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# DENSITOMETRIC DENSITY OF URINARY STONES AS A PREDICTIVE FACTOR DEMONSTRATING THEIR EFFICIENCY OF DISINTEGRATION IN TREATMENT OF UROLITHIASIS

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Urolithiasis is one of the most common urological diseases, occurring in at least 3% of the human population and 34.2% of the Russian population. Data from the Ministry of Health of the Russian Federation show that in the past 4 years, the incidence of urolithiasis has increased from 405.2 to 460.3 patients per 100,000 population. The purpose of this study was to assess the significance of determining the density of urinary stones via computed tomography, as well as the chemical composition of urinary stones, in order to choose an optimal treatment strategy for patients with urolithiasis. The results of treatment of 108 patients with stones of different localization and sizes were investigated. The patients were subjected to laboratory examination to determine the urinary salt environment; moreover, the levels of electrolytes were examined in blood samples from the patients, and computed tomography densitometry was performed to determine the density of the detected stones. The qualitative chemical compositions of urinary stones in patients with urolithiasis were determined. The density of urinary stones was evaluated by computed tomography densitometry in these patients. The relationship was determined between the chemical compositions of stones and their corresponding densitometric densities. The densitometric density of urinary stones, as determined by computed tomography, can serve as a predictor of the effectiveness of stone disintegration, because it allows selection of the best method to destroy stones for treatment of urolithiasis.

***Keywords:*** urolithiasis; disintegration of stones; computed tomography; densitometrical density.

# ДЕНСИТОМЕТРИЧЕСКАЯ ПЛОТНОСТЬ МОЧЕВЫХ КОНКРЕМЕНТОВ КАК ФАКТОР ПРОГНОЗА ЭФФЕКТИВНОСТИ ИХ ДЕЗИНТЕГРАЦИИ ПРИ ЛЕЧЕНИИ УРОЛИТИАЗА

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Мочекаменная болезнь является одним из наиболее распространенных урологических заболеваний и встречается не менее чем у 3 % населения. Данные МЗ РФ свидетельствуют, что только за последние четыре года заболеваемость уролитиазом увеличилась с 405,2 до 460,3 больных на 100 000 населения. Мочекаменная болезнь занимает одно из первых мест среди урологических заболеваний, составляя в среднем по России 34,2 %. Цель исследования — оценить значимость определения плотности конкрементов мочевыделительной системы по данным компьютерной томографии и химический состав мочевых камней для выбора оптимальной тактики лечения. В статье обобщены результаты лечения 108 пациентов с камнями различной локализации и размеров. Пациентам проводили лабораторное обследование с целью определения солевого фона мочи, исследовали уровень электролитов в сыворотке крови, выполняли компьютерную томографию с определением плотности конкрементов методом денситометрии. Изучены особенности качественного химического состава мочевых камней у пациентов с уролитиазом. Определена зависимость между химическим составом конкрементов и их денситометрической плотностью. Денситометрическая плотность мочевых конкрементов, определяемая по данным компьютерной томографии, может выступать в качестве фактора прогноза эффективности их дезинтеграции, поскольку позволяет подобрать оптимальный способ разрушения камней при лечении уролитиаза.

***Ключевые слова:*** мочекаменная болезнь; дезинтеграция конкрементов; компьютерная томография; денситометрическая плотность.

## INTRODUCTION

Urolithiasis is one of the most common urological diseases and occurs in at least 3% of the population. According to data of the Ministry of Health of the Russian Federation, in the last 4 years alone, the incidence of urolithiasis has increased from 405.2 to 460.3 patients per 100,000 populations. In Russia, urolithiasis is a leading urological disease with an average of 34.2%. Men are affected three times more than women. The endemicity of urolithiasis has been proven not only in its frequency in various regions of Russia but also in the type of urinary stones, including the uric acid stones, which are more prevalent in the southern regions and oxalates, which are more prevalent in the Central Federal District [1, 2]. Knowledge of the physicochemical properties of urinary tract stones is important in determining indications and developing methods for the treatment of patients with urolithiasis [1, 3, 4]. Stones differ in the structure and interposition of crystals, which causes their different levels of fragmentation when subjected to the action of a shock wave [5]. The strongest stones are oxalates; the urates are the least strong, but contain more plastics, phosphates, and stones and a high protein component. Oxalates have the highest compressive strength, and urates have the highest elastic properties [6–8].

Computer densitometry may be able to estimate the structural density of stones, effectiveness, and number of treatment sessions [9, 10]. High density is employed only after several sessions of extracorporeal shock wave lithotripsy (SWL), which often dictates the choice of alternative methods of treatment [11]. In addition, the use of SWL in high-density stones (>1000 Hounsfield units (HU)) and >2 cm in size can lead to complications. Computed tomography (CT) with densitometry allows not only specifying the indications of urolithiasis treatment methods but also optimizing the technical parameters of disintegration that prevents possible complications and markedly reduces the rate of unsuccessful sessions [1, 12, 13].

The most common treatment for urolithiasis is SWL. The accomplished advantage of SWL is the absence of direct invasion into the patient's body with sufficient effectiveness [9, 14].

One of the main prognostic criteria for clinical efficacy of SWL is the structural density of stones, which can be determined by CT with densitometry. For stones with density <1000 HU, the efficiency of the first SWL session is 70.2%, at a density of up to 1200 HU, effective disintegration is observed after two sessions of the SWL and accounts for 24.5% of patients, and at a stone density of 1500 HU or more, SWL is effective in 5.3% of patients. Homogeneous stones with smooth edges and a radial-concentric structure are the most difficult to destroy. Uric acid stones are the hardest for SWL. Dzeranov et al. (2003) noted that 92% of struvite, 87% of oxalate, 67% of urate, and 60% of cystine stones are completely destroyed with SWL [1, 4, 15]. However, SWL is not always effective. An alternative to SWL can be contact ureterolithotripsy (CULT) and percutaneous nephrolithotripsy (PCNL) [3, 5]. The efficiency of CULT for treating stones located in the lower ureter accounted for not less than 95% [16]. CULT is indicated for high-density stones (>1000 HU), stones with >5 mm size, stones existing in the lower and middle ureters for a long period, extended steinstrasse after SWL, multiple distal ureteral stones, X-ray negative ureteral stones, stones in the bladder, and stones in the ureter [6, 17]. Recently, the number of percutaneous surgeries performed for urolithiasis for one-step removal of urinary stone of any localization, composition, and density has significantly increased [18, 19]. However, this treatment method is invasive and associated with complications [20].

*The aim of this study* was to assess the role CT densitometry of urinary calculi and stone composition analysis for choosing the optimal treatment strategy for patients with urolithiasis.

## MATERIAL AND METHODS

The study involved adults who received an inpatient treatment in the urological department at Ivanovo Regional Clinical Hospital, a clinical base of the department of faculty surgery and urology in Ivanovo State Medical Academy, in the period from 2013 to 2015.

Treatment results were evaluated retrospectively. The materials for the study were stones removed by extracorporeal lithotripsy, contact lithotripsy, and laparoscopic retroperitoneal surgery and laboratory data from medical records of patients (Form No. 003 / U).

The study enrolled 108 patients with urolithiasis (126 calculi) including 42 men and 66 women. The incidence was significantly higher in men than in women (38.9% vs. 61.1%, $p < 0.05$). The patients' age ranged from 27 to 76 years (mean age, 51.3 ± 1.7 years).

The eligibility criteria were one or multiple urinary stones, retroperitoneal and pelvic CT with densitometry, and data on stone composition.

Preoperatively, all patients underwent laboratory tests to identify urine electrolyte profile (urine pH, salts in urine sediment) and level of serum electrolytes (Ca, Na, K, and uric acid) and CT with densitometry of stones in HU.

To determine the qualitative and quantitative chemical composition of calculi, standard chemical analysis was performed, the results of which were compared with the results of their densitometric density.

The patients were divided into two groups. The study group included 50 patients who had CT data on stone density and data on stone composition according to chemical analysis with urine test and biochemical blood test. The control group included 58 patients who only had data on stone composition according to chemical analysis with urine and blood tests. The results of urolithiasis treatment with different methods (SWL, CULT, laparoscopic retroperitoneal surgery, and non-surgical therapy) with complete disintegration of stones as an efficacy criterion were compared in both groups.

Statistical data analysis was performed by Excel 7.0, Statistica for Windows 5.3, using computational methods recommended for biology and medicine. The following parameters were calculated: mean of variables ($M$), standard error of mean ($m$), dispersion, and standard deviation ($\delta$). Student's $t$-test was used to evaluate difference between groups.

## RESULTS AND DISCUSSION

The average size of urinary stones in patients with urolithiasis was 12.7 ± 0.4 mm and was comparable in both groups. The locations of urinary stones were different. The most common location of stones was the pelvicaliceal system, in which 39.9% of stones were detected ($p < 0.05$). This is followed by the stones in the different parts of the ureter: upper and middle ureter stones were found with similar rates, that is, 21.4% and 24.0% of cases, respectively ($p < 0.01$), and lower ureters stones were found in 12.9% of cases ($p < 0.05$). The rarest stone location was the urinary bladder with only 1.8% of cases. The two groups did not differ significantly in terms of stone location. Several stones of various locations occurred in 29.2% of cases.

Patients had predominantly urinary stones of mixed chemical composition: oxalate–phosphate, oxalate–urate, and oxalate–phosphate–urate stones (54%). Of monocomponent stones, oxalate stones (25%) were the most common, urate stones (8%) were the rarest, and phosphate stones occurred with intermediate frequency (13%).

The two groups did not differ in terms of the mineral composition of stones. The results of laboratory tests and densitometry of stones are represented in Table 1.

Oxalate stones had very high density (>1200 HU). The urine pH level was neutral. Hyperoxaluria was a specific characteristic of the electrolyte profile of urine sediment. No abnormalities were noted in serum parameters, and moderate hypercalcemia occurred in some cases.

Phosphate stones had average density values (470–600 HU). Alkaline urine is typical for the formation of these stones. Phosphate and oxaluria prevailed in the urine test. No abnormalities in blood tests were noted. Urate stones had the lowest CT density of <400 HU. Distinctive features of this stone type included acid urine pH level, hyperuricemia, and hyperuricuria. The stones of mixed chemical composition (oxalate–phosphate and oxalate–urate) had average values in many criteria. The mean densitometric density of the stones was 600–900 HU.

They were associated with neutral or acid urine. Microscopy of the urine sediment revealed phosphate, oxalate, or uraturia. No significant abnormalities in blood tests were noted.

On diagnostic evaluation, the densitometric density of the stone may presumably indicate chemical composition. When these data are used, the most effective treatment strategy for maximum disintegration and evacuation of the stone can be selected. The pharmacological treatment should be considered for low-density stones (<400 HU). For large stones, for which litholysis was not accepted, SWL and medication were employed. For stones of average densitometric density (400–600 HU), minimally invasive treatment methods (SWL or contact lithotripsy) can be performed, considering stone location and size. High-density stones (>1000 HU) can be treated more effectively using traditional methods of stone removal. SWL can be performed in small stones and appropriate location; if SWL is impossible or in case of large stones, laparoscopic retroperitoneal surgery is preferred. For stones of mixed composition, the predominant chemical element of stone composition and CT density plays a key role in the choice of treatment strategy.

In patients with urolithiasis, different methods of disintegration and evacuation of stones can be employed (Table 2). The following treatment methods were used according to the initial size, type, location, and number of stones: SWL (62% in the study group vs. 51.7% in the control group), CULT (24% vs. 41.3%), laparoscopic retroperitoneal surgery (10% vs. 3.5%), and non-surgical therapy for spontaneous stone removal (4% vs. 3.5%) ($p < 0.05$).

In patients of the study group with densitometric density data and chemical analysis of composition of stones, the treatment strategy and method of stone disintegration was chosen individually. The treatment was successful in 56% of cases (stones were disintegrated and removed); the control examina-

*Table 1*

**Chemical compositions of urinary calculi and their densities according to computed tomography assessment**

*Таблица 1*

**Химический состав мочевых конкрементов и их плотность по данным компьютерной томографии**

| Parameters | Stone composition | | | | |
|---|---|---|---|---|---|
| | Oxalate | Phosphate | Urate | Oxalate–phosphate | Oxalate–urate |
| Stone density, HU | 1207.2 ± 119.4 | 527.3 ± 58.5 | 333.4 ± 43.6 | 773.3 ± 74.7 | 592.6 ± 47.9 |
| Urine pH level | Neutral | Alkaline | Acidic | Neutral | Acidic |
| Urine electrolyte profile | Oxaluria | Phosphate(oxal) uria | Uraturia | Oxal(phosphate) uria | Oxal(urat)uria |
| Level of blood electrolytes | Hypercalcemia | Normal | Hyperuricemia | Normal | Normal |

*Table 2*

**Methods of treatment for patients with urolithiasis (*n* = 108)**

*Таблица 2*

**Методы лечения больных с уролитиазом (*n* = 108)**

| Treatment method | Study group (*n* = 50) | | Control group (*n* = 58) | |
|---|---|---|---|---|
| | *n* | % | *n* | % |
| Extracorporeal shock wave lithotripsy | 31 | 62.0 | 30 | 51.7 |
| Contact lithotripsy | 12 | 24.0* | 24 | 41.3 |
| Laparoscopic retroperitoneal surgery | 5 | 10.0* | 2 | 3.5 |
| Non-surgical treatment | 2 | 4.0* | 2 | 3.5 |

*Note.* * Significant differences relative to group 2 ($p < 0.05$).
*Примечание.* * Достоверность различий в сравнении со второй группой при $p < 0,05$.

tion (ultrasonography and X-ray study) showed no stones in the urinary tract (Table 3). Positive treatment results (partial disintegration of stones) with residual fragments or stone gravel were found in 34% of cases, requiring additional therapeutic manipulations in the postoperative period ($p < 0.05$, compared with the control group). No changes after treatment was recorded in 10% of cases (stones of the previous location and initial sizes were determined in the urinary system). Such results were observed after SWL, when one session did not lead to stone fragmentation ($p < 0.01$, compared with the control group).

Differences in treatment results were found between the study and control groups. Patients of the control group underwent standard methods of stone removal according to location, size, and composition of stones without CT densitometry. The treatment was successful with complete disintegration and evacuation of stones only in 32.8% of cases, which was almost two times less compared to that in the study group. Partial evacuation and/or fragmentation of stones were achieved in 44.8% of cases ($p < 0.05$). Treatment failure was observed in 22.4% of cases; moreover, the rate was two times higher than that in the study group ($p < 0.01$).

Thus, based on the results of this study, the following conclusions were made.

1. Specifics of stone composition in patients with urolithiasis involve the prevalence of oxalate–phosphate and oxalate–urate types (54%). Of monocomponent stones, oxalate stones (25%) were the most

*Table 3*

**Results of treatment for patients with urolithiasis ($n$ = 108)**

*Таблица 3*

**Результаты лечения больных с уролитиазом ($n$ = 108)**

| Treatment results | Study group ($n$ = 50) | | Control group ($n$ = 58) | |
|---|---|---|---|---|
| | *n* | % | *n* | % |
| Complete removal/disintegration of the stone | 28 | 56.0 | 19 | 32.8 |
| Partial removal/disintegration камня | 17 | 34.0* | 26 | 44.8 |
| No changes | 5 | 10.0** | 13 | 22.4 |

*Note.* * Significant differences relative to group 2 ($p < 0.05$); ** significant differences relative to group 2 ($p < 0.01$).
*Примечание.* * Достоверность различий в сравнении со второй группой при $p < 0,05$; ** достоверность различий в сравнении со второй группой при $p < 0,01$.

common, urate stones (8%) were the rarest, and phosphate stones occurred with intermediate frequency (13%).

2. According to CT, oxalate stones had high density values (>1200 HU). Phosphate stones were characterized by average density (470–600 HU). Urate stones had the least density (<400 HU). The average density of mixed stones accounted for 600–900 HU.

3. Stones with density less than 400 HU require SWL with litholysis. For stones with average density (400–600 HU), minimally invasive methods are used: SWL or contact lithotripsy depending on stone location and size. For high-density stones (>1000 HU), laparoscopic retroperitoneal surgery is more efficient.

Thus, densitometric density of urinary stones measured by CT may be a prognostic factor for efficiency of disintegration because it allows selecting optimal method of stone disintegration for urolithiasis.

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