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Effect of the Hounsfield Unit Calculated on the Non-contrast Computed Tomography of Kidney and Ureteral Stones on the Success of Fragmentation with a Holmium: YAG Laser in Ureterorenoscopy and Retrograde Intrarenal Surgery

Böbrek ve Üreter Taşlarının Kontrastsız Bilgisayarlı Tomografi Üzerinde Hesaplanan Hounsfield Ünitesinin Holmium Yag Laser ile Yapılan Üreterorenoskopi ve Retrograd İntrarenal Cerrahi Tedavisinde Fragmantasyon Üzerindeki Etkisi

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Abstract

Objective: This study aimed to investigate the effect of stone density on the success of ureterorenoscopy (URS) and retrograde intrarenal surgery (RIRS).
Materials and Methods: The data of patients who underwent URS or RIRS due to kidney and ureteral stones between January 2013 and March 2018 were retrospectively screened. For all patients, age, gender, comorbidities, the American Society of Anesthesiologists (ASA) score, the presence of preoperative double-J (DJ) stents, extracorporeal shock wave lithotripsy (ESWL) history, ipsilateral stone surgery history, the presence of renal anomalies, stone laterality, stone opacity, stone density, stone size, stone volume, operative time, stone-free status, and the presence and size of residual stones were recorded.
Results: The study included 566 patients who underwent URS or RIRS, including 186 women (32.9%) and 380 (67.1%) men. The mean age of the patients was 47 years. The mean stone size was 10 mm, and the mean stone density was 886 Hounsfield units. The mean stone volume was 426.13 mm^3. The mean operative time was 31 minutes. The stone-free rate was 89.4%. Stone density, stone size, and stone volume were positively correlated with operative time ($p<0.001$) and residual stone size ($p<0.001$). Additionally, stone density and residual stone size were positively correlated in the group that did not achieve stone-free status ($p=0.003$).
Conclusion: In this study, it was determined that stone density, stone size, and stone volume were positively correlated with residual stone size and operative time. In addition, stone density was positively correlated with residual stone size among patients who were not stone-free after treatment, indicating that high stone density negatively affects the success of treatment even in cases presenting with small stone size and volume preoperatively.
Keywords: ureteroscopy, retrograde intrarenal surgery, stone density, stone size, stone volume

Özet

Amaç: Bu çalışmada, taş dansitesinin üreterorenoskopi (URS) ve retrograt intrarenal cerrahi (RIRS) başarısı üzerine etkisini araştırmayı amaçladık.
Gereçler ve Yöntemler: Ocak 2013-Mart 2018 tarihleri arasında böbrek ve üreter taşı nedeniyle URS veya RIRS yapılan hastaların verileri retrospektif olarak tarandı. Hastaların yaşı, cinsiyeti, eşlik eden hastalıkları, ASA (American Society of Anesthesiologists) skoru, preoperatif double-J (DJ) stent varlığı, ESWL öyküsü, ipsilateral taş cerrahisi öyküsü, renal anomalinin varlığı, taş lateralitesi, taş opasitesi, taş dansitesi, taş boyutu, taş hacmi, operasyon süresi, taşsızlık durumu ve rezidü taş varlığı kaydedildi.
Bulgular: Çalışmamızda 186 kadın (%32.9), 380 (%67.1) erkek olmak üzere URS ve RIRS yapılan 566 hasta mevcuttu. Hastaların yaş ortalaması 47 idi. Hastaların ortalama taş boyutu 10 mm, ortalama taş dansitesi (HU) 886 idi. Ortalama taş hacmi ise 426.13 mm^3'tü. Ortalama operasyon süresi 31 dakikaydı. Taşsızlık oranı %89.4 idi. Taş dansitesi, taş boyutu ve taş hacminin operasyon süresi ($p<0.001$) ve rezidü taş ($p<0.001$) boyutuyla pozitif korele olduğu belirlendi. Ayrıca, stone free olmayan hastalarda taş dansitesi ile rezidü boyutunun pozitif korele olduğu belirlendi ($p=0.003$).
Sonuç: Çalışmamızda taş dansitesi, taş boyutu ve taş hacminin rezidü taş boyutu ve operasyon süresiyle pozitif korele olduğu belirlendi. Ayrıca, stone-free olmayan hastalarda taş dansitesinin rezidü boyutu ile pozitif korele olması yüksek taş dansitesinin taş boyutu ve hacmi düşük olsa dahi taşsızlığı olumsuz etkilediğini göstermektedir.
Anahtar kelimeler: üreteroskopi, retrograt intrarenal cerrahi, taş dansitesi, taş boyutu, taş hacmi

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Introduction

Urinary system stone disease is one of the oldest diseases affecting human health. The prevalence rate of stone disease varies between 1 and 20%, depending on climate, ethnic characteristics, genetics, and dietary habits. Among individuals with stone disease experiencing at least one episode in their lifetime, the recurrence rate has been reported to be approximately 50% [1]. The prevalence of stone disease is 3-11% in Europe; however, in regions with hot climates, such as Africa and the Middle East, it can reach 20% [2,3]. In Türkiye, this rate was found to be 14.8% according to a study conducted by Akınci et al. [4].

Non-contrast computed tomography (CT) has now replaced urography as the gold standard due to its high sensitivity and accuracy in diagnosing urolithiasis and the incorporation of new techniques to reduce radiation doses [5,6]. In addition to the diagnosis of urolithiasis, CT also provides important information concerning stone location, stone density, stone size, stone volume, stone-to-skin distance, hydronephrosis, and perinephric stranding. Stone density is determined by measuring the Hounsfield unit (HU) of the stone on CT. Through these measurements, the hardness, composition, heterogeneity, or homogeneity of the stone can be calculated. This information is important for clinicians to determine the fragility of the stone [7-9]. Evaluation of stone density has been integrated into daily medical practice to decide on the best treatment option for urinary tract stone disease. It has been suggested that HU affects the success of lithotripsy in treatment methods such as extracorporeal shock wave lithotripsy (ESWL), ureterorenoscopy (URS), and percutaneous nephrolithotomy (PCNL) [10-12].

We hypothesized that stone density would affect the duration of lithotripsy performed with a Holmium laser as well as the postoperative stone-free outcome. Thus, large-volume kidney and ureteral stones with low stone density can be treated with URS and RIRS, and stone density can be an important determinant in case selection. In this study, we aimed to investigate the effect of stone density on the success of URS and RIRS in the treatment of kidney and ureteral stones.

Materials and Methods

After obtaining approval from the Ethics Committee of Bozok University Faculty of Medicine (approval number: 2018-KAEK-189_2018.02.27_13), the data of patients who underwent URS or RIRS due to kidney and ureteral stones from January 1, 2013, to March 31, 2018, were retrospectively screened. Patients who had undergone CT as an imaging modality and whose stone follow-up forms were completed were included in the study. Excluded from the sample were patients aged under 18 years, pregnant women, patients using anticoagulants, those with preoperative urinary tract infections, and those who had a double-J (DJ) stent placed due to reasons such as ureteral stenosis, surgical complications, inability to reach the stone, and pus discharge.

For all patients, age, gender, comorbidities, the American Society of Anesthesiologists (ASA) score, the preoperative presence of a DJ stent and an ESWL history, ipsilateral stone surgery history, the presence of renal anomalies, stone laterality, stone opacity, stone density, stone size, stone volume, operative time, stone-free status, and the presence of and size residual stones were recorded. Taking the length and width obtained from the transverse section and the depth obtained from the coronal plane on CT images, the longest measured diameter was determined as the stone size and recorded in mm. In the presence of multiple stones, stone size was determined by summing the longest diameters of each stone. Stone volume was calculated with the following formula: length x width x depth x 0.52. In the presence of multiple stones, stone volume was determined by calculating the stone volume of each stone and taking their total. In the measurement of stone density, the level where the stone had the largest diameter in transverse sections was determined. Using the circular drawing tool, the largest ellipse that remained in the stone was drawn. The average density of the area within the drawn ellipse was determined in HU. Postoperative DJ stent requirements were recorded. Postoperative DJ stenting was performed according to the surgeon's preference, taking into account factors such as operation time, ureteral calibration-edema, and complete fragmentation of the stone. Plain radiography or urinary ultrasonography was performed the third week after surgery to evaluate whether there was any residual stone. Stones below 2 mm were considered clinically insignificant residual fragments. The size of residual stones was also recorded.

Statistical Analysis

The obtained data were evaluated using the IBM-SPSS software package. Number, percentage, mean ± standard deviation, median, minimum, maximum, and 25-75th percentile values were used as descriptive statistics. The Shapiro-Wilk test was conducted to compare continuous data. Since the normality test result revealed that the data did not comply with a normal distribution, non-parametric methods were employed. The Mann-Whitney U and Kruskal-Wallis tests were used to compare categorical groups, and Spearman correlation analysis was used to compare continuous data. $P \leq 0.05$ was accepted as the statistical significance level.

Results

The study included a total of 566 patients, of whom 186 (32.9%) were women and 380 (67.1%) were men. The mean age of the patients was 47 years. Of all patients, 108 (19.1%) had a history of RIRS, 58 (10.2%) had a history of URS, 28 (4.9%) had a history of PCNL, 16 (2.8%) had a history of open surgery, one (0.2%) had a history of pyeloplasty, and 21 (3.7%) had a history of other genitourinary operations. Preoperatively, DJ stents were present in 54 (9.5%) of the patients. The mean stone size was 10 mm, and the mean stone density was 886 HU. The mean stone volume was 426.13 mm^3. Of the stones, 28.6% were in the distal ureter, 25.6% in the proximal ureter, 18.4% in the renal pelvis, 12.7% in the lower calyx, 3.2% in the upper calyx, 3% in the middle calyx, and 2.7% in the ureteropelvic junction, while the remaining 5.6% were multicalyceal. RIRS was performed in 265 (46.8%) of the patients, and URS in 301 (53.2%). The mean operative time was 31 minutes. The stone-free rate was 89.4%. Of all stones, 387 (68.4%) were opaque, and 179 (31.6%) were non-opaque. No DJ stent was required in

Table 1. Correlation analysis of stone density, stone size, stone volume, residual stone size, and operative time

	Stone density (HU)	Stone size (mm)	Stone volume (mm3)	Residual stone size (mm)	Operative time (min)
Stone density	-	<0.001	<0.001	<0.001	<0.001
Stone size	<0.001	-	<0.001	<0.001	<0.001
Stone volume	<0.001	<0.001	-	<0.001	<0.001
Residual stone size	<0.001	<0.001	<0.001	-	<0.001
Operative time	<0.001	<0.001	<0.001	<0.001	-

HU: Hounsfield unit

Table 2. Statistical comparison of stone density with other parameters

Stone density (HU)									
		Count	Column n %	Mean	SD	Median	Min	Max	P
Stone localization	Upper calyx	18	3.20%	1016	350	1165	404	1400	<0.001
	Middle calyx	17	3.00%	889	386	1002	283	1388	
	Lower calyx	72	12.70%	943	382	960	322	1601	
	Pelvis	104	18.40%	1016	366	1100	330	1605	
	UPJ	15	2.70%	893	384	841	337	1522	
	Proximal ureter	145	25.60%	851	392	911	208	1674	
	Distal ureter	162	28.60%	760	367	737	108	1506	
	Multiple calyces	33	5.80%	1054	314	1110	305	1518	
Opacity	Non-opaque	179	31.60%	469	210	414	108	1450	<0.001
	Opaque	387	68.40%	1079	280	1110	309	1674	
DJ stent requirement	Absent	28	4.90%	529	267	441	108	1303	<0.001
	Present	538	95.10%	905	381	938	119	1674	
Surgical technique	RIRS	265	46.80%	994	364	1056	283	1632	<0.001
	URS	301	53.20%	791	378	789	108	1674	

HU: Hounsfield unit; SD: standard deviation; UPJ: ureteropelvic junction; DJ: double-J; RIRS: retrograde intrarenal surgery; URS: ureterorenoscopy

28 (4.9%) of the patients after surgery. DJ stents were placed in 538 (95.1%) patients after the operation.

Correlation analysis revealed that as stone density increased, stone size (p<0.001), stone volume (p<0.001), residual stone size (p<0.001), and operative time (p<0.001) increased. In addition, as stone volume increased, residual stone size (p<0.001) and operative time (p< 0.001) also increased **(Table 1)**. There was a statistically significant relationship between stone density and stone localization (p<0.001). The highest stone density was detected in the upper calyx and the lowest stone density in the distal ureter. The stone density of opaque stones was found to be significantly higher than that of non-opaque stones (p<0.001). Furthermore, stone density was significantly higher in patients with a postoperative DJ stent requirement than in the remaining patients (p<0.001) **(Table 2).** Among patients who were not stone-free, there was a significant positive correlation between stone density and residual stone size (p=0.003). In the stone-free group, stone density was significantly positively correlated with stone size (p<0.001), stone volume (p<0.001), and operative time (p<0.001) **(Table 3).**

Table 3. Correlation analysis of stone density, stone size, stone volume, residual stone size, and operative time according to stone-free status

Stone-free status		Stone density (HU)	Stone size (mm)	Stone volume (mm^3)	Operative time (min)	Residual stone size (mm)
Absent	Stone density (HU)	-	0.310	0.232	0.455	0.003
	Stone size (mm)	0.310	-	<0.001	<0.001	<0.001
	Stone volume (mm3)	0.232	<0.001	-	<0.001	<0.001
	Operative time (min)	0.455	<0.001	<0.001	-	=0.001
	Residual stone size (mm)	=0.003	<0.001	<0.001	=0.001	-
Present	Stone density (HU)	-	<0.001	<0.001	<0.001	0.894
	Stone size (mm)	<0.001	-	<0.001	<0.001	0.372
	Stone volume (mm3)	<0.001	<0.001	-	<0.001	0.043
	Operative time (min)	<0.001	<0.001	<0.001	-	0.117
	Residual stone size (mm)	0.894	0.372	0.043	0.117	-

HU: Hounsfield unit

Discussion

With the developments in technology, treatment of urinary system stone disease has become more non-invasive and comfortable. When determining the treatment method, factors such as stone size, stone volume, stone localization, and stone density are taken into account. The main objective is to achieve stone-free status. However, residual stone fragments after treatment may cause new stone formation and lead to the need for repeated operations. In the current study, we investigated the effect of stone density on the success of URS and RIRS. Our results revealed that stone density was significantly positively correlated with operative time and residual stone size. In addition, we found that stone density was significantly correlated with residual stone size among patients that did not achieve stone-free status after treatment and with operative time among stone-free patients. These findings demonstrate the importance of the preoperative evaluation of stone density.

There was a significant relationship between stone localization and stone density. The highest stone density was found in the upper calyx, and the lowest stone density in the distal ureter. To the best of our knowledge, the literature contains no study comparing stone density according to stone localization. Our finding may indicate that high stone density negatively affects spontaneous stone passage. In two studies conducted in the literature on this subject, although the stone density of stones with spontaneous passage was lower than that of those without spontaneous passage, there was no statistically significant difference [13,14]. This may be due to the small number of patients. Based on the results of our study, we consider that there is a need for further studies with a higher volume to investigate the impact of stone density on the occurrence of spontaneous stone passage.

In this study, stone density was significantly higher in patients who required postoperative DJ stent placement than in those without this requirement. This can be attributed to the more effective fragmentation of low-density stones by laser and the shorter time of the procedure. The endourologist's decision may have been influenced by the expectation that effective fragmentation in a short time would reduce postoperative edema and pain. In the literature, the only study evaluating postoperative DJ stent requirements reported that a low stone burden, the presence of a ureteral stent, the absence of an access sheath, and a short operative time were associated with postoperative stent-free status [15]. Based on the results obtained from our study and the limited existing literature on this topic, further research is warranted to explore the use of postoperative DJ stents in patients undergoing URS or RIRS.

Stone density has been the subject of many investigations in the literature since it is a parameter that can be easily calculated on CT. Studies have reported that stone density is an important criterion in predicting the success of ESWL [16,17]. It is also a parameter included in the R.I.R.S. scoring system to predict the success of RIRS, and in an external validation study, this scoring system was determined to be an independent predictor of stone-free status [18,19]. Similarly, stone density is among the parameters included in the T.O.H.O score (Tallness, Occupied lesion, Hounsfield unit evaluation) scoring system used to predict RIRS success, and an external validation study reported this score to be an independent predictor of stone-free status [20,21]. In the current study, we observed a positive correlation between stone density, operative time, and residual stone size, consistent with the literature. Additionally, we found a positive correlation between stone density and residual stone size among patients who did not achieve stone-free status after surgery.

One of the important parameters affecting stone-free status in URS is stone diameter or volume. Scoring systems and external validation studies used to predict the success of RIRS have also found that stone size is one of the important parameters [18-22]. In our study, we detected a positive correlation between stone size, operative time, and residual stone size, consistent with the literature. Furthermore, we observed that among patients who were not stone-free after surgery, stone size was positively correlated with operative time and residual stone size.

Although URS and RIRS are safe procedures, infectious complications are frequently encountered. In previous studies, one of the important parameters that increased the risk of infectious complications was reported to be operative time [23,24]. In a study conducted with 219 patients who underwent RIRS, Ito et al. found that high stone density negatively affected fragmentation efficiency and reduced the efficiency of operative and fragmentation times in stones smaller than 20 mm [11]. In our study, there was a positive correlation between stone density and operative time, which is in agreement with the literature.

Concerning the limitations of our study, the major drawbacks are related to the retrospective design and the absence of stone analysis. Another limitation is that multivariate analysis was not performed to evaluate independent factors predicting stone-free status. The lack of complication evaluation can also be considered an important limitation. The notable findings of our study are that a statistically significant difference was detected between stone localization and stone density and that stone density was significantly higher in patients who required postoperative DJ stent placement than in those without this requirement.

Conclusion

In this study, it was determined that stone density, stone size, and stone volume were positively correlated with residual stone size and operative time. In addition, stone density was positively correlated with residual stone size in patients who did not achieve stone-free status, indicating that high stone density negatively affects stone-free status even in cases presenting with small stone size and volume preoperatively. That is, as the stone density increases, more time and energy must be spent to achieve the stone-free status. Preoperative determination of these parameters, which can be easily performed on CT, can facilitate the prediction of treatment success, and provide more patient information before surgery. We consider that this study will significantly contribute to the decision-making process of urologists when selecting the appropriate treatment in their daily clinical practice.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Bozok University Faculty of Medicine (approval number: 2018-KAEK-189_2018.02.27_13).
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References

[1] EAU 2023 Guidelines on Urolithiasis, Arnhem, The Netherlands: EAU Guidelines Office; n.d.

[2] Robertson WG, Peacock M, Baker M, Marshall DH, Pearlman B, Speed R, et al. Studies on the Prevalence and Epidemiology of Urinary Stone Disease in Men in Leeds. Br J Urol. 1983;55(6):595-8.
https://doi.org/10.1111/j.1464-410X.1983.tb03383.x

[3] Vahlensieck EW, Bach D, Hesse A. Incidence, prevalence and mortality of urolithiasis in the German Federal Republic. Urol Res. 1982;10(4):161-4.
https://doi.org/10.1007/BF00255937

[4] Akinci M, Esen T, Tellaloglu S. Urinary stone disease in Turkey: An updated epidemiological study. Eur Urol. 1991;20(3):200-3.
https://doi.org/10.1159/000471700

[5] Wiesenthal JD, Ghiculete D, John D'A Honey R, Pace KT. Evaluating the importance of mean stone density and skin-to-stone distance in predicting successful shock wave lithotripsy of renal and ureteric calculi. Urol Res. 2010;38(4):307-13.
https://doi.org/10.1007/s00240-010-0295-0

[6] Andrabi Y, Patino M, Das CJ, Eisner B, Sahani D V., Kambadakone A. Advances in CT imaging for urolithiasis. Indian J Urol. 2015;31(3):185-93.
https://doi.org/10.4103/0970-1591.156924

[7] Gupta NP, Ansari MS, Kesarvani P, Kapoor A, Mukhopadhyay S. Role of computed tomography with no contrast medium enhancement in predicting the outcome of extracorporeal shock wave lithotripsy for urinary calculi. BJU Int. 2005;95(9):1285-8.
https://doi.org/10.1111/j.1464-410X.2005.05520.x

[8] Yoshida S, Hayashi T, Ikeda J, Yoshinaga A, Ohno R, Ishii N, et al. Role of volume and attenuation value histogram of urinary stone on noncontrast helical computed tomography as predictor of fragility by extracorporeal shock wave lithotripsy. Urology. 2006;68(1):33-7.
https://doi.org/10.1016/j.urology.2006.01.052

[9] McCarthy CJ, Baliyan V, Kordbacheh H, Sajjad Z, Sahani D, Kambadakone A. Radiology of renal stone disease. Int J Surg. 2016;36(Pt D):638-46. https://doi.org/10.1016/j.ijsu.2016.10.045

[10] El-Assmy A, Abou-El-Ghar ME, El-Nahas AR, Refaie HF, Sheir KZ. Multidetector computed tomography: Role in determination of urinary stones composition and disintegration with extracorporeal shock wave lithotripsy-an in vitro study. Urology. 2011;77(2):286-90. https://doi.org/10.1016/j.urology.2010.05.021

[11] Ito H, Kawahara T, Terao H, Ogawa T, Yao M, Kubota Y, et al. Predictive value of attenuation coefficients measured as hounsfield units on noncontrast computed tomography during flexible ureteroscopy with holmium laser lithotripsy: A single-center experience. J Endourol. 2012;26(9):1125-30. https://doi.org/10.1089/end.2012.0154

[12] Gücük A, Üyetürk U, Öztürk U, Kemahli E, Yildiz M, Metin A. Does the hounsfield unit value determined by computed tomography predict the outcome of percutaneous nephrolithotomy? J Endourol. 2012;26(7):792-6. https://doi.org/10.1089/end.2011.0518

[13] Hada A, Yadav SS, Tomar V, Priyadarshi S, Agarwal N, Gulani A. Assessment of factors affecting the spontaneous passage of lower ureteric calculus on the basis of lower ureteric calculus diameter, density, and plasma C- reactive protein level. Urol Ann. 2018;10(3):302-7. https://doi.org/10.4103/UA.UA_89_17

[14] Erturhan S, Bayrak O, Mete A, Seckiner I, Urgun G, Sarica K. Can the Hounsfield unit predict the success of medically expulsive therapy? J Can Urol Assoc. 2013;7(11-12): E677-80. https://doi.org/10.5489/cuaj.352

[15] Hamouche F, Unno R, Hakam N, Charondo LB, Yang H, Ahn J, et al. Clinical and postoperative characteristics of stentless ureteroscopy patients: a prospective analysis from ReSKU. Can J Urol. 2023;30(3):11532-7

[16] El-Nahas AR, El-Assmy AM, Mansour O, Sheir KZ. A Prospective Multivariate Analysis of Factors Predicting Stone Disintegration by Extracorporeal Shock Wave Lithotripsy: The Value of High-Resolution Noncontrast Computed Tomography. Eur Urol. 2007;51(6):1688-94. https://doi.org/10.1016/j.eururo.2006.11.048

[17] Nakasato T, Morita J, Ogawa Y. Evaluation of Hounsfield Units as a predictive factor for the outcome of extracorporeal shock wave lithotripsy and stone composition. Urolithiasis. 2015;43(1):69-75. https://doi.org/10.1007/s00240-014-0712-x

[18] Xiao Y, Li D, Chen L, Xu Y, Zhang D, Shao Y, et al. The R.I.R.S. scoring system: An innovative scoring system for predicting stone-free rate following retrograde intrarenal surgery. BMC Urol. 2017;17(1):105. https://doi.org/10.1186/s12894-017-0297-0

[19] Wang C, Wang ST, Wang X, Lu J. External validation of the R.I.R.S. scoring system to predict stone-free rate after retrograde intrarenal surgery. BMC Urol. 2021;21(1):33. https://doi.org/10.1186/s12894-021-00801-y

[20] Hori S, Otsuki H, Fujio K, Kobayashi H, Nagao K, Nakajima K, et al. Novel prediction scoring system for simple assessment of stone-free status after flexible ureteroscopy lithotripsy: T.O.HO. score. Int J Urol. 2020;27(9):742-7. https://doi.org/10.1111/iju.14289

[21] Senel S, Kasap Y, Kizilkan Y, Tastemur S, Ozden C. External validation of the T.O.HO. score as predictor of success after retrograde intrarenal surgery. BMC Urol. 2022;22(1):68. https://doi.org/10.1186/s12894-022-01018-3

[22] Resorlu B, Unsal A, Gulec H, Oztuna D. A new scoring system for predicting stone-free rate after retrograde intrarenal surgery: The "resorlu-Unsal Stone Score." Urology. 2012;80(3):512-8. https://doi.org/10.1016/j.urology.2012.02.072

[23] Baboudjian M, Gondran-Tellier B, Abdallah R, Sichez PC, Akiki A, Gaillet S, et al. Predictive risk factors of urinary tract infection following flexible ureteroscopy despite preoperative precautions to avoid infectious complications. World J Urol. 2020;38(5):1253-9. https://doi.org/10.1007/s00345-019-02891-8

[24] Moses RA, Ghali FM, Pais VM, Hyams ES. Unplanned Hospital Return for Infection following Ureteroscopy—Can We Identify Modifiable Risk Factors? J Urol. 2016;195(4 Pt 1):931–6. https://doi.org/10.1016/j.juro.2015.09.074