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Comparison of Shockwave Lithotripsy and Microperc for Treatment of Kidney Stones in Children

Namık Kemal Hatipoglu, MD,[1] Ahmet Ali Sancaktutar, MD,[1] Abdulkadir Tepeler, MD,[2] Mehmet Nuri Bodakci, MD,[1] Necmettin Penbegul, MD,[1] Murat Atar, MD,[1] Yasar Bozkurt, MD,[1] Haluk Söylemez, MD,[1] Mesrur Selcuk Silay, MD,[2] Mustafa Okan Istanbulluoğlu, MD,[3] Tolga Akman, MD,[2] and Abdullah Armagan, MD[2]

Abstract

Purpose: We aimed to compare the outcomes of microperc and shockwave lithotripsy (SWL) for treatment of kidney stones in children.

Patients and Methods: The medical records of 145 patients under the age of 15 years with opaque and single kidney stones treated with either SWL or microperc were retrospectively reviewed. Both groups were compared in terms of fluoroscopy and operative time, re-treatment, complications, success rate, and secondary and total number of procedures.

Results: Microperc and SWL were performed on 37 and 108 pediatric patients, respectively. The mean age of the patients was 5.91 ± 4.03 years (1–15) and 8.43 ± 4.84 (1–15) years in the SWL and microperc groups, respectively ($P = 0.004$). The mean stone size was 11.32 ± 2.84 (5–20) mm in the SWL group and 14.78 ± 5.39 (6–32) mm in the microperc group ($P < 0.001$). In the SWL group, 31 (28.7%) patients underwent a second SWL session and 6 (5%) had a third session. Finally, 95 (88%) patients were stone free at the end of the SWL sessions. In the microperc group, the stone-free rate was 89.2% in a single session ($P = 0.645$). The mean duration of hospitalization was 49.2 ± 12.3 (16–64) hours in the microperc group and 8.4 ± 2.3 (6–10) hours per one session in the SWL group ($P < 0.001$). The fluoroscopy time was significantly longer in the microperc group compared with the SWL group (147.3 ± 95.3 seconds *vs* 59.6 ± 25.9 seconds, $P < 0.001$). The rate of requirement for an auxiliary procedure was higher in the SWL group than in the microperc group. The overall complication rates for the microperc and SWL groups were 21.6% and 16.7%, respectively ($P = 0.498$).

Conclusions: The results of our study demonstrate that microperc provides a similar stone-free rate and a lower additional treatment rate compared with SWL in the treatment of kidney stone disease in children.

Introduction

Pediatric urolithiasis is an important health problem worldwide and especially so in some countries. Urolithiasis is often associated with metabolic/anatomic abnormalities or infectious disease. In these patients, the risk of recurrence is higher.[1] For these reasons, it is more important for the modality of treatment to be as minimally invasive as possible for the pediatric population. The goal of stone disease treatment is to be totally stone free after a session while avoiding injuries or complications. Today, with improvements in minimally invasive treatment modalities, the use of shockwave lithotripsy (SWL), percutaneous nephrolithotomy (PCNL), and retrograde intrarenal surgery (RIRS) is increasing.

Stone size and localization affect the success rate of treatment modalities. Today, SWL is the most frequently chosen treatment modality for renal stones in the pediatric population because it is effective and safe. Many studies, however, have shown that the success rate of SWL decreases significantly with increasing stone size and multiplicity.[2,3] The other disadvantages of SWL are the need for general anesthesia and for multiple sessions neded for children.[3]

It has been reported that PCNL can be performed safely and effectively in most patients despite its well-known hazardous and serious complications. Most of these complications are related to tract formation and size.[4] Efforts to decrease the complications of PCNL have focused on size. The researchers aimed to decrease complications by decreasing the size of the access point. As a result of these investigations,

[1]Department of Urology, University of Dicle, Diyarbakir, Turkey.
[2]Department of Urology, Faculty of Medicine, Bezmialem Vakif University, Istanbul, Turkey.
[3]Department of Urology, Mevlana University, Konya, Turkey.

Bader and associates[5] reported an optical system named the ''all-seeing needle'' for renal access. Some studies also reported the first series of microperc results that skip the access dilation, which greatly improves the management of renal stone disease.[6–8]

We conducted this study to compare the outcomes of microperc and SWL for the treatment of kidney stones in children.

Patients and Methods

The medical records of 145 patients under the age of 15 with opaque and single kidney stones treated with either SWL or microperc years between January 2010 and September 2012 were retrospectively reviewed. The patients who had abnormal kidney anatomy, musculoskeletal system deformity, nonopaque or semiopaque stones that might be associated with the metabolic abnormalities or patients with ureteral stones or ureteral obstructions were excluded from the study. The selection of treatment modality was primarily based on factors such as stone size and location and collecting system anatomy that might affect the success of SWL. The patients with kidney stone >2 cm underwent microperc. The patients with kidney stone <2 cm in whom SWL failed were treated with microperc.

A detailed medical history, physical examination, urinalysis, urine culture, complete blood cell count, serum biochemistry, coagulation test, radiography of the kidneys, ureters, and bladder (KUB), renal ultrasonography (US), and/or intravenous urography were performed on all patients. CT was used only in special situations because of the concerns about radiation exposure. Patients who had positive urine cultures were treated with appropriate antibiotics immediately. Stone size was calculated by measuring the longest axis on preoperative imaging.

SWL technique

All SWL procedures were performed using Siemens Medical Systems (Modularis Uro-Variostar, Germany). The lithotripsy was performed under general anesthesia. The lung and genitourinary fields were shielded for all patients. Fluoroscopy was used to localize the stone and to monitor fragmentation. The SWL procedure was performed with a total of 2500 shocks delivered with a frequency of 60 shocks/min and 8–14 kV energy for each session. The SWL session was stopped when no visible stone was detected, tiny fragments were the only visible stone remnants, or the desired number of shocks had been given. Patients were assessed at the first week, and first and third month after the SWL session by KUB and US to assess stone-free status. If stone fragments were smaller than 4 mm, watchful waiting was chosen. Additional SWL sessions were performed in the presence of fragments >4 mm or in the case of a failure in the initial session. Stone free was defined as no visible stone fragments on both US and/or KUB. In the case of SWL failure after two or three sessions of SWL, patients were told about other treatment modalities such as microperc or ureteroscopy and treated according to the patient's choice.

Microperc technique

A 5F open-ended ureteral catheter was installed in patients under general anesthesia and placed in the lithotomy position. The patient was then positioned in the prone position, and all pressure points were padded. The anatomy of the calix was visualized by infusing contrast media via the ureteral catheter. After detecting the suitable calix, access was made under the guidance of fluoroscopy by a 4.5F "all-seeing needle" (Poly Diagnost, Pfaffenhofen, Germany) by a senior endourologist experienced in endoscopic stone treatment modalities in all centers. After removing the needle, a three-way connector was applied to the proximal part of the sheath to connect the laser probe and irrigation. The stone was fragmented by a 200-μm holmium:yttrium-aluminum-garnet (8Hz [6.4 W] 0.8 J) laser fiber under the direct vision of the stone. The surgeon controlled a water pump that aided in vision and the clearance of stone fragments. Drainage of the kidney was supplied by the open-ended ureteral catheter. Stone fragmentation was confirmed by direct vision and by fluoroscopy. The procedure was terminated with no need of any nephrostomy tube.

The ureteral catheter was removed on postoperative day 1. The patients were re-evaluated with KUB radiography on postoperative day 7 and at the first and third month by US. The postoperative complications were classified according to the Clavien grading system.[9,10]

Both groups were compared in terms of re-treatment rate, complication rate, fluoroscopy time, stone-free rate (SFR), and secondary and total number of procedures and duration of operation. An auxiliary procedure was defined as using a method of treatment other than the primary treatment to render the patient free of stones.

Statistical analysis

Statistical analysis was performed using the Statistical Package for Social Sciences, version 15 (SPSS, Chicago, IL). Categorical variables were compared with the chi-square test or Fisher exact test, and continuous variables were compared with the *t* test. $P < 0.05$ was accepted as statistically significant. Multivariate linear regression analysis was performed for additional evaluation if any parameter was found to be significant with univariate tests.

Results

Microperc and SWL were performed on 37 and 108 pediatric patients, respectively. The mean age of patients was 5.9 ± 4.03 years (1–15) and 8.43 ± 4.84 (1–15) years in the SWL and microperc groups, respectively. The mean stone size was 11.32 ± 2.84 (5–20) mm in the SWL group and 14.78 ± 5.39 (6–32) mm in the microperc group. The mean age and stone size were statistically higher in the microperc group compared with the SWL group. The stones were located in the pelvis, upper pole, midpolar, and lower pole in 10, 2, 4, and 21 patients in the microperc group, respectively, while in 50, 9, 20, and 29 patients in the SWL group, respectively. The demographic values of the patients for both groups are summarized in Table 1.

In the SWL group, 31 (28.7%) patients needed a secondary SWL session and 6 (5%) neededed a tertiary SWL session. Thirteen (12%) patients had residual stone fragments (>4 mm), and they were considered as treatment failures. Finally, 95 (88%) patients were stone free at the end of the SWL sessions. In the microperc group, the SFR was 89.2% after a single session. The need for auxiliary procedures was more

Table 1. Demographic Data and Stone Characteristics

Characteristics	*SWL group*	*Microperc group*	P
N	108	37	
Mean age ± SD (years)	5.91 ± 4.03(1–15)	8.43 ± 4.84(1–15)	0.004
Male/female	61/47	15/22	
BMI (kg/m^2)	17.03 ± 5.03(8.00–27.98)	17.04 ± 3.35(12.80–23.67)	0.371
Mean stone size ± SD (mm)	11.32 ± 2.84(5–20)	14.78 ± 5.39(6–32)	< 0.001
Laterality (right/left)	51/57	21/16	
Stone location			0.012
Pelvis	50	10	
Upper pole	9	2	
Middle calix	20	4	
Lower pole	29	21	
Grade of hydronephrosis			0.060
0	36	4	
I	33	17	
II	28	12	
III	11	4	

SWL = shockwave lithotripsy; SD = standard deviation; BMI = body mass index.

common after SWL than after microperc. Operative and postoperative data and the SFR are detailed in Table 2.

The mean duration of hospitalization was 49.2 ± 12.3 (16–64) hours in the microperc group and 8.4 ± 2.3 (6–10) hours per one session in the SWL group. The fluoroscopy time was significantly longer in the microperc group compared with the SWL group (147.3 ± 95.3 sec *vs* 59.6 ± 25.9 sec). The stone size and the treatment modality were the factors affecting the fluoroscopy ($p = 0.004$; $p < 0.001$; respectively) and hospitalization time ($p < 0.001$; $p < 0.001$; respectively). The mean hemoglobin drop was 0.9 ± 0.4 (0.1–2.5) g/dL. A Double-J stent was inserted into 24% and 0.5% of patients before intervention in the SWL and microperc groups, respectively, while the Double-J stent placement was needed for 10% and 10.8% of patients after the intervention, respectively (Table 2).

The overall complication rates for the microperc and SWL groups were 21.6% and 16.7%, respectively. Renal colic (Clavien grade I complication) occurred in four patients in the microperc group and in seven patients in the SWL group who were treated by medical interventions. A Double-J stent placement was needed for 11 patients with persistent renal colic (Clavien grade IIIb complication) because of stone fragments in the SWL group. In the microperc group, there was urinary extravasation in three patients (Clavien grade IIIb complications) who were managed peroperatively by the placement of a drain. Conversion to mini-PCNL was necessitated by bleeding causing a loss of vision. Steinstrasse occurred in 11 (10%) patients in the SWL group, and they were treated with SWL or ureteroscopy (Table 2).

Discussion

All available treatment modalities for urolithiasis aimed to clear stones completely and to preserve renal functions.

Table 2. Perioperative and Operative Findings of the Patients

Characteristic	*SWL group*	*Microperc group*	P
Operative time (minutes)	–	63.6 ± 34.5 (30–180)	NA
Fluoroscopy time (seconds)	59.6 ± 25.9 (15–140)	147.3 ± 95.3 (20–390)	< 0.001
Duration of hospitalization (hour)	8.4 ± 2.3 (6–10)	49.2 ± 12.3 (16–64)	< 0.001
Stone free (n, %)			
1st day	–	28 (75.7)	
1st week	77 (71.3)	29 (78.4)	0.688
1st month	92 (85.2)	32 (86.5)	0.803
3rd month	95 (88)	33 (89.2)	0.645
Conversion to mini–PCNL	–	3	
Auxiliary procedure	11	–	
Complications	18	8	0.498
Clavien grade I (renal colic)	7	4	
Clavien grade IIIb			
Steinstrasse necessitating Double-J stent insertion	11	1	
Extravasation necessitating drain placement		3	
Preprocedural Double-J stent	26	2	0.013
Postprocedural Double-J stent	11	4	0.914

SWL = shockwave lithotripsy; PCNL = percutaneous nephrolithotomy.

Technologic developments resulted in less invasive techniques in the management of stones, especially those in children. Currently, most child patients with urolithiasis can be treated by SWL, PCNL, or RIRS alone or in combination.[11] The guidelines for urolithiasis recommend SWL for renal calculi ≤ 2 cm as the first-line therapy.[12] There are multiple factors that may affect the success rate of SWL, and several researchers have tried to find which patients are more likely to have an unsuccessful outcome.[13–15] In these studies, they mentioned the significance of stone location, stone size, stone shape, patient age, number of stones, congenital anomalies, and renal morphology.[15,16] The success rates of SWL ranged between 57% and 97% in the short-term and between 57% and 92% for the long-term follow-up.[17–19] The SWL results also have a high rate of re-treatment (13.9% to 53.9%) and additional interventions (7% to 33%).[3,20,21]

Managing renal stones in children with PCNL remains a challenge, however.[22] The sizes of instruments are continually decreasing to avoid large renal access. The miniperc procedure is almost the same procedure as traditional PCNL procedures except for its size, which ranges from 12F to 20F.[6,7] In this study, we compared the efficacy and safety of SWL and microperc in treating children with renal stones.

The SFR is the best indicator for the success of treatment. The success rate of SWL varied from 52.6% to 100%[34] in children. The rate decreases to 33% to 44% when the stone is larger than 15 mm or is located in the lower pole, however.[3,23] In the present study, the SFR in the SWL group was 57.4% after the first session, 70.3% after the second session, and 71.3% after the third session. The overall SFR was 88% after 3 months in the SWL group. It has been reported that microperc had SFRs of 83% to 88.9%.[6,7,24,25] In our study, we detected a SFR of 75.7%, 78.4%, and 86.5% after the first day, the first week, and the first month after microperc, respectively. After the third month postoperatively, we achieved a SFR of 89.2%. Conversion to mini-PCNL was necessitated in bleeding that caused a loss of vision. The SFR was higher in the SWL group than in the microperc group at the first day because the pulsatile high-pressurized endoscopic perfusion pump was used to remove stone fragments.

After an SWL session, re-treatment is needed for most of the residual fragments. As discussed above, re-treatment rates are between 13.9% and 53.9%.[3,26] After a single session of SWL, a 44% success rate was reported. The high success rate levels should be the result of repeated SWL sessions.[3] In the present study, the success rate was 57.4% after a single session. A second session of SWL was performed, however, on 31 (28.7%) patients, while a third session was needed in six (0.05%) patients.

The requirement of additional SWL sessions has the disadvantages such as prolonged discomfort, increased risk of radiation exposure, and use of anesthesia, analgesics, and antibiotics that result in stress in children and their families. The mean fluoroscopic screening time, however, was significantly prolonged in the microperc group. This difference might be related with to the use of fluoroscopy with continuous mode during the percutaneous renal access.[27] Pulsed fluoroscopy was used to localize the stone and monitor the stone fragmentation during SWL. The multivariate analysis has shown that fluoroscopy time was affected by the stone size and the treatment modality ($p = 0.004$; $p < 0.001$; respectively). It is reported that there were 16% auxiliary procedures in the SWL group and 2% in the PCNL group.[28] In the present study, auxiliary treatment rates were higher for patients in the SWL group.

In pediatric patients, general anesthesia is needed during SWL sessions. Although the requirement for anesthesia may be minimized in adult patients for SWL by applying intravenous sedation, it is hard to minimize anesthesia in children because patient movement can shift the stone off target, causing a loss in stone fragmentation efficacy if not readjusted back onto the target.[29] Additional treatment modalities such as Double-J stent placement before SWL also require general anesthesia. Thus, patients must undergo general anesthesia for SWL, Double-J stent placement, and Double-J stent removal. Studies have indicated that children 2 years of age and younger exposed to more than two anesthetics or more than a total of 120 minutes of anesthesia are at risk for learning disabilities.[30,31] The duration of total or procedural anesthesia in the SWL group was not recorded, however. This is accepted as one of the limitations of the study.

In the literature, the rate for Double-J stent placement before SWL is reported to be 15.4%. These Double-J stents were used for either a large stone burden or a high grade of obstruction.[32] As a result, these patients undergo general anesthesia for both Double-J stent placement and for multiple sessions of SWL. In our study, a Double-J stent was applied in 26 (24%) patients who underwent SWL. In the microperc arm, only two patients had Double-J stents placed before the intervention.

The duration of hospitalization for the microperc group (49.2 hours) was longer than in the SWL group (8.4 hours). The stone size and the treatment modality were the factors affecting the duration of hospitalization ($p < 0.001$; $p < 0.001$; respectively). If the duration of hospitalization needed for the Double-J stent placement before SWL is considered, and removing the Double-J stent after SWL and multiple sessions of SWL are added to the hospitalization duration, then the real duration time will be longer, however. The pretreatment rate for auxiliary procedures (Double-J stent) was significantly reduced in those patients undergoing microperc compared with those undergoing SWL.

Complications such as renal colic, Steinstrasse formation, fever, and hematuria were reported as between 5.26% and 30% after SWL treatment and from 0% to 25% after PCNL.[1,3,22,23] In an animal model, Kaji and colleagues[33] reported renal fibrosis and permanent histologic changes such as tubular atrophy, interstitial fibrosis, glomerular destruction, and capsular thickening resulting in an increase in mean arterial pressure.[33] Diabetes mellitus was related to the number of shocks administered and the total intensity of SWL treatment. Hypertension strongly correlated with bilateral SWL treatment.[34] It is reported that the complications for PCNL were strongly related to the size and the multiplicity of the tract. The presence of diabetes and stone size are reported to be the main factors affecting bleeding.[35] During percutaneous procedures, bleeding usually occurs during renal access.[35] Small instruments reduced the complications and blood loss in patients who underwent the PCNL procedure.[22,36] Recently, Bader and coworkers[5] reported an optical puncture system to obtain safe and optimal renal access. They used this system to avoid many complications related to access such as adjacent organ injury, intraoperative bleeding, and perforation of the collecting system.[5] The overall

complication rates for microperc and SWL were 21.6% and 16.7%, respectively.

There are several limitations of the present study. The retrospective design, comparison of the groups unmatched by stone size, composition, and density that are accepted as the factors affecting the success of SWL, and lack of multivariant analysis are regarded as the main limitation factors of the study. Despite the limitations, this is the first study comparing the outcomes of SWL and microperc in the management of kidney stones in children, and we believe that the outcomes of the study contribute to the literature. Further prospective and randomized studies are needed to help in making a decision about the safest and effective treatment modality for nephrolithiasis in children.

Conclusion

SWL is attractive in the pediatric population because of its relatively noninvasive nature. A probable necessity for multiple treatment sessions and the possibility of needing additional procedures and therefore multiple general anesthetic sessions should clearly be considered. Microperc resulted in stone-free patients after a single session for the management of pediatric renal stones, and microperc resulted in a similar SFR, a lower complication rate, and a lower re-treatment rate.

Disclosure Statement

No competing financial interests exist.

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Address correspondence to:
Namik Kemal Hatipoglu, MD
Department of Urology
University of Dicle
Diyarbakır 21280
Turkey

E-mail: nkhatipoglu@gmail.com

Abbreviations Used

CT = computed tomography
KUB = kidneys, ureters, and bladder
PCNL = percutaneous nephrolithotomy
RIRS = retrograde intrarenal surgery
SFR = stone-free rate
SWL = shockwave lithotripsy
US = ultrasonography

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Editorial Comment for Hatipoglu *et al.*

Amy E. Krambeck, MD

Determining the appropriate surgical treatment for nephrolithiasis in the pediatric patient population can be problematic, because the condition is infrequently encountered even at high-volume stone centers and standard treatment protocols are lacking. Care must be taken to weigh the risks and benefits of each treatment modality, including success rate, potential complications, radiation and anesthesia exposure, and surgeon experience. Furthermore, the surgical treatment should be tailored to each patient and stone situation. Because of the low prevalence of childhood nephrolithiasis, few comparative treatment studies exist in the literature to guide the urologist through the therapeutic decision-making process.

Hatipoglu and colleagues present their study comparing treatment outcomes of microperc and shockwave lithotripsy (SWL) for nephrolithiasis in 145 pediatric patients. Microperc is an exciting new technology that allows for visual directed laser stone fragmentation without tract dilation. Because the stones are not actually extracted through the tract, the patient must still pass stone fragments down the ureter much like SWL; however, the irrigation at the time of stone fragmentation facilitates early passage of debris. The current study is unmatched, with the microperc group having older children (mean 8.4 *vs* 5.9 years) and larger stones (mean 14.78 mm *vs* 11.32 mm) compared with the SWL group.

Despite the study limitation, valuable information on risks and treatment outcomes was obtained. First, there was no difference in overall stone-free rates (89% *vs* 88%) or complications rates (21% *vs* 16%) between the two treatments, despite microperc being more invasive and having an 8% case conversion rate to mini-percutaneous nephrolithotomy for bleeding. These findings are a testament to the safety of the appropriately performed microperc and perc techniques, but perhaps just as important, the results highlight the excellent stone-free outcomes that can be obtained with minimally invasive SWL in the pediatric population. It must be pointed out, however, that some children in the SWL group did require a second and even a third procedure to achieve the high stone-free rate, which ultimately increased their anesthetic exposure time.

Second, the mean hospitalization time for the microperc was 2 days compared with 8 hours in the SWL group. In the current era of cost containment, the ability to perform a procedure as an outpatient must seriously be taken into consideration. Furthermore, in the pediatric population the amount of stress to the patient and family is potentially limited when they are able to return to their home environment after treatment.

Department of Urology, Mayo Clinic, Rochester, Minnesota.