

## A comparison of shock wave lithotripsy, semirigid and flexible ureteroscopy in the management of proximal ureteral calculi

Proksimal üreter taşlarının tedavisinde şok dalga tedavisi, semirijid ve fleksibl üreteroskopinin karşılaştırılması

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### Abstract

**Objective:** We compared the efficacy of extracorporeal shock wave lithotripsy (ESWL), semirigid and flexible ureteroscopy (URS) in patients with proximal ureteral calculi.

**Materials and methods:** The study included 165 patients (103 males, 62 females; mean age 43±10 years; range 18 to 62 years) who were treated for a single radiopaque proximal ureteral stone in three clinics. Treatment modalities included ESWL (n=83, 50.3%), semirigid URS (n=54, 32.7%), and flexible URS (n=28, 17%). The results obtained from each of the three approaches were compared.

**Results:** While 77 patients (92.8%) in the ESWL group were stone-free after three sessions, 41 patients (75.9%) and 27 patients (96.4%) were stone-free after a single-step procedure in semirigid and flexible groups, respectively. Reasons for failure in the ESWL group were impacted stone in four patients and steinstrasse formation in two patients. These patients were eventually managed by endoscopy. Of 13 failures (24.1%) in the semirigid group, the most frequent cause was stone migration into the kidney (n=9, 16.7%), followed by macroscopic hematuria (n=2, 3.7%), inability to reach the stone (n=1, 1.9%), and ureteral avulsion (n=1, 1.9%). These patients were further managed by ESWL (n=10), flexible URS (n=2), or open surgery (n=1). In the flexible group, the stones migrated into the kidney in three cases (10.7%), but they were immediately removed during the operation. The only failure (3.6%) in this group was associated with bleeding originating from mucosal injury, which was further treated with ESWL. No procedure-related ureteral strictures occurred during the follow-up.

**Conclusion:** Even though ESWL is a successful treatment modality in the management of proximal ureteral calculi, flexible URS may be an effective and safe alternative in patients demanding an efficient and quick stone relief in a single session.

**Key words:** Lithotripsy/methods; ureteral calculi/therapy/surgery; ureteroscopy/methods.

### Özet

**Amaç:** Proksimal üreter taşlarının tedavisinde vücut dışı şok dalga tedavisi (ESWL), semirijid üreteroskopi (ÜRS) ve fleksibl ÜRS'nin etkinliği karşılaştırıldı.

**Gereç ve yöntem:** Çalışmada soliter ve radyopak proksimal üreter taşı nedeniyle tedavi edilen 165 hasta (103 erkek, 62 kadın; ort. yaş 43±10; dağılım 18-62) değerlendirildi. Bu hastaların 83'ünde (%50.3) ESWL, 54'ünde (%32.7) semirijid ÜRS, 28'inde (%17) fleksibl ÜRS uygulandı. Bu yaklaşımlardan elde edilen sonuçlar karşılaştırıldı.

**Bulgular:** Şok dalga tedavisi grubunda üç seans sonunda 77 hastada (%92.8), semirijid ÜRS grubunda tek seferde 41 hastada (%75.9) ve fleksibl ÜRS grubunda tek seferde 27 hastada (%96.4) taşsızlık elde edildi. Şok dalga tedavisi grubunda başarısızlık nedeni dört hastada impakte taş varlığı, iki hastada taş yolu oluşumu idi. Bu hastalarda endoskopi sonrası taşsızlık elde edildi. Semirijid ÜRS grubunda 13 olguda (%24.1) görülen başarısızlığın en sık nedeni taş migrasyonu (n=9, %16.7) idi. Diğer nedenler makroskopik hematüri (n=2, %3.7), taşa ulaşamama (n=1, %1.9) ve üreter avülzyonu (n=1, %1.9) idi. Bu gruptaki başarısızlıklar ESWL (n=10), fleksibl ÜRS (n=2) ve açık cerrahi (n=1) ile giderildi. Fleksibl ÜRS grubunda üç hastada (%10.7) böbreğe kaçan taşlar ameliyat sırasında böbrekten alındı ve taşsızlık sağlandı. Bu gruptaki tek başarısızlık (%3.6) nedeni mukozal hasara bağlı kanama idi ve bu hasta ESWL ile tedavi edildi. Tedavi gruplarının hiçbirinde işlemle ilgili üreter striktürü gelişmedi.

**Sonuç:** Proksimal üreter taşlarına yaklaşımda ESWL etkili ve başarılı bir tedavi yöntemi olmasına rağmen, taşların tek seferde hızlı ve etkili bir şekilde temizlenmesini isteyen hastalarda fleksibl ÜRS de etkili ve güvenilir bir tedavi seçeneğidir.

**Anahtar sözcükler:** Litotripsi/yöntem; üreter taşı/tedavi/cerrahi; üreteroskopi/yöntem.

Among factors affecting urologists' decisions regarding the management of upper urinary tract stones, efficacy of the procedure in leading to stone-free status with low morbidity seems to be the most crucial. Although extracorporeal shock wave lithotripsy (ESWL) has been used with varying success and complication rates, optimal management of proximal ureteral calculi remains controversial.<sup>[1,2]</sup> In this regard, as a non-invasive option, ESWL has traditionally been recommended as the first-line therapy with high success.<sup>[3]</sup> However, development of small and fine ureteroscopes (flexible or semirigid) combined with holmium:YAG laser or pneumatic lithotripsy have increased the success rates of the endoscopic approach.<sup>[2,3]</sup>

Some limitations related to both ESWL and stone characteristics affect retreatment rates, surgeon's preference, and final outcome of treatment. Many studies have shown that ESWL is not capable of effectively handling all ureteral stones because of focusing difficulties and/or limited space for disintegrated stones.<sup>[2-4]</sup> Steinstrasse formation, obstruction, and radiation exposure are other drawbacks of ESWL. Moreover, application of high-energy shock waves (HESW) may increase the degree of adhesion of residual stones to the ureteral mucosa. In addition, a certain subset of patients with relatively harder stones and/or severe ureteral obstruction may require rapid relief of obstruction to avoid possible irreversible renal morphological and functional alterations that may take place during prolonged treatment and follow-up period.<sup>[2,3,5]</sup>

Ureteroscopic treatment (URS) of ureteral stones has become more common in the last 10-15 years, with increasingly practical, tolerable, and successful results. In combination with certain auxiliary procedures, URS has become the standard procedure in the management of certain ureteral stones.<sup>[2,6,7]</sup> Advances in endoscopic equipment has expanded the indication range of URS, so that not only distal and midureteral stones, but also more proximally located calculi can be successfully managed.<sup>[8]</sup>

In the present study, we compared the results obtained with three commonly used management alternatives for proximal ureteral calculi: ESWL, semirigid URS in combination with pneumatic lithotripsy, and flexible URS associated with holmium:YAG lithotripsy.

## Materials and methods

In three clinics, 165 patients (103 males, 62 females; mean age 43±10 years; range 18 to 62 years) having a

single radiopaque proximal ureteral stone were retrospectively evaluated. Proximal ureter was defined as the ureteral segment between the ureteropelvic junction and upper margin of the sacroiliac joint. Exclusion criteria were pregnancy, bleeding disorders, congenital ureteral abnormality or ureteral reimplantation, and a history of previous ipsilateral ureteral stone and ureteral surgery (endoscopic or open).

Eighty-three patients (50.3%) underwent ESWL by using Compact Sigma 3902 (Dornier MedTech GmbH, Wessling, Germany) or Complit (Elmed, Turkey) lithotripsy systems. The patients were treated under intravenous sedation with meperidine or metamizol sodium analgesia. The upper limit for shock waves (SW) in one session was 2,500 SW and sessions were performed at 7 to 10-day intervals. Cases in which stones were not disintegrated after three ESWL sessions or particles bigger than 3 mm that persisted during a three month follow-up period were classified as a failure.

Fifty-four patients (32.7%) were treated with semirigid URS with a 9.8/8.0 F tapered ureteroscope (Richard Wolf GmbH, Knittlingen, Germany or Storz, Tuebingen, Germany) under general anesthesia. After performing retrograde ureterorenography, two 0.038 inch guidewires (security and working guidewires) were inserted up to the renal pelvis under direct scope vision to avoid stone migration to the kidney. A Stone Cone retrieval device was inserted before disintegration if the stone was mobile or close to the ureteropelvic junction. Disintegration of calculi was performed using a ballistic lithotriptor (EMS Swiss LithoClast, Switzerland or Vibrolith Elmed, Turkey) with a 2.4 F probe after reaching the stone. Stone particles were removed with a 4.0 F foreign body grasper and/or basket catheter.

Flexible URS was performed in 28 patients (17%). First the ipsilateral upper urinary tract was visualized by radiopaque media (Visipaque) under general anesthesia. Then, a 0.038 inch safety guidewire and a 0.035 inch working guidewire were introduced up to the pelvis renalis by using a dual lumen catheter (Boston Scientific, Natick, MA, USA), which also allowed initial dilatation of the ureteral orifice before ureteral access sheath (12 F, 35 cm) placement into the distal ureter. A 7.5 F flexible ureteroscope (Richard Wolf GmbH) was slid over the guidewire up to the stone under fluoroscopy. Holmium:YAG laser lithotripsy was performed using a 365 or 200 µm core size fiber until the stone was disintegrated into <2 mm fragments to avoid the need for basket extrac-

**Table 1. Demographic and stone characteristics of the patients and operation-related features**

	SWL (n=83)			Semirigid URS (n=54)			Flexible URS (n=28)			p
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	
Age (years)			44.8±9.9			40.1±8.7			43.2±10.1	0.492
Male	52	62.7		34	63.0		17	60.7		0.926
Female	31	37.4		20	37.0		11	39.3		0.593
Body mass index (kg/m <sup>2</sup> )			26.7±1.5			28.3±1.9			27.2±2.5	0.866
Stone size (mm)			12.1±1.9			11.9±1.2			12.4±2.2	0.671
Operation time (min)			18.2±3.7			33.4±8.9			31.8±6.2	0.024
			(each session)							
Stone-free rate	77	92.8		41	75.9		27	96.4		0.001
Hospitalization (hrs)			—			32.0±9.2			27.0±8.1	0.07*
			(outpatient)							

SWL: Shock wave lithotripsy; URS: Ureteroscopic treatment; \*Statistical analysis between semirigid and flexible groups.

tion. Success for both ureteroscopic approaches was defined as complete removal of all stone particles. In case of suspicion about stone-free status, unenhanced computed tomography was performed rather than routine abdominal radiography to confirm stone removal.

Results obtained from each of the three approaches (stone-free status, auxiliary procedures, complications) were comparatively evaluated. Statistical analyses were made using one-way ANOVA, Tukey HSD test, t-test, chi-square test, and Kolmogorov-Smirnov test.

## Results

Patient characteristics, operation time, and success rates of the procedures are shown in Table 1. No significant differences were found with respect to mean age, body mass index, or stone size between the three groups. While ESWL procedures were performed on an outpatient basis, hospitalization in semirigid and flexible groups differed in favor of flexible URS which was not statistically significant ( $p=0.07$ , Table 1).

While 77 (92.8%) of 83 patients in the ESWL group were stone-free after three sessions; 41 patients (75.9%) and 27 patients (96.4%) were stone-free after the single-step procedure in semirigid and flexible groups, respectively (Table 1). Stone-free rate was 67.4% after the first session of ESWL, 81.9% after the second, and 92.8% after the third session. Reasons for failure in the ESWL group were impacted stone in edematous ureteral wall in four patients and stricture formation in two patients. These patients were eventually managed by endoscopy.

A comparison of procedure-related factors is given in Table 2. Of 13 failures (24.1%) in the semirigid group, the most frequent cause was stone migra-

tion into the kidney ( $n=9$ , 16.7%), followed by blurred vision due to evident hematuria ( $n=2$ , 3.7%), inability to reach the stone because of prominent angulation of the proximal ureter ( $n=1$ , 1.9%), and ureteral avulsion ( $n=1$ , 1.9%). JJ stents were placed in 10 cases and further managed by ESWL, and retrograde intrarenal stone removal was applied by flexible URS in two cases. Two ureteral strictures distal to the stone in the semirigid group were managed by balloon dilatation before the operation. Of these, the URS procedure was successfully finished in one and a 12-month follow-up showed no recurrence of stricture. In the other case, ureteral avulsion caused conversion to open surgery, and the case was classified as a failure. In the flexible group, however, although the stones migrated into the pelvis renalis/calix in three cases (10.7%), they were removed from the kidney with a Nitinol basket during the operation and the cases were classified as success. On the other hand, bleeding originating from mucosal injury was the reason for failure in one case (3.6%). After insertion of JJ stents, this stone was treated with subsequent ESWL. No procedure-related ureteral strictures occurred in ESWL, semirigid or flexible groups during the follow-up.

Regarding ureteral stenting, 15 patients (27.8%) in the semirigid group received JJ stents because of stone migration ( $n=9$ ), gross hematuria ( $n=2$ ), balloon dilatation of the ureteral orifice ( $n=2$ ), or ureteral stricture ( $n=2$ ). In the ESWL group, preoperative severe hydronephrosis ( $n=10$ ) and large stone burden ( $n=4$ ) were reasons for preoperative JJ stent insertion. Lastly, three JJ stents were placed in flexible URS cases owing to gross hematuria in one, and embedded stones associated with severe mucosal edema formation in two cases. The need for JJ stent insertion was significantly higher in

**Table 2. Evaluation of the complications and auxiliary procedures in the three groups**

	SWL (n=83)			Semirigid URS (n=54)			Flexible URS (n=28)			p
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	
Gross hematuria	13	15.7		2	3.7		1	3.6		0.01
	(Transient hematuria after SWL session)									
Stone migration	–			9	16.7		3	10.7		0.02**
							(Treated at the time of procedure)			
Steinstrasse formation	2	2.4#		–			–			
Skin ecchymosis	5	6.0#		–			–			
Postoperative pain*	29	34.9		11	20.4		4	14.3		0.01
Postoperative fever	4	4.8		1	1.9		1	3.6		0.97
Procedure related stricture	–			–			–			
Overnight stent	–			13	24.1		6	21.4		0.12**
JJ stent	14	16.9		15	27.8		3	10.7		<0.01
Use of a Stone Cone device	–			17	31.5		–			

SWL: Shock wave lithotripsy; URS: Ureteroscopic treatment; #SWL specific complication; \*Pain requiring an additional medication other than hycosine-N-butylbromide; \*\*Only ureteroscopy groups were compared.

the semirigid group ( $p<0.01$ ). Thirteen stents in the semirigid group and six stents in the flexible group were inserted as overnight fashion ( $p=0.12$ ). Stone Cone catheters were used only in the semirigid group in 17 patients (31.5%) to prevent stone migration into the kidney due to close proximity of the stones to the ureteropelvic junction (Table 2).

Procedure-related complications were seen in 51 patients (61.5%) in the ESWL group, including need for medications other than hycosine-N-butylbromide due to pain during the passage of fragmented stones ( $n=29$ , 34.9%), fever treated with appropriate antibiotics ( $n=4$ , 4.8%), transient hematuria ( $n=13$ , 15.7%), and skin ecchymosis ( $n=5$ , 6%), and steinstrasse formation ( $n=2$ , 2.4%). Requirement of additional medications other than hycosine-N-butylbromide because of postoperative pain was significantly less in the flexible URS group ( $p=0.01$ ) (Table 2).

## Discussion

Optimal management of proximal ureteral stones is a controversial subject of urolithiasis. Following the clinical introduction of new treatment approaches, decision making became more complex than ever.<sup>[1,2,9]</sup> Currently, the ultimate goal is to achieve complete stone-free status with minimal morbidity. Therefore, in addition to stone- and patient-related factors, surgeon's experience and availability of technologic instruments are other important issues that should be considered on an individual basis.<sup>[2]</sup>

Today, both ESWL and ureteroscopy with different lithotripter systems are highly effective methods

in the treatment of ureteral calculi.<sup>[2,3,10]</sup> As an outpatient procedure, ESWL is still accepted as a practical and non-invasive first-line treatment method in the majority of cases because of its high success rates.<sup>[2,3,11,12]</sup> However, despite its minimally invasive nature, ESWL achieves good results at the expense of repeated treatment sessions and extensive follow-up, making total duration of the treatment longer than other methods. Additionally, passage of fragmented calculi may sometimes cause colicky pain and urinary symptoms lasting several days as a further discomfort to the patients. Last but not least, the success rate is affected by several factors, such as stone burden and location, lithotripter type, operator's experience, secondary procedures, and in particular retreatment rates.<sup>[5,7,13]</sup> Despite all, ESWL has proven to be an attractive approach for the patient who desires treatment with minimal or no anesthesia.<sup>[2,11]</sup>

As an evolving and valuable option in such patients, increasing experience has clearly shown that the ureteroscopic approach may have some advantages over ESWL. Patients on anticoagulant medications, those with morbidly obese body habitus and simultaneous bilateral ureteral stones can be treated selectively with this option in a safe and practical manner.<sup>[2]</sup> However, one major drawback of this modality is the requirement of general anesthesia in a great majority of patients. Clinical introduction and use of smaller and fine equipment have influenced the urologist's choice between ESWL and URS in ureteral calculi management.<sup>[2,9]</sup> Moreover, widespread use of different lithotripter systems such as pneumatic and holmium:YAG lasers has made

ureterolithotripsy easier than before, decreasing the incidences of both ureteral injury and stricture formation. Although laser application in ureteral calculi disintegration has changed the treatment concept to a meaningful extent, some studies have shown that pneumatic intracorporeal lithotripsy is also a well-tolerated, cost-effective alternative that achieves stone-free rates up to 85%.<sup>[14-17]</sup> However, it may sometimes be associated with stone migration that lowers the stone-free rates. While the fragmentation rates in pneumatic lithotripsy have been reported to be 84-100%, the overall stone-free rates are 83-98.6% for distal and 90% for middle, but as low as 70% for upper ureteral stones without complications.<sup>[15-18]</sup> In our study, a relatively lower stone-free rate for upper ureteral calculi was found in the semirigid-pneumatic group compared with ESWL and flexible URS-holmium laser.

As a result of development of semirigid and flexible ureteroscopes, together with increased experience in ureteroscopy, the need for ureteral dilation has been minimized and precise fragmentation and removal of the stones have become easier. Thus, compared with ESWL, ureteroscopic stone removal may be performed more quickly and with less morbidity. Consequently, the increasing number of non-complicated ureteroscopic procedures resulted in decreased use of ureteral stents after the procedure, which may ultimately lower the incidence of procedure-related morbidity rates. All these improvements again have brought the ureteroscopic stone management to a position where this modality is now deemed appropriate for stones of any size in the proximal ureter.<sup>[19-21]</sup> While ureteral balloon dilatation was performed in two cases in the semirigid group, it was not required for any patients in the flexible group. On the other hand, use of a dual lumen catheter and 12 F ureteral access sheaths in flexible URS cases may produce a certain degree of orifice dilatation. Indeed, stenting was not necessary in those patients and no complications were noted during follow-up. With respect to success rates for ureteral stones, there are several studies reporting successful results with either ESWL or ureteroscopic technique, indicating the advantages and/or disadvantages of both techniques.<sup>[10,22-25]</sup> A meta-analysis published by the AUA Nephrolithiasis Guideline Panel in 1997 documented the overall stone-free rate of ESWL for proximal ureteral stones as 83% (78 studies, 17,742 patients), and the panel recommended ESWL as the initial choice for stones smaller than 1 cm, and either ESWL or ureteroscopy for larger (>1 cm) calculi in the proximal ureter.<sup>[2]</sup>

On the other hand, they reported stone-free results of ESWL for proximal ureteral stones as 82%, with surprisingly little difference in stone-free rates with respect to stone size (93% for stones <10 mm and 87% for stones >10 mm).<sup>[2]</sup> Flexible ureteroscope methods were largely associated with improved access to the proximal ureter, providing superior stone-free rates with the use of flexible URS (87%), compared with rigid or semirigid URS (77%), and comparable to those achieved with ESWL.<sup>[2]</sup> The primary reason for the relatively low success rates obtained with ureteroscopy in earlier series was the inability to reach and fragment the stone due to migration into the renal collecting system. However, in experienced hands, the removal of calculi from the renal system with flexible ureterorenoscopes is possible, increasing the success rates as high as 96%.<sup>[3,6,9,10]</sup> Similarly, the three cases of stone migration in our flexible group were not classified as a complication or failure, since all the stones were removed during the operation. In addition to high success rate, complication rate was very low in this group as previously reported in the literature.<sup>[11,12]</sup>

Lastly, complication rates which represent a clear drawback of the ureteroscopic approach, most notably ureteral perforation rates have been reduced to less than 5%, and long-term complications such as stricture formation occur with an incidence of 2% or less, due to the use of fine ureteroscopes and increased safety margin of laser and pneumatic lithotripsy devices compared with that of older electrohydraulic lithotripsy systems.<sup>[26]</sup> In a recent study focusing on the results of 1,000 ureteroscopic procedures, no ureteral perforation was reported.<sup>[27]</sup> Considering early reports on stricture rates up to 4% with 9.5 to 12.5 F ureteroscopes, the use of small-caliber, semirigid, and flexible ureteroscopes has decreased the rate of this complication meaningfully (<1%).<sup>[28,29]</sup> Overall stone-free rates were reported to be remarkably high (81% to 94%) depending on stone location, with the vast majority of patients becoming stone-free in a single procedure.<sup>[2,30]</sup>

The innovative developments in flexible ureteroscopes have changed the scope of modern management for proximal ureteral stones. Currently, flexible ureteroscopy procedures are performed for proximal ureteral calculi at most institutions. In this study, we aimed to evaluate the success rates of three different management modalities in the removal of such stones. Regarding the success rates, the use of semirigid ureteroscopy with pneumatic lithotripsy was found to be less effective than others. This is mainly

due to a high percentage of stone migration. Stone-free rates obtained with flexible ureteroscopy with holmium:YAG laser and ESWL were comparable. With respect to complication rates, the flexible ureteroscopic approach showed no significant complications, which makes this technique a valuable alternative to ESWL in the management of these stones. If we add the established advantages of the same system over ESWL, where the application of HESW is not feasible or contraindicated, the use of flexible ureteroscopy with laser technology gains more importance in the removal of the relatively larger stones located in the upper part of the ureter.

The major limitations of the present study are its retrospective design, which potentially represents a selection bias, and varying experience of different surgeons in different clinics. Considering the absence of prospective randomized studies comparing the three treatment modalities, our study will be helpful for endourologists to assess efficacy of these three treatment choices for proximally located ureteral calculi.

In conclusion, ESWL is a successful treatment fashion in the management of proximal ureteral stones. However, limited number of cases in our series showed that flexible ureteroscopy with holmium:YAG laser may be an effective and safe alternative in patients demanding efficient and quick stone relief in a single session.

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