Согласно данным объемной динамической микционной компьютерной цистоуретрографии средняя скорость потока мочи у больных со стриктурами уретры составила 4.3±1.3 мл/с, после устранения стриктуры средняя скорость потока мочи составила 8.1±5.4 мл/с. Чувствительность, специфичность и точность в диагностике стриктур уретры составили 95,7%, 94,1%, 95,0% для динамической микционной компьютерной цистоуретрографии и 86,9%, 88,2%, 87,5% для микционной цистуретерографии.

Заключение. Полученные результаты демонстрируют более высокие показатели диагностической эффективности динамической микционной компьютерной цистоуретрографии в оценке стриктур уретры, в сравнении с рентгеновской микционной цистуретерографией. К тому же данная современная методика позволяет получать дополнительную информацию об изменении скорости потока мочи.

Ключевые слова: МСКТ, микционная цистуретрография, стриктура уретры, облитерация уретры.

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Introduction.

The lower urinary tract is represented by the urinary bladder and urethra. The average length of the female urethra is 3-5 cm, with an internal diameter of 6 mm. The male urethra has a length of 16-22 cm, with an average internal diameter of 5-7 mm [1]. One of the most common urethral pathology is stricture.

A urethral stricture is a polyetiological disease manifested by symptoms of the lower urinary tract with a urethral lumen narrowing up to the total obliteration as a result of scar tissue regeneration in the urethral wall.

The length, localization, causes and severity of the urethral strictures are varied. First of all, it is determined by the occurrence etiology. It can be caused by various iatrogenic urethral injuries, bony pelvic ring injury with displacement of bone fragments leading to urethral ruptures, direct perineal trauma, endoscopic manipulations during transurethral operations, injury after prolonged bladder catheterization in patients in intensive care units, chronic inflammation in the urethra with the ineffective treatment of acute urethritis [2].

Currently, the primary diagnostic method is an X-ray examination of the urethra, which includes: retrograde (ascending) urethrography and voiding cystourethrography, also known as a micturating cystourethrography. These techniques have been used for a century as a main visualization method in the examination of the structure and lower urinary tract function [3-

5].

However, the X-ray techniques have several disadvantages. The visible X-ray image due to physical limitation does not always reflect the true shape, size, position and structure of the study object, i.e. there is a distortion of the resulting image. Invasive procedures associated with retrograde injection of a contrast agent impose limitations because of possible infection development [6-8].

In some cases, using of X-ray examination does not provide comprehensive data about the urethral anatomy, localization and length of the stricture, complications, etc. In such cases, there is a need for additional examination methods, such as ultrasound (US), magnetic resonance imaging (MRI) and computed tomography (CT) [9-10].

Computed tomography, performed by scanners with multi-row detectors, provides a quick diagnostic image acquisition and the ability to perform dynamic examinations, which include volumetric dynamic voiding computed cystourethrography (VDVCC). It is a relatively new diagnostic technique that can be used to assess the lower urinary tract changes [7-9]. VDVCC performed using a 640-slice computed tomography scanner, has good spatial resolution, a wide range of coverage area and a fast data acquisition system with subsequent construction of 3D and 4D reconstructions of the interest area [10-13]. However, at present, the method is not insufficiently studied.

Materials and methods.

This study included 56 patients (n=100%) with a pathology of the urethra, such as a urethral defect after injury 18 (32%) or inflammation 6 (11%), as well as 32 patients (57%) with transsexualism after sex confirmation surgery. All patents were treated in the department of plastic and reconstructive surgery of the University Clinical Hospital № 1 of the Sechenov University (Moscow, Russia) from March 2017 to April 2022. The mean age of patients was 44,8±14,6 years.

For the reconstruction of the urethra and/or the penis free revascularized microsurgical autografts were used.

In the framework of preoperative preparation and postoperative results monitoring, all patients underwent X-ray voiding cystourethrography and volumetric dynamic voiding computed cystourethrography, X-ray voiding cystourethrography being performed using X-ray machine General Electric Advantx (USA).

The VDVCC being performed using the multispiral computed tomography scanner Aquilion One (Toshiba, Japan). The 640-slice computed tomography scanner has 320 rows of detectors, each 0.5 mm wide. 16 centimeters wide detector allows covering the whole urogenital area per one rotation. Such technical parameters of the scanner make it possible to perform a dynamic examination of the entire area of urogenital region.

The examinations being performed in a supine patient's position with hands widened behind the head. Before the examination, the patient drank up to 500 ml of water for the bladder filling. After occurrence of a sufficient urge to urinate the patient was laid on the table of a computed tomography scanner. The diaper was used to collect urine. Since urination in the prone position for certain patients presents difficulties, they were taught to urinate on back for 1-2 days before the examination.

The iodine based contrast agent with an iodine concentration of at least 350 mg/ml was used. The volume of the injected contrast agent was calculated based on the patient's weight - 1.0 ml per kilogram. The contrast agent rate of injection was at least 4.0 ml/sec. Immediately after the end of the injection of the contrast agent 50 ml of saline was injected intravenously.

The first stage is performing of two scanograms - images at the coronal and sagittal planes, which serve to mark the examination region. The second stage is a noncontrast examination of the abdominal cavity, the pelvis and the external genitalia. The third stage is the arterial, venous, and delayed phases. The resulting images in the axial plane were processed with the construction of multiplanar and three-dimensional reconstructions. The fourth stage is volumetric dynamic voiding computed cystourethrography. Tomography parameters are presented in Table 1. This part of the examination performs in a volumetric dynamic mode, without moving the table relative to the scanner detector, therefore the examination area is limited by the width of the detector, i.e. 16 cm. The zone was marked in such a way that the external genital organs and the bladder got into the examination area. By this time, the bladder is filled with the excreted contrast urine, therefore, no additional invasive procedures for the injection of a contrast agent into the bladder are required. The examination lasts 10 seconds. After the operator's indication patient starts to urinate in the diaper.

Then analysis of the obtained images in multiplanar, 3D and 4D reconstructions was performed (Fig. 1). The voiding cystourethrography was performed at the last stage. The measurement of the urethra lumen width in all parts was performed, the zones of its' narrow-

Table №1. VDVCC tomography parameters.

Tomography parameters	Tomography settings
X-ray tube voltage	100 kV
X-ray current	250 mA
X-ray tube rotation speed	0,5 sec.
Tomography time	10 sec.
Tomography area	16 sm.
Tomography mode	Intermittent

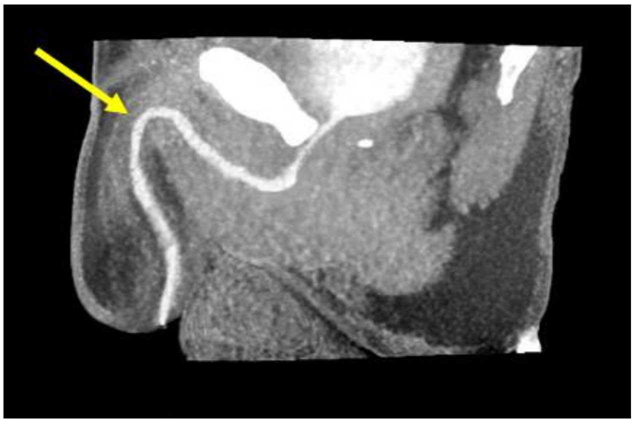

Fig. 1 a (Рис. 1 а)

Fig. 1 b (Рис. 1 б)

Fig. 1. Volumetric dynamic voiding computed cystourethrography: a – sagittal plane. b – three-dimensional reconstruction.

Arrow - neourethra formed during surgery without narrowing signs.

Рис. 1. Объемная динамическая микционная цистуретерография: а – сагиттальная плоскость, б – трехмерная реконструкция.

Стрелка – сформированная во время оперативного вмешательства неоуретра без признаков сужения на всем протяжении.

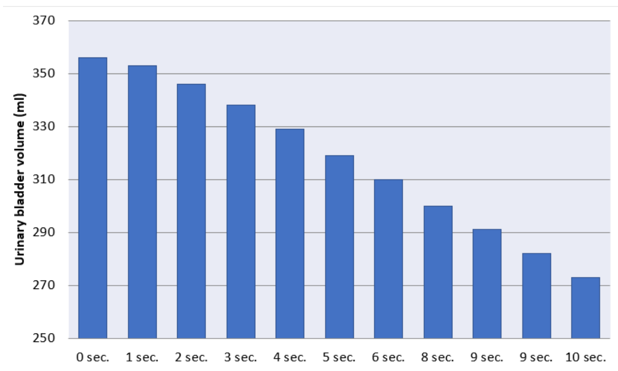

Рис. 2 (Fig. 2)

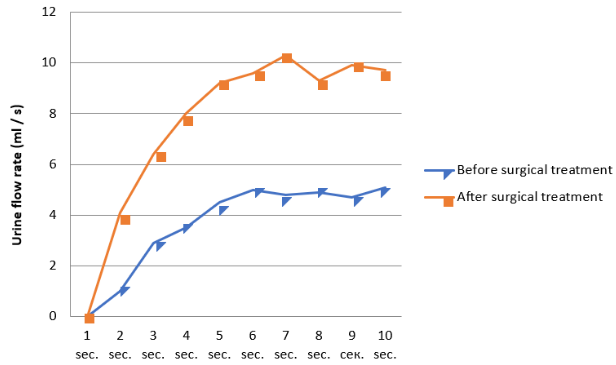

Рис. 3 (Fig. 3)

Рис. 2. Diagram. The bladder volume change during volumetric dynamic voiding computed cystourethrography were used to calculate the velocity indicators of the urine stream flow.

Patient K., 34 years old, with urethral stricture.

Fig. 2. Диаграмма. Изменение объема мочевого пузыря при проведении объемной динамической микционной компьютерной цистоуретрографии, применяемое для расчета скоростных показателей потока струи мочи.

Пациент К., 34 года, со стриктурой уретры.

Рис. 3. Graph. The urine flow rate in the various voiding phases during volumetric dynamic voiding computed cystourethrography calculated according to the urinary bladder volume changes.

Patient K., 34 years old, with urethral stricture. Blue line is the urine flow rate in a patient with a urethral stricture. The red line is the urine flow rate in a patient after elimination of the stricture using a replacement urethroplasty.

Fig. 3. График. Скорость потока мочи в различные фазы мочеиспускания во время объемной динамической микционной компьютерной цистоуретрографии, рассчитанная на основании изменения объема мочевого пузыря.

Пациент К., 34 года, со стриктурой уретры. Синяя линия – скорость потока мочи у пациента со стриктурой уретры. Красная линия – скорость потока мочи у больного после устранения стриктуры с помощью заместительной уретропластики.

ing and their length were detected. The surrounding tissues in these areas and the bladder neck opening during the urination were assessed. The bladder volume and the urine stream flow rate during different urinary phases were estimated.

Vascular anatomy, especially of the inferior deep epigastric arteries was examined for planning urethroplasty using a free revascularized microsurgical radial autograft in arterial phase. After analyzing the obtained data, the cause and location of the urethral stricture or other pathology were established in every patient.

Results.

Thirty two of fifty six examined patients underwent phallus and urethra reconstruction using free revascularized microsurgical autografts. The rest of the patients underwent only a reconstruction of the urethra. At the postoperative stage after removal of the urinary catheter, all patients urinated on their own and did not have complaints associated with voiding.

The average volume of the urinary bladder according to VDVCC data was 349.4 ± 154.5 ml, while the actual volume of urine excreted during the voiding was 287.4 ± 142.6 ml, which is associated with the residual volume of urine in the bladder, which was 55.1 ± 24.3 ml. These results at the pre- and postoperative stages did not differ.

The rate of the urine flow stream was calculated based on the bladder volume changes during each phase of the dynamic examination (from 1 to 10 seconds). Example of bladder volume changes calculation of the patient K. 34 years old with urethral stricture is represented

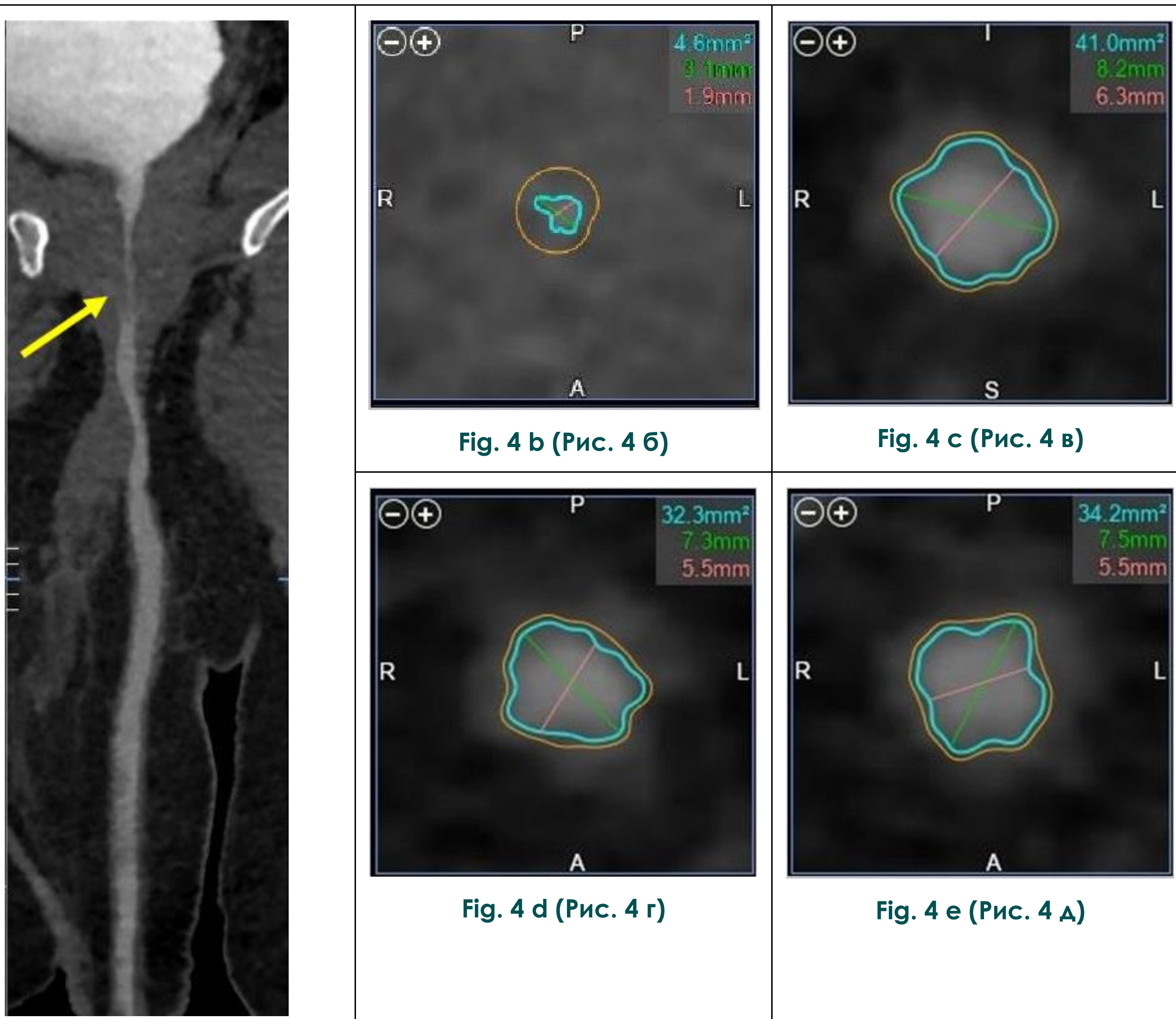

Fig. 4 a (Рис. 4 а)

Fig. 4 b (Рис. 4 б)

Fig. 4 c (Рис. 4 в)

Fig. 4 d (Рис. 4 г)

Fig. 4 e (Рис. 4 д)

Fig. 4. Volumetric dynamic voiding computed cystourethrography: a - curvilinear reconstruction, b-e - transverse sections of the urethra..

The arrow indicates the extended narrowing zone of the perineal urethra in a patient after phallo- and urethroplasty. The lumen area of the perineal urethra in Fig.4 b is 6 times smaller than the not changed areas in Fig.4 c-e.

Рис. 4. Объемная динамическая микционная компьютерная цистоуретрография: а - криволинейная реконструкция, б-д – поперечные срезы уретры.

Стрелкой указана область сужения промежностной части уретры у пациента после фалло- и уретропластики. Площадь просвета промежностной уретры на рис. 4 б в 6 раз меньше площади не изменённых участков на рис. 4 в-д.

in Fig. 2. The average rate of urine stream flow in patience with strictures of the urethra was 4.3 ± 1.3 ml/sec, after elimination of the stricture 8.1 ± 5.4 ml/sec. The maximum recorded speed was 19 ml/sec. It was not possible to determine the total voiding time in this study, because the tomography protocol was limited to 10 seconds to reduce the patient's radiation dose.

After reconstruction of the urethra using a free revascularized microsurgical autograft, there was an improvement in uroflowmetric indicators determined on the basis of VDVCC data (Fig. 3).

All obtained images were processed at the Vitrea workstation with the construction of curvilinear reconstructions of the urethra and automatic determination of its diameter in all

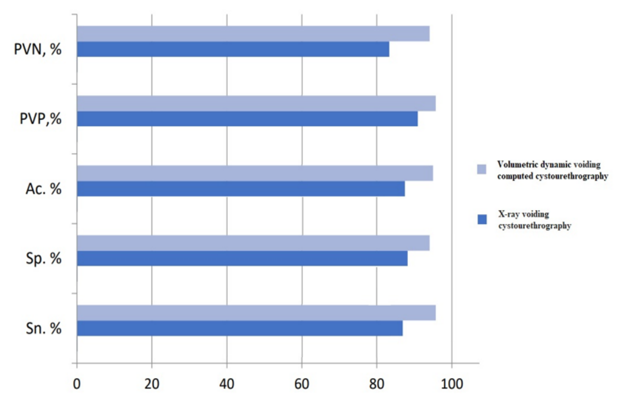

Fig. 5 (Рис. 5)

Fig. 5. Diagram.

Diagnostic accuracy of volumetric dynamic voiding computed cystourethrography and voiding cystourethrography.

Рис. 5. Диаграмма.

Значения диагностической эффективности объемной динамической микционной компьютерной цистоуретрографии и микционной цистуретерографии.

parts (Fig. 4). The average diameter of the urethra according to the VDVCC after urethroplasty was 7.4 ± 2.0 mm. The minimum length of urethral strictures was 17 mm, the maximum length was 32 mm.

VDVCC had better overall diagnostic accuracy then voiding cystourethrography. Sensitivity, specificity and accuracy for urethral stricture detecting were 95,7 %, 94,1 %, 95,0% for VDVCC and 86,9%, 88,2%, 87.5% for voiding cystourethrography (Fig. 5).

For all the examined patients, the radiation dose obtained during the VDVCC was determined. On average, it was 11.2 ± 4.3 mSv. These values for most patients were lower than the average value of the individual effective dose for the procedure of fluoroscopic examination of the pelvic organs (voiding cystourethrography or retrograde urethrocystoscopy) [14].

Discussion.

At the moment standard examination method for patients with urogenital area pathology is retrograde urethrography in combination with voiding cystourethrography [15-18]. These methods allow determining the localization and length of the urethral stricture, which does not always lead to a significant urodynamics violation and can be asymptomatic for a long time. Despite its high sensitivity and specificity urethrography has two significant drawbacks. First, with a standard oblique ¾ patient positioning occurs projection distortions of the urethral size, which can cause an underestimation of the stricture length, and, consequently, the wrong choice of surgical treatment method. Secondly, retrograde urethrography does not give information of the depth and extent of spongiofibrosis, which is the most important factor in the choice of treatment tactics. It should also be noted the possibility of different interpretations of urethrography by radiologists and urologists [19].

The best way of objectively evaluation of changes is a comprehensive analysis, under conditions as close as possible to the physiological one that is during voiding [26]. The advantage of the method is that the contrast agent is injected intravenously, after a while the bladder is sufficiently filled with excreted contrast urine.

In this way, it is possible to assess the anatomy of the abdominal cavity of the pelvis, including the vascular, for further planning of surgical treatment during single examination. Another undoubted advantage of the developed technique is the possibility of examination of the urine stream velocity parameters in dynamic, which allows making conclusions about the contractility of the urinary bladder. The results obtained are similar to those of traditional urofluometry performed for all patients, but the lower urine stream velocity may be due to the fact that patients had to urinate while lying down.

The disadvantage of the method is the need to urinate in the supine position. In our study it did not work out in three patients. This technique makes it possible to avoid traditional endoscopic urethroscopy, which is extremely important nowadays, since iatrogenic infection of the urinary tract during endoscopic manipulations still reaches high level (8-34%). In addition, volumetric dynamic voiding cystourethrography allows assessing the paraurethral tissue state and surrounding organs, which is available only to some invasive methods and MRI [20].

Conclusion. Analyzing our data, including intraoperative, we can assert that CT in combination with VDVCC is highly informative method for assessing of urethra and it`s postoperative complications (stricture, fistula, diverticula, etc.). VDVCC diagnostic efficiency parameters exceed the X-ray urethrography rates in the assessment of urethral stricture. The proven efficiency of the developed method suggests that it may be promising in examining patients with the urogenital area diseases.

Conflicts of Interest.

The authors declare that there is no conflict of interest regarding the publication of this article.

Источник финансирования.

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References:

1. Darenkov, S.P., Kotov S.V., Glinin K.I. Erectile function in patients with anterior urethral strictures. Medical messenger of Bashkartostan. 2013; 8 (2): 47-50.

2. Kogan M.I., Mitusov V.V., Krasulin V.V. Internal optical urethrotomy with stricture urethral disease complicates the subsequent reconstructive surgery. Urology. 2012; 3: 27-30.

3. Trapeznikova M.F., Bazaev V.V., Urenkov S.B. Comparative analysis of the results of open and endoscopic operations with obliteration of the posterior urethra in men. Urology. 2004; 1: 47-54.

4. Pavlica P., Menchi I. and Barozzi L. New imaging of the anterior male urethra. Abdom Imaging. 2003; 28: 180-186.

5. Kim B., Kawashima A., LeRoy A.J. Imaging of the male urethra. Semin Ultrasound CT MR. 2007; 28: 258-273.

6. Shahsavari R., Bagheri S.M., Iraji H. Comparison of Diagnostic Value of Sonourethrography with Retrograde Urethrography in Diagnosis of Anterior Urethral Stricture. Open Access Macedonian Journal of Medical Sciences. 2017; 5 (3): 335-339.

7. Vilalta L, Altuzarra R, Espada Y, Dominguez E, Novellas R and Martorell J: Description and comparison of excretory urography performed during radiography and computed tomography for evaluation of the urinary system in healthy New Zealand white rabbits (Oryctolaguscuniculus). Am J Vet Res. 2017; 78: 472-481.

8. Diefenderfer D.L., Brightling P. Dysuria due to urachalabscessation in calves diagnosed by contrast urography. Can Vet J. 1983; 24: 218-221.

9. Meduri S., DePetri T., Modesto A., Moretti C.A. Multislice CT: technical principles and clinical applications. Radiol. Med. 2002; 103 (3): 143-157.

10. Gallentine M.L., Morey A.F. Imaging of the male urethra for stricture disease. UrolClin North Am. 2002; 29: 361-372.

11. Milosevic M., Voruganti S., Blend R., Alasti H., Warde P., McLean M., Catton P., Catton C., Gospodarowicz M. Magnetic resonance imaging (MRI) for localization of the prostatic apex: Comparison to computed tomography (CT) and urethrography. RadiotherOncol. 1998; 47: 277-284.

12. Chou C.P., Huang J.S., Wu M.T., Pan H.B., Huang F.D., Yu C.C., Yang C.F. CT voiding urethrography and virtual urethroscopy: Preliminary study with 16 MDCT. AJR Am J Roentgenol. 2005; 184: 1882-1888.

13. Zhang X.M., Hu W.L., He H.X., Lv J., Nie H.B., Yao H.Q., Yang H., Song B., Peng G.M. and Liu H.L. Diagnosis of male posterior urethral stricture: Comparison of 64 MDCT urethrography vs. standard urethrography. Abdom Imaging. 2011; 36: 771-775.

14. Theisen K.M., Kadow B.T., Rusilko P.J. Three dimensional imaging of urethral stricture disease and urethral pathology for operative planning. CurrUrol Rep. 2016; 17: 54.

15. Guidelines for ensuring radiation safety. Russian consumer supervision. Moscow. 2007. 17 p.

16. Osman Y., El Ghar M.A., Mansour O., Refaie H., El Diasty T. Magnetic resonance urethrography in comparison to retrograde urethrography in diagnosis of male urethral strictures: Is it clinically relevant? EurUrol. 2006; 50: 587-593.

17. Kawashima A., Sandler C.M., Wasserman N.F., LeRoy A.J., King B.F. Jr., Goldman S.M. Imaging of urethral disease: A pictorial review. Radiographics. 2004; 24 Suppl 1: S195-S216.

18. Watanabe H., Takahashi S., Ukimura O. Urethra actively opens from the very beginning of micturition: A new concept of urethral function. Int J Urol. 2014; 21: 208-211.

19. Vorobev V.A., Beloborodov V.A., Popov S.L., Shumara M.A., Antipina I.V., Sedykh E.A., Mamedov E.G., Bardonov.V. Diagnosis of stricture disease of the urethra. Siberian Medical Journal. 2017; 4: 34-36.

20. Oh MM, Jin MH, Sung DJ, Yoon DK, Kim JJ., Moon du G. Magnetic resonance urethrography to assess obliterative posterior urethral stricture: Comparison to conventional retrograde urethrography with voiding cystourethrography. J Urol. 2010; 183: 603-607.