ORIGINAL PAPER

UROLITHIASIS

Laser fibers and baskets. How do they affect suction and intrarenal pressures using the novel single-use flexible direct in-scope suction ureteroscopes?

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Introduction To evaluate intrarenal pressures (IRP) and suction performance of two novel flexible ureteroscopes equipped with a direct-in-scope suction (DISS) feature – the 7.5 Fr PU3033AH and the 9.2 Fr PU400A – both with an empty working channel and with various working instruments inserted.

Material and methods An *ex vivo* experimental study was conducted using a freshly harvested porcine kidney. Measurements were performed under the following conditions: empty working channel, with a 200 µm laser fiber, a 272 µm laser fiber, and a 2.2 Fr nitinol basket. The evaluated parameters included: irrigation flow rates with gravity irrigation and an automated pump, maximum IRP without suctioning, time to collapse of the pelvicalyceal system, and time to regain baseline IRP after suctioning.

Results The highest IRP of 34 mmHg was recorded with the 9.2 Fr scope under 100 mmHg irrigation pressure. Irrespective of the irrigation system used, the introduction of working instruments significantly reduced the IRP for both 7.5 Fr and 9.2 Fr DISS scopes. A longer time was required to collapse the pelvicalyceal system and regain the basal intrarenal pressure when working instruments were used. The thicker the diameter of the instrument, the greater the impact on flowrate, IRP, collapse of the system, and regain of the pressure was observed. The latter trends were less pronounced with the 9.2 Fr scope with a wider 5.1 Fr working channel.

Conclusions The 9.2 Fr DISS ureteroscope demonstrated higher irrigation flow rates and IRP, and shorter times to system collapse and recovery compared to the 7.5 Fr scope. However, the insertion of working instruments negatively affected all measured parameters, with a greater impact observed in the 7.5 Fr scope due to its narrower channel.

Key Words: direct in-scope suction ‹› intrarenal pressure ‹› suction ‹› single-use flexible ureteroscopy ‹› laser ‹› basket

INTRODUCTION

With the development of newer-generation flexible ureterorenoscopes, high-power holmium:YAG and thulium fiber lasers, retrograde intrarenal surgery (RIRS) indications have expanded to stones larger than 2 cm [1], competing, in selected cases, with percutaneous nephrolithotripsy (PCNL) [2]. However, achieving a high stone-free rate (SFR) in stones >2 cm in a single procedure is still challenging [3]. To improve visibility without an increase in intra-renal pressure, ureteroscopes with direct in-scope suction (DISS) have been commercialized since 2022 [4]. Several advantages have been reported for DISS ureteroscopes, including high SFR [5, 6], short operative time, and good maneuverability [7]. Among the highlighted advantages of DISS is the improved visibility during lithotripsy, facilitating the retrieval of dust and small debris from the pelvicalyceal system (PCS) [8, 9]. Another potential strength of the inbuilt suction technology is the reduction of intrarenal pressure (IRP) aiming ultimately to decrease the risk of postoperative infectious complications [6]. Additionally, the DISS scopes were beneficial in relocating larger stone fragments using only the force of suction [10]. To date, while some of the aspects of DISS scopes have been evaluated, how the intrarenal pressure changes when the working channel is free or occupied by different fibers or baskets has yet to be investigated. Thus, in this study, we aimed to evaluate the intrarenal pressures and suction properties of 7.5 Fr and 9.2 Fr DISS ureteroscopes with an empty working channel and with different working instruments.

MATERIAL AND METHODS

Evaluated ureteroscopes

For the current experimental study, 2 single-use digital flexible ureteroscopes (7.5 Fr PU3033AH and 9.2 Fr PU400A [Pusen, ZhuHai Pusen Medical Technology Co, Ltd, Guangdong, China]) were tested. The main differential characteristic of these novel ureteroscopes is the integrated direct-in-scope suction feature. As such, the working channel acts for irrigation and suction if the suction button is activated. The 7.5 Fr PU3033AH DISS scope features a 3.6 Fr working channel, whereas a larger 5.1 Fr diameter working channel is incorporated on the available 9.2 Fr PU400A ureteroscope.

Experimental design and setting

We performed an *ex vivo* experimental study. We used a fresh porcine kidney harvested from slaughter together with the 15 cm proximal ureter. The kidney was cleaned of the surrounding fat and fixed on the operating table.

A hydrophilic guidewire (Bioteq Blackwire, Bioteque corporation, Taipei, Taiwan) was inserted into the kidney, followed by insertion of a 9.5/11.5 Fr or 12/14 Fr ureteral access sheath (UAS) (Flexor, Cook Medical, Indiana, USA) and depending on the scope used, was placed below the level of the ureteropelvic junction. A flexible ureteroscopy was performed, and upper, middle, and lower renal calyces were visualized. Under ureteroscopic vision a 20 G intravenous catheter was inserted through the middle calyx. This catheter was connected to a Medicath disposable pressure transducer (Medicath LTD, Guangdong, China) and eventually to a pressure monitor (Vista 120, Drägerwerk AG & Co., Lübeck, Germany). The latter experimental setting allowed real-time IRP measurement. Calibration of the system was performed before the start of the experimental trials (Figure 1).

The ureteroscopes were inserted into the porcine pelvicalyceal system (PCS) through the lumen of the UAS. The distal end of the UASs was constantly kept 25–30 cm above the table level, mini-

Figure 1. *Experimental setup.*

mizing the irrigation fluid leak from the PCS system. For the purpose of irrigation, two 3-liter saline bags were utilized. The bags were fixed at the level of 1 m above the operating table. The irrigation systems used in all trials were the gravity irrigation (Cook Medical, Indiana, USA) and the automated pump irrigation with the pump set at 40, 60, 80, and 100 mmHg (Endomat, Karl Storz Se & Co. Tuttlingen, Germany). Suction parameters were kept constant across all experimental trails and set at 100 mmHg.

Tested parameters

Experimental measurements were performed with an empty working channel, 200 μm (1.1 Fr) and 272 μm (1.3 Fr) core diameter laser fibers (Quanta systems, Samarate, Italy), and 2.2 Fr nitinol basket (Ngage, Cook Medical). The evaluated parameters included irrigation flow rate under different irrigation settings, maximal intrarenal pressure without suctioning, pressure decrease time required to collapse the porcine pelvicalyceal system, and time required to regain the initial IRP.

Statistical analysis

SPSS v25 software (IBM Statistics, NY, USA) was used for the statistical analysis. Medians were used for descriptive analysis. Comparative evaluation was performed using the non-parametric Kruskal-Wallis test. A p-value < 0.05 was considered statistically significant.

Bioethical standards

Due to the nature of the study, approval from the bioethics committee was not required.

RESULTS

In every experimental scenario, the 9.2 Fr DISS scope featuring a 5.1 Fr working channel was associated with both higher flow rates and intrarenal pressures compared to the 7.5 Fr scope. The flow rates and intrarenal pressures were significantly higher with the empty working channel for both 7.5 Fr and 9.2 Fr DISS scopes. Irrespective of the irrigation system used, the introduction of working instruments significantly reduced the IRP for both 7.5 Fr and 9.2 Fr DISS scopes. Using gravity irrigation, the highest and lowest irrigation flow rates of 35, 22, 17 and 5 ml/min, and 80, 66, 59 and 35 ml/min were observed with 7.5 Fr and 9.2 Fr DISS scopes with the empty channel, and 200 μm, 272 μm and 2.2 Fr instruments, respectively (Table 1).

Using a 7.5 Fr ureteroscope under gravity irrigation, IRPs of 12, 8, 7, and 4 mmHg were reported with the empty, 200 μm laser fiber, a 272 μm laser fiber, and a 2.2 Fr nitinol basket, respectively. Similar IRP trends were observed with an automated pump irrigation system under different irrigation settings. The differences of the IRPs were more pronounced with the empty channel and minimal with the basket. The time to collapse the PCS was significantly longer for trials with the 2.2 Fr basket reaching 20 s compared to 8–9 s with an unoccupied channel ($p = 0.012$) (Figure 2).

The highest IRP of 34 mmHg was recorded with the 9.2 Fr scope under 100 mmHg irrigation pressure. A significant reduction of the irrigation flow rates and IRPs was also reported from experimental settings with no instruments to trials with baskets. On the contrary, the time required to collapse the PCS was prolonged from 8–9 seconds with the empty working channel to 15 seconds with a basket in place (Figure 2). Although this change was statistically significant, it was less pronounced with the 9.2 Fr DISS scope compared to the 7.5 Fr scope.

The use of instruments also impacted the time to regain the initial pressure. For 7.5 Fr DISS scope, the longest time of 20 s was reported with the inserted 2.2 Fr basket under 40 mmHg irrigation pressure, compared to 12 s with empty working channel. Similarly, the use of instruments impaired the time to regain the baseline IRP with 9.2 Fr scope, but the time prolongation was less pronounced compared to 7.5 Fr DISS scope (Table 1).

DISCUSSION

The introduction of DISS flexible ureteroscopes in clinical practice offers the ability to use the irrigation flow channel also for stone dust aspiration, allowing for better visualization and a decrease in intrarenal pressure during the procedure, potentially reducing the operative time and infection rates. Speculatively, this can improve the SFR and further push the limits of RIRS in the PCNL territory [9, 11, 12].

Our experimental study investigated the irrigation and suction properties of 7.5 Fr and 9.2 Fr DISS ureteroscopes and the intrarenal pressure modifications with the empty working channel and with different working instruments. We found that these parameters vary largely in relation to the diameter of the working instrument: using larger diameter instruments inside the working channel reduces the irrigation and aspiration power of both scopes,

Table 1. *Irrigation, intrarenal pressure and suction effectiveness with 7.5 Fr and 9.2 Fr DISS ureteroscopes*

	Gravity	Pump 40 mmHg	Pump 60 mmHg	Pump 80 mmHg	Pump 100 mmHg
7.5 Fr DISS					
Empty channel					
Irrigation flowrate [ml/min]	35	25	35	45	52
No suction, max pressure [mmHg]	12	9	12	16	19
Time to collapse the system [s]	9	8	9	9	9
Pressure regain time after collapse [s]	10	12	10	9	9
200 µm laser fiber					
Irrigation flowrate [ml/min]	22	17	22	28	32
No suction, max pressure [mmHg]	8	7	8	10	11
Time to collapse the system [s]	15	15	15	15	15
Pressure regain time after collapse [s]	12	14	12	10	10
272 µm laser fiber					
Irrigation flowrate [ml/min]	17	12	17	23	28
No suction, max pressure [mmHg]	7	6	7	8	10
Time to collapse the system [s]	17	17	17	17	17
Pressure regain time after collapse [s]	14	15	14	11	10
2.2 Fr nitinol basket					
Irrigation flowrate [ml/min]	5	4	5	6	7
No suction, max pressure [mmHg]	4	4	4	4	5
Time to collapse the system [s]	20	20	20	20	20
Pressure regain time after collapse [s]	16	20	16	14	14
9.2 Fr DISS					
Empty working channel					
Irrigation flowrate [ml/min]	80	42	72	93	111
No suction, max. pressure [mmHg]	24	14	23	29	34
Time to collapse the system [s]	8	8	8	9	9
Pressure regain time after collapse [s]	8	9	8	9	9
200 µm laser fiber					
Irrigation flowrate [ml/min]	66	34	58	76	95
No suction, max. pressure [mmHg]	20	12	20	24	28
Time to collapse the system [s]	12	12	12	12	13
Pressure regain time after 1 sec of suctioning [s]	9	10	9	9	9
272 µm laser fiber					
Irrigation flowrate [ml/min]	59	27	45	60	75
No suction, max. pressure [mmHg]	20	10	15	20	24
Time to collapse the system [s]	13	13	13	13	13
Pressure regain time after 1 s of suctioning [s]	10	10	9	9	9
2.2 Fr nitinol basket					
Irrigation flowrate [ml/min]	35	11	24	35	42
No suction, max. pressure [mmHg]	12	6	10	12	14
Time to collapse the system [s]	16	16	16	16	16
Pressure regain time after collapse [s]	10	13	10	9	9

and this must be evaluated and expected in the surgical planning.
Some aspects of our *in vitro* setup need further discussion. First, the 7.5 Fr DISS is combined with a 3.6 Fr suction channel, while the suction channel diameter is 5.1 Fr on the 9.2 Fr DISS scope: these diameters are correlated to our results for the irrigation flow rate, max IPS pressure, PCS collapsing time, and time to regain pressure after system collapse with the 9.2 Fr scope achieving constantly higher flow rates and pressure and having shorter times. These results demonstrated that increasing the diameter of the working channel is beneficial for fast reduction of IRP during the procedure even with the occupied working channel compared to the 7.5 Fr scope. However, the demonstrated advantages of miniaturization of the instruments should be accounted [13, 14].

During the evolution of RIRS, various technological novelties have been proposed to decrease IRP and improve visibility, including using UAS and after UAS with integrated suction [4, 17]. The reduction in IRP achieved through suction UASs has been associated with a lower risk of complications, including postoperative fever rate [15]. However, the increase in use of UASs inherently raises the risk of ureteric injury [18]. In terms of ureteroscopes, similar beneficial outcomes were obtained using a suctioning ureteroscope equipped with IRP control [16]. Their findings indicated that reducing IRP during lithotripsy correlated with a low incidence of fever, with no cases of postoperative sepsis, even in patients with larger stones. In the current study, with fast times to collapse the system allowed by DISS scopes, we report a new tool for surgeons to rapidly decrease IRP all available with an ergonomic finger-press.

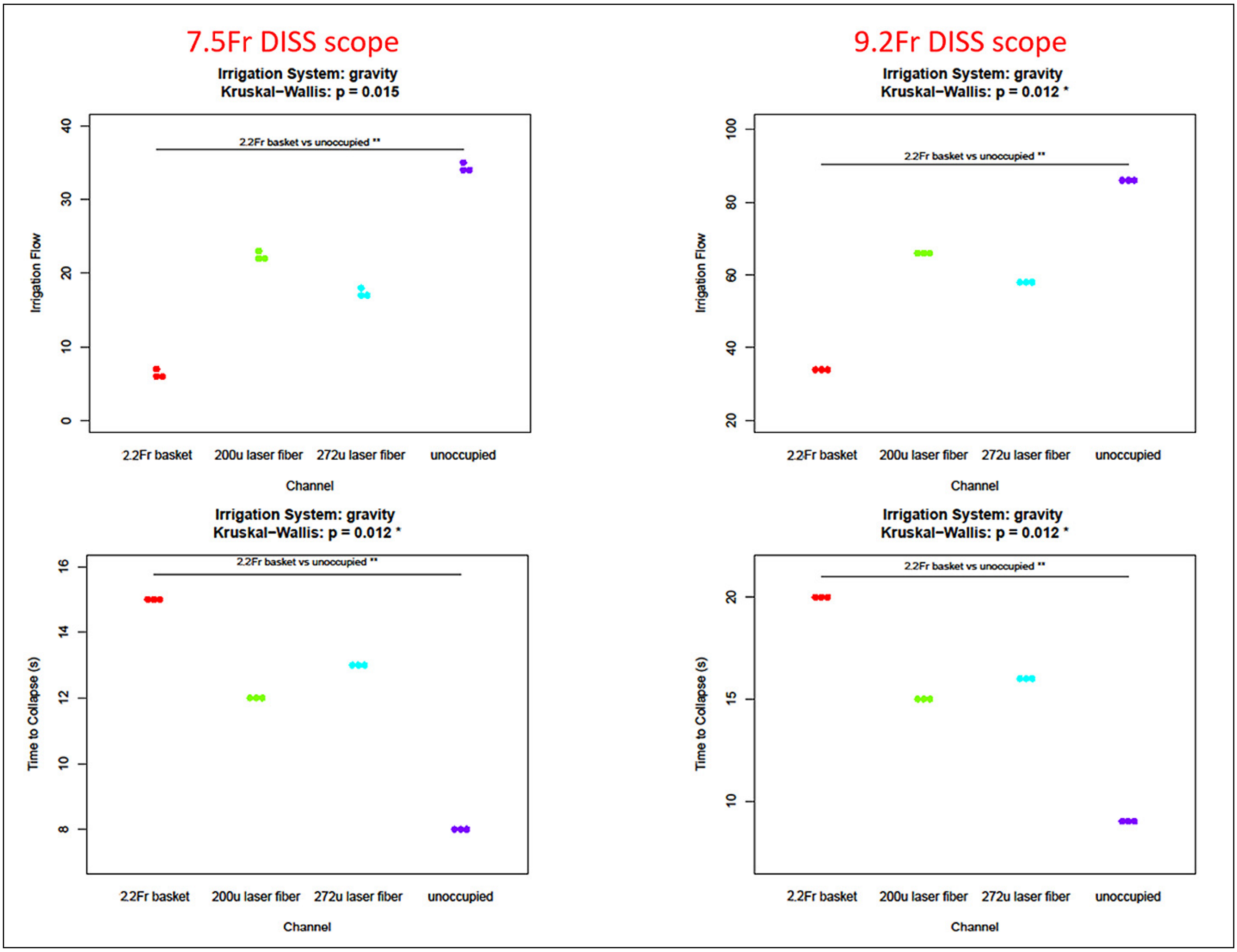

Figure 2. *Comparative depiction of irrigation flow and collapse time of the pelvicalyceal system with 7.5 Fr and 9.2 Fr DISS scopes under gravity irrigation.*

A well-recognized limitation of conventional RIRS lithotripsy is the "snow globe" effect, which impairs visibility during surgery and extends operative time by requiring the surgeon to pause laser lithotripsy to clear dust. By removing small debris, dust, and blood, DISS may offer improved intraoperative visibility, potentially preventing damage to the pelvicalyceal system, allowing more precise lithotripsy, and revealing residual fragments obscured by dust or the snow globe effect [9].

Endoscopic baskets are often needed during RIRS to clear residual stone fragments from the renal cavities and collect material for stone analysis. The use of endoluminal instruments, in particular, the large core baskets, has been shown to significantly reduce the irrigation flow rate. While the irrigation flow was significantly impaired for both scopes, the wider 5.1 Fr working channel allowed for irrigation even with the 2.2 Fr basket possessing almost the same irrigation pressure as of 7.5 Fr DISS scope with an empty working channel.

This study has some drawbacks that need further discussion. First, the porcine model we used has been evaluated before [21], however, it could have slightly different anatomy related to the human kidney, because it has a smaller PCS, which could impact the outcomes. Second, *in vivo* variables such as ureteral peristalsis, blood flow, and irrigation-induced pressure fluctuations are not included in the model. Second, only one kidney was used, and a different PCS anatomy could yield different results. Lastly, using the UAS placed below the ureteropelvic junction level could also influence our results.

Further studies should confirm our discoveries in a clinical setting. Assessing the modification of IRP and suction flow when performing laser lithotripsy would be optimal. To our knowledge, this is the first study to evaluate intrarenal pressures and suction flow modification of 7.5 Fr and 9.2 Fr DISS ureteroscopes with different working instruments in an *ex vivo* model with different instruments, and despite the few above-mentioned limits, our results depend on a reliable porcine model and multiple repeat measurements.

CONCLUSIONS

The 9.2 Fr DISS scope was related to significantly higher irrigation flow rates and IRP, and shorter time to collapse of the pelvicalyceal system and regain baseline IRP compared to 7.5 Fr DISS scope. The use of intraluminal working instruments significantly impaired all parameters, being more pronounced in 7.5 Fr scope. Surgeons should be aware of the effect of working instruments on irrigation flow and suction properties when using DISS ureteroscopes.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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ETHICS APPROVAL STATEMENT

The ethical approval was not required.

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