Research Square

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Dusting Versus Fragmentation in Flexible and Navigable Suction Access Sheath Ureteroscopy

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Abstract

Background:

Flexible and navigable suction access sheath (FANS) usage improves stone clearance by simultaneous application of laser lithotripsy and suction. However, the optimal laser lithotripsy technique remains unclear. This study compares the efficiency of fragmentation versus dusting laser lithotripsy techniques during ureteroscopy with FANS in a benchtop model.

Methods:

Silicone collecting system models were created using de-identified patient CT scans. Fifteen trials per group were performed using a 12/14-Fr 50-cm FANS paired with a flexible disposable 9.2-Fr ureteroscope. One cm BegoStones were deposited in the upper pole for each trial. Holmium laser lithotripsy was performed using a 200-µm fiber, pressurized irrigation (300-mmHg), and wall suction (160-mmHg). Fragmentation was performed at 1.6 J and 5 Hz while dusting was performed at 0.2 J and 40 Hz. The primary outcome was stone clearance time (minutes) and secondary outcomes included laser time (minutes), laser energy (J), and surgeon workload (SURG-TLX). Outcomes were compared using Welch's t-test or Mann-Whitney U ($p < 0.05$ significant).

Results:

Mean stone clearance time was shorter for fragmenting (13.3 vs. 41.9 minutes; $p < 0.001$). Fragmentation also demonstrated shorter lasing time compared with dusting (8.0 vs 35.3 minutes; $p = 0.002$) and lower total lasing energy (3,911 vs 16,971 J; $p = 0.002$). There was no difference in surgeon workload between groups (40/120 vs. 43/120; $p = 0.69$).

Conclusions:

Pairing FANS technology with laser lithotripsy using a fragmentation technique was 68.3% more efficient at stone clearance compared to dusting in this benchtop model. Further evaluation of lithotripsy techniques in a clinical setting is warranted to confirm these benchtop findings.

Introduction

Flexible ureteroscopy (URS) has become a central modality for treating urolithiasis, supported by advances in digital ureteroscopes, laser lithotripsy, and ureteral access sheath technology. Laser lithotripsy was traditionally performed using two principal strategies: dusting, in which low-energy pulses and high frequency were used to reduce the stone into fine particles intended for spontaneous passage, and fragmentation, in which higher-energy pulses and lower frequency produced larger fragments that were subsequently extracted with basket. Conventional ureteroscopy literature has demonstrated competing advantages of these approaches, and long-term follow-up has not established a clear overall

superiority of either technique[1, 2]. Dusting may reduce operative time and ureteral wall injury, whereas fragmentation with active retrieval may achieve more complete immediate stone clearance[1, 3].

The development of flexible and navigable suction ureteral access sheaths (FANS) may fundamentally alter the traditional balance between dusting and fragmentation. Unlike conventional access sheaths, FANS combine active aspiration with a flexible distal segment that can be advanced into individual calyces, facilitating the removal of stone fragments and debris during ureteroscopy. The 2026 American Urological Association (AUA) guidelines recognize that active suction can improve stone clearance and procedural efficiency during ureteroscopy[4]. A systematic review and meta-analysis involving 7,193 patients found that FANS-URS was associated with higher stone-free rates and lower infectious and overall complication rates than conventional URS[5]. Notably, substantial heterogeneity existed in sheath dimensions, suction parameters, irrigation protocols, and operative techniques.

When employing FANS, the strategy for dusting is to reduce the stone particles to a size small enough to be aspirated between the ureteroscope and the inner wall of the sheath. On the other hand, the fragmentation strategy uses higher energy to fragment the stone into pieces that are just small enough to be evacuated through the sheath lumen, therefore requiring less laser time. However, fragmentation requires additional time passing the ureteroscope into and out of the sheath to remove these larger stone fragments. The relative efficiency of the two techniques in FANS-URS has not been determined. The purpose of this study is to compare the efficiency of dusting and fragmentation in a benchtop kidney model during FANS-URS.

Methods

Devices

The FANS evaluated was the 12/14-Fr Dornier Hoover Negative Pressure UAS 50-cm (Dornier MedTech, Weßling, Germany), paired with a Pusen 9.2-Fr disposable flexible ureteroscope (Pusen Medical, Zhuhai, China) to maintain the proper ratio of endoscope-sheath diameter of 0.75[6].

Model creation

Silicone kidney models were generated from de-identified patient computed tomography (CT) scans. The kidney and collecting system were segmented using 3D slicer (Kitware, New York, USA) and the resulting molds were 3D printed by an Ultimaker 3 Extended 3D printer (Ultimaker, Utrecht, Netherlands) using polylactic acid filament (3D Universe, Chicago, IL, USA). Dragon Skin™20 (Smooth-On, Macungie, PA, USA) was poured into the molds and left to cure. A medical-grade thermoplastic tube was inserted into the upper pole as a channel to introduce stones into the kidney (Fig. 1B, 1D).

(A) Overview of the setup, with the silicone kidney–ureter model submerged in a stainless-steel basin and the FANS and flexible ureteroscope. (B) Overhead view of the kidney model, the upper pole stone-

introduction channel (white tube), and the ureteral model held in its anatomic course by 3D-printed clips; a stainless steel mesh keeps the kidney model submerged, and an immersion circulator maintains the water at 37°C. (C) Proximal end of the FANS, showing the ureteroscope entering the sheath and the side-port suction tubing. (D) In vitro silicone kidney model created from three-dimensional reconstructions of de-identified patient CT scans to replicate renal collecting system anatomy, with an upper pole channel for stone introduction.

Ureteral models were constructed by 3D printing a mold of the inner lumen of the ureter and coating it with silicone. Autodesk Fusion 360 (Autodesk, San Francisco, CA, USA) was used to design the lumen model based on physiologic ureteral dimensions[7–9]. Dragon Skin™20 was applied to form the ureteral wall. Parafilm (Uline, Pleasant Prairie, WI, USA) was used to attach the ureter to the kidney and create a watertight seal.

Stone creation

Artificial kidney stones were made using a 15:6 BegoStone-to-water ratio by weight (Bego USA, Lincoln, RI, USA)[10]. After the BegoStone mixture had fully dried, the resulting block was fragmented. Individual pieces were chipped and sanded into irregular shapes measuring 1-cm in maximum diameter and weighing 0.60 g. The stones were fully submerged in 0.9% saline at room temperature for 24 hours prior to use to ensure complete hydration.

Study trials

Trials were conducted by placing the kidney model into a scaffold designed to reproduce the natural ureteral course. The setup was submerged in an 18×28” stainless-steel basin filled with water maintained at 37°C using an immersion heater (Vpcok Direct, Dongguan, China) (Fig. 1A, 1B). Prior to each trial, the FANS and ureteroscope were advanced into the upper pole (Fig. 1C) and the stone was inserted. Irrigation was delivered from a saline bag pressurized to 300-mmHg using a pressure infusion cuff. Suction was applied using wall suction set to 160-mmHg. These settings were kept constant across all trials. With the ureteroscope positioned at sheath tip, the sheath was advanced until the stone was identified. Trials alternated between dusting and fragmentation until 15 trials were completed per group, distributing any learning or fatigue effects evenly. Secondary outcomes and operator workload were recorded in the final five trials of each group.

Laser Lithotripsy Protocol

Laser Lithotripsy Protocol
All procedures used the Odyssey 30 Holmium:YAG Laser System (Convergent, Alameda, CA, USA) and an OptiLITE 200-µm single-use holmium flat-tip fiber (Convergent, Alameda, CA, USA). All trials were performed by a single fellowship-trained endourologist to minimize inter-operator variability.

In the fragmentation group, lithotripsy was performed using laser settings of 1.6 J and 5 Hz, corresponding to a total power of 8.0 W. These settings were selected to create larger stone fragments that could be evacuated using the suction of the FANS system. In the dusting group, laser lithotripsy was performed using the settings of 0.4 J and 20 Hz, also corresponding to a total power of 8.0 W. The surgeon directed the laser around the surface of the stone using a painting technique to reduce the stone into fine particulate debris. The FANS system was used to evacuate the debris into a collection canister.

Outcome Measures

The primary outcome was stone clearance time, measured from laser activation with the fiber positioned in front of the stone until all visible stone fragments and debris were evacuated using the FANS system. Secondary outcomes included lasing time (minutes), laser energy delivered (J), number of complete ureteroscope passes through the sheath, active suction time (minutes), irrigation delivered (mL), and fluid suctioned (mL). Lasing time and energy were recorded from the laser console; irrigation volume was calculated from initial and final saline volumes, and suctioned volume was measured in the collection canister. Operator workload was assessed after each trial using the Surgery Task Load Index (SURG-TLX)[11], a validated measure of surgical workload evaluating 6 domains (mental demands, physical demands, temporal demands, task complexity, situational stress, and distractions) on a 20-point scale. Unweighted domain ratings and their sum (raw total score) were reported.

Statistical analysis

Continuous outcomes are reported as mean ± standard deviation (SD) and were compared between groups using Welch's unequal-variance t-test, with mean differences and 95% confidence intervals (CIs). SURG-TLX ratings were treated as ordinal, reported as median (interquartile range [IQR]), and compared using the exact Mann–Whitney U test. Trends in clearance time across trial sequence were assessed with Spearman's rank correlation. Significance was set at $p < 0.05$. Analyses were performed in Python (version 3.12) using SciPy (version 1.17).

Results

Stone clearance time

Clearance of all visible fragments was achieved in all 30 trials. Mean stone clearance time was 13.3 ± 2.4 minutes with fragmentation and 41.9 ± 9.6 minutes with dusting (mean difference − 28.7 minutes; 95% CI − 34.1 to − 23.2; $p < 0.001$), corresponding to a 68.3% reduction in clearance time with fragmentation (Table 1; Online resource, Supplementary Fig. S1). Clearance times did not overlap between groups: the longest fragmentation trial (17.2 minutes) was shorter than the fastest dusting trial (28.5 minutes).

Table 1
Stone clearance, lasing, suction, fluid, and surgeon-reported workload outcomes by laser lithotripsy technique

Outcome	Fragmentation	Dusting	Mean difference (95% CI)	p value
Procedural outcomes				
Stone clearance time, min	13.3 ± 2.4	41.9 ± 9.6	−28.7 (− 34.1 to − 23.2)	**< 0.001**
Lasing time, min	8.0 ± 1.3	35.3 ± 8.8	−27.3 (− 38.2 to − 16.5)	**0.002**
Laser energy delivered, J	3,911 ± 627	16,971 ± 4,197	−13,060 (− 18,242 to − 7,879)	**0.002**
Active suction time, min	7.6 ± 0.9	37.4 ± 9.9	−29.8 (− 42.0 to − 17.5)	**0.002**
Ureteroscope passes through sheath, n	10.8 ± 0.8	5.8 ± 1.3	5.0 (3.4 to 6.6)	**< 0.001**
Irrigation used, mL	2,080 ± 347	4,000 ± 912	−1,920 (− 3,033 to − 807)	**0.007**
Fluid suctioned, mL	1,774 ± 465	4,670 ± 1,280	−2,896 (− 4,459 to − 1,333)	**0.005**
Derived efficiency measures				
Lasing time, % of clearance time	53.4 ± 4.1	90.0 ± 2.3	−36.7 (− 41.8 to − 31.6)	**< 0.001**
Non-lasing time, min	7.1 ± 1.5	3.8 ± 0.8	3.3 (1.5 to 5.1)	**0.004**
Stone ablation rate, mg/min	76.3 ± 12.1	17.9 ± 4.9	58.4 (43.6 to 73.1)	**< 0.001**
Energy per stone mass, J/mg	6.5 ± 1.0	28.3 ± 7.0	−21.8 (− 30.4 to − 13.1)	**0.002**
Irrigation rate, mL/min	143 ± 44	103 ± 12	40 (− 14 to 95)	0.112
SURG-TLX measures				
Mental demands	4 (2–6)	6 (5–6)	—	0.841
Physical demands	5 (5–11)	8 (6–10)	—	0.841
Temporal demands	9 (6–15)	8 (4–12)	—	0.548
Task complexity	5 (3–5)	4 (4–6)	—	1.000
Situational stress	2 (2–5)	4 (2–4)	—	0.841
Distractions	7 (4–8)	7 (7–9)	—	0.548

Outcome	Fragmentation	Dusting	Mean difference (95% CI)	p value
Raw total score	40 (22–41)	43 (33–47)	—	0.690

Values are presented as mean ± standard deviation for procedural and derived efficiency outcomes and median (interquartile range) for SURG-TLX domains. Mean differences (95% confidence intervals) are calculated as fragmentation minus dusting. Procedural and efficiency outcome *p*-values were calculated from Welch's t-test, and SURG-TLX *p*-values were calculated from Mann–Whitney U tests. Ablation rate and energy per stone mass assume a stone mass of 0.60 g. SURG-TLX raw total scores represent the sum of the six domain ratings.

Lasing, suction, and fluid outcomes

In the subset with secondary outcome data, fragmentation required significantly less lasing time (8.0 ± 1.3 vs 35.3 ± 8.8 minutes; $p = 0.002$) and less laser energy (3,911 ± 627 vs 16,971 ± 4,197 J; $p = 0.002$) (Table 1; Online resource, Supplementary Fig. S2). Active suction time (7.6 ± 0.9 vs 37.4 ± 9.9 minutes; $p = 0.002$), irrigation volume (2,080 ± 347 vs 4,000 ± 912 mL; $p = 0.007$), and suctioned fluid volume (1,774 ± 465 vs 4,670 ± 1,280 mL; $p = 0.005$) were also lower with fragmentation. Conversely, fragmentation required more ureteroscope passes through the sheath (10.8 ± 0.8 vs 5.8 ± 1.3; $p < 0.001$).

Efficiency measures

Laser activation accounted for 53.4 ± 4.1% of clearance time with fragmentation compared with 90.0 ± 2.3% with dusting ($p < 0.001$) (Table 1; Online resource, Supplementary Fig. S3). Non-lasing time was longer with fragmentation (7.1 ± 1.5 vs 3.8 ± 0.8 minutes; $p = 0.004$). The stone ablation rate was 76.3 ± 12.1 mg/min with fragmentation and 17.9 ± 4.9 mg/min with dusting ($p < 0.001$), and fragmentation required less energy per milligram of stone (6.5 ± 1.0 vs 28.3 ± 7.0 J/mg; $p = 0.002$). Irrigation rate did not differ significantly between techniques (143 ± 44 vs 103 ± 12 mL/min; $p = 0.112$). Within the dusting group, clearance time decreased modestly across successive trials (Spearman $\rho = -0.52$; $p = 0.044$), whereas no trend was observed with fragmentation ($\rho = 0.21$; $p = 0.459$).

Operator workload

SURG-TLX ratings were similar between techniques (Table 1; Online resource, Supplementary Fig. S4). The median raw total score was 40 (IQR 22–41) for fragmentation and 43 (IQR 33–47) for dusting ($p = 0.690$), and no individual domain differed significantly (all $p \geq 0.5$).

Discussion

In this benchtop model of FANS-URS, fragmentation cleared a 1-cm stone in less than one-third of the time required for dusting when both techniques were delivered at the same power. Given that operating room costs have been estimated at $57.71/minute in California hospitals[12], the 28.66-minute reduction in mean stone clearance time observed with fragmentation (13.27 vs. 41.93 minutes) could

translate to a cost savings of $1,654 per procedure, suggesting meaningful economic implications for clinical practice. The advantage was consistent across every trial and accompanied by an approximately 77% reduction in lasing time and laser energy and half the irrigation volume, without an increase in perceived workload. These findings suggest that when a sheath capable of aspirating fragments is in place, reducing stones to dust may sacrifice efficiency without a proportional gain in clearance.

Because power was held constant, differences in efficiency reflect energy delivery rather than the amount of energy. At equal power, fragmentation delivers fewer, higher-energy pulses, and dusting delivers more, lower-energy pulses. Laboratory testing shows that stronger pulses produce greater stone ablation at the same energy[13]. Accordingly, fragmentation achieved approximately fourfold faster stone ablation and used less than one-quarter of the energy per milligram of stone removed. In contrast, dusting requires systematically ablating the stone into fine particles, with laser activation accounting for 90% of clearance time in our trials. FANS changes the endpoint of lithotripsy: once fragments are smaller than the sheath, they can be aspirated, theoretically up to 4-mm with a 12/14-Fr FANS[14]. Dusting therefore adds laser time without improving evacuation. Conventional ureteroscopy presents a trade-off: dusting produces particles of ≤ 250-μm that pass spontaneously[15], avoiding the need for individual basket retrieval. One series reported mean operative times of 91 minutes for fragmentation with basket extraction compared with 76 minutes for dusting using a conventional sheath[3], FANS eliminates this trade-off by aspirating both fragments and dust, removing the time penalty of basketing while avoiding the additional lasing time required for dusting, ultimately allowing faster stone clearance with fragmentation.

In a prior comparison of dusting and fragmentation, Demirkıran et al. used an 11/13-Fr aspiration access sheath with thulium fiber laser (TFL) in a syringe model[16]. Fragmentation reduced lasing time (31.15 vs 45.15 minutes) and energy consumption, while dusting produced smaller particles and required less suction time and fewer ureteroscope entries. Our findings extend these results to an anatomically representative collecting system using a holmium laser, the most commonly used laser in a contemporary global survey of endourologists[17]. The larger relative difference in our study may reflect the use of holmium laser and the anatomical complexity of locating and aspirating dispersed debris. Given its higher peak power, the holmium system is well-adapted to fragmentation[18]. Clinical data are limited and less consistent. In a prospective multicenter FANS cohort of 704 patients, Gauhar et al. reported shorter lasing times and higher 30-day complete clearance with dusting than with popcorning[19]. However, popcorning differs from fragmentation. Fragmentation is a contact technique in which high-energy pulses break the stone into retrievable pieces, whereas popcorning is a non-contact technique in which high-frequency pulses progressively reduce clustered fragments[20]. Gauhar et al. therefore did not evaluate fragmentation as performed in the present study. Moreover, lasing strategy was not randomized, the popcorning group had larger and denser stones, and laser technology rather than technique was the strongest predictor of clearance[19]. A randomized clinical trial comparing fragmentation and dusting with FANS is currently registered[21].

Fragmentation was not without trade-offs. It required nearly twice as many ureteroscope passes and more non-lasing time, likely due to repeated ureteroscope withdrawal for fragment evacuation through the sheath. This is consistent with prior findings of more frequent ureteroscope entries during fragmentation and concerns regarding endoscope wear[16], although disposable ureteroscopes mitigate this concern. The additional handling added approximately 3 minutes of non-lasing time per trial, a modest increase compared with the 27 minutes of lasing time saved with fragmentation. The additional ureteroscope passes also did not increase SURG-TLX ratings.

The secondary outcomes carry implications beyond efficiency. Dusting consumed nearly twice the irrigation volume and delivered more than four times the laser energy into the collecting system. Because irrigation rate did not differ between techniques, the excess fluid with dusting was a consequence of procedure duration. Greater irrigation consumption increases workload and reliance on fluid supplies. Irrigation system management requires additional circulating nurse time[22] and saline shortages have highlighted the importance of conservative irrigation use during endourologic procedures[23]. Collecting system fluid temperature during holmium laser lithotripsy depends on both laser power and irrigation[24], and at equal power, prolonged laser activation increases cumulative thermal exposure.

This study has a few limitations to be considered. First, the silicone benchtop model does not perfectly replicate each physiological variable of in-vivo surgery. However, the shape of the kidney and collecting system was created based on real patient anatomy and the use of this benchtop model allowed us to control variables in a reproducible way that is not possible in a clinical study. Second, a single stone composition, size, and location (1-cm BegoStone in the upper pole) was tested. The results with different stone densities and locations remain to be elucidated. Third, each technique was evaluated at a single holmium power setting; results may differ with different power, pulse-modulated, or thulium lasers. Fourth, all trials were performed by a single unblinded fellowship-trained endourologist, and the decrease in dusting clearance time across successive trials suggests a possible learning effect, although even the fastest dusting trial exceeded the slowest fragmentation trial. Finally, SURG-TLX scores are inherently subjective and may reflect surgeon preference, familiarity with each technique, and operating conditions.

Conclusions

In an anatomically representative benchtop kidney model, fragmentation during FANS-assisted ureteroscopy cleared 1-cm stones 68% faster than dusting at equivalent laser power, while requiring less than one-quarter of the lasing time and laser energy and approximately half the irrigation volume, with comparable operator workload. When fragments can be actively aspirated, the efficiency of fragmentation may outweigh the traditional rationale for dusting. Prospective clinical studies are needed to determine whether these efficiency gains translate into shorter clinical operative times and improved stone-free outcomes.

Declarations

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Author Contribution Statement

M Guirgus: Project development, Data collection, Data analysis, Writing – original draft, Writing- review and editing.

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HC Sims: Data collection, Data analysis, Writing – original draft, Writing – review and editing.

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A Albaghli: Project development, Supervision, Data collection.

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Data availability: The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

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Figures

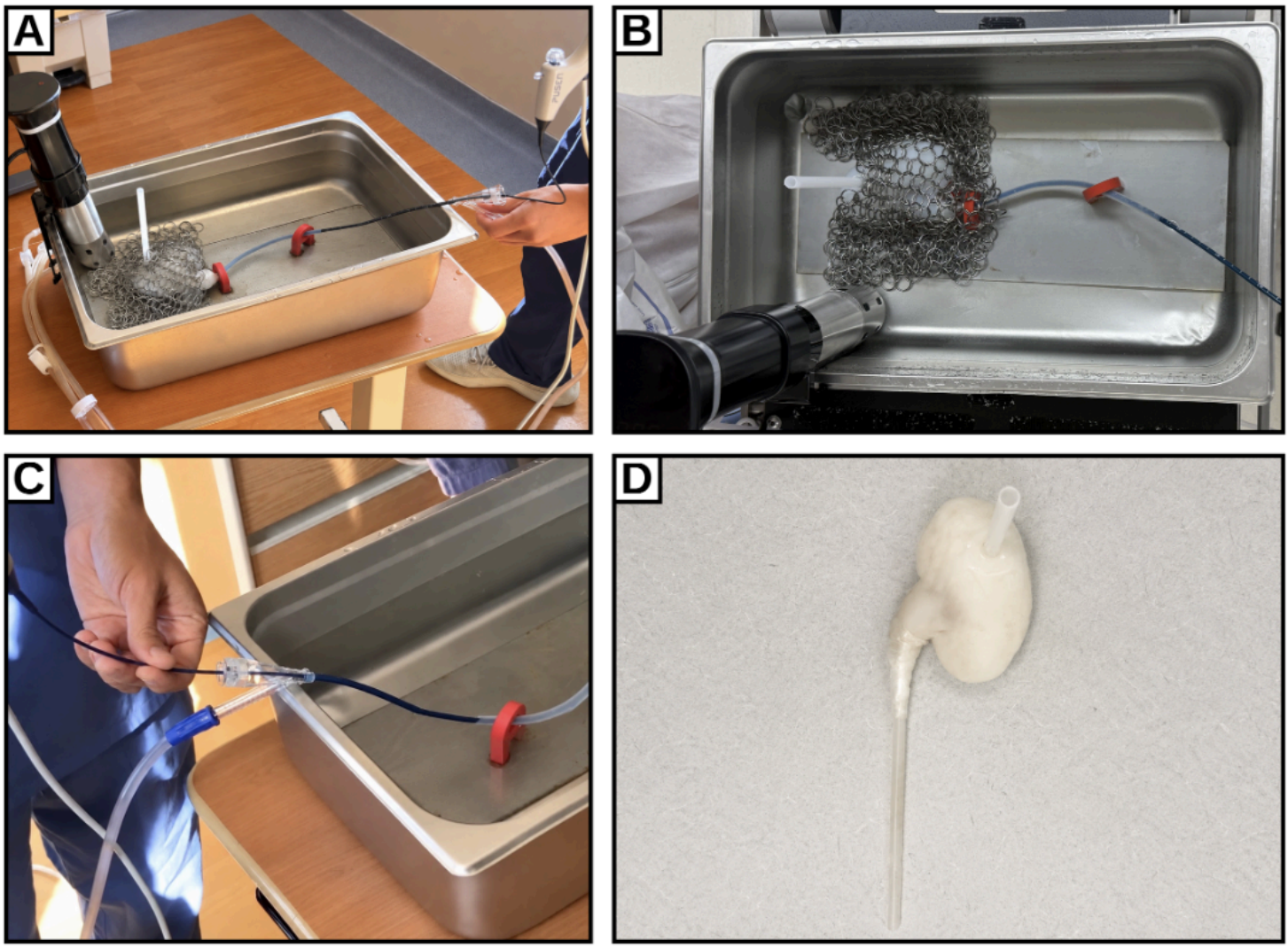

Figure 1

(A) Overview of the setup, with the silicone kidney–ureter model submerged in a stainless-steel basin and the FANS and flexible ureteroscope. (B) Overhead view of the kidney model, the upper pole stone-introduction channel (white tube), and the ureteral model held in its anatomic course by 3D-printed clips; a stainless steel mesh keeps the kidney model submerged, and an immersion circulator maintains the water at 37 °C. (C) Proximal end of the FANS, showing the ureteroscope entering the sheath and the side-

port suction tubing. (D) In vitro silicone kidney model created from three-dimensional reconstructions of de-identified patient CT scans to replicate renal collecting system anatomy, with an upper pole channel for stone introduction.

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