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ORIGINAL PAPER

Supine mini percutaneous nephrolithotomy in horseshoe kidney

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Summary ***Objective: The percutaneous nephrolithotomy (PCNL) in Horseshoe kidneys (HSK) is usually performed in the prone position, allowing entry through the upper pole and providing good access to the collecting system. However, in patients with normal kidney anatomy, the supine position is reliable and safe in most cases, but it is unknown whether the supine position is adequate in patients with HSK. The purpose of this study was to describe the results of PCNL in HSK in three different surgical institutions and to evaluate the impact of supine position during surgery, comparing pre-operative and post-operative data, complications, and stone status after surgery.***

Material and Methods: Between 2017 and 2022, a total of 10 patients underwent percutaneous renal surgery for stone disease in HSK. All patients were evaluated pre- and post- operatively with non-contrast CT. We evaluated patients (age and gender), stones characteristics (size, number, side, site and density), and outcomes. The change in haemoglobin, hematocrit, creatinine and eGFR were assessed between the most recent preoperative period and the first postoperative day. Procedure success was defined as stone-free or presence of ≤4 mm fragments (Clinically Insignificant Residual Fragments – CIRF). Complications were registered and classified according to Clavien-Dindo Grading System, during the 30 - day postoperative period and Clavien scores ≥ 3 were considered as major complications. Statistical analysis was performed using "R 4.2.1" software, with a 5% significance level. We also compared pre-operative and post-operative data using "Wilcoxon signed-rank test".

Results: No statistical difference was observed between pre-operative and post-operative renal function data. At one post operative day CT scan, an overall success rate of 100% was registered. 9/10 patients were completely free from urolithiasis (stone-free rate: 90%), while 1/10 patients had ≤4 mm residual stone fragments (CIRF rate: 10%). No cases of intraoperative complications were registered. Post-operative complications were reported in 1/10 patients. A patient developed urosepsis (defined as SIRS with clinical signs of bacterial infections involving urogenital organs - Clavien-Dindo Grade II) after procedure, and was treated with intravenous antibiotic therapy successfully.

Conclusions: This study shows that in patients with HSK mini-PCNL in supine position allows to achieve good stone free rate with a very low morbidity. According to our series, the described technique for PCNL in HSK should be an option. Nevertheless these results must be confirmed by further studies.

KEY WORDS: *Galdakao modified supine Valdivia; Horseshoe kidney; Percutaneous nephrolithotomy.*

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INTRODUCTION

The guidelines of the *American and European Urological Associations* advise to treat stones larger than 2 cm the *percutaneous nephrolithotomy* (PCNL) including the patients with *Horseshoe kidneys* (HSK) (1). This in HSK is usually performed in the prone position, allowing entry through the upper pole and providing good access to the collecting system. Several case series have investigated prone PCNL in patients with HSK. However, in patients with normal kidney anatomy, the supine position is reliable and safe in most cases, but it is unknown whether the supine position is adequate in patients with HSK (2). The purpose of this study was to describe the results of PCNL in HSK in three different surgical institutions and to evaluate the impact of supine position during surgery, comparing pre-operative and post-operative data, complications, and stone status after surgery.

Setting, patients and outcomes

We conducted a retrospective analysis of procedures performed between 2017 and 2022 that studied supine mini-PCNL in patients with horseshoe kidney. All patients were evaluated with non-contrast CT as the preferred pre- and post-operative imaging method. We evaluated 10 mini-PCNLs performed in three medical centres including *S. Croce and Carle Cuneo Hospital* (4 cases), *Cannizzaro Hospital* (3 cases) and *Mater Dei Clinic of Catania* (3 cases). The following pre-operative data were collected in all patients: gender, age, side, mean stone size and density (using Hounsfield classification derived from CT scan), number of stones for single patient, stone position frequencies, mean pre-intervention values of Creatinine and eGFR. The change in haemoglobin, hematocrit, creatinine and eGFR were assessed between the most recent preop-

erative period and the first postoperative day. Procedure success was defined as stone-free or presence of ≤ 4 mm fragments *Clinically Insignificant Residual Fragments* (CIRF) (3). Complications were registered and classified according to Clavien-Dindo Grading System, during the 30 - day postoperative period and Clavien scores ≥ 3 were considered as major complications (4).

Preparation and operative technique

All procedures were performed by three experienced endourologists. Placement was chosen based on surgeon preference. All surgeons are trained and experienced with PCNL in supine position. The positions used for PCNL were the complete supine or supine modified *Galdakao-Valdivia* (GMSV). After positioning the patient, it is important to mark the inferior edge of the 12th rib, the iliac crest and the posterior axillary line on the patients 'skin in order for the surgeon to maintain his or her orientation after the patients are draped. For the *Valdivia* modified by *Galdakao* the patient's legs are placed in a modified lithotomy position with both legs in stirrups in order to facilitate simultaneous percutaneous antegrade access and ureteroscopic retrograde to the urinary system. All procedures started with retrograde pyelography. After these propaedeutic steps, a *ureteral access sheath* (UAS) was positioned (9.5, 10/12 or 12/14 Ch) in 6/10 cases depending on the ureteral diameter and compliance and position used. In some patients, and precisely in 6/10, it was decided to place an ureteral sheath with the aim to perform a flexible ureteroscopy to obtain stone clearance. Nevertheless, horseshoe kidney unfavourable anatomy made retrograde approach unfeasible, then switching to real-time PCNL was carried out.
In all patients the puncture was performed with ultrasound/radiological guidance followed by a "*single-step dilation*". A 12 Fr Mini nephroscope MIP M (*Karl Storz, Berlin GmbH, Germany*) was used for stone fragmentation and removal. Lithotripsy was performed in 9 cases with Holmium YAG laser (550 µ fiber laser) and Lithoclast EMS in 1 case. An intraoperative stone-free status was verified with fluoroscopy and flexible nephroscope. A 8 Fr nephrostomy tube and 6 Fr x 26 cm ureteral stent was placed in all cases at the end of surgery.

Statistical analysis

Statistical analysis was performed using "R 4.2.1" software, with a 5% significance level. Qualitative variables were reported as numbers and percentages. Quantitative discrete variables were described as median *interquartile range* (IQR) values, while Quantitative continuous variables were reported as mean *standard deviation* (DS) values. We also compared pre-operative and post-operative data using "*Wilcoxon signed-rank test*".

Results

Patient characteristics

Demographics and stones characteristics are reported in Table 1. Mean age was 54.7 (SD: 10,18). Male sex percentage was 90% (9 patients) and female sex percentage was 10%, (1 patient). 2 (20%) *vs* 8 (80%) stones were located in the right and left kidney; in detail, 3 (30%) stones were located in the lower pole and 7 stones (70%) in the renal pelvis, respectively. The median stone size was 23.3 mm (SD: 6), in 1/10 (10%) case the stones were multiple; CT stone density was 1233 (HU) (SD: 54).

Table 1.
Patient's demographic data and baseline characteristics.

Age, years mean (SD)	54.7 (SD: 10.18)
Gender, n (%)	Male: 9 (90%) Female: 1 (10%)
Side, n (%)	Left: 8 (80%) Right: 2 (20%)
Past kidney stone interventions, n (%)	Yes: 0 No: 10 (100%)
Number of stones/single patient	1 (IQR: 1-1.25)
Stone size (mm)	23.3 (SD: 6)
Stone density HU	1233 (SD: 54)
Stone site - n° of patients (%)	Upper calyx: 0 Middle calyx: 0 Inferior calyx: 3 (30%) Renal pelvis: 7 (70%)
Mean Pre-intervention Creatinine (mg/dl)	0.85 (SD: 0.22)
Mean Pre-intervention eGFR (ml/min/1.73 m^2)	95.50 (SD: 15.48)

Peri-operative data and outcomes

Mean operative time was 110 (SD: 11.17) minutes (Table 2). Mean post-operative Serum Creatinine and eGFR at day 1 after surgery were 0.86 (SD: 0.2) mg/dl and 93.10 (SD: 12.55) ml/min/1.73m^2, while preoperative values were 0.8 (SD: 0.22) mg/dl and 95.50 (SD: 15.48) ml/min/1.73m^2. Nevertheless, any statistical difference was observed between pre-operative and post-operative renal function data (p = 1 and p = 0.294 respectively), as listed in Table 3.

Table 2.
Surgical outcomes and features.

Diameter Access, mean (SD)	16,16 (SD: 6.69)
Calyx of puncture	Upper: 5 (50%) Middle: 5 (50%) Lower: 0
Dilation technique	Balloon: 3 (30%) Serial: 7 (70%)
Energy, n (%)	Laser: 9 (90%) Ultrasonic: 1 (10%) Pneumatic: 0 Combined: 0
Surgical time (minutes)	110 (SD: 11, 17)
Amplatz-sheath	Yes: 10 (100%) No: 0
Post-operative Stent	Yes: 10 (100%) No: 0

Table 3.
Pre-operative and post-operative data.

	Pre-operative mean	Post-operative mean	p-value
Creatinine (mg/dl)	0.85 (SD: 0.22)	0.86 (SD: 0.20)	1
eGFR (ml/min/1.73 m^2)	95.50 (SD: 15.48)	93.10 (SD: 12.55)	0.294
Hemoglobin (g/dl)	14.62 (SD: 2.05)	13.61 (SD: 1.89)	0.012
Hematocrit (%)	43.73 (SD: 6.63)	40.23 (SD: 6.40)	0.009

Table 4.
Stone composition to spectrophotometric analysis.

Stone composition. no. (%)	Value
Calcium oxalate monohydrate	5/10 (50%)
Calcium oxalate dihydrate	1/10 (10%)
Mixed	4/10 (40%)

At one day CT scan, an overall success rate of 100% (10/10) was registered. 9/10 patients were completely free from urolithiasis (stone-free rate: 90%), while 1/10 patients had ≤ 4 mm stone fragments in the same renal localization of previously treated lithiasis (CIRF rate: 10%). At stone analyses, 5 (50%) patients were found to have *Calcium oxalate monohydrate* stones (COM), 1 (10%) patient had *Calcium oxalate dihydrate* stones (COD), and 4 (40%) patients had *mixed Calcium-Uric acid* stones (Mixed Ca-UA) Table 4.

Table 5.
Clinical complications following mini-PCNL classified according to Clavien-Dindo Grading System.

Clavien-Dindo Grade System	Number of patients	Description	Treatment
Grade I	1/10	1: Nausea and Vomiting	Anti-emetics and supportive care
Grade II	1/10	1: Urosepsis	Antibiotic therapy
Grade III a	-	-	-
Grade III b	-	-	-
Grade IV a	-	-	-

Complications

No cases of intraoperative complications were registered. Post-operative complications were reported in 1/10 patients (10%). The patient developed urosepsis (defined as SIRS with clinical signs of bacterial infections involving urogenital organs - Clavien-Dindo Grade II) after procedure. Septic complication was treated with intravenous antibiotic therapy successfully, without necessity of transfer to Intensive Care Unit. None "*late*" post-operative complication emerged during the follow-up until the visit at third month after surgery. All complications are reported in Table 5. There were no hollow visceral injuries, which indicates that supine operations have a lower risk of any abdominal or thoracic injuries. There were no IRA complication and renal function was normal in all the patients. A non-contrast CT scan was performed in all cases during the first post-operative day and for the first follow up after 30 days.

Discussion

Horseshoe kidney (HSK) is the most common fusion defect of the kidneys, although it amounts to only about 0.25% of the population (5). There is no clear genetic cause for, but the incidence is higher in those with chromosomal disorders such as *Edward syndrome* (67%), Turner syndrome (from 14% to 20%) and *Down syndrome* (1%) (6-8). In 1522, *Carpi* described HSK during autopsies for the first time (9). He identified functioning renal masses present on both sides of the vertebral column fused together with ureters that remain uncrossed from the renal hilum to the urinary bladder (10). In most cases the fusion occurs at the lower pole, but it may occur at the upper pole (11). Due to fusion, malrotation and anatomical defects, HSK shows high insertion and lateralization of the ureter which causes urine stasis with a consequent greater risk of hydronephrosis, infection and stone formation (9). Although ureteropelvic junction obstruction is the most common complication associated with HSK, Pawar et al. estimated that that 36% of patients with a horseshoe kidney will develop nephrolithiasis throughout their life (12). About treatment of renal stones, all surgical techniques can be used in patients with HSK, but success rates are usually lower than in kidneys with regular anatomy, especially with *external shockwave lithotripsy* (ESWL) (13, 14). The guidelines of the American and European Urological Associations recommend the use of PCNL to treat renal stones larger than 2 cm 1. In patients with normal kidney anatomy, this procedure is performed in the supine position, but in patients with HSK many surgeons prefer to use the prone position because it allows access through the upper pole and provides good access to the collecting system 2. However, it is unknown whether the prone position is more adequate than supine approach to treat renal stones in patients with HSK. Most urologists believe that PCNL should be performed in the prone position in patients with HSK and that access should be obtained through the upper pole, which is usually subcostal and offers a straight way to most calyces. The results are good, and the technique is well-established. However, the supine position for PCNL is gaining popularity worldwide, even in the US, where it was less used (15). Using this position, it is not necessary to turn the patient prone and therefore, the total operative time can be reduced 2. This position has also been used for complex cases, showing similar effectiveness (16). A group used to perform PCNL in the supine position, facing HSK, would probably tend to use that position. However, until now, little information was available to support this choice. Therefore, this study shows that supine mini-PCNL in the horseshoe kidney, as performed in several centres, can achieve optimal results. Vicentini et al. in a multicentric comparison study retrospectively analyzed 106 PCNLs performed for complex stones in HSK in the prone and supine positions (17). The analysis of their large cohort of patients confirmed that supine PCNL is also suitable in HSK because it is characterized by a lower complication rate and shorter operating time. In our study, we aimed to answer the question of whether supine PCNL is an option as good as prone PCNL for complex kidney stones in case of HSK. Our date show that the supine PCNL seems to be suitable for complex stones in the horseshoe kidney, as the immediate success, complications, transfusion rates and operative times were like those found in the literature in the prone position. Furthermore, sepsis and visceral injury rates were significantly low or absent, showing a possible safer profile for the supine position. Our hypothesis is that during the supine position there is less chance of pyelovenous urinary reflux due to the lower intrarenal pressure compared to prone cases, as the better irrigation flow through the Amplatz sheath is intuitive. This could explain the lower

sepsis rate observed in our cases. Our study included patients from three different centres, the demographics were similar in all groups, and we used a comprehensive prospective database which reduced the possibility of bias in the similarity of results regarding position. The surgeries were performed by different expert endourologists, not just one surgeon. Another positive point of our study was that all patients underwent a pre- and postoperative non-contrast CT scan, making outcome evaluations more accurate.

Conclusions

This study shows that mini-PCNL in supine position allows to achieve good stone free rate with a very low morbidity in patients with HSK. According to our series, the described technique for supine PCNL in HSK should be an option. Nevertheless, these results must be confirmed by further studies.

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