# Comparison of the effectiveness of crushing concrements in the urinary tract with the use of holmium laser and sonotrode

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KEY WORDS

urinary stones ◗ lithotripsy ◗ holmium laser ◗ sonotrode

ABSTRACT

**Introduction.** Holmium lasers and ultrasound probes are widely used in urinary stone lithotripsy. The authors present a comparison of both methods in urinary stones lithotripsy.

**Materials and methods.** We analyzed 164-patients who underwent endoscopic lithotripsy. Ninety-eight of them (group I) were treated with the holmium laser Omni-Pulse Max 80 and were compared to the other 66-patients (group II) who were operated on with an ultrasound probe (sonotrode). Prior to the procedures, all patients were exposed to urological ultrasound and radiological imaging in order to localize the stone. The state where the stones were invisible in the radiological and renal ultrasound imaging that was performed after the operation was considered to be effective. Patients were operated under intravenous general or subepidural anesthesia.

**Results.** The effectiveness of laser lithotripsy in the bladder amounted to 100% (25 of 25 patients). In the case of stones localized in the ureter it reached 89%. The total effectiveness of the procedure reached 92% (90 out of 98 procedures). In group II, the total effectiveness of the procedure reached 79% (52 out of 66 procedures). In group I, two cases the inflammatory changes of the ureter made the endoscopy impossible. These two patients were operated with open surgery. In one case, the laser lithotripsy was complicated with a perforation of the ureter.

**Conclusion.** The results prove that laser lithotripsy is a method of high effectiveness with a low risk of complication. It might surpass sonotrode and become its alternative. Both methods have both advantages and disadvantages.

## INTRODUCTION

The first trials of bladder endoscopy, with the use of primitive instruments, were performed in the year 1806 and this date can be admitted as the beginning of urinary endoscopy [1]. Gradual improvement of the instruments, changing their shape and introduction of fiber optics, allowed not only for the endoscopic bladder assessment, but also for performing the first surgery in 1980, during which concrement was removed with the procedure of ureterorenoscopy (URS). From this time on, many methods of crushing concrements in the urinary tract have been introduced. The method widely used until today, created convenient conditions for endoscopic treatment of urolithiasis and is referred to as sonotrode, which uses ultrasound waves for its effects. In the 90s, laser radiation was adopted for endoscopic treatment of urolithiasis. Its physiochemical features proved to be very useful in urinary stone crushing [2-4]. Nowadays, the most popular device using this type of energy is the holmium laser. It provides exceptional conditions for effective and safe treatment of urolithiasis [5]. Since 2008, the 2nd Clinic of Urology in Łódź has used the holmium laser Omni Pulse Max 80 Watt (USA). It is a device whose medium is a solid body with the addition of holmium. It works within the wavelength spectrum of 2,100 nm and is an impulse laser. Its functionality is based largely on photomechanical and photoacoustic effect [6]. Under the influence of the energy provided by the laser, in the aqueous environment located between the concrement surface and the laser fiber, a vaporization follicle appears. The implosion of the follicle causes a shockwave, which destroys the stone structure. Additionally, this wave causes turbulence of liquid surrounding the stone and disperses the pieces of the crushed calculi. The auxiliary photothermal effect consists in direct absorption of the laser energy by the stone. The water molecules contained in the stone absorb particular lengths of the laser light wave, which lead to their vaporization. Moreover, the high temperature accompanying the laser impulse energy has a destabilizing effect on the chemical structure of the concrement. As a result of the changes in chemical bonds, disintegration of its structure occurs. In the case of direct laser influence on the ureter mucosa, the depth of the thermal influence amounts to 0.4 mm [7, 8].

Another device for crushing concrements in the urinary tract, still very popular and recognized by urologists today, is an ultrasound probe set (sonotrode). It is an ultrasound generator producing output voltage of frequency equal to the resonance frequency of the oscillating set consisting of a converter and a sonotrode. The ultrasound energy is generated in the converter outside the body and outside the device. Output voltage from the ultrasound generator agitates two piezo ceramic elements, transmitting the vibrations to the sonotrode. Agitating the sonotrode generates a standing wave of resonance frequency, whose maximum value falls on its end.

The purpose of the paper is comparing procedures of crushing concrements in the urinary tract performed with the use of sonotrode and holmium laser. Effectiveness, procedure duration,

**Table 1.** Patients

| Sex | Group I | Group II |
|---|---|---|
| Women | 41 (42%) | 32 (49%) |
| Men | 57 (58%) | 34 (51%) |

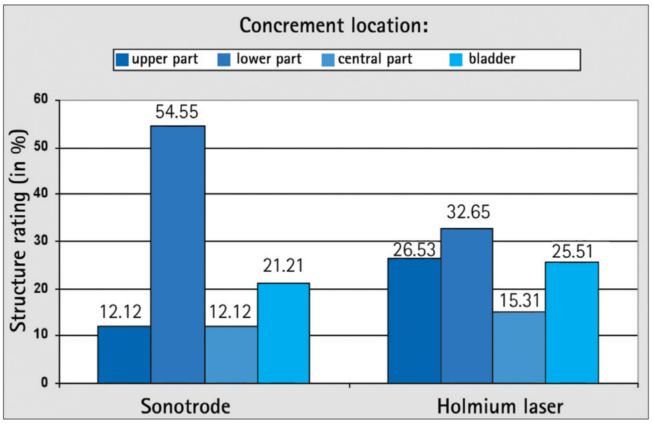


**Fig. 1.** Concrement location.

prevalence rate of intraoperative and postoperative complications, and the complexity level of the procedures were evaluated.

## MATERIAL

The evaluated group consisted of 168-patients who underwent the procedure of endoscopic crushing of concrements in the urinary tract. The procedures were performed in the 2nd Clinic of Urology in Łódź within the period from September 2008 to March 2010. All 66 subsequent procedures, starting from September 2008 up to the moment of buying holmium laser Omni Pulse Max 80 W, were performed with the use of sonotrode (group II). Starting from this moment, 98 subsequent patients were operated with the use of holmium laser (group I). Group I consisted of 41 (42%) women and 57 (58%) men (Tab. 1). The average age of patients is 39-years (18-63). In 25 (26%) cases the stone was located in the bladder and in 73 (74%) cases – the ureter (in 32 cases (32%) – its lower part; in 15 cases (15%) – its central part; and in 26 cases (26%) – its upper part). The size of the concrements ranged from 10- to 21-mm in the case of the bladder and from 5- to 17-mm in the ureter. The group of patients operated on with the sonotrode (group II) consisted of 32 (49%) women and 34 (51%) men. The average age of patients was 45-years (range: 19-67). In 14 cases (21%) the stones were crushed in the bladder and in 52 cases (79%) in the ureter (in 36 cases (55%) - its lower part; in 8 cases (12%) – its central part; and in 8 cases (12%) – its upper part) (Fig. 1). The size of the concrements was between 7- and 30-mm. The statistic analysis did not show a statistically significant difference between the evaluated groups in terms of the size of the crushed concrements (arithmetic average: 9.44-mm in group II and 9.76-mm in group I) (Table 1).

## METHOD

For performing the procedures, holmium laser Omni Pulse Max 80 Watt™ (Trimedyne®, USA) was used. Fibers of 550- to 1,000-nm were used for crushing stones in the bladder, and in the case of the ureter, 365- to 550-nm as suggested by European Guidelines [15]. The laser power used in the procedures was 40-W in the case of bladder stones and 20-W for the concrements located in the ureters. The other operating tool was the Ultrasound Probe (Richard Wolf, Germany), the sonotrode. A sonotrode with the diameter of 3.5-mm was used for crushing stones in the bladder and in the ureters, a 1.5-mm probe was used. For introducing both devices, a 8/9- or 8-Ch with optic 12° ureterorenoscope (Richard Wolf) was used. The indication for performing the procedures were based on identification of the concrements in imaging examinations, done either ambulatory or during the stay in the clinic, were the same for all patients. In the case of every patient qualified for the procedure, ultrasound examination of the urinary tract was done, as well as urography or an X-ray image. In group I, 81 (83%) patients were operated on with general intravenous anesthesia and 17 (17%), as the planned duration of the procedure was long, received subarachnoid anesthesia. In group II, 59 (89%) patients received general intravenous anesthesia and 7 (11%) – subarachnoid anesthesia. Preoperative examinations, the manner of qualifying patients for the surgery, the surgery conditions, the manner of inserting the instrument into the urinary tract, the postoperative care, and the way of assessing the effectiveness of the procedure were identical for all patients. For the surgery the patients were laid in a lithotomy position. The procedure was performed by one operator accompanied by a single assistant. In order to fill the bladder, treated sterile water from the water treatment station Medsys 20 HP was used. After the introductory cystoscopy, in the case of ureter stones, a leading wire was inserted into the ureter and afterwards – a rigid ureterorenoscope made by Wolf. An anti-migration device was not used to perform lithotripsy, however, the Dormia basket was used to evacuate fragments of crushed stones. After performing lithotripsy, depending on the extent of concrement disintegration, a ureteral catheter and bladder catheter 16-Fr was left. In case of uncomplicated URS stenting was optional as following European Guidelines [15]. In the case of lithotripsy of concrements in the bladder, laser cystoscope was used and fragments of disintegrated concrements were washed out with the use of Elik type aspirator. As the follow-up examination after the surgeries, ultrasound examination of the urinary tract was performed during the patient's stay in the clinic or plain abdominal X-ray as ambulatory control in the Urological Outpatient Clinic.

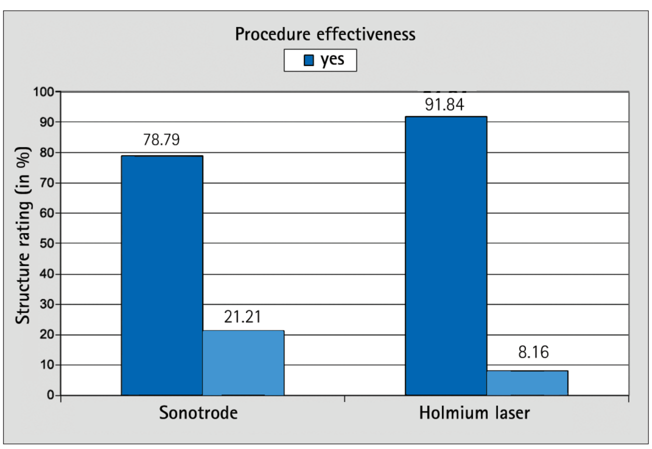


**Fig. 2.** Procedure effectiveness.

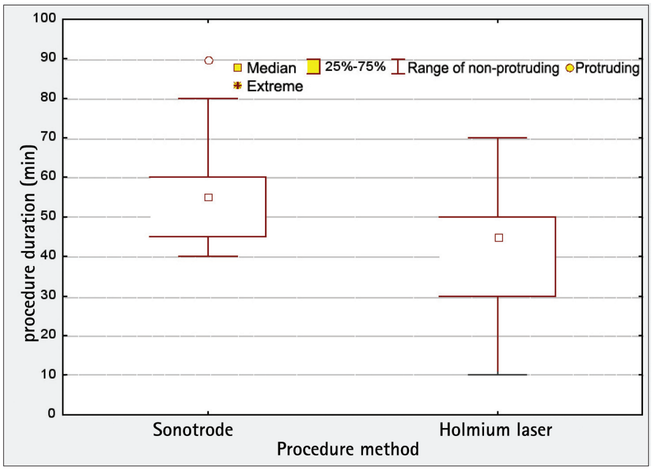


**Fig. 3.** Procedure duration.

As a criterion of effectiveness, the following state was approved: the concrement was invisible in the postoperative follow-up image examinations or it formed a shadow of sand with the grain diameter smaller than 2-mm. Following the European Guidelines [15], each patient was subject to oral antibiotic prophylaxis (ciprofloxacin).

## RESULTS

In the case of procedures performed with the use of holmium laser, the effectiveness of crushing stones in the bladder amounted to 100% (25 out of 25 cases). The effectiveness of crushing concrements in ureters reached 89%. Total effectiveness of procedures (stone-free rate) with the use of holmium laser amounted to 92% (90 out of 98 procedures), which correlates with other authors' reports [9-14]. Ilker et al. describes an effectiveness of 95.1% in a group of 205 patients. Devarajan, analyzing 300 procedures with the use of holmium laser, achieved effectiveness on the level of 90%. In their study, Scarpa et al. obtained 92.6% effectiveness. In the case of the sonotrode, the effectiveness amounted to: 85% (12 out of 14 procedures) in the bladder and 76% (40 out of 52 procedures) in the ureter, which resulted in total effectiveness (stone-free rate) of 79% (52 out of 66 procedures). Juxtaposition of the given results showed statistical significance ($p < 0.05$) (Fig. 2). All patients who were not stone-free after first ureterorenoscopy underwent ESWL procedure. There were no indications for second URS. The composition of the stones was not identified and was not taken under consideration. The average duration of the procedure with the use of holmium laser is 42 minutes (17-135 min), whereas in the case of sonotrode – 56 minutes (20-120 min), which is statistically significant ($p < 0.05$) (Fig. 3). In the case of 75 (76%) patients, total disintegration of concrement was observed, after using holmium laser. After using sonotrode, total disintegration of concrement was achieved in the case of 33 (50%) patients. In cases of four (6%) patients the uncrushed concrements were dislocated into the renal pelvis and in cases of three (4%) a piece of crushed concrement was dislocated into the renal pelvis. In cases of four (6%) patients the stones turned out to be utterly resistant to the operation of sonotrode. These concrements were successfully crushed with the use of a holmium laser during the same procedure. No concrements were observed to be utterly resistant to the influence of the holmium laser light. In cases of two patients (2%) operated on with the use of holmium laser, reaching the concrement proved to be impossible, because of significant constriction of the ureter. These patients were subject to an open surgery, which resulted in successful concrement removal. In case of 1 (1%) patient, ureter multi-focal perforation occurred as a result of direct influence of the laser beam on the ureter wall. Because of massive urinary leakage in the retroperitoneum and severe abdominal pain the patient underwent an emergency surgery. After supplying the perforation spot, the catheter D-J was left in the ureter for a period of 3-weeks. This complication occurred at the initial stage of using the laser. The complications prevalence rate in the examined group of patients amounts to 6% (6 patients). The average duration of patients' stay in the Clinic after the laser procedure is 2.55 days and after the sonotrode procedure 3.55 days ($p < 0.05$). The ureter catheter was left in cases of 13 (13%) patients after the laser procedure and in cases of 12 (18%) patients after the sonotrode procedure ($p > 0.05$). The average energy dose in the case of bladder lithotripsy amounted to 23.5 J, whereas in the case of ureter 1.8 J. In cases of all patients, directly after the surgery, preventive antibiotherapy was instituted (ciprofloxacin).

## DISCUSSION

The analysis of two patient groups demonstrated that in the light of the studied parameters: procedure effectiveness, procedure duration, extent of concrement disintegration, prevalence of intraoperative and postoperative complications, using holmium laser might outperform using sonotrode. One should remember, though, that both methods have both advantages and disadvantages. A small diameter of laser fiber and its flexibility facilitate insertion of the instrument through the ureterorenoscope and into the urinary tract. The laser „pointer" makes it significantly easier to determine the location of the fiber against the concrement, as well as reduces the risk of directing the laser beam outside the requested area. Our experience shows that it is important to place the fiber ending as close to the concrement surface as possible and by using „short series" of laser radiation impulses. The trial of crushing from further distances, in the case of the concrement location change, might lead to ureter mucosa damage or wall perforation. One needs to remember then, that despite a relatively small depth of thermal influence on the tissues (0.4 mm), the holmium laser is able to cut and perforate the environment formed by the ureter wall. The possibility of advancing the thin laser fiber before the ureterorenoscope ending even by 2- to 3-cm is a big convenience. It makes it possible to reach the surface of the concrements located in the swollen tissues (impacted stone) or in places that are hard to reach. A significant percentage of procedures resulting in total disintegration of the concrements (76%) makes it unnecessary to repeatedly insert a dislodger of Dormia type into the ureter, in order to evacuate the pieces and stone fragments. It was observed that in the case of concrements located in the upper part of the ureter, the possibility of moving into the pyelocalyceal system is higher in the case of sonotrode (11%) than in the case of holmium laser (2%). A big disadvantage of holmium laser is the impossibility to simultaneously crush the concrement and suck off the disintegrated fragments, which is an advantage of sonotrode. The visibility during the surgery becomes poor at times, as a result of the appearance of a thick stone dust, consisting of tiny particles of crushed stone. The disadvantage of sonotrode is its possibility of overheating, which may result in ureter thermal injury. Monitoring of the probe's temperature by touch and taking rest periods to allow the probe to cool when necessary is important. A small diameter of laser fiber makes it possible to perform the surgery even with the use of diagnostic ureterorenoscope, which can make the procedure safe with little trauma to the tissues.

## CONCLUSIONS

Holmium laser is a device creating superb conditions for crushing stones in the urinary tract; it is a safe and highly effective method. In light of the analyzed parameters, the holmium laser might surpass sonotrode and become its alternative. One needs to remember, though, that both methods have both advantages and disadvantages. The holmium laser, when used in a wrong or reckless manner, may cause extensive urinary tract damage (perforation of ureter, bladder or renal pelvis wall) requiring further treatment.

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