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Mini-percutaneous nephrolithotomy in surgery of nephrolithiasis

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Abstract. *The present study aimed to assess the effectiveness and safety of mini-percutaneous nephrolithotomy (mPNL) in comparison with standard percutaneous nephrolithotomy (sPNL) for the treatment of complex nephrolithiasis.*

Methods. *During the period from 2012 to 2020, 1021 patients with solitary (10.0-30.0 mm), staghorn and multiple renal calculi were retrospectively divided into two groups: sPNL (500 patients) and mPNL (521 patients). The groups were compared by the stone-free rate (%), SFR, the duration of the surgery, complications and hospital stay.*

Results. *sPNL and mPNL were highly effective procedures for the treatment of nephrolithiasis. The mPNL group had longer operative times (81.0±15.5 vs 69.1±13.9 min, p<0.001) and higher frequency tubeless/totally tubeless procedures (41.1 vs 6.8%, p<0.001). mPNL showed a higher SFR (96.4 vs 91.8%, p=0.002 in patients with complete staghorn (90.1 vs 77.3%, p<0.05) and multiple kidney stones (89.5 vs 70.8%, p=0.03). Postoperative decrease in hemoglobin was lower in mPNL group 1.1±0.34 vs 2.1±0.26 g/dl (p<0.001). The incidence rate of urinary tract infections and postoperative hospital stay was lower in the mPNL group: 7.3 vs 13.2%, p=0.03 and 1.9±0.6 vs 4.3±2.4 days, p<0.001.*

Conclusions. *MPNL is a safe and effective treatment for patients with complex renal stones with an improved stone-free rate and lower complication rate and shorter hospital stay. Smaller diameter tract in mPNL procedures was associated with a longer duration of surgery.*

Key words: *nephrolithiasis, standard percutaneous nephrolithotomy, mini-percutaneous nephrolithotomy.*

Conflict of interest statement. The authors declare no competing interest.

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Міні-перкутанна нефролітотрипсія в хірургії нефролітіазу

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Резюме. Метою роботи було оцінити ефективність та безпеку виконання міні-перкутаної нефролітотрипсії (міні-ПНЛ) у порівнянні зі стандартною черезшкірною нефролітотрипсією (ПНЛ) при лікуванні нефролітіазу.

Матеріали та методи. У представленому ретроспективному дослідженні проаналізовано результати лікування 1021 пацієнта з коралоподібними та множинними каменями нирок (10-30мм) за період з 2012 по 2020 роки. Хворі були розділені на 2 групи: ПНЛ (500) та міні-ПНЛ (521). Результати лікування в обох групах порівнювались між собою за такими показниками: стан вільний від камення (SFR), тривалість операції, наявність ускладнень та кількість післяопераційного ліжка-дня.

Результати. Обидві методики є високоефективними в хірургічному лікуванні нефролітіазу. При цьому тривалість операції міні-ПНЛ була більшою ($81,0 \pm 15,5$ проти $69,1 \pm 13,9$ хв, $p < 0,001$) та частіше закінчувалась за бездренажними методиками ($41,1$ проти $6,8\%$, $p < 0,001$). При міні-ПНЛ показник SFR був вищим ($96,4$ проти $91,8\%$, $p = 0,002$ при лікуванні коралоподібного нефролітіазу ($90,1$ проти $77,3\%$, $p < 0,05$) та множинному нефролітіазі ($89,5$ проти $70,8\%$, $p = 0,03$). Післяопераційне падіння рівня гемоглобіну було меншим у групі міні-ПНЛ $1,1 \pm 0,34$ проти $2,1 \pm 0,26$ г/дл ($p < 0,001$). Частота інфекційних ускладнень та тривалість післяопераційного перебування в лікарні була нижчою у групі міні-ПНЛ ($7,3$ проти $13,2\%$, $p = 0,03$ та $1,9 \pm 0,6$ проти $4,3 \pm 2,4$ дня, $p < 0,001$).

Висновки. Міні-ПНЛ – безпечний та ефективний метод лікування при множинному та коралоподібному нефролітіазі, при котрому відмічається вищий показник SFR, менша частота післяопераційних ускладнень та післяопераційне перебування в лікарні. Збільшення тривалості операції при виконанні міні-ПНЛ пов'язана зі зменшенням діаметра тубуса.

Ключові слова: нефролітіаз, черезшкірна нефролітотрипсія, міні-перкутанна нефролітотрипсія.

Introduction. According to the clinical guidelines of the European and American Associations of Urology, PNL is a first-line procedure in the treatment of large (>1,5-2,0cm) renal stones [1]. Technical advancements and increasing experience have led to improvements in the safety and effectiveness of this procedure [2]. However, due to the invasive nature of this surgical approach, known complications of PNL include urinary tract infection, hemorrhage, damage to adjacent organs, and perforation of the renal collecting system [3, 4].

One of the methods to decrease the trauma to the renal unit has been adoption of miniaturized instruments [5-7] with increasing use of mini-percutaneous nephrolithotomy (mPNL), with tracts less than 22 Ch, instead of the standard percutaneous nephrolithotomy (sPNL) with tract size between 24-30 Ch [8-10]. Despite the higher safety profile mPNL a number of authors have reported differences in stone-free rate

(SFR) in favor of sPNL. These differences are most notable when comparing the results of treatment of staghorn and multiple renal calculi [11-13].

With increasing literature and experience in the adoption mPNL the question arises regarding the comparative success of these approaches.

Thus, **our study aimed** to assess the effectiveness and safety of mini-percutaneous nephrolithotomy in comparison with standard percutaneous nephrolithotomy, across various types of renal calculi.

Patient and methods. We performed a retrospective review of patients undergoing surgical treatment of nephrolithiasis between January 2012 to January 2020 in the Kyiv regional hospital. The Department of Urology Inspection Commission, Shupyk National Medical Academy of Postgraduate Education, has approved this study. All procedures performed in our study involving human participants were in accordance with the ethical standards of the institutional and/ or national research committee and Declaration of Helsinki (1964) and its later amendments or comparable ethical standards. For this type of study, formal consent is not required.

We identified 1021 patients with solitary (10.0-30.0 mm), staghorn stones and multiple renal calculi. The patients were divided into two groups based on the treatment approach. Patients with uncontrolled coagulopathy, acute urinary tract infection, severe chronic

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kidney disease, pregnant and patients <18 years old were excluded from the study.

Patients underwent preoperative investigations including complete hemogram, serum urea, creatinine, urine culture, sonography, and cross-sectional computed tomography (CT). Patients with urinary tract infections were treated with culture-specific antibiotics and a repeat urine culture was obtained. All of the procedures were performed by a single surgeon with 20-year experience of performing PNL.

Procedures were performed under regional combined spinal-epidural (men) and epidural anesthesia (women) (Bupivacaine, 20ml/50mg), with intravenous sedation (Propofol, 10mg/1ml). A 6F ureteric catheter was initially placed up to the renal pelvis in lithotomy position, and then the patient was turned to a prone position. Percutaneous access to the pelvic-calyceal system of the kidney was obtained under combined ultrasound and fluoroscopic controlled caliceal puncture through the papilla of the Calix in line with the axis of the infundibulum, most appropriate for calculus removal.

In the mPNL group, the tract was expanded by serial dilatation up to mini-nephroscope tube diameters a 16/17.5/22Ch (Karl Storz, Germany). In the sPNL group, the percutaneous tract was dilated using telescoping Alken's metal dilators up to nephroscope tube diameters of 24-26 Ch (Karl Storz, Germany) or Amplatz sheath up to 28-30Ch. The choice of the size of the nephroscope was based on its presence, until 2016 we did not have a mPNL, and since 2016 we have used exclusively a mPNL. In the future the choice of a nephroscope depended both on the size of the involved calyces and on the size of the calculus: for single (10.0-30.0 mm) and multiple stones used tubes 16-17,5Ch, and for staghorn stones – 17,5-22Ch.

Lithotripsy for sPNL was performed using ultrasonic Calucson (Karl Storz), pneumatic Calcusplit (Karl Storz) and Ho: YAG laser Medilas H (Dornier) lithotriptors. When performing mPNL, lithotripsy was performed solely with laser or in combination with a pneumatic lithotripter. The decision for the type of lithotripsy was at the discretion of the operating surgeon

taking into consideration the clinical scenario (the size of the nephroscope; the size of the stone, its density). After stone fragments were removed, the renal cavity system was inspected by visual inspection and fluoroscopy, and in select cases sonography was performed. Flexible renoscopy was not performed due to economic limitations. The surgery concluded: with drainage of the kidney with Foley silicone catheter (open end) 14/16Ch during sPNL or 12Ch during mPNL; tubeless (antegrade ureteral stent placement) or total tubeless.

The stone-free rate (SFR) status was assessed on the first postoperative day with sonographic monitoring, in rare cases - CTU. Successful treatment was considered a 100% SFR or the presence of clinically insignificant residual fragments (<3-4 mm).

A comparative analysis of both groups was performed with regard to SFR, operative time, the number and type of intra- and postoperative complications, and the duration of postoperative hospital stay.

Statistical analysis. The data was performed using the Statistica 10 for Windows software package (manufacturer - StatSoft.Inc, USA). Quantitative parameters are represented by average levels of indicators - (M) ± standard deviation (SD), qualitative parameters by frequency characteristics. The reliability of differences between groups was determined based on the Student's t-test or Mann-Whitney U-test. A comparative analysis of the statistical significance of the differences between the groups was performed with the help of the Chi-square (χ^2) or Chi-square with Yates's correction. In some cases (a small number of observations) used Fisher's exact test. For all statistical estimates, the statistical significance was checked at a level not lower than 95.0%.

Results. We identified 1,021 patients of which 500 patients were treated with sPNL and 521 patients that underwent mPNL. The average age of the patients in both groups was 44.5±15 years. There were no differences between groups concerning age, sex, body mass index, preoperative hemoglobin level, presence of hydronephrosis, kidney stones (stones size, density, location and their number) (Table 1).

Table 1

Patient demographics and stone characteristics (n=1021)

	Group A (sPNL)	Group B (mPNL)	P value*
Number of patients (n)	500	521	
Age (years)	46.7 ± 16.4	43.3 ± 14.1	0.305
Body mass index (kg/m²)	29.4 ± 5.7	29.0 ± 5.1	0.194
Sex			
Male (n, %)	226 (45.2)	287 (55.1)	0.002
Female (n, %)	274 (54.8)	234 (44.9)	
Pre-operative Hb (g/dl)	13.51±1.25	13.42±1.25	0.195
The average size of the stone, mm	27.5 ± 7.3	25.7 ± 6.4	0.479

Continuation of Table 1

	Group A (sPNL)	Group B (mPNL)	P value*
Side of the stone location, n (%)			
Right kidney	236 (47.2)	262 (48.4)	0.324
Left kidney	264 (52.8)	259 (51.6)	
Number of stones, n (%)			
Single stones (10.0-30.0 mm)	305 (61.0)	325 (62.4)	0.651
Partial staghorn stones	81 (16.2)	76 (14.6)	0.476
Complete staghorn stones	66 (13.2)	63 (12.1)	0.595
Multiple	48 (9.6)	57 (10.9)	0.481
Stone density, HU	1195±174	1216±185	0.091
Hydronephrosis, n (%)			
None	121 (24.2)	145 (27.8)	0.187
Mild	197 (39.4)	178 (34.2)	0.083
Moderate	142 (28.4)	145 (27.8)	0.840
Severe	40 (8.0)	53 (10.2)	0.228

* Statistically significant, if $p < 0.05$

Single parenchymal tract was performed in 395 (79.0%) cases sPNL group, and 365 (70.1%) in mPNL group ($p < 0.001$), where access through the lower poles was performed more often in the sPNL group - 345 (87.3%) vs mPNL - 275 (76.0%), $p < 0.001$, with the frequency of access through the middle and upper pole

was higher with mPNL: 51 (12.9%) and 90 (7.5%) vs 32 (6.4%) and 18 (3.6%), respectively. Multiple tracts were utilized more commonly in the mPNL group: two access - 83 (15.9%) vs 67 (13.4%), $p < 0.254$; three - 51 (9.8%) vs 29 (5.8%), $p < 0.018$; four - 22 (4.2%) vs 9 (1.8%), $p < 0.039$ (Table 2).

Table 2

Intraoperative results of surgeries

	Group A (sPNL), n=500	Group B (mPNL), n=521	P value*
Renal tract location, n (%)			
One access tracts:	395 (79.0)	365 (70.1)	<0,001
Lower pole	344 (87.1)	275 (76.0)	<0,001
Middle pole	33 (8.4)	51 (13.6)	0,014
Upper pole	18 (4.6)	39 (10.4)	0,002
Two access tracts:	67 (13.4)	83 (15.9)	0.254
Lower + Middle pole	35 (52.2)	30 (36.1)	0.048
Lower + Upper pole	25 (37.4)	19 (22.9)	0.05
Middle + Upper pole	7 (10.4)	34 (41.0)	0.001
Three access tracts:	29 (5.8)	51 (9.8)	0.018
Lower + Middle + Upper pole	19 (65.5)	45 (88.2)	0.032
Lower + Middle + Middle pole	10 (34.5)	6 (11.8)	0.032
Four access tracts:	9 (1.8)	22 (4.2)	0.039
Lower + Lower + Middle + Upper pole	3 (33.3)	16 (72.7)	0.041
Lower + Middle + Middle + Upper pole	6 (66.7)	6 (27.3)	0.041
Tube size (Ch), with one access, n (%)	395	365	
30	6 (1.5)	-	

Continuation of Table 2

	Group A (sPNL), n=500	Group B (mPNL), n=521	P value*
28	17 (4.3)	-	
26	159 (40.3)	-	
24	213 (53.9)	-	
22	-	114 (31.2)	
17,5	-	163 (44,7)	
16	-	88 (24.1)	
Operative Time (min)			
Total	69.1 ± 13.9	81.0 ± 15.5	<0,001
Single stones 10.0 – 30.0 mm	35.3 ± 10.2	46.3 ± 12.4	<0.001
Partial staghorn stones	41.1 ± 11.4	57.4 ± 10.3	<0.001
Complete staghorn stones	78.4 ± 15.2	91.5 ± 19.1	<0.001
Multiple stones	91.2 ± 11.8	106.5 ± 19.3	<0.001
SFR, n (%)			
Total	459 (91.8)	502 (96.4)	0.002
Single stones 10.0 – 30.0 mm	297 (97.4)	320 (98.5)	>0.05
Partial staghorn stones	77 (95.1)	73 (96.1)	>0.05
Complete staghorn stones	51 (77.3)	58 (90.1)	<0.05
Multiple stones	34 (70.8)	51 (89.5)	0.03
Surgeries completion			
Nephrostomy	391 (78.2)	210 (40.3)	<0.001
Nephrostomy + uretr. stent	75 (15.0)	97 (18.6)	0.123
Tubeless	23 (4.6)	129 (24.8)	<0.001
Total tubeless	11 (2.2)	85 (16.3)	<0.001
Second-look operations, n (%)	29 (5.8)	5 (0.9)	<0.001
Postoperativ stay, days	4.3 ± 2.4	1,9 ± 0.6	<0.001

* Statistically significant, if $p < 0.05$

When performing single access among 395 sPNL, nephroscope tube size 24/26/28/30Ch were used in 213 (53.9%), 159 (40.3%), 17 (4.3%) and 6 (1.5%) cases, respectively. And when performing single access among 365 mPNL, tubes 16/17.5/22Ch were used in 114 (31.2%), 163 (44.7%) and 88 (24.1%) cases, respectively. In the sPNL group additional access was performed with a 24Ch nephroscope tube, and in the mPNL group - 16 or 17.5Ch.

The average operative time was 81.0 ± 15.5 minutes in the mPNL group and 69.1 ± 13.9 minutes in the sPNL group ($p < 0.001$). The surgical duration was longer in patients with complete staghorn and multiple calculi in both groups: group mPNL (91.5 ± 19.1 and 106.5 ± 19.3 min) and group sPNL (78.4 ± 15.2 and 91.2 ± 11.8 min), $p < 0.001$, respectively.

Stone-free status was achieved in 459 (91.8%) patients of the sPNL group and the mPNL group - 502 (96.4%), $p = 0.002$. The highest SFR rates were seen among patients with solitary renal calculus: 97.4%

in the sPNL group versus 98.5% in the mPNL group ($p > 0.05$). A lower SFR was observed in patients with staghorn stones in both groups: with similar SFR in patients with partial staghorn stones across both groups: sPNL and mPNL (95.1 vs 96.1%, $p > 0.05$), however, in patients with complete staghorn stones SFR was significantly higher in the mPNL group (90.1 vs 77.3%, $p < 0.05$). In patients with multiple kidney stones, SFR also was significantly higher in the mPNL group - 89.5 vs 70.8% ($p = 0.03$). Second-look procedures in patients with complex staghorn and multiple stones was required in 29 (5.8%) patients in the sPNL group and only 5 (0.9%) in the mPNL group ($p < 0.001$). Median length of postoperative stay was 4.3 ± 2.4 days (range: 2-10) in group sPNL and 1.9 ± 0.6 days (range: 1-7) in group mPNL ($p < 0.001$).

Tubeless procedure was performed in 214/521 (41.1%) patients in mPNL group compared to 34/500 (6.8%) in the sPNL ($p < 0.001$): tubeless - in 129 (24.8%) mPNL group vs 23 (4.6%) sPNL group ($p < 0.001$), and

total tubeless - 85 (16.3%) vs 11 (2.2%), $p < 0.001$, respectively.

Complication-free stay was seen in 465 (89.3%) mPNL and 394 (78.8%) sPNL, $p < 0.001$. Intraoperative bleeding (more 500 ml) was observed in 28 (5.6%) patients sPNL vs 9 (1.7%) mPNL group ($p = 0.002$) and urinary tract infection in 66 (13.2%) vs 38 (7.3%), respectively ($p < 0.001$). The average postoperative hemoglobin

decrease level in mPNL patients was lower than after sPNL: 1.1 ± 0.34 vs 2.1 ± 0.26 g/dl, $p < 0.001$. In the mPNL group complications more than Clavien IIIa were not observed, in contrast to patients in sPNL group, where hemotransfusion was performed in 3 (0.6%) patients. Postoperative selective embolization of pseudoaneurysm was needed in one (0.2%) patient. There were no visceral injuries in either group (Table 3).

Table 3

Complications of surgeries

	Group A (sPNL), n=500	Group B (mPNL), n=521	P value
Complications, Clavien, n (%)			
0	394 (78.8)	465 (89.3)	<0.001
I	59 (11.8)	37(7.1)	0.011
II	26 (5.2)	11(2.1)	0.009
IIIa	19 (3.8)	8 (1.5)	0.04
IIIb	1(0.2) **	0 **	>0.05
IVa	1(0.2)	0	>0.05
Specification of complications, n (%)			
Intraoperative bleeding	28 (5.6)	9 (1.7)	0.002
Decrease in hemoglobin level (g/dl)	2.1 ± 0.26	1.1 ± 0.34	<0.001
Urinary tract infection	66 (13.2)	38 (7.3)	0.003
Pseudoaneurysm	1 (0.2)	0	
Treatment of complications, n (%)			
Hemotransfusion	3 (0.6)	0	>0.05
Selective embolization	1 (0.2)	0	>0.05
Ureteral stenting	19 (3.8)	8 (1.5)	0.04

* Statistically significant, if $p < 0.05$

** Excluding repeated operations in the treatment of complex staghorn stones.

Discussion. To date, the main surgical methods for treatment of renal stones with sizes up to 1.5-2.0 cm are shock wave lithotripsy and retrograde intrarenal surgery (RIRS), with PNL reserved for larger calculi or branched staghorn calculi or in cases where anatomic abnormalities preclude successful treatment with SWL or RIRS. The most important advantage of RIRS over PNL is its lower invasiveness and, accordingly, lower complication rate [13, 14]. However, the higher cost of operating the equipment, need for frequent multiple procedures and lower stone-free rates are an important drawback which maintains a role for various PNL techniques [15, 16].

SPNL has a number of specific complications, including hemorrhagic, 29-83% of them are caused by dilation of the parenchymal tract of the kidney and intraoperative manipulations of the tract. The desire to reduce surgical morbidity of PNL has led to miniaturization with the implementation of smaller diameter tubes: mini-, ultra-mini-, micro-, super-mini-PNL [9, 17]. There is supporting evidence of a negative ef-

fect on the functional state of the kidney when the parenchymal tract is formed with a nephroscope tube of more than 26 Ch, which may lead to the development of local scars in the parenchyma involving up to 2-5% of the total renal cortex. Various studies have shown reductions in blood loss, postoperative hospital stay, and complications with reduced percutaneous tract diameters with comparable efficacy ranging from 75% to 98% [18]. However, as the diameter of the nephroscope tube decreases, a number of disadvantages arise, including increased pressure in the renal collecting system and the need to create smaller fragments for removal, which increases the duration of the operation, especially in patients with large stone burden [18-20].

The positive aspects of mPNL include the presence of space between the nephroscope and the sheath, which allows better visualization and evacuation of small stone fragments outside the surgeon's field of view due to the vacuum cleaner effect (Bernoulli's principle). This may facilitate improvements in stone-free rates as smaller fragments are formed which can irrigate

out through the tract. Similar to our study, improved effectiveness of mPNL was seen in a study by Zhong W., et al. [21] where the mPNL was associated with significantly better SFR (89.7 vs 68.0%, $p=0.049$) compared to sPNL and lower need for a secondary procedure (13.8 vs 28.0%, $p=0.048$); and in the meta-analysis by Deng J, et al. [22], where the stone-free rate was 87.6% with sPNL and 87.8% with mPNL ($p=0.57$). In our experience, higher SFR of mPNL among all types of renal calculi were, compared with sPNL (96.4 versus 91.8%, $p=0.002$). The most significant differences were noticed in the treatment of complete staghorn stones, where the SFR results among mPNL and sPNL were 90.1 vs 77.3%, $p<0.05$; and in the treatment of multiple kidney stones - 89.5 vs 70.8%, $p=0.03$. This feature is associated with the possibility of more active use of additional (from 1 to 4 or) percutaneous tracts, due to their less traumatic qualities. In our study, multiple renal access in the sPNL group was performed in 105 (21,0%) cases, and with mPNL 156 (29.9%), ($p<0.05$) which may influence the higher SFR in mPNL group.

In order to reduce the risks of intraoperative bleeding, we tried not to perform additional accesses with sPNL (24-26 Ch), when the size of the renal calyx with the calculus was smaller than the size of the nephroscope (<24Ch). Similarly, to minimize the risk of bleeding, we did not perform dilatation of the narrow necks of the calyx (<20-22Ch), followed by the introduction of a standard nephroscope. Since the larger size and number of tracts increases the incidence of hemorrhagic complications [23].

It is commonly known, the access via the upper pole of the kidney most often corresponds to access in the intercostal space, where the risk of pleural injuries increases compared to subcostal access. A number of studies note a significant reduction of pleural injuries during puncture and dilatation of the kidney to a smaller diameter tract [24, 25]. In our study, in neither of the groups studied, pleural injuries or injuries of abdominal organs were noted. When performing percutaneous access, we always adhered to the technique of the combined use of sonography and fluoroscopy, that according to some studies and as confirmed from our findings, confirms the safety of access due to this technique and not only by minimizing the diameter of the used nephoscopes [26].

During the mPNL, we preferred laser lithotripsy. This combination requires the form of smaller fragments and longer operative times. Pneumatic lithotripsy was performed much less frequently with mPNL, due to the large diameter of the pneumatic probe, which impaired the flow of irrigation fluid. In the sPNL group, calculi fragmentation was performed using an ultrasonic and pneumatic lithotripter. A study by Zeng G., et al. [21] comparing different lithotripters in the sPNL and mPNL groups in terms of the surgical technique, and in the difference in the internal space of the working channel of the nephroscope, after insertion of the probe lithotripter found that the type of lithotripsy devices did not affect the difference in SFR.

In our opinion, mPNL is the optimum alternative for percutaneous nephrolithotomy, where the known drawbacks of using miniature nephroscope (mini, ultra-mini-, micro-, super-mini-PNL) are not so pronounced, and the size of the access tract (14-21Ch) is sufficient for independent evacuation of stone fragments, without requiring the use of grasping devices (forceps and baskets). This feature allowed us to note that the evacuation of stone fragments during mPNL is more comfortable and faster than in sPNL, which still often rely on grasping forceps or baskets for fragment extraction. We hypothesize that gaining experience and proper fragmentation techniques, may also help to shorten the operation time.

In our study, the duration of mPNL was longer in comparison with sPNL: 81.0 ± 15.5 vs 69.1 ± 13.9 min, $p<0.001$. The longest operation was in patients in mPNL group with complete staghorn stones (91.5 ± 19.1 vs 78.4 ± 15.2 , $p<0.001$) and multiple stones (106.5 ± 19.3 vs 91.2 ± 11.8 , $p<0.001$). This feature may not only be the function of the diameter of the nephroscope, the method and technique of fragmentation of calculi, but also on the number of additional percutaneous accesses that were necessary for the mPNL group (29.9 vs 21.0%, $p<0.05$).

The main advantages of mPNL manifested themselves when we analyzed operative complications. According to the Clavien–Dindo classification, only one (0.2%) important complication was noted in the sPNL group (Clavien IIIb), pseudoaneurysm bleeding, requiring selective embolization. In the mPNL group, we did not encounter any complications above the Clavien IIIa category, moreover, the number of complications of the Clavien I-IIIa category was half as many as after sPNL: 10.7 vs 20.8. In the mPNL group there was a statistically smaller decrease in hemoglobin level (1.1 ± 0.34 vs 2.1 ± 0.26 g/dl, $p<0.001$), whereas in the sPNL group, blood transfusion was necessary in 3 (0.6%) patients. This is logical because of the larger difference in the surface area of renal parenchyma trauma between 15-21 Ch and 24-26 Ch nephroscope tubes.

In examining infectious complications, we noted a marked reduction in these complications less in the mPNL group (7.3 vs 13.2, $p=0.003$). Considering the preoperative homogeneity of the studied groups, it is possible to explain this by the lower intraoperative pressure in the renal cavity system when using mPNL. So Tokas T., et al, [27] notes that the design of the mini nephroscope is designed to maintain a reduced intrarenal pressure, at any irrigation pressure. And the strongest effect can be observed when using a nephroscope of 15Ch. This circumstance favorably distinguishes mini-nephroscope from nephroscope of smaller diameter (ultra-, mini- and micro-PCNL), where the intracavitary pressure remains uncontrolled.

In some cases, postoperative clamping the nephrostomy, there was a violation of urodynamics, due to the presence of residual blood clots or edema of the mucous membrane of the upper urinary tract, thus requir-

ing insertion of ureteral stent, which was seen higher in the sPNL group (3.8 vs 1.5%, $p=0.04$).

In our study population we observed a shorter postoperative period for patients that underwent mPNL with an average length of stay just short of 2 days. We believe that decreased trauma associated with smaller tract may in part account for the difference, though we did not measure analgesia requirement in the postoperative setting. Of course, the duration of postoperative hospital stay is affected not only by the quantitative and qualitative complications composition, but also the possibility of using tubeless techniques [28-30]. We successfully completed mPNL without nephrostomy drainage placement in 214 (41.1%) patients: 129 (24.8%) tubeless mPNL with antegrade ureteral stenting and 85 (16.3%) total tubeless mPNL. These options for completing the surgery were lower ($p<0.001$) in sPNL group – 34 (6.8%) cases: 23 (4.6%) tubeless and 11 (2.2%) total tubeless techniques.

One of the main limitations of our study is a retrospective review and the lack of comparative characteristics on the methods and technique of fragmentation of calculi. Despite all these limitations, our findings are informative in accumulating experience of using mini PNL and require additional study.

Conclusions. mPNL is a safe and effective treatment for patients with solitary, multiple and staghorn renal calculi. Compared to sPNL, mPNL is associated with increased operative times, a significantly lower incidence of intra- and postoperative complications, an increased rate of tubeless techniques and decreased hospitalization period. Hence, the mPNL should be considered a sensible alternative to sPNL.

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