Single-Step Percutaneous Nephrolithotomy (Microperc): The Initial Clinical Report

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Abbreviations and Acronyms

CIRF = clinically insignificant residual fragments

KUB = plain x-ray of kidneys, ureters and bladder

PNL = percutaneous nephrolithotomy

SWL = shock wave lithotripsy

VAS = visual analog score

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Purpose: To our knowledge we report the first technical feasibility and safety study of 1-step percutaneous nephrolithotomy using the previously described 4.85Fr all-seeing needle (PolyDiagnost, Pfaffenhofen, Germany). We defined microperc as modified percutaneous nephrolithotomy in which renal access and percutaneous nephrolithotomy are done in 1 step using the all-seeing needle.

Materials and Methods: Microperc was performed in 10 cases using the 4.85Fr all-seeing needle to achieve collecting system access under direct vision. Percutaneous nephrolithotomy was done through the same 16 gauge needle sheath with a 3-way connector allowing irrigation, and passage of a flexible telescope and a 200 μm holmium:YAG laser fiber. We prospectively analyzed preoperative, intraoperative and postoperative parameters.

Results: Mean calculous size was 14.3 mm. Two of the 10 patients were of pediatric age, and 1 each had an ectopic pelvic kidney, chronic kidney disease and obesity. Microperc was feasible in all cases with mean $\pm$ SD surgeon visual analog score for access of 3.1 $\pm$ 1.2, a mean 1.4 $\pm$ 1.0 gm/dl hemoglobin decrease and a mean hospital stay of 2.3 $\pm$ 1.2 days. The stone-free rate at 1 month was 88.9%. In 1 patient intraoperative bleeding obscured vision, requiring conversion to mini percutaneous nephrolithotomy. There were no postoperative complications and no auxiliary procedures were required.

Conclusions: Microperc is technically feasible, safe and efficacious for small volume renal calculous disease. Further clinical studies and direct comparison with available modalities are required to define the place of microperc in the treatment of nonbulky renal urolithiasis.

Key Words: kidney; kidney calculi; nephrostomy, percutaneous; endoscopes; miniaturization

Percutaneous nephrolithotomy is widely established as a standard percutaneous technique for large bulk renal urolithiasis. A major morbidity of standard PNL is bleeding.[1–4] Kukreja et al prospectively identified that decreasing the tract size for standard PNL could decrease bleeding.[4] As reported by Helal et al,[5] the mini PNL technique decreased tract related morbidity by limiting the sheath to a size small enough to accommodate a standard rigid nephroscope. Mini PNL can be performed with a tract size of 16Fr to 20Fr.[5–11]

Many maneuvers are required to set up standard PNL. After placing the patient prone and inserting an appropriately sized ureteral catheter these maneuvers are initial ultrasound or fluoroscopic access, guidewire placement in the system, preferably in the

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ureter, removal of the initial puncture needle guidewire, serial dilation of the tract with resultant tract bleeding during the maneuvers and finally placing an Amplatz sheath after removing the tract dilators.[12] These individual maneuvers are time-consuming and often have disadvantages, such as increased fluoroscopic time and radiation, tract bleeding and inadvertent complications, including calyceal infundibular tearing and pelvic perforation.[1,2] A solution to these 2 problems would be to decrease the number of maneuvers (steps) required to set up standard PNL so that the entire procedure could be done as a single step without dilation or the need for multiple maneuvers for access, tract dilation and nephroscopy.

The all-seeing needle was presented in 2010 by Bader et al at the American Urological Association Annual Meeting in San Francisco.[13] The all-seeing needle permits visualization of the entire tract during percutaneous access, including successful and correct calyceal entry into the pelvicalyceal system. They used the needle in 15 patients during standard PNL to achieve kidney access. In all cases they visualized the punctured kidney calyces and confirmed calculi before dilating the tract to 30Fr for standard PNL.

We further extended the concept of all-seeing needle to assess the technical feasibility of performing 1-step PNL through a 4.85Fr tract. We define the term microperc as modified PNL in which renal access and PNL are performed in a single step through the all-seeing needle with a 4.85Fr tract size. We selected small renal calculi that were otherwise suitable for SWL or flexible ureteroscopy. To our knowledge we present the initial technical feasibility and safety report of this new technique.

MATERIALS AND METHODS

We performed microperc on 10 patients from June 29 to September 29, 2010. Before initiating the study we obtained institutional review board approval. Patient details were prospectively analyzed after entering them into a database. The intraoperative parameters analyzed were ease of access, as determined by a surgeon VAS rating on a scale of 1 to 10, renal access method, number of punctures required, stone fragmentation method, intraoperative assessment of stone fragmentation and intraoperative complications. Postoperative parameters analyzed were the hemoglobin decrease, the analgesic requirement in mg tramadol, complications, as graded by the Clavien-Dindo classification, stent requirement, clearance at 1 day and 1 month on KUB and ultrasound, and the need for auxiliary procedures.

Armamentarium

This procedure was performed through a 3-part all-seeing needle, consisting of micro-optics 0.9 mm in diameter with a 120-degree angle of view and resolution up to 10,000 pixels (fig. 1). Micro-optics with an integrated light lead are inserted in the working sheath of the puncture needle. This special needle, including the shaft, has an outer diameter of 1.6 mm (4.85Fr), slightly larger than the diameter of a standard 1.3 mm needle. Optics are length adjusted so that the distal end is flush with the needle tip. Optics are connected via a zoom ocular and light adapter to a standard endoscopic camera system and a xenon light source at least 100 W in power. The highly flexible fiberoptic telescope contains 10,000 fiber-optic bundles and can be bent over itself without causing damage (fig. 2, *A* and *B*). Optics are relayed through a multijointed mounting arm with attached camera and light cable (fig. 2, *C*). There is an outlet from the connector to an irrigation pump. After access is achieved the inner sharp beveled needle housing the telescope is removed. A 3-way connector is then attached to the proximal end of the 4.85Fr sheath. The 3 ends of the connector allow use of a 200 μm laser fiber from the central port, an irrigation connection to 1 side port and an telescope through the other side port (fig. 2, *D*).

Technique

After general anesthesia is induced a 5Fr ureteral catheter is placed transurethrally. Under ultrasound and/or fluoroscopic guidance a selective calyceal puncture is made with the 16 gauge all-seeing needle under optical guidance. The beveled inner needle is removed and a 3-way connector is attached to the proximal end of the sheath. The telescope is passed through the connector side port and the other side port is used for irrigation. The connector central port is used to pass the laser fiber.

The calculus is then fragmented by a holmium:YAG laser using a 200 μm Sphinx 30 fiber (LISA Laser, Pleasanton, California). Vision is controlled to the optimum level using an irrigation pump as required, which is controlled by a foot pedal by the operating surgeon.

At the end of the procedure fragmentation and clearance are assessed by fluoroscopy. The patient is monitored for postoperative complications. The Foley catheter is removed on postoperative day 1 and the patient is subsequently discharged home. KUB is done to assess the stone-free rate in all patients at day 1 and 1-month followup. Clearance was defined as no residual stone on KUB and ultrasound. All fragments less than 4 mm were considered CIRF. Data were recorded prospectively in a database and reported as the number and percent or mean $\pm$ SD as appropriate.

RESULTS

Table 1 lists patient demographic data and stone characteristics. Average calculous size was 14.3 mm (range 6 to 25 mm). Table 2 lists intraoperative parameters. In 5 patients (50%) access was achieved by ultrasound and in 5 (50%) initial access was achieved by ultrasound with adjustment under fluoroscopic guidance. Fluoroscopy was not used alone. For PNL the lower, upper and mid calyx was accessed in 7, 2 and 1 patients, respectively. In all cases the stone was immediately seen as soon as the

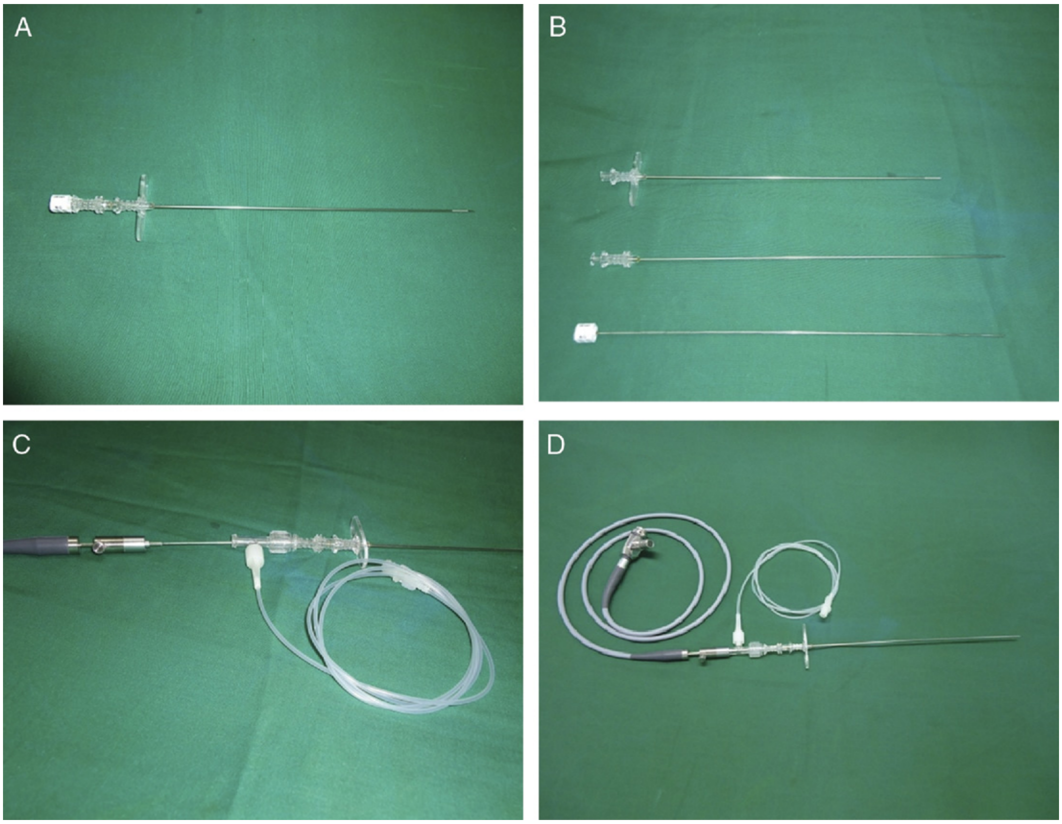

Figure 1. *A* and *B*, all-seeing needle and its parts. *C* and *D*, needle prepared for renal access.

needle traversed the appropriate calyx. Correct calyceal entry also ensured no bleeding before stone disintegration. Mean surgeon VAS to access the pelvicalyceal system was 3.1 ± 1.2 (range 1 to 5).

A holmium-YAG laser was used as energy for fragmentation in all cases. In 1 patient intraoperative bleeding during initial access placement resulted in poor vision, requiring conversion to mini PNL for stone clearance. No nephrostomy tube was left at the end of the procedure.

Table 2 also lists postoperative parameters. There were no postoperative complications and no patient required an auxiliary procedure. As assessed by KUB, the overall clearance rate at 1 month was 88.9% (8 of 9 cases). The patient who required conversion to standard PNL was excluded from postoperative analysis.

DISCUSSION

Since its introduction in 1976,[14] PNL has had an important role in urologist treatment strategies. There have been significant advances in PNL, including instrument miniaturization.[5–11] Enough evidence in the literature suggests that mini PNL decreases morbidity by reducing tract size.[10,11] In a continuing quest for miniaturization the question is how small can we go? If tract size is kept to a minimum, ie up to the size of the initial puncture needle, it could theoretically eliminate tract morbidity. Performing PNL through the initial 1-step access needle would also avoid multiple exchanges of dilators and instruments during tract dilation, decreasing complications resulting from tract dilation errors.

We used these 2 concepts to innovate microperc. We duplicated the concept of optical visualization of the tract in laparoscopic surgery[15] and extended it to PNL. In laparoscopic surgery a fiber-optic equipped 3 mm safety needle allows visually controlled access to the abdominal cavity.[15] Similarly for microperc the 1.6 mm all-seeing needle, incorporating a 0.9 mm telescope, provides optical confirmation of tract access during PNL to ensure perfect calyceal entry and, thus, avoid access related mishaps. To our knowledge microperc has the smallest available tract that can be feasibly used to fragment the stone under direct vision.

Microperc is different from mini PNL. Mini PNL duplicates standard 2-step PNL with miniaturized instruments. However, microperc involves 1-step PNL without tract dilation. Unlike standard or mini PNL, microperc does not allow fragments to be retrieved during PNL. This limitation is noted in SWL,

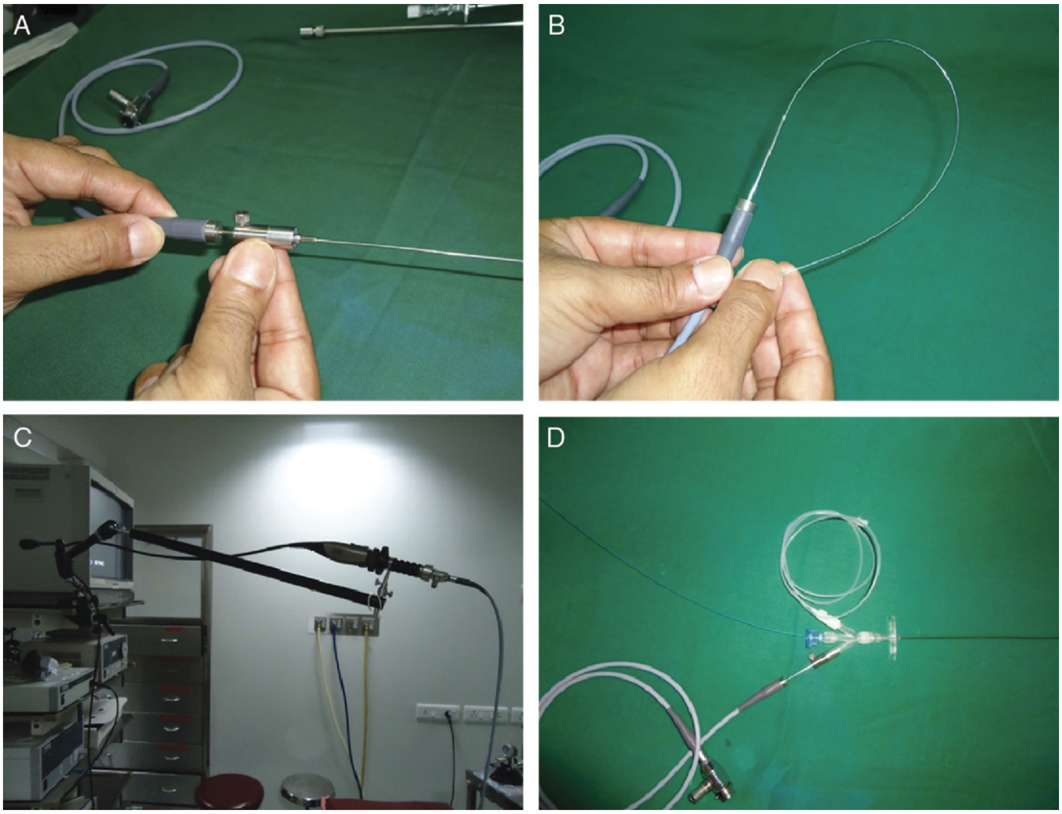

Figure 2. *A* and *B*, fiber-optic telescope. *C*, multijointed mounting arm. *D*, 4.85Fr sheath assembled for microperc. Laser fiber passes through the central channel. Irrigation connection and telescope are each attached to 1 side port.

although with numerous differences, including ensured stone localization with the all-seeing needle as opposed to assumed stone localization for SWL; ensured, complete stone fragmentation under direct vision, as opposed to assumed stone fragmentation for SWL, regardless of stone density; ensured fragmentation leading to vaporization in most cases, as opposed to only fragmentation for SWL; minimal CIRF and intraoperative fragment clearance due to a pressurized irrigation system, as reported in our series, as opposed to 100% CIRF at postoperative day 1 for SWL.

Microperc may be compared in terms of clinical outcome data with flexible ureteroscopy for small renal calculi. Flexible ureteroscopy uses long instruments with many interfaces. Each interface accounts for light loss except chip on the tip technology. This disadvantage is not present in microperc since the instruments are small and straight. There is a real chance of trauma to the ureteroscope when the laser is applied in a deflected position. This is not encountered in microperc. A surgeon competent to perform PNL would be able to perform this pro-

Table 1. *Patient demographics and stone characteristics*

Mean ± SD age	43.9 ± 19.0	(9–63)
No. male/female	6/4	
No. lt/rt side	7/3	
Mean ± SD kg/m^2 body mass index (range)	23.7 ± 7.8	(8.9–33.7)
No. comorbidity:		
Hypertension	2	
Diabetes	1	
Chronic kidney disease	1	
Mean ± SD mm stone size (range)	14.3 ± 6.3	(6–25)
No. stone site:		
Lower calix	4	
Pelvis	5	
Multiple	1	
No. special situation:		
Failed flexible ureteroscopy	1	
Ectopic kidney	1	
Pediatric age	2	
Obesity	1	

Table 2. *Intraoperative and postoperative parameters*

No. intraop clearance:		
Complete	8	
Residual fragments	0	
CIRF	2	
No. Double-J stent (%)	4	(40)
Mean ± SD mg tramadol postop analgesia (range)	60.0 ± 22.4	(50–100)
Mean ± SD gm/dl postop hemoglobin decrease (range)	1.4 ± 1.0	(0.3–3.6)
Mean ± SD days hospital stay (range)	2.3 ± 1.2	(1–4)
No. 1-mo postop clearance:		
Complete	8	
CIRF	1	

cedure with no additional learning curve required for flexible ureteroscopy.

Currently the life expectancy of a flexible ureteroscope is around 5 to 14 cases.[16] Microperc would be more cost-effective in terms of instrument related wear and tear. Further durability studies of microperc instruments are required. Microperc would avoid the transureteral route and consequent trauma due to dilatation in occasional cases. A randomized, controlled trial could determine the comparability of microperc in a scientific manner. Similarities to flexible ureteroscopy are its limited field of vision and limited therapeutic accessory options. Currently microperc optics are definitely low resolution compared to those of available flexible ureteroscopy models (fig. 3). The current telescope has 10,000 pixel resolution in a 0.9 mm working diameter, which can be increased to 20,000 pixels with a diameter increase of 0.97 mm. These refinements of optics are under way and certainly vision will improve in the future.

The other obvious disadvantage is the long duration of stone fragmentation required in a few cases. We can also dilate the tract to 8Fr and manage the stone with a 365 μm holmium laser fiber or a 1.6 mm pneumatic lithoclast. We did not study fluid absorption during the procedure. The limited tract size requires a pressurized irrigation system and simultaneous aspiration from the ureteral catheter is done to decrease pressure in the pelvicalyceal system.

Microperc would be of interest in select cases of renal calculous disease. For microperc to be an appealing alternative to SWL or flexible ureteroscopy it must be fully effective in 1 step with acceptable morbidity. In our opinion only a stone-free rate that approximates 100% would outweigh the drawbacks

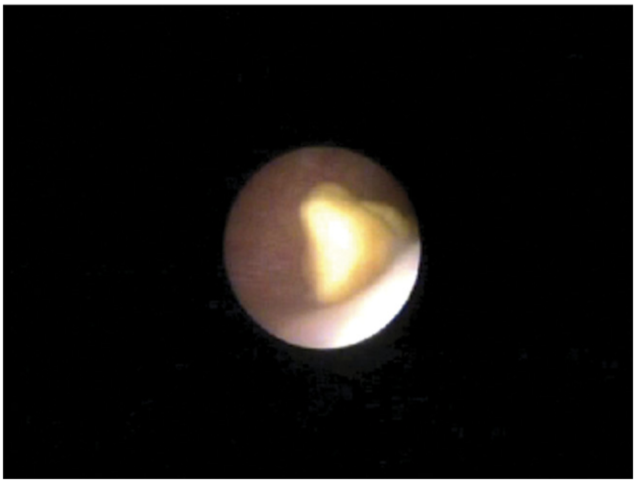

Figure 3. Intraoperative photograph of microperc shows vision through 0.9 mm telescope.

of a surgical procedure requiring general anesthesia. The Lower Pole Study Group suggested a higher clearance rates for PNL monotherapy over SWL for stones 1 to 10, 10 to 20 and greater than 20 mm in the lower pole. SWL became the treatment of choice for small stones less than 10 mm due to the obvious advantages of decreased morbidity.[17] For stones greater than 15 mm SWL provides a low stone-free rate and has a high re-treatment rate.[17] Microperc would be of interest for such stone sizes less than 20 mm for which morbidity and efficacy would be comparable to those of SWL. Microperc provides the ability to gain direct access to the lower pole calyx while micro-optics confirm the stone site and holmium laser lithotripsy ensures stone fragmentation in a single step. The pressurized irrigation theoretically helps clear fragments from the lower pole.

PNL has been described in the ectopic kidney with laparoscopy or ultrasound guidance.[18–20] Percutaneous access through the all-seeing needle permits optical visualization while accessing the pelvicalyceal system in ectopic kidneys, where it can help avoid the bowel during puncture. We performed 1 case of ectopic pelvic kidney in our series to determine efficacy. This patient underwent 2 prior failed flexible ureteroscopy attempts to remove the stone. This highlights the additional usefulness of microperc when flexible ureteroscopy fails, such as in cases of a lower calyceal diverticular stone, narrow infundibular width, awkward lower calyceal anatomy and a horseshoe kidney isthmus stone.

An additional area in which microperc may prove beneficial is pediatric PNL. Although SWL is known to have a higher clearance rate, results at some sites may be unpredictable. Flexible ureteroscopy in pediatric patients has debatable issues, such as passing through a small caliber urethra and ureter with unpredictable long-term safety results. In such cases microperc may prove advantageous with no morbidity associated with tract size.

There are anticipated concerns regarding the limitations of this technique. Calculi more than 20 mm are technically challenging since they require prolonged intracorporeal lithotripsy and a postoperative Double-J® stent. Although multiple calyceal calculi can be treated with multiple micropercs, the advantages are questionable. Vision can be a limitation in the event of bleeding due to faulty access. The pressurized irrigation could result in fluid absorption with its consequent morbidity. If required, Double-J stent insertion at the end of the procedure is difficult and expertise is required to pass the stent antegrade. Further randomized studies are needed to define the place of microperc in the management of renal calculous disease, including cost analysis of the procedure with respect to the durability and life expectancy of the instruments relative to flexible ureteroscopy, pelvicalyceal irrigant fluid pressure analysis and an efficiency quotient comparison among SWL, flexible ureteroscopy and microperc for 1 to 2 cm renal calculi. Applications at special stone sites and in patient subgroups are also mandated.

CONCLUSIONS

To our knowledge we report the first clinical study of 1-step PNL. Microperc is a new technological advancement in the field of percutaneous management for renal stones that has a promising future for treating nonbulky urolithiasis. This technique appears feasible, safe and efficacious, and has the potential of decreasing the morbidity associated with standard PNL. Its role in select populations, including patients with nonbulky urolithiasis such as a lower pole stone, the pediatric group and patients with ectopic, anomalous kidneys, needs further evaluation.

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