UCSF

UC San Francisco Previously Published Works

Title

Identifying factors associated with need for flexible ureteroscope repair: a Western Endourology STone (WEST) research consortium prospective cohort study.

Permalink

<https://escholarship.org/uc/item/8j80h7vr>

Journal

Urolithiasis, 46(6)

ISSN

2194-7228

Authors

Taguchi, Kazumi
Harper, Jonathan D
Stoller, Marshall L
et al.

Publication Date

2018-11-01

DOI

10.1007/s00240-017-1013-y

Peer reviewed

Identifying factors associated with need for flexible ureteroscope repair: a Western Endourology STone (WEST) research consortium prospective cohort study

Kazumi Taguchi^{1,6} · Jonathan D. Harper² · Marshall L. Stoller¹ · Brian D. Duty³ · Mathew D. Sorensen^{2,8} · Roger L. Sur⁴ · Manint Usawachintachit^{1,7} · David T. Tzou¹ · David L. Wenzler⁴ · Dylan Isaacson⁵ · Angela Xu¹ · Carissa Chu¹ · Uwais B. Zaid¹ · Eric R. Taylor¹ · Krishna Ramaswamy¹ · Thomas Chi¹

Received: 23 June 2017 / Accepted: 29 October 2017
© Springer-Verlag GmbH Germany, part of Springer Nature 2017

Abstract

Maintenance of flexible ureteroscopes can involve high costs and administrative burden. Instrument fragility necessitates eventual repair, rendering scopes inaccessible during refurbishment. We conducted a multi-institutional prospective cohort study to identify perioperative factors influencing flexible ureteroscope durability. Patients undergoing flexible ureteroscopy (URS) at six United States endourology centers were enrolled between August 2014 and June 2015. Surgeon self-reported concern and satisfaction with scope performance as well as upward and downward angles of deflection for each scope tip were measured before and after each procedure. The need for scope repair was determined by the operating surgeon at the time of the procedure and recorded. 424 URS cases using 74 flexible ureteroscopes were identified. Scope repair was required in 28 cases (6.6%) involving 26 scopes (35.1%). Upon univariate analysis, shorter patient height, absence of guidewire use, presence of a ureteral access sheath (UAS), longer procedure time, larger stone size, lithotrite type, surgeon training level, and self-reported concern were associated with scope repair. Upon multivariate analysis, UAS use (OR = 2.53, $p = 0.005$) and degree loss of scope upward flexion during a case (OR = 1.02, $p = 0.03$) increased the odds of a scope needing repair while the use of safety guidewire decreased the odds of a scope repair (OR = 0.50, $p = 0.045$). Lithotrite use and surgeon concern were associated with degree loss of scope upward flexion. The use of a UAS, absence of a safety guidewire, and the loss of upward ureteroscope flexion should be considered when evaluating means of optimizing reusable ureteroscope durability.

Keywords Ureteroscopy · Reusable flexible ureteroscope · Scope repair · Durability · Ureteral access sheath

Introduction

Since its inception by Marshall in 196 [1, 4] flexible ureteroscopy (URS) has become a frequently performed procedure for examination and therapeutic intervention in the upper urinary tract. In combination with laser lithotripsy, flexible URS has become a standard treatment for upper urinary tract calculi, producing safe outcomes and a high stone clearance rate [2]. Though flexible ureteroscopes are indispensable instruments in contemporary urologic practice, both traditional fiber optic and newer digital flexible ureteroscopes are fragile and subject to breakage. Common reasons for repairs

include loss of deflection, fractured eyepieces and broken optical fibers [3–5].

The variable durability of flexible ureteroscopes results in a substantial repair cost to institutions and healthcare systems. Recent studies in the United States have shown the average cost of a repair ranges from \$355 to \$605 per procedure [3–5] with the latest digital and fiber-optic ureteroscopes lasting an average of 3–14 cases before requiring repair [6–10]. While existing studies in the literature have focused on durability differences between individual ureteroscope models, specific factors broadly associated with scope durability and long-term performance have not been well characterized.

The aim of this study was to measure perioperative factors and surgeon attitudes predictive of scope repair during flexible URS in a prospective, multi-institutional fashion.

✉ Thomas Chi
tom.chi@ucsf.edu

Extended author information available on the last page of the article

Methods

Study design

This was a prospective cohort study involving members of the Western Endourology STone (WEST) research consortium, a group comprised of six high-volume stone centers: University of California San Francisco (UCSF), San Francisco General Hospital (SFGH), Oregon Health and Sciences University (OHSU), University of Washington (UW), University of California San Diego (UCSD), and Puget Sound VA Hospital. Institutional review board approval was obtained at the coordinating center (UCSF) and each individual participating institution (CHR 14-14,533). Flexible URS procedures were enrolled at all institutions between August 2014 and June 2015. Inclusion criteria were: all patients older than 18 years of age undergoing flexible ureteroscopy for diagnostic purposes or for treatment of upper urinary tract stone, ureteral stricture, or malignancy. Patients with pregnancy and severe morbidity (greater than ASA III) were excluded from the study.

Data collection

Patient demographic data, procedure indications, stone characteristics, ureteroscope model, primary surgeon, and intraoperative details were prospectively collected into a Research Electronic Data Capture (REDCap) database [11]. Selection of model and manufacturer for flexible ureteroscopes, guidewires, ureteral access sheaths (UAS) and lithotrites were per the preference of each individual surgeon. The primary surgeon was defined as the physician who spent the most time operating the ureteroscope during the operation. This was classified as attending/fellow/resident. The primary surgeon's reported levels of concern and satisfaction with the ureteroscope performance were recorded following each case.

Photographs of each scope's maximal upward and downward flexion were taken at the beginning and the end of every case. Degree of upward and downward flexion was measured from the point at which the main shaft begins to flex to the tip of the scope (Fig. 1). Cases for whom images taken were not of sufficient quality to accurately measure were excluded for this analysis. The decision to send any

Fig. 1 Measurement method for the degree of up/downward flexion of a ureteroscope at the beginning and end of each case. Representative pictures demonstrate the maximal flexion of ureteroscopes photographed at the beginning and end of each case. The downward (diagonal angle) and upward (dotted angle) degree of ureteroscope flexion

were measured as the angle between the start point of main shaft (dashed line) curl, which intersects as a right angle from the center of the curling scope, and the end of the curl, which intersects as a right angle from the tip direction (solid line) of the ureteroscope

ureteroscope for repair was made by the primary surgeon based on scope condition, such as visibility, flexion, and any scope damage experienced during the case. We tracked individual ureteroscopes by serial number and collected repair logs to confirm scope repairs performed throughout the lifespan of each individual scope during the study period.

This was a pragmatic trial and scope lifespan prior to entering the study was not known. To understand factors cumulatively influencing need for repair, cases were divided into two groups—those performed with scopes requiring repair at some point during the study period (repair required group) and those performed on scopes that did not require repair during the study period (no repair required group).

Statistical analysis

The primary endpoint of the study was the need for ureteroscopy repair. Means (SD: standard deviation) were presented for continuous, normally distributed variables whereas non-normally distributed variables were expressed as medians (25, 75% IQR: interquartile range). Categorical variables were presented with the number in each group (percentage within each group). Two-sample *t* tests and the Mann–Whitney *U* test were used to identify differences between groups. Categorical variables were compared using Fisher's exact and Chi-squared tests. Logistic and linear regressions were performed as univariate and multivariate analyses, respectively. Differences were considered statistically significant at $\alpha < 0.05$. All statistical analyses were performed using EZR for R [12].

Results

A total of 74 ureteroscopes were used to perform 424 flexible URS procedures during the study period. The distribution of procedures by institution was 118 (28%) at UCSF, 26 (6%) at SFGH, 64 (15%) at OHSU, 157 (37%) at UW, 28 (7%) at UCSD, and 30 (7%) at Puget Sound VA Hospital. URF-P6 (Olympus, Tokyo, Japan) and Flex-X2 (Karl Storz, Tuttlingen, Germany), were the most commonly used ureteroscopes and accounted for 181 (43%) and 156 (37%) procedures, respectively. Digital ureteroscopes, including URF-V (Olympus), URF-V2 (Olympus), and Flex-XC (Karl Storz), were used in 49 (12%), 9 (2%), and 3 (1%) procedures, respectively. Upper urinary tract stone treatment (79%) was the most common indication for flexible URS, followed by diagnostic URS (12%). Scope repair was required in 28/424 procedures (6.6%), with 26/74 scopes (35.1%) sent for repair at least once during the study period. Amongst cases where the ureteroscope was sent for repair, the primary reasons cited were poor visibility (21%), suboptimal deflection (29%), shaft damage (18%), and working channel breakage

(4%), with no specific known reason cited in 29% of cases. The median total procedure time was 61 min for all cases, and the median stone size was 10 mm for urinary stone treatment cases.

The average number of procedures performed by each non-repaired scope was 4.8 ± 4.2 during the study period. Amongst scopes requiring repair during the study period, the mean number of cases performed before repair was needed was 7.3 ± 4.1 , and there was no statistical difference between the two groups.

Table 1 details patient demographics, stone characteristics, and intraoperative parameters, and primary surgeon training level as well as self-reported concern and satisfaction ratings regarding the ureteroscope's performance during that case. In the repair required group, mean patient height was 3 cm shorter ($p = 0.018$), and there was larger size of stone [10 (6, 15) vs 10 (7, 20), $p = 0.013$] than in the no repair required group. There were no statistically significant differences in sex, body mass index (BMI), and stone location between the groups. Intraoperatively, the cases performed with scopes that required repair experienced fewer procedures utilizing a guidewire through a scope ($p < 0.001$) and as safety ($p = 0.014$), but more procedures utilizing a UAS ($p < 0.001$), and a nine minutes longer median total procedure time per case ($p = 0.028$). The uses of 365-micron flat-tip, and 200- and 273-micron ball-tip laser lithotrites were also more common in the repair required group. There were no differences between groups in rates of stone repositioning, or duration of time the scope was in the patient. There was a significant difference in the level of training of the primary surgeon between the two study groups. In the repair required group, endourology fellows performed more and attending fewer of the procedures ($p = 0.001$). After the procedure, the primary surgeon stated that they were concerned with the scope condition more often with scopes that needed repair during the study period. However, there was no difference in self-reported surgeon satisfaction between groups.

We also compared degrees of maximal deflection for each ureteroscope based on flexion measurement before and after each procedure (Fig. 1). There were no differences between groups in degree of maximal up- or downward flexion either at the beginning or at the end of the case. Mean degree loss of upward flexion during each case was 5.2 ± 19.0 and 4.7 ± 19.2 in the repair required and no repair required groups, respectively ($p = 0.810$). Mean degree losses of downward flexion during each case were 7.8 ± 21.1 and 6.7 ± 17.2 in the repair required and no repair required groups ($p = 0.387$), respectively (Table 2).

Multivariate analysis of the factors associated with scope repair is shown in Table 3. The model was adjusted for gender, height, primary surgeon, concern, satisfaction, lithotrite type, stone size, procedure time, ureteral access sheath

Table 1 Comparison of patient characteristics, intraoperative characteristics, and surgeon evaluation between ureteroscopes requiring and not requiring repair during the study period

		Total cases <i>n</i> = 424	No repair required <i>n</i> = 234	Repair required <i>n</i> = 190	<i>p</i> value
<i>Patient characteristics</i>					
Sex	Male:female	235 (55):189 (45)	139 (59):95 (41)	96 (51):94 (49)	0.077
Height (cm)		169 (13)	170 (12)	167 (13)	0.018
BMI (kg/m ²)		30.6 (9.6)	30.1 (9.4)	31.2 (9.9)	0.251
Stone location	None	99 (23)	55 (24)	44 (23)	0.282
	Upper/middle calyx	64 (15)	30 (13)	34 (18)	
	Lower calyx	140 (33)	76 (33)	64 (34)	
	Ureter	74 (18)	40 (17)	34 (18)	
	Kidney and ureter	42 (10)	29 (12)	13 (7)	
	Others	5 (1)	4 (2)	1 (1)	0.013
Stone size (mm) ^a		10 (6, 16)	10 (6, 15)	10 (7, 20)	
<i>Intraoperative characteristics</i>					
Using a wire through a scope (+)		278 (66)	171 (73)	107 (57)	<0.001
Safety wire usage		129 (31)	83 (36)	46 (24)	0.014
Ureteral access sheath usage		190 (45)	81 (35)	109 (58)	<0.001
Stone repositioned ^a		91 (22)	57 (24)	34 (18)	0.124
Type of lithotrite ^a	200 micron Flat	174 (67)	109 (75)	65 (57)	0.004
	365 micron Flat	22 (9)	7 (5)	15 (13)	
	200/273 micron Ball	59 (23)	26 (18)	33 (29)	
	Others	4 (2)	3 (2)	1 (1)	
Total procedure time (min)		61 (45, 100)	59 (43, 88)	68 (49, 113)	0.002
Primary surgeon	Attending	105 (25)	66 (28)	39 (21)	0.001
	Fellow	44 (10)	13 (6)	31 (16)	
	Resident	273 (65)	153 (66)	120 (63)	
Primary surgeon concern	Concerned	50 (12)	19 (8)	31 (16)	0.001
	Neutral	169 (40)	111 (47)	58 (31)	
	Unconcerned	204 (48)	104 (44)	100 (53)	
Primary surgeon satisfaction	Like new	309 (73)	175 (75)	134 (71)	0.097
	Somewhat compromised	91 (22)	52 (22)	39 (21)	
	Severely compromised	12 (3)	3 (1)	9 (5)	
	Unusable	11 (3)	4 (2)	7 (4)	

Continuous variables are listed as either means (SD) or medians (25% IQR, 75% IQR); categorical and binary variables are described as the number in each group (%)

URS ureteroscope, BMI body mass index, UAS ureteral access sheath

^aOnly cases performed for treatment of urinary stones are included for these measures

Table 2 Comparison of ureteroscope flexion during each procedure between ureteroscopes that did and did not require repair

	No repair required <i>n</i> = 225	Repair required <i>n</i> = 180	<i>p</i> value
Degree of maximal upward flexion at case start	274 (48)	278 (30)	0.293
Degree of maximal upward flexion at case end	269 (47)	273 (32)	0.346
Degree of maximal downward flexion at case start	267 (30)	269 (28)	0.422
Degree of maximal downward flexion at case end	260 (35)	261 (33)	0.842
Degree loss of upward flexion during a case	4.7 (19.2)	5.2 (19.0)	0.810
Degree loss of downward flexion during a case	6.2 (17.2)	7.8 (21.1)	0.387

Variables are listed as means (SD)

Table 3 Multivariate analysis of factors associated with the need for ureteroscope repair during the study period, adjusted for sex, height, primary surgeon, concern, satisfaction, lithotrite type, stone size, procedure time, ureteral access sheath usage, safety wire usage, and degree loss of upward or downward flexion during a case

Factor	Odds ratio	<i>p</i> value	95% CI
Ureteral access sheath usage	2.53	0.005	1.31–4.87
Degree loss of upward flexion during a case	1.02	0.030	1.00–1.04
Safety wire usage	0.50	0.045	0.26–0.98
Concern (concerned)	2.58	0.067	0.93–7.14
Usage of 365 micron flat-tip fiber ^a	2.20	0.164	0.73–6.64
Height	0.17	0.207	0.01–2.65
Total procedure time	1.01	0.210	1.00–1.01
Primary surgeon (fellow)	1.69	0.308	0.62–4.64
Stone size ^a	1.02	0.350	0.98–1.05
Satisfaction (unusable)	0.38	0.395	0.04–3.51
Degree loss of downward flexion during a case	1.00	0.545	0.99–1.02
Sex (male)	0.91	0.795	0.44–1.87

95% CI 95% confidence interval

^aIncluded for these analyses are only cases performed for urinary stone treatment

usage, safety wire usage, and degree of upward or downward flexion loss during a case. The use of a UAS (OR = 2.53, $p = 0.005$, 95% CI = 1.31–4.87) and the degree loss of upward flexion during a case (OR = 1.02, $p = 0.03$, 95% CI = 1.00–1.04) were significantly associated with subsequent scope repair while the use of a safety wire (OR = 0.50, $p = 0.045$, 95% CI = 0.26–0.98) was protective.

In examining factors associated with the use of a UAS, both univariate and multivariate analyses demonstrated that stone size was significantly associated with the use of a UAS during a case (OR = 1.05, $p < 0.001$, 95% CI = 1.02–1.07) (Table 4).

Likewise, we also examined factors associated with the loss of scope upward flexion. While univariate analysis showed no factors significantly associated with loss of scope flexion, multivariate analysis demonstrated that the use of a lithotrite (coefficient = 4.88, $p = 0.03$, 95% CI = 0.49–9.26) and operator's concern over scope ability to complete the case (for "concern," estimate = 6.14, $p = 0.032$, 95% CI = 0.53–11.76) were predictive for the loss of upward flexion of the scope. There was no significant correlation between the other factors and degree loss of upward flexion during a case (Table 5).

Discussion

Our results demonstrated that usage of a UAS, absence of a safety guidewire, and loss of scope upward flexion were associated with the need for scope repair during a 10-month period of usage. The present study was designed as a pragmatic investigation, meant to represent a current fleet in any institutions' possession. Therefore, rather than purchasing new ureteroscopes at the beginning of the study period, prospective evaluation was performed with scopes currently in use. This approach may not be able to answer how we can improve a new ureteroscope life span in general but rather we aimed to answer the question of how we can preserve the durability of a set of ureteroscopes already owned and currently in use. This may better reflect real-world clinical centers' experience.

The use of flexible ureteroscopes has become mainstream, accompanied by improvements in visibility, maneuverability and surgical outcomes [13]. As such, scope maintenance and cost management are relevant for any centers that utilize reusable ureteroscopes; maintaining ureteroscope durability requires significant continued

Table 4 Univariate and multivariate analysis of factors associates with ureteral access sheath usage during a case

	Univariate			Multivariate		
	Odds ratio	<i>p</i> value	95% CI	Odds ratio	<i>p</i> value	95% CI
Stone size ^a	1.04	0.001	1.02–1.07	1.05	< 0.001	1.02–1.07
Sex (male)	0.69	0.061	0.47–1.02	0.47	0.005	0.28–0.79
Safety wire usage	1.14	0.535	0.75–1.73	1.16	0.557	0.71–1.91
Height	0.22	0.054	0.05–1.03	1.11	0.913	0.17–7.46

Multivariate model is adjusted for sex, height, stone size, and safety wire usage

95% CI 95% confidence interval

^aIncluded for these analyses are only cases performed for urinary stone treatment

Table 5 Univariate and multivariate analysis of factors associates with degree loss of upward flexion during a case

	Univariate			Multivariate		
	Coefficient	<i>p</i> value	95% CI	Coefficient	<i>p</i> value	95% CI
Lithotrite usage	3.31	0.084	− 0.44 to 7.06	4.88	0.030	0.49 to 9.26
Concern (concerned)	4.18	0.150	− 1.52 to 9.88	6.14	0.032	0.53 to 11.76
Sex (male)	3.70	0.480	0.03 to 7.36	2.14	0.328	− 2.16 to 6.45
Height	− 0.02	0.773	− 0.17 to 0.12	− 0.07	0.394	− 0.22 to 0.09
Stone size ^a	− 0.01	0.924	− 0.18 to 0.16	− 0.07	0.414	− 0.25 to 0.10
Using a wire through a scope (+)	− 0.49	0.803	− 4.36 to 3.38	− 0.99	0.663	− 5.44 to 3.47
Safety wire usage	2.74	0.176	− 1.24 to 6.72	0.72	0.723	− 3.29 to 4.74
Ureteral access sheath usage	1.11	0.554	− 2.57 to 4.79	0.28	0.899	− 4.13 to 4.70

Multivariate model is adjusted for sex, height, stone size, surgeon concern, ureteral access sheath usage, safety wire usage, usage of wire through a scope, and lithotrite usage

95% CI 95% confidence interval

^aIncluded for these analyses are only cases performed for urinary stone treatment

repair investment. Older generations of flexible ureteroscopes required repair every 6–15 uses [14], and subsequent study demonstrated that newer scopes could be used for a comparable number of procedures before repair, ranging from 3.25 to 14.4, depending on the scope model [9]. The durability of new generation flexible ureteroscopes may be slightly better compared to these prior studies, with up to 18 procedures performed before scope repair was required [8]. Fewer studies describe the durability of digital flexible ureteroscopes, and no substantive improvements have been shown compared to prior and current generations of fiber-optic ureteroscopes [6, 15].

Many suggestions exist to improve scope longevity in clinical practice. Proposed guidelines emphasize appropriate laser energy settings, precise fiber positioning in the scope relative to the scope tip, stone repositioning from the lower pole into the upper pole and the avoidance of continued maximal scope flexion. These measures prolonged the number of usages before repair from 10.6 to 21.6 cases [7]. For institutions that employ refurbished scopes, refurbishment by the original manufacturer may have superior durability compared to those refurbished by other vendors [10].

In this study, degree loss of upward scope flexion after scope utilization increased the odds of scope repair by 0.02 per degree of flexion loss. Others have shown that the flexion mechanism is a significant source of mechanical weakness for flexible ureteroscopes [16], and the present study may help explain how the need for scope repair may accumulate over time.

Interestingly, the use of a UAS increased the odds of scope repair by 2.53 times. This effect appeared to be independent of the primary surgeon or laser fiber type, two factors often shown to influence scope breakage [7]. This finding contradicts other studies which have shown that ureteral access sheaths help preserve scope integrity [17]. A possible

explanation is that the use of a UAS may allow for more aggressive use of the scope as one does not need to finesse the repeated passage of the scope back into the kidney. Multiple passages into the kidney with or without the need for severe flexion may be responsible in part for scope breakage and need for repair. Interestingly, while stone size itself was not associated with scope repair, larger stone size was associated with usage of a UAS. Taken together, these findings may influence the decision of when to use a UAS, either for or during a case.

The increased popularity of UAS use is likely due to their beneficial effects on decreased intrarenal pressure, decreased operative time, increased stone free rates, and protection against ureteral damage [18]. While other studies have suggested that use of a UAS resulted in a greater number of procedures possible prior to need for scope repair [15, 19], our study has demonstrated the opposite. This difference may reflect that prior studies did not directly compare procedural outcomes between cases with and without UAS use. Other confounding factors may explain their observed increases in scope longevity. While this present study is unable to completely explain this finding, aggressive scope flexion over the distal edge of the UAS may lead to scope deflection mechanism damage during intrarenal scope manipulation.

Surprisingly, the use of a safety guidewire decreased the odds of needing scope repair by a half. Safety guidewire usage has been an important dimension for safer URS procedures, however, the reduction contemporary ureteroscope diameter questions the need for safety guidewires during URS [20]. As a possible explanation for our finding, the use of a safety guidewire may prevent severe scope flexion by releasing ureteral tortuosity and straightening it.

The use of lithotrite and operator concern were associated with degree of upward scope flexion loss, a proxy for subsequent scope repair. Univariate analysis demonstrated

that shorter height, larger stone size, scope passage without a guidewire, use of 365-micron flat and 200/273-micron ball laser fibers, longer procedure time, endourology fellow as the primary surgeon, and surgeon self-reported concern with scope performance were associated with scope repair; these associations were not apparent in multivariate analysis. Several studies document surgeon preferences regarding quality of visibility and maneuverability for different types of ureteroscopes [6, 8, 9]. This study demonstrates that subjective rating of operator concern regarding scope performance was significantly associated with the loss of upward flexion; loss of scope flexion appears to be a good surrogate for the need for subsequent scope repair. It may be that as loss of flexion increases, loosening of flexor cables precedes eventual breakage.

This study has inherent limitations including the use of heterogeneous sets of ureteroscopes with regard to their repair history rather than the use of all new scopes. Service records regarding prior scope repairs and the time period scopes had been in circulation prior to the study could not be definitively ascertained. Individual ureteroscopes had differing use histories at study initiation, and thus it was hard to accurately quantify the overall cumulative usage and damage for individual scopes. By necessity, the average value of each variable was used to perform our analysis. Additionally, there was a diversity in case numbers and lithotripsy approaches (i.e. dusting/fragmentation/combination of both) among these institutions driven by data entry personnel availability and surgeon preference. These factors were not standardized between surgeons or institutions; this potential confounder could not be included in the analysis model. The outcome reflects daily practice for surgeons, but did not adhere to strict criteria to quality for need for repair. Therefore, results may have been influenced by practice patterns or surgeon habits specific to these centers. Finally, as this was not a randomized controlled trial, our ability to identify true causative factors was also limited.

In conclusion, use of a ureteral access sheath, absence of a safety guidewire, and degree loss of scope maximal upward flexion after ureteroscopic procedures were significantly associated with need for scope repair. Loss of scope maximal upward flexion was correlated with the use of lithotrite and surgeon's concern.

Acknowledgements This work was supported by the educational grant from the Boston Scientific Foundation (TC), the US National Institutes of Health with grants K12-DK-07-006 (TC), and P20-DK-100863 (MLS, TC). This material is also the result of work supported by resources from the Veterans Affairs Puget Sound Health Care System, Seattle, Washington. The sponsors played no direct role in the study.

Compliance with ethical standards

Funding This study was funded by the educational grant from the Boston Scientific Foundation, the US National Institutes of Health with grants K12-DK-07-006, and P20-DK-100863.

Conflict of interest Marshall L. Stoller and Thomas Chi serve as paid speakers and consultants for Boston Scientific Corporation and have received educational grant funding from Richard Wolf. Marshall L. Stoller has served as a paid speaker for the Karl Storz Company.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of each institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

1. Marshall V (1964) Fiber optics in urology. *J Urol* 91:110–114
2. de la Rosette J, Denstedt J, Geavlete P et al (2014) The clinical research office of the endourological society ureteroscopy global study: indications, complications, and outcomes in 11,885 patients. *J Endourol* 28:131–139
3. Tosoian JJ, Ludwig W, Sopko N, Mullins JK, Matlaga BR (2015) The effect of repair costs on the profitability of a ureteroscopy program. *J Endourol* 29:406–409
4. Kramolowsky E, McDowell Z, Moore B, Booth B, Wood N (2016) Cost analysis of flexible ureteroscope repairs: evaluation of 655 procedures in a community-based practice. *J Endourol* 30:254–256
5. Semins MJ, George S, Allaf ME, Matlaga BR (2009) Ureteroscope cleaning and sterilization by the urology operating room team: the effect on repair costs. *J Endourol* 23:903–905
6. Shah K, Monga M, Knudsen B (2015) Prospective randomized trial comparing 2 flexible digital ureteroscopes: ACMI/Olympus invisio DUR-D and olympus URF-V. *Urology* 85:1267–1271
7. Karaolides T, Bach C, Kachrilas S, Goyal A, Masood J, Buchholz N (2013) Improving the durability of digital flexible ureteroscopes. *Urology* 81:717–722
8. Knudsen B, Miyaoka R, Shah K et al (2010) Durability of the next-generation flexible fiberoptic ureteroscopes: a randomized prospective multi-institutional clinical trial. *Urology* 75:534–538
9. Monga M, Best S, Venkatesh R et al (2006) Durability of flexible ureteroscopes: a randomized, prospective study. *J Urol* 176:137–141
10. Carey RI, Martin CJ, Knego JR (2014) Prospective evaluation of refurbished flexible ureteroscope durability seen in a large public tertiary care center with multiple surgeons. *Urology* 84:42–45
11. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG (2009) Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform* 42:377–381
12. Kanda Y (2013) Investigation of the freely available easy-to-use software “EZ” for medical statistics. *Bone Marrow Transplant* 48:452–458
13. Ghani KR, Wolf JS (2015) What is the stone-free rate following flexible ureteroscopy for kidney stones? *Nat Rev Urol* 12:281–288

14. Afane JS, Olweny EO, Bercowsky E et al (2000) Flexible ureteroscopes: a single center evaluation of the durability and function of the new endoscopes smaller than 9Fr. *J Urol* 164:1164–1168
15. Multescu R, Geavlete B, Georgescu D, Geavlete P (2014) Improved durability of Flex-Xc digital flexible ureteroscope: how long can you expect it to last? *Urology* 84:32–35
16. Canales BK, Gleason JM, Hicks N, Monga M (2007) Independent analysis of olympus flexible ureteroscope repairs. *Urology* 70:11–15
17. Kaplan AG, Lipkin ME, Scales CD, Preminger GM (2015) Use of ureteral access sheaths in ureteroscopy. *Nat Rev Urol* 13:135–140
18. Breda A, Territo A, López-Martínez JM (2016) Benefits and risks of ureteral access sheaths for retrograde renal access. *Curr Opin Urol* 26:70–75
19. Pietrow PK, Auge BK, Delvecchio FC et al (2002) Techniques to maximize flexible ureteroscope longevity. *Urology* 60:784–788
20. Dutta R, Vyas A, Landman J, Clayman RV (2016) Death of the safety guidewire. *J Endourol* 30:941–944

Affiliations

Kazumi Taguchi^{1,6} · Jonathan D. Harper² · Marshall L. Stoller¹ · Brian D. Duty³ · Mathew D. Sorensen^{2,8} · Roger L. Sur⁴ · Manint Usawachintachit^{1,7} · David T. Tzou¹ · David L. Wenzler⁴ · Dylan Isaacson⁵ · Angela Xu¹ · Carissa Chu¹ · Uwais B. Zaid¹ · Eric R. Taylor¹ · Krishna Ramaswamy¹ · Thomas Chi¹

Kazumi Taguchi
ktaguchi@med.nagoya-cu.ac.jp

Jonathan D. Harper
jdharper@uw.edu

Marshall L. Stoller
marshall.stoller@ucsf.edu

Brian D. Duty
dutyb@ohsu.edu

Mathew D. Sorensen
mathews@uw.edu

Roger L. Sur
rlsur@mail.ucsd.edu

Manint Usawachintachit
manint.u@chula.ac.th

David T. Tzou
david.tzou@ucsf.edu

David L. Wenzler
dwenzler@gmail.com

Dylan Isaacson
dylan.isaacson@ucsf.edu

Angela Xu
angelaxu2006@gmail.com

Carissa Chu
carissa.chu@ucsf.edu

Uwais B. Zaid
uwaiszaid@gmail.com

Eric R. Taylor
etaylo3@gmail.com

Krishna Ramaswamy
krishna.rama@gmail.com

¹ Department of Urology, University of California, San Francisco, 400 Parnassus Ave., Sixth Floor, Suite A610, San Francisco, CA 94143, USA

² Department of Urology, University of Washington, Seattle, USA

³ Department of Urology, Oregon Health and Science University, Portland, USA

⁴ Department of Urology, University of California, San Diego, USA

⁵ School of Medicine, University of California, San Francisco, USA

⁶ Department of Nephro-urology, Nagoya City University Graduate School of Medical Sciences, Nagoya, Japan

⁷ Division of Urology, Faculty of Medicine, King Chulalongkorn Memorial Hospital, Chulalongkorn University, Bangkok, Thailand

⁸ Division of Urology, Department of Veteran Affairs Medical Center, Seattle, WA, USA