Journal of Lasers in Medical Sciences

J Lasers Med Sci 2023;14:e29

Original Article

http://journals.sbmu.ac.ir/jlms

doi 10.34172/jlms.2023.29

A Good Craftsperson Knows Their Tools: Understanding of Laser and Ureter Mechanics in Training Urologists

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Received: April 12, 2023
Accepted: June 27, 2023
Published online August 29, 2023

Abstract

Introduction: Recent decades have seen a move to minimally invasive techniques to manage urolithiasis. Trainees are expected to develop competency in common endourology procedures. Knowledge of ureter mechanics and the theory behind new technologies is important to ensure safe and efficient techniques. We aim to evaluate the exposure to endourology, self-reported competency in common techniques and knowledge of basic ureter biomechanics and technology in training urologists.

Methods: An online survey was circulated to all training urologists in the Republic of Ireland. Questions focused on self-reported competency, clinical knowledge, ureter mechanical properties and laser technology.

Results: Thirty responses were received with a range of 1-8 years of urology experience (mean = 4 years). The respondents reported high levels of exposure to endourology with the majority reporting competency in flexible ureterorenoscopy (FURS) (n = 18, 60%) and semi-rigid ureteroscopy (URS) (n = 21, 70%). The respondents demonstrated good clinical knowledge but variable knowledge of laser settings, laser thermodynamics and ureter mechanics. Half of the respondents (n = 15, 50%) correctly described fragmentation laser settings, with 10 trainees (n = 33%) accurately identifying both factors that increase ureteral access sheath (UAS) insertion force. Most of the respondents (n = 20, 67%) described the proximal ureter as the site with the greatest compliance, while the site of the greatest force during ureteroscope insertion was correctly identified by 17% (n = 5).

Conclusion: To our knowledge, this represents the first study evaluating urologist understanding of laser technology and the mechanical properties of the human ureter. Despite trainees reporting high levels of experience in endourology, there is a variable understanding of the principles of laser technology and ureter mechanics. Further research and education are needed with a focus on laser safety, suitable laser settings and the safe limit of insertion forces.

Keywords: Laser technology; Ureter mechanical properties; Urology training and education; Urolithiasis; Endourology.

Introduction

Urolithiasis is a common problem for the practicing urologist, with the prevalence of stone disease increasing worldwide.[1,2] Advancements in technology and access to new techniques have seen a move to minimally invasive endourological techniques with contemporary series reporting an increase of 143% in ureteroscopies performed.[3,4] This is reflected in the logbooks of training urologists with a 32.8% increase in ureteroscopy (URS) cases performed by training urologists between 2009 and 2016.[5] Trainees are expected to be competent in URS prior to the completion of surgical training reflecting contemporary work practices.[6]

As well as surgical competency, knowledge of the mechanics of the ureter and the theory behind new technologies is important to ensure safe and efficient URS. Animal and human studies have sought to evaluate the biomechanics of the ureter, including the safe upper limit of ureter insertion force, and variation in compliance according to anatomical location (proximal, middle etc.).[7,8] It is important that the surgeon performing the procedure understand certain mechanical principles so as to ensure safe surgery and optimal patient outcomes as excess force has been associated with ureteric trauma in animal and human studies.[8-10]

Laser technology has become widely used in the management of ureteric and renal stones, overtaking pneumatic techniques for stone destruction.[11] A fundamental understanding of the science of laser technology enables safe and effective laser settings and usage.[12]

Currently, data evaluating surgeons' knowledge of

Please cite this article as follows: O'Meara S, Croghan S, O'Brien FJ, Davis NF. A good craftsperson knows their tools: understanding of laser and ureter mechanics in training urologists. *J Lasers Med Sci.* 2023;14:e29. doi:10.34172/jlms.2023.29.

mechanical properties and laser technology are lacking. Therefore, the aim of this study was to evaluate the clinical endourology experience and the knowledge of laser technology and basic ureter mechanics in training urologists.

Materials and Methods

Following a review of the literature on ureter mechanical properties, laser thermodynamics and endourology training guidelines, an online questionnaire was developed using Google Forms. The survey was distributed to all urology trainees in the Republic of Ireland (ROI) in September 2022 (Supplementary File 1).

The questionnaire consisted of 11 questions of multiple-choice answer or free text style. Respondents were asked to report their exposure to common endourology procedures and rate their competence in semirigid URS, flexible ureterorenoscopy (FURS) and percutaneous nephrolithotomy (PCNL). Respondents were provided with common clinical scenarios and were asked about their preferred management options as well as their preferred laser settings for stone fragmentation and dusting. We evaluated respondents' understanding of ureter biomechanics with questions on ureter compliance, temperature change with laser usage and ureteric insertion force.

The data was collated in Microsoft Excel, and descriptive statistics were calculated and presented in a descriptive format.

Results

Thirty trainees responded (response rate = 100%) with urology experience ranging from 1 to 8 years (mean = 4 years) (Figure 1). All respondents are urology residents in Ireland, and no attendings or trainees who had completed an overseas fellowship were included.

Endourology Training and Experience

Most of the respondents reported they were competent to perform FURS and URS independently, with 60% and 70% reporting competence in complex cases (Table 1). Exposure to PCNL was lacking with nineteen (63%) respondents reporting performing less than ten cases and three (10%) respondents reported competence performing a straightforward procedure independently (Table 1).

The respondents were presented with three clinical scenarios and asked to select their preferred management for each case (Supplementary file 1 and Table 2). All of the respondents correctly identified case two as a septic obstructed kidney, recommending decompression with a stent (n = 23, 77%) or percutaneous nephrostomy (PCN) (n = 7, 23%). Half of the group (n = 15) selected primary FURS for the management of an 8mm proximal ureteric stone, with the remainder choosing external shock wave lithotripsy (ESWL) (n = 6, 20%) or URS (n = 9, 30%). FURS was the most common choice for the management of an upper pole renal stone (n = 24, 80%), with one respondent (3%) selecting PCNL and the remainder ESWL (n = 5, 17%).

Biomechanical Properties

Figure 2 and Table 3 detail responses to questions on the mechanical properties of the ureter. The proximal ureter was selected as the most compliant part of the ureter by twenty respondents (66%), with twenty-one (70%) identifying the distal ureter as having the greatest resistance to ureteroscope insertion. Most respondents identified that a larger diameter sheath increases the force required to insert a ureteral access sheath (UAS) (N = 26, 87%), with ten (33%) also selecting the presence of a safety wire. The force required to cause significant trauma to the ureter was determined to be 6 Newtons (N) by twelve respondents (40%), 8 N by eleven respondents (37%), and > 12 N by four respondents (13%). The options of 10 N, 2 N and "don't know" were each selected by one respondent (3%) respectively.

Laser Settings

Twenty-Nine respondents described the energy settings

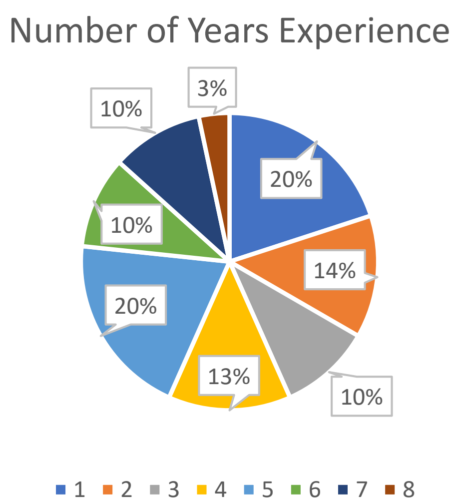

Figure 1. Reported Years of Urology Experience

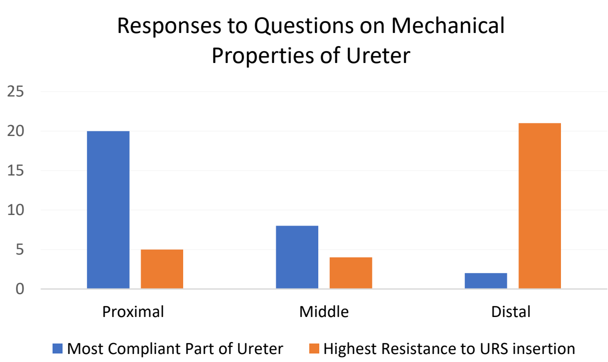

Figure 2. Responses to Questions on Mechanical Properties of Ureter

Table 1. Self-reported competency and number of times procedures performed.

	FURS No. (%)	URS No. (%)	PCNL No. (%)
Self-defined competency in procedure			
Not competent	0 (0)	0 (0)	16 (53)
With supervision	2 (7)	2 (7)	11 (37)
Straightforward case independently	10 (33)	7 (23)	3 (10)
Complex case independently	18 (60)	21 (70)	0 (0)
Total	30 (100)	30 (100)	30 (100)
Number of times procedure performed			
<5	0 (0)	0 (0)	12 (40)
5-10 times	0 (0)	0 (0)	7(23)
10-20 times	1 (3)	0 (0)	9 (30)
20-30 times	5 (17)	2 (7)	1 (3)
40-50 times	5 (17)	3 (10)	1 (3)
>50 times	19 (63)	25 (83)	0 (0)
Total	30 (100)	30(100)	30 (100)

Table 2. Breakdown of Responses to Clinical Scenarios

Scenario	Primary URS + Laser	Primary FURS + Laser	Ureteric Stent With Delayed Ureteroscopy	PCNL	PCN	ESWL
45-year-old man presents with renal colic. CT shows an 8mm proximal stone with mild hydronephrosis. He has no medical history, normal laboratory investigations and is apyrexial.	9 (30%)	15 (50%)	0 (0%)	0 (0%)	0 (0%)	6 (20%)
65-year-old woman presents with pyrexia, tachycardia and flank pain. CT shows a 6mm left mid ureteric stone with associated perinephric stranding. Medical history is significant for hypothyroidism.	0 (0%)	0 (0%)	23 (77%)	0 (0%)	7 (23%)	0 (0%)
33-year-old man referred to outpatient clinic with non-visible haematuria. Work-up shows a 1.5cm left upper pole stone. No previous stone history, normal stone profile, no previous medical history.	0 (0%)	24(80%)	0 (0%)	1(3%)	0 (0%)	5 (17%)

they use for dusting and fragmentation, with one respondent reporting use of pre-defined settings. The median power selected for dusting was 0.5 J (range 0.2-10 J) and the median frequency was 12 Hz (range = 5-70 Hz). For fragmentation, the median power selected was 10J (range 5-100), with frequency of 6 Hz (range 3-300 Hz). Half of the respondents (n = 15, 50%) accurately described dusting settings that were within the combined ranges of 12-20 Hz and 02-0.5 J.[13,14] A combination of power settings within 5-10 Hz and 1-2 J was selected by sixteen (52%) respondents.

Table 4 shows the temperature changes with laser use time selected by the respondents. Nine (30%) of the respondents suggested there is no change within one minute, with the remainder choosing a temperature increase of between one and eight degrees.

Table 3. Factors that may Increase the Force Required to Insert a UAS

Factors That May Increase the Force Required to Insert a UAS	No. (%)
None	3 (10)
Larger diameter sheath	26 (87)
Smaller diameter sheath	1 (3)
Pre-stented ureter	2 (7)
Safety wire	10 (33)
Warmed irrigation fluid	0 (0)
Pre-operative alpha blocker	0 (0)

Table 4. Temperature Change with 1 Second of Laser

Temperature Change	No. (%)
No change	9 (30%)
+1°C	9 (30%)
+3°C	7 (23%)
+6°C	3 (10%)
+8°C	2 (7%)

Discussion

Endourology Training and Experience

Endourology training in the ROI forms part of the structured urology training programme under the auspices of the intercollegiate surgical curriculum programme. The updated curriculum necessitates rotation through placements in areas of interest to include endourology.[6] All trainees are expected to be able to perform URS fluently without guidance or intervention as a minimum by certification of competency, with FURS competency mandatory in those who take a special interest in endourology.[6] The majority of our respondents describe themselves as competent in both FURS and URS with high levels of exposure to retrograde procedures (Table 1). This echoes previous data showing that 95% of the UK and Irish trainees achieved the required competency numbers in ureteroscopy prior to the completion of training.[15] Respondents had a lower rate of competency and exposure to PCNL compared to international residents. Approximately 34% of the final year residents in Canada reported participating in more than twenty PCNLs in the preceding year, compared to 2 (6%) of our respondents performing the same number throughout the entirety of their training.[16] This may be attributable to the variety of clinical rotations and sub-specialists' interests. A move to endourological management of stones has been described in international studies and surveys, as well as in societal guidelines.[2,4,17] This is reflected in our results with most of the respondents choosing FURS to manage a proximal ureteric calculus and 1.5 cm intrarenal upper pole stone (Table 2).

All trainees surveyed correctly answered the presented endourology clinical scenarios according to the most recent European Association of Urology (EAU) guidelines.[2] The optimal management of an obstructed septic kidney is urgent decompression with a PCN or retrograde ureteric stent.[2] As would be expected from urology trainees, all of our respondents correctly managed this clinical scenario, with the majority recommending ureteric stent insertion over PCN (Table 2). This may reflect variations in access to interventional radiology out of hours in different centres. Clinical judgement is key to the identification of these patients to ensure rapid decompression.[18]

Laser Settings and Safety

The selection of appropriate laser settings depends on the stone type, location and size, surgeon's skill, preferred technique, and anatomical factors. The 'perfect' settings have yet to be defined.[19,20] One respondent reported using pre-settings; however, there is a wide variety of pre-settings with no adjustment for fibre sizes.[19] Thus, these should be used with caution. A previous review article described "typical" fragmentation settings of 6-10 Hz and 1.0-1.2 J, with dusting settings of 0.2-0.4 J and 12-15 Hz.[13] Traxer and Ventimiglia suggest energy of 0.5 J with frequency of 15-20 Hz for dusting and energy of 1.5-2 J and frequency of 5 Hz for fragmentation.[14] Despite reported high exposure to endourology cases, only half of our respondents chose laser settings that were within these parameters.

The Holmium:YAG laser may cause thermal ureteral injury with 43°C considered the safe upper threshold.[21,22] The Irrigation rate and laser settings have been shown to affect temperature changes.[21-24] Benchtop testing has shown a temperature change of over 6 °C to occur in under one second at high power settings with no irrigation, and the threshold of thermal injury to be reached within nine seconds with 40 W of power.[22,24] Temperature increases with increasing the laser output and decreasing the irrigation flow. Urologists should be aware of this risk and consider steps such as smaller fibres, higher irrigation flow rates, and intermittent laser activation during prolonged cases to reduce the risk of thermal injury.[12,25]

Previous studies evaluating physicians' knowledge of laser settings and safety are scant. Early work by Rodriguez and Sattin noted that laser-related complications in practicing ophthalmologists were lower in those that had done a laser training course in the preceding year.[26] All of our trainees have to complete a short laser safety course prior to laser usage in the operating theatre. There have been numerous educational papers aimed at practising urologists that explain laser science, settings and interactions with the surrounding tissue.[14,20,25,27] Despite this, there was significant variety in the results from our trainees (Table 4), suggesting that further education in laser settings, thermodynamics and their clinical relevance is needed.

Biomechanical Properties

To our knowledge, this is the first research evaluating surgeons knowledge of the mechanical properties of the human ureter with respondents displaying mixed understanding. Previous *in vivo* studies have shown maximum ureteroscope insertion force in the proximal ureter.[28,29] Much of this resistance may be due to the increased contact area between the ureteroscope and ureteric wall and the gripping of the scope by the distal ureter with axial advancement. As seen in Figure 2, the proximal ureter was chosen as the site of the greatest resistance by only five respondents (17%). Compliance was correctly identified as being the greatest in the proximal ureter by 67% (n = 20) of the respondents.[30-32]

The use of UASs has become mainstream with benefits including reduced intrarenal pressure, effective stone clearance and better vision.[33] Previous global surveys of endourologists have reported usage rates of 67-76% for intra-renal stones.[34,35] Concerns with UAS use include reduced blood flow, ureteral strictures and direct mechanical trauma.[7,33] Increased insertion force is associated with increasing sheath diameter and the presence of a safety wire in-situ in human and porcine studies.[29,36-38] Meanwhile, the use of pre-operative alpha adrenergic antagonists or pre-operative stenting has been seen to significantly reduce the force required to insert a UAS.[39] The majority of our respondents reported competency in straightforward and complex FURS cases and thus should be familiar with UAS insertion. Despite this, only ten respondents (33%) were able to accurately select both of the factors that may increase the force required to insert a UAS.

Multiple studies have attempted to determine safe insertion forces for a UAS.[7,10,36,40] Two groups reported significant ureteric injury (post ureteroscopic lesion score of 3 or greater) with insertion forces of eight newtons and above.[10,36] Eleven of our respondents correctly identified 8N as the upper limit of force for UAS insertion. Previous studies have shown significant variation in the stone basket extraction force considered "safe" by trainee urologists when compared to attendings.[41] There is a need for the use of sensors during the training of urologists to enable the understanding of the force required to insert instruments, sites of maximum insertion force and the impact of force on the ureter. Further in-vivo testing is also needed to define the safe upper limit of URS and UAS insertion.

Limitations

Limitations to our study include the use of self-defined competence. However, previous studies have shown surgeons to be accurate self-assessors.[42] The use of Newtons as a measure of force is routinely used in biomechanical research but not in a medical setting. We used an example of 0.5 N being the force exerted when a finger is tapped on a smartphone as a reference for respondents.[43] In the absence of ready availability of force sensors to demonstrate force, this allows limited evaluation of trainees' understanding of mechanical properties.

Conclusion

Training urologists report large volumes of endourology cases with competency in retrograde endourological techniques and a good demonstration of clinical knowledge. Despite high levels of exposure to endourology, trainees display limited knowledge of the theory behind laser settings, laser safety and the mechanical properties of the upper urinary tract. Further research is needed in the clinical setting to accurately describe the biomechanical properties of the human ureter and to apply this to day-to-day practice. Surgical training should focus on the science behind technologies to ensure effective use and best patient outcomes. It is essential to have good tools, but it is also essential that we use them in the correct way.

Future Prospects

Training urologists report large volumes of endourology cases with competency in retrograde endourological techniques and a good demonstration of clinical knowledge. Despite high levels of exposure to endourology, trainees display limited knowledge of the theory behind laser settings, laser safety and the mechanical properties of the upper urinary tract. Further research is needed in the clinical setting to accurately describe the biomechanical properties of the human ureter and to apply this to day-to-day practice. Surgical training should focus on the science behind technologies to ensure effective use and best patient outcomes. It is essential to have good tools, but it is also essential that we use them in the correct way.

Authors' Contribution

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Formal analysis: Sorcha O'Meara, Stefanie Croghan.
Investigation: Sorcha O'Meara.
Methodology: Sorcha O'Meara, Stefanie Croghan.
Project administration: Sorcha O'Meara.
Resources: Sorcha O'Meara.
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Supervision: Niall F. Davis, Fergal J. O'Brien.
Validation: Niall F. Davis, Sorcha O'Meara.
Visualization: Niall F. Davis, Sorcha O'Meara
Writing–original draft: Sorcha O'Meara
Writing–review & editing: Niall F. Davis, Sorcha O'Meara

Competing Interests

The authors declare no conflict of interest.

Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1975 Declaration of Helsinki and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the authors.

Funding

This research was funded by the RCSI Blackrock Clinic StAR MD programme 2020.

Supplementary Files

Supplementary file 1. Survey Circulated to Training Urologists.

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