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Factors predicting outcomes of micropercutaneous nephrolithotomy: results from a large single-centre experience

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Objectives

To present our single-centre experience of the micropercutaneous nephrolithotomy (microperc) technique and define its role in the management of renal calculi as well as to analyse the factors predicting outcome.

Patients and Methods

We retrospectively analysed data from 139 patients who underwent microperc for renal calculi between June 2010 and November 2014 at our institution. The factors analysed were demographic variables, which included age, sex, stone volume, stone density (Hounsfield units [HU]) and stone location, and intra- and peri-operative variables, such as operating time, drop in haemoglobin level, stone clearance and complications.

Results

The mean ± SD (range) patient age was 38.99 ± 17 years (9 months to 73 years), stone volume was 1 095 ± 1 035 (105–6 650) mm^3 and stone density was 1 298 ± 263 HU. The mean ± SD (range) operation duration was 50.15 ± 9.8 (35–85) min, hospital stay was 2.36 ± 0.85 (2–5) days and drop in haemoglobin level was 0.63 ± 0.84 (0–3.7) mg/dl. Eight patients had renal colic that was managed by antispasmodic medication, four patients had renal colic severe enough to warrant JJ stenting and three patients had urinary tract infections which were managed with appropriate antibiotics. We were able to complete microperc in 130 patients, with 119 (91.53%) patients being rendered completely stone-free, while in 11 patients (8.46%) there were some residual fragments seen on imaging. On multivariate analysis, stone number, volume and density were found to be significant predictors of clearance. Conversion to mini- or standard percutaneous nephrolithotomy was required in nine patients (6.47%), with intra-operative complications and stone number being the significant factors warranting conversion on a multivariate basis.

Conclusion

The outcomes in the present study suggest that microperc is a promising treatment method for solitary renal stones with volumes <1 000 mm^3 and stones with low density (HU), regardless of stone location. In the present series we achieved a high success rate with low morbidity; however larger, prospective and comparative studies from multiple centres are required to further establish the role of microperc in the management of renal calculi.

Keywords

microperc, percutaneous nephrolithotomy, renal calculi, nephrolithiasis

Introduction

Percutaneous nephrolithotomy (PCNL) has been considered the standard of care in the management of renal calculi measuring >2 cm [1]; however, it was found that increasing the tract size was associated with greater morbidity, including bleeding complications [2]. This led to miniaturization of and modifications to the standard PCNL technique, such as 'miniperc', 'ultra-miniperc' and 'microperc', with the guiding principle of these new techniques being to maintain high success rates with minimal complications. These modifications appear to be particularly relevant when the stone burden is <2 cm, a scenario in which extracorporeal shockwave lithotripsy (ESWL) and flexible ureteroscopy have also become widely accepted treatment methods. The factors that dictate the choice of approach are stone location, stone size and stone density. A number of studies have been published regarding the efficacy of each of these techniques [3–5].

The most minimally invasive modification, microperc, uses the 4.85-F 'all-seeing' needle introduced by Bader et al. [6]. Since the feasibility study on this needle by Desai et al. [7],

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there a few case series and reports and one multicentre study have reported on microperc outcomes. In the present paper, we report our single-centre experience of the technique, with the aim of defining its role in the management of renal calculi and analysing factors predicting outcomes.

Patients and Methods

Institutional review board approval was received before the study commenced. We retrospectively analysed data from 139 patients who underwent microperc for renal calculi between June 2010 and November 2014 at our hospital. The factors analysed were demographic variables, which included age, sex, stone volume, stone density (Hounsfield units [HU]) and stone location, and intra- and peri-operative variables such as operating time, drop in haemoglobin level, stone clearance and complications.

The pretreatment evaluation consisted of a clinical examination, serum creatinine measurements, urine analysis, urine culture, plain abdominal film of kidney, ureter and bladder (KUB), ultrasonography and CT-intravenous urography. Patients with positive cultures, however, were treated with appropriate culture-guided antibiotics before undergoing the procedure. A single dose of cefoperazone was administered 1 h before surgery. We determined stone volume instead of stone size, based on the product of the three dimensions obtained on CT-intravenous urography. In patients with multiple stones the cumulative volume of the stones was taken into account.

Equipment

The equipment required for microperc has been described previously [7,8]. Briefly, the microperc needle is a 4.85-F three-part needle. The three parts consist of an external hollow sheath, a central needle and stylet. The Tuohy-Borst adaptor is a three-way adapter. One channel, preferably the central channel, of the adaptor is for the introduction of the fibreoptic telescope. The side channels are used for the introduction of laser fibre. Irrigation can be performed with an irrigation pump keeping the pump pressure at 100–150 mL/min on intermittent mode. The fibre-optics consist of a fibre-optic cable, a hub (which facilitates the attachment of the fibre-optic to the light cable), light cable and the light pillar. The resolution of the currently available fibre-optics is 10 000 pixels. The fibre-optic cable is flexible and can be bent to 180°. The weight of the assembly when in place cannot be borne by the needle and therefore requires a special fixed arm for deployment.

Procedure

As with any percutaneous procedure the first step is to gain ureteric access. It is our practice to use a 7-F open-end ureteric catheter as the initial step. The position of the patient for microperc mimics that of standard PCNL. We prefer to place the patient in the prone position with two bolsters, one bolster under the chest and one under the hip (except for patients with an ectopic kidney, which requires a supine approach). Access can be gained using fluoroscopy- or ultrasonography-guided control. The surgeon can also deploy the all-seeing needle while gaining access, or alternatively he/she can gain access and deploy the needle once the calyceal entry is confirmed with free egress of fluid. Once the stone is seen a 272-μm laser fibre (through a 4.85-F needle) is used, or if using a 8-F sheath one can use a 365-μm fibre. A standard holmium-YAG laser is used with setting (high frequency–low energy at 0.4–0.8 J and 10–20 Hz), adjusted so that the stone is preferentially dusted and not fragmented. In the majority of the cases in the present study, we exited the pelvicalyceal system without any nephrostomy tube, but in three patients a nephrostomy tube was left; this was removed after 24 h. An indwelling ureteric catheter secured to a Foley bladder catheter was kept in place for 1–2 days and then removed.

'Success' in the present study was defined as complete stone-free status with microperc, which was assessed 1 day and 1 month postoperatively using ultrasonography, KUB and/or CT. The latter being carried out in patients who had radiolucent calculi not visible on plain X-ray KUB. Complications were classified according to the Clavien grading system [9]. Patients and intervention-related factors were assessed based on pre- and postoperative variables.

Statistical Analysis

In the statistical analysis we report mean and SD values, as well as the occurrence of the various outcomes. The usual demographic characteristics were evaluated from the available data. The univariate analysis was carried out using Student's *t*-tests and chi-squared tests were used to analyse statistical significance. Multivariate regression analysis was carried out using the outcome of surgery as a dependent variable and the various covariates were also evaluated for their effect on the outcome. The analysis was performed using statistical software SPSS 15.0 (SPSS Inc., Chicago, IL, USA).

Results

The mean ± SD (range) patient age was 38.99 ± 17 years (9 months to 73 years), stone volume was 1 095 ± 1 035 (105–6 650) mm^3 and stone density was 1 298 ± 263 HU. Stones were present in the upper ureter (n = 7), pelvis (n = 47), upper calyx (n = 11), middle calyx (n = 9), lower calyx (n = 57) and in multiple locations (n = 8). The anatomical abnormalities/anomalies among the series were duplex system (n = 2), horseshoe kidney (n = 1) and pelvic kidney (n = 1). The patients' demographic characteristics and stone-related variables are summarized in Table 1.

Table 1 Demographic and stone characteristics.

Total number of cases	139
Microperc completed, *n* (%)	130 (93.52)
Conversion to another procedure, *n* (%)	9 (6.47)
Mean ± SD (range) age, years	38.99 ± 17 (9 months to 73 years)
Male: female	100:39
Mean ± SD (range) stone volume, mm^3	1 095 ± 1 035 (105–6 650)
Laterality, left: right	74:65
Mean ± SD stone density, HU	1 298 ± 263
Stone location, *n*	
Upper ureter	7
Pelvic	47
Upper calyx	11
Middle calyx	9
Lower calyx	57
Multiple locations	8
Multiple stones	16
Anatomical abnormalities, *n*	
Duplex system	2
Pelvic kidney	1
Horse shoe kidney	1

For patients who underwent microperc, the mean ± SD (range) operation duration was 50.15 ± 9.8 (35–85) min. The imaging techniques used for obtaining access were fluoroscopy in 26 patients, ultrasonography in 16 patients and a combination of the two in 88 patients. The mean ± SD (range) hospital stay was 2.36 ± 0.85 (2–5) days and drop in haemoglobin level was 0.63 ± 0.84 (0–3.7) mg/dl. Eight patients had renal colic that was managed by antispasmodic medication and four patients had renal colic severe enough to warrant JJ stenting. Three of the patients had UTIs with accompanying fever. None of the patients required blood transfusion. Intra- and peri-operative variables are shown in Table 2.

On univariate analysis (Table 3), stone volume (<1 000 mm^3) and stone number (single vs multiple) were significant predictors of clearance rates. The correlations were also assessed for multiple other variables.

Stepwise multivariate regression analysis was conducted with the help of SPSS software version 15 (Table 4). This showed that stone density (HU), stone number and stone volume were significantly associated with the dependent variable stone clearance.

Table 2 Peri-operative and operative findings in the patients undergoing microperc (*n* = 130).

Characteristic	
Mean ± SD (range) operative time, min	50.15 ± 9.8 (35–85)
Mean ± SD (range) duration of hospitalization, days	2.36 ± 0.85 (2–5)
Access method, *n*	
Fluoroscopy	26
Ultrasonography	16
Combined	88
Mean ± SD (range) drop in haemoglobin drop, g/dL	0.63 ± 0.84 (0–3.7)
Complete clearance, *n* (%)	119 (91.53)
Incomplete clearance, *n* (%)	11 (8.46)
Complications, *n* (%)	15 (11.53)
Clavien grade I: renal colic	8
Clavien grade II: UTI	3
Clavien grade IIIa: renal colic necessitating JJ stent insertion	4

Table 3 Univariate analysis for stone volume and number (microperc, *n* = 130).

Variable	No. of cases and outcome		Chi-squared test *P*
	Complete clearance	Incomplete clearance	
Stone volume			
<1 000 mm^3	84	1	0.0001
>1 000 mm^3	35	10	
Stone number			
Single (*n* = 118)	112	6	0.001
Multiple (*n* = 12)	7 (multiple location *n* = 1)	5 (multiple location *n* = 4)	

Microperc was successful (*n* = 130) in 119 (91.53%) patients, while in 11 patients (8.46%) some residual fragments were seen on imaging. Of the total study group (*n* = 139), conversion to mini- or standard PCNL was required in nine patients (6.47%; Table 5).

Multivariate analysis showed that intra-operative complications and stone number were significantly associated with conversion to mini- or standard PCNL (Table 6).

Discussion

Miniaturization of instruments, and modifications to puncture needles, sheaths and energy sources has led to lower complication rates and a reduction in the morbidity associated with PCNL, while at the same time maintaining success rates [2,10]. The development of modifications to the standard PCNL technique has led to the emergence of miniperc, ultra-miniperc and microperc.

Miniperc involves the use of a smaller-sized nephroscope (12 or 14 F), an Amplatz sheath (<20 F) and correspondingly small-sized working instruments as compared with standard PCNL [11,12]. The literature shows that miniperc is associated with a similar clearance rate to that of standard PCNL, but with a smaller drop in haemoglobin level, a shorter hospital stay, less analgesic requirement and lower complication rates [4,13,14].

Consistent with the concept of decreasing tract size and maintaining promising outcomes, Desai et al. [15] introduced the ultra-miniperc technique. For this technique the tract is dilated up to 11–13 F, stone fragmentation is achieved using a 365-μm holmium laser fibre under direct vision of the 3.5-F ultrathin telescope, and fragment retrieval is performed using a specially designed sheath by creating an eddy current of saline.

A step further in miniaturization was the application of the all-seeing needle developed by Bader et al. [6] in a feasibility study of microperc conducted by Desai et al. [7]. In this

Table 4 Multivariate analysis for patients successfully completed microperc.

	β	t	95% CI		P
			Lower	Upper	
Operating time	−0.357	−1.619	−0.022	0.002	0.108
Microperc duration	0.334	1.511	−0.003	0.020	0.133
Stone density	0.170	2.090	0.000	0.000	0.039*
Stone number	0.391	4.356	0.205	0.547	0.000*
Stone location	−0.071	−0.841	−0.044	0.018	0.402
Tract size	−0.108	−1.239	−0.036	0.008	0.218
Intra-operative complications	0.060	0.754	−0.121	0.270	0.452
Drop in haemoglobin level	0.037	0.434	−0.157	0.245	0.665
Stone volume	0.209	2.414	0.022	0.222	0.017*

*Dependent variable: outcome *P<0.05.*

Table 5 Cases with conversion and details (*n* = 9).

No. of cases	9
Mean ± SD age	35.55 ± 17.36
Male: female	6:3
Mean ± SD stone volume	2 064 ± 1 882
Laterality (left:right)	6:3
Mean ± SD stone density, HU	1 266 ± 178
Cases with single stone, *n*	5
Cases with multiple stones, *n*	4
Conversion to	
Miniperc, *n*	8
Standard PCNL, *n*	1
Access method, *n*	
Fluoroscopy	0
Ultrasonography	0
Combined	9
Event leading to conversion, *n*	
Stone migration and retrieval of larger fragments	7
Bleeding and poor vision	2

PCNL, percutaneous nephrolithotomy; HU, Hounsfield units.

initial study incorporating 10 patients with a mean stone size of 14.3 mm, the authors reported a success rate of 89%. Since then there have been studies reporting the use of microperc as a minimally invasive form of standard PCNL, although most of them were small case series [16–19], with the exception of the study by Hatipoglu et al. [20], in which the authors report their experience from four referral hospitals. In the present study, we report outcomes from a single-centre series.

In the study by Kukreja et al. [2], the method of tract dilatation, number of tracts and tract size were predictors of bleeding and associated morbidity with PCNL. The small needle size (4.85 F) and the associated single-step dilatation produced favourable results. In the present study a single tract was used to perform the technique. The mean drop in haemoglobin level in studies on microperc ranges from 0.1 to 1.4 (g/dL) [7,18]. In the present series the mean drop in haemoglobin level was 0.63 ± 0.84 (g/dL).

The various factors that predict the success of a given procedure are stone size, stone location and stone density. Most of the studies on microperc have used the technique for stones 1.5–2 cm in size and reported those outcomes. In the present study we looked at stone volume when reporting outcomes and it was interesting to find that a stone volume threshold of 1 000 mm^3 was a significant predictor of stone clearance in univariate and multivariate analyses (Tables 3 and 4), regardless of the stone location.

Anastasiadis et al. [21] assessed the relationship between stone density and outcomes of PCNL by analysing the Clinical Research Office of the Endourological Society (CROES) PCNL global study database. The authors found that very low and high stone densities were associated with lower rates of treatment success and longer operating times in PCNL and concluded that preoperative assessment of stone density may help in the selection of treatment technique for patients with renal lithiasis. Similarly, in our multivariate analysis, we found stone density in HU to be a significant predictor of stone clearance.

Although microperc is presently being used for small to moderate stones, the very indication that holds for ESWL as well, it is notable that microperc uses the principles of precise stone localization, direct visualization and laser-mediated lysis, which have all translated into high success rates with a reduced requirement for ancillary procedures. Conversely, ESWL is influenced by stone location and pelvicalyceal anatomy and may require multiple sessions. Hatipoglu et al. [22] conducted a comparative retrospective study between ESWL and microperc in a paediatric population and found lower retreatment rates for microperc.

Another technique with which microperc is compared is retrograde intra-renal surgery. When compared with PCNL, retrograde intra-renal surgery is associated with: a lower disintegration rate because of the limited manoeuvres that are possible with ureteroscopes and the inability to clear all the debris [23] (although this has been supplanted by newer-generation flexible scopes); the need to postpone the procedure in case of a tight ureter; severe ureteric injuries; and the need for a longer ureteric stenting duration [24]. In a

Table 6 Multivariate analysis for patients requiring conversion.

	β	t	95% CI		P
			Lower limit	Upper limit	
Stone volume	0.043	0.685	−0.042	0.086	0.495
Tract size	−0.010	−0.143	−0.014	0.012	0.887
Location	−0.075	−1.201	−0.032	0.008	0.232
Intra-operative complications	0.683	11.221	0.434	0.619	0.000*
Stone density	−0.040	−0.668	0.000	0.000	0.505
Operating time	0.272	1.546	−0.002	0.014	0.125
Drop in haemoglobin level	−0.044	−0.699	−0.174	0.083	0.486
Stone number	0.139	2.073	0.005	0.210	0.040*
Microperc duration	−0.152	−0.876	−0.011	0.004	0.383

*Dependent variable: outcome *P<0.05*

randomized comparative study by Sabnis et al. [25] the authors reported similar clearance and complication rates for a mean stone size of ~1.1 cm, but found that the microperc was associated with a greater drop in haemoglobin level and analgesic requirement, a greater requirement for stent placement in the retrograde intra-renal surgery group and success rates similar to those for flexible ureteroscopy. Nevertheless, microperc has an inherent limitation in that the stone fragments cannot be retrieved for analysis.

The microperc procedure has a high efficacy rate, ranging from 82% in the largest reported series by Hatipoglu et al. [20] to 100% in the smaller ones [16]. The success rate of the technique in our case series was 91.53%, with 119 patients being rendered stone free and 11 (8.46%) patients having residual fragments on imaging studies. As the technique is a refinement of conventional PCNL, microperc does not require any different facet of learning, as targeting and calyceal access techniques remain the same. So any urologist well versed in the conventional technique can readily become acquainted with microperc.

Conversion to miniperc or a standard PCNL may be required in circumstances where there is impaired vision as a result of oozing or stone migration into different calices. In a series by Armagan et al. [26] conversion to miniperc was required in 3/30 patients (10%), in a series by Piskin et al. [19] it was required in 2/9 patients and in a series by Hatipoglu et al. [20] it was required in 12/140 patients (8.57%). In the present series the conversion rate was 6.47% (nine patients), similar to that reported in the previous studies.

In a large series from a PCNL database Labate et al. [27] reported that 20.5% of patients experienced one or more complications. In the present series we had an overall complication rate of 11.53%, primarily minor complications comprising renal colic and UTI.

During the microperc procedure, the small fragments and debris resulting from laser-mediated lysis are flushed out during the saline irrigation and can occasionally obstruct the collecting system, leading to colic episodes and even Steinstrasse. In a series by Armagan et al. [26] two patients developed renal colic or Steinstrasse, the latter requiring JJ insertion. Similarly, Silay et al. [18] reported two cases of renal colic and Hatipoglu et al. [20] reported eight cases of renal colic and five cases of Steinstrasse. In our present series, 12 patients developed renal colic, of whom four required JJ stent insertion, whereas the remaining cases were managed by medical therapy.

Since the first feasibility study by Desai et al. [7], it has been noted that the closed system leads to a pressure rise, especially in scenarios of impacted pelvic stones and longer operating times. The studies by Armagan et al.[26], Silay et al. [18] and Hatipoglu et al. [20] do, however, show extravasation requiring drain placement. The anticipation of this led to placement of ureteric catheters ranging from 5 to 7 F in size before commencing the procedure. In the present series, however, we did not encounter extravasation or fluid collection.

We acknowledge the limitations that are inherent in the retrospective and non-comparative design of the present study; however, the outcomes in the present study suggest that microperc is a promising treatment method for solitary renal stones with volumes <1 000 mm^3 and with low density (HU), regardless of stone location. We achieved a high success rate with low morbidity; however, larger, prospective and comparative studies from multiple centres will be needed to further establish the precise role of microperc in the management of renal calculi.

Conflict of Interest

None declared.

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Abbreviations: PCNL, percutaneous nephrolithotomy; microperc, micropercutaneous nephrolithotomy; ESWL, extracorporeal shockwave lithotripsy; KUB, plain abdominal film of kidney, ureter and bladder.