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Comparison of intrarenal pelvic pressure during micro-percutaneous nephrolithotomy and conventional percutaneous nephrolithotomy

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Abstract The micro-percutaneous nephrolithotomy (microperc) is a recently introduced percutaneous nephrolithotomy (PNL) technique that is performed through a 4.8Fr all-seeing needle. We aimed to measure the intrarenal pelvic pressure (IPP) during microperc and compare it with the levels of conventional PNL. A total of 20 patients with 1- to 3-cm renal calculi resistant to shock wave lithotripsy were treated either with microperc (Group-1, *n*: 10) or conventional PNL (Group-2, *n*: 10) by the same surgical team. The IPP was measured during different stages (entrance into the collecting system, stone fragmentation, and before termination) of the procedures by an urodynamic machine using the 6Fr ureteral catheter. All the variables were statistically compared between the two groups. The demographic values of the patients were similar. The operation time and duration of hospitalization were significantly prolonged in conventional PNL group ($p = 0.034$, $p = 0.01$, respectively). The mean drop in hematocrit levels was significantly lower in microperc group (3.5 ± 1.5 vs. 1.8 ± 0.8; $p = 0.004$). The IPP was significantly higher in microperc group during all steps of the procedure. The highest level of the IPP was measured as 30.3 ± 3.9 and 20.1 ± 3.1 mmHg in Group 1 and Group 2, respectively ($p < 0.0001$). However, the complication and success rates were found comparable. In conclusion, we demonstrate that the level of IPP is significantly increased during microperc compared to conventional PNL. Microperc should be used cautiously in cases with impaired drainage of the collecting system.

Keywords Renal calculi · Microperc · Conventional percutaneous nephrolithotomy · Pressure

Introduction

The minimally invasive treatment of kidney stones involves the access to the renal collecting system either through the ureter (retrograde) or a percutaneous renal access tract (antegrade) via using flexible or rigid endoscopes. The operations are performed under direct visualization with the aid of irrigation fluid. During the procedures, the balancing of the intrarenal pelvic pressure (IPP) is utmost important in order to prevent from systemic absorption of the irrigant which may cause complications such as postoperative fever and sepsis [1, 2].

The microperc is a recently introduced percutaneous nephrolithotomy (PNL) technique that is performed using a 4.8 or 8Fr micro-sheath with no need of a tract dilation and additional access sheath [3–6]. During this procedure, the drainage of the collecting system is mainly provided through the ureteral catheter inserted preoperatively. Different than the conventional PNL or mini-PNL, the lack of an access sheath leads to concerns about probability of the increased IPP during microperc.

In this prospective randomized trial, we aimed to measure the IPP during microperc and compare it with the levels of conventional PNL.

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Materials and methods

Between August 2012 and February 2013, a total of 20 patients with 1-to-3 cm renal calculi resistant to SWL were treated either with microperc or conventional PNL by the same surgical team. The patients were randomly assigned into one of the groups according to the PNL technique: microperc (Group-1, *n*: 10) or conventional PNL (Group-2, *n*: 10).

Randomization was performed using computer-based simple random tables in a 1:1 ratio. Local ethics committee approved the study, and all patients signed the written informed consent. Patients with narrow infundibulum impacted uretero-pelvic stone or ureteral obstruction preventing the insertion of ureteral catheter up to the collecting system, age of ≤18 years and requiring multiple renal accesses were excluded from the study. All patients were preoperatively evaluated with complete blood count, routine biochemistry, coagulation profile and radiographic methods. The patients with positive urine culture were treated accordingly. Radiological investigation included plain film of kidney, ureters and bladder (KUB), renal ultrasonography, intravenous urography (IVU) and/or computed tomography (CT). The stone size was measured according to the longest axes of the stone.

Pre-procedural preparation

Under general anesthesia, lithotomy position was given and 6Fr open end-ureteral catheter (Geotek Medical, Ankara, Turkey) was placed into the renal pelvis over a guidewire under fluoroscopic guidance. Then the patient was repositioned to the prone position for the performance of PNL. The renal pelvic pressure was monitored by urodynamic machine (Aymed, Ankara, Turkey) through the 6Fr ureteral catheter. The connection of the ureteral catheter and urodynamic device was done properly using a special connector preventing any leakage. The sinusoidal pressure tracings were observed by the compression of ipsilateral flank region. By this way, the functionality of the system was controlled and the collecting system pressure was adjusted to zero preoperatively [7, 8].

Microperc technique

After opacification and distension of collecting system with saline injection through the ureteral catheter, percutaneous renal access was performed using all-seeing needle under fluoroscopy. After making an access to the collecting system, a three-way connector that allows passage of laser fiber, micro-optic and irrigation fluid attached to the proximal part of the 4.8Fr micro-shaft. The irrigation pumping system was set to pressure of 50 mmHg [3]. The stone fragmentation was enabled with Ho-YAG laser with dusting technique under direct vision. The clearness of the vision and wash out of stone fragments were obtained by the irrigation pump system that was controlled by the assistance. The drainage of the collecting system was mainly provided through the 6Fr ureteral catheter. The space outside the catheter along the ureter lumen also supports drainage during the procedure. The maintenance of the irrigation passage through ureteral catheter was observed during the procedure. The blockage of the irrigation with stone debris or clot was resolved by syringe irrigation through the distal end of the ureteral catheter. The stone clearance was determined using with the endoscopic and fluoroscopic imaging. The procedure was terminated without placing a nephrostomy tube in all patients.

PNL technique

The percutaneous renal access was done using 18G access needle under C-arm fluoroscopy in prone position as previously described [9]. The tract was dilated up to 30Fr over the guidewire using the Amplatz dilators. A 30Fr Amplatz sheath was placed into the collecting system under fluoroscopic imaging. A 24Fr nephroscope was used during the procedure. The stone fragmentation and retrieval was performed with pneumatic lithotripter (Lithoclast®, EMS, Nyon, Switzerland) and graspers. After the evaluation of the stone clearance with fluoroscopy and endoscopy, a 14Fr nephrostomy tube was placed to the majority of the cases. During the procedure, the irrigation of the collecting system was provided by the irrigation bags hanged up to 90 cm above the kidney level as described previously [8].

The renal pelvic pressure was measured after the entrance into the collecting system, during stone fragmentation and irrigation, and at the end of the procedure using the urodynamic machine in all patients treated with conventional PNL or microperc. The monitorization of the IPP could be performed during certain steps of the procedure for a very short time in order to avoid the prevention of the drainage of the collecting system during microperc. The patients were evaluated on postoperative day 1 with biochemical tests and plain radiograph. The ureteral catheter removal was done on postoperative day 1 for all patients. The nephrostomy tube was removed on postoperative day 2. The patients treated with microperc or tubeless PNL were discharged on postoperative day 1, unless complications necessitated prolonged hospitalization. The complications were documented according to the Clavien Grading system [10]. All of the patients were re-assessed with CT on the first month following the surgery.

Statistical analysis

Results were presented as the mean ± SD. Data were processed using SPSS-16 for Windows (SPSS, Inc., Chicago,

Table 1 The demographic values of the patients treated with conventional PNL or microperc

	Conventional PNL	Microperc	*p*
N	10	10	
Age (years)	44.3 ± 10.1 (27–62)	47.2 ± 15.1 (28–66)	0.62
BMI (kg/m^2)	27.8 ± 2.8 (23.7–33.1)	27.5 ± 3.6 (21.8–33.5)	0.85
Stone size (mm)	21.9 ± 4.8 (15–30)	19.9 ± 5.0 (12–30)	0.37
M/F	6/4	4/6	0.65

IL). A required sample size of 10 was based on proposed clinically significant difference of 3 mmHg between two groups, with a beta error level of 80 % and an alpha error of 5 %. Continuous variables were compared with the Student *t* test or the Mann–Whitney *U* test, as appropriate. Proportions of categorical variables were analyzed for statistical significance using the Chi square test or Fisher exact test. In all analyses, two-sided hypothesis testing was performed, and probability values <0.05 were deemed significant.

Results

The demographic values of the patients in each group including age, BMI, stone size and male/female ratio were statistically similar ($p = 0.62$, 0.85, 0.37, 0.65, respectively) (Table 1). The duration of operation and hospitalization was significantly prolonged in conventional PNL group ($p = 0.034$, 0.01, respectively). The mean fluoroscopic screening time was shorter in the microperc group (68.4 vs. 92.4 s, $p = 0.12$). The drop in hematocrit level was significantly higher in the conventional PNL group (3.5 vs. 1.8 %; $p = 0.004$). The stone-free rates of the procedures were statistically similar in both groups (90 vs. 80 %) (Table 2). Postoperative fever (Clavien grade 1) was detected only in one patient in microperc group. Prolonged urine leakage necessitating DJ insertion (Clavien grade 3a) was observed in one patient after removal of nephrostomy tube in conventional PNL group. The IPP was significantly higher in microperc group in all steps of the procedure (Table 3). The highest level of the IPP was measured as 20.1 ± 3.1 and 30.3 ± 3.9 mmHg during conventional PNL and microperc, respectively ($p < 0.0001$).

Discussion

Although many researchers previously studied the effect of PNL and flexible URS on the IPP, no information is available regarding the microperc [7, 8, 11–15]. The drainage of the collecting system and irrigation fluid is mainly provided through the space between the nephroscope and the outer (Amplatz) sheath during conventional PNL. The situations that lead to impaired drainage and elevated IPP were clearly described previously [8, 15]. The IPP might be elevated in case of narrow infundibulum that restricts the outer drainage around the nephroscope [8]. In addition, the improper positioning of the tip of the Amplatz sheath within collecting system causes the collapse of the renal parenchyma around the nephroscope and leads to elevation of IPP. In the present study, the patients with narrow infundibulum were excluded from the study.

The microperc is primarily based on the creation of renal access with a 4.8Fr all-seeing needle and fragmentation

Table 2 The peri-operative measures related to the procedures are summarized

	Conventional PNL	Microperc	*p*
Operation time (min)	49 ± 9.8 (32–65)	36.5 ± 14.2 (20–60)	0.034
Fluoroscopy time (s)	92.4 ± 38.7(48–180)	68.4 ± 26.9(30–120)	0.12
Hospitalization (days)	2 ± 0.5 (1–3)	1.1 ± 0.3 (1–2)	0.001
Hematocrit drop (%)	3.5 ± 1.5(1.2–6.1)	1.8 ± 0.8(0.9–3.2)	0.004
Success	9/10	8/10	1.0
Complication	1	1	1.0
Fever		1	
Prolonged urine leakage	1		

Table 3 Pelvic pressure (mmHg) during different phases of the conventional PNL and microperc procedures

	Conventional PNL	Microperc	*p*
Introduction	8.7 ± 2.4 (4.5–11.4)	12.2 ± 2.5 (9.02–16.5)	0.005
Fragmentation	15.3 ± 3.5 (9.02–21.05)	22.1 ± 3.3 (18.2–28.3)	<0.0001
Irrigation	20.1 ± 3.1 (15.03–26.8)	30.3 ± 3.9 (25.6–37.6)	<0.0001
End	8.9 ± 1.9 (5.26–11.2)	11.3 ± 1.8 (9.5–15.03)	0.011

of stone through the same needle shaft with no need for further dilation and any access sheath [3–6]. The irrigation during the procedure is maintained through a 0.5 mm space when the optic is inserted into the needle shaft. Furthermore the easily blurred low-resolution micro-optic makes the irrigation system an essential tool for microperc. Although Bader et al. [3] defined that irrigation should be done with irrigation pump system or 20-ml syringe, irrigation pump system is a more efficient method that provides consistent and standard pressure of irrigation. The irrigation pump system that has two set ups (50 and 100 mmHg) is used for irrigation of the collecting system during the procedure [3]. Bader et al. assessed the irrigation flow at two pressure settings (50 and 100 mmHg) of the pump system in an ex vivo model. And it is found that the pump system provides an irrigation flow of 80 ml/min through the needle shaft inserted with 0.018-in. guidewire in the setting of 50 mmHg of the machine [3]. However, the effect of the irrigation flow on IPP was not evaluated. This is the first prospective and randomized study evaluating the IPP during microperc and comparing with the IPP levels during conventional PNL.

The drainage of the collecting system is basically provided through the ureteral catheter and ureter lumen during microperc. Therefore, the authors recommend insertion of larger sized catheter prior to microperc [5, 6]. However, the situations preventing the passage of the ureteral catheter into the collecting system such as ureteral or uretero-pelvic obstruction, impacted ureteral calculi or clogging of the catheter with stone debris or blood clot lead to elevated IPP during microperc. Therefore, the patients with impacted uretero-pelvic stone or ureteral obstruction preventing the passage of ureteral catheter up to the collecting system were excluded from the study. Moreover, the monitorization of the IPP could be performed during certain steps of the procedure for a short time in order to avoid the prevention of the drainage of the collecting system.

It has been previously demonstrated that pyelovenous backflow may occur at the IPP levels above 30–35 mmHg [16]. However, some other researchers have presented that pyelovenous backflow may also occur in lower IPP levels (10–20 mmHg) [1, 2]. In routine urological practice, the levels of IPP <30 mmHg are accepted as safety limits for percutaneous chemo dissolution of kidney stones, instillation of immunotherapy, RIRS and PNL [7, 8]. In the present study it is observed that the IPP was significantly higher in microperc group in all steps of the procedure. Moreover, the mean IPP was significantly increased above the safety limits (30.3 ± 3.9 mmHg) during irrigation using the pressured pump system (Table 3). The increased IPP leads to the pyelovenous, pyelolymphatic, pyelotubular backflow, and forniceal rupture [7, 8]. The systemic absorption of bacteria and endotoxins from the irrigation fluid is the suspected factor for the postoperative fever and sepsis. However, Troxel and associates could not find any association with increased IPP and postoperative fever. On the other hand, they found a correlation between postoperative fever and PNL for infection stones [10]. In the present study, a fever of 38 °C was developed postoperatively in a patient in microperc group. It was controlled with conservative treatment with no need to administer additional antibiotherapy.

In the study presenting the outcomes of microperc in patients with moderate-sized kidney stones, the authors presented a complication related to the elevated IPP [6]. Abdominal distention and intravasation of the irrigation fluid were reported in a child with an impacted renal pelvis stone that prevents the drainage of the collecting system. In conclusion, the authors recommended conventional PNL in patients with obstructed systems due to impacted calculi. In the present study, the patients with impacted pelvis or uretero-pelvic stones were excluded. In an attempt to reduce the IPP during microperc, Penbegul et al. [17] defined a micro-sheath that enables the passage of 4.8Fr all-seeing needle through its lumen. They used a 14G angiocath to gain a proper percutaneous renal access with the guidance of ultrasound. Finally, they performed microperc through the transparent lumen of angiocath without any important complication. Despite the structural limitations, the lumen of the angiocath acts as an Amplatz sheath used during conventional PNL and contributes to the drainage of the collecting system. However, the IPP was not measured in that study.

The lack of information about the stone composition, stone culture, and small number of the cases are considered as the major limitation factors of the present study. Despite of the mentioned limitations, this is the first prospective and randomized study measuring the levels of IPP during microperc and comparing it with the IPP levels of conventional PNL. We believe that our results provide important information for the clinicians using the microperc system.

Conclusion

The results of the present study clearly demonstrate that the level of IPP is significantly increased during microperc compared to conventional PNL. The microperc may not be a proper treatment modality in cases with impaired drainage of the collecting system. Further technological advances and production of a proper outer sheath is required for safer microperc performance.

Conflict of interest No conflict of interest.

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