



# Flexible ureteroscopy for lower pole calculus: is it still a challenge?

Anil Shrestha<sup>1,2</sup> · Baikuntha Adhikari<sup>1</sup> · Frederic Panthier<sup>3</sup> · Saroj Baidya<sup>2</sup> · Vineet Gauhar<sup>4</sup> · Olivier Traxer<sup>3</sup>

Received: 29 July 2023 / Accepted: 28 August 2023 / Published online: 20 September 2023

© The Author(s), under exclusive licence to Springer-Verlag GmbH Germany, part of Springer Nature 2023, Corrected publication 2023

## Abstract

**Purpose** Flexible ureteroscopy (fURS) is steadily gaining popularity in the management of renal calculi, including those located in the lower pole (LP). Due to difficulty in accessing to the LP of kidney in minority of cases with fURS and reports of lower stone-free rate (SFR), it is still considered as a challenge in selected cases. The purpose of the review was to analyze the various aspects of fURS for LP stones.

**Methods** An extensive review of the recent literature was done including different factors such as anatomy, preoperative stenting, stone size, flexible scopes, types of lasers, laser fibers, suction, relocation, stone-free rates, and complications.

**Results** The significance of various lower pole anatomical measurements remain a subject of debate and requires standardization. Recent improvements in fURS such as single-use digital scopes with better vision and flexibility, high power laser, thulium fiber laser, smaller laser fiber, and accessories have significantly contributed to make flexible ureteroscopy more effective and safer in the management of LP stone. The utilization of thulium fiber lasers in conjunction with various suction devices is being recognized and can significantly improve SFR.

**Conclusions** With the significant advancement of various aspects of fURS, this treatment modality has shown remarkable efficacy and gaining widespread acceptance in management of LP kidney stones. These developments have made the fURS of LP stones less challenging.

**Keywords** Flexible ureteroscopy · Laser · Stone free rate · Lower pole anatomy · Urolithiasis · Flexible ureterorenoscope

## Introduction

Lower pole is considered as most prevalent location for renal stones [1]. Flexible ureteroscopy has gained significant popularity globally among both urologists and patients due to its minimally invasive nature and comparable rates of stone clearance, which makes it an effective management option for urolithiasis [2]. However, LP presents unique anatomical challenges that can impede lithotripsy access and hinder the removal of stone fragments, even after thorough lithotripsy treatment [3]. Despite recent advancements in laser technology, scopes, and lithotripsy accessories, the SFR for

LP stones is reported to be inferior to that of stones in other locations [4]. Clinical guidelines recommend endoscopic interventions for renal stones up to 20 mm in size, as well as for challenging LP stones [5–7].

This review aims to focus on various aspects of fURS for LP stones and attempt to analyze whether this treatment modality remains challenging in that location.

## Materials and methods

A systematic literature search was conducted using PubMed and Google Scholar database in March–June 2023 using the following terms in several combinations: lower pole, lower calyx, inferior calyx, renal stones, urinary lithiasis, lower pole anatomy, flexible ureteroscopes, retrograde intrarenal surgery, laser, treatment and stone-free rates. The articles published between 2013 and 2023 were included. The aim was to analyze the different aspects of fURS for the treatment of LP stones.

✉ Anil Shrestha  
any177@me.com

<sup>1</sup> National Academy of Medical Sciences, Bir Hospital, Kathmandu, Nepal

<sup>2</sup> B&B Hospital, Lalitpur, Nepal

<sup>3</sup> Hôpital Tenon, Sorbonne Université, Paris, France

<sup>4</sup> NgTeng Fong General Hospital, Singapore, Singapore

## Lower pole anatomy

Numerous studies have examined the impact of LP anatomy on treatment success. However, the significance of various anatomical measurements such as the infundibulo-pelvic angle (IPA), infundibular width (IW), and infundibular length (IL) remains a subject of debate and requires standardization. As reported by Karim et al., there is significant variation in IPA value that determines successful and unsuccessful procedure in four different studies [8]. The challenges associated with the study of LP anatomy in relation to treatment success include a wide variety of measurement methods of IPA, significant intra-observer and inter-observer variations of IPA measurement, inconsistencies in measurement obtained through different imaging modalities, and the absence of established cutoff values. The reported IPA cutoff for difficult LP access and low SFR ranges from 30 to 90 degree [3, 9, 10]. Whereas, Kilicarslan could not find any correlation of IPA and IL with success of fURS [11]. Similarly, the correlation between preoperative imaging measurements of LP anatomy and intraoperative retrograde pyelogram warrants further investigation.

## Pre-stenting for LP Stone

The available data on the advantages of pre-stenting in treating LP stones with fURS are limited. Specifically, studies conducted by Golomb et al. and Giulioni et al. have shown that preoperative stenting can predict long-term SFR in LP stones [12, 13]. Pre-stenting being a predictor factor for SFR is supported by other studies, although they were not specifically focused on LP stones [14, 15]. Conversely, some studies have found no significant difference in SFR between patients who underwent pre-stenting and those who did not [16–19]. Additionally, two meta-analyses have indicated that pre-stenting is associated with higher stone-free rates, increased success in ureteral access sheath (UAS) placement, and decreased risk of intraoperative ureteric injuries [20, 21]. However, it is important to note that these meta-analyses did not specifically investigate stones in LP. Given the existing evidence, reaching a definitive conclusion is challenging, and further prospective studies are needed to provide more conclusive insights.

## Flexible ureterorenoscopes

The performance characteristics of the flexible ureteroscope are the most important parameters that significantly influence the success of fURS.

Even with the availability of modern ureterorenoscopes with 275° upward and downward active deflections,

approaching an acute-angled LP calyx can sometimes pose challenges. A study conducted by Dragos et al., employing a bench-training model (K-Box, Porgès-Coloplast) and utilizing nine different scopes models (BOA vision, COBRA vision, R.Wolf; FLEX X<sup>2</sup>, FLEX Xc, K.Storz; LithoVue, Boston Scientific; URF-P5, URF-P6, URF-V, URF-V2, Olympus), demonstrated that digital scopes were less effective in accessing the sharply angled inferior calyx and exhibited reduced end-tip deflection compared to fiber optic ones [22]. Consequently, fiber optic ureteroscopes appear to be a logical choice when encountering a challenging inferior calyx [22]. Likewise, a prospective comparison between reusable fiber optic and reusable digital scopes revealed a higher failure rate in accessing the entire pelvicalyceal system with the digital scope [23]. Golomb et al. reported an incidence of 5.4% unreachable stones during retrograde intrarenal surgery (RIRS) for LP stones using fiber optic scope Flex-X2 (Karl Storz, Germany) [12]. We could interrogate on the possibility for in situ thulium fiber laser (TFL) lithotripsy in those 5.4% unreachable stones for basketing. This specific aspect represents a major limitation when looking for high-level data that compare fURS to percutaneous procedures for LP stones. Given the advent of 7.5Fr single-use scopes and TFL, updating these studies would be of significant interest.

Single-use digital flexible ureteroscopes have visual image quality and intraoperative maneuverability approaching that of a reusable digital flexible ureteroscope [24]. Furthermore, the deflection ability of these scopes appears to be comparable to that of reusable scopes under various conditions, even when ancillary equipment such as guidewires and baskets are used [25, 26]. The perceived advantages of the disposable scope include immediate availability for use, elimination of the need for reprocessing and sterilization, reduced acquisition cost, as well as decreased costs associated with breakage and maintenance [27]. Studies have documented that the use of disposable scopes during flexible ureteroscopy (fURS) in the LP results in shorter mean operative duration and fluoroscopy duration, while maintaining a similar complication rate compared to reusable scopes [28–30]. Additionally, there is a non-significant increase in the stone-free rate favoring the use of disposable scopes [29, 31, 32]. A multi-center FLEXOR study demonstrated that urologists prefer disposable scopes for larger LP stones [33]. Over the course of time, reusable scopes are likely to perform worse due to reduction in tip deflection with repeated use. The tip deflection of 215° and less makes it impossible to reach LP [34]. The economic superiority of disposable scopes has been shown in centers with low case volumes or in cases involving large-volume lower pole stones, whereas reusable scopes tend to be more cost-effective in high-volume centers [30, 35]. Moreover, the availability of disposable scopes also facilitates the training of residents in fURS.

The position of the working channel in various flexible ureteroscopes exhibits variability depending on the manufacturer [36]. This variation in the working channel position directly affects the placement of the laser fiber/basket that is inserted through the channel, subsequently influencing the ability to reach and treat stones located in different positions within the kidney [37]. Villa et al. conducted an ex vivo study, revealing that the 3 o'clock position of the working channel demonstrated greater effectiveness for the right posterior surfaces and left lateral surface of the lower pole, while the 9 o'clock position proved more effective for the left posterior and right lateral surfaces of the LP [38]. The position of the working channel in endoscopes during the treatment of LP stones has the potential to enhance access to the stone and subsequently facilitate easier lithotripsy procedures [38, 39]. However, there is currently a lack of studies specifically examining the role of the working channel's position in flexible ureterorenoscopes and its efficacy during in vivo fURS for the LP. The challenge posed by the working channel position can be mitigated through the availability of movable channel endoscopes. Moreover, some manufacturers have started two different single-use scopes of same model with working channel in two different positions at 11 and 2 o'clock position for this purpose.

## Laser

Laser lithotripsy has become widely used for the treatment of urinary stones during fURS [7]. Pulsed lasers are the only suitable choice for lithotripsy, and among them, the holmium:yttrium–aluminium–garnet (Ho:YAG) laser remains the preferred and most effective option for lithotripsy due to its specific characteristics, effectiveness, and safety [40, 41]. Nevertheless, new lasers, such as the TFL and the pulsed thulium:yttrium–aluminium–garnet (Tm:YAG) laser, have recently been introduced for stone treatment. These lasers differ in terms of their technological aspects, including the smallest laser fiber size [42, 43]. Theoretically, TFL can be used with laser fiber size as small as 50  $\mu\text{m}$ , but currently, only 150- $\mu\text{m}$ -diameter fibers are available. In comparison, the minimum laser fiber size for Ho:YAG and Tm:YAG lasers are 200  $\mu\text{m}$  and 272  $\mu\text{m}$ , respectively. Considering that the laser fiber size affects the deflection of the flexible ureteroscope during laser lithotripsy, it is evident that the thinnest fiber allows for optimal deflection and access to the lower pole of the kidney [22]. Furthermore, a smaller laser fiber provides more space for irrigation, enhancing visibility, temperature control, and pressure control, which are crucial factors during fURS [44]. Currently, there is a lack of specific evidence comparing these three laser technologies for laser lithotripsy during fURS, and international guideline panels have not provided any recommendations on this matter [6, 7, 45–47]. However,

in vitro studies have reported laser outcomes using a bending radius of 180° to replicate in vivo access to the LP of the kidney. Additionally, use of smaller diameter fiber (150 micron TFL fiber) produces smaller fissures and fragments which are more likely to pass from LP spontaneously [48].

There is currently no consensus regarding the ideal laser settings for both Ho:YAG and TFL lasers [48–50]. Various laser modes have been suggested to distinguish between fragmentation, dusting, and pop-corning effects during Ho:YAG lithotripsy. However, the existing data appear to suggest that urologists should first define their objectives: whether they aim for fragmentation, pulverization, or a combination of both (i.e., pop-corning) [51]. Additionally, individual presets are associated with specific lithotripsy techniques, such as continuous or burst modes, which depend on the duty cycle of the operator [52].

During in situ lithotripsy for LP stones, laser fiber diameter and laser settings should be considered not only to achieve better access and efficient lithotripsy but also to prevent fracture of the fiber and subsequent scope damage. Haddad et al. showed in Ho:YAG laser low pulse energy (0.5 J)–long pulse duration, a 20% risk of fiber fracture at 9 mm 180° bend, which is lower to the one (50%) reported with high pulse energy (1.5 J) and short pulse duration [53]. These results were consistent with another in vitro study that showed in dusting settings (0.2–0.8 J, long pulse) for 200  $\mu\text{m}$  laser fibers, a 50% fracture rate at bending radius  $\leq 6$  mm, while none broke at radius  $\geq 7.5$  mm [54]. All fractures occurred during laser activation. The pulse rate was not found to be an influencing factor on fiber fracture risks. Moreover, at 25 mm 180° bending, no fiber fracture were reported by Bourdouis et al., and no significant power loss occurred in fiber output after 15 min continuous firing of laser [55]. Authors also reported that bending was not associated with power loss. Regarding TFL, no fiber fracture was reported in vitro within the range of 150 to 365  $\mu\text{m}$  laser fiber diameter [54]. To date, no evidence has been published for Tm:YAG about fiber fracture risk.

For in situ lithotripsy for LP stone, TFL could represent an interesting tool with smaller laser fiber diameter (150  $\mu\text{m}$ ) and better dusting efficiency (fragments < 250  $\mu\text{m}$ ) [42, 56]. Thus, by a better irrigation/visualization and finer dust production, need of fragment retrieval from LP will be significantly less with TFL, compared to Ho:YAG. As previously said, TFL allows in situ lithotripsy with small laser fibers and limit the scope deflection minimally. In an in vitro study by Buell et al. using 3D printed kidney benchtop model, TFL lithotripsy for lower pole stones showed remarkable 35% reduction in residual fragments when compared to Ho:YAG lithotripsy. Moreover, the use of a 150  $\mu\text{m}$  TFL fiber resulted in significantly lower deflection loss compared to both the 200  $\mu\text{m}$  TFL fiber and the 272  $\mu\text{m}$  Ho:YAG fiber. Additionally, the irrigation flow rate was notably improved when the

smaller TFL fiber was used [57]. The benefits of TFL for LP stone over Ho:YAG, needs to be established with good quality in vivo studies. Similarly, to our knowledge, there is no comparative trial between in situ TFL lithotripsy and PCNL for lower pole stones.

## Stone factors

### (a) Stone < 10 mm

Both shockwave lithotripsy (SWL) and fURS are the recommended treatment options for LP stones < 10 mm by AUA and EAU guidelines [6, 7]. However, higher stone-free rate has been reported with fURS, whereas pretreatment rate was significantly higher with patients undergoing SWL. While stone composition and density are to be considered while opting for SWL, it is less likely to affect fURS. A systematic review and meta-analysis of percutaneous nephrolithotomy (PCNL), fURS, and SWL for LP stones less than 20 mm by Kallindonis et al. concurred that no study reported PCNL as treatment option for stones < 10 mm [58]. Additionally, the SFR was significantly higher for fURS group whereas the complications rate was similar for both the groups and re-treatment events were high for SWL in comparison to fURS (OR 8.46, 95% CI 3.59e19.94) ( $I^2=3%$ ,  $p<0.00001$ ) [58].

### (b) Stone 10–20 mm

Ureteroscopy is an established and commonly preferred option for the treatment of LP stones up to 20 mm with high stone-free rates and low morbidity. Bozzini et al. in their RCT reported similar SFR for fURS and PCNL in LP stone of 10–20 mm size (82.1 and 87.3%,  $p>0.05$ , respectively). The fURS offer the best outcome in terms of procedure length, radiation exposure, and hospital stay compared to PCNL [59]. Another RCT by Kandemir et al. showed both microperc and fURS had similar stone clearance and complication rates in the management of LP stones < 15 mm and both are safe and effective alternatives. However, microperc group had prolonged hospital stay [60].

Rehman et al. compared mini-PCNL to fURS in LP stones of mean maximum diameter of  $15.30\pm 2.21$  mm. Stone clearance after mini-PCNL was higher compared to retrograde intrarenal surgery (RIRS) (92.0 vs. 78.67%,  $p$  value = 0.021). Mean hospital stay after RIRS was  $1.1\pm 0.09$  days, while it was  $2.3\pm 0.64$  days after mini-PCNL ( $p<0.001$ ). Two (2.67%) patients in the mini-PCNL group developed bleeding postoperatively [61]. Similar results were reported comparing super-mini-PCNL and RIRS for < 20 mm LPS (100 vs. 92.61%,  $p=0.171$ ), and comparing for mini-PCNL and RIRS (86.2% vs. 61.4%,  $p=0.002$ ) in obese patients for

20–30 mm LP stones, but with higher complication rate [62, 63].

A recent meta-analysis of 14 randomized control trials involving 2194 patients with (10–20 mm) LP renal stone reported a 90% SFR for RIRS, lower to mini-PCNL (RR = 2.43 91.52; 3.89), but with low complication rate, short hospital stays, and operation time [64]. We have to acknowledge the important variability in stone burden and SFR report in this meta-analysis, decreasing the impact of these results. Moreover, the stone burden evaluation would benefit from the volume utilization instead of the maximum or cumulative diameter, especially for complex LP stones, for without possible relocation [64, 65]. Finally, the SFR definition is variable among surgical techniques and studies. A standardized reporting methodology for endourological procedures is needed to homogenize reported outcomes and improve meta-analysis results.

### (c) Stone > 20 mm

PCNL is the recommended primary modality for stones more than 20 mm [6, 7]. Although the 2 cm has been considered as a cutoff for fURS, it remains an option for patients unfit for the more morbid options such as PCNL. Recent studies have shown the feasibility and efficacy of fURS for stone larger than 2 cm with varying SFR ranging from 50 to 94.2%. Higher complication rate and higher possibility of residual fragments had been observed in those with stone more than 20 mm undergoing fURS [66, 67]. In a study by Sari et al., higher risk of failure of fURS (approximately nine times higher) was reported for stones larger than 17 mm in lower pole [66]. Liu et al. showed better stone free with higher complication rate with mini-PCNL (86.1 vs. 61.4%) when compared to fURS for 20–30 mm lower pole calculus among obese patients [62]. Study comparing fURS and ultra-mini-PCNL in lower poles stones 15 to 35 mm demonstrated similar SFR and complication rate with lesser hemoglobin drop and lower hospital stays in the fURS group [68].

Recently other parameters such as stone area and volume rather than size have also been considered when deciding treatment options for lower pole stones. The lower pole stone size more than  $132.5\text{ mm}^2$  was an independent risk factor that negatively affected the success following fURS [10]. The stone density is less likely to influence the success of fURS unlike that in SWL; however, higher stone density and brushite stones had shown to negatively affect the stone-free status following fURS [9, 69].

## Relocation vs. in situ lithotripsy

Scope deflection, dust clearance from LP, and risk of fiber fracture during lithotripsy are the main reasons to relocate a LPS into the renal pelvis or favorable calyx [53, 54]. Recently, we reported in a prospective randomized trial that there is no difference in the stone-free rate at 1-month follow-up comparing in situ lithotripsy and relocation for LP stones during RIRS with Ho:YAG (35 vs. 33 patients, respectively) [70]. Despite a recent report indicating improved SFR in LP stones using the displacement technique compared to in situ lithotripsy, one of the two surgeons involved in the study failed to achieve a significant difference in SFR [71]. Furthermore, there is currently no tool available to predict the possibility of retrogradely accessing and relocating LP stones. Consequently, relocation may not be deemed mandatory for achieving favorable SFR, particularly when utilizing advanced laser technology like TFL. However, the primary challenge lies in achieving access to LP stones.

Both scopes and surgical skills would be crucial in this scenario [22, 72]. For in situ lithotripsy in LP stones, TFL could represent an interesting tool with smaller laser fiber diameter (150  $\mu\text{m}$ ), better dusting efficiency (fragments < 250  $\mu\text{m}$ ) [42, 56]. Thus, by a better irrigation/visualization and dust production, lower fragments retrieval will be required with TFL use, compared to Ho:YAG. To our knowledge, there is no comparative trial between fURS with TFL in situ dusting and percutaneous procedures for LP stones.

## Assessment of SFR

Although there is strong agreement that SFR should be assessed during follow-up, there is no uniformity regarding the timing or modality of imaging study. Assessment of residual stone fragments after fURS is important to assess need of auxiliary procedures. The studies also vary in their definition of stone-free rate [73]. A standardized reporting methodology for endourological procedures is needed to homogenize reported outcomes and improve meta-analysis results. Although non-contrast computed tomography (NCCT) is considered the gold standard for assessing residuals, there is growing concern related to the cumulative ionizing radiation exposure following repeated scans. Therefore, efforts to reduce radiation exposure such as low-dose NCCT and use of other modalities such as surgeon's endoscopic evaluation at the end of the procedure, ultrasound (US) and kidneys–ureters–bladder X-ray (KUB) had been evaluated [63, 70]. Danilovic et al. compared the role of endoscopic evaluation at the end of surgery, 90th postoperative day NCCT, USG and KUB in patients undergoing RIRS [74]. They suggested it was reasonable to delay the first imaging

follow-up study to 90 postoperative days as residual fragments observed at endoscopic evaluation were significantly reduced by 90th POD (62.6% residual vs. 25.2%). They suggested low-dose NCCT for those with endoscopic evaluation showing stone free or residual of 0–2 mm and, ultrasound if endoscopic evaluation showing residual fragments > 2 mm [74]. Sensitivity of USG and X-ray KUB needs to be considered during assessment of smaller stones and dust. There is no different protocol proposed and described to our knowledge for the assessment of SFR in LP stones after fURS, that includes need of post-operative stenting and duration of stenting in LP stones.

A recent multi-center cohort study including 2946 patients reported a 77.8% SFR after RIRS for mean 10 mm LP stones, with or without relocation [13]. Multiple stones (OR 1.380), stone size (OR 1.865), and reusable ureteroscopes (OR 1.414) were significantly associated with the presence of residual fragments (> 2 mm). On the contrary, thulium fiber laser (TFL) (OR 0.341) and pre-stenting (OR 0.750) were less likely associated with the presence of residual fragments [13].

## Use of suction

With scope and laser advancements, LP access and stone disintegration has become better yet the residual fragments challenge persists especially in large stone volume as shown by Guiloini C et al. [13]. In an attempt to improve SFR, in situ dusting and fragmentation with extraction have been compared and both are equally effective [75] but the common issue being removal of LP dust/fragments which sediment by virtue of the anatomical configuration often needing ancillary techniques for removal [9]. To further help clear these fragments, using a suction ureteral access sheath (SUAS) during RIRS has been proposed as an adjunct maneuver [76], yet its limitation is the inability to reach the fragments and need for active manipulation to negate the same. In an audit study using the scope as a direct conduit for aspiration of Gauhar V et al., proposed direct in-scope suction (DISS) may help overcome the residual fragments problem even in LP and larger stones [77]. Another technique described using a flexible and navigable suction UAS (FANS) whereby aided by the scope and maneuvered successfully to the desired stone position including LP, fragments upto 4 mm and dust could be actively aspirated [78]. The team proposed 7.5fr scope and 10fr sheath as a good combination with no sepsis and 94.7% single-stage SFR even with LP stone [79].

The steerable ureteroscopic renal evacuation (SURE) technique performed using the CVAC™ Aspiration System a steerable catheter (with introducer) post-laser lithotripsy is developed by Sur RL et al. [80]. It is effective in stone removal compared to basketing alone and under fluoroscopy

can be placed in LP as well. As quoted by Giulioni C et al., RIRS with aspiration devices favors a higher SFR in all locations, reduces infectious complications, and is a natural successor to the traditional technique [81].

## Complication

fURS has made its mark as more balanced treatment modality in terms of SFR and complication rate in comparison to SWL and PCNL. The complication rate of fURS for lower pole stone is comparable to other locations and it is lower than PCNL for similar size stones [59]. Complication rates of fURS have been reported to be approximately 10–15% with majority of the complications being Clavien II or less [60]. Similarly, in recent study out of 2946 patients undergoing fURS for LP stones, 383 (12.6%) had some complications; however, higher grade complications were seen only in 33 (1.1%) patients [13]. There is higher risk of scope deflection loss and damage of scope by laser fiber in lower pole in case requiring extreme deflection [82].

## Conclusion

With the significant advancement of various aspects of fURS, this treatment modality has shown remarkable efficacy and gaining widespread acceptance in management of LP kidney stones. The introduction of newer generation flexible scopes, single-use scopes, and newer laser technologies including thulium fiber laser, further consolidates the role of fURS for LP stones. The SFR achieved with fURS is significantly superior to that of SWL and marginally lower compared to PCNL for stones up to 20 mm in this anatomical region. Nevertheless, a comparative analysis of PCNL and fURS, incorporating TFL and suction techniques for treating LP stones, holds potential to alter the existing differences in SFR between these modalities. Hence, this area presents an intriguing subject for future research and investigation.

**Author contributions** AS: project/Protocol development, literature search, manuscript writing, critical manuscript editing. BA: protocol development, literature search, manuscript writing and editing. FP: protocol development, literature search, manuscript writing. SB: literature search, manuscript editing. VG: manuscript writing. OT: project development, critical manuscript editing.

**Data Availability** Not applicable.

## Declarations

**Conflict of interest** The authors have no relevant financial or non-financial interests to disclose.

**Ethical approval** No ethical approval required for literature review.

## References

- McClinton S, Starr K, Thomas R, MacLennan G, Lam T, Hernandez R et al (2020) The clinical and cost effectiveness of surgical interventions for stones in the lower pole of the kidney: the percutaneous nephrolithotomy, flexible ureterorenoscopy and extracorporeal shockwave lithotripsy for lower pole kidney stones randomised controlled trial (PUR E RCT) protocol. *Trials* 21(1):479. <https://doi.org/10.1186/s13063-020-04326-x>
- Geraghty RM, Jones P, Somani BK (2017) Worldwide trends of urinary stone disease treatment over the last two decades: a systematic review. *J Endourol* 31(6):547–556. <https://doi.org/10.1089/end.2016.0895>
- Dresner SL, Iremashvili V, Best SL, Hedican SP, Nakada SY (2020) Influence of lower pole infundibulopelvic angle on success of retrograde flexible ureteroscopy and laser lithotripsy for the treatment of renal stones. *J Endourol* 34(6):655–660. <https://doi.org/10.1089/end.2019.0720>
- Yuri P, Hariwibowo R, Soeroharjo I, Danarto R, Hendri AZ, Brodjonegoro SR et al (2018) Meta-analysis of optimal management of lower pole stone of 10–20 mm: flexible ureteroscopy (FURS) versus extracorporeal shock wave lithotripsy (ESWL) versus percutaneous nephrolithotomy (PCNL). *Acta Med Indones* 50(1):18–25
- Zeng G, Traxer O, Zhong W, Osther P, Pearle MS, Preminger GM et al (2023) International Alliance of Urolithiasis guideline on retrograde intrarenal surgery. *BJU Int* 131(2):153–164. <https://doi.org/10.1111/bju.15836>
- Assimos D, Krambeck A, Miller NL, Monga M, Murad MH, Nelson CP et al (2016) Surgical management of stones: American Urological Association/Endourological Society Guideline. *PART I J Urol* 196(4):1153–1160. <https://doi.org/10.1016/j.juro.2016.05.090>
- Skolarikos A, Jung H, Neisius A, Petrik A, Somani B, Thomas T, et al (2023) EAU guidelines on urolithiasis. <https://uroweb.org/guidelines/urolithiasis/chapter/guidelines>. Accessed 20 Feb 2023
- Karim SS, Hanna L, Geraghty R, Somani BK (2020) Role of pelvicalyceal anatomy in the outcomes of retrograde intrarenal surgery (RIRS) for lower pole stones: outcomes with a systematic review of literature. *Urolithiasis* 48(3):263–270. <https://doi.org/10.1007/s00240-019-01150-0>
- Inoue T, Hamamoto S, Okada S, Imai S, Yamamichi F, Fujita M et al (2023) Pelvicalyceal anatomy on the accessibility of reusable flexible ureteroscopy to lower pole calyx during retrograde intrarenal surgery. *Int J Urol* 30(2):220–225. <https://doi.org/10.1111/iju.15091>
- Tastemur S, Senel S, Kizilkan Y, Ozden C (2022) Evaluation of the anatomical factors affecting the success of retrograde intrarenal surgery for isolated lower pole kidney stones. *Urolithiasis* 50(1):65–70. <https://doi.org/10.1007/s00240-021-01279-x>
- Kilicarslan H, Kaynak Y, Kordan Y, Kaygisiz O, Coskun B, Gunseren KO et al (2015) Unfavorable anatomical factors influencing the success of retrograde intrarenal surgery for lower pole renal calculi. *Urol J* 12(2):2065–2068
- Golomb D, Goldberg H, Tapiero S, Stabholz Y, Lotan P, Darwasha AE et al (2023) Retrograde intrarenal surgery for lower pole stones utilizing stone displacement technique yields excellent results. *Asian J Urol* 10(1):58–63. <https://doi.org/10.1016/j.ajur.2021.09.001>
- Giulioni C, Castellani D, Somani BK, Chew BH, Taily T, Keat WOL et al (2023) The efficacy of retrograde intra-renal surgery (RIRS) for lower pole stones: results from 2946 patients. *World J Urol*. <https://doi.org/10.1007/s00345-023-04363-6>
- Assimos D, Crisci A, Culkun D, Xue W, Roelofs A, Duvdevani M et al (2016) Preoperative JJ stent placement in ureteric and renal stone treatment: results from the Clinical Research Office

- of Endourological Society (CROES) ureteroscopy (URS) Global Study. *BJU Int* 117(4):648–654. <https://doi.org/10.1111/bju.13250>
15. Chen H, Pan Y, Xiao M, Yang J, Wei Y (2022) The outcomes of pre-stenting on renal and ureteral stones: a meta-analysis. *Urol Int* 106(5):495–503. <https://doi.org/10.1159/000519473>
  16. Mahajan PM, Padhye AS, Bhavne AA, Sovani YB, Kshirsagar YB, Bapat SS (2009) Is stenting required before retrograde intrarenal surgery with access sheath. *Indian J Urol* 25(3):326–328. <https://doi.org/10.4103/0970-1591.56185>
  17. Yuk HD, Park J, Cho SY, Sung LH, Jeong CW (2020) The effect of preoperative ureteral stenting in retrograde intrarenal surgery: a multicenter, propensity score-matched study. *BMC Urol* 20(1):147. <https://doi.org/10.1186/s12894-020-00715-1>
  18. Assantachai K, Srinualnad S, Leewansangtong S, Taweemonkongsap T, Liangkobkit K, Chotikawanich E (2023) Surgical outcomes of patients who underwent retrograde intrarenal surgery using a ureteral access sheath to manage kidney stones sized 1–2 cm compared between patients who did and did not undergo preoperative ureteral stenting. *Heliyon*. 9(5):e15801. <https://doi.org/10.1016/j.heliyon.2023.e15801>
  19. Lee MH, Lee IJ, Kim TJ, Lee SC, Jeong CW, Hong SK et al (2019) The effect of short-term preoperative ureteral stenting on the outcomes of retrograde intrarenal surgery for renal stones. *World J Urol* 37(7):1435–1440. <https://doi.org/10.1007/s00345-018-2519-9>
  20. Chang X, Wang Y, Li J, Han Z (2021) Pre-stenting versus nonpre-stenting on the outcomes of flexible ureteroscopy for large upper urinary stones: a systematic review and meta-analysis. *Urol Int* 105(7–8):560–567. <https://doi.org/10.1159/000506652>
  21. Law YXT, Teoh JYC, Castellani D, Lim EJ, Chan EOT, Wroclawski M et al (2022) Role of pre-operative ureteral stent on outcomes of retrograde intra-renal surgery (RIRS): systematic review and meta-analysis of 3831 patients and comparison of Asian and non-Asian cohorts. *World J Urol* 40(6):1377–1389. <https://doi.org/10.1007/s00345-022-03935-2>
  22. Dragos LB, Somani BK, Sener ET, Buttice S, Proietti S, Ploumidis A, et al. (2017) Which flexible ureteroscopes (Digital vs. Fiber-Optic) Can easily reach the difficult lower pole calices and have better end-tip deflection: in vitro study On K-box. A PETRA evaluation. *J Endourol* 31(7):630–7. <https://doi.org/10.1089/end.2017.0109>
  23. Somani BK, Al-Qahtani SM, de Medina SD, Traxer O (2013) Outcomes of flexible ureterorenoscopy and laser fragmentation for renal stones: comparison between digital and conventional ureteroscope. *Urology* 82(5):1017–1019. <https://doi.org/10.1016/j.urology.2013.07.017>
  24. Kam J, Yuminaga Y, Beattie K, Ling KY, Arianayagam M, Canagasingham B et al (2019) Single use versus reusable digital flexible ureteroscopes: A prospective comparative study. *Int J Urol* 26(10):999–1005. <https://doi.org/10.1111/iju.14091>
  25. Scotland KB, Chan JYH, Chew BH (2019) Single-use flexible ureteroscopes: how do they compare with reusable ureteroscopes? *J Endourol* 33(2):71–78. <https://doi.org/10.1089/end.2018.0785>
  26. Bragaru M, Multescu R, Geavlete P, Popescu R, Geavlete B (2023) Comparison of flexible ureteroscope performance between reusable and single-use models. *J Clin Med*. 12(3):1093. <https://doi.org/10.3390/jcm12031093>
  27. Ventimiglia E, Somani BK, Traxer O (2020) Flexible ureteroscopy: reuse? Or is single use the new direction? *Curr Opin Urol* 30(2):113–119. <https://doi.org/10.1097/mou.0000000000000700>
  28. Göger YE, Özkent MS, Kılınç MT, Taşkapu HH, Göger E, Aydın A et al (2021) Efficiency of retrograde intrarenal surgery in lower pole stones: disposable flexible ureterorenoscopy or reusable flexible ureterorenoscopy? *World J Urol* 39(9):3643–3650. <https://doi.org/10.1007/s00345-021-03656-y>
  29. Salvadó JA, Cabello JM, Moreno S, Cabello R, Olivares R, Velasco A (2019) Endoscopic treatment of lower pole stones: is a disposable ureteroscope preferable? Results of a prospective case-control study. *Cent Eur J Urol* 72(3):280–284. <https://doi.org/10.5173/cej.2019.1962>
  30. Usawachintachit M, Isaacson DS, Taguchi K, Tzou DT, Hsi RS, Sherer BA et al (2017) A prospective case-control study comparing lithoviv, a single-use, flexible disposable ureteroscope, with flexible, reusable fiber-optic ureteroscopes. *J Endourol* 31(5):468–475. <https://doi.org/10.1089/end.2017.0027>
  31. Mager R, Kurosch M, Höfner T, Frees S, Haferkamp A, Neisius A (2018) Clinical outcomes and costs of reusable and single-use flexible ureterorenoscopes: a prospective cohort study. *Urolithiasis* 46(6):587–593. <https://doi.org/10.1007/s00240-018-1042-1>
  32. Yang E, Jing S, Niu Y, Qi S, Yadav PK, Yang L et al (2021) Single-use digital flexible ureteroscopes as a safe and effective choice for the treatment of lower pole renal stones: secondary analysis of a randomized-controlled trial. *J Endourol* 35(12):1773–1778. <https://doi.org/10.1089/end.2021.0170>
  33. Gauhar V, Chai CA, Chew BH, Singh A, Castellani D, Tailly T et al (2023) RIRS with disposable or reusable scopes: does it make a difference? Results from the multicenter FLEXOR study. *Ther Adv Urol* 15:17562872231158072. <https://doi.org/10.1177/17562872231158072>
  34. Legemate JD, Kamphuis GM, Freund JE, Baard J, Zanetti SP, Catellani M et al (2019) Durability of flexible ureteroscopes: a prospective evaluation of longevity, the factors that affect it, and damage mechanisms. *Eur Urol Focus* 5(6):1105–1111. <https://doi.org/10.1016/j.euf.2018.03.001>
  35. Martin CJ, McAdams SB, Abdul-Muhsin H, Lim VM, Nunez-Nateras R, Tyson MD et al (2017) The economic implications of a reusable flexible digital ureteroscope: a cost-benefit analysis. *J Urol* 197(3 Pt 1):730–735. <https://doi.org/10.1016/j.juro.2016.09.085>
  36. Lildal SK, Andreassen KH, Baard J, Brehmer M, Bultitude M, Eriksson Y et al (2021) Consultation on kidney stones, Copenhagen 2019: aspects of intracorporeal lithotripsy in flexible ureterorenoscopy. *World J Urol* 39(6):1673–1682. <https://doi.org/10.1007/s00345-020-03481-9>
  37. Inoue T, Yamamichi F, Okada S, Hamamoto S, Fujisawa M (2020) Change in irrigation flow through a flexible ureteroscope with various devices in the working channel: comparison between an automatic irrigation pump and gravity-based irrigation. *Int J Urol* 27(4):333–338. <https://doi.org/10.1111/iju.14197>
  38. Villa L, Ventimiglia E, Proietti S, Giusti G, Briganti A, Salonia A et al (2020) Does working channel position influence the effectiveness of flexible ureteroscopy? Results from an in vitro study. *BJU Int* 125(3):449–456. <https://doi.org/10.1111/bju.14923>
  39. Doizi S, Traxer O (2018) Flexible ureteroscopy: technique, tips and tricks. *Urolithiasis* 46(1):47–58. <https://doi.org/10.1007/s00240-017-1030-x>
  40. Fried NM, Irby PB (2018) Advances in laser technology and fibre-optic delivery systems in lithotripsy. *Nat Rev Urol* 15(9):563–573. <https://doi.org/10.1038/s41585-018-0035-8>
  41. Terry RS, Whelan PS, Lipkin ME (2020) New devices for kidney stone management. *Curr Opin Urol* 30(2):144–148. <https://doi.org/10.1097/mou.0000000000000710>
  42. Traxer O, Keller EX (2020) Thulium fiber laser: the new player for kidney stone treatment? A comparison with Holmium: YAG laser. *World J Urol* 38(8):1883–1894. <https://doi.org/10.1007/s00345-019-02654-5>
  43. Petzold R, Miernik A, Suarez-Ibarrola R (2021) In vitro dusting performance of a new solid state thulium laser compared to holmium laser lithotripsy. *J Endourol* 35(2):221–225. <https://doi.org/10.1089/end.2020.0525>

44. Panthier F, Pauchard F, Traxer O (2023) Retrograde intra renal surgery and safety: pressure and temperature. A systematic review. *Curr Opin Urol* 33(4):308–317. <https://doi.org/10.1097/mou.0000000000001102>
45. Ulvik Ø, Æsøy MS, Juliebø-Jones P, Gjengstø P, Beisland C (2022) Thulium fibre laser versus holmium: YAG for ureteroscopic lithotripsy: outcomes from a prospective randomised clinical trial. *Eur Urol* 82(1):73–79. <https://doi.org/10.1016/j.eururo.2022.02.027>
46. Kraft L, Yilmaz M, Petzold R, Gratzke C, Suarez-Ibarrola R, Miernik A (2022) Dusting efficiency of a novel pulsed thulium: yttrium aluminum garnet laser vs a thulium fiber laser. *J Endourol* 36(2):259–265. <https://doi.org/10.1089/end.2021.0441>
47. Epidemiologie Des Urgences Urologiques En C.H.U.: Accessed
48. Panthier F, Doizi S, Lapouge P, Chaussain C, Kogane N, Berthe L et al (2021) Comparison of the ablation rates, fissures and fragments produced with 150 µm and 272 µm laser fibers with superpulsed thulium fiber laser: an in vitro study. *World J Urol* 39(6):1683–1691. <https://doi.org/10.1007/s00345-020-03186-z>
49. Sierra A, Corrales M, Piñero A, Kolvatzis M, Somani B, Traxer O (2022) Glossary of pre-settings given by laser companies: no consensus! *World J Urol* 40(9):2313–2321. <https://doi.org/10.1007/s00345-022-04090-4>
50. Sierra A, Corrales M, Piñero A, Traxer O (2022) Thulium fiber laser pre-settings during ureterorenoscopy: Twitter's experts' recommendations. *World J Urol* 40(6):1529–1535. <https://doi.org/10.1007/s00345-022-03966-9>
51. Aldoukhi AH, Roberts WW, Hall TL, Teichman JMH, Ghani KR (2018) Understanding the popcorn effect during holmium laser lithotripsy for dusting. *Urology* 122:52–57. <https://doi.org/10.1016/j.urology.2018.08.031>
52. Louters MM, Dau JJ, Hall TL, Ghani KR, Roberts WW (2022) Laser operator duty cycle effect on temperature and thermal dose: in-vitro study. *World J Urol* 40(6):1575–1580. <https://doi.org/10.1007/s00345-022-03967-8>
53. Haddad M, Emiliani E, Rouchousse Y, Coste F, Doizi S, Berthe L et al (2017) Impact of the curve diameter and laser settings on laser fiber fracture. *J Endourol* 31(9):918–921. <https://doi.org/10.1089/end.2017.0006>
54. Uzan A, Chiron P, Panthier F, Haddad M, Berthe L, Traxer O et al (2021) Comparison of holmium: YAG and thulium fiber lasers on the risk of laser fiber fracture. *J Clin Med*. 10(13):2960. <https://doi.org/10.3390/jcm10132960>
55. Bourdounis A, Christopoulos P, Raj N, Fedder A, Buchholz N (2016) A comparative in vitro study of power output deterioration over time between Ho: YAG laser fibers from different manufacturers as a function of deflection and power input. *Curr Urol* 9(1):12–18. <https://doi.org/10.1159/000442844>
56. Keller EX, De Coninck V, Doizi S, Daudon M, Traxer O (2021) What is the exact definition of stone dust? An in vitro evaluation. *World J Urol* 39(1):187–194. <https://doi.org/10.1007/s00345-020-03178-z>
57. Buell MI, Amasyali AS, Chen N, Belle JD, Keheila M, Baldwin EA et al (2022) Thulium versus holmium in situ lower pole laser lithotripsy. *Can J Urol* 29(6):11371–11377
58. Kallidonis P, Ntasiotis P, Somani B, Adamou C, Emiliani E, Knoll T et al (2020) Systematic review and meta-analysis comparing percutaneous nephrolithotomy, retrograde intrarenal surgery and shock wave lithotripsy for lower pole renal stones less than 2 cm in maximum diameter. *J Urol* 204(3):427–433. <https://doi.org/10.1097/ju.0000000000001013>
59. Bozzini G, Verze P, Arcaniolo D, Dal Piaz O, Buffi NM, Guazzoni G et al (2017) A prospective randomized comparison among SWL, PCNL and RIRS for lower calyceal stones less than 2 cm: a multicenter experience : A better understanding on the treatment options for lower pole stones. *World J Urol* 35(12):1967–1975. <https://doi.org/10.1007/s00345-017-2084-7>
60. Kandemir A, Guven S, Balasar M, Sonmez MG, Taskapu H, Gurbuz R (2017) A prospective randomized comparison of micropercutaneous nephrolithotomy (Microperc) and retrograde intrarenal surgery (RIRS) for the management of lower pole kidney stones. *World J Urol* 35(11):1771–1776. <https://doi.org/10.1007/s00345-017-2058-9>
61. Ur Rehman O, Imran M, Rafaqat M, Haider FUR, Rehman A, Farooq U et al (2023) Outcomes in lower pole kidney stone management using mini-percutaneous nephrolithotomy compared with retrograde intra renal surgery: a randomized controlled trial. *Cureus*. 15(2):e35343. <https://doi.org/10.7759/cureus.35343>
62. Liu X, Xia D, Peng E, Tong Y, Liu H, Wang X et al (2022) Comparison of two techniques for the management of 2–3 cm lower pole renal calculi in obese patients. *World J Urol* 40(2):513–518. <https://doi.org/10.1007/s00345-021-03872-6>
63. Pillai SB, Chawla A, de la Rosette J, Laguna P, Guddeti R, Reddy SJ et al (2022) Super-mini percutaneous nephrolithotomy (SMP) vs retrograde intrarenal surgery (RIRS) in the management of renal calculi ≤ 2 cm: a propensity matched study. *World J Urol* 40(2):553–562. <https://doi.org/10.1007/s00345-021-03860-w>
64. Awedew AF, Seman YS, Yalew DZ, Wondmeneh YC, Yigzaw WA (2023) Efficacy and safety of surgical treatment for 1–2 cm sized lower pole of renal stone: network meta-analysis of randomized control trials. *Urolithiasis* 51(1):82. <https://doi.org/10.1007/s00240-023-01454-2>
65. Panthier F, Doizi S, Illoul L, Berthe L, Traxer O (2021) Developing free three-dimensional software for surgical planning for kidney stones: volume is better than diameter. *Eur Urol Focus* 7(3):589–590. <https://doi.org/10.1016/j.euf.2020.06.003>
66. Sari S, Ozok HU, Topaloglu H, Cakici MC, Ozdemir H, Karakoyunlu AN et al (2017) The association of a number of anatomical factors with the success of retrograde intrarenal surgery in lower calyceal stones. *Urol J* 14(4):4008–4014
67. Sebaey A, Taleb AA, Elbashir S, Gomaa R, Elshazli A, Saber W (2022) Flexible ureterorenoscopy (RIRS) vs. Mini-percutaneous nephrolithotomy (MINI-PCNL) for renal stones 20–30 mm a prospective randomized study. *African J Urol* 28(1):13. <https://doi.org/10.1186/s12301-022-00278-7>
68. Li Z, Lai C, Shah AK, Xie W, Liu C, Huang L et al (2020) Comparative analysis of retrograde intrarenal surgery and modified ultra-mini percutaneous nephrolithotomy in management of lower pole renal stones (1.5–3.5 cm). *BMC Urology*. 20(1):27. <https://doi.org/10.1186/s12894-020-00586-6>
69. Jessen JP, Honeck P, Knoll T, Wendt-Nordahl G (2014) Flexible ureterorenoscopy for lower pole stones: influence of the collecting system's anatomy. *J Endourol* 28(2):146–151. <https://doi.org/10.1089/end.2013.0401>
70. Shrestha A, Adhikari B, Shah AK (2023) Does relocation of lower pole stone during retrograde intrarenal surgery improve stone-free rate? A prospective randomized study. *J Endourol* 37(1):21–7. <https://doi.org/10.1089/end.2022.0050>
71. Yaghoubian AJ, Anastos H, Khusid JA, Shimonov R, Lunden DJ, Khargi R et al (2023) Displacement of lower pole stones during retrograde intrarenal surgery improves stone-free status: a prospective randomized controlled trial. *J Urol* 209(5):963–970. <https://doi.org/10.1097/ju.0000000000003199>
72. Baghdadi M, Emiliani E, Talso M, Servián P, Barreiro A, Orosa A et al (2017) Comparison of laser fiber passage in ureteroscopic maximum deflection and their influence on deflection and irrigation: Do we really need the ball tip concept? *World J Urol* 35(2):313–318. <https://doi.org/10.1007/s00345-016-1873-8>
73. Donaldson JF, Lardas M, Scrimgeour D, Stewart F, MacLennan S, Lam TB et al (2015) Systematic review and meta-analysis of the clinical effectiveness of shock wave lithotripsy, retrograde



- intrarenal surgery, and percutaneous nephrolithotomy for lower-pole renal stones. *Eur Urol* 67(4):612–616. <https://doi.org/10.1016/j.eururo.2014.09.054>
74. Danilovic A, Cavalanti A, Rocha BA, Traxer O, Torricelli FCM, Marchini GS et al (2018) Assessment of residual stone fragments after retrograde intrarenal surgery. *J Endourol* 32(12):1108–1113. <https://doi.org/10.1089/end.2018.0529>
75. Gauhar V, Teoh JY, Mulawkar PM, Tak GR, Wroclawski ML, Robles-Torres JI et al (2022) Comparison and outcomes of dusting versus stone fragmentation and extraction in retrograde intrarenal surgery: results of a systematic review and meta-analysis. *Cent Eur J Urol* 75(3):317–327. <https://doi.org/10.5173/cej.2022.0148>
76. Inoue T, Okada S, Hamamoto S, Fujisawa M (2021) Retrograde intrarenal surgery: past, present, and future. *Investig Clin Urol* 62(2):121–135. <https://doi.org/10.4111/icu.20200526>
77. Gauhar V, Somani BK, Heng CT, Gauhar V, Chew BH, Sarica K et al (2022) Technique, feasibility, utility, limitations, and future perspectives of a new technique of applying direct in-scope suction to improve outcomes of retrograde intrarenal surgery for stones. *J Clin Med*. 11(19):5710. <https://doi.org/10.3390/jcm11195710>
78. Gauhar V, Traxer O, Mohammed S, Hamri SB, Lim EJ, Khi Yung F et al (2022) Three different techniques to show utility and outcomes of suction in retrograde intrarenal surgery. *Eur Urol Open Sci* 39:S131–S132. [https://doi.org/10.1016/S2666-1683\(22\)00191-4](https://doi.org/10.1016/S2666-1683(22)00191-4)
79. Gauhar V, Traxer O, Castellani D, Ragoori D, Heng CT, Chew BH et al (2023) A feasibility study on clinical utility, efficacy and limitations of two types of flexible and navigable suction ureteral access sheaths in retrograde intrarenal surgery for renal stones. *Urology*. <https://doi.org/10.1016/j.urology.2023.05.032>
80. Sur RL, Agrawal S, Eisner BH, Haleblan GE, Ganpule AP, Sabnis RB et al (2022) Initial safety and feasibility of steerable ureteroscopic renal evacuation: a novel approach for the treatment of urolithiasis. *J Endourol* 36(9):1161–1167. <https://doi.org/10.1089/end.2021.0759>
81. Giulioni C, Castellani D, Traxer O, Gadzhiev N, Pirola GM, Tanidir Y et al (2023) Experimental and clinical applications and outcomes of using different forms of suction in retrograde intrarenal surgery. Results from a systematic review. *Actas Urol Esp (Engl Ed)*. <https://doi.org/10.1016/j.acuroe.2023.06.001>
82. Forbes CM, Rebullar KA, Teichman JMH (2018) Comparison of flexible ureteroscopy damage rates for lower pole renal stones by laser fiber type. *Lasers Surg Med* 50(8):798–801. <https://doi.org/10.1002/lsm.22822>

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.