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ORIGINAL ARTICLE

Ureteroscopic holmium laser-assisted retrograde nephrostomy access: a novel approach to percutaneous stone removal

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Abstract

Introduction and objectives Percutaneous nephrolithotomy remains a challenging procedure primarily due to difficulties obtaining access. Indeed, few urologists obtain their own access due to difficulties using a fluoroscopic or ultrasonic based antegrade puncture technique. Herein we report the first experience using holmium laser energy to obtain access in a retrograde fashion.

Methods After a pretreatment week of tamsulosin 0.4 mg/day (one center only) and following a documented sterile urine, a total of ten patients underwent retrograde holmium laser-assisted endoscopic-guided nephrostomy access in a prone split leg position.

Results In nine of ten patients, ureteroscopic guided, holmium laser access via an upper pole posterior calyx was achieved. In one patient, the laser tract could not be safely dilated and antegrade endoscopic and fluoroscopic guided access was performed. The mean operative time was 202 min; the mean fluoroscopy time was 32 s (6/9 cases). The mean pre-operative stone volume was 14,420 mm^3. CT imaging on post-operative day 1 revealed 6/6 patients had residual stone fragments with total mean volume of 250 mm^3 (96% reduction); there were no residual fragments in three patients who were evaluated with non-CT radiographic imaging (KUB). There was a single complication requiring angioembolization due to a subcapsular hematoma with associated secondary tearing of an inter-polar vessel remote from the nephrostomy site.

Conclusions Holmium laser-assisted endoscopic-guided retrograde access in a prone split-leg position was successfully performed at two institutions. The accuracy of nephrostomy placement and lessening of fluoroscopy time are two potential benefits of this approach.

Keywords Retrograde nephrostomy · Holmium laser · Percutaneous nephrolithotomy · Nephrolithiasis · Technique · Nephrostomy access

Introduction

With increasing incidence of nephrolithiasis, the volume of ureteroscopy (URS) and percutaneous nephrolithotomy (PCNL) continue to rise [1]. PCNL is the gold standard treatment for large renal calculi [2]. Throughout the United States, 80% of PCNL nephrostomies access is established by interventional radiology (IR) using an antegrade approach [3–6]. However, despite its lack of frequency, urologist-acquired percutaneous access is actually superior in terms of stone-free rates and access-related complications. The challenges of antegrade targeting of a commonly non-dilated calyx and the skills necessary in the fluoroscopic or ureteroscopic manipulation of guidewire placement, tract dilation, and positioning of the working sheath combine to dissuade the majority of urologists from obtaining their own percutaneous access.

Lawson et al. described the retrograde approach as an alternative to the traditional antegrade access and was later modified by Hosking in the modified lithotomy position [7, 8]. Recently, this technique has been performed with ureteroscopic assistance to facilitate accurate passage of the Lawson puncture wire ("rocket wire") in both the modified

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lithotomy position as well as in the prone split leg position [9–11]. Subsequently, we hypothesized that the Lawson wire could be replaced with the 365 µm holmium laser fiber to obtain access with minimal fluoroscopy and potentially less chance of an errant path; the latter plagued the Lawson approach given the errant path of the rocket wire in cases of morbidly obese patients. After initial cadaver work, we proceeded with clinical application of retrograde holmium laser-assisted endoscopic-guided nephrostomy access.

Methods

Patient selection and pre-operative planning

Patients undergoing PCNL underwent pre-operative computed tomography (CT) scans with axial, coronal and sagittal images. After taking into account the surrounding organs and ensuring there is no overlying liver, bowel or spleen posterior to the kidney, tract length to the selected calyx of entry, and angles necessary to access the stone via the selected point of entry are determined. For this initial experience, we routinely selected patients with a tract length < 10 cm on the sagittal CT imaging for an upper pole posterior calyx planned site of entry as this provided the shortest distance from the flank to the kidney as well as the most direct route of access to the renal pelvis, ureteropelvic junction, and ureter (Fig. 1).

At one center (UCI), all seven patients were pre-treated with oral tamsulosin 0.4 mg/day for a week prior to surgery to potentially facilitate passage of a 16 French ureteral access sheath [12]. Urine cultures were confirmed to be negative and patients were given ciprofloxacin (or alternative antibiotic if allergic to ciprofloxacin) 500 mg PO twice daily for 7 days prior to surgery to minimize risk of urinary sepsis. At the second center (HPTU), all three patients were documented to have sterile cultures and patients were given Cefazolin 2 g intravenously pre-operatively; no preoperative tamsulosin was given.

Technique: University of California-Irvine

Patient positioning and ureteroscopy

After administration of general anesthesia, the patient was placed in the prone position with lower extremities split on spreader bars; the genitalia and ipsilateral flank were prepared and draped. Flexible cystoscopy was performed and an Amplatz Super Stiff ™ guidewire (Boston Scientific®, Natick, MA, USA) was inserted up to the level of the kidney. An 8/10-French ureteric dilator set (Boston Scientific®, Natick, MA, USA) was inserted over the guidewire up to

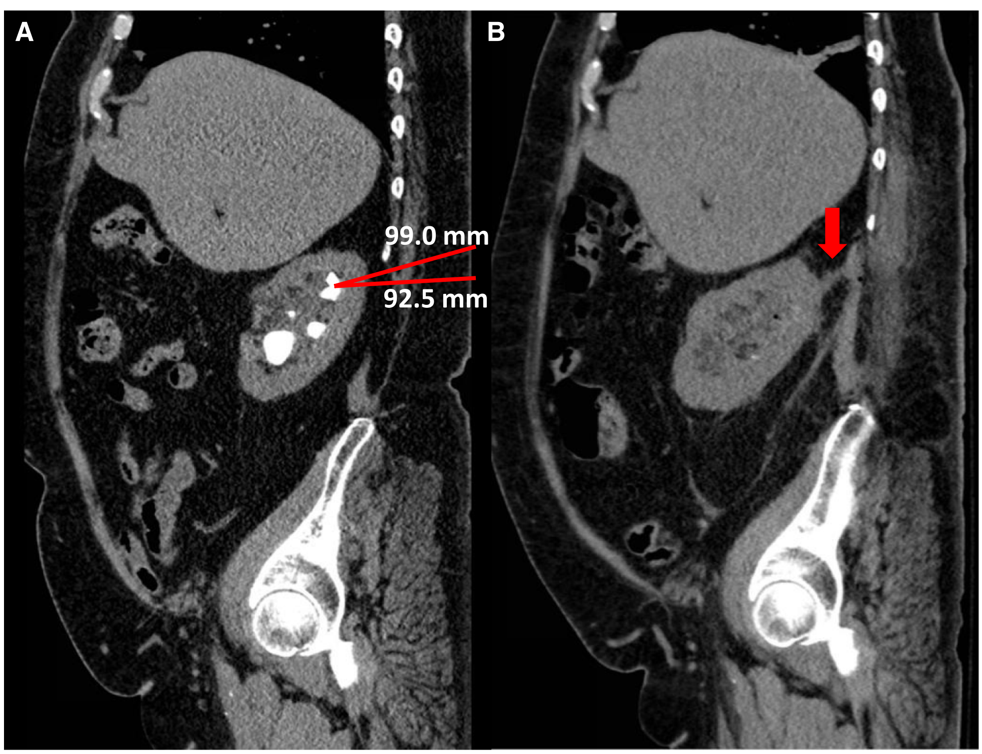

Fig. 1 Sagittal **a** pre-operative nephrostomy tract length and **b** post-operative CT imaging of renal calculi showing the actual nephrostomy tract (red arrow)

the level of the kidney under fluoroscopic guidance. Retrograde pyelography was performed to map the calices, then the 8/10-French ureteric dilator was removed and the bladder was drained with a 12-French Foley catheter for the duration of the case. A 16-French 35 cm ureteric access sheath (UAS) (Cook Medical®, Bloomington, IN, USA) was placed up to the level of the ureteropelvic junction over the Amplatz Super Stiff guidewire under fluoroscopic guidance. The flexible ureteroscope, with a preloaded 365 µm holmium laser probe, was introduced and the calices were inspected.

Holmium laser-assisted endoscopic-guided retrograde access

Two cc of air were injected (air congregates in the most posterior calyx of the upper pole when the patient is in the prone position thus guiding the puncture) via the ureteroscope (Cobra—Richard Wolf®, Vernon Hills, IL, USA or Flex X^{c}—Karl Storz Endoscopy-America Inc., El Segundo, CA, USA) and with combined ureteroscopic and fluoroscopic guidance, a posterior calyx was identified (Fig. 2). Once the tip of the ureteroscope was fluoroscopically confirmed to be positioned directly posterior, and beside/into the air bubble, respirations were suspended during exhalation to prevent pleural injury and the 365 µm laser fiber at 1 J and 10 Hz (i.e. same settings we use for performing a laser endopyelotomy) was activated and advanced directly through the posterior upper calyceal fornix towards the flank. The continuous audible sound of the laser and its forward progress confirmed ongoing advancement of the laser probe until the laser cut through the skin. The exiting tip of the laser fiber was grasped and 8–10 in. of the laser fiber were delivered onto the flank. An incision was made on either side of the laser fiber (Fig. 3). The obturator of the 18-gauge

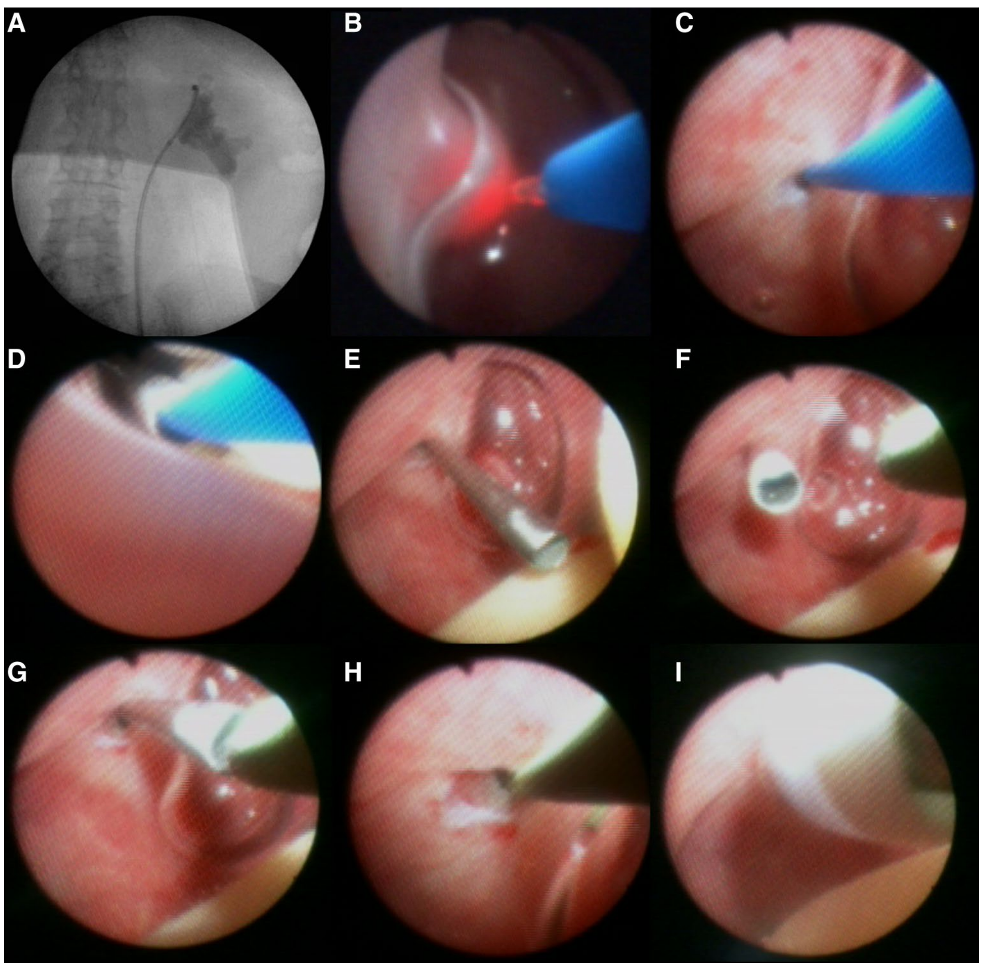

Fig. 2 Endoscopic laser-assisted retrograde access (ureteroscopic views). **a** Flexible ureteroscope positioned in a posterior upper pole calyx. **b** 365 µm laser fiber aimed at the fornix. **c** Activated laser passed into the fornix; passage continued until the laser exits the flank. **d** Nephrostomy needle obturator passed over the laser fiber. **e** Laser fiber removed, leaving nephrostomy needle obturator in place. **f** 260 cm exchange guidewire passed through the flexible ureteroscope. **g** Docking of 260 cm exchange guidewire and the needle obturator. **h** Through-and-through 260 cm guidewire. **i** 10 mm nephrostomy dilating balloon passed over the 260 cm guidewire

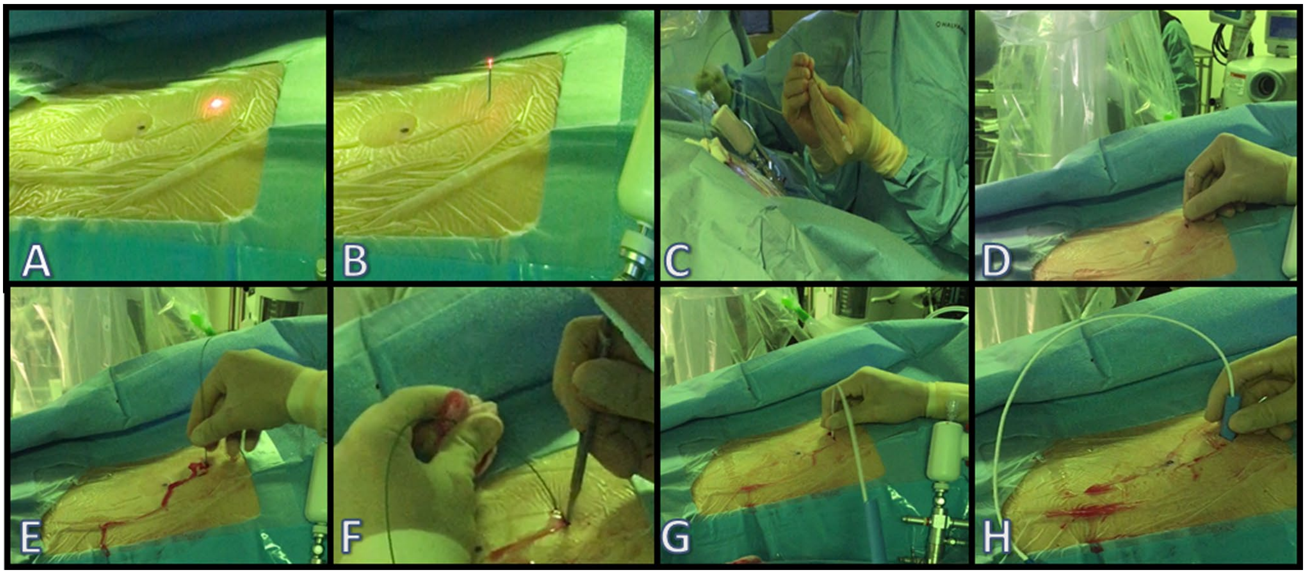

Fig. 3 Endoscopic laser-assisted retrograde access (flank view). **a** Glow of laser fiber seen just beneath the skin. **b** Laser fiber exiting the skin. **c** Threading the nephrostomy needle over the laser fiber. **d** Nephrostomy needle's obturator in place with the laser fiber now withdrawn. **e** Retrieving the 260 cm exchange guidewire from the needle's obturator. **f** Needle's obturator removed and skin incision enlarged. **g** Passage of 10 mm dilating balloon. **h** Final position of 30 French nephrostomy sheath

nephrostomy needle was then advanced over the laser fiber and into the collecting system, under fluoroscopic and endoscopic control. Once the obturator was seen in the collecting system, the laser fiber was removed from the ureteroscope. A 260 cm exchange guidewire was inserted through the ureteroscope and "docked with" the nephrostomy needle's obturator; the 260 cm guidewire was advanced until roughly 50 cm of it was lying on the flank. The nephrostomy needle was removed. The skin incision was extended to 1 cm; the 5 mm fascial incising needle (Cook Medical®, Bloomington, IN, USA) was passed over the exchange guidewire to cut the lumbodorsal fascia. Under endoscopic guidance, the 10 mm nephrostomy balloon (NephroMax™—Boston Scientific®, Natick, MA, USA) was advanced over the exchange guidewire until it was seen to enter the calyx. The tract was dilated and a 30-French nephrostomy access sheath was positioned under endoscopic control within the collecting system.

Lithotripsy, stone fragment extraction, stent insertion, and sealing of nephrostomy access

Lithotripsy was performed using a 26-French Karl Storz Inc. nephroscope and LithAssist™ (Cook Medical®, Bloomington, IN, USA) with a 1000 µm laser fiber (1–2 J at 10–20 Hz). All accessible stone fragments were removed after which flexible nephroscopy, and flexible ureteroscopy were used to remove any remaining stones until the kidney appeared to be endoscopically and fluoroscopically stone free. The access sheath was then withdrawn, the entire ureter was evaluated with antegrade flexible ureteroscopy using the Post-Ureteroscopic Lesion Scale (PULS) (UCI only). The 12-French Foley catheter was removed and a ureteric stent was inserted over the 260 cm exchange guidewire; the proximal coil was positioned under nephroscopic control as the guidewire was withdrawn and the distal coil was confirmed by fluoroscopy. A 16-French Foley was inserted for post-operative bladder drainage. Five cc of Surgiflo® (Ethicon Endo-Surgery Inc., Cincinnati, OH, USA) was instilled as the 30F Amplatz sheath was removed; flank compression was applied for 10 min. The skin incision was closed with 4-0 Monocryl and Dermabond (Ethicon Endo-Surgery Inc., Cincinnati, OH, USA).

Results

Nine of ten patients underwent successful holmium laser endoscopic guided retrograde access (Table 1). The remaining patient underwent an uncomplicated standard endoscopic-guided antegrade access as the laser path wandered, and was deemed too long for routine dilation. Among the nine laser access patients, the mean operative time was 202 min and mean fluoroscopy time was 32 s (only 6 cases had this information available). The mean pre-operative stone volume was 14,420 mm^3 with mean density of 1016 HU units. The mean tract length was 8.4 cm, and 33% of the nephrostomy tracts were supracostal. A CT scan on post-operative day 1 revealed that all 6 UCI patients had residual stone fragments ranging from 2.1 to 8.8 mm; at HPTU KUB revealed no residual fragments in all 3 patients. The mean absolute stone volume

Table 1 Patient, stone and surgical characteristics

Variable	
Number of patients	9 (3 males, 6 females)
Age in years (mean)	51.8 (19–74)
BMI (mean)	27.0 (20.2–40.5)
ASA (mean)	2.4 (2–3)
Mean stone to skin distance (cm)	8.3 (3.9–12.1)
Mean tract length (cm)	8.4 (3.99–10.0)
Stone locations (%) ($n = 14$)	
Lower pole	43%
Ureteropelvic junction	29%
Middle calyx	14%
Staghorn	14%
Mean pre-operative cumulative stone diameter (cm)	6.68 (3.5–10.3)
Mean pre-operative stone volume (mm^3)[a]	14,420 (2594–26,405)
Mean absolute stone volume reduction (mm^3)	14,170 (2594–26,405)
Mean absolute stone volume reduction (%)	96 (88.0–99.7)
Mean case time (min)	202 (117–250)
Mean fluoroscopy time (s)	32 (5–64)
Ureteral injury mean (PULS)	1.25 (0–2)
Stone free rate (%) on CT scan post-op day 1 ($n = 6$)	
Complete stone free rate	0
< 4 mm stones	0
Stone free rate (%) on KUB X-ray post-op day 1 ($n = 3$)	100
Mean pre-operative Hounsfield units	1016 (485–1400)
Concomitant procedures	Cystolithopaxy ($n = 1$), contralateral ureteroscopy ($n = 2$)
Complications ($n = 1$)	Clavien IIIa (required embolization for hematoma under MAC)

[a]Stone volume = $\pi/6 \times$ length (mm) $\times$ width (mm) $\times$ depth (mm)

reduction was 96%. There were no ureteral urothelial tears noted during ureteral access sheath withdrawal, the average PULS score was 1.25.

There was one major complication (Clavien IIIa) in an ASA 3 patient. The patient was noted to have a subcapsular hematoma on her postoperative CT scan with an attendant drop in her hemoglobin. An angiogram showed bleeding from an interpolar vessel located well away from the upper pole nephrostomy tract. She was embolized and transfused with two units of packed red blood cells. The remainder of her hospital course was unremarkable.

Discussion

Accurate placement of the nephrostomy tract is essential for performing a successful PCNL. Although urologists are exposed to PCNL cases during their residency, only a few are comfortable in achieving their own percutaneous access [13–15]. As such, today, the majority of percutaneous accesses for PCNL are obtained by interventional radiologists [3, 4].

An alternative to the traditional antegrade approach was first described by Lawson et al. in 1983 when they developed the retrograde Lawson rocket wire technique [8]. After placement of a retrograde catheter into the calyx of choice, the rocket wire was passed through the catheter and out the flank. This retrograde access for PCNL provided a short learning curve (10 cases) [16, 17]. Moreover, with flexible ureteroscopy the most appropriate calyx could be selected under direct visualization, and thus further reduce the need for fluoroscopy [7, 10, 17]. Further, by passing the rocket wire through the ureteroscope, the platform became much more stable opening up the use of this approach in some obese patients [9, 18].

Building on our prone Lawson rocket wire retrograde experience, we hypothesized the holmium laser would "cut" through tissue as it was passed and result in a more consistent path. In June 2017, we were able to do a holmium laser retrograde exit in a cadaver. Concurrently Uribe and colleagues performed the first successful clinical case using holmium laser-assisted endoscopic retrograde access [19]. Based on our laboratory work and Dr. Uribe's report, we proceeded with holmium laser-assisted retrograde access in seven patients.

There are several potential benefits of using the holmium laser to establish retrograde access. First, the holmium laser is already familiar and widely available to urologists. Second, the holmium laser is often used for both lithotripsy during the PCNL, and can be used for lithotripsy of stones blocking the renal pelvis allowing ureteroscopic access to the calyx of choice [11]; thus, its use for retrograde access incurs no additional costs. Third, the forward cutting nature of the laser allows it to pass through the tissues with minimal resistance, potentially creating a straighter and more direct tract than with a rocket wire. Fourth, the prone position does not preclude standard (or endoscopic) antegrade access. Lastly, in our experience, this approach has markedly reduced the amount of fluoroscopy time to achieve percutaneous renal access. Indeed, our average fluoroscopy time for laser assisted endoscopic access is 32 s (range 5–64 s). This is far less than the 82–204 s commonly reported for antegrade fluoroscopic access [20–22].

We successfully achieved laser retrograde access in nine of ten patients. In the non-successful patient, there was likely an error in aiming the tip of the ureteroscope prior to laser advancement resulting in an excessively long tract that we elected to not dilate. This patient underwent an uncomplicated antegrade endoscopic guided PCNL. Of note, no bleeding was noted within the collecting system upon withdrawal of the laser fiber. To preclude this problem from recurring, we presently check the position of the tip of the ureteroscope in both the AP and lateral planes to make sure the tip of the ureteroscope is pointing directly posterior or posterior and slightly cephalad ($< 10°$) prior to advancement of the laser fiber. Further, using a single or preferably a dual-lumen ureteroscope allows for more rigidity during initial targeting and maintaining the desired angle.

There are several potential drawbacks to the laser approach that need further review. First, since the laser fiber is not radiopaque, its forward progress is signaled by the continuous sound of the activated laser and minimal resistance during its advancement. Resistance to passage or absence of the laser-firing sound, signals either a "cracked" laser fiber or contact with a rib. In the latter case, the laser cannot fire, as there is not a sufficient fluid medium [23]. Second, a "cracked" laser fiber is a major concern as it could result in retention of a foreign body. To date we have noted in two cases that when the fiber cracks, the outer coating remains sufficiently intact such that the fiber, if it has not exited the skin, can be withdrawn into the ureteroscope and removed. Alternatively, if the fiber has exited the skin, it can be pulled out further until the cracked area is delivered onto the flank and then cut and removed. A third concern is that as the laser reaches the skin, one must be cautious to avoid the theoretical risk of eye injury from continued firing of the laser [24]. However, this complication only occurs if the activated laser tip is within 5 cm of the surgeon's eyes [25]. To date, use of the holmium laser for lithotripsy has resulted in no reports of laser eye injury [26]. Lastly, the directly posterior targeting of the ureteroscope within the calyx is similar to the bullseye technique (versus triangulating) which could result in increased bleeding as there may be more torque placed on the site of renal access [27]. To date we have not tried to use a triangulation method with the laser approach.

Conclusion

The novel approach of using an ureteroscopic holmium laser-assisted retrograde technique to establish a percutaneous tract may be a viable alternative to antegrade access. Early experience shows a short learning curve and reduced fluoroscopic use.

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