RESEARCH INSTITUTE OF UROLOGY
OF THE MINISTRY OF HEALTH OF THE RUSSIAN FEDERATION

Experimental and clinical urology

SCIENTIFIC AND PRACTICAL REVIEW EDITION
№4 2013

EDITORIAL BOARD OF THE MAGAZINE

Chief Editor	O.I. Apolikhin, Doctor of Medical Sciences, Professor
Deputy Chief Editor	A.V. Sivkov, Ph.D.
Scientific editor	A.G. Pugachev, Doctor of Medical Sciences, Professor
Executive Secretary	YES. Beshliev, MD
Editors	V.A. Komarova, Ph.D. N.G. Moskaleva, Ph.D. I.A. Shaderkin

S.A. Golovanov, MD
V.V. Evdokimov, MD
E.A. Efremov, MD
N.S. Ignashin, MD
A.V. Kazachenko, MD
M.I. Katibov, MD
V. I. Kirpatovsky, Doctor of Medical Sciences, Professor
D.S. Merinov, Ph.D.
E.O. Osmolovsky, MD
V.V. Oshchepkov, Ph.D.
T.S. Perepanov, MD Professor
V.V. Romikh
R.M. Safarov, Doctor of Medical Sciences, Professor
V.N. Sinyukhin, Doctor of Medical Sciences, Professor
I.V. Chernyshev, MD
L.A. Khodyreva, MD
E.K. Yanenko, MD Professor
E.K. Yanenko, MD, professor

EDITORIAL BOARD OF THE JOURNAL

F. Akilov, Doctor of Medical Sciences, Professor (Republic of Uzbekistan)
M.K. Alchinbaev, Doctor of Medical Sciences, Professor (Republic of Kazakhstan)
S.Kh. Al-Shukri, Doctor of Medical Sciences, Professor (St. Petersburg)
A.V. Amosov, Doctor of Medical Sciences, Professor (Moscow)
IN AND. Voshchula, Doctor of Medical Sciences, Professor (Republic of Belarus)
A.B. _ Gudkov, Doctor of Medical Sciences, Professor (Tomsk)
A.A. Erkovich, Doctor of Medical Sciences, Professor (Novosibirsk)
V N. Zhuravlev, Doctor of Medical Sciences, Professor (Yekaterinburg)
E.P. Kakorina, Doctor of Medical Sciences, Professor (Moscow)
HELL. Kaprin, MD, Professor, Corresponding Member RAMS (Moscow)
V.L. Medvedev, Doctor of Medical Sciences, Professor (Krasnodar)
A.I. Neimark, Doctor of Medical Sciences, Professor (Barnaul
V.N. Pavlov, Doctor of Medical Sciences, Professor (Ufa)
N.N. Tarasov, Doctor of Medical Sciences, Professor (Chelyabinsk)
A.Ch. Usupbaev, Doctor of Medical Sciences, Professor (Kyrgyz Republic)
A.V. Shulyak, Doctor of Medical Sciences, Professor (Ukraine)

EDITORIAL JOURNAL

Publishing house "Uromedna"

Project Manager	Designer	Corrector
V.A. Shaderkina	O.A. Belova	E.V. Bolotov

CONTACT INFORMATION

The journal "Experimental and Clinical Urology" is included in the List of JAK
(No. 2135, the conclusion of the Presidium of the BAK dated 25.{)5.12 No. 22/49)
Circulation 5000 copies.
Index according to the catalog of the agency "Rospechat" 36563

Comparative study of the efficiency of electropulse and electrohydraulic lithotripters in-vitro.

A. G. Margpov [1], A. V. Gudkov [2], V. M. Diamant [2], G. I. Chepovetsky [2], and M. I. Lerner [2]
[1] Department of Urology FGOU DPO IPK FMBA, Moscow
[2] Department of Urology, Siberian State Medical University of the Ministry of Health of the Russian Federation, Tomsk

In order to rid the patient of urinary tract stones, various conservative and surgical methods of treatment are used. Until the end of the 70s of the twentieth century, the main surgical method for treating patients with urolithiasis (M K B) was open surgery. The search for less traumatic ways to remove stones from the upper and lower urinary tract led to the creation of special endoscopic instruments, contact lithotripters and the development of minimally invasive tools, such as percutaneous (percutaneous) nephrolithotripsy, transurethral contact uretera- and pyslocalicolithotripsy, as well as percutaneous and transurethral contact cystolithotripsy [1-3].

The actual destruction of stones in the urinary tract is carried out using ultrasonic, pneumatic, electrokinetic, electrohydraulic and laser contact lithotripters, or a combination of them. In addition, each lithotripter has its own advantages and disadvantages [3, 4]. Thus, only rigid probes and rigid endoscopes are used in ultrasonic lithotripsy, and its scope is currently limited mainly to kidney stones. Impact lithotripsy (pneumatic or electrokinetic lithotripters) is one of the most effective and safe methods of contact destruction of stones. However, the use of such lithotripters is also limited to rigid endoscopes, and retrograde propulsion of the stone during transurethral lithotripsy is considered a disadvantage of the method. Electrohydraulic and laser methods of lithotripsy, being effective methods of contact crushing, can be used with both rigid and flexible endoscopes, which greatly expands the scope of their use in modern urology. However, electrohydraulic lithotripsy causes significantly more complications compared to other methods, since the shock wave produced damages the surrounding tissues. Laser lithotripsy is less traumatic, but requires more expensive equipment and more time for stone fragmentation. At the same time, one of the disadvantages of the method is the presence of a potential danger of laser radiation for others and the possibility of damage to expensive flexible endoscopes due to breakage of the laser fiber in a curved instrument [3–7].

In order to overcome the disadvantages of intracorporeal lithotripsy devices on the market, Lithotech Medical Ltd (Israel) has developed a new lithotripter that allows the safe destruction of stones in all parts of the urinary tract of patients using probes of various diameters that are compatible with both rigid and flexible endoscopes [8]. This method of lithotripsy essentially differs in its principle of operation from the existing ones and uses short nanosecond electric pulses with steep fronts to destroy stones [9–12].

The aim of this work was to conduct a comparative laboratory study of the efficiency of fragmentation of artificial urinary stones using a nanosecond electric pulse lithotripter (NEIL) and a standard electrohydraulic lithotripter (EHL).

MATERIALS AND METHODS

Despite the outward similarity of the two considered contact lithotripters (a probe with two electrodes at the distal end, to which an electric pulse is applied), they differ fundamentally from each other. Electrohydraulic lithotripsy was the first method of intracorporeal fragmentation of urinary stones, which used a thin probe brought directly to the stone to be destroyed and containing two electrodes. When voltage is applied to the probe, a discharge electric arc occurs between the electrodes, which evaporates the liquid in contact with the distal end of the probe. The electrical breakdown of the liquid creates cavitation bubbles, which rapidly expand, creating, in turn, the first shock wave. After the rupture (burst) of cavitation bubbles, the secondary shock wave creates pressure, which is then transferred to a nearby stone. A shock wave applied many times creates compressive and tensile mechanical stresses, which lead to the destruction of the urinary stone. [13-15]. At the same time, the new technology of electropulse destruction of solid biological stones is based on the following phenomenon: when short nanosecond electrical pulses of a certain voltage are applied to a solid body in a liquid medium, it is found that a solid dielectric has a lower breakdown voltage than a liquid medium. When a nanosecond high-voltage pulse with a steep front is applied to the urinary stone, which is basically a solid inorganic - dielectric, its breakdown occurs and the electric current flows through the plasma channels formed in the volume of the dielectric. In this case, tensile thermomechanical stresses arise in the stone, which lead to its cracking and, ultimately, destruction [8, 9].

On fig. Figure 1 schematically shows a comparison of the volt-second breakdown characteristics for the same discharge gap for a solid and a liquid medium. The point of intersection of the volt-second characteristics Ac corresponds to the equality of the dielectric strengths of the compared media. When the pulsed voltage is exposed to less than 2-3 x 10^{-7} s, the solid body becomes electrically weaker than such a liquid dielectric as technical water, and in the region of the diagram to the left of Ac, the electrical breakdown of the solid body, causing its destruction, prevails. At the same time, with the known electrohydraulic method of fragmentation, the electric discharge and breakdown always occur through the liquid (the areas of the diagram to the right of Ac), producing a shock wave in it due to the use of much longer pulses and a lower voltage compared to NEIL. This shock wave caused by the EHL can cause severe damage to the surrounding tissues, which is the reason why the EHL has almost ceased to be used for endoscopic stone crushing. With the electropulse method of destruction of stones, in contrast to the electrohydraulic method, the energy of the electric impulse is released directly in the volume of the body being destroyed, and not in the liquid, which requires much lower energies for its disintegration.

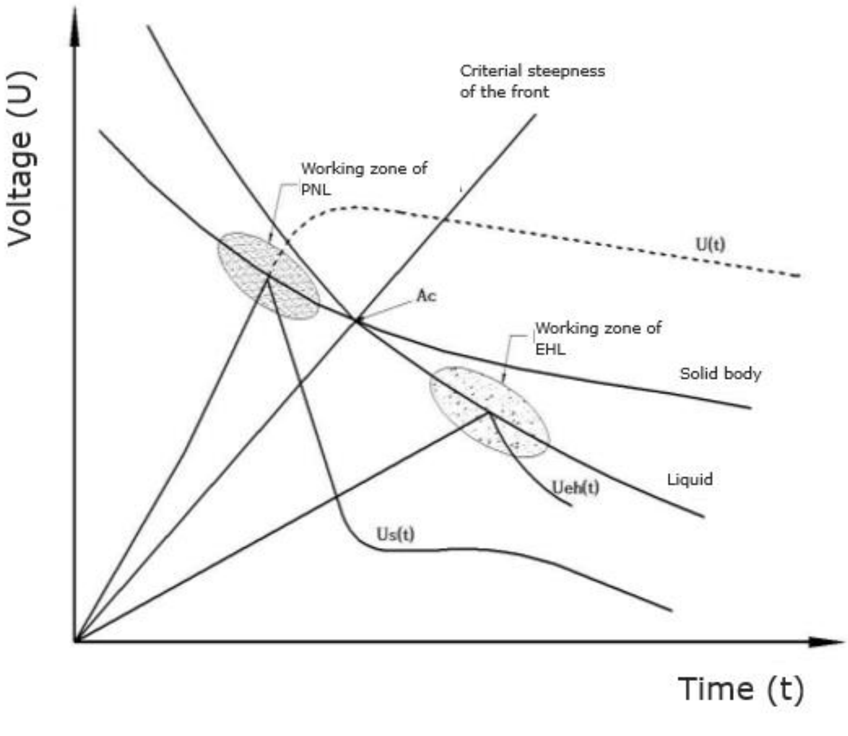


Fig. 1. Principles of electropulse and electrohydraulic destruction. Comparison of the volt-second characteristics of various media (explanations in the text). Ac is the point where the breakdown probabilities of liquid and solid are equal; U (t) - voltage pulse in the absence of breakdown, Us (t) - voltage pulse during breakdown of a solid dielectric, Ueh (t) - voltage pulse during liquid breakdown. Here and below: NEIL - nanoscale electropulse lithotripsy, EHL - electrohydraulic lithotripsy

On fig. Figure 2 schematically shows the operating principle of NESA using the inversion of the dielectric strength between a liquid and a solid in the range of short nanosecond pulses with steep fronts. Voltage pulse U (t), having parameters corresponding to the left side of the diagram from point Ac (Fig. 1), is applied to the electrodes installed on the surface of the solid heat (Fig. 2 a). In this case, breakdowns of solid heat occur in the gap inside the solid body, and not along the shortest path on its surface (Fig. 2 b). The phenomenon shown in Figure 2b is known as "discharge penetration into a solid body" [9]. The discharge initiation stage is characterized by current pulse I (t) flowing in the discharge channel and energy release (Fig. 2b). If the release of energy in the discharge channel occurs fast enough, then a microexplosion will occur in the solid body, leading to the formation of a crater with the separation of part of the material from the solid body (Fig. 2c). The environment surrounding the destructible array of material with current-carrying electrodes plays the role of an agent in the process that promotes electrical breakdown of the solid. This variety of the method of destruction of solids by electric breakdown is called the electric pulse method of destruction of materials [9].

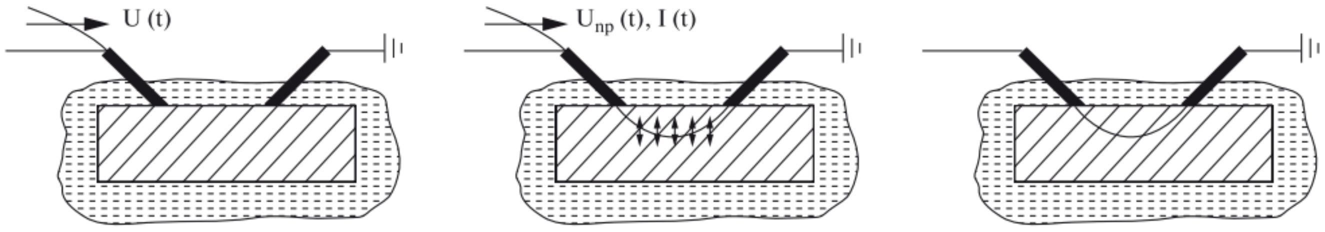


Fig. 2. a, b, c. The sequence of processes of breakdown and destruction of a solid body during NESA (explanations in the text). U (t) - voltage pulse applied to the solid; Us (t) - voltage pulse at breakdown. i () - current pulse

Fig. 3 schematically shows the principle of operation of the EHL. A voltage pulse U (t) with parameters corresponding to the right side of the diagram from the point Ac (Fig. 1) is applied to the electrodes located in the immediate vicinity of the surface of the solid. When the voltage Ueh (t) is reached, breakdown of the liquid occurs near the surface of the solid. This stage is characterized by current pulse I (t) flowing in the discharge channel and energy release (Fig. 3a). In this case, as already noted above, during the electrical breakdown of the liquid, cavitation bubbles are created (Fig. 3b), leading to the appearance of a shock wave, the creation of a pressure area on the solid and its subsequent destruction (Fig. 3c).

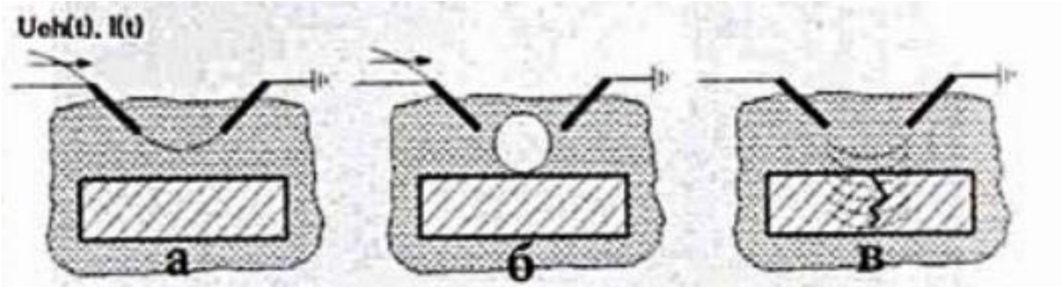


Fig. 3 a, b, c, Sequence of processes of liquid breakdown and destruction of a solid body during EHL (explanations in the text); Ueh (t) - voltage pulse during liquid breakdown, I (t) - current pulse

The mechanism of destruction of urinary stones with the help of NEIL, based on the theory of the process, can be represented by the following interrelated stages. Initially, the stone surface, which is located between the electrodes, is destroyed under the action of an electric arc, which creates the effect of a microexplosion and leads to the creation of a spall hole in the electrode zone (Fig. 2 a-c, Fig. 4 a). Further, there is an accumulation of microdamages in the volume of the stone due to the creation of thermomechanical stresses in it caused by electrical breakdown. Then there is a combination of damage in the main crack, connecting with the original hole - the zone of destruction between the electrodes and leading to subsequent splitting of the stone (Fig. 4 6).

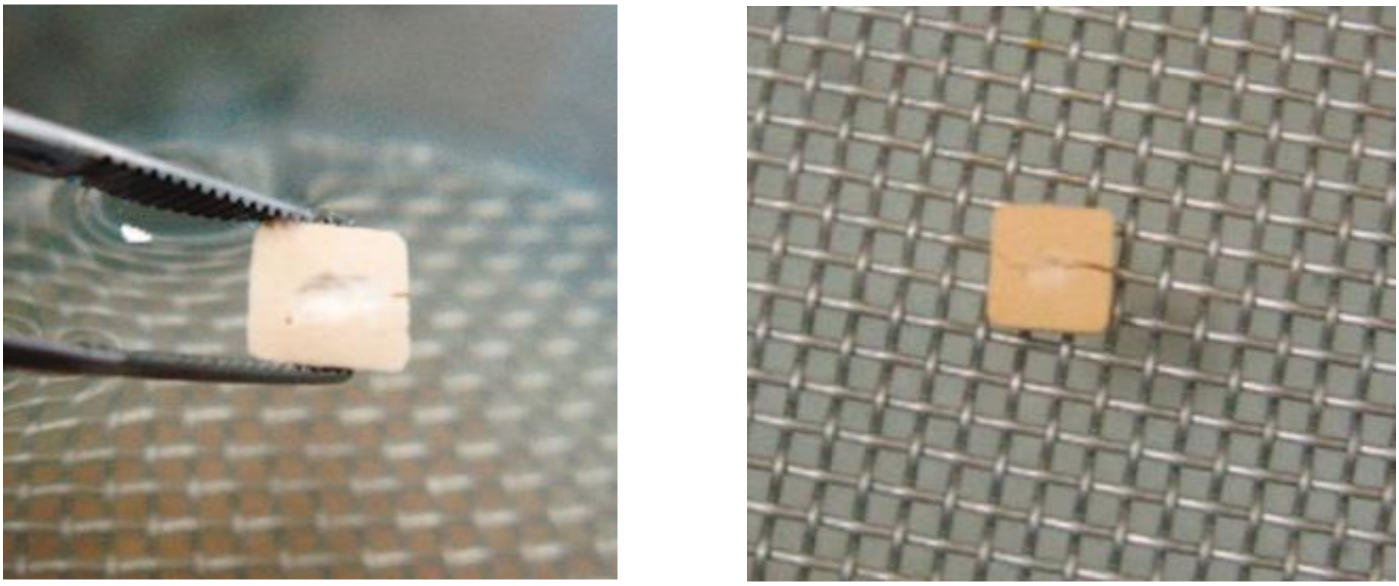


Fig. 4 a, b. Stages of destruction of an artificial "urinary stone" sample during the operation of a nanosecond electric pulse lithotripter (explanations in the text).

At the same time, during EHL, at the initial stage, no crater is created (Fig. 5a), and mechanical stresses caused by the passage of a shock wave through a solid body accumulate in its volume and, ultimately, lead to cracking of the solid body. (Fig. 5 6).

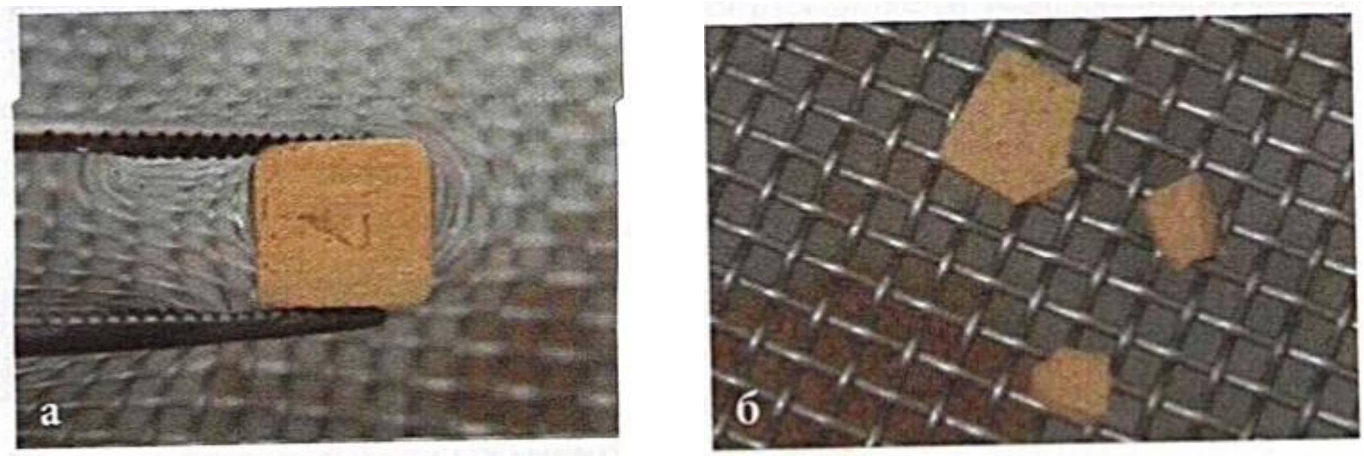


Fig. 5 a, b. Stages of destruction of an artificial “urinary stone” sample during operation electrohydraulic lithotripter (explanations in the text).

On the basis of the electropulse method, a new, unparalleled, nanosecond electropulse lithotripter (NEIL) was developed, which makes it possible to create an electrical breakdown in urinary stones with their subsequent fragmentation [8]. Currently, NEIL is used in clinical practice in dozens of Russian clinics and has established itself as an effective and safe lithotripter [10-12]. The basic characteristics of the developed device are the creation of a nanosecond pulse with a front of less than 50 nanoseconds, a duration of 250–500 nanoseconds, and a voltage of up to 10 kV at an energy applied to the object from 0.3 to 1.0 J.

At the same time, it should be noted that if, during NEIL, the lithotripter probe for some reason does not have direct contact with the stone, or an appropriate voltage is applied to it when the probe is located only in the liquid, then we will also receive a discharge, a breakdown of the liquid. bones and creating a pressure wave. In this regard, experiments were performed on dogs to test the safety of NEIL, where the low invasiveness of the method for the urethra and bladder of dogs was shown [1b]. In addition, when testing for model stone repulsion, we found that NEIL produced significantly lower pressures than EHL, and significantly less sample propulsion was observed.

To simulate "hard" and "soft" urinary stones, we used two types of artificial stones " Begostone " [17], the physical properties of which are presented in Table. 1. The sample preparation procedure was followed in accordance with the manufacturer's recommendations [18]. The difference in the density and hardness of the materials was achieved by changing the proportion of the initial material powder to water during their mixing (Table 1).

Table 1. Properties of Begostone artificial stones

Begostone ratio: water	15:3 / 15:6
Volume of samples used in tests	100, 256, 320mm3
Tensile strength	7 MPa / 3.2 MPa
Longitudinal wave speed	8.2 * 10^6 kg /m2/sec / 4.9 * 10^6 kg / m2/sec
Transverse Wave Velocity	4.6 * 10^6 kg/m2/sec / 2.8 * 10^6 kg /m2/sec

Density in units according to the Hounsfield scale (HU) and hardness according to the Vickers method (HV) were measured on the obtained materials. The measured average density of "hard" samples was 2530 HU units, "soft" samples -1400 HU units. The Vickers hardness measurement was carried out with a load of 100 g and a holding time of 10 seconds. The measured value of microhardness for "hard " specimens was 90 HV, and for "soft" specimens it was 60 HV. For testing, 3 sizes of stone samples in the form of a rectangular parallelepiped were made. Each stone size corresponded to a specific size of the lithotripter probe. In experiments with EHL, probes of three standard sizes were used: 3.0 Fr, 4.5 Fr, and 7.0 Fr. For NEIL, 2.7 Fr, 4.5 Fr, and 6.0 Fr probes were used. We chose the sizes of stones for the respective probes so that hard stones were destroyed by NESA approximately within 1/3 of the working life of the probe at maximum pulse energy. Comparison of the efficiency of lithotripters in experiments was performed for pairs of probes, which corresponded to a certain stone size (Table 2).

Table 2. Choice of probes and stones to compare the effectiveness of lithotripters.

Comparison No.	NEIL probe	EHL probe	Cameo size, mm
1	2.7Fr	3.0Fr	5x5x4
2	4.5Fr	4.0Fr	8x8x4
3	6.0Fr	7.0Fr	8x8x5

In all experiments, one probe was used to destroy one stone of a certain size.

EXPERIMENTAL TECHNIQUE

Comparative studies were carried out in physiological saline (0.9% NaCl solution, at room temperature). Stones of the specified size for each type of lithotripter probe were placed on a stainless steel grid with a cell size of 2x2 mm, immersed in the solution. The distal part of the probe was placed at an angle of 90 degrees to the horizontal surface of the “stone” and brought into contact with the sample (NESA) or placed in close proximity to the surface of the stone (EHL). After this, an electric impulse was applied to the probe from the corresponding lithotripter. After a series of pulses was applied, the surface of the destroyed stone was examined, after which the experiment continued. Reinstallation of the probe was also performed after each loss of contact with the destroyed stone. The experiment was terminated when no fragments of the destroyed stone remained on the surface of the mesh, that is, when the fragmented sample was crushed into pieces less than 2 mm. This was the successful criterion for the experiment. To prevent the influence of the “stone” repulsation effect (repulsion effect) on the results of the experiment, the stone or its part was held in the crushing process with special tweezers. Each experiment with a given type and size of the "stone" and the probe was repeated at least 5 times.

At a given energy, the number of pulses needed to destroy a certain stone behind a given type of probe was recorded. The performance of NEIL and EHL was compared at comparable energy levels using the same stone types and corresponding probe diameters. Subsequently, the recorded data were recalculated for both cases into the accumulated energy required for the complete fragmentation of the stone into pieces less than 2 mm in size.

The experiments used:

1. Nanosecond electric pulse lithotripter " Urolit -105 M " (Lithotech Medical Ltd., Israel) (Fig. 6 a), having an energy n pulse from 0.3 to 1 j. (in this case, the energy range is divided into 8 parts1 with a step of 0.1 J.), operating in the mode of single pulses and a frequency mode of 1-5 Hz (1 Hz step).

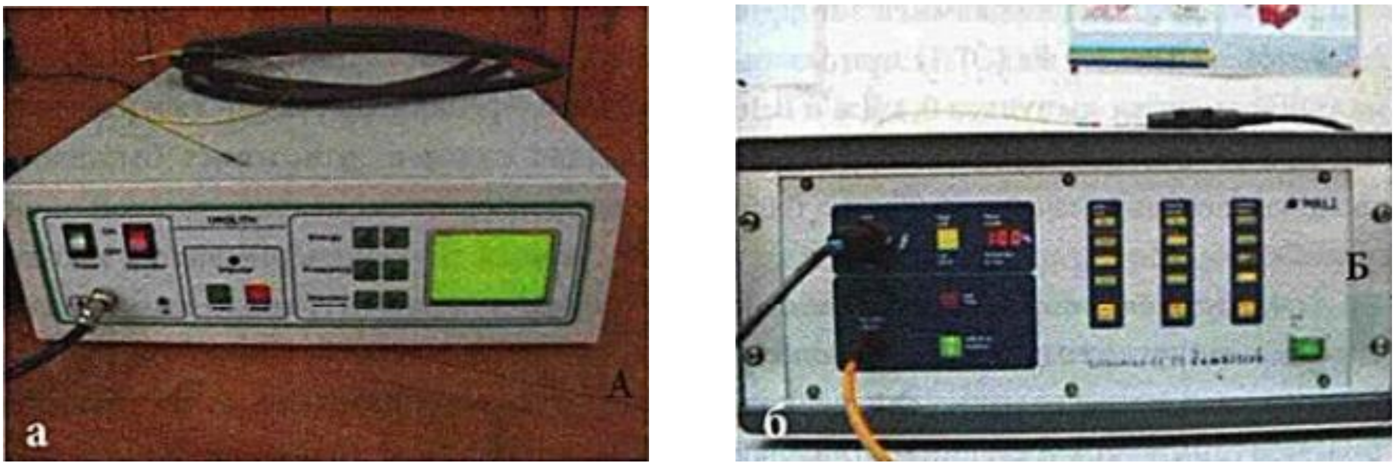


Fig.6. Instruments used in experiments. A. nanosecond electropulse lithotripter "Urolit-105M"; b. electrohydraulic lithotripter « Lithotron EL 25".

2. Electrohydraulic lithotripter " Lithotron" EL 25 Combilith " (" Walz Elektronik GmbH, Germany) (Fig. 6 b), which has an energy per pulse of 0.36 and 0.96 J, operates in the mode of single pulses and the same frequency mode.

The operating parameters of the equipment for performing comparative tests are given in Table. 3. As can be seen from the table. 2 and 3, some difference in the minimum and maximum powers of the compared devices is partially compensated by the difference in probe diameters.

Table 3. Experimental conditions for the considered lithotripters.

NEIL			EHL		
Energy per impulse, J	Emin	0.4	Energy per impulse, J	Emin	0.36
	Emax	1		Emax	0.96
frequency mode		Single pulse mode	frequency mode		Single pulse mode
Number of consecutive pulses applied to the stone		changeable	Number of consecutive pulses applied to the stone		changeable

After the tests, a statistical analysis of the measurement results was performed. The criterion for evaluating the significant difference between the results obtained for the two devices under study was the p -value criterion. At a statistical significance level of 5%. The calculation was carried out using the program SPSS statistics.

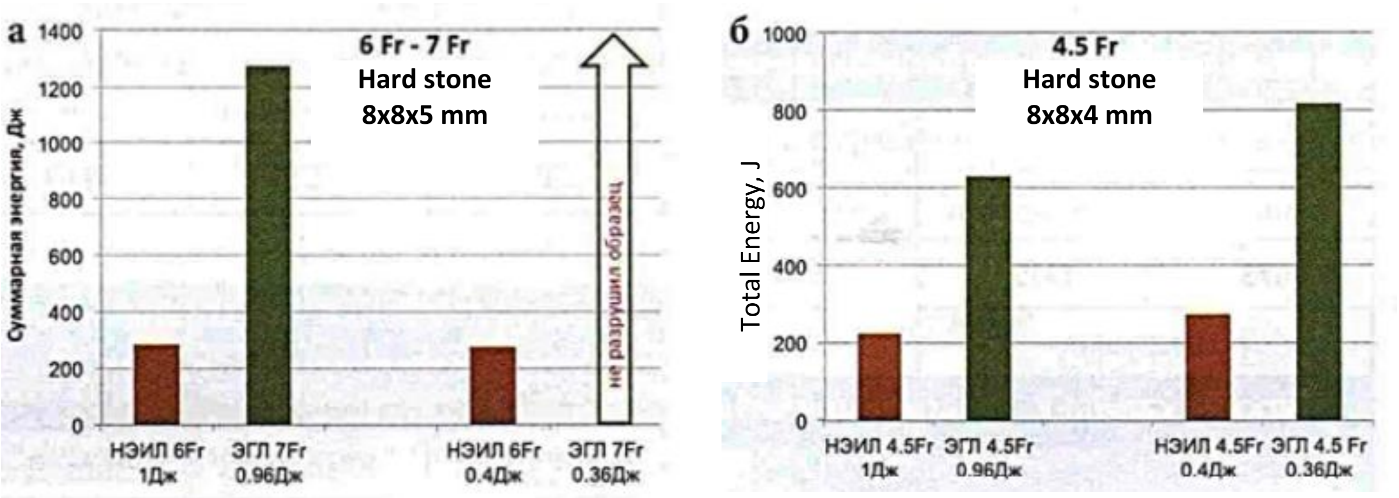
EXPERIMENTAL RESULTS AND DISCUSSION

Total energy (E sum) and the number of pulses required to destroy a "stone " of a certain type and size for two compared lithotripters in the experiment are given in Table. 4.

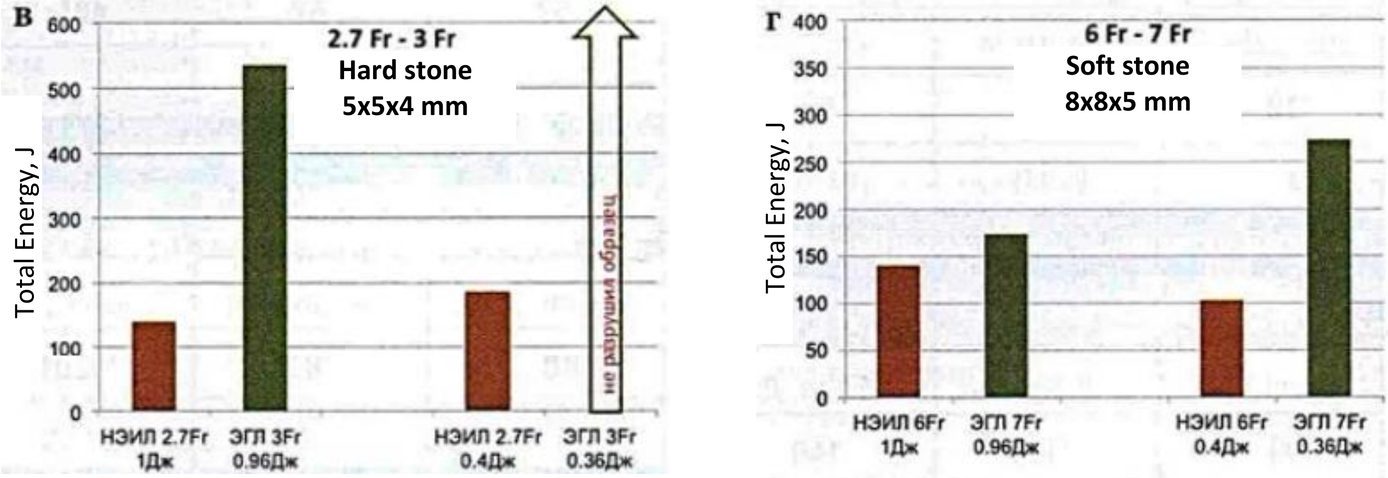
Table 4. Test results, where E sum is the total energy required to destroy the stone.

Hard "stone", Electropulse Lithotripter, Pulse Energy 1 J					
Probe 2.7 Fr, stone 5 x 5 x 4 mm		Probe 4.5 Fr, stone 8 x 8 x 4 mm		Probe 6 Fr, stone 8 x 8 x 5 mm	
E sum, J	Impulse count	E sum, J	Impulse count	E sum, J	Impulse count
141	141	222	222	280	280
(± 76)		(± 22)		(± 59)	
Hard "stone", Electrohydraulic Lithotripter, Pulse Energy 0.96 J					
Probe 3 Fr, stone 5 x 5 x 4 mm		Probe 4.5 Fr, stone 8 x 8 x 4 mm		Probe 7 Fr, stone 8 x 8 x 5 mm	
E sum, J	Impulse count	E sum, J	Impulse count	E sum, J	Impulse count
535	557	630	656	1276	1329
(± 169)	(± 176)	(± 200)	(± 208)	(± 181)	(± 189)
Hard "stone", Electropulse Lithotripter, Pulse Energy 0.4 J					
Probe 2.7 Fr, stone 5 x 5 x 4 mm		Probe 4.5 Fr, stone 8 x 8 x 4 mm		Probe 6 Fr, stone 8 x 8 x 5 mm	
E sum, J	Impulse count	E sum, J	Impulse count	E sum, J	Impulse count
186	465	273	683	275	688
(± 90)	(± 225)	(± 82)	(± 205)	(± 70)	(± 176)
Hard "stone", Electrohydraulic Lithotripter, Pulse Energy 0.36 J					
Probe 3 Fr, stone 5 x 5 x 4 mm		Probe 4.5 Fr, stone 8 x 8 x 4 mm		Probe 7 Fr, stone 8 x 8 x 5 mm	
E sum, J	Impulse count	E sum, J	Impulse count	E sum, J	Impulse count
473	1315	818	2272	1904	5288
Has not been destroyed		(± 86)	(± 238)	Has not been destroyed	
Soft "stone", Electropulse Lithotripter, Pulse energy 1 J					
Probe 2.7 Fr, stone 5 x 5 x 4 mm		Probe 4.5 Fr, stone 8 x 8 x 4 mm		Probe 6 Fr, stone 8 x 8 x 5 mm	
E sum, J	Impulse count	E sum, J	Impulse count	E sum, J	Impulse count
57	57	129	129	139	139
(± 10)		(± 45)		(± 38)	
Soft "stone", Electrohydraulic Lithotripter, Pulse energy 0.96 J					
Probe 3 Fr, stone 5 x 5 x 4 mm		Probe 4.5 Fr, stone 8 x 8 x 4 mm		Probe 7 Fr, stone 8 x 8 x 5 mm	
E sum, J	Impulse count	E sum, J	Impulse count	E sum, J	Impulse count
80	83	201	209	172	179
(± 17)	(± 18)	(± 90)	(± 94)	(± 48)	(± 50)
Soft "stone", Electropulse Lithotripter, Pulse energy 0.4 J					
Probe 2.7 Fr, stone 5 x 5 x 4 mm		Probe 4.5 Fr, stone 8 x 8 x 4 mm		Probe 6 Fr, stone 8 x 8 x 5 mm	
E sum, J	Impulse count	E sum, J	Impulse count	E sum, J	Impulse count
38	95	90	224	101	253
(± 5)	(± 13)	(± 40)	(± 99)	(± 22)	(± 55)
Soft "stone", Electrohydraulic Lithotripter, Pulse energy 0.36 J					
Probe 3 Fr, stone 5 x 5 x 4 mm		Probe 4.5 Fr, stone 8 x 8 x 4 mm		Probe 7 Fr, stone 8 x 8 x 5 mm	
E sum, J	Impulse count	E sum, J	Impulse count	E sum, J	Impulse count
41	113	140	389	274	761
(± 17)	(± 41)	(± 56)	(± 140)	(± 138)	(± 346)

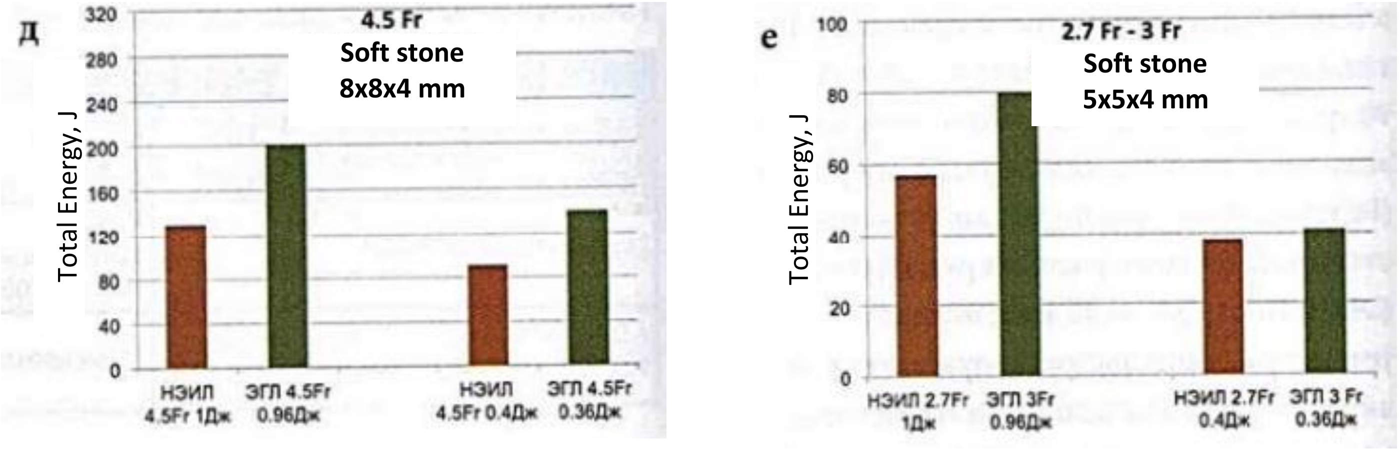
The criterion for comparing the efficiency of devices was the total energy expended on the destruction of the stone and leading to its required fragmentation. For clarity, the data on the total energy of the pairs of probes under consideration (Table 4) are shown in Figs. 7.



A – probes 6.0 and 7.0 Fr, hard stone 8x8x5 mm	B – probes 4.5 and 4.5 Fr, hard stone 8x8x4 mm



C – probes 2.7 and 3.0 Fr, hard stone 5x5x4 mm	D – probes 6.0 and 7.0 Fr, soft stone 8x8x5 mm



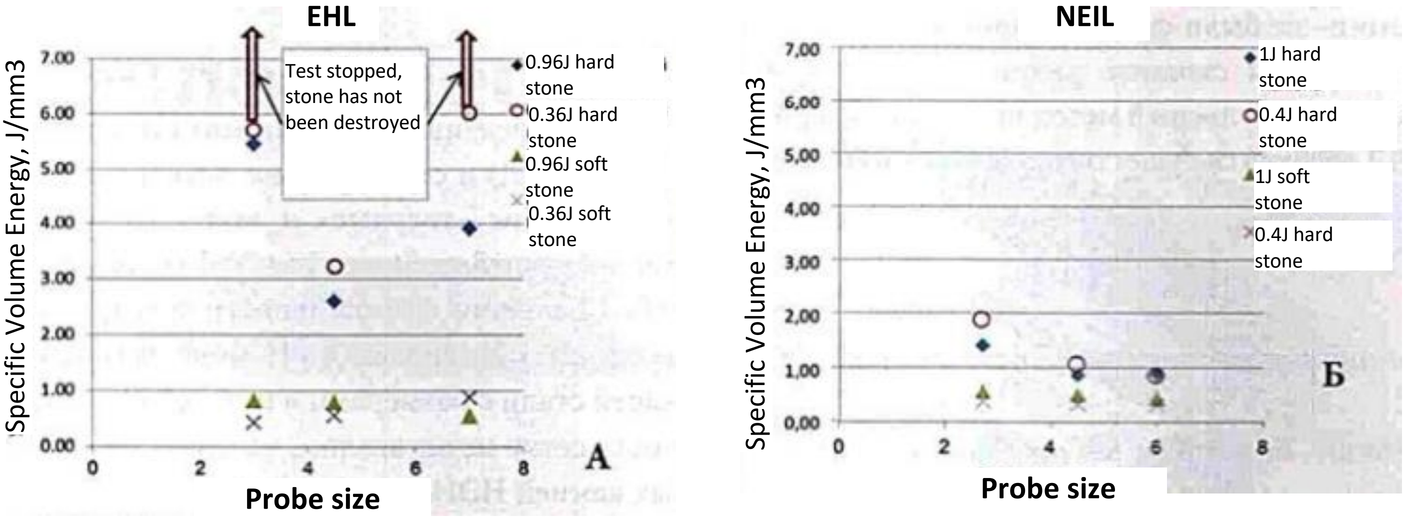
E – probes 4.5 and 4.5 Fr, soft stone 8x8x4 mm	F - probes 2.7 and 3.0 Fr, soft stone 5x5x4 mm

Figure 7. Comparison of the total energy spent on stone fragmentation for the selected pairs of probes.

Thus, from the given data (Table 4) and the constructed diagrams (Fig. 7 a-f) it is clearly seen that in almost all the cases studied, during the destruction of artificial stones, NEIL requires significantly lower energies than EHL, which indicates its higher efficiency. At the same time, it should be noted that the number of successfully fragmented stones in our work using NESA was 100%, that is, in all the experiments performed, the samples were destroyed into pieces less than 2 mm. At the same time, when EHL was used in two experiments, the “stones” were not fragmented (Fig. 7a, c; “hard stones”, energy 0.36 J). The calculated value of " p " for most of the considered cases in which it was possible to carry out a statistical assessment (except for two experiments in which the electrohydraulic lithotripter failed to destroy the studied samples at all) was less than 0.04 ($p < 0.04$). And only in one case, when soft stones were destroyed by probes of 2.7 Fr (NEIL) and 3.0 Fr (EHL) at a minimum pulse energy of 0.4 J and 0.36 J, respectively, the value of « p » was above the threshold value of 0.05 ($p > 0.05$) (Fig. 7f).

From the data presented (Table 4, Fig. 7) it follows that for the vast majority of the studied cases, when fragmenting artificial stones, a nanosecond electropulse lithotripter requires significantly more low total energy for their destruction than the electrohydraulic lithotripter, that is, it is more efficient. The differences in the total energy of destruction, the number of pulses, and the operating time of the device in many cases differ by several times. At the same time, based on the results of statistical processing of the data obtained in experiments with the destruction of soft stones with probes of 2.7 F g (NEIL) and 3.0 F g (EHL) at a minimum pulse energy of 0.4 J and 0.36 J, we can say that, despite for some difference in the results of the experiment (Table 3, Fig. 7f), we cannot unambiguously declare the advantage of NEIL in this specific case, since the calculated value of the “ p ” criterion is above the threshold value. That is, in this case, only at low pulse energies, probes of small diameter and “soft” stones, we have similar results for the two methods of contact lithotripsy under consideration. In all other cases studied (especially when using - pulses with an energy of approximately 1 J on “hard” stones), the electric impulse method of stone destruction demonstrated its significant advantage over the electrohydraulic method, which is unambiguously confirmed by the statistical processing of the data. In addition to a significant difference in the values of the recorded indicators, the spread of their values in most cases is also significantly lower for NEIL compared to EHL.

Taking into account the obtained results, it is also interesting to consider the dependence of the total energy expended for the destruction of the “stone” reduced to its volume (the specific energy of fragmentation of the “stone”) on the density of the “stone” and the size of the probe for both lithotripters. The data on the specific total energy of fragmentation for each lithotripter depending on the size of the probe and the density of the “stone” are shown in Fig. 8 a, b.



A. Electrohydraulic lithotripter

B. Nanosecond electric pulse lithotripter

Fig. 8. Dependence of the specific energy of stone fragmentation on its density and the size of the lithotripter probe.

The results obtained show completely different dependences of the specific energy spent on the destruction of "stones ", both on the density of the sample and on the diameter of the probe. Thus, for the EHL, there is no explicit dependence of the specific pulse energy applied to the “stone” on the density of the sample material and on the probe diameter. At the same time, the destruction of "hard stones" always requires significantly higher specific energies than the destruction of "soft stones" (Fig. 8 a). At the same time, for LESA, there is a clear dependence of the specific energy on the density of the material being destroyed, and there is a clear decrease in the specific energy required for the destruction of the "stone" with an increase in the size of the probe (Fig. 8 b). At the same time, the total, averaged over all the results, the level of the required specific energy of fragmentation of "stones" for NEIL is more than 4 times lower than for EHL (Fig. 9).

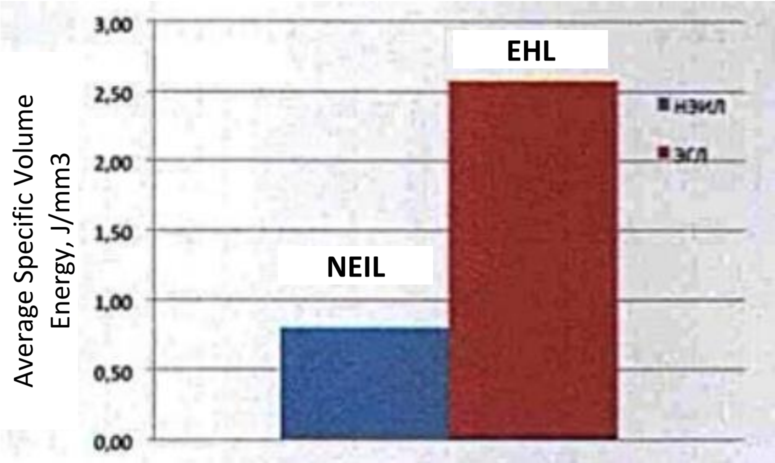


Figure 9. Total specific energy required for the destruction of experimental samples.

Thus, for LESA, significantly lower values of the total energy for the destruction of the “stone” and, accordingly, the time spent for this, are required for comparable pulse parameters.

As described earlier, the actions of the compared lithotripters differ in the mechanism of destruction of the samples and, first of all, in the way of transferring energy to the stone with the aim of its subsequent destruction. In the case of nanosecond electropulse destruction, the energy is, as it were, directly “pumped” into the stone, in contrast to electrohydraulic lithotripsy with AI. In this regard, NEIL requires significantly less energy for the destruction of stones compared to EHL, which was proved experimentally. In addition, the NESA efficiency depends on the penetration distance between the probe electrodes, and this distance is related to the probe diameter; therefore, with an increase in its diameter, less specific energy is required to destroy the stone. Thus, the obvious differences in the experimental results and dependences shown in Figs. 7 and fig. 8 experimentally confirm the statement that, despite the external similarity of the two methods (feeding an electric pulse to the probe, an electric discharge at the end of the probe), we are dealing with different mechanisms of destruction of solids. The difference in the mechanisms of destruction of stones explains the significant difference in the obtained lengths x, as well as the different infusion of density (hardness) of samples of artificial stones on the results obtained.

CONCLUSION

In the present work, comparative experimental studies of the efficiency of a nanosecond electropulse lithotripter with an electrohydraulic lithotripter were carried out. The compared lithotripters differ in the mechanisms of sample destruction, which leads to a different effect of the density and hardness of stone samples on the results obtained. The research results show that for most modes of operation and types of stone samples, NEIL requires significantly lower energy and less time to destroy the "stone" than EHL. At the same time, the number of successfully fragmented x samples when using NEJL was 100%, that is, in all the experiments performed, the samples were destroyed into pieces less than 2 mm, while when using EHL, in some cases, it was not possible to obtain positive results, that is, the stones did not were fragmented. Therefore, in all respects, an electropulse lithotripter is a more efficient device for contact crushing of urinary stones than an electrohydraulic one.

Summary:

The purpose of this work is a comparative study of the efficiency of fragmentation of artificial urinary stones with a new nanosecond electric pulse lithotripter (NEIL) and a standard electrohydraulic lithotripter (EHL). Samples of two types of stones were used, simulating "hard " and "soft" urinary stones, for the preparation of which BegoStone heavy-duty gypsum was used. Three sizes of probes were used for EHL: 3.0 Fr, 4.5 Fr, and 7.0 Fr; for NEIL, probes 2.7 Fr, 4.5 Fr, and b.0 Fr. Comparison of the efficiency of lithotripters in experiments was carried out for pairs of probes, which corresponded to a certain stone size. "Stones" of the specified size for each type of lithotripter probe were placed on a stainless steel grid with a cell size of 2x2 mm, immersed in water at room temperature. The experiment was terminated when no fragments of the destroyed stone remained on the surface of the grid. The results showed that for the destruction of most artificial stones, NEIL required significantly lower energy and less time than EHL. The number of successfully fragmented "stones" when using NEIL was 100%, at the same time, when using EHL in two experiments, "stones" were not fragmented. Only at low pulse energies, probes of small diameter and "soft " stones, similar results were obtained for the two methods of contact lithotripsy under consideration. In all other cases, the electropulse method demonstrated a significant advantage over the electrohydraulic method. It is shown that LESA requires significantly lower values of the total energy for the destruction of the "stone".

Key words: electropulse lithotripter, electrohydraulic lithotripter, urinary stones.

Literature

1. Urology: Textbook / Ed. ON THE. Lopatkin. 7th ed., revised. and additional M.: GEOTAR-MED, 2011. 815 p.: ill.
2. Martov A.G., Ergakov D.V. Achievements of modern endourology: Proceedings of the XII Congress of the Russian Society of Urology. Moscow, 2012, pp. 417–426.
3. Martov A.G., Safarov R.M., Gushchin B.L. Comparative characteristics of the effectiveness and safety of the use of various types of contact lithotripters. Plenum of the Board of the Russian Society of Urology. Saratov, September 15–17, 1998. Moscow, 1998, pp. 312–313.
4. Piergiovanni M., Desgrandchamps F., Cochand-Priollet B. et al. Ureteral and Bladder Lesions After Ballistic, Ultrasonic, Electrohydraulic, or Laser Lithotripsy. J. Endourol. 1994;8(4): 293–299.
5. Sofer M., Watterson JD, Wollin TA et al. Holmium:YAG laser lithotripsy for upper urinary tract calculi in 598 patients. J. Urol. 2002;167:31–34.
6. Marks AJ, Teichman JM Lasers in clinical urology: state of the art and new horizons. World J Urol. 2007; 25(3): 227–233.
7. Santa-Cruz RW, Leveillee RJ, Krongrad A. Ex vivo comparison of four lithotripters commonly used in the ureter: what does it take to perforate? J. Endourol. 1998;12(5):417–422
8. Chernenko V, Diamant V, Lerner M, Khachin S, Khachin V. Method for intracorporeal lithotripsy fragmentation and apparatus for its implementation. // Patent US 7087061 and US 20070021754
9. Usov A.V., Semkin B.V., Zinoviev N.T. Transient processes in installations of electropulse technologies. St. Petersburg: Nauka, 2000. 160 p.
10. Gudkov A.V., Boshchenko V.S., Afonin V.Ya. Contact electropulse lithotripsy. Urology. 2009;2:32–37.
11. Rumyantsev A.A., Dutov V.V., Belyaev V.V. Transurethral contact electropulse ureteropyelolithotripsy. Urology. 2011;3:40–45.
12. Boshchenko VS, Gudkov AV, Afonin VY et al. Assessment of efficiency and safety of retrograde contact electropulse lithotripsy: Simple pilot multicenter study. 27th Annual Congress of the European Association of Urology, Paris 2012. European Urology – Supplements, 2012-02-01, e496.
13. Siegel JH, Ben-Zvi JS, Pullano WE. Endoscopic electrohydraulic lithotripsy. // Gastrointest Endosc. 1990 Vol. 36. P. 134.
14. Grocela JA, Dretler SP. Intracorporeal lithotripsy. instrumentation and development. // Urol Clin North Am. 1997 Vol. 24. No. 1. P. 13-23.
15. Zhong P, Tong HL, Cocks FH, Preminger GM. Transient oscillation of cavitation bubbles near stone surface during electrohydraulic lithotripsy.// J Endourol. 1997 Vol. 11, No. 1. P. 55-61.
16. Boshchenko VS, Gudkov AV, Arseniev AV, Afonin VY. Contact electric pulse impact on urinary tract wall in dogs: 1-year experimental morphological study. // 27th Annual EAU Congress, February 2012, Paris. Eur Urol Suppl. 2012. Vol. 11. P. e101.
17. Esch E, Simmons WN, Sankin G, Cocks HF, Preminger GM, Zhong P. A simple method for fabricating artificial kidney stones of different physical properties. // Urol Res. 2010 Vol. 38, No. 4. P. 315-319

18. Liu Y, Zhong P: BegoStone – a new stone phantom for shock wave lithotripsy research. // J Acoust Soc Am. 2002 Vol. 112. No. 4. P. 1265-1268.