The Association of Encrustation and Ureteral Stent Indwelling Time in Urolithiasis and KUB Grading System

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Purpose: To evaluate the management of prolonged indwelling ureteral stents and the newly developed KUB (kidney, ureter, and bladder) grading system for the classification of encrusted stents in urolithiasis.

Method: This study involved 69 patients that had indwelling and forgotten ureteral stents for more than 6 months after urolithiasis treatment. They were categorized into 4 groups based on indwelling time and were reviewed retrospectively. Patients whose ureteral stent could not be removed with simple cystoscopy were graded according to stone surface area and the KUB system.

Results: The mean stent indwelling time was 23.1 months. Stone burden in KUB and, in proportion to that, total KUB (T) score showed increased association that was directly proportional to indwelling time ($p < 0.001$, $p = 0.008$). Surgical intervention was required in 73.9% of patients. Among patients requiring surgery, 78.4% were treated in a single session and multi-modal interventions were performed in 70.5%. K score ≥ 3 was found to be associated with multiple surgery requirements (odds ratio [OR];11.25, %95 confidence interval [CI]:2.132-59.375), multi-modal procedure requirements (OR;16.50, %95 CI:3.434-79.826), and lower stone-free rates ($p = 0.04$). B score ≥ 3 was associated with multi-modal procedure requirements (OR;8.90, %95 CI:1.052-75.462). *U* score ≥ 3 and T score ≥ 9 were associated with an operating time >180 minutes ($p < 0.001$, $p = 0.008$).

Conclusion: Prolonged indwelling time of the ureteral stent in urolithiasis is associated with increased encrustation and stone burden. Since the KUB system specifies stone burden and its particular localization, it can be used as a simple, convenient method for the planning treatment of encrusted ureteral stents.

Keywords: bladder; kidney; stent; ureter; urolithiasis

INTRODUCTION

After entering the armamentarium of urologists, the ureteral stent has provided very valuable contributions and has become an irreplaceable tool. The risk factors for encrustation vary from patient to patient, and include prolonged indwelling time, urinary tract infection, previous history of stone disease, lack of health insurance, pregnancy, chemotherapy, chronic kidney disease, and metabolic or congenital anomalies[1,2]. Various strategies exist for the timely removal of a ureteral stent; however, it is not always possible to remove a stent on time or to prevent encrustation[3].

Prolonged stent indwelling time can lead to the development of a broad range of complications from hematuria, obstructive symptoms due to occlusion, migration, encrustation to serious complications like renal failure, uretero-iliac artery fistula, and even death[4]. Considering the affected renal functions, it is obvious that treatment of encrusted stents is a requirement.

Ureteral stent encrustation and stone formation start with bacterial adhesion, colonization, and biofilm formation. The biofilm layer protects the bacteria from the immune system and antibiotics[5]. Encrustation can occur in both sterile and infected urine depending on urinary pH, bacterial enzymes, and stent biomaterials[6]. El-Faqih et al. reported that the increase in encrustation was directly proportional to stent indwelling time, which was present in 76.3% after 12th week[7]. Consistent with this, Kawahara et al. also found similar results, which was present in 75.9% of the patients after 3rd month[2].

Several grading systems have been described to predict the difficulty of treatment due to the difficulty of the surgery level of encrusted stents[8,9]. Arenas et al. designed a better KUB grading system in order to predict surgical difficulty and to aid in management of patient expectations[10]. They reported that this system was reliable and convenient for predicting surgical session requirement, modality requirement, operation time and stone-free rates. In our study, we employed the KUB grading system that included a classification system by Sing et al. This system is based on the volume and a localization component for each patient. The present study was designed to evaluate management of prolonged stent applications and as per our knowledge it is the first study regarding the clinical use of KUB grading system in urolithiasis.

MATERIALS AND METHODS

We retrospectively reviewed patients that presented to our tertiary care urolithiasis treatment center from Jan-

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Received May 2018 & Accepted July 2018

Table 1. KUB grading criteria

K-Kidney
1-Absence of calcification at the coil at the renal end
2-Presence of calcification with width ≤5 mm, apparent at the coil at the renal end, but not filling the coil
3-Presence of calcification with width >5mm, apparent at the coil at the renal end, but not filling the coil
4-Presence of calcification filling the coil at the renal end, and its extent from the coil ≤5 mm
5-Presence of calcification filling the coil at the renal end, and its extent from the coil >5mm (including staghorn stones)
U-Ureter
1-Absence of calcification along the ureter
2-Presence of calcification at only one area along the ureter, and its width ≤5 mm
3- Presence of calcification at only one area along the ureter, and its width >5 mm
4-Presence of multiple calcifications occupying less than 50% of the total length of ureter, and their widths >5 mm
5-Presence of multiple calcifications occupying more than 50% of the total length of ureter, and their widths >5 mm
B-Bladder
1-Absence of calcification at the coil at the vesical end
2-Presence of calcification with width ≤5 mm, apparent at the coil at the vesical end, but not filling the coil
3- Presence of calcification with width >5 mm, apparent at the coil at the vesical end, but not filling the coil
4- Presence of calcification filling the coil at the vesical end, and its extent from the coil is ≤5 mm
5- Presence of calcification filling the coil at the vesical end, and its extent from the coil is >5 mm

uary 2007 to July 2017 with indwelling and forgotten ureteral stents for longer than 6 months following urolithiasis treatment. Although, etiologically, there are cases where stents were placed for other reasons and encrustation took place, due to its distinctive pathophysiology, only patients that had prolonged ureteral stents following urolithiasis treatment were included in the study. For each patient, kidney-ureter-bladder (KUB) radiography, blood biochemistry, and urinary culture were performed. Patients with positive urinary culture results were treated via hospitalization if necessary, and the procedures were performed afterwards. At the end of the first month after treatment, creatinine levels were measured, both KUB and ultrasound were performed in each patient, and additional investigations were made as necessary. In cases with prolonged ureteral stent, the presence of encrustation was assessed with KUB ± non-contrast computed tomography (NCCT). NCCT was performed as an ancillary imaging when ureteral stent could not be removed using simple cystoscopy and if encrustation was suspected. Encrustations were categorized according to localization as kidney, ureter, and bladder areas. Stone surface areas were calculated with KUB using the formula: length x width. After calculat-

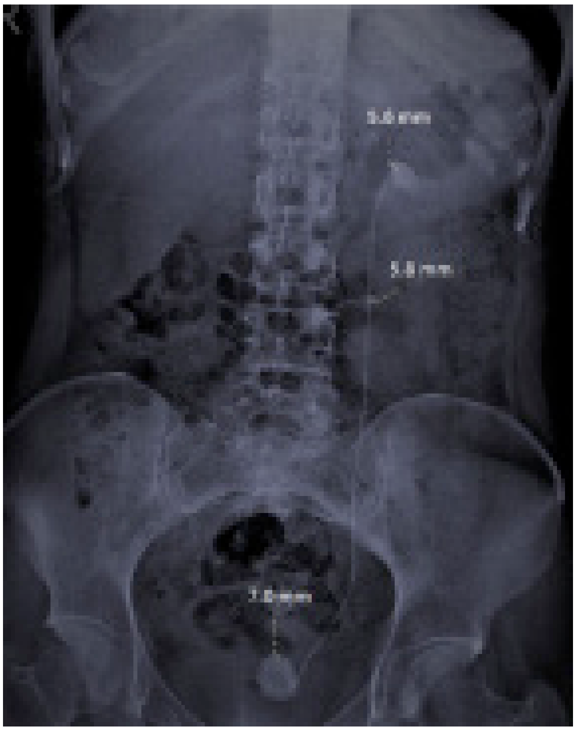

Figure 1. A 30-year old female patient presenting with a urinary tract infection had a ureteral stent present for 33 months. The KUB score was 13 (K=5, U=3, B=5) and the stone surface area was calculated as 360 mm² in the kidney, 90 mm² in the ureter, 624 mm² in the bladder. The patient underwent transurethral cystolithotripsy, semi-rigid URS, and flexible URS in a multi-modal fashion in a single session, and stent-free and stone-free status was achieved.

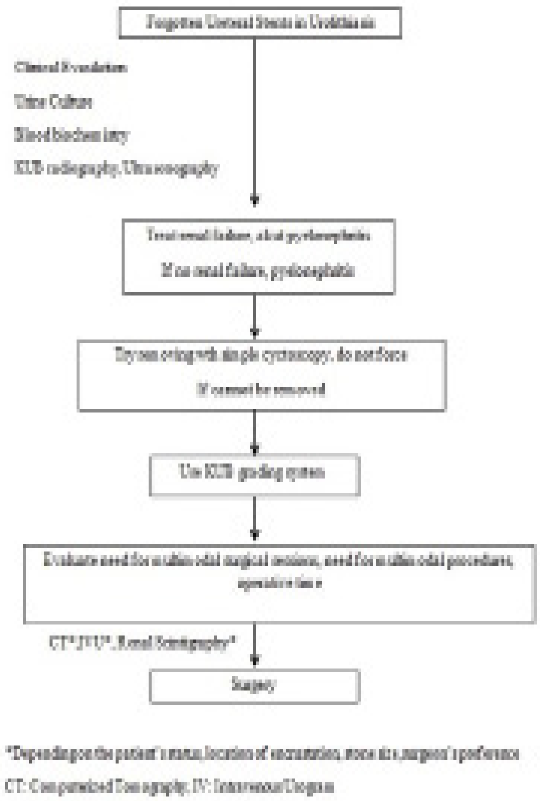

Figure 2. Management of Forgotten Ureteral stents in Urolithiasis

Table 2. Clinical properties of patients with encrusted ureteral stent

	6-12 months (n=5)	13-24 months (n=20)	25-36 months (n=16)	> 36 months (n=10)	*p*-value	Total (n=51)
Age	55.0 ± 12.9	50.3 ± 17.4	47.4 ± 16.0	40.9 ± 16.3	0.374†	48.0 ± 16.5
Gender					0.039‡	
Male	5 (100.0%)[a]	15 (75.0%)	9 (56.3%)	4 (40.0%)[a]		33 (64.7%)
Female	0 (0.0%)[a]	5 (25.0%)	7 (43.8%)	6 (60.0%)[a]		18 (35.3%)
Affected side					0.900‡	
Right	2 (40.0%)	10 (50.0%)	8 (50.0%)	6 (60.0%)		26 (51.0%)
Left	3 (60.0%)	10 (50.0%)	8 (50.0%)	4 (40.0%)		25 (49.0%)
CT scan	5 (100.0%)	14 (70.0%)	16 (100.0%)	10 (100.0%)	-	45 (88.2%)
Stone burden in KUB						< 0.001‡
< 100 mm²	4 (80.0%)[a,b]	9 (45.0%)	2 (12.5%)b	0 (0.0%)[a]		15 (29.4%)
100-400 mm²	1 (20.0%)	11 (55.0%)	5 (31.3%)	3 (30.0%)		20 (39.2%)
> 400 mm²	0 (0.0%)[a,b]	0 (0.0%)c,d	9 (56.3%)[b,c]	7 (70.0%)[a,d]		16 (31.4%)
KUB score						
K	3.2 ± 0.45	2.7 ± 1.62	3.5 ± 1.09	4.1 ± 1.28	0.086¶	3.3 ± 1.39
U	1.6 ± 0.55	1.9 ± 1.07	2.2 ± 1.33	2.6 ± 1.07	0.247¶	2.1 ± 1.14
B	1.4 ± 0.55	1.6 ± 1.09	2.8 ± 2.01	2.9 ± 1.85	0.160¶	2.2 ± 1.64
T	6.2 ± 0.45[a,b]	6.2 ± 2.77[c,d]	8.5 ± 2.68[b,c]	9.6 ± 2.59[a,d]	0.008¶	7.6 ± 2.87
Hospital stay length	0 (0-2)[a,b]	0 (0-11)[c,d]	3 (0-8)[b,c]	5 (0-15)[a,d]	< 0.001¶	1 (0-15)
Number of modalities	2 (1-3)	2 (1-3)	2 (1-3)	2 (1-4)	0.190¶	2 (1-4)
Number of surgeries	2 (1-2)	2 (1-2)	2 (1-3)	1 (1-3)	0.708¶	2 (1-3)

† One-Way ANOVA, ‡ Likelihood ratio test, ¶ Kruskal Wallis test, a: statistically significant difference between 6-12 months group and >36 months group ($p < 0.05$), b: statistically significant difference between 6-12 months group and 25-36 months group ($p < 0.05$), c: statistically significant difference between 13-24 months group and 25-36 months group ($p < 0.05$), d: statistically significant difference between 13-24 months group and > 36 months group ($p < 0.05$), e: statistically significant difference between 25-36 months group and >36 months group ($p = 0.009$).

ing encrustation areas with KUB, they were graded; < 100 mm², 100-400 mm² and > 400 mm². The grading of encrustation was made according to the KUB grading system developed by Arenas J.L. et al[10]. Appropriate treatment modality was decided after evaluating radiological examinations and patient's clinical condition. All calculations and surgical procedures were done by the three endourologists at our clinic. Non-encrusted stents were removed in the outpatient setting, under local anesthesia, and in a non-traumatic way using a forceps with the help of simple cystoscopy. Patients requiring surgery were examined separately. For each patient, the number of surgical sessions required evaluation of multi-modal procedures performed in a session, operating time, postoperative complications, and stone-free rates. Multi-modal surgery was defined as 2 or more modalities combined in a surgical session. If more than one surgical session was performed, the operating time was calculated as the sum of operating times of each surgery. Post-operative complications were categorized according to the Modified Clavien-Dindo Classification. Additionally, the ability of the KUB degree to predict the possible difficulties encountered in the treatment was evaluated. Stones ≥4 mm were defined as residual stones.

Statistical Analysis

Data analysis was carried out with IBM SPSS Statistics 17.0 (IBM Corporation, Armonk, NY, USA) package software. Normality assessment for distribution of continuous numerical variables was made with Kolmogorov-Smirnov test, and homogeneity of variance was assessed using the Levene test. Descriptive statistics was expressed as mean ± standard deviation or median (minimum-maximum) for numerical variables, and case number and (%) for categorical variables. The significance of the difference between the groups for continuous numerical variables was analyzed with one way analysis of variance (one-way ANOVA) for parametric data, or Kruskal Wallis test for non-parametric data. If the Kruskal Wallis test result was statistically significant, the condition(s) causing the difference was detected using Conover's multiple comparison test. Correlation of Tscore with stone burden and ureteral stent indwelling time was analyzed with Spearman's rank numbers correlation test. Categorical variables were analyzed with Pearson's chi-square, Fisher's exact probability, and continuity correction chi-square or probability ratio tests. The ability of the KUB component scores and T score to predict prognosis was analyzed by calculating odds ratio and 95% CI. A p-value of less than 0.05 was accepted as statistically significant.

RESULTS

A retrospective review covering the time from January 2007 to October 2017 yielded 69 patients that had a prolonged ureteral indwelling stent placed for treatment of urolithiasis. Mean age of the patients was 48 ± 16 years. Mean indwelling stent time was 23.1 months (7-102). Indications for placing ureteral stent were SWL in 4 cases (5.8%), semi-rigid ureteroscopy (URS) in 30 cases (43.5%), flexible URS in 33 cases (47.8%), and percutaneous nephrolithotomy (PNL) in 2 cases (2.9%). Primary presenting complaints were pain in 37 cases (53.7%), infection in 20 cases (28.9%), hematuria in 6 cases (8.7%), and 6 cases (8.7%) were detected incidentally.

Eighteen patients (26.1%) were treated by removing the ureteral stent under simple cystoscopy guidance only with no need for additional procedures. The remaining 51 patients (73.9%) were accepted as encrusted, and additional procedures were made. Surgical modalities included transurethral cystolithotripsy, percutaneous cystolithotripsy, semi-rigid URS, flexible URS, PNL, SWL, and for one patient, open pyelolithotomy.

The median operating time in patients with encrusted

Table 3. Effect of KUB score on prognosis in patients with an encrusted ureteral stent

	Multiple surgery sessions requirement				Multimodal procedure requirement			
	No (n=22)	Yes (n=29)	*p*-value	OR (95% CI)	No (n=15)	Yes (n=36)	*p*-value	OR (95% CI)
K				0.004†				< 0.001‡
< 3	10 (45.5%)	2 (6.9%)		1.000	9 (60.0%)	3 (8.3%)		1.000
≥ 3	12 (54.5%)	27 (93.1%)		11.250 (2.132-59.375)	6 (40.0%)	33 (91.7%)		16.500 (3.434-79.286)
U			> 0.999†				0.333‡	
<3	15 (68.2%)	20 (69.0%)		1.000	12 (80.0%)	23 (63.9%)		1.000
≥ 3	7 (31.8%)	9 (31.0%)		0.964 (0.292-3.180)	3 (20.0%)	13 (36.1%)		2.261 (0.538-9.508)
B			> 0.999†				0.040‡	
< 3	16 (72.7%)	20 (69.0%)		1.000	14 (93.3%)	22 (61.1%)		1.000
≥ 3	6 (27.3%)	9 (31.0%)		1.200 (0.353-4.083)	1 (6.7%)	14 (38.9%)		8.909 (1.052-75.462)
T			0.859†				0.184†	
< 9	13 (59.1%)	19 (65.5%)		1.000	12 (80.0%)	20 (55.6%)		1.000
≥ 9	9 (40.9%)	10 (34.5%)		0.760 (0.242-2.387)	3 (20.0%)	16 (44.4%)		3.200 (0.769-13.315)

	Operating time ≥180 minutes				Complete stone-free status after treatment				
	No (n=44)	Yes (n=7)	*p*-value	OR (95% CI)	Yes (n=40)	No (n=11)	*p*-value	OR (95% CI)	
K			0.177‡				0.040‡		
< 3	12 (27.3%)	0 (0.0%)		1.000	12 (30.0%)	0 (0.0%)		1.000	
≥ 3	32 (72.7%)	7(100.0%)		NA	28 (70.0%)	11 (100.0%)		NA	
U			<0.001‡				0.288‡		
< 3	35 (79.5%)	0 (0.0%)		1.000	29 (72.5%)	6 (54.5%)		1.000	
≥ 3	9 (20.5%)	7 (100.0%)		NA	11 (27.5%)	5 (45.5%)		2.197 (0.556-8.688)	
B			0.174‡				0.264‡		
< 3	33 (75.0%)	3 (42.9%)		1.000	30 (75.0%)	6 (54.5%)		1.000	
≥ 3	11 (25.0%)	4 (57.1%)		4.000 (0.772-20.727)		10 (25.0%)	5 (45.5%)		2.500 (0.625-9.996)
T			0.008‡				0.291‡		
< 9	31 (70.5%)	1 (14.3%)		1.000	27 (67.5%)	5 (45.5%)		1.000	
≥ 9	13 (29.5%)	6 (85.7%)		14.308 (1.564-130.928)		13 (32.5%)	6 (54.5%)		2.492 (0.640-9.699)

Abbreviations: OR, Odds ratio; CI, confidence interval; NA, Not analyzed
† Continuity corrected Chi-square test), ‡ Fisher's exact test)

stent was 75 minutes, and operating times varied from 15 to 360 minutes. The single surgical session was adequate in 40 of 51 patients (78.4%) and multi-modal interventions were required in 36 of 51 patients (70.5%). The median number of surgeries required to achieve a stent-free state was 1 (minimum: 1 and maximum: 3). Stone-free status was achieved in 40 patients (78.4%). Twelve patients (17.3%) developed 13 complications following removal of the ureteral stent. These complications were urinary tract infection, postoperative fever, blood transfusion, sepsis, and drainage lasting more than 12 hours after PNL, urinary retention, urinoma, and sepsis. According to the Modified Clavien-Dindo classification, 2 complications (15.4%) were grade 1; 5 (38.6%) were grade 2; 4 (30.8%) were grade 3a; 1 (7.6%) was grade 4a; and 1 (7.6%) was grade 4b. The median hospital stay length was 3 days (min: 1 – max: 15).

Two patients presenting with pain and fever were evaluated with NCCT and were diagnosed with infective hydronephrosis. Their treatment was initiated with percutaneous nephrostomy prior to definitive treatment.

Encrustation was graded according to the KUB grading criteria (**Table 1 and Figure 1**). After the patients were distributed to groups based on their stent indwelling times as 6-12, 13-24, 25-36 and >36 months, they were compared in terms of their clinical properties as seen in Table 2. The distribution of gender showed a statistically significant difference based on stent indwelling time ($p = 0.039$). This difference was caused by a higher frequency of female patients in the group with stent indwelling time greater than 36 months compared to the 6-12 months group ($p = 0.044$). Distribution of stone burden in KUB showed statistically significant difference according to stent indwelling time ($p < 0.001$).

When comparing the groups stratified according to stent indwelling time, each of the mean K, U, or B component scores showed an increase in parallel with indwelling time. However, the differences were not statistically significant ($p = 0.086$, $p = 0.247$, and $p = 0.160$, respectively). Conversely, there was a statistically significant difference in terms of T score that represents total stone burden ($p = 0.008$). There was statistically significant difference between stent indwelling time groups in regards to hospital stay length ($p < 0.001$). The patients were then evaluated regarding the effects of the KUB score on the prognosis in the case of encrusted ureteral stents as shown in Table 3. Of the KUB scores, only the K component was found to be significant in the prediction of multiple surgery sessions. K and B components were significant in predicting the multi-modal procedure requirement. For predicting an operating time of ≥180 minutes, the U component of the KUB scores and T score were found to have significance. Since there was no patient with a *U* score < 3 and operating time □180 minutes, the odds ratio and 95% CI was not applicable (shown as "NA" in Table 3). For predicting complete stone-free status/residual stones after treatment, only the K score was found to have any significance ($p = 0.04$), whereas U and B components or T scores did not have statistically significant predicting power ($p > 0.05$)

DISCUSSION

There is no consensus on how long a stent should be kept in place after treatment for urolithiasis. Indwelling time for commonly used polymer-based stents should not exceed 3-6 months[11]. Because our study sample included patients whose stents could not be removed with only a simple cystoscopy after 7 months indwelling time, we categorized patients in 4 groups starting from 6 months. Encrusted stents present serious challenges for urologists since they have been known to cause complications that can even lead to death[12,13]. In addition, their treatment is difficult and costly[14]. Researchers have described several classification methods for encrusted stents in order to provide guidance to urologists facing these challenges[8-10].

As reported by many previous studies, increased stent indwelling time results in increased encrustation and stone burden, which makes treatment more difficult and complex[15-18]. For evaluation of our patients with an encrusted stent, we classified our patients in various ways. The classification described by Sing et al., which considers the total stone burden, has categories including < 100 mm², 100-400 mm², and > 400 mm². These do not specify localization of encrustation, and it overlooks an important component of treatment planning[9]. In their study, Weedin et al. used the FECal (forgotten, encrusted, calcified) grading system described by Acosta-Miranda to determine both the size and the localization of the stone. They reported that treatment became more difficult when encrustation was localized at the proximal. Furthermore, they showed that localization of the stone was important when planning the treatment[19]. Disadvantages to the FECal grading system is that it was described in a very small sample during its development, which does not account for some possible scenarios of stent encrustation[10].

There is a need for a grading system that will take every possible scenario into account. It must describe stone localization, stone burden, and encrustation in proximal and distal coil in a simple manner. Furthermore, the consideration of the fact that the stone burden, especially localized at the proximal makes treatment difficult. Based on these criteria, Arenas et al. defined the KUB grading system. It was advocated that by specifying the localization, burden, and grade of encrustation in the KUB radiography and KUB grading can predict possible challenges in treatment[10].

Previous studies have shown that encrustation is most frequent at the proximal coil[2,19]). Weedin et al. reported that proximal stone burden was particularly of significance in stent removal because of the requirement for multiple surgeries. In their series, they found that patients with stone burden > 400 mm² were 18 times more likely to require multiple surgeries[19]. Arenas et al. also reported that patients with a K score showing proximal stone burden as ≥ 3 had 3.59 times higher probability of multiple surgery requirement[10]. In our study, we found that only the K component of KUB scores was significant in predicting multiple surgery requirements, and that multiple surgery session risk was 11.25 times higher in those with a K score ≥ 3.

For predicting the multi-modal procedure requirement, which is another factor related to the difficulty and costliness of treatment, we found that the K score and B score had significance, which is contradictory to what Arenas et al. reported. Unlike the studies by Weedin et al. and Arenas et al., patients with higher B scores had a higher probability of multimodal surgery requirement. However, the B score was not found to influence the number of surgical sessions, operating time >180 minutes, stone-free status, or morbid procedure requirement in proximal stones such as complicated ureteroscopy and PNL. Therefore, our results are consistent with the literature. Thus, it can be deduced that the B score does not have a significant effect on the difficulty of surgery. However as the B score increases, the more modalities will be required. This will have negative effect on the cost.

In the KUB system, the K score specifies the proximal stone burden and patients with a K score ≥ 3 have less stone-free rates. This was statistically significant and consistent with the study by Arenas et al[10].

For predicting an operating time of 180 minutes or longer, the U component of the KUB scores and T score were found to have a significance.

In the light of all these findings, it can be said that the K score is associated with multiple surgeries, multi-modal surgery requirement, and lower stone-free rate. The U score is associated with longer operating time and the B score is associated with more treatment modalities. Higher T score has been associated with longer stent indwelling time and longer operating time. Therefore, it can be used in planning. As T score has a statistical significance with regard to surgical difficulty, the U and B scores should not be ignored.

One of the limitations of the study is its retrospective design. Current guidelines do not give any recommendations about the management and treatment of encrusted stents. The lack of systematic treatment approach constitutes an impediment in previous and future studies related with encrusted stent. Presently, there is no systematic approach to the treatment principle as shown in **Figure 2**. In addition, several studies recommended that treatment planning for encrusted ureteral stents should be made from the distal to the proximal direction[20,21]. Therefore, we generally adopted this principle in our selection of treatment other than SWL. No ideal stent exists at the market for the moment. When we consider that the material and thickness of the stent can influence encrustation, another limitation of the study is that the stent types were not identified. Additionally, some of the patients were referred from different centers, and the treatment was administered by surgeons that had different endourological experiences. In our study, stent encrustation occurred after treatment for urolithiasis, and this helped to increase homogeneity to some extent.

CONCLUSIONS

Prolonged indwelling time of ureteral stents leads to increased encrustation and makes the treatment more difficult. Good planning and multi-modal endoscopic approaches when necessary can help to achieve high treatment success. The KUB system can be used as an ancillary tool for the management of encrusted ureteral stents and in the prediction of surgical difficulty.

CONFLICT OF INTEREST

The authors report no conflict of interest.

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