OBESITY: A DELICATE ISSUE CHOOSING THE ESWL TREATMENT FOR PATIENTS WITH KIDNEY AND URETERAL STONES?

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Abstract

Context. Urolithiasis and obesity are now public health problems with an increased incidence worldwide. Management of urolithiasis in patients with morbid obesity is usually associated with higher morbidity and mortality compared to non-obese patients. ESWL is a nonsurgical procedure for the treatment of lithiasis. In obese patients the ESWL efficacy is influenced by the skin-to-stone distance or poorer detection of the calculus because of the fatty tissue.

Objective. To highlight the overweight or obese lithiasic patient profile that could be best treated by ESWL.

Subjects and Methods. We evaluated ESWL results in 1393 patients with kidney or ureteral stones between 5 and 20 mm. They were divided into 4 groups according to the BMI: Group A-overweight (BMI=25-30 kg/m²); Group B-grade I obesity (BMI=30-35 kg/m²); Group C-grade II obesity (BMI=35-40 kg/m²) and a control group of normal weight (BMI=18-25 kg/m²).

Results. Patients with a higher BMI required a greater number of ESWL sessions. A statistically significant greater number of patients with a waist circumference of >102 cm required more than 2 SWL sessions (p=0.007). Location of the stones in the pelvic ureter had the highest rate of success for obese patients (p=0.00001). The ESWL success rate in overweight and obese patients can be negatively influenced by BMI, abdominal circumference over 102 cm, and hardness of calculi reflected in the radiopacity on KUB.

Conclusions. In patients with grade II obesity, pyelocaliceal calculus and increased hardness, other urological alternatives to lithiasis should be considered from the beginning.

Key words: Lithiasis, Obesity, Lithotripsy, Lithotripter.

INTRODUCTION

The prevalence of renal lithiasis has increased over the past half century (in men from 6.3% in 1997 to

10.6% in 2007, and from 4.1% to 7.1% in women) (1), it seems that this has occurred simultaneously with major changes in food habits in all European societies (2). At the same time, in industrialised countries, according to Figal *et al.*, obesity has a prevalence of approximately 35% at present, while Finkelstein *et al.* estimate an increase of around 33% over the next two decades(3). In addition, Taylor *et al.* examined a group of 45,988 patients and revealed a positive association between obesity and, respectively weight gain and lithiasis (4).

Other epidemiological studies have indicated that prevalence of nephrolithiasis is double in obese patients compared to non-obese patients (5). The formation of lithiasis is universally considered to be of multifactorial etiology, including genetics, environmental and hormonal interactions, resulting in excessive excretion of stone-forming elements (6). Approximately 80% of renal lithiasis contains calcium, and most calcium lithiasis is mainly composed of calcium oxalate (7). Obesity is also associated with insulin resistance and hyperinsulinemia, metabolic defects that can lead to calcium lithiasis. Urolithiasis has a multifactorial etiology. The most common recognised risk factors are: anatomical anomalies in the kidneys and/or urinary tract, dehydration, family history of renal stones, gout, hyperparathyroidism and metabolic disorders which increase excretion of solutes (e.g.: chronic metabolic acidosis, hypercalciuria, hyperuricosuria).

In the early 1980s the treatment of patients with kidney stones was revolutionised by the introduction of extracorporeal shock wave lithotripsy (ESWL). ESWL is a non-surgical procedure which involves the administration of a series of shock waves, generated by a machine called a lithotripter, to the targeted stone. The shock waves travel into the body, through the skin and tissues, reaching the stone, where they break it into

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small fragments which are passed out with the urine.

Management of urolithiasis in patients with morbid obesity is usually associated with higher morbidity and mortality compared to non-obese patients. In patients with morbid obesity the skin-to-stone distance (SSD) is considerably higher than in non-obese patients, this could mean that it is more difficult positioning of the patient so that the stone is at the focal point of the lithotripter. Furthermore, technically, radiologically or in terms of ultrasound, detection of the calculus may be difficult because fatty tissue can prevent its visualisation.

PATIENTS AND METHOD

We performed a retrospective study on overweight and obese patients who had SWL practised in the Urology and Renal Transplantation Clinic of “Dr. C.I. Parhon”-Iasi, using a second-generation electrohydraulic lithotripter, from January 1, 2015 to January 1, 2018. The ethics committee of the Clinical Hospital “C. I. Parhon” agreed to the study protocol. All procedures were in agreement with the Helsinki declaration, GCP and national Romanian ethics regulations for studies on human subjects. We excluded from the study patients with coagulation disorders and calculi less than 4 mm. Ultrasound, simple kidney radiography (KUB) and intravenous urography were used as imaging methods to diagnose renal and ureteral lithiasis. Based on the WHO classification system we divided the patients into 4 groups: Group A group $n=276$ – overweight ($BMI=25-30 \text{ kg/m}^2$); Group B $n=156$ grade I obesity ($BMI=30-35 \text{ kg/m}^2$); Group C $n=20$ grade II obesity ($BMI=35-40 \text{ kg/m}^2$) and a control group $n=532$ of normal weight ($BMI=18-25 \text{ kg/m}^2$). Demographics were also collected, including patient age, sex and abdominal circumference. For the ESWL procedure we used a second generation electrohydraulic lithotripter with energies between 18 and 20 kV and with a focal area of 4 cm.

Since renal simple radiography was performed on different devices and different levels of exposure to radiations, a comparison between radioopacity calculation and the bone (about 1000 HU) to determine the hardness of lithiasic fragments would have been extremely subjective. To assess the density of the calculus and produce a fair comparison between radioactivity and Hounsfield units, it would have been necessary to evaluate the patients' CT, a method that is too expensive and with higher radiation. For this reason, the efficacy of ESWL was evaluated through KUB (by comparing with the initial X-ray film and using the

opacity of the ribs as an etalon for stone hardness) and sonography. ESWL success was defined as stone-free or clinically insignificant residual fragments. The type of calculus was determined by the opacity on the KUB (lower/equal or higher compared to the opacity of the ribs) and urinalysis, a chemical analysis of the stones was not available.

In order to avoid the renal damage induced by the shock waves we repeat, if necessary, ESWL sessions at 28-30 days.

Although the treatment of the kidney stone disease requires a multidisciplinary team (urologist, nephrologist, endocrinologist, nutritionist and so on), in our hospital we have only urology and nephrology clinics, as such, we need to refer the patients to another centre for further investigations and frequently the feed-back is often poor.

The data were statistically processed using the Student's t-test, chi-square and ANOVA, with $p<0.05$ considered statistically significant.

RESULTS

A total of 1393 patients (639 men and 754 women) were included in the study. Depending on the lithiasis location, 556 patients were treated with SWL for renal lithiasis while 219 were treated for lumbar ureteral lithiasis and 189 for pelvic ureteral lithiasis, in 429 patients we recorded SWL failure and were treated through other endourological methods or were lost from follow-up. The size of the stones was between 5 and 20 mm, the mean calculus size in each group is highlighted in Table 1, there were no differences between groups related to the size of the calculi ($p = 0.39$).

Waist circumference was significantly different between the four groups ($p = 0.00001$) - (mean abdominal circumference - Group A = 96.6 ± 4.2 cm, Group B = 106 ± 5.6 cm, Group C = 114 ± 5.2 cm, Group D = 84 ± 4.4 cm).

The relationship between BMI and number of ESWL sessions is shown in the Table 1.

Depending on the waist circumference we divided the patients into 2 groups: Group 1 - normal circumference (<102 cm in males and <88 cm in females) and Group 2 - increased waist circumference (>102 cm in males and >88 cm in females).

The relationship between sex distribution and number of ESWL sessions is shown in Table 3.

The distribution of calculus localization according to the number of lithotripsy sessions is shown in Table 4.

The stones located in the pelvic ureter required

a significantly lower number of SWL sessions ($p = 0.00001$) compared to lumbar or renal localization according to the Table 5.

Depending on the location of the calculus, the “stone-free” status is shown in Table 5.

SWL failure was recorded in 30.8% of cases (192 men and 237 women):

- 11% of patients with renal lithiasis (percutaneous nephrolithotomy being the treatment of choice afterwards in 7% of patients and 4% of patients, being lost to follow-up);

- 14.8% of patients with lumbar ureteric lithiasis (semirigid ureteroscopy being performed on 8.5% of patients and 6.3 % being lost to follow-up);

- 5% in the pelvic ureteric lithiasis (semirigid ureteroscopy being performed on 3.4% of patients and 1.6% being lost to follow-up).

DISCUSSION

We are currently dealing with the emergence of an obesity epidemic and it is becoming a challenge for health authorities across the globe. Obesity is defined as an increase in body weight by more than 20% over ideal weight (8). In practice, it is expressed by the Body Mass Index (BMI) $> 30 \text{ kg/m}^2$. It can also be classified according to waist circumference $> 102 \text{ cm}$ in males and 88 cm in women according to U.S. Department of Health and Human Services (9).

According to WHO, the percentage of overweight adults in most European countries is 30-80%, while the issue of being overweight and obesity are responsible for over 1 million deaths annually.

The European Association for the Study of Obesity showed that the prevalence of obesity on our

Table 1. The relationship between BMI and number of ESWL sessions

	Group A n=276	Group B n=156	Group C n=20	Group D n=532	P value
Age (years)	42.3±6.2	39.8±2.4	38.2±0.8	41.6±5.3	p=0.47
Sex n F,(%F)	160 (57.97%)	86 (55.12%)	14 (70%)	255 (47.93%)	p=0.06
BMI (Kg/m ²)	26.9±1.2	33.4 ±0.9	36.6±0.4	23.2±1.4	
Waist (cm) F/M	92/104	98/119	109/121	134/129	79/88
Calculus size (mm)	9.3± 1.23	9.8±1.98	9.7±1.33	9.1±1.72	p = 0.39
Calculus location K/UI/Up	154/49/53	78/46/32	11/5/4	313/117/102	p=0.31
1 session	178	95	10	302	p=0.35
2 sessions	68	44	7	175	p=0.039
3 sessions	30	17	3	35	p=0.12

Calculus location at first admission K-kidney; UI= Ureteral lumbar; Up=Ureteral pelvic.

Table 2. The relationship between waist circumference and number of ESWL sessions

No. of ESWL sessions	Group 1(<102 cm)	Group 2 (>102 cm)	
1 session	434	151	p=0.93
2 sessions	232	62	p=0.029
3 sessions	50	35	p=0.0006

Table 3. The relationship between BMI and number of ESWL sessions

No. of SWL sessions	Males	Females
1 session	279	306
2 sessions	111	183
3 sessions	57	28

Table 4. The relationship between calculus localisation and number of ESWL sessions

No. of SWL sessions	Kidney stone	Lumbar ureteral calculus	Pelvic ureteral calculus
1 session	342	102	141
2 sessions	146	104	44
3 sessions	68	11	6

Table 5. The relationship between calculus localisation and stone-free rate after ESWL

No. of SWL sessions	Kidney stone	Lumbar ureteric calculus	Pelvic ureteric calculus
1 session	60%	54.1%	80%
2 sessions	26%	29.1%	13%
3 sessions	3%	2%	2%

continent is 10-25% for men and 10-30% for women. Over the past 10 years, the prevalence of obesity has increased by 10-40% in most European countries, over 50% of the population are overweight or obese (10). According to Roman *et al.* in Romania, in 2014, the prevalence of overweight and obesity was 31.1% and 21.3%, respectively, while in young Romanian adults according to Mocanu the prevalence of overweightness is 17% and for obesity 7%.

Obesity is associated with excessive intake of foods and drinks rich in nutrients responsible for excessive secretion of lithogenic elements such as oxalate, uric acid and sodium, such nutrients lead not only to an increase in lithiasis prevalence, but also in the size of the stones (11).

It seems that obesity and nephrolithiasis are two linked conditions and according to Taylor *et al.* obesity and weight gain increase the risk of kidney stone formation. After surveying 3 very large cohorts (approximately 250.000 individuals), the authors noticed that, for men weighing more than 100 kg, the relative risk (RR) for stone formation was 1.44 (95% confidence interval [CI], 1.11-1.86; $p=0.002$ for trend) vs. men weighing less than 68.2 kg. In older women, RRs for these weight categories were 1.89 (95% CI, 1.52-2.36; $p<0.001$ for trend) while in younger women it was 1.92 (95% CI, 1.59-2.31; $p<0.001$ for trend). Obesity could influence some urinary metabolic risk factors for kidney stone formation (12).

According to Shavit, obese and overweight kidney stone formers have a higher concentration of urinary uric acid and sodium, lower urinary pH and a higher prevalence of hypercalciuria compared with normal weight kidney stone formers. Moreover, the authors established a higher level of uric acid, but not calcium, in stones found in obese and overweight kidney stone formers (13). We could not compare our data, as the stones analysis was not available for our patients.

In the present day, surgery options for kidney stones include shockwave lithotripsy (SWL), percutaneous nephrolithotomy (PCNL), ureteroscopy (URS), and, in selected cases, open surgery. With regard to upper ureteric stones the most common treatments are extracorporeal shock wave lithotripsy (SWL) and ureteroscopy (URS). In our study SWL failure was recorded in 429 cases. In 98 patients PCNL was performed and semirigid ureteroscopy in 160 cases, 171 being lost from follow-up. In a meta-analysis by Drake *et al.* URS, compared with SWL, was associated with a significantly greater SFR up to 4 weeks although the

difference was not significant at 3 months in the included studies. Moreover, URS was associated with fewer retreatments and less of a need for secondary procedures, but also with a greater need for adjunctive procedures, higher complication rates, and longer hospital stay (14). Regarding the upper/middle calyx and renal pelvis renal stones of approximately 2 cm, according to Chaussy *et al.* ESWL should be the standard therapy (15). PCNL, on the other hand, in obese patients with renal stones of approximately 2 cm could be an alternative. In approximately 7% ($n=98$) of our patients, PCNL was the definitive treatment. Trudeau *et al.* in a group of 90,529 individuals and noted that PCNL in obese patients, compared with nonobese patients did not result in higher rates of individual complications or transfusions although it did result in higher rates of prolonged length of hospitalisation and increased total hospital charges (16). Overall, according to the EAU guidelines, compared to PNL and ureterorenoscopy (URS), there are fewer overall complications with ESWL although high BMI can pose a greater anaesthetic risk, and lead to a lower success rate after ESWL. Counterbalancing URS's higher SFRs, SWL is associated with lower morbidity, reported to Clavien-Dindo grading system which has five degrees, from I (any deviation from the normal postoperative course without the need for pharmacological treatment or surgical, endoscopic and radiological interventions) to V (death of the patient) is less frequent in patients treated with ESWL (17,18). In our study we recorded only grade I complication in 8.6% ($n=83$) of patients.

Although for many patients ESWL has become the preferential treatment modality, the success rate can be influenced by many factors such as stone location, size, shape, density, and skin-to-stone distance (SSD). Moreover, stone fragility correlates with the stone density on the radiological plain film. Chaussy *et al.* compared stone density with that of a vertebral spine on a plain abdominal film and concluded that a stone was less likely to break if its density was greater than the rib (19). Bon *et al.* used the 12th rib as an opacity etalon and suggested that smooth, uniform stones that appeared denser than bone on a plain abdominal film will have a poor response to ESWL (20). However, this method has some major drawbacks related to the subjective nature of assessment and therefore is rarely used in clinical practice.

Since lately non-contrast enhanced computed tomography is replacing intravenous urography as an investigation method for urinary stone disease, SSD is often used to predict the success of ESWL in patients

with renal calculi. On the other hand, according to Pareek *et al.* obesity and skin-to-stone distances >10 cm will, in general, not affect the ESWL outcome, the main problem would be the precise focusing of the stone (21). However, according to Cho *et al.* SSD as predictor of ESWL success remains controversial in patients with ureter stones (22). On the other hand, Patel *et al.* surveyed a group of 83 patients and found that the “stone-free” patients had a SSD of 83.3 +/- 21.9 mm vs. 107.7 +/- 28.9 mm ($p < 0.05$). The authors concluded that SSD is an independent factor for the success of ESWL regardless of the location of the calculus (23). Because of the technical conditions, our results could not be compared from this point of view.

Karatzas *et al.* attempted to verify whether the position of obese patients during ESWL can influence the success rate. The authors compared a group of 19 patients who underwent ESWL in the lateral decubitus with another group of 17 patients in whom lithotripsy was performed in the dorsal decubitus. There was no difference in the “stone-free” rate (68.4 vs. 64.7%) or the average number of sessions (2.2 vs. 2.6). The only significant difference was the duration of the meetings which were much shorter in the first group (56 vs. 76 minutes). Therefore, the patient’s position may not have influenced our results, in all patients the manoeuvre was carried out in the dorsal decubitus (24).

The location of the stone could also influence the outcomes of ESWL. The EAU guidelines recommend URS for ureteral stones of >10 mm while for those measuring <10 mm either ESWL or URS is recommended. According to Sampaio and Pareek, extracorporeal lithotripsy is only indicated in normoponderal patients with upper or middle caliceal lithiasis (21,25). Delakas *et al.* evaluated a group of 688 patients who underwent 1099 ESWL sessions and tried to identify factors associated with the failure of ESWL. The authors verified the treatment outcomes by using a KUB film 1 day and 1 week after each ESWL session and revealed that unsuccessful outcome was significantly related to: pelvic ureteral stones, stone size of >10 mm, obstruction and obesity (26). In our patients the best results were obtained for pelvic ureteric stones. Our findings are similar to those of Mezentssev. The latter author, after surveying a sample of 37 patients, found an 87% success rate of ESWL treatment on the pelvic ureter (27). Moreover, Muñoz *et al.* surveyed 150 obese patients with kidney and/or ureteral stones; it was found that those with a mean stone size of 12 mm had a 72% stone-free rate with the best results obtained in pelvic and lumbar ureter stones (88%) (28).

Increased BMI could be an independent factor for the success of ESWL, while the type of lithotripter could also influence the results. Pareek *et al.* evaluated 100 patients who underwent ESWL for a solitary renal stone measuring between 5 and 10 mm using an electrohydraulic lithotripter (Medstone). At 6 weeks 72 were stone free and 28 had residual fragments larger than 3 mm. The stone free patients had a significantly smaller mean BMI (26.9 +/-0.5) than patients with residual fragments (30.8 +/-0.9). Logistic regression analysis performed by the authors revealed that an unsuccessful outcome was statistically significantly related to the BMI (odds ratio 1.34, $p < 0.01$) (29). On a larger cohort of 688 patients, Delakas *et al.* using a second-generation electrohydraulic shockwave lithotripter (Dornier 9000MPLX) found no association between increased BMI and ESWL failure. We have also used a second generation spark gap lithotripter (KS-88-4), but BMI negatively influenced the results. The former authors showed that the strongest independent predictors of failure were pelvic stones and stones of >10 mm (26). According to Hatiboglu *et al.*, when using a third generation lithotripter BMI is not an independent predictor of stone-free rate after SWL. The authors performed ESWL in 172 patients using a third generation electromagnetic lithotripter (Siemens Lithoskop). The BMI did not differ between stone free patients and those with residual fragments (30). Surprisingly, Neisius *et al.*, after performing ESWL in 183 patients also using a third generation electromagnetic lithotripter with mean BMI of 27.0, found that after 3 months 91% were stone-free. The authors concluded that their results are similar to those produced using other types of lithotriptors, including the reference standard HM-3 lithotripter (31).

When facing a patient with theoretically lower chances of SFR, according to Elmansy and Lingeman, we could apply some strategies with the potential to improve SWL. A better stone fragmentation and a reduced tissue damage can be achieved with an optimal rate of shock wave application. Although the optimal treatment rate is not clear, it seems that ESWL at 60 to 90 shocks/min results in better fragmentation when compared to 120 shocks/min. We used in all patients a frequency of 60 shocks/min. We followed the recommendations of Lingeman and Elmansy in order to minimise tissue injury; this called for ramping up the energy voltage of the device, by administering of 300 pre-treatment lower energy shock waves which can initiate a protective response in the majority of treated kidneys. Last but not least, a proper coupling of the ESWL generator head to the patient in an air-tight

manner can maximise the energy delivered to the stone (32).

In conclusion, the ESWL success rate in overweight and obese patients can be negatively influenced by BMI, abdominal circumference over 102 cm, and hardness of calculi reflected in the radiopacity on KUB. In our cohort, location of the stones in the pelvic ureter had the highest rate of success in this category of patients. In patients with grade II obesity, pyelocalyceal calculus and increased hardness, other urological alternatives to lithiasis should be considered from the beginning.

Conflict of interest

The authors declare that they have no conflict of interest.

References

- Knoll T, Pearle MS. Clinical management of urolithiasis, Springer Verlag, Berlin, Heidelberg. 2013.
- Robertson WG. Diet and calcium stones. *Miner Electrolyte Metab* 1987;13(4):228-234.
- Flegal KM, Carroll MD, Ogden CL, Johnson CL. Prevalence and trends in obesity among US adults, 1999–2000. *JAMA* 2002;288(14):1723-1727.
- Taylor EN, Stampfer MJ, Curhan GC. Obesity, weight gain, and the risk of kidney stones. *JAMA* 2005;293(4):455-462.
- Pagano R, La Vecchia C, Decarli A, Negri E, Franceschi S. Trends in overweight and obesity among Italian adults, 1983 through 1994. *Am J Public Health*. 1997;87(11):1869-1870.
- Knoll T. Epidemiology, pathogenesis, and pathophysiology of urolithiasis. *Eur Urol Suppl* 2010;12(9):802-806.
- Coe FL, Parks JH, Asplin JR. The pathogenesis and treatment of kidney stones. *N Engl J Med*. 1992;327(16):1141-1152.
- U.S. Department of Health and Human Services Classification of Overweight and Obesity. accessed September 10, 2018 at site: https://www.nhlbi.nih.gov/health/educational/lose_wt/BMI/bmi_dis.htm
- Levy FL, Adams-Huet B, Pak CY. Ambulatory evaluation of nephrolithiasis: an update of a 1980 protocol. *Am J Med*. 1995;98(1):50-59.
- World Health Organisation. Obesity. Preventing and Managing the Global Epidemic. Geneva. 1997, accessed September 10, 2018 at site: http://www.who.int/nutrition/publications/obesity/WHO_TRS_894/en/
- U.S. Centers for Disease Control and Prevention, Prevalence of Obesity in the United States, 2009-2010 (Atlanta: U.S. Centers for Disease Control and Prevention, 2012), accessed Sept. 10, 2018 at site www.cdc.gov/nchs/data/databriefs/db82.pdf
- Taylor EN, Stampfer MJ, Curhan GC. Obesity, weight gain, and the risk of kidney stones. *JAMA*. 2005;293(4):455-462.
- Shavit L, Ferraro PM, Johri N, Robertson W, Walsh SB, Mochhala S, Unwin R. Effect of being overweight on urinary metabolic risk factors for kidney stone formation. *Nephrol Dial Transplant*. 2015;30(4):607-613.
- Drake T, Grivas N, Dabestani S, Knoll T, Lam T, MacLennan S, Petrik A, Skolarikos A, Straub M, Tuerk C, Yuan CY, Sarica K. What are the benefits and harms of ureteroscopy compared with shock-wave lithotripsy in the treatment of upper ureteral stones? A systematic review. *Eur Urol*. 2017;72(5):772-786.
- Chaussy C, Thorsten B. The preferred treatment for upper tract stones is extracorporeal shock wave lithotripsy (ESWL) or ureteroscopic: pro ESWL. *Urology*. 2009;74(2):259-262.
- Trudeau V, Karakiewicz PI, Boehm K, Dell'Oglio P, Tian Z, Briganti A, Shariat SF, Valiquette L, Bhojani N. The effect of obesity on perioperative outcomes following percutaneous nephrolithotomy. *J Endourol*. 2016;30(8):864-870.
- Türk C, Petřík A, Sarica K, Seitz C, Skolarikos A, Straub M, Knoll T. EAU Guidelines on Diagnosis and Conservative Management of Urolithiasis. *Eur Urol*. 2016 Mar;69(3):468-474.
- Clavien PA, Sanabria JR, Strasberg SM. Proposed classification of complications of surgery with examples of utility in cholecystectomy. *Surgery* 1992;111(5):518-26.
- Chaussy C, Brendel W, Schmiedt E. Extracorporeally induced destruction of kidney stones by shock waves. *Lancet* 1980;2(8207):1265-1268.
- Bon D, Dore B, Irani J, Marroncle M, Aubert J. Radiographic prognostic criteria for extracorporeal shock-wave lithotripsy: a study of 485 patients. *Urology* 1996;48(4):556-560 [discussion 560-1].
- Pareek G, Hedican SP, Lee FT Jr, Nakada SY. Shock wave lithotripsy success determined by skin-to-stone distance on computed tomography. *Urology*. 2005;66:9141-9144
- Cho KS, Jung HD, Ham WS, Chung DY, Kang YJ, Jang WS, Kwon JK, Choi YD, Lee JY. Optimal skin-to-stone distance is a positive predictor for successful outcomes in upper ureter calculi following extracorporeal shock wave lithotripsy: A Bayesian model averaging approach. *PLoS One*. 2015;10(12):e0144912
- Patel T, Kozakowski K, Hruby G, Gupta M. Skin to stone distance is an independent predictor of stone-free status following shockwave lithotripsy *J Endourol*. 2009;23(9):1383-1385.
- Karatzas A, Gravas A, Tzortzis V, Aravantinos E, Zachos I, Kalogeras N, Melekos M. Feasibility and efficacy of extracorporeal shock-wave lithotripsy using a new modified lateral position for the treatment of renal stones in obese patients. *Urol Res*. 2012;40(4):355-359
- Sampaio FJ, Aragao AH. Inferior pole collecting system anatomy: it's probable role in extracorporeal shock wave lithotripsy. *J Urol*. 2005; 173:2013-2016.
- Delakas D, Karyotis I, Daskalopoulos G, Lianos E, Mavromanolakis E. Independent predictors of failure of shockwave lithotripsy for ureteral stones employing a second-generation lithotripter. *J Endourol*. 2003;17(4):201-205.
- Mezentsev VA. Extracorporeal shock wave lithotripsy in the treatment of renal pelvicalyceal stones in morbidly obese patients. *Int Braz J Urol*. 2005;31(2):105-110
- Muñoz RD, Tirolien PP, Belhamou S, Desta M, Grimberg R, Dulys P, Chevallier H. Treatment of reno-ureteral lithiasis with ESWL in obese patients. Apropos of 150 patients. *Arch Esp Urol*. 2003;56(8):933-938.
- Pareek G, Armenakas NA, Panagopoulos G, Bruno JJ, Fracchia JA. Extracorporeal shock wave lithotripsy success based on body mass index and Hounsfield units. *Urology*;65:33–36.
- Hatiboglu G, Popenciu V, Kurosch M, Huber J, Pahernik S, Pfizenmaier J, Haferkamp A, Hohenfellner M. Prognostic variables for shockwave lithotripsy (SWL) treatment success: no impact of body mass index (BMI) using a third generation lithotripter. *BJU Int*. 2011;108(7):1192-1197.
- Neisius A, Wöllner J, Thomas C, Roos FC, Brenner W, Hampel C, Preminger GM, Thüroff JW, Gillitzer R. Treatment efficacy and outcomes using a third generation shockwave lithotripter. *BJU Int*. 2013;112(7):972-981.
- Elmansy HE, Lingeman JE. Recent advances in lithotripsy technology and treatment strategies: A systematic review update. *Int J Surg*. 2016;36(Pt D):676-680.