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Initial experience of micro-percutaneous nephrolithotomy in the treatment of renal calculi in 140 renal units

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Abstract The aim of this study was to investigate the effectiveness and reliability of the micro-percutaneous nephrolithotomy (PNL) method for the management of kidney stones. We performed a retrospective analysis of 136 patients (140 renal units) who underwent micro-PNL for renal stones between September 2011 and February 2013 in four referral hospitals in Turkey. The selection of treatment modality was primarily based on factors such as stone size and location. In this study, we analyzed patient- and procedure-related factors. The mean age of patients in this study was 28.7 ± 20.6 (1–69) years, and the mean stone size was 15.1 ± 5.15 (6–32) mm. Conversion to mini-PNL was required in 12 patients. All interventions were performed with the patient in the prone position, except for the 3-year-old patient with the pelvic kidney who was placed in the supine position. The mean hospital stay was 1.76 ± 0.65 (1–4) days, and the mean drop in the hemoglobin level was 0.87 ± 0.84 (0–4.1) mg/dL. One of our patients required transfusion. Ureteral J stent was implanted in nine (6.43 %) patients because of residual stones. Seven (6.43 %) patients complained of postoperative renal colic which was managed conservatively. Abdominal distension related to extravasation of the irrigation fluid was observed in three patients (2.19 %). There were no other postoperative complications. An overall success rate of 82.14 % was achieved. Micro-PNL can be effectively and safely used for small and moderate kidney stones resistant to shock wave lithotripsy or as an alternative to other minimally invasive treatment methods.

Keywords Micro-percutaneous nephrolithotomy · Kidney stone · Treatment · Efficacy · Safety

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Abbreviations

CT	Computed tomography
US	Ultrasonography
IVU	Intravenous urography
PNL	Percutaneous nephrolithotomy
SWL	Shockwave lithotripsy
YAG	Yttrium-aluminum-garnet
DJ stent	Double J stent
BMI	Body mass index
CIRF	Clinically insignificant residual fragments

Introduction

Percutaneous nephrolithotomy (PNL) has become the gold standard for the management of large kidney stones [1]. Percutaneous access is the most important step of PNL and is directly correlated to the success and complication rates of the procedure [2]. Intra-procedural complication rates range from 29 to 38 %, with bleeding being the most commonly reported complication [3, 4]. A prospective study performed by Kukreja et al. [4] demonstrated decreased bleeding with the use of smaller access tracts. A separate study found that sheaths with smaller diameters were associated with lower rates of complications related to the access tract [5]. The generation of a working channel during PNL is accomplished in a stepwise fashion [6]. These procedural steps are both time-consuming and also may cause potential complications such as prolonged fluoroscopy times, bleeding through the access tract, infundibular rupture, and pelvic perforation [3, 7].

In order to prevent these complications from occurring, the micro-percutaneous nephrolithotomy (micro-PNL) method was developed. In this technique, certain procedural steps are skipped, and only one step is used to gain access and no tract dilatation is performed [8, 9]. This method is different from the standard PNL and the minimally invasive PNL. In the minimally invasive PNL, after gaining an access to the collecting system and single-step dilation, stone fragmentation was done with a 12Fr nephroscope through the 15Fr Amplatz sheath. In this technique, the stone fragments were extracted with vacuum cleaner effect with no need of any extraction tool [10]. However, in the micro-PNL procedure, only one step, performed under direct visualization, is used to gain access and stone fragmentation is achieved using a Holmium-yttrium-aluminum-garnet (Ho: YAG) laser fiber inserted through a 4.85F access sheath which is left in situ. The stone fragments were passed spontaneously with the aid of the irrigation fluid.

The efficacy of the micro-PNL method has been demonstrated previously in a limited number of patients [11–16]. In this multicenter study, the goal was to report the outcomes of patients who had been treated using micro-PNL. To our knowledge, this is the largest series in the literature on this subject.

Materials and methods

We performed a retrospective analysis of 136 patients (140 renal units) who underwent micro-PNL to treat nephrolithiasis between September 2011 and February 2013 in four referral hospitals in Turkey. Micro-PNL was preferred as a treatment option for patients with single kidney stones <2 cm and resistant to SWL. In addition, it was also used for patients with multiple kidney stones with a total size of 2–3 cm that were located in the same direction (treated with single access). Patient- and procedure-related factors, demographic characteristics and perioperative and postoperative parameters were retrospectively analyzed.

The pre-treatment evaluation consisted of a detailed medical history, physical examination, serum urea and creatinine measurements, urinalysis, kidney–ureters–bladder (KUB) film, ultrasound (US) and computed tomography (CT) and/or intravenous urography (IVU). Patients with positive urine cultures were treated for a urinary tract infection and a negative culture was obtained prior to starting surgery. The largest diameter of the stone was determined using imaging, and in multi-stone disease, the sum of the largest diameters of all stones was calculated.

Micro-PNL technique

Micro-PNL was performed based on the previously defined technique [8]. Under general anesthesia, a 5Fr or 6Fr open-ended ureteral catheter was inserted through the urethra while the patient was in the lithotomy position. The patient was then placed in the prone position, and all pressure points were supported with cushions. Contrast material was delivered through the ureteral catheter in order to delineate caliceal anatomy. After selection of a suitable calyx, with visualization via fluoroscopy and/or US a 4.85 all-seeing needle (PolyDiagnost, Pfaffenhofen, Germany) was advanced to the desired calyx. The entrance to the collecting system was also visualized by the all-seeing needle. After insertion of the needle into the collecting system, the optical instrument and the inner sheath were removed and a 3-way connector was advanced that enabled the insertion of the micro-optic and laser probe. An irrigation system was attached to the other side of the 3-way connector. The stones were fragmented using [8 Hz (6.4 W) 0.8 J] 200 μm Ho: YAG laser fiber under direct visualization. The maintenance of the visualization and the removal of stone debris through the ureter were achieved using an irrigation pump controlled by the surgeon, and drainage of the intrarenal fluid collection was performed using an open-ended ureteral catheter. The stone-free status was evaluated with endoscopic and fluoroscopic images at the end of the procedure. The procedure was terminated with no need of any nephrostomy tube. The operation time was defined as the period starting from the access to the collecting system to the end of the procedure.

Stone-free rates 1 day and 1 month postoperatively were assessed by US, KUB and/or CT. The stone-free rate at the end of the first month was one of the endpoints of this study. Complications were classified according to Clavien [17, 18] grading system. Patient and intervention related factors were assessed based on pre and postoperative parameters. Data were reported as mean ± standard deviation (SD).

Results

The mean age of the patients was 28.7 ± 20.6 (1–69) years, and the mean stone size was 15.1 ± 5.15 (6–32) mm. The

Table 1 Demographic data and stone characteristics

Characteristics	Value, mean ± SD (range)
N (renal unite)	140
Mean age (years)	28.67 ± 20.64 (1–69)
Male/female	63/73
BMI (kg/m^2)	23.44 ± 7.42 (8.74–39.06)
Mean stone size (mm)	15.07 ± 5.15 (6–32)
Laterality	
Right	65
Left	67
Bilateral	4
Stone opacity	
Opaque	130
Radiolucent	6
Stone location	
Pelvis	23
Upper pole	5
Middle calix	16
Lower pole	62
Multi-caliceal	34
Grade of hydronephrosis	
0	33
I	58
II	34
III	11
Anatomic abnormalities	
Horseshoe kidney	1
Pelvic kidney	1
Kyphoscoliosis	1

SD standard deviation, *BMI* body mass index

Table 2 Perioperative and operative findings of the patients

Characteristic	Value, mean ± SD (range)
Operative time (min)	55.76 ± 30.83 (20–200)
Fluoroscopy time (s)	107.40 ± 79.07 (0–360)
Duration of hospitalization (day)	1.76 ± 0.65 (1–4)
Access method	
Fluoroscopy	128
Ultrasound	12
Hemoglobin drop (g/dL)	
Success rate, *n* (%)	0.87 ± 0.84 (0–4.1)
Stone free	115 (82.14)
Residual fragments (≤4 mm)	17 (12.14)
Failure	8 (5.71)
Conversion to mini-PNL, *n* (%)	12 (8.57)
Complications, *n* (%)	20 (14.28)
Clavien grade I	
Renal colic	7
Clavien grade II	
Urinary tract infection	3
Blood transfusion	1
Clavien grade III-a	
Renal colic necessitating D-J stent insertion	1
Steinstrasse requiring D-J stent insertion	2
Clavien grade III-b	
Steinstrasse requiring D-J stent insertion (pediatric patients)	3
Extravasation requiring drain placement	3
Perop D-J stent, *n* (%)	9 (6.43)

PNL percutaneous nephrolithotomy, *D-J stent* double J stent

stones were located in pelvis, upper, middle, lower calix and multi-caliceal in 23, 5, 16, 62 and 34 cases, respectively. The mean BMI of the patients was calculated as 23.4 ± 7.4 kg/m^2. The anatomical abnormalities among the series were kyphoscoliosis (*n* 1), horseshoe kidney (*n* 1), and pelvic kidney (*n* 1). The demographic characteristics and stone-related variables are summarized in Table 1.

The duration of operation and fluoroscopic screening were 55.76 ± 30.8 (20–200) min and 107.40 ± 79.07 (0–360) s, respectively. Intrarenal access was achieved using US in 12 patients and fluoroscopy was used in the remaining patients. Conversion to mini-PNL was required in 12 patients because of impaired visualization (*n* 7) and maneuvering disability to reach the displaced stone fragments (*n* 5). All interventions were performed with the patient in the prone position except for the 3-year-old patient with a pelvic kidney stone treated with laparoscopy-assisted micro-PNL in the supine position.

Intra- and postoperative variables are listed in Table 2. The mean hospital stay was 1.76 ± 0.65 (1–4) days, and the mean drop in the hemoglobin level was 0.87 ± 0.84 (0–4.1 g/dL). Bleeding requiring blood transfusion was observed in only one patient in the present series. Ureteral J stent was implanted peri-operatively in nine (6.43 %) patients because of residual stones. Seven (6.43 %) patients complained of postoperative renal colic which was managed conservatively. Ureteral stent insertion was applied for six patients with severe renal colic (*n* 1) and steinstrasse (*n* 5). In three (2.19 %) patients, abdominal distension developed due to extravasation of the irrigation fluid, and managed with peri-operatively percutaneous drain insertion. There were no other postoperative complications in the rest of the patients. Definitive success rates were as follows: the stone-free rate was 82.14 % ($n = 115$), residual fragments ≤4 mm were observed in 17 (12.14 %) patients. The procedure was failed in eight patients (5.71 %) with rest renal calculi (>4 mm).

Table 3 The distribution of the success and complication rate according to the stone size

Stone size	≤10 mm	10–20 mm	≥20 mm	*p*
Number of patients	31	74	31	
Success rate (%)	87.1	83.8	87.1	0.990
Complication rate (%)	–	10.8	9.7	0.168

Table 5 The distribution of the success and complication rate according to the age groups of the patients

Age	<7 year	7–16 year	>16 year	*p*
Number of patients	26	30	80	
Success rate (%)	84.6	76.7	88.8	0.210
Complication rate (%)	3.8	6.7	10	0.576

The success and complication rates were analyzed in patients classified according to the stone size (≤10, 10–20 and >20 mm), stone location (renal pelvis, upper, middle, lower calix and multi-caliceal), and patient age (<7, 7–16, and >16 years old) (Tables 3, 4, 5). No statistical significant difference was detected between groups in terms of success and complication rates.

Discussion

EAU Guidelines have expanded the indications for endourological interventions (PNL and other flexible ureteroscopic procedures) for the management of renal stones. The goal of performing endoscopic procedures with smaller instruments is to decrease the complication rate, morbidity and mortality with no decrease in the success rates. The mini-PNL, which uses smaller sized instruments, and thus small access tracts (12–18F) relative to the standard PNL, has been described [19, 20]. Studies have found the mini-PNL to be superior to the standard PNL in terms of hospital stay and morbidity [20, 21].

The minimally invasive PNL is modified PNL technique that single-step dilation was done up to 15Fr after gaining a proper percutaneous renal access. The stone fragments that were disintegrated using lithotripter through 12Fr nephroscope were extracted with vacuum cleaner effect with no need of any extraction tool [10]. The latest modified PNL technique "ultramini PNL" was described by Desai et al. [22]. In this technique the tract was dilated up to 11–13Fr and the stone fragmentation was performed using Ho: YAG laser fiber under direct vision of the 3.5Fr ultra-thin telescope. The fragments were evacuated using the specialized sheath. In contrast to the previous techniques, the micro-PNL is a single-step procedure which uses an access tract even smaller than those of the mini-PNL or the ultramini PNL [8, 9, 11, 12, 14]. There are only a few studies on the micro-PNL with small-sized series [8, 12, 14]. This study is the largest scale investigation conducted so far.

The most important advantage of the micro-PNL is reduced bleeding. In the micro-PNL, single-step access under direct visualization helps to prevent potential complications occurring during access and dilatation of the tract and decreases the risk of intraoperative bleeding. Indeed, intrarenal bleeding can lead to premature termination of the operation or even organ loss or mortality [4, 23]. Studies have demonstrated that the size of the nephroscope and tract influences the amount of intraoperative bleeding [4, 23]. Kukreja et al. [4] showed that technique-related factors such as method of access (fluoroscopy vs. ultrasonography), number of tracts, method of tract dilatation, size of tracts, and rate of operative complications played a large role in predicting total blood loss [23]. In the first micro-PNL study, the mean decrease in hemoglobin was found to be 1.4 mg/dL [8], and subsequent studies did not report the need for postoperative transfusion [11, 12, 14]. In our study, the mean decrease in hemoglobin levels was 0.87 mg/dL. However, blood loss requiring transfusion was observed in only one patient (0.71 %).

The other difference of the microperc rather than the conventional PNL is no need of stone extraction. Although the technique is similar to SWL in this aspect, the advantage of micro-PNL is that precise stone localization under direct visualization enables complete and definitive fragmentation of the stone using with laser without being limited by stone density [8]. On the other hand, SWL is a relatively less invasive procedure. However its success depends on various variables such as the density and location of the target stone(s) and the distance between the stone and the skin entry site [24].

Micro-PNL can be compared to flexible ureteroscopic stone fragmentation procedures. Though retrograde

Table 4 The distribution of the success and complication rate according to location of stone

Stone location	Renal pelvis	Upper calix	Middle calix	Lower calix	Multiple caliceal	*p*
Number of patients	23	5	16	58	34	
Success rate (%)	95.7	100	93.8	81	79.4	0.109
Complication rate (%)	13	–	6.3	8.6	5.9	0.824

intrarenal surgery (RIRS) has good efficacy and a low complication rate such as severe bleeding or infection in patients with small renal stones [25, 26], when compared with PNL, it has a lower disintegration rate [26]. The steep learning curve is another limitation of the RIRS. On the other hand any surgeon who can perform PNL can learn micro-PNL procedures relatively easily [8]. In a prospective and randomized study, Desai et al. [27] compared micro-PNL and RIRS for the management of renal calculi <1.5 cm. According to their results, they concluded that micro-PNL is a safe and effective alternative to RIRS and has similar stone clearance and complication rates. As the disadvantages of these procedures, micro-PNL is associated with higher analgesic requirements due to increased pain and higher hemoglobin loss, while RIRS is associated with a higher DJ stenting rate.

Previous studies have reported success rates for micro-PNL ranging between 85 and 93 % [8, 11, 12, 14], and in our study an average success rate of 82.14 % was obtained. Even though the complete removal of tiny residual stone fragments is facilitated by serial saline irrigation performed during the procedure, stone fragments can lead to postoperative renal colicky pains and the formation of steinstrasse, particularly in patients with large stones. In a study conducted by Armagan et al. [11], postoperative renal colic ($n = 2$) and steinstrasse ($n = 2$), were managed by medical therapy and drainage through an implanted DJ stent, respectively. In our series, renal colic developed postoperatively in eight patients and steinstrasse occurred in five patients. Seven patients with complaints of renal colic received medical therapy. The remaining renal colic patients and the steinstrasse group were managed by DJ stent implantation. Because of our experience and observation of the relationship between increased stone burden and complications related to the stone fragments, we inserted DJ stents as a part of the routine preoperative procedures in subsequent patients ($n = 9$) with stones larger than 2 cm.

Although the drainage of the collecting system during micro-PNL is provided by a large ureteral catheter (6Fr), the lack of an outer access sheath used during conventional PNL may lead to elevation of the intrarenal pelvic pressure especially in cases with prolonged operation time and impacted pelvic calculi obstructing the drainage. Desai et al. mentioned the concerns about the elevated intrarenal pelvic pressure in the first series of micro-PNL. In the following study, the authors reported a case with abdominal distension related to fluid intravasation as a complication of micro-PNL. The authors attributed this nasty complication to impacted pelvic stone leading to impaired renal drainage [11]. In our study, fluid intravasation developed in three patients and management consisted of implantation of a percutaneous drain inserted under US guidance.

The low resolution of the micro-optic and fine and small-sized micro-sheath are the main limitations of the technique that can affect the outcome of the procedure. The vision can be affected by the minimal hemorrhage. And to reach the other calyxes that include scattered stone fragments, it may be restricted because of the limited maneuverability. Conversion to mini-PNL is a solution to overcome these limitations of the micro-PNL technique. In the limited past literature available on the subject, 4.8–8.57 % of the cases required an intraoperative conversion to mini-PNL [11, 12, 14]. In the present study, this rate was 8.57 %, because of impaired visualization (n 7) and maneuvering disability to reach the displaced stone fragments (n 5).

Previous studies demonstrated that tubeless procedure is the most important factor in reducing length of hospitalization after percutaneous nephrolithotomy [28]. In addition to the advantages that are described above, duration of hospitalization is reduced because of totally tubules technique and the smaller incision with micro-PNL.

This study has some limitations such as the retrospective study design and data being compiled from multiple centers and surgeons. Although CT is the most sensitive method to assess the stone-free status, in the present study a limited number of patients (n 20) were evaluated with CT postoperatively. In the most of the patients success was assessed with KUB and US. This situation is another limitation point of the study. In addition, prospective controlled trials with other treatment modalities are needed. However, this study is the largest to date about micro-PNL. And we believe that our findings will contribute to the literature.

Conclusions

Micro-PNL is an innovative technological development for the management of renal stones with promising outcomes for the clearance of smaller sized urinary calculi. This technique can be effectively and safely utilized, and has the potential to decrease morbidity rates compared to standard PNL. Another advantage of the micro-PNL is that it can be converted at any time during the procedure to a mini-PNL.

Conflict of interest The authors declare that they have no conflict of interest.

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