Endoscopic guided PCNL in the prone split-leg position versus supine PCNL: a comparative analysis stratified by Guy's stone score

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Introduction: *The optimal patient positioning for percutaneous nephrolithotomy (PCNL) based on the complexity of stone burden is not yet defined. Thus, we aimed to evaluate the intraoperative parameters, effectiveness and complications of patients undergoing PCNL between the endoscopic-guided prone split-leg PCNL (ePSL) and the supine PCNL by stratifying patients according to Guy's stone score (GSS).*

Materials and methods: *A retrospective chart review was conducted of patients undergoing PCNL at two high-volume tertiary referral centers. At one center, patients underwent PCNL using the ePSL technique, while at the second center, patients underwent PCNL in supine. Patient demographics and stone characteristics, operative details, complications and effectiveness were compared between groups. The impact of obesity was also investigated.*

Results: *Of 830 subjects, a total of 449 (54%) underwent PCNL in ePSL and 381 (46%) in supine. The ePSL group had a greater mean age and body mass index. No statistical differences were found in gender, serum chemistry and Charlson comorbidity index. After stratifying patients by GSS, the differences in baseline stone burden between PSL and supine lost significance and both groups could be compared. Complications were not statistically different between both groups. Univariate analysis demonstrated that multiple tracts and lower pole access were more prevalent in supine. In addition, for GSS1-3, ePSL was correlated with reduced operative time, radiation exposure, length of hospital stay and need for secondary procedure. Multivariate analysis correlated ePSL with lower radiation exposure and need for secondary procedures (p = 0.01). In comparison to the whole trial population, the same tendencies were appreciated for obese cohort.*

Conclusions: *This is the first report focusing on the performance differences between ePSL and supine PCNL stratified by GSS. Both techniques are safe, with a low rate of complications. For GSS1-3, ePSL reduces radiation exposure and requires less need for both multiple access and secondary procedure.*

Key Words: percutaneous nephrolithotomy, urolithiasis

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Introduction

Percutaneous nephrolithotomy (PCNL) has become the gold standard procedure for the treatment of large and staghorn calculi.[1] However, the optimal patient positioning is not defined and has been hotly debated.[2] Published trials comparing the supine and prone techniques for PCNL have not consistently shown significant superiority of either approach regarding stone-free rates and complications, relying on the surgeon experience and preference the most important factors in selecting the position.[3-8]

Since its first description,[9] the prone PCNL has been the most popular worldwide.[10-12] Straightforward identification of renal anatomy and broader surface area for percutaneous access are noted advantages of prone positioning. However, concerns related to airway control and cardiopulmonary function during anesthesia, potential nerve injuries, and time spent turning the patient to the prone position have spurred growing interest for the supine PCNL.[13] It is important to note that the hypothetical anesthetic and neurologic risks attributed to prone PCNL have not been documented in the endourologic literature. Despite cumulative literature, the prone versus supine debate remains unresolved.

First described as an alternative when fluoroscopic-guided access had failed,[14] the endoscopic-guided access has evolved as a more precise method of renal access.[15,16] Considering that gaining optimal renal access is the most critical step for effective PCNL, the endoscopic guidance provides the opportunity to select an appropriate calix, and to monitor the renal puncture, tract dilation, and Amplatz sheath advancement under direct vision.[16] These advantages for endoscopic-guided PCNL have been documented in the supine and prone positions.[15-18] However, no study to date has compared the endoscopic-guided PCNL in the prone split-leg positioning (ePSL) versus the supine PCNL.

In this study, we adopted the Guy's stone score (GSS) to stratify patients according stone complexity since it has proved to be reproducible, easy and fast to use in the clinical setting.[19-22] Herein, through an international multicenter collaboration, we aimed to compare outcomes and complications between the ePSL and supine PCNL stratified by the complexity of the stone as defined by the GSS.

Materials and methods

Study population

After Institutional Review Board approval, a retrospective chart review on prospectively collected databases was performed on patients undergoing PCNL at two high-volume tertiary referral centers between January 2010 and October 2017. At one center, patients underwent PCNL using the ePSL technique, while at the other center, patients underwent supine PCNL. The attending surgeons involved in this study have a focused endourology and stone disease practice each performing > 150 PCNL yearly.

Baseline information and patient demographics included age, gender, body mass index (BMI) and comorbidities (Charlson Comorbidity Index - CCI). Stones were categorized by size (defined as the sum of the maximum diameter of all stones on non-contrasted computed tomography [NCCT]) and GSS.[21] Pre and post-treatment serum chemistry studies were recorded. Inclusion criteria included all patients ≥ 18 years old who underwent unilateral PCNL for renal stones during the defined study period.

Guy's stone score (GSS)

GSS was determined by the urologist during the preoperative consultation and was confirmed just before the surgery. All urologists were previously trained in GSS. In case of divergence, the most experienced urologist made the final decision. GSS consists of four grades, defined as set out below:

1. *GSS1:* a solitary stone in the mid and/or lower pole or in the renal pelvis with normal anatomy (normal anatomy = no dilation, infundibular stenosis, calyceal diverticulum, UPJ obstruction, no malrotated, pelvic or horseshoe kidney, and a simple collecting system);
2. *GSS2:* a solitary stone in the upper pole, multiple stones in a patient with simple anatomy, or a solitary stone in a patient with abnormal anatomy;
3. *GSS3:* multiple stones in a patient with abnormal anatomy or in a calyceal diverticulum or partial staghorn calculus (defined as a stone involving in the renal pelvis and at least two calices);
4. *GSS4:* a complete staghorn calculus (all calices and the pelvis occupied by stones) or any stone in a patient with spina bifida or a spinal injury with clinical neurological alterations.

Study design

Patients were divided into two groups based on PCNL technique: ePSL or supine. Baseline patient demographics, operative and postoperative variables were compared between groups. In addition, the patients were stratified according to the GSS to evaluate the impact of each technique controlling for the stone complexity. A subgroup analysis of the obese patients, stratified by World Health Organization (WHO) obesity classification, was also performed.

Operative technique

All procedures were carried out under general anesthesia. Antibiotic prophylaxis was performed according to the AUA Best Practice Policy Statement[23] and each hospital's infection committees.

Endoscopic-guided PSL

The patient was placed in PSL position and the renal access was performed under endoscopic guidance by the attending surgeon as previously described.[15] Tract dilatation was performed using a balloon to 30F. At the end of the procedure, high-magnification fluoroscopy and antegrade flexible nephroscopy was performed to identify residual fragments. Antegrade flexible ureteroscopy was performed as the ureteral access sheath was withdrawn to confirm clearance of any residual ureteral calculi. The tubeless method for kidney drainage was employed in all patients, leaving a ureteral stent in place for 5-7 days postoperatively.

Supine

The procedures were carried out on the modified complete supine position[24] or Barts flank-free modified position,[25] according the surgeon preference. The renal access was performed under fluoroscopic guidance by the attending surgeon. Dilatation was done using semi rigid fascial dilator (Amplatz) to 30F. Flexible antegrade nephroscopy and high-magnification fluoroscopy were used at the end of the procedure to achieve stone-free status. A 16F nephrostomy tube (Foley) was placed at the end of the procedure in case of bleeding, residual stones, pelvic perforation and multiple accesses. Otherwise, tubeless PCNL was preferred, leaving a ureteral stent in place for 7 days postoperatively.

Patient follow up and stone clearance evaluation

In both groups, if the urine remained clear the Foley catheter was removed on postoperative day (POD) #1. Serum hemoglobin and creatinine were also collected. To assess residual fragments (RFs), intraoperative high-magnification imaging and endoscopic inspection at the end of the procedure were employed in both centers. However, for the supine patients, abdominal NCCT was routinely used to complement the intraoperative evaluation of RFs. In order to address the potential bias of stone-free evaluation between groups, a subanalysis was performed in the supine group to evaluate the concordance of the intraoperative versus tomographic evaluation of the stone-free status and the needed for secondary procedures. Prior studies have demonstrated that intraoperative high magnification fluoroscopy and endoscopic inspection are equivalent to CT imaging for the detection of residual stones > 4 mm.[26]

Both centers followed a protocol that patients with RFs greater than 4 mm underwent secondary procedures according to stone burden and location, since second-look flexible nephoscopy in patients with RFs of ≤ 4 mm in size was not cost effective.[27]

Outcome analysis

Recorded operative parameters included operative time (from insertion of the cystoscope to placement of the urethral catheter), number of tracts, location of calyceal access, method of tract dilation, radiation time, nephrostomy use, and length of hospital stay. The primary outcome study endpoint was surgical and clinical complications, including blood transfusion, embolization, pleural effusion, colonic injury, and pulmonary embolism. Secondary outcomes were operative time, radiation exposure, and need for secondary procedures. For both groups, a secondary procedure was defined as an ipsilateral stone procedure (PCNL, RIRS or SWL) within 3 months of the index PCNL to achieve stone free status.

Statistical analysis

Data were presented as means and standard deviations (SD) or medians and interquartile ranges (IQR) for continuous variables. For categorical variables, percentages or proportions were given. Group comparisons were done using Wilcoxon rank sum test for continuous variables, while chi-square test or Fisher's exact test (when cell counts were lower than 5) were used for categorical variables. Univariate analysis was used to identify risk factors for complications. Controlling for age, BMI, stone size, GSS, tract dilation and number of accesses, linear regression analysis was employed to identify risk factors related to longer operative time and high radiation exposure. To estimate the effect of each variable in the model, relative increase (RI) and 95% confidence intervals (CI) in the outcome effected was quantified. In addition, logistic regression was used to investigate factors associated with need for secondary procedure. Odds ratio (OR) and 95% CI were estimated. All analysis was done using R version 3.3.2. All tests were considered significant at the level of $\alpha = 0.05$.

Results

Patient demographics

Table 1 outlines the baseline patient and stones characteristics. A total of 830 consecutive patients undergoing PCNL were included in the analysis; 449 (54%) in ePSL position and 381 (46%) in supine. The ePSL group had a greater mean age (56.8 versus 47.4y; $p < 0.001$) and higher BMI (33.3 versus 29.3 kg/m^2;

TABLE 1. **Patient demographics characteristics and stone features**

	ePSL	Supine	p value
Total patients, n	449	381	
Age (y; mean [SD])	56.8 (14.4)	47.4 (12.7)	< 0.001
Body mass index (mean [SD])	33.3 (9.1)	29.3 (6.6)	< 0.001
Right laterality (n [%])	202(45)	196(51.4)	0.074
Female (n [%])	260 (57.9)	247 (64.8)	0.06
Charlson index (mean [SD])	2.3 (2.3)	2.3 (2.1)	0.672
Preoperative level (mean [SD])			
Hb	13.3 (1.8)	13.2 (1.6)	0.284
Cr	0.99 (0.36)	1.03 (0.50)	0.618
Stone features			
Right laterality (n [%])	202 (45.0)	196 (51.4)	0.074
Size (mm; mean [SD])	35.6 (22)	41.9 (25.8)	< 0.001
Guy's stone score (n [%])			
1	72 (16)	42 (11)	0.047
2	165 (36.7)	97 (25.5)	< 0.001
3	171 (38.1)	155 (40.7)	0.489
4	41 (9.1)	87 (22.8)	< 0.001

ePSL = endoscopic guided prone split-leg PCNL

$p < 0.001$). No statistical differences in gender, comorbidities (CCI), laterality, and preoperative serum chemistry. Regarding stone features, supine was represented by more complex cases (22.8% versus 9.1% of GSS4) and higher stone size (25.8 versus 22 mm; $p < 0.001$). However, after stratifying patients by GSS, the differences in baseline stone burden were no longer significant between groups, Table 2.

Operative parameters

The differences in operative parameters between supine and ePSL technique are listed in Table 3. Operative time of supine was significantly longer by an average of 25 minutes ($p < 0.001$). Multiple tracts were required more often in the supine (25.1% versus 1.6%; $p < 0.001$). The ePSL positioned patients were more likely to receive a puncture at the upper pole of the kidney (81.7%), whereas the lower pole was the preferred access calyx for supine (63.9%).

Despite controlling for number of accesses, radiation time was significantly higher in the supine (13.7 versus 3.2 min; $p < 0.001$). Fluoroscopic guidance was employed for all patients in the supine group and in 16 (3.5%) of the ePSL, when the ureteral access sheath failed to reach the proximal ureter. The most common ureteral sheath size used in the PSL was 14/16F (47.5%) and 17.8% (82) patients were stented before ePSL PCNL.

For kidney drainage, a higher percentage of patients in the ePSL group were tubeless ($p < 0.001$). Hospital length of stay was longer for supine group (2.21 versus 1.87 days; $p < 0.001$). After stratification by GSS, the differences in operative time and length of hospital stay remained significant for GSS 1-3, Table 2.

Complications

There were no statistical differences between supine and ePSL regarding blood transfusion, embolization, chest tube, colonic injury or pulmonary embolism, Table 3. The complication rate between groups remained not significant after stratification by GSS, Table 2, albeit more frequent toward complex cases (GSS3 and GSS4).

Effectiveness and secondary procedures

As surrogate measures of the efficacy of the PCNL, secondary procedures were reported. To evaluate the potential bias of routine NCCT at POD#1 on diagnosis of residual fragments and need for secondary procedures in the supine group, an internal comparison data was performed. A concordance of 88.26% between intraoperative and POD#1 CT evaluation of stone-free status was demonstrated. From all patients considered stone-free by intraoperative evaluation, 29 (11.74%) harbored a residual stone between 5 mm and 7 mm on 1POD CT and no secondary procedure was needed.

TABLE 2a. **Patient demographic characteristics, operative parameters and outcomes according Guy's stone score 1 and 2**

	Guy's 1			Guy's 2		
	ePSL	**Supine**	**p value**	**ePSL**	**Supine**	**p value**
Total patients, n	72	42		165	97	
Age (y; mean [SD])	58.8 (11.9)	48.7 (12.0)	< 0.001	56.2 (14.0)	48.2 (13.5)	< 0.001
BMI (mean [SD])	36.0 (8.0)	28.5 (6.9)	< 0.001	32.7 (9.1)	28.8 (6.0)	< 0.001
Charlson index	2.5 (2.2)	2.0 (1.8)	0.341	2.2 (2.2)	2.3 (2.2)	0.738
Stone size (mm; Mean [SD])	19.3 (7.3)	21.1 (7.5)	0.116	32.2(14.4)	32.9 (25.4)	0.152
Operative time (min; mean [SD])	68 (24)	125.7 (38.5)	< 0.001	89.7(35.0)	124.4 (46.9)	< 0.001
Number of tracts (n; %)						
One	72 (100)	33 (78.5)	< 0.001	165 (100)	63 (67.7)	< 0.001
Two	0 (0)	6 (21.4)	0.001	0 (0)	27 (29.0)	< 0.001
Three	0 (0)	0 (0)	-	0 (0)	3 (3.2)	0.456
Calyx puncture (n; %)						
Lower	11 (15.3)	27 (69.2)	< 0.001	16 (9.7)	60 (64.5)	< 0.001
Middle	10 (13.9)	10 (25.6)	0.2	18 (10.9)	27 (29)	< 0.001
Upper	51 (70.8)	2 (5.1)	< 0.001	131 (79.4)	6 (6.5)	< 0.001
Tubeless (%)	72 (100)	25 (59.5)	< 0.001	162 (98.2)	44 (45.4)	< 0.001
Radiation time (min; mean [SD)	3.9 (7.7)	13.7 (6.5)	< 0.001	3.1 (3.7)	14.3 (15.8)	< 0.001
Hospital stay (days)	1.4 (1.3)	1.9 (1.0)	< 0.001	1.6 (1.4)	2.2 (1.2)	< 0.001
Secondary procedure (mean [SD)	0 (0)	4 (9.5)	0.016	7 (4.2)	12 (12.4)	0.027
Complications (n; %)						
Blood transfusion	1 (1.4)	0 (0)	1.000	5 (3)	2 (2.2)	1.000
Embolization	2 (2.8)	0 (0)	0.531	0 (0)	0 (0)	-
Chest tube	1 (1.4)	0 (0)	1.000	4 (2.4)	0 (0)	1.000
Colonic lesion	0 (0)	0 (0)	-	0 (0)	0 (0)	-
Pulmonary embolism	0 (0)	0 (0)	-	0 (0)	0 (0)	-

ePSL = endoscopic guided prone split-leg PCNL; BMI = body mass index

The supine group needed significantly more secondary procedures to achieve stone-free status (22.3% versus 8.2%; $p < 0.001$), Table 3, although no significant difference was seen with GSS4 ($p = 0.247$) Table 2. When a secondary procedure was needed, RIRS was the main modality in ePSL group while SWL was preferred for supine, Table 3.

Obese patients

The obese patients were stratified according WHO obesity classification in order to evaluate outcomes and complications in this particular group. The same significant findings were noted for both primary and secondary endpoints in comparison to the whole trial population, Table 4. No significant statistical difference in the complication rate was demonstrated for all BMI levels.

Multivariate analysis

Linear regression analysis was employed to identify risk factors for longer operative time while logistic regression analysis was used for radiation exposure and need of secondary procedures, controlling for age, BMI, stone size, stone density, GSS, technique of tract dilation and number of accesses. Operative time was positively associated with stone size (RI 19.1, 95% CI: 12-26.2; $p < 0.001$) while negatively associated with single access (RI 24.4, 95% CI: -35.8-13; $p < 0.001$), Figure 1a. Radiation exposure was negatively associated with balloon (-5.2, 95% CI: -9.8-0.7; $p = 0.025$) and single access (-3.9, 95% CI -6.4-1.4; $p = 0.002$) while positively correlated to supine (4.7, 95% CI 0.02-9.43; $p = 0.05$), Figure 1b. The need for higher secondary procedures was positively associated with supine position (4.29, 95% CI: 1.28-14.4; $p = 0.01$), stone size

TABLE 2b. **Patient demographic characteristics, operative parameters and outcomes according Guy's stone score 3 and 4**

	Guy's 3			Guy's 4		
	ePSL	**Supine**	**p value**	**ePSL**	**Supine**	**p value**
Total patients, n	171	155		41	87	
Age (y; mean [SD])	57.3 (15.4)	48.5 (12.3)	< 0.001	54.1 (15.4)	43.7 (12.5)	< 0.001
BMI (mean [SD])	32.7 (9.2)	29.4 (6.3)	< 0.001	33.3 (10.1)	30.2 (7.4)	0.944
Charlson index	2.3 (2.3)	2.6 (2.2)	0.164	2.2 (2.5)	2 (2)	0.994
Stone size (mm; Mean [SD])	41.3 (24.4)	42.6 (22.4)	0.196	56.2 (31.0)	61.7 (24.5)	0.190
Operative time (min; mean [SD])	109 (49.6)	123.1 (44.1)	< 0.001	125.5 (52.6)	115.1 (46.5)	0.242
Number of tracts (n; %)						
One	166 (97.6)	114 (78.6)	< 0.001	38 (92.7)	61 (74.4)	0.030
Two	4 (2.4)	30 (20.7)	< 0.001	3 (7.3)	18 (22.0)	0.075
Three	0 (0)	1 (0.7)	0.460	0 (0)	3 (3.7)	0.550
Calyx puncture (n; %)						
Lower	12 (7.1)	84 (58.3)	< 0.001	1 (2.4)	57 (70.4)	< 0.001
Middle	13 (7.6)	43 (29.9)	< 0.001	1 (2.4)	15 (18.5)	0.028
Upper	145 (85.3)	17 (11.8)	< 0.001	39 (95.1)	9 (11.1)	< 0.001
Tubeless (%)	171 (100)	44 (28.4)	< 0.001	38 (92.7)	14 (16.1)	< 0.001
Radiation time (min; mean [SD)	2.8 (1.8)	13.6 (9.8)	< 0.001	3.9 (3.2)	13.5 (14.1)	< 0.001
Hospital stay (days)	2.2 (3.3)	2.1 (1.0)	< 0.001	2.3 (2.0)	2.5 (1.9)	0.240
Secondary procedure (mean [SD)	19 (11.1)	35 (22.6)	0.008	11 (26.8)	34 (39.1)	0.247
Complications (n; %)						
Blood transfusion	11 (6.4%)	5 (3.2)	0.279	2 (4.9)	3 (3.4)	0.655
Embolization	1 (0.6)	0 (0)	1.000	1 (2.4)	0 (0)	0.320
Chest tube	4 (2.3)	1 (0.6)	0.374	2 (4.9)	0 (0)	0.100
Colonic lesion	0 (0)	1 (0.6)	0.476	0 (0)	1 (1.1)	1.000
Pulmonary embolism	0 (0)	0 (0)	-	1 (2.4)	1 (1.1)	0.540

ePSL = endoscopic guided prone split-leg PCNL; BMI = body mass index

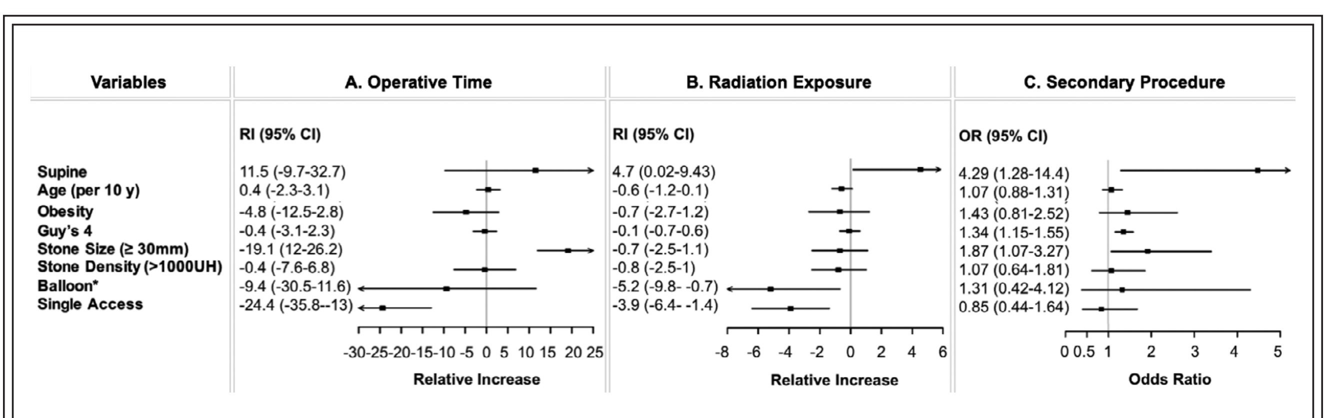

Figure 1. Multivariate analysis. Factors related to operative time, radiation time and need for secondary procedure.
*no statistical influence for serial dilation

TABLE 3. **Operative parameters, complications and secondary procedures**

	ePSL	**Supine**	**p value**
Operative time (min; mean [SD])	96.8 (44.8)	121.9 (44.8)	< 0.001
Number of tracts (n [%])			
One	441 (98.4)	269 (74.9)	< 0.001
Two	7 (1.6)	81 (22.6)	< 0.001
Three	0 (0)	9 (2.5)	< 0.001
Calyx puncture (n [%])			
Lower	40 (8.9)	228 (63.9)	< 0.001
Middle	42 (9.8)	95 (26.6)	< 0.001
Upper	366 (81.7)	34 (9.5)	< 0.001
Tract dilatation method (n [%])			
Serial dilation	1 (0.2)	333 (88.1)	< 0.001
Balloon	446 (99.3)	22 (5.8)	< 0.001
Metalic	0	18 (4.8)	< 0.001
Serial dilation + balloon	2 (0.4)	5 (1.3)	0.256
Tubeless PCNL (n [%])	443 (98.7)	138 (36.3)	< 0.001
Hospital length of stay (days; mean [SD])	1.87 (2.34)	2.21 (1.33)	< 0.001
Radiation time (min; mean [SD])	3.20 (4.19)	13.76 (12.31)	< 0.001
Complications (n [%])			
Blood transfusion	19 (4.2)	10 (2.6)	0.286
Embolization	4 (0.9)	0 (0)	0.129
Chest tube	11 (2.4)	3 (0.8)	0.113
Colonic injury	0 (0)	2 (0.5)	0.210
Pulmonary embolism	1 (0.2)	1 (0.3)	1.000
Secondary procedure (n [%])	37 (8.2)	85 (22.3)	< 0.001
Secondary procedure type (n [%])			
SWL	4 (10.8)	32 (37.6)	0.006
URS	24 (64.9)	22 (25.9)	< 0.001
PCNL	9 (24.3)	31 (36.5)	0.270

PCNL = percutaneous nephrolithotomy; SWL = shock wave lithotripsy; URS = ureteroscopy

(1.87, 95% CI: 1.07-3.27; p = 0.027) and GSS4 (1.34, 985% CI: 1.15-1.55; p = 0.001), Figure 1c.

Discussion

Despite cumulative literature,[3-8,10,28-30] the optimal position for PCNL based on complexity of stone burden has not yet been determined, Table 5. Through an international multicenter collaboration, we compared the ePSL versus supine technique for PCNL stratifying patients according to GSS.

Nomograms have been proposed in order to stratify stone patients according the stone complexity. The S.T.O.N.E. Nephrolithometry (STONE)[31] uniquely includes variables that have been shown to have significant impact on postoperative outcomes, as follows: stone size, distance to the skin, the degree of obstruction in the urinary tract, the number of renal calices involved, and stone density. However, it was validated with a small cohort and this may limit its applicability to a wider patient population.[20,32] The nomogram of the Clinical Research Office of the Endourological Society (CROES) uses variables such as area, number and location of the stones, previous treatment, staghorn stone and number of cases treated per year in the institution.[33] Despite being widely generalizable (based on global data), CROES database was not created specifically for the development of a predictive model for classification of stone disease prior to PCNL and, therefore, lacks important variables affecting the outcomes such as radiologic data on hydronephrosis and other pelvicalyceal abnormalities.[20] In addition, the CROES nomogram is complex, requiring

TABLE 4. **Complications between ePSL and supine stratified by WHO obesity classification**

	Non obese (IMC < 30)			Obesity I (IMC 30-34.9)		
	ePSL	**Supine**	**p value**	**ePSL**	**Supine**	**p value**
Total patients, n	176	242		116	103	
Age (y; mean [SD])	55.8 (16.8)	47 (13.1)	< 0.001	59.2 (12.3)	51.1 (12.6)	< 0.001
Charlson Index (mean [SD])	1.89 (2.1)	2.17 (2.1)	0.192	2.29 (2.1)	3 (2.2)	0.018
Stone size (mm; mean [SD])	34.4 (23)	40.9 (26.7)	0.160	32.4 (17.1)	44.2 (24.3)	< 0.001
Radiation time (min; mean [SD])	3.12 (3.7)	14 (14.1)	< 0.001	3.12 (2.08)	12.65 (7.25)	< 0.001
Hospital stay (days)	2.18 (2.9)	2.20 (1.1)	0.958	1.4 (0.96)	2.1 (1.1)	< 0.001
Secondary procedure (n [%])	18 (10.2)	46 (19)	0.014	19 (7.0)	43 (27.2)	< 0.001
Complications (n [%])						
Blood transfusion	13 (7.4)	8 (3.3)	0.071	4 (3.4)	1 (1.0)	0.374
Embolization	0 (0)	0 (0)	-	0 (0)	0 (0)	-
Chest tube	7 (4)	3 (1.2)	0.103	1 (0.9)	0 (0)	0.530
Colonic injury	0 (0)	0 (0)	-	0 (0)	2 (1.3)	0.134
Pulmonary embolism	0 (0)	0 (0)	-	0 (0)	0 (0)	-
	Obesity II (IMC 35-39.9)			**Obesity III (IMC ≥ 40)**		
	ePSL	**Supine**	**p value**	**ePSL**	**Supine**	**p value**
Total patients, n	57	35		100	20	
Age (y; mean [SD])	59.5 (12.1)	47.69 (11.3)	< 0.001	54.4 (12.3)	41.2 (11.7)	< 0.001
Charlson Index (mean [SD])	2.49 (2.1)	2.43 (2.2)	0.895	2.9 (2.6)	1.9 (1.7)	0.036
Stone size (mm; mean [SD])	35.98 (25.67)	43 (22.85)	0.147	36 (23)	39 (19)	0.513
Radiation time (min; mean [SD])	4.82 (9.47)	14.74 (9.83)	< 0.001	2.61 (1.65)	9.76 (1.82)	< 0.001
Hospital stay (days)	1.9 (2.7)	2.9 (2.5)	0.109	1.83 (1.76)	2 (1.17)	0.695
Secondary procedure (n [%])	1.9 (2.7)	2.9 (2.5)	0.109	9 (9.0)	5 (25)	0.057
Complications (n [%])						
Blood transfusion	3 (5.3)	1 (2.9)	0.660	5 (5.0)	0 (0)	0.588
Embolization	0 (0)	0 (0)	-	4 (4)	0 (0)	1
Chest tube	1 (1.8)	0 (0)	1	2 (2.0)	0 (0)	1
Colonic injury	0 (0)	1 (2.9)	0.380	0 (0	0 (0)	-
Pulmonary embolism	1 (1.8)	1 (2.9)	0.619	0 (0)	0 (0)	-

a more time consuming evaluation of preoperative variables.[19,21] Here in, we adopted the GSS to stratify patients according stone complexity since it has proved to be reproducible, easy and fast to use in the clinical setting.[19-22] Moreover, Thomas et al demonstrated that GSS was the only factor that significantly and independently predicted the stone-free rate.[21]

The differences observed in patient demographic characteristics reflect each country epidemiological trend: older patients and higher BMI in the USA. According the Center for Disease Control and Prevention (CDC), 36.5% of the U.S. adults have obesity,[34] while in Brazil, the Brazilian Institute of Geography and Statistics (IBGE)[35] states that obesity can reach 18.9% of the adult population.[34] In addition, people age 65 and over made up 14.5% of the North American population while in Brazil up to 8%.[35] Despite having an older, more obese population, outcome with ePSL compared favorably to supine.

Operative time remains controversial between the classic prone and supine PCNL. From the four available prospective randomized trials,[3-5,28] three have reported reduced operative time for supine,[3-5] which was attributed to the lack of repositioning of patients at the beginning and end of the procedure in the classic prone position. The CROES PCNL Global study, on the other hand, reported longer operative time for supine,[10] even when staghorn stones were present.[29] However,

TABLE 5. **Published reports comparing prone versus supine PCNL**

Study design	Number of patient; positioning	Population characteristic	Operative time	Complications	Stone-free rate	Author
Prospective randomized trial	39; modified supine* 36; prone	Single tract No staghorn calculi	Supine < prone	ND	ND	De Sio et al 2008[3]
Prospective randomized trial	40; complete supine 40; prone	Stones >= 2 cm No renal anomalies	Supine < prone	ND	ND	Falahatkar et al 2008[4]
Prospective randomized trial	60; modified supine** 62; prone	Stones > 2 cm Upper ureteral stones > 1.5 cm	Supine > prone	ND	Supine > prone	Wang et al 2013[28]
Prospective randomized trial	101; oblique supine** 102; prone	Stones >= 2.5 cm Upper ureteral stones > 1 cm Failed ESWL	Supine < prone	ND	ND	Al-Dessoukey et al 2014[5]
Prospective Nonrandomized trial	53; modified supine* 77; prone	Stones >= 2 cm/ staghorn Failed ESWL Upper ureteral stones		ND	ND	Shoma et al 2002[6]
Retrospective trial	1138 supine 4637; prone	Candidates for PCNL Failed ESWL	Supine > prone	Supine < prone⊛	Supine < prone	Valdivia et al 2011***
Retrospective trial	30; complete supine 12; prone	BMI > 30 Stones >= 2 cm	Supine < prone	ND	ND	Mazzucchi et al 2012[7]
Retrospective trial	36; Galdakao-modified Valdivia 36; prone	Large or complex stones	Supine > prone	ND	ND	McCahy et al 2013[8]
Retrospective trial	232; supine 1079: prone	Partial staghorn calculi Complete staghorn calculi	Supine > prone	ND	Supine < prone	Astroza et al 2013[29]***
Retrospective trial	96; complete flank-free**** 101; prone	Candidates for PCNL	Supine < prone	Supine < prone⊛⊛	ND	Sohail et al 2017[30]

* = described by Valdivia et al, 1998[13]
** = ipisilateral lower limb is placed on the leg elevator/roll (angle 20-50)
*** = CROES (Clinical Research Office of the Endourological Society) PCNL global study; 96 centers
**** = two silicone gel pads (under ipsilateral chest and buttocks)
⊛ = prone position exhibited higher rates of blood transfusion and fever, without difference for hydrotorax
⊛⊛ = prone position exhibited higher rates of urinary leakage
ND = no statistically difference between prone and supine position

since patient repositioning is not required in the PSL, surgical time can be more precisely compared to the supine. In our study, univariate analysis demonstrated that operative time was significantly longer by an average of 25 minutes in the supine group. After GSS stratification, no significant difference in operative time was found for complex stones (GSS4) between groups, therefore the advantage in operative time for ePSL in conferred to the GSS1-3 subgroups. Multivariate analysis revealed that operative time was positively correlated to stone size and negatively associated with number of access, Figure 1a. In fact, 98.4% of ePSL was performed by a single tract while in supine multiple tracts were more common, suggesting the primary tract obtained in a prone position is more favorable than that obtained in a supine position. The higher use of multiple tracts then translates to a lower tubeless rate for supine.

Concerns related to radiation exposure, both to the patient and healthcare providers, have become an important issue.[36] The fluoroscopy time to gain the renal access and perform the surgery was significantly lower in the ePSL group ($p < 0.001$), and remained significant after GSS stratification. Linear regression analysis demonstrated that balloon dilation and single tract were correlated with low radiation exposure while supine was correlated to higher radiation exposure ($p = 0.05$), Figure 1b. As such, when controlling for number of access and the use of balloon dilation, supine PCNL was still associated with a higher fluoroscopy time. It must be pointed that both ePSL PCNL and balloon dilatation contribute to less radiation exposure, but ePSL should be the focus here since its technique primarily includes the use of balloon.

The best calyx to approach is also a debated issue in the literature. The proponents of the prone position advocate that the upper pole calyx provides a direct tract down the renal pelvis and the ureter, allowing access to almost all calices with rigid and flexible nephroscopes.[37] However, supine advocates emphasize that the lower pole tract in supine permits access to the upper calyx in the majority of cases.[38] Indeed, in our study, most of the renal percutaneous tracts in supine were through the inferior calyces (63.9%) while in the ePSL it was mainly in the upper calix (81.7%), and these trends remained after GSS stratification. Of note however, though the ePSL were accessed through a supracostal superior calyceal puncture, there was no significant difference in rates of pulmonary complications.

There were no statistical differences in the complication rates between supine and ePSL techniques, even after GSS and BMI stratification, Tables 2a, 2b, and 4. This may be related to the low incidence of complications in both groups, despite appropriate power analysis. However, complications were more frequent in patients with higher GSS. Therefore, GSS can be used as good predictor for complications.[22]

Notwithstanding being the first comparative study between supine and ePSL PCNL techniques, powered by almost 900 patients, some limitations warrant mentioning. First, as an international multicenter study, the differences in the patient demographics (age, BMI and stone size) reflects epidemiological differences in the respective practices. Similarly, length of stay may be flavored by cultural expectations, as well as the use of tubeless technique may be influenced by the surgeon preference. However, through GSS stratification, the groups become homogeneous, since the statistical difference related to stone burden noted in the overall analysis loses significance. As a limitation of our study, the strict stone free-rate between groups could not be investigated, as postoperative imaging was not routinely performed in the PSL group. As such, secondary procedures for residual stones > 4 mm were used as a surrogate measure of efficacy. Prior literature justifies this comparison when demonstrated that intraoperative high magnification fluoroscopy and endoscopic inspection is equivalent to CT imaging for the detection of residual stones > 4 mm. In fact, we conducted an internal comparison in the supine group and demonstrated that the majority of patients considered stone-free by the intraoperative evaluation were stone-free in the POD#1 CT and no secondary procedure was needed in these cases. In the univariate analysis, supine position was correlated to higher number of secondary procedures. However, after patient's stratification by GSS, the higher need for secondary procedures remained significant for GSS1, GSS2 and GSS3, and lose significance for GSS4, reflecting the complexity of the treatment of the complete staghorn stones despite patient positioning.

Despite these limitations, ePSL demonstrates significant advantages over supine PCNL with regards to operative time, fluoroscopy time and need for secondary procedures in patients with low-moderate complexity of nephrolithiasis.

Conclusion

This is the first report focusing on the performance differences between ePSL and supine PCNL stratified by Guy's score. Both techniques are safe, with a low rate of complications. For GSS1-3, ePSL reduces radiation exposure and requires less need for both multiple access and secondary procedure. □

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