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Alteration in Irrigant Flow and Deflection of Flexible Ureteroscopes with Nitinol Baskets

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ABSTRACT

***Background and Purpose*: Introduction of an instrument into the working channel of ureteroscopes adversely affects flow and deflection. We evaluated the alterations in ureteroscope channel flow and deflection caused by available Nitinol® baskets.**

***Materials and Methods*: We compared the effects of 11 Nitinol baskets on irrigation flow and deflection of three flexible ureteroscopes (Olympus P3, ACMI DUR8, and ACMI DUR8 Elite). ANOVA was used to compare the loss of flow and deflection for each basket, with *P* values adjusted for multiple comparisons by the Tukey method.**

***Results*: Ureteroscope flow and deflection were progressively adversely affected by all baskets as their diameter increased. The average baseline irrigant flow (46.6 mL/min) was decreased significantly: by 78.5% (to 9.9 mL/min), with the smaller baskets (Microvasive 1.9F and Cook 2.2F) and by 99.1% (to 0.4 mL/min) with the larger baskets (ACMI 3.0F and Microvasive 3.0F). Similarly, the mean baseline upward deflection (162°) decreased by 2° (1.2%) for the Cook 2.4F N-Compass and by 20° (12.3%) for the ACMI 3.0F. Loss of downward deflection from baseline (170°) ranged from 6° (3.5%) for the Microvasive 1.9F to 17° (10%) for the Microvasive 2.6F grasping forceps. The least deterioration in flow and deflection occurred with the two smallest baskets (Microvasive 1.9F and Cook 2.2F).**

***Conclusion*: Ureteroscope irrigation flow and deflection deteriorate progressively with larger-caliber Nitinol baskets. The Microvasive 1.9F and Cook 2.2F baskets resulted in the least deterioration of irrigation and deflection metrics. However, basket size is not the only factor responsible for changes in flow and ureteroscope deflection.**

INTRODUCTION

DESPITE THE INTRODUCTION of novel ureteroscope technologies, lower-pole renal pathology presents a treatment dilemma. Shockwave lithotripsy (SWL) is an attractive option because of its noninvasive nature with rare complications. Unfortunately, SWL offers suboptimal stone-free rates for lower-pole stones, especially for stone burdens exceeding 1 cm.[1,2] Conversely, percutaneous nephrolithotomy (PCNL) is an invasive procedure with attendant risks that offers excellent results for lower-pole calculi.[3] In a randomized trial for lower-pole nephrolithiasis, the 3-month postoperative stone-free rates were 95% for PCNL and 37% for SWL.[3] However, in the same series, PCNL had double the morbidity rate.

As a result of technologic innovations, flexible ureterorenoscopy has become a more useful minimally invasive option for the treatment of lower-pole stones.[4] New-generation ureteroscopes have greater active tip deflection and narrower shaft diameters that permit access to the entire upper collecting system, including the lower-pole calices.[5] However, passage of stone extractor baskets through the working channel of even contemporary ureteroscopes significantly decreases the irrigant flow rate and active deflection.[6,7] Because of the diminutive nature of the working channel in contemporary small-caliber ureteroscopes, work in all portions of the upper urinary tract can be challenging as a result of the decreased flow, which can significantly impair visibility. We evaluated the deterioration of irrigant flow and deflection in three contemporary flexible

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ureteroscopes with the currently available Nitinol® baskets in the working channel.

MATERIALS AND METHODS

The flow characteristics and active upward and downward deflection angles of three contemporary ureteroscopes — URF/P3 (Olympus America, Melville, NY) and DUR-8 and DUR-8 Elite (ACMI Corporation, Southborough, MA) — were measured with Nitinol baskets in the working channel. Each of the ureteroscopes has a 3.6F working channel. We evaluated 11 Nitinol tipless stone extractor baskets: the 2.2F, 3.0F, and 3.2F N-Circle® and 2.4F N-Compass® (Cook Urological, Spencer, IN); the 2.2F and 3.0F Sur-Catch-NT™ (ACMI); the 2.4F Dimension™ (C.R. Bard, Inc., Murray Hill, NJ); and the 1.9F, 2.4F, and 3.0F Zerotip™ and 2.6F Graspit™ Urological Grasping Forceps (Boston Scientific Corporation, Natick, MA). The baskets were advanced through the working channel until they extended 1 cm beyond the tip of the ureteroscope.

Saline irrigation was standardized at a pressure of 100 cm H_2O and was attached to each ureteroscope using standard irrigation tubing (Baxter Healthcare Corporation, Deerfield, IL). Three 1-minute flow measurements were performed with the working channel empty. Each flow trial was then repeated with the individual baskets in the channel. The irrigation fluid was collected from the distal end of the ureteroscope and measured in a graduated cylinder.

The maximum active upward and downward deflection was measured for each ureteroscope with the working channel empty and then with the basket loaded in the working channel. The deflected ureteroscope was placed on a photocopy machine to create an image that facilitated accurate measurement of the deflection angle. The tangents of the deflected segment and the neutral position defined the deflection angle. Three trials were performed to determine each deflection angle.

ANOVA was used to compare the loss of flow and deflection for each basket, with *P* values adjusted for multiple comparisons by the Tukey method.

RESULTS

Ureteroscope flow and deflection were progressively reduced as the diameter of the Nitinol baskets in the working channel increased. Figure 1 shows the average loss of flow for each basket relative to the flow in the empty channel for each ureteroscope. The average baseline irrigant flow (46.6 mL/min) was decreased by 78.5% (to 9.9 mL/min) with smaller baskets (Microvasive 1.9F and Cook 2.2F) and by 99.1% (to 0.4 mL/min) with larger baskets (ACMI 3.0F and Microvasive 3.0F).

With an empty working channel, the P3, DUR-8, and DUR-8 elite ureteroscopes had an average upward deflection of 150°, 167°, and 169°, respectively, and an average downward deflection of 159°, 170°, and 180°, respectively. Figure 2 shows the average loss of upward and downward deflection with baskets in the working channel. The average baseline upward deflection (162°) decreased from 2° (1.2%) for the Cook 2.4F N-Compass basket to 20° (12.3%) for the ACMI 3.0F basket. Similarly, loss of downward deflection from baseline (170°) ranged from 6° (3.5%) for the Microvasive 1.9F to 17° (10%) for the Microvasive 2.6F grasping forceps. The least deterioration in flow and deflection occurred with the two smallest baskets (Microvasive 1.9F and Cook 2.2F).

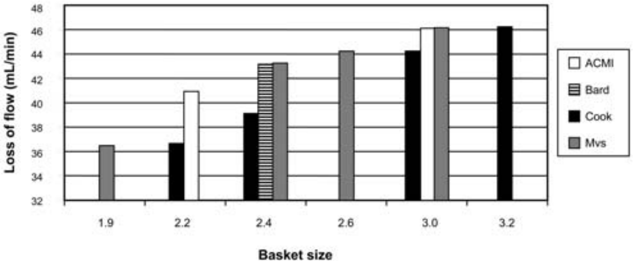

FIG. 1. Average loss of irrigant flow for all three ureteroscopes with increasing size of baskets by different manufacturers.

As a general rule, irrigant flow decreased progressively with increasing basket size. The smallest baskets manifested the lowest impact on irrigant flow (decrease of 36 mL/min (Microvasive 1.9F and Cook 2.2F), and the largest baskets manifested the greatest decrease (decrease of 46 mL/min [ACMI 3.0, Microvasive 3.0F, and Cook 3.2F]). Notable exceptions to this rule were the Cook 2.2F basket, which had flow equal to that with the Microvasive 1.9F basket in two of the three ureteroscopes ($P = 0.65$, $P < 0.01$, and $P = 0.73$ for the Olympus, DUR8, and DUR8 Elite, respectively). Similarly, the Cook 2.2F basket allowed better flow than the ACMI 2.2F basket for all three ureteroscopes ($P < 0.01$, $P < 0.01$, and $P < 0.01$, respectively), and the Cook 2.4F basket manifested significantly higher flow than the Bard 2.4F ($P < 0.01$, $P < 0.01$, and $P < 0.01$, respectively) or the Microvasive 2.4F ($P < 0.01$, $P < 0.01$, and $P < 0.01$, respectively) baskets. Changes in irrigant flow and deflection for each ureteroscope are listed in Table 1. Deflection was also generally increasingly affected by increasing basket size. However, the Cook baskets manifested significantly less deterioration in upward and downward deflection compared with equivalent ACMI and Microvasive baskets.

DISCUSSION

With continuing improvements in Nitinol technology and decreasing diameter of stone baskets, periodic reassessment of ureteroscopic functionality with baskets in the working channel is prudent. Our study confirms that irrigant flow rate and ureteroscope deflection are significantly and dramatically affected adversely as the diameter of the basket increases. While the concept of progressive decrease in irrigant flow and deflection with increasing basket size may be intuitive, we also show that size is not the only factor impacting deflection and flow. In fact, the 1.9F Microvasive and 2.2F Cook baskets were almost identical in terms of changes in irrigant flow. Similarly, the Cook basket permitted better flow than the other manufacturers' baskets for both the 2.2F and the 2.4F baskets.

Although deflection was also generally affected increasingly by increasing basket size, we again found significantly less deterioration in upward and downward deflection by the Cook

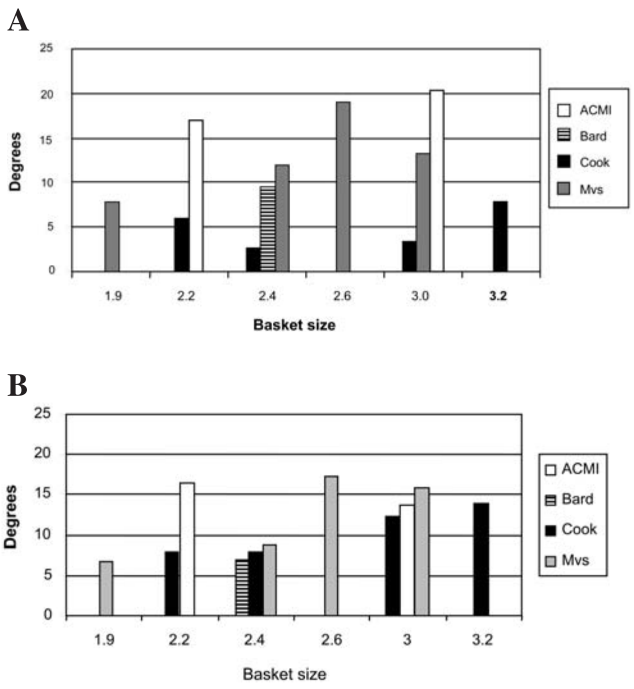

FIG. 2. Loss of deflection (degrees) in all three ureteroscopes with increasing size of baskets. (**A**) Upward deflection. (**B**) Downward deflection.

baskets compared with equivalent-size competitors' baskets. The basket that had the least impact on upward deflection was not the smallest basket but the 2.4F Cook N-Compass, likely because this basket is a different product with a different manufacturing process than the Cook 2.2F, 3.0F, and 3.2F N-Circle baskets. The basket with the greatest impact on downward deflection was not the largest basket but the 2.6F Microvasive grasping forceps. For both upward and downward deflection, the ACMI 2.2F basket showed significantly worse performance than the Cook 2.2F and 2.4F or Bard 2.4F baskets. Again, there was no significant difference in upward or downward deflection between the 1.9F and 2.2F baskets, but there was a significant difference with the Cook product out-deflecting its same-size competitors in the 2.2F, 2.4F, and 3.0F categories. Even within a specific manufacturer's product line, the smallest sheath did not always have the least impact on ureteroscope deflection, suggesting variances in manufacturing process and materials. Abdelshehid and colleagues[8] have shown that the degree of flexibility of the product's tip (a result of the materials used in production) impacts the change in deflection more than does size alone.

On the basis of our findings, we believe the basket and sheath composition and specific manufacturing practices must play an important role in basket performance, as there were significant differences even among baskets of identical size. Physicians should keep in mind that not all baskets (even of equivalent sizes) perform equally in terms of adverse effects on irrigant flow and ureteroscope deflection.

Even with the smallest baskets evaluated in this study (Microvasive 1.9F and Cook 2.2F baskets), the average baseline irrigant flow decreased 78.5%. Our study correlates the findings of others[6,7] that irrigant flow is minimized when baskets 3.0F or larger are passed through the ureteroscope working channel. Similarly, our study reveals the loss of upward deflection ranging from 1.2% with the Cook 2.4F N-Compass basket to 12.3% with the ACMI 3.0F basket. The average loss of downward deflection ranged from 3.5% with the Microvasive 1.9F basket to 10% with the Microvasive 2.6F grasping forceps.

In the authors' experience, even small alterations in ureteroscope deflection can have a meaningful impact on patient outcome. It is not uncommon for lower-pole pathology to be identified with an empty working channel only to have subsequent attempts to access the lesion be very challenging because of the deterioration in ureteroscope deflection that results from the passage of instruments through the working channel. As such, the *in-vitro* deflection information established in this study can help optimize the choice of basket, determining which is most appropriate in each clinical setting. Smaller baskets may help the ureteroscopist achieve access to pathology in challenging sites such the lower pole.

Similarly, the authors have noted that a decrease in irrigant flow can result in significant deterioration in endoscopic visibility. What is easy to discern with an empty channel can often become challenging with an instrument blocking irrigant flow if debris or bleeding is present in the endoscopic field of

TABLE 1. CHANGES IN FLOW (ML/MIN) AND DEFLECTION (UP/DOWN) FROM BASELINE FOR INDIVIDUAL URETEROSCOPES

	P3			*DUR 8*			*DUR 8 ELITE*		
	Flow	*Up*	*Down*	*Flow*	*Up*	*Down*	*Flow*	*Up*	*Down*
MVS 1.9	31.30	7.66	9.66	31.80	4.33	2.00	46.34	11.34	8.33
Cook 2.2	31.47	8.66	10.33	32.50	−0.34	1.66	46.00	9.34	12.00
ACMI 2.2	35.00	23.33	28.66	36.00	12.00	5.33	51.80	15.67	15.33
Bard 2.4	33.43	10.00	6.33	34.40	6.00	2.33	49.54	12.67	12.33
Cook 2.4	36.60	3.66	13.00	37.73	0.66	−0.67	55.17	3.67	11.33
MVS 2.4	36.37	16.33	12.66	37.83	8.33	9.00	55.57	11.00	4.67
MVS 2.6	37.43	27.00	29.33	38.93	14.33	6.67	56.30	16.00	16.00
MVS 3.0	37.27	16.33	28.00	39.00	11.66	9.00	56.47	11.67	10.33
ACMI 3.0	38.83	18.66	19.66	40.53	17.66	6.67	58.97	24.67	14.67
Cook 3.0	38.87	3.66	18.33	40.57	−0.67	6.00	59.07	7.34	12.67
Cook 3.2	38.90	9.66	21.33	40.67	5.00	7.00	59.07	9.00	13.33

vision. Again, the proper choice of ureteroscopic instrumentation can help to optimize patient outcome.

Other reports have suggested techniques to improve ureteroscope performance. Monga and coworkers[9] suggested holding the ureteroscope taut, placing a superstiff guidewire in the working channel, or using an access sheath to maximize active deflection. Application of an unsheathed Nitinol basket ("naked basket" concept) can also optimize ureteroscopic flow and deflection.[10] The application of an unsheathed basket can allow an additional 15° to 20° of active deflection and a 2- to 30-fold increase in irrigant flow. Kourambas and colleagues[4] described optimizing outcomes in ureteroscopic procedures by transferring lower-pole calculi to more easily accessible sites in the collecting system before fragmentation and extraction.

Of note, baskets manufactured by Cook resulted in less deterioration in flow and deflection than equivalent-diameter baskets from the other manufacturers. Discussion with the manufacturer revealed that basket size with Cook products is determined by the point of greatest diameter. Cook baskets are produced with a tubing reinforcement at the distal tip, which increases the diameter of the instrument by 0.2F. As such, with the tip of the instrument beyond the end of the ureteroscope, the basket has a smaller diameter with less associated deterioration in flow and deflection parameters.

Although this study was performed without a pressurized irrigation system (as one might use in the operating room), changes in flow rate with irrigation standardized at 100 cm should be consistent and applicable to situations involving a mechanically pressurized irrigation system. Application of proper equipment and technique can help achieve optimal patient outcomes by increasing irrigant flow and minimizing the decrease in ureteroscope deflection.

CONCLUSIONS

Contemporary ureteroscopic baskets all result in significant deterioration of irrigant flow and ureteroscope deflection. Small-caliber Nitinol baskets such as the Microvasive 1.9F and the Cook 2.2F cause the least overall deterioration of irrigant flow and deflection metrics. Importantly, all baskets of similar size do not perform equally. The Cook baskets consistently outperformed other baskets of the same size and performed as well as some smaller-caliber baskets. Surgeons should take care in choosing baskets solely on the basis of size.

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