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ORIGINAL PAPER

Flow matters: irrigation flow differs in flexible ureteroscopes of the newest generation

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Abstract The development of new-generation flexible ureteroscopes has improved diagnostic and therapeutic endourological procedures. Despite technical improvement irrigation flow and quality of vision is often unsatisfactory. This study describes inter-manufactural differences in the latest available flexible ureteroscopes in terms of irrigation flow in correlation to different deflection angles and the use of 1.9 Fr. stone baskets. Irrigation flow measurements were performed in five new-generation flexible ureterorenoscopes with 3.6 Fr. working channels: Wolf (Uretero-Renoscope 270°), Storz (Flex-X² and Flex-X^c), ACMI (DUR-D) and Olympus (URF Type P5) in 0°, 90° and 180° deflection. All measurements were carried out five times with an empty working channel as well as with inserted 1.9 Fr. stone baskets. Mean flow rates with empty instruments (SD) counted 50 ml/min (0.8), 50 (1.0), 48 (1.7), 48 (1.6) and 44 (0.7) for ACMI, Wolf, Storz (FlexX² and Flex-X^c), and Olympus, respectively. Stone baskets significantly reduced irrigation flows in all tested ureteroscopes ($p < 0.05$). In channels with inserted baskets, the highest flow rates were measured for ACMI and Wolf with 12 ml/min (0.7) each. The lowest reduction of flow rate was detected in the ACMI and the Wolf ureteroscope (76.0%, 38 ml/min each). Measurements after flexion showed no significant differences between the ureteroscopes. Latest generation of flexible ureteroscopes offer various new product developments, including excellent deflection capacities. This study showed inter-manufactural differences in terms of irrigation flow rates with either empty or occupied working channels resulting in significant alterations in endoscopic view.

Keywords Flexible ureteroscopes · Irrigation flow · Endourology · Upper urinary tract

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Introduction

Technical innovations including improvement of active and passive deflection, decrease in size and development of superior digital visualization have increased the use of endourology in diagnosis and management of upper urinary tract pathology. Flexible ureterorenoscopic stone management already has proven to be an alternative and efficient treatment either to shock wave lithotripsy or percutaneous nephrolithotomy in many cases. Five new flexible ureteroscopes (Wolf Uretero-Renoscope 270°, Storz FlexX², Storz Flex-X^c, ACMI DUR-D and Olympus URF Type P5) with high deflection capacities, ergonomic handling and small 3.6 Fr working channels offer easy access for sufficient stone workup combined with excellent visualization. The Karl Storz, Flex-X^2 contains a laser-resistant distal tip that reduces laser beam induced damages. It offers a deflection range of 270° in both directions. According to manufacturer's data, it also provides an improved durability and a novel developed shock absorber. In addition to aforementioned features the successor Flex-X^c provides a complementary metal oxide semiconductor (CMOS) image sensor and light-emitting diode technology (LED). The third of five tested ureteroscopes, the ACMI, digital flexible ureteroscope (DUR-D) uses an ultra-miniature 1 mm CMOS digital sensor and two LED lights in the ureteroscope-tip. An integrated laser detection system prevents accidental misfiring. The DUR-D has no second deflection mechanism and an angulation range of 250°. The Richard Wolf, Uretero-Renoscope 270° has an active bilateral deflection of 270° and a wide range of passive angulation. In addition, this ureteroscope offers an award winning ergonomic handle design. The Olympus, URF Type P5 ureteroscope offers a 275° down angulation and a small radius 180° up angulation with optional passive deflection by rotation of the control section. The new slim 5.3 Fr. ureteroscope tip might be easier to insert. Despite technological advances, a sufficient irrigation flow particularly in haemorrhagic or infected urine is of significant clinical importance for effective treatment. In this study, we compared the effect of different deflection angles with the use of 1.9 Fr. stone baskets on irrigation flow volume in the aforementioned new instruments.

Materials and methods

The aforementioned commonly available flexible ureteroscopes and baskets were received new and unused from manufacturers. The features (working length, field of view, direction of view, depth of field, angulation angles, outer diameters, inner diameters and weight) are shown in Table 1. Flow rates in straight and deflected position (90° and 180° angulation) with empty and filled working channel were measured in a laboratory setting using an irrigation system calibrated to a pressure of 100 cm H_2O as previously described [6]. The irrigation system was filled with commercially available saline irrigation solution (Fresenius Kabi AG, Bad Homburg, Germany) and connected to the luer lock inflow of the ureterorenoscopes after fixating the instrument on a table in a horizontal position. Equilibration was performed for 30 s before measurement was recorded. Irrigation volume was measured in calibrated cylinders in five 1 min trials. The flowmetry was processed with 0°, 90° and 180° bended instrument with and without use a 1.9 Fr. stone basket (Boston Scientific Zero-Tip 1.9 Fr.) 1 cm outside of the ureteroscope tip. Mean flow values from the five measurements of each setting were used for demonstration and statistical analysis. Recorded Data was analysed by JMP (SAS Inc., Cary, USA) software using Wilcoxon/Kruskal–Wallis tests and all pair Tukey–Kramer tests as post hoc analyses.

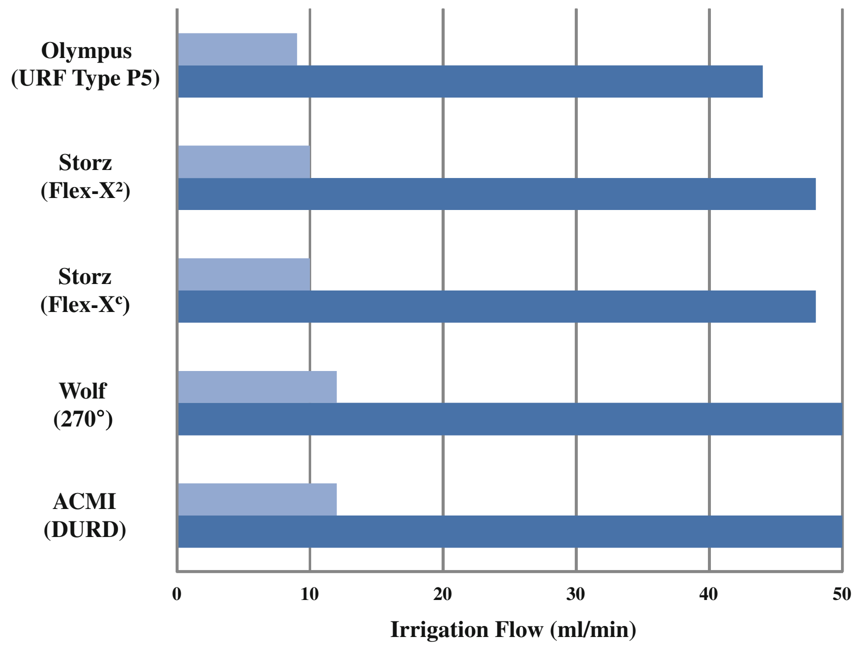
Results

Measurement of empty working channels in all five tested ureteroscopes (three with optical and two with digital visualization) showed differences in irrigation flow. Mean flow rates with empty instruments counted 50 ml/min (SD 0.8) for ACMI (DUR-D) as well 50 ml/min (SD 1.0) for Wolf (Uretero-Renoscope 270°) followed by Storz (Flex-X² and Flex-X^c) mean values of 48 ml/min (SD 1.7/1.6) and 44 ml/min (SD 0.7) for Olympus (URF Type P5), respectively. Empty instruments showed no significant reductions of irrigation flow depending on ureteroscope deflection between 0°, 90° and 180°. The use of a 1.9 Fr. stone basket significantly reduced irrigation flows in all tested ureteroscopes ($p < 0.05$ each). The flow rates are summarized in Fig. 1. The highest flow rates with basket loaded working channels were measured for ACMI (DUR-D) and Wolf (Uretero-

Table 1 General technical specifications (according to manufacturer's data) and irrigation flow rates in tested flexible ureteroscopes

	ACMI (DUR-D)	Olympus (URF type P5)	Storz (Flex-X²)	Storz (Flex-X^C)	Wolf (URS-270°)
Irrigation flow rate (empty Instrument)	50 ml/min	44 ml/min	48 ml/min	48 ml/min	50 ml/min
Irrigation flow rate (1.9. Fr. Stone basket)	12 ml/min	9 ml/min	10 ml/min	10 ml/min	12 ml/min
Field of view	80°	90°	88°	90°	85°
Direction of view	0°	0°	0°	0°	0°
Depth of field	2 ~ 40 mm	2 ~ 50 mm	2 ~ 50 mm	2 ~ 50 mm	3 ~ 50 mm
Distal end (outer diameter)	8.7 Fr.	5.3 Fr.	7.5 Fr.	8.5 Fr.	6 Fr.
Insertion tube (outer diameter)	9.3 Fr.	8.4 Fr.	7.5 Fr.	8.5 Fr.	8.8 Fr.
Inner channel diameter	3.6 Fr.	3.6 Fr.	3.6 Fr.	3.6 Fr.	3.6 Fr.
Working length	650 mm	700 mm	670 mm	700 mm	680 mm
Angulation range up/down	250°	180°/275°	270°/270°	270°/270°	270°/270°
Total weight	540 g	250 g	306 g	342 g	297 g

Fig. 1 Mean irrigation flow rates (ml/min) at 100 mmHg pressure in tested ureteroscopes with 1.9 Fr. stone basket and empty working channel



	ACMI (DURD)	Wolf (270°)	Storz (Flex-X^2)	Storz (Flex-X^c)	Olympus (URF Type 5)
1.9 Fr. Stone Basket (ml/min)	12	12	10	10	9
EmptyInstrument (ml/min)	50	50	48	48	44

Renoscope 270°) with 12 ml/min (SD 0.7) compared to Storz (Flex-X^2 and Flex-X^c) with 10 ml/min (0.5/1.0) and Olympus (URF Type P5) with 9 ml/min (0.7).

The Olympus ureteroscope showed significant difference to the remaining instruments ($p < 0.05$). In the stone basket carrying cases, flexions showed no significant differences. Carrying a basket, the lowest reduction in flow rate of 76.0% (38 ml/min) was detected in the ACMI as well as the Wolf ureteroscope. For Olympus and both Storz instruments, the flow decreased by 79.5% (35 ml/min) and 79.2% (38 ml/min), respectively.

Discussion

Flexible ureterorenoscopy is a minimally invasive standard procedure for diagnosis and therapy of upper urinary tract pathology [7, 8]. Decrease of irrigation flow and therefore reduced visualization remains a major limitation even in modern flexible ureteroscopes. The downsizing and improvement of flexible ureteroscopes with better active and passive deflection has further improved endoscopic treatment [3]. Smaller outer ureteroscope diameters and the use of auxiliary instruments provide minimally invasive access. Previous studies have evaluated irrigation flow, deflection, costs and durability in previous generations of flexible ureterorenoscopes [5, 6]. Abdelshehid and co-workers examined the predecessor models, demonstrating a better handling but also problematic endoscope fragility, suboptimal vision and deflection during instrumentation [1]. In the meantime, image quality, deflection and durability have improved remarkably. As a result, better deflection mechanisms, the development of ultra-miniature digital chips and LED-technology allow better visualisation and manipulation in the upper urinary tract [2, 4]. Despite these major improvements, fast and effective handling is based on an unrestricted view guaranteed by sufficient irrigation. Light absorption and reduced vision caused by haemorrhage, stone fragments after laser fragmentation or sludge are important drawbacks, even with digital visualization. In the present study, we investigated irrigant flow characteristics of flexible ureterorenoscopes of the newest generation. Best irrigation flows in empty and filled instruments were demonstrated for ACMI (DUR-D) and Wolf (Uretero-Renoscope 270°). The present study confirmed a significant decrease of irrigation flow in all tested flexible ureteroscopes with the use of standard 1.9 Fr. stone baskets. There was no significant reduction of flow in 90° and 180° ureterorenoscope deflection, regardless the optional use of stone baskets. Although ACMI (DUR-D) and Wolf (Uretero-Renoscope 270°) demonstrated higher flow rates compared to (Flex-X^2 and Flex-X^c) and Olympus (URF Type P5), only minor differences in irrigation were recorded. The authors would like to point out, however, that the intensity of irrigation flow depicts only one aspect of many regarding clinical practicability and therapeutic success.

Other technical specifications, such as a small external diameter for easy ureteral passage or high-resolution video technology are also important in quality of diagnostic and therapeutic endourological procedures. The importance of new developments in endourology, such as improvement of deflection mechanisms, laser detection systems, or reduction of instrument weight has to be evaluated further in clinical studies. These studies have to prove—or not—if each and every new technical innovation translates into an easier use, fewer side effects and complications or better therapeutic outcome for our patients.

Conclusion

This study confirmed significant differences in irrigation flows of new generation flexible ureteroscopes with the use of small 1.9 Fr. diameter stone baskets and unloaded working channels resulting in a considerable difference in endoscopic view. These parameters provide important information for endourologists when it comes to clinical decision making in everyday practice.

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