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Comparison of flexible ureteroscopy and micropercutaneous nephrolithotomy in terms of cost-effectiveness: analysis of 111 procedures

Murat Bagcioglu[1] · Aslan Demir[1] · Hasan Sulhan[2] · Mert Ali Karadag[1] · Mehmet Uslu[1] · Umit Yener Tekdogan[1]

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Abstract The objective of this study was to audit the costs of retrograde intrarenal surgery (RIRS) and micropercutaneous nephrolithotomy (microperc) and compare them in terms of cost-effectiveness. We performed a retrospective analysis of 63 patients who underwent microperc and 48 patients who underwent RIRS. The cases, performed between first use and first repair, were used for this initial study. The costs associated with performing RIRS and microperc, including the costs of devices, disposables, hospitalization, and additional required treatments, were audited. The main perioperative and postoperative parameters were collected, including operation time, JJ stent requirements, used disposables, stone-free rates, and complications. Statistical analyses of the means of continuous variables were performed using Student's *t* test and the Mann–Whitney *U* test. Categorical variables were analyzed using Chi-squared tests. The mean cost of RIRS was \$917.13 ± 73.62 and the mean cost of microperc was \$831.58 ± 79.51; this difference was statistically significant ($p < 0.001$). The mean operation time of the RIRS group was significantly shorter than the microperc group (55.62 ± 19.62 min and 98.50 ± 29.64 min, respectively, $p < 0.001$). The assessment of required additional treatment showed that it was significantly higher in the RIRS group than the microperc group ($p = 0.02$). The stone-free rate for RIRS was 66.6 and 80.9 % for microperc; this difference was not statistically significant ($p = 0.12$). In our series, the use of microperc is less expensive than RIRS due to additional required treatments and ancillary equipment in RIRS. RIRS is more effective than microperc in terms of operation time and more effective use of operation rooms.

Keywords Micropercutaneous nephrolithotomy · Retrograde intrarenal surgery · Cost-effectiveness · Stone treatment · Endourology

✉ Murat Bagcioglu
dr.muratbagcioglu@hotmail.com

Aslan Demir
draslandemir@yahoo.com

Hasan Sulhan
hasan.sulhan@hotmail.com

Mert Ali Karadag
karadagmert@yahoo.com

Mehmet Uslu
dr.mhmtuslu@gmail.com

Umit Yener Tekdogan
yenertekdogan@yahoo.com

[1] Urology Department, Faculty of Medicine, Kafkas University, Kars, Turkey

[2] Urology Department, Bingol Public Hospital, Bingol, Turkey

Introduction

Kidney stones can be managed by several treatments: observation, shock wave lithotripsy (SWL), percutaneous nephrolithotomy (PNL), retrograde intrarenal surgery (RIRS), and laparoscopic and open pyelolithotomy. Stone characteristics, including location, size, opacity, and density, affect the useable treatments, as do anatomical structures, such as the diameter and length of the infundibulum and the infundibulopelvic angle, the patient's preference, the surgeon's skills, and the availability of surgical equipment [1, 2]. The European Association of Urology guidelines for urolithiasis are useful resources that suggest how to choose the most appropriate approach to cases, such as recommending SWL as a first-line treatment for kidney stones smaller than 2 cm [3]. The limited effectiveness of SWL and poor stone clearance rates for lower calyceal stones extend the indications for endourological interventions. In some cases, more than one treatment choice can be available for same stone pathology.

Endourology allows access and treatment of kidney stones with flexible ureteroscopy or a nephroscope during a single procedure, especially in RIRS and PNL. The competition between the two surgical techniques necessitates the improvement of optical systems, technical advances in ureteroscopic design, and miniaturization of devices; in this spirit, a new technique called micro-PNL or microperc allows treatment of intermediate-size kidney stones in difficult-to-reach locations with lower morbidity [4].

Minimally invasive techniques and new advances in laser and optical system design have produced high equipment costs, and miniaturization of devices led to limited equipment lifespans. Expensive repairs and the high costs of disposable instruments constitute the major economic problem; this reminds us that physicians have responsibilities and important roles in determining the allocation of healthcare resources, and the choice of less-expensive treatment alternative for same pathology, considering the rise in health expenditures [5].

We aimed to audit the costs of RIRS and microperc and compare them in terms of cost-effectiveness. To our knowledge, this is the first cost-effectiveness study comparing these techniques and also presents the largest microperc series dataset from a single center.

Materials and methods

Our study was approved by the local ethics committee of Kafkas University, Faculty of Medicine, with number 80576354-050-99/97 and international clinical trial registry number ChiCTR-OOC-14005598. We performed a retrospective analysis of 63 patients who underwent microperc and 48 patients who underwent RIRS between August 2013 and January 2015 at our hospital. Patients who underwent microperc or RIRS due to one or more shock wave-resistant kidney stones between 1 and 3 cm in size were included in the study. The cases between the first case and first repair were included. The cut-off sign for the cases, for both techniques, was device breakdown. Patients who underwent RIRS due to ureteral stones and patients who underwent RIRS with any other surgical procedures during the same admission were excluded from the study. The cases after repair were excluded.

Informed consent was obtained from all of the patients. All patient-related demographic and preoperative details, which included a medical history, physical examination, body mass index (BMI), anesthetic risk as defined by the American Society of Anesthesiologists (ASA), urine analysis, urine culture, serum urea and creatinine levels, plain abdominal film of kidney ureter bladder (KUB), and non-contrast computed tomography records, were analyzed. Kidney stone size was assessed by computer tomography and defined using both the formula for the surface area of the stone (length × width × π × 0.25) and the largest diameter of the stone. Both procedures were performed by two different surgeons with same experience. All procedures were performed under general anesthesia. A similar antibiotic coverage policy was used for both procedures.

RIRS technique

A semi-rigid ureteroscopy was performed to cannulate the ureteric orifice with a safety guide wire (Microvasive, Boston Scientific Corp, Natick, MA, USA) and to perform active dilatation. An 11/13-Fr ureteral access sheath (UAS) (Cook Medical Inc., Bloomington, IN, USA) was placed under fluoroscopic vision. A flexible ureteroscopy (Cobra, Richard Wolf Gmbh, Knittlingen, Germany) was used in all procedures. Upon reaching the stone, a 365-μm laser fiber (Quanta System, Spa OAF, Solbiate Olona VA, Italy) was inserted and the stone was fragmented using a holmium:YAG laser (Quanta System, Spa Litho, Solbiate Olona, Italy). Large fragments were removed using a 1.7-Fr basket catheter (Zero tipped, Boston Scientific Corp, Natick, MA, USA). At the end of the procedure, a JJ stent was inserted due to visualized ureteric injury, significant stone burden, or placement of the access sheath for more than 45 min.

Microperc technique

A 6-Fr open-ended ureteric catheter was placed under cystoscopic guidance in the dorsal lithotomy position. After that, the patient was placed in the prone position and the puncture was performed using a 4.8-Fr (16 gage) all-seeing needle (PolyDiagnost, Pfaffenhofen, Germany) to the suitable calyx. After visualization of the stone, the inner part was removed and a three-way connector was attached to the outer tip of the shaft. The central connector side port was used for insertion of an optical fiber. The other ports were used for an irrigation system, and a 272-μm laser fiber (Quanta System, Spa OAF, Solbiate Olona VA, Italy) to disintegrate the stone. At the end of the procedure, the ureteric catheter was left until the first postoperative day or replaced with a JJ stent in case of significant stone burden or residual stones.

Study design

The main perioperative parameters were collected, including operation time (accepted as the time interval between placement of the UAS and the urethral catheter for RIRS, and the time interval between the puncture with the all-seeing needle and the moment of device removal for microperc), JJ stent requirements, amount of irrigation fluid, used disposables related to surgical technique, and complications according to Clavien classification. The patients were discharged after removal of ureteral and urethral catheters and clearance assessment with KUB on the first postoperative day. The abdominal computed tomography without intravenous contrast at 1-month follow-up was used to assess stone clearance.

All costs are presented in United States of America Dollars ($) and costs were based on current conversion rates. Initial purchase cost of the holmium:YAG laser was $32,000 and annual upkeep was free during the study due to the warranty. The number of other procedures performed with the laser machine, including semi-rigid ureteroscopy (174 cases) and endoscopic cystolitholapaxy (24 cases), were added to the number of RIRS and microperc procedures to calculate the cost of the laser machine for one case. The cost of laser machine, $32,000, was divided by a total of 309 cases.

The cost of the laser fibers was audited as dividing the cost of fiber by the total number of procedures that used them. A 365-µm laser fiber was used for all RIRS procedures and a 272-µm laser fiber was used for all microperc procedures during the study. A fiber cost $1217 regardless of the type.

The cost of the flexible ureteroscope was $19,200 and it was divided by a total of 48 cases; the cost of microperc was $29,080 and was divided by a total of 63 cases.

The cost of disposables, like guide wires, ureteral catheters, basket catheters, ureteral access sheaths, access needles, irrigation sets, and JJ stents, was audited by considering the durability of the equipment and reusable features. Guide wire cost $20, and ureteral catheters' cost was $3.50. They were both used for one case. Basket catheters cost $131, and they were used only in 24 RIRS cases. The number of basket catheters used in the study was eight and every basket catheter was used in three RIRS cases. The total cost for eight basket catheters was divided by the total number of RIRS cases to calculate the cost for one case; the costs of ureteral access sheaths, access needles, and irrigation sets were calculated similarly. Ureteral access sheath cost $285, and 15 sheaths were used in 48 RIRS cases. Access needle and irrigation set (bought as a single kit) cost $180, and 14 access needles and irrigation sets were used in 63 microperc cases. A JJ stent cost $33. The cost of the irrigation fluid was audited according to amount and the usage of 500 cc, 1000 cc, and 3000 cc bags ($0.7, $2.1, and $3.8, respectively). The cost of contrast material was $15 and antibiotic was $7; they were added for all cases. The cost of the hospital stay was calculated using the 1-day room fee of $13.50.

The cost of the required additional treatment, like SWL, JJ stent replacement, JJ stent insertion, and anesthesia, was audited as $100, $100, $200, and $56, respectively, according to data from our Billing Department.

Statistical analysis

Results are presented as mean ± standard deviation (SD). The data were analyzed using Statistical Package for the Social Science (SPSS®, Inc., Chicago, IL, USA) version 22.0. Statistical analyses of the means of continuous variables were performed using Student's *t* test for operation times in terms of the stone location and the Mann–Whitney *U* test for total cost. Categorical variables were analyzed using Chi-squared tests. A p value of <0.05 was considered statistically significant.

Results

The demographic characteristics of the patients in both groups are summarized in Table 1. There was not any statistically significant difference between the two groups in terms of age, gender, BMI, stone location, stone lateralization, and ASA scores ($p > 0.05$). The mean stone size of the microperc group was significantly larger than the RIRS group (173.9 ± 81.06 mm^2, 1.81 cm and 120.06 ± 77.60, 1.46 cm, respectively, $p = 0.04$) (Table 2).

The mean operation time of the RIRS group was significantly shorter than the microperc group (55.62 ± 19.62 min and 98.50 ± 29.64 min, respectively, $p < 0.001$). There was no significant difference between the two groups in the assessment of mean hemoglobin decrease (0.76 ± 0.9 and 0.91 ± 0.83, for RIRS and microperc, respectively, $p = 0.62$) and none of the patients required blood transfusion. With regard to complications in the RIRS group, ureteral wall injury was seen in one patient and one patient complained of postoperative colic pain that required intravenous analgesic treatment and JJ stent insertion was

Table 1 Patient demographics and clinical characteristics

Variables	Microperc group	RIRS group	p value
Number of patients	63	48	
Age, years (mean ± SD)	41.5 ± 13.9	38.5 ± 12.6	0.31
Sex (male:female)	34:29	22:26	0.64
Body mass index, kg/m^2 (mean ± SD)	29.3 ± 4.1	28.4 ± 4.3	0.33
ASA			1
I	16	15	
II	32	22	
III	14	11	

Table 2 Stone characteristics

Variables	Microperc group	RIRS group	*p* value
Stone size, cm (mean ± SD)	1.77 ± 0.56	1.46 ± 0.83	0.052
Surface cm^2 (mean ± SD)	1.36 ± 0.64	1.17 ± 1.19	0.38
Number of stones, *n*	1.22 ± 0.59	1.34 ± 0.74	0.44
Laterality (right:left)	32:31	23:25	0.95
Site of stone			0.11
Upper calyx	8	4	
Middle calyx	8	12	
Lower calyx	20	10	
Pelvis	27	22	

Table 3 Comparison of intraoperative and postoperative variables in both groups

Variables	Microperc group	RIRS group	*p* value
Operation time, min (mean ± SD)	98.50 ± 29.64	55.62 ± 19.62	<0.001
Complications, *n* (%)			0.46
Ureteral injury (Clavien I)		1 (2.1)	
Colic pain (Clavien I)	2 (3.1)	1 (2.1)	
Steinstrasse (Clavien III-a)	5 (7.9)	3 (6.3)	
Stone migration (intra-operative)	1 (1.7)		
Hemoglobin drop g/dL (mean ± SD)	0.91 ± 0.83	0.76 ± 0.9	0.62
Hospital stay, day	2.72 ± 1.58	2.66 ± 1.23	0.85
JJ stenting, *n* (%)	36 (57.1)	41 (85.4)	<0.001
Required additional procedures			0.02
ESWL	5	8	
JJ stent insertion	5	3	
JJ stent replacement	36	41	
Stone-free rates (%)	80.9	66.6	0.12

applied for three patients with steinstrasse. In the microperc group, the ureteral JJ stent was inserted peri-operatively in one patient because of residual stone migration to the ureter, two patients complained of postoperative colic pain that required intravenous analgesic treatment, and JJ stent insertion was applied for five patients with steinstrasse. There was not any statistically significant difference between the two groups in terms of complications ($p = 0.46$) (Table 3).

A total of 41 patients required JJ stent insertion in the RIRS group, while a total of 36 patients required it in the microperc group. JJ stent insertion was more frequent in the RIRS group ($p < 0.001$). The assessment of required additional treatment showed that it was significantly higher in the RIRS group than the microperc group ($p = 0.02$). Eight patients required SWL, while, in the microperc group, five patients required SWL. There was no statistically significant difference in terms of hospital stay (2.66 ± 1.23 for RIRS, 2.72 ± 1.58 for microperc, $p = 0.85$). The stone-free rate at 1 month for RIRS was 66.6 and 80.9 % for microperc; this difference was not statistically significant ($p = 0.12$).

The costs per procedure are shown in Tables 4 and 5. The mean cost of RIRS was $814.13 ± 73.62 and the mean cost of microperc was $728.58 ± 79.51; this difference was statistically significant ($p < 0.001$).

Discussion

After Goodwin et al. reported the first renal access to a prone-positioned patient, Fernstrom and Johansson performed the first PNL procedure in 1976, which has undergone significant changes in the last three decades and become the first-line treatment option for kidney stones larger than 2 cm [3, 6, 7]. The most common complication of the procedure is bleeding, which is related to the size of access tract [8, 9], shown by decreased bleeding with the use of smaller access tracts. With equipment miniaturization, endourology has been moving toward minimally invasive, mini, ultra-mini, and micro approaches. The introduction of flexible ureterocopes, the holmium:YAG laser, and improved renal stone treatment success rates attracted urologists' attention [10]. The new techniques, RIRS and microperc, were performed effectively and safely for kidney stone fragmentation [11, 12]. Despite technical advances, the scopes are not durable and the increase in the costs of procedures increases the pressure to perform these techniques in an economical fashion due to limited financial resources [13].

Cost-effectiveness analysis, as an economic evaluation method, can provide the most efficient distribution of healthcare resources and aims to determine the value for money associated with new interventions. The cost-effectiveness analysis compares a new intervention to another commonly accepted intervention and estimates which has extra effects and costs [5]. When comparing two treatments, four possibilities exist for the intervention under study: the new modality can be more expensive and more effective, more expensive and less effective, less expensive and less effective, and less expensive and more effective [5]. We evaluated the cost of microperc, a new intervention, with the commonly accepted RIRS and tried to estimate additional costs per unit to additional gains using our results. To our knowledge, this is the first study in the literature which compares the initial costs of microperc and RIRS.

According to our results, the mean total cost of microperc is less than RIRS, driven by the costs of additional

Table 4 The costs per one case for microperc

Laser machine	$32,000	Used in 309 cases
Laser fiber	$1217	Used in 63 cases
Microperc	$29,080	Used in 63 cases
Access needle and irrigation set	$180	Used 14, in 63 cases
Ureteral catheter	$3.5	Per case
JJ stent (preoperative)	$33	Used in 36 cases
Antibiotics	$7	Per case
Anesthesia cost	$56	Per case
Irrigation cost	500 cc $0.7 1000 cc $2.1 3000 cc $3.8	
Contrast material	$15	Per case
Hospital stay	$13.5 per day	2.72 days
SWL	$100	5 patients
JJ stent replacement	$100	36 cases
JJ stent insertion (postoperative)	$200	5 cases
The mean cost for microperc	$728.58 ± 79.51	

Table 5 The costs per one case for RIRS

Laser machine	$32,000	Used in 309 cases
Laser fiber	$1217	Used in 48 cases
Flexible ureteroscope	$19,200	Used in 48 cases
Ureteral access sheath	$285	Used 15, in 48 cases
Basket catheter	$131	Used 8, in 48 cases
Guide wire	$20	Per case
JJ stent (preoperative)	$33	Used in 41 cases
Antibiotics	$7	Per case
Anesthesia cost	$56	Per case
Irrigation cost	500 cc $0.7 1000 cc $2.1 3000 cc $3.8	
Contrast material	$15	Per case
SWL	$100	8 patients
JJ stent replacement	$100	41 cases
JJ stent insertion (postoperative)	$200	3 cases
Hospital stay	$13.5 per a day	2.66 days
The mean cost for RIRS	$814.13 ± 73.62	

required treatments and the ancillary equipment of RIRS. The biggest part of the additional required treatments was JJ stent replacement. The placement of a JJ stent in a RIRS case, also required an additional treatment as JJ replacement were caused an extra cost $133 per case (a JJ stent cost $33 + a JJ stent replacement $100 = $133). This difference was an important factor in RIRS cost, because JJ stent insertion was performed in 85.4 % of RIRS cases, while the rate was 57.1 % for microperc. Sabnis et al., in a comparative study between microperc and RIRS, obtained a JJ stenting rate of 20 and 62.8 %, respectively. Their result was quite lower than ours, which might be attributable to the larger stone sizes in our study; however, they, like us, observed a greater requirement for JJ stent placement in RIRS patients. The lack of a required JJ stent placement is an important advantage of microperc in terms of the need for another procedure and avoiding stent-related symptoms [14].

Our results showed that the mean operation times for RIRS and microperc were 55.62 ± 19.62 min and 98.50 ± 29.64 min, respectively, and the difference was significant ($p < 0.001$). The mean operation time for RIRS was similar in Sabnis's study; however, the time of microperc was 51.6 min, which was lower than ours. In that study, they included patients with a single kidney stone or multiple stones in the same line, which can be accessed in a single puncture [14]. In our study, the mean stone count was 1.22 ± 0.5 and patients with multiple kidney stones in different calyceal locations were included in the study for microperc cases, and in some cases, additional access to the kidneys was required. Additional renal access requires extra time, increasing the operation time. Despite the shorter mean operation time of microperc cases in our study than another comparative study by Ramon de Fata et al., RIRS was two times faster than the microperc procedure and this may be important in terms of effective use of the operating room and therefore hospital income, as described in another cost-effectiveness study by Demir et al. [15, 16].

The complications in both groups did not significantly affect cost-effectiveness ($p = 0.46$). In our series, postoperative colic pain developed in two patients and steinstrasse occurred in five patients, similar to a study conducted by Hatipoglu et al. [17].

Other important factors that affected the result were the costs of ancillary equipment and disposables used in RIRS. The use of guide wires, ureteral access sheaths, and basket catheters added $121 per RIRS case. Instead, the use of a utereral catheter, access needle, and irrigation set added $50.50 per microperc case. Using a ureteral access sheath has procedural advantages, such as allowing direct visualization of ureteroscope insertion with simple ureteral re-entry and assisting in renal access with minimal morbidity, but has the disadvantage of increased cost [13], which should be considered to determine routine use. Similarly, use of a basket catheter not only positively impacts operation time, but also has a negative impact on the cost of the procedure.

The stone-free rates at first month in our study were 80.9 % for microperc and 66.6 % for RIRS; our results are lower than other studies [14, 18]. It should be considered that we assessed the stone clearance at 1-month follow-up with non-contrast computed tomography, instead of a 3-month follow-up with KUB; additionally, the mean stone size in our study was greater.

The mean hospital stay time was 57 and 49 h for microperc and RIRS, respectively, in a randomized controlled trial [14]. The hospital stay for microperc was 37.5 h in a study by Tepeler et al. and was 24 h for RIRS in another study [15, 18]. Our results for both procedures are longer (63.84 h for RIRS and 65.28 h for microperc) than other studies, affecting the total costs because of the $13.50/day room fee. This difference may be attributed to experience and the fact that most of our patients were farmers and coming to our center from peripheral localizations or villages (likely 80–90 km away). To avoid surprises, such as early colic pain or hematuria, we preferred a longer hospital stay for patients' safety and comfort.

The limitation of our study is that we excluded the costs associated with staffing, laboratory tests, and operating times; however, staff fees for operations are not standardized, especially for private hospitals, and laboratory tests are minimally related to surgery. The other limitation of this study is we performed the cost-effectiveness analysis for cases between first use and first repair. The damaged scopes usually were replaced with a new one instead of being repaired because of contracts with the manufacturers. A long-term study, which includes the cases after repair or change, could show the lower costs of the procedures, and that will be presented in another study. Another limitation is that cost-effectiveness analysis was not performed by a chartered accountant; it was performed by one of the authors (AD) who studied healthcare management and administration. Also, the difference in mean stone size of both groups and retrospective design of the study were the major limitations. Another limitation of our study is that the cost discrepancies like cost of a day might be expected from country to country due to the variation of price regulation, so the generalization of our data to other countries could be difficult [13].

Conclusions

The use of microperc in patients with kidney stones is less expensive than RIRS due to additional required treatments and ancillary equipment in RIRS. RIRS is more effective in terms of operation time and more effective use of operation rooms. The appropriate option should be chosen individually by considering the hospital- and patient-based factors. The cost-effectiveness must be taken into consideration when choosing the surgical technique by clinics, which have several options for kidney stone treatment.

Compliance with ethical standards

Conflict of interest In this study, there are no potential or actual competing interests.

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