Basket Design as a Factor in Retention and Release of Calculi in Vitro

ILIA S. ZELTSER, M.D., and DEMETRIUS H. BAGLEY, M.D.

ABSTRACT

Purpose: To compare stone retrieval and release from seven basket designs in vitro.

Materials and Methods: We tested two tipped and one tipless NCompass models, three other tipless Nitinol® designs (NCircle, Sur-Catch, and Dimension), and the Segura Hemisphere for their ability to retrieve and release single beads 8, 6, 5.6, and 5 mm diameter and multiple beads 3.6 mm diameter in both a ureteral and a caliceal model in three separate attempts.

Results: In the ureteral model, all baskets were successful in retrieving all sizes of single beads. With multiple 3.6-mm beads, only the NCompass and Dimension designs were able to retrieve at least two of three beads in all attempts. With the exception of the Segura Hemisphere, all designs were successful in releasing all bead sizes. In the caliceal model, only the NCircle, Dimension, and tipless NCompass models were able to retrieve all bead sizes in 100% of the trials. The tipped NCompass and Hemisphere designs were unable to retrieve any beads in this model. The Sur-Catch basket was successful in the retrieval of large beads only. The Dimension articulating design was the only basket able to release all bead sizes in all attempts. The tipless NCompass basket did not release any of the beads once engaged.

Conclusion: Nitinol basket designs show excellent retrieval and release capabilities in the in-vitro ureteral model. The articulating Nitinol basket has the best stone-releasing capability of all baskets tested.

INTRODUCTION

Many stone-retrieval baskets are now available. Each instrument is designed to provide optimal stone retrieval and release in different locations in the urinary tract. Since Dormia presented his experience with a spiral basket in 1982,1 basket designs evolved from simpler three- and four-wire models with either single or paired wires to more complex articulating and woven designs utilizing multiple interlacing wire combinations. The drive to reduce the problem of basket entrapment and to improve ureteroscope deflection led to changes in basket materials as well. Previously used stainless steel gave way to Nitinol®, a flexible and kink-resistant alloy of nickel and titanium.

Understanding of benefits and limitations of different designs is essential for effective ureteroscopic stone extraction and prevention of complications such as basket entrapment in the ureter. Because the retrieval and release properties of the new woven designs have not been evaluated, we conducted this study to assess the performance of the seven currently available basket designs in both ureteral and caliceal in-vitro models.

MATERIALS AND METHODS

The seven baskets tested included six Nitinol designs: 2.4F three- and four-wire tipped NCompass Stone Extractors and the 2.4F four-wire tipless NCompass Stone Extractor (Cook Urological, Spencer, IN); the 2.4F four-wire tipless N-circle Stone Extractor (Cook Urological); the 2.4F 13-mm actively articulating Dimension Stone Basket (Bard, Covington, GA); the 3F 16-mm Sur-Catch NT Stone Retrieval Basket (ACMI, Southborough, MA), and a modified flat-wire Segura Hemisphere Stone Retrieval Basket (Boston Scientific, Watertown, MA) (Fig. 1). The ability to retrieve and release single beads 8, 6,
5.6, and 5 mm in diameter and multiple beads 3.6 mm in diameter was evaluated in both a ureteral and a caliceal model. No attempt was made to retrieve beads larger than the individual basket diameter. Commercially available light plastic beads of uniform diameter were utilized, and their size was determined with a micrometer.

In the ureteral model, beads were placed halfway into a transparent (10 cm long; 9 mm internal diameter) uniform cylindrical plastic endotracheal tube fixed on a level surface. Each basket was opened at or beyond the bead and withdrawn from the tube. Engagement and removal of the bead was counted as successful retrieval. Three separate 3.6-mm beads were used in the multiple-bead trials, and the number of beads engaged was noted for each basket. The retrieval attempt was repeated three times for each basket and bead size.

The basket, with the entrapped bead, was then returned to the tube, and disengagement of the bead was attempted by opening the basket and either articulating the wires or advancing the basket beyond the bead. The release was considered successful when an empty basket could be removed from the tube. This release attempt was repeated three times for each basket and bead size.

In the caliceal model, beads were placed on the bottom of a stabilized upright clear round-bottom test tube (length 7.5 cm; internal diameter 11 mm). Each basket was opened at the bottom of the tube, and bead engagement was attempted by advancement and withdrawal of the wires or wire articulation. Retrieval was considered successful when the bead was removed from the tube. For assessment of bead release, the basket with the engaged bead was returned into the tube, and an attempt was made to disengage the bead after the basket was opened. Removal of an empty basket from the tube was counted as successful release. Three attempts were made to release and retrieve with each basket and bead size.

These models have been utilized previously to evaluate various basket designs, and we found that the retrieval and release properties observed in vitro correlated well with our clinical experience. The testing was performed by a junior resident in urology with some expertise in stone extraction. However, to eliminate the bias of operator experience, each bead engagement and release was attempted in a single pass of the basket without any maneuvers other than those inherent in the basket design.

The statistical analysis was performed using a multiple regression model fitted by least standard squares. A model was then constructed with N-way analysis of variance (ANOVA) to assess the effect of both basket type and bead size on retrieval and release results. A P value <0.05 was considered significant.

RESULTS

In the ureteral model, all baskets were successful in retrieving all sizes of single beads in all three trials. In the multiple-bead trials, only the tipless NCompass four-wire Stone Extractor retrieved all three beads in all attempts. The other two NCompass designs were the only other baskets able to retrieve all three beads at least once. The Dimension Stone Basket retrieved two of the three beads in all attempts (Fig. 2A). Bead size showed a significant effect on successful retrieval in the ureteral model, favoring larger sizes (P = 0.0133).

With the exception of the Segura Hemisphere basket, all designs were successful in releasing all bead sizes once engaged. The Segura Hemisphere basket was able to release only the 5- and 3.6-mm beads in all three attempts and showed significantly lower release rates for all bead sizes (P < 0.0001)(Fig. 2B). Basket type was the only significant predictor of ureteral-bead release (P = 0.0011).

In the caliceal model, only the NCircle, Dimension, and tipless NCompass models were able to retrieve all bead sizes in 100% of the trials. The tipped NCompass and Segura Hemisphere designs were unable to retrieve any beads in this model. The Sur-Catch NT was successful in retrieval in all attempts with 8-, 6-, and 5.6-mm beads only (Fig. 3A). Basket type was the only significant predictor of successful bead retrieval in the caliceal model (P < 0.0001).

The Dimension articulating design was the only basket to release all bead sizes in all attempts in the caliceal model (Fig. 3B). Release of the 8-mm bead required articulation of the wires. The NCircle and Sur-Catch baskets were successful 100% of the time in releasing 5- and 3.6-mm beads only. The Tipless NCompass basket did not release any of the beads once engaged. Basket type was the only significant predictor of successful bead release in the caliceal model (P = 0.0007).

DISCUSSION

With the advent of small-diameter, flexible endoscopes, ureteroscopic lithotripsy has moved to the forefront in the minimally invasive treatment of renal and ureteral calculi. Even with significant technological improvements in shockwave lithotripsy (SWL), ureteroscopy has superior stone-free rates and lower overall cost in patients with similar stone burdens.2 The higher efficacy of ureteroscopic lithotripsy is especially evident with lower-pole stones. In a recent randomized trial comparing the outcomes of ureteroscopic lithotripsy and SWL for the treatment of ≤10-mm lower-pole calculi, ureteroscopy patients showed higher stone-free rates, as assessed by CT.3

FIG. 2. Ureteral model. (A) Bead retrieval. (B) Bead release.
Retrieval devices are essential for the manipulation and removal of calculi during ureteroscopic lithotripsy. A perfect retrieval device would be flexible enough to allow full deflection of the ureteroscope, have low impedance to irrigant flow, and possess secure but easily reversible grasping ability. The ability of stone baskets to engage and release stones is critical, especially for lower-pole calculi unreachable by standard ureteroscope deflection with the laser fiber in place. These stones can be displaced with a retrieval device into a less-dependent location for easier access and fragmentation with a larger laser fiber.

The ability to release a stone is critical during stone manipulation. Entrapment of the basket containing the stone in the ureter during withdrawal can significantly complicate stone extraction by prolonging anesthesia time and may necessitate a secondary intervention to release the entrapped basket. Disengagement can be accomplished by simple maneuvers such as opening the basket and advancing it, but often, a more complicated solution is needed. A number of interventions to release an entrapped basket have been reported and include ureteroscopic laser lithotripsy of the engaged calculus, SWL of the stone–basket complex, disassembling the basket, breaking of the wires with a holmium laser, and balloon dilatation at the site of entrapment. The problem of basket entrapment may be reduced by the new generation of instruments utilizing Nitinol and the ability to articulate the wires.

One of the most common designs is the Dormia or helical basket with either single or paired wires. Retrieval is accomplished by rotating the basket to engage the wires around the stone. In contrast, some of the new designs employ a meshwork of interlacing Nitinol wires on the distal end of the basket to prevent small fragments from falling through once engaged.

With this multitude of designs, it is at times difficult to decide which basket is best suited to a specific task. Assessing the performance of the various designs with in-vitro models may help select an appropriate instrument for clinical ureteroscopy. Previous evaluations of older basket designs have been completed in both in-vitro and ex-vivo models. Honey demonstrated faster, less traumatic, and more effective caliceal-stone extraction with a Nitinol tipless basket than with the flat-wire basket in a porcine kidney model. El-Gabry and Bagley compared five basket designs using in-vitro ureteral and caliceal models. In the simulated ureteral model, helical basket designs failed to retrieve smaller beads, and the Segura flat-wire basket was least effective in the retrieval of multiple 4-mm beads. In the caliceal model, only tipless baskets were successful in bead retrieval. More recently, Chenven and Bagley compared five basket designs using in-vitro ureteral and caliceal models. In the simulated ureteral model, helical basket designs failed to retrieve smaller beads, and the Segura flat-wire basket was least effective in the retrieval of multiple 4-mm beads. In the caliceal model, only tipless baskets were successful in bead retrieval.
evaluated four basket designs, namely, a modified flat-wire, a double-helical, and two tipless Nitinol models (passive and an articulating type), in a similar model. All baskets retrieved all beads in the ureteral model, yet only the tipless types succeeded in the simulated calix. More importantly, a clear advantage of an articulating basket in releasing beads in both ureteral and caliceal models was demonstrated.

Recently, new models of Nitinol stone extractors have been introduced. They feature a tightly woven meshwork of wires in the distal portion of the basket to improve the capture of intact stones as well as multiple small fragments. The purpose of this study was to evaluate the retrieval and releasing capabilities of these designs compared with the earlier passive and articulating Nitinol extractors in both ureteral and caliceal in-vitro models. Although each basket has its own most effective manipulation technique, we attempted to standardize the retrieval and release of different sizes of plastic beads to eliminate variation in technique and manipulation.

In the ureteral model, all baskets easily engaged both large and small beads. Similar observations were made by Lukasewycz and associates, who found no statistically significant difference in stone-extraction times with tipless Nitinol and helical baskets in an in-vitro ureteral model. The N-Circle showed the fastest overall time to stone extraction. As expected, all tested Nitinol baskets released all bead sizes within the ureter. If the bead did not disengage with just opening of the basket, release could be accomplished by opening the basket and advancing it past the bead, and then closing it above the bead prior to withdrawal. The Dimension basket did not require wire manipulation to release the beads, and the helical basket did not release large beads once they were engaged.

In the caliceal model, only the tipless designs proved to be useful in bead engagement. A tip does not allow the wires to be planted on the bottom of the calix, and therefore, it is difficult to place the stone inside the basket for engagement. With exception of the Sur-Catch design, the tipless baskets showed excellent retrieval capability. The Sur-Catch was 100% successful with the retrieval of larger beads, but the 5-mm and 3.6-mm beads fell through the wires just prior to complete closure of the basket. These findings are consistent with the results of Lukasewycz et al., who demonstrated the slowest stone capture with the Sur-Catch NT basket for all stone sizes in the caliceal in-vitro model. Those investigators postulated that the prolonged capture times with this basket were attributable to its complex six-wire design, which may have complicated stone entry into the basket. However, our observations did not confirm their analysis. We found no difficulty in placing the wires within the Sur-Catch basket but rather saw small beads fall through the spaces between the wires as the basket was being closed around the bead. This problem was not apparent with beads > 5 mm.

The Dimension basket was the only one to release all of the bead sizes in 100% of the trials in the caliceal model. This articulating design easily released even large beads when the space between the wires was increased by changing the shape of the basket. Our observations suggest that this innovative design may be ideally suited for manipulation of calculi within the intrarenal collecting system. Moreover, in clinical applications, the Dimension basket’s superior capture and release properties may prove particularly useful for calculus displacement.

The NCompass designs showed excellent retrieval and release capabilities in the ureteral model. However, releasing the beads proved difficult in the caliceal model. In the ureteral model, the beads were disengaged by advancing the opened basket past the bead. However, in the calix, because of the limited space, this maneuver is impossible. These baskets utilize a meshwork of interlacing wires on their distal portion to prevent stones from falling through once they are engaged. This interesting design can serve its purpose flawlessly, not allowing any beads to be released in the caliceal model. In general, it appears that designs utilizing a complex multiwire geometry, such as the three pairs of interlacing wires of the Sur-Catch and the N-Wire distal lattice of the NCompass, may limit their releasing capability, especially when used to manipulate large intrarenal fragments.

The successful release of a stone also depends on the relationship between the size of the calculus and the size of the extracting basket. Although a 10-mm basket can engage a 10-mm calculus, for stone release, a larger basket must be employed. From our observations, it seems that a nonarticulating basket must be at least 4 to 5 mm larger than the calculus to allow release during stone manipulation. However, this rule applies less stringently to the Dimension basket, which can increase the space between the wires as it changes its shape during articulation.

There are limitations to this study that must be recognized. Unfortunately, the in-vitro models do not simulate the true anatomy of the urinary tract perfectly. The rigid, straight tubes with uniform diameter do not account for the normal distensibility and tortuosity of the ureter, and the perfectly spherical, smooth-surfaced plastic beads do not simulate the irregular shape and the uneven surface of most urinary calculi. To reduce the bias related to the operator’s experience, we limited basket manipulation in-vitro. However, during in-vivo applications, experienced surgeons can utilize multiple maneuvers to facilitate the engagement and release of calculi. Despite these limitations, the observed differences in retrieval and release capabilities correlate well with our clinical experience and can be useful in deciding which stone extractor is best suited to a specific clinical situation.

**CONCLUSION**

Nitinol basket designs show excellent retrieval and release capabilities in the in-vitro ureteral model. Tipped baskets are poorly suited for stone retrieval in the in-vitro caliceal model. The articulating Nitinol basket has the best stone-releasing capability of all baskets tested.

**REFERENCES**


Address reprint requests to:
Demetrious H. Bagley, M.D.
Dept. of Urology
Thomas Jefferson University Hospital
1025 Walnut Street, Room 1108
Philadelphia, PA 19107
E-mail: demetrius.bagley@jefferson.edu

ABBREVIATIONS USED

CT = computed tomography; SWL = extracorporeal shock-wave lithotripsy.