A Steerable Kidney Stone Basket

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INTRODUCTION

While kidney stone removal is a standard clinical procedure, surgeons can encounter stones which lie in recessed areas that are challenging to reach. Particularly, stones which are present in the lower pole (accounting for 25-35% of all kidney stones [PMC10039418]) can be difficult due to anatomical constraints and the limited maneuverability of existing ureteroscopes and ureteroscopic tools. We hypothesize that an independently steerable stone retrieval basket will provide improved access to difficult-to-reach kidney regions, enabling quicker stone removals compared to standard techniques.

METHODS

We designed, manufactured, and evaluated a stone retrieval device with an independently steerable tip based on recently invented concentric push-pull technology [PMC10871709]. To demonstrate access, we performed an experiment where a user navigated the device through a porcine kidney to demonstrate reachability of all calyces and found that complete access was possible. To demonstrate usability and the potential to improve procedure times, a cohort of users (N=11, experience level ranging from novice to expert) used the device to remove as many stones as possible from the lower pole of a synthetic kidney simulator, both with and without our device. The stone capture rate for each trial was recorded.

RESULTS

We found that a user was able to deploy our basket into all calyces of the kidney without adverse effects (as confirmed by a post-operative inspection), even those in the lower pole. Users in the stone removal trials were able to remove lower pole stones significantly more rapidly using our device compared to standard techniques (2.7±1.8 stones/min with our basket compared to 0.9±0.10 stones/min with a standard basket).

CONCLUSION

Our device not only provides increased reachability within the kidney to remove challenging stones, but also enables faster retrieval of more typical stones. These results demonstrate that a steerable basket retrieval device can improve the process of stone retrieval.

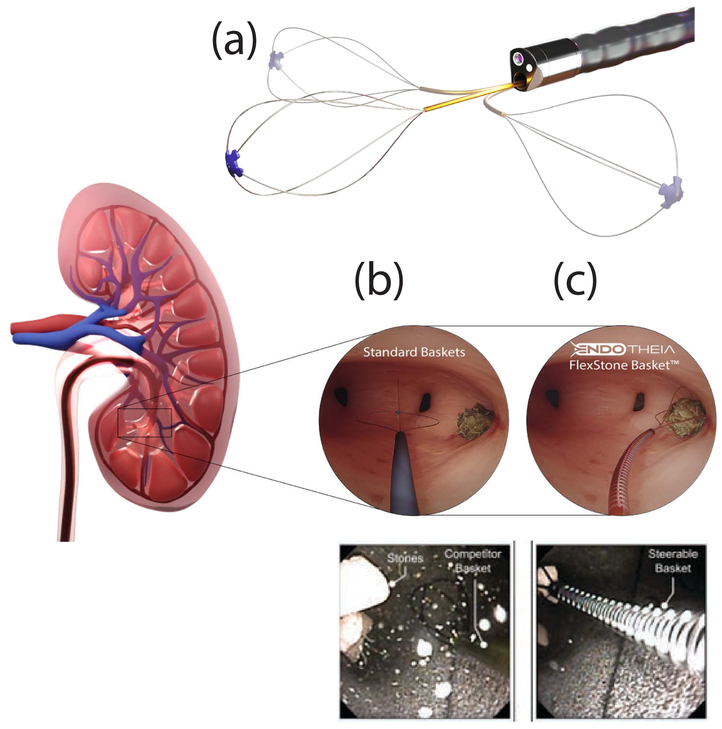

Figure 1: (a) Image of our steerable basket deployed through a flexible ureteroscope, (b) a standard basket unable to reach a challenging stone due to anatomical constraints, and (c) the steerable basket capturing a challenging stone

A Fiber-Steering Device to Reduce Laser Lithotripsy Procedure Time

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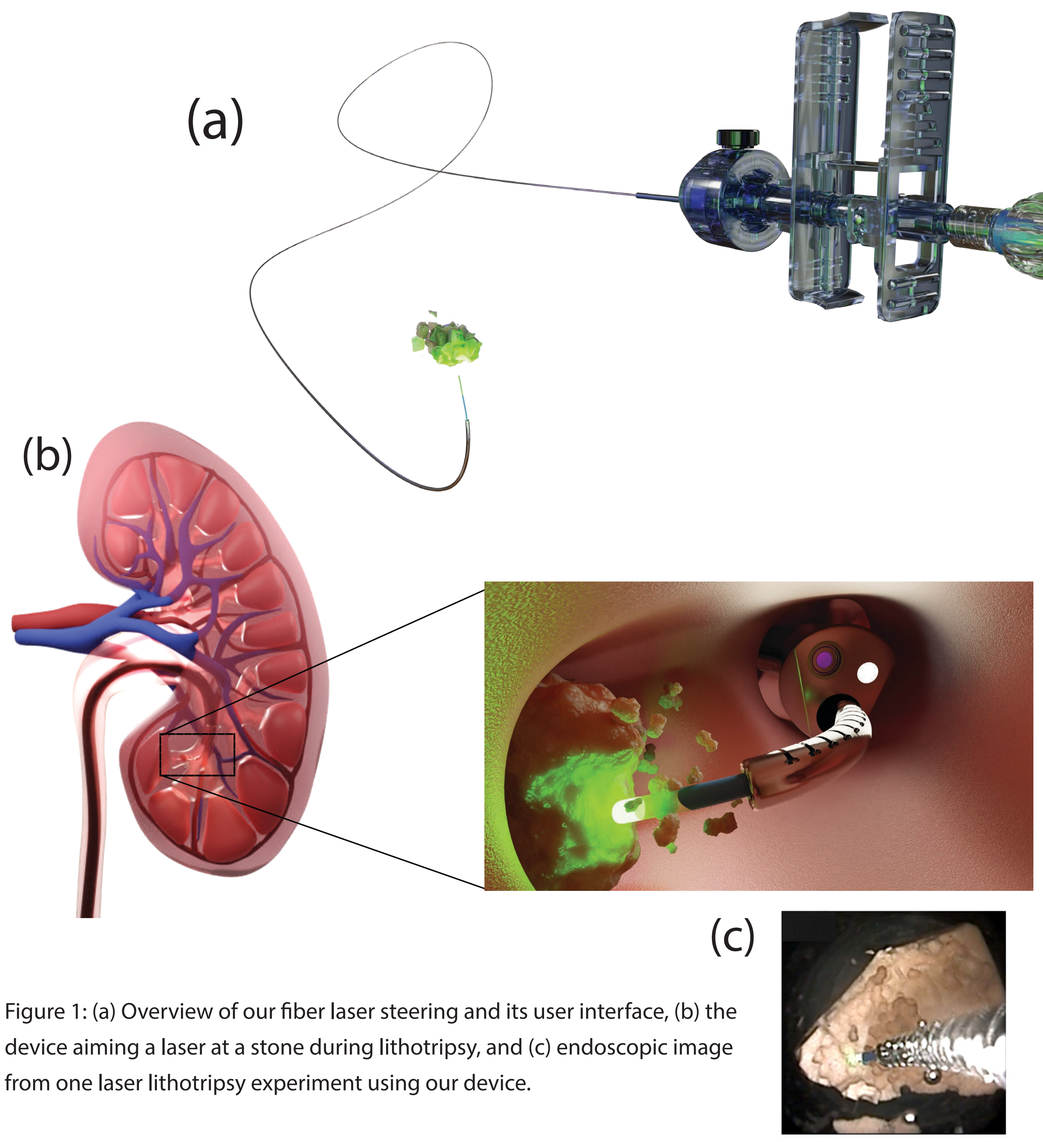

Figure 1: (a) Overview of our fiber laser steering and its user interface, (b) the device aiming a laser at a stone during lithotripsy, and (c) endoscopic image from one laser lithotripsy experiment using our device.

INTRODUCTION

During laser lithotripsy, it is important for surgeons to maintain consistent and controlled motions of the laser across the surface of the stone, to ensure that all fragments are reduced to an acceptable size expeditiously. Existing ureteroscopes can be challenging to consistently sweep across the stone. We hypothesize that an independently steerable laser guide device can help the physician aim the laser as desired and thereby reduce procedure time.

METHODS

We designed and manufactured a steerable sheath based on recently invented concentric push-pull technology [PMC10871709] which has an open central lumen to carry a laser fiber. The device is shown in Figure 1. It passes through the working channel of the ureteroscope and enables users to independently aim and steer laser fibers, instead of relying solely on the ureteroscope's motion when performing laser lithotripsy. To demonstrate the potential of the device to improve lithotripsy procedure times, we performed a series of stone lithotripsy experiments in a synthetic kidney phantom using a Karl Storz flexible ureteroscope outfitted with (a) our device, and (b) a standard laser fiber. A range of novice to expert users (N=11) fragmented and removed a 12 mm artificial stone (BegoStone [PMID: 12398432]) using both a standard ureteroscope and our new device. We recorded the stone lithotripsy rates (stone volume removed per minute) for each procedure to compare the rates with and without our device.

RESULTS

Users performed stone fragmentation faster with our steerable device than with standard techniques. Users removed stones at a rate of 14.4±3.74 〖mm〗^3/min using the steerable device compared to a rate of 11.0±1.99 〖mm〗^3/min using standard endoscopic techniques. Thus, there is a 23% reduction in procedure time ($p<0.05$) when using our device.

CONCLUSION

Our fiber-steering device enhances laser precision, enabling the surgeon to perform the desired laser sweeping technique more rapidly and consistently - resulting in a 23% reduction in procedure time. This benefit holds true regardless of surgeon experience level, demonstrating that the device offers advantages for surgeons of all skill levels.

Disclaimer: Not cleared by FDA. Not available for sale in the US.

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