Upper Calyx Approachability through a Lower Calyx Access for Prone Versus Supine Percutaneous Nephrolithotomy

Mario Sofer,* Guido Giusti, Silvia Proietti, Ishai Mintz, Maharan Kabha, Haim Matzkin and Galit Aviram

From the Endourology Unit (MS) and Departments of Urology (IM, MK, HM) and Radiology (GA), Tel-Aviv Sourasky Medical Center, Sackler Faculty of Medicine, Tel-Aviv University, Tel-Aviv, Israel, and Stone Center at Department of Urology, Humanitas Clinical and Research Center (GG, SP), Rozzano, Italy

Purpose: We assessed the approachability of the upper calyx through lower calyx access for prone and supine percutaneous nephrolithotomy and used computerized tomography to analyze anatomical factors that may influence it.

Materials and Methods: A prospective series of 45 patients treated with percutaneous nephrolithotomy were operated on in the prone (20) and supine (25) positions. Computerized tomography simulated access to the lower and upper calyx longitudinal axes were used to measure skin-to-lower calyx distance, thickness of the body wall, muscle and fat, the muscle-to-fat thickness ratio and the angle between the lower calyx tract and the upper calyx axis. Intraoperative approachability to the upper calyx was also evaluated.

Results: The upper calyx was successfully approached in 20% of prone and 80% of supine percutaneous nephrolithotomies ($p < 0.0001$). The average skin-to-lower calyx distance was 98.4 mm (range 65.3 to 128.6) in the prone position and 98.7 mm (range 60.8 to 150) in the supine position ($p = 0.99$). Body wall and muscular thickness, and the muscle-to-fat thickness ratio were significantly lower in supine than prone nephrolithotomy ($p < 0.001$, < 0.0005 and < 0.05, respectively). The average angle between the lower and upper calyces axes was wide in the supine position (141 degrees, range 90 to 170) and acute in the prone position (84 degrees, range 65 to 110, $p < 0.05^{E-10}$).

Conclusions: Upper calyx endoscopic approachability through the lower calyx is significantly higher in supine than in prone percutaneous nephrolithotomies, possibly due to a thinner body wall, a thinner muscular layer, a lower muscle-to-fat thickness ratio and a wider angle between the lower and upper calyx axes.

Key Words: kidney; calculi; nephrostomy, percutaneous; patient positioning; anatomy, regional

Abbreviations and Acronyms

3D = 3-dimensional

CT = computerized tomography

PCNL = percutaneous nephrolithotomy

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* Correspondence: Department of Urology, Tel-Aviv Sourasky Medical Center, 6 Weizman St., Tel-Aviv 642390, Israel (telephone: 972-3-6973359; FAX: 972-3-6973798; e-mail: mariosofer@hotmail.com).

THE current consensus among endourologists is that approachability to the upper calyx through a lower calyx is highly limited during prone PCNL. For that reason large and complex staghorn stones must be preferentially accessed through an upper calyx, which provides a direct tract down the renal pelvis, the upper ureter, the lower calyx and with the aid of a flexible nephroscope to most of the mid calyces.[1,2] However, the upper calyx tracts are mostly supracostal. Therefore, they are associated with significantly higher intrathoracic and overall complication rates

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compared to lower calyx subcostal tracts.[2,3] As such this approach should be restricted to cases when no other alternatives are available.[2] Performing lower calyx access may decrease the risk of complications but its limitations in reaching the upper calyx represent an obstacle to achieving completely stone-free status when dealing with complex calculi.[1,3]

To our knowledge the limitation of endoscopically accessing the upper calyx through a lower calyx puncture has not yet been validated. Rather it relies on expert opinions formed from reported series on prone position PCNL and clinical deductions from the endocast anatomical studies by Sampaio et al.[4] The introduction of supine PCNL with its variations in patient positioning offered a new and more lateral flank area of puncture in comparison to the posterior flank area used in the prone position.[5–7] The spatial anatomical relation between the site of entry and the intrarenal collecting system in the supine position differs considerably from that of the prone position.

These differences led us to propose the hypothesis that the upper calyx is more endoscopically accessible through a lower calyx with the patient in a supine position than in a prone position. We assessed this hypothesis and analyzed anatomical factors that may influence it by multidetector CT.

MATERIALS AND METHODS

This study was approved by the institutional review board. All patients undergoing PCNL were prospectively and consecutively enrolled in this study during the 6-month period of March to September 2014. Patients who entered the study during the first 3 months were operated on while prone and those who entered during the last 3 months were operated on while supine. Our basic approach consisted of insertion of a No. 5 open-ended ureteral catheter, retrograde pyelography and puncture of the lower posterior calyx under multiplanar fluoroscopy guidance for the prone position, and combined ultrasonographic and anteroposterior fluoroscopic guidance for the supine position. Further details of our prone[8] and supine[9] techniques have been reported previously. The operations were performed without postoperative nephrostomy tubes (tubeless). An internal stent was left in place for 5 days.

Approachability to the upper calyx through the lower calyx was assessed using rigid 18Fr to 21Fr nephroscopes (Richard Wolf Medical Instruments, Vernon Hills, Illinois). It was considered successful when the upper calyx papillae were endoscopically identified in the center of the operative field and the position of the nephroscope was demonstrated by intraoperative pyelography as being in the upper calyx (fig. 1).

The 20 patients in the prone PCNL group and the 25 in the supine PCNL group were compared in terms of upper calyx accessibility. Preoperative CTs of these patients were performed in the prone position for prone PCNL and in the supine position for supine PCNL. These studies were used for anatomical analysis in standard cross-sectional fashion, including axial, coronal and sagittal reconstructions.

In addition, 3D volume rendering reconstructions were performed. Using the CT software tools on the 3D reconstructions a line was electronically drawn to simulate the ideal access axis to the lower pole. A sagittal view was used to simulate the access for the prone position and a coronal view was used for the supine position. A second line was drawn perpendicular to the upper calyx to mark the upper calyx axis. Using these lines parameters were measured to compare anatomical features related to the prone and supine positions, including the distance between the skin and the lower calyx; the thickness of the body wall, muscular layer and fat layer; the muscle-to-fat thickness ratio; and the angle between the lower calyx tract axis and the upper calyx axis (fig. 2).

The stone-free rate was assessed 3 months following the procedure by plain x-ray of the kidney, ureters and bladder, and ultrasound for patients with intraoperative fluoroscopic radiopaque stones and by noncontrast CT for patients with radiolucent stones. In addition, patients with a nephrostomy tube were assessed by noncontrast

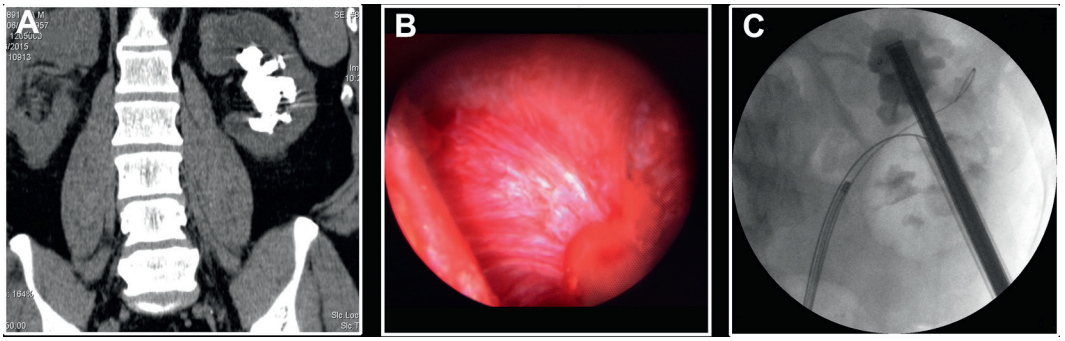

Figure 1. Typical successful rigid nephroscope access to upper calyx through lower calyx tract with patient supine. *A,* preoperative coronal CT shows 55 mm complete staghorn stone in left kidney. Note characteristic position of kidney with upper pole median and lower pole lateral. *B,* Intraoperative endoscopic view reveals upper calyx papilla in center of endoscopic field. *C,* intraoperative pyelography demonstrates position of nephroscope tip in upper calyx.