Characteristics of Double-J Stent Encrustations and Factors Associated with their Development

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Purpose: To evaluate the chemical composition of double-J stent encrustation and to assess risk factors associated with their development.

Materials and Methods: Patients who had double-J stents removed between July 2016 and June 2017 were recruited for this study prospectively. The clinical features of the patients were recorded and the composition of encrustation material was analyzed by infrared spectroscopy.

Results: Encrustments from a total of 372 double-J stents were collected. The mean age of patients was 50.4±13.1 years and deposits possible to analyze were obtained from 228 males (61.3%) and 144 females (38.7%). Calcium oxalate monohydrate was the most common constituent of stone and encrustments. The encrustation rate of vesical coils was significantly higher than that of renal coils ($P < 0.001$). There was no significant difference in chemical composition between stone and encrustation regarding renal ($P = 0.086$) and vesical coils ($P = 0.072$). The only predictive risk factor for the development of encrustation on double-J stents was indwelling time. This phenomenon was observed in both renal ($P < 0.001$) and vesical coils ($P = 0.021$). Interestingly, patient with chronic kidney disease (CKD) was associated with less risk of encrustation on both renal ($P < 0.001$) and vesical coils ($P = 0.001$).

Conclusion: The chemical composition of double-J stent encrustation was the same as the urinary stone. The prevention strategy for stone composition is also suitable for the prevention of encrustation of double-J stent. The only predictive factor for double-J stent encrustation was the indwelling time. CKD patient was shown to be less at risk for the development of encrustation.

Keywords: Double-J stent; encrustation; chemical composition; urolithiasis; renal coil; vesical coil

INTRODUCTION

In 1967, Zimskind et al. were the first to use silicone ureteral splints to remedy ureteral obstruction(1). In 1978, Finney introduced a neoteric double-J stent with a hook molded into each end with the purpose of adding a self-retaining function and preventing migration(2). With this innovation, double-J stent became a fundamental device in many urological procedures such as the management of patients with obstructing ureteral stone, ureteral or ureteropelvic junction strictures, retroperitoneal tumors or fibrosis. Also, stent is regular after laparoscopic or open urologic surgery(1,3). The double-J stent serves as a significant therapeutic option to moderate the obstruction and counteract renal failure (4). However, there are several side effect accompanied by the insertion of double-J stent, such as flank pain, storage symptoms, dysuria and hematuria, etc.(5). Moreover, as a foreign body within the collecting system, there is concern that the double-J stent will be subject to deposition of organic and mineral material, contributing to the formation of stone and encrustation(6-7). Accordingly, it was assumed that encrustation on stents was caused by deposition of layers of organic material, uropathogens and salt in urine(8). It's reported that the bacteria adhering to a double-J stent is the main process of biofilm formation. The aggregation of the biofilm produced by the bacteria and the precipitated urinary components causes the formation of double-J stents encrustation(9-12). Encrustation may occur on renal and vesical coils of double-J stent. Severe encrustation of the stent may prevent stent removal in the traditional, routine transurethral manner. The removal of encrusted stents, thus, is a challenging problem of clinical urology(13). Focusing on methods aiming at prevention of encrustation is important. There is, however, a shortage of information on the characteristic of stent encrustation, such as their risk

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Table 1. General characteristics of patients with stent encrustations

Index	Value	Renal coil				Vesical coil			
		Encrustation (%)	No encrustation (%)	*p* value	OR	Encrustation (%)	No encrustation (%)	*p* value	OR
Total, n (%)	372 (100)	239 (64.2)	133 (35.8)			277 (74.5)	95 (25.5)		
Age, years	50.4±13.1	50.4±13.3	50.1±12.8	0.855	-	50.3±13.0	50.4±13.6	0.969	-
Gender, n (%)				0.439	0.841			0.498	0.846
Male	228 (61.3)	143 (62.7)	85 (37.3)			167 (73.2)	61 (26.8)		
Female	144 (38.7)	96 (66.7)	48 (33.3)			110 (76.4)	34 (23.6)		
BMI, kg/m^2	23.6±3.7	23.6±3.7	23.6±3.7	0.929	-	23.6±3.7	23.6±3.5	0.831	-
Frequent stone former, n (%)	177 (47.6)	117 (66.1)	60 (33.9)	0.477	0.857	138 (78)	39 (22)	0.140	0.701
Hydronephrosis, n (%)	270 (72.6)	175 (68.4)	95 (35.2)	0.710	1.094	207 (76.6)	63 (23.3)	0.113	1.502
Chronic renal insufficiency, n (%)	67 (18.0)	30 (44.8)	37 (55.2)	< 0.001	0.372	39 (58.2)	28 (41.8)	0.001	0.392
Preoperative urinary tract infection, n (%)	145 (39.0)	91 (62.8)	54 (37.2)	0.632	0.900	108 (74.5)	37 (25.5)	0.994	1.002
Stone location, n (%)									
Ureter	84 (22.6)	55 (65.3)	29 (34.5)	0.789	1.072	68 (81.0)	16 (19.0)	0.121	1.606
Kidney	228 (61.3)	151 (66.2)	77 (33.8)	0.316	1.248	164 (71.9)	64 (28.1)	0.159	0.703
Kidney and ureter	60 (16.1)	33 (55.0)	27 (45.0)	0.103	0.629	45 (75.0)	15 (25.0)	0.917	1.034
Stone free status, n (%)	232 (62.4)	149 (64.2)	83 (35.8)	0.990	0.997	175 (75.4)	57 (24.6)	0.581	1.144
Ureteral and/or ureteropelvic junction stricture, n	60 (16.1)	43 (71.7)	17 (28.3)	0.190	1.497	51 (85.0)	9 (15.0)	0.041	2.156
Double-J stent caliber, n (%)				0.213	1.313			0.210	1.350
5 Fr	152 (40.9)	92 (60.5)	60 (39.5)			108 (71.1)	44 (28.9)		
6 Fr	220 (59.1)	147 (66.8)	73 (33.2)			169 (76.8)	51 (23.2)		
Indwelling time, n (%)				< 0.001	-			0.019	-
≤ 14 days (9.5±3.5)d	48 (12.9)	17 (35.4)	31 (64.6)			28 (58.3)	20 (41.7)		
>14 days-1 month (24.1±4.7)d	133 (35.8)	85 (63.9)	48 (36.1)			99 (74.4)	34 (25.6)		
> 1 month-2 months (39.4±7.6)d	170 (45.7)	121 (71.2)	49 (28.8)			131 (77.1)	39 (22.9)		
> 2 months (108.9±70.6)d	21 (5.6)	16 (76.2)	5 (23.8)			19 (90.5)	2 (9.5)		
Stone composition, n (%)									
Calcium oxalate monohydrate	163 (58.8)	103 (63.2)	60 (36.8)	0.657	0.893	120 (73.6)	43 (26.4)	0.637	1.137
Calcium oxalate dihydrate	21 (7.6)	14 (66.7)	7 (33.3)	0.811	1.122	16 (76.2)	5 (23.8)	0.698	1.228
Ammonium magnesium phosphate	8 (2.9)	5 (62.5)	3 (37.5)	1	0.925	4 (50)	4 (50)	0.294	0.365
Uric acid	40 (14.4)	28 (70.0)	12 (30.0)	0.413	1.353	31 (77.5)	9 (22.5)	0.449	1.358
Carbonate apatite	43 (15.5)	26 (60.5)	17 (28.3)	0.572	0.825	28 (65.1)	15 (34.9)	0.234	0.658

Figure 1. Distribution of stone and renal coil encrustation composition. p = 0.086 as analyzed with Bowker's test of symmetry.

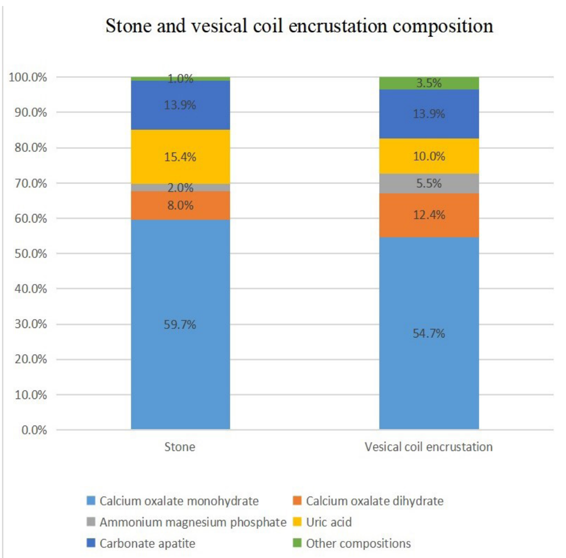

Figure 2. Distribution of stone and vesical coil encrustation composition. p=0.072 as analyzed with Bowker's test of symmetry.

Table 2. McNemar test for double-J stent encrustation of renal and vesical coils.

	Vesical coil		Total
Renal coil	Encrustation	No encrustation	
Encrustation	221	18	239
No encrustation	56	77	133
Total	277	95	372

factors or chemical composition. For that reason, we prospectively collected data of patients with double-J stents in order to explore the features of stent encrustation by separately considering renal and vesical coils. The aim was to evaluate the chemical composition of double-J stent encrustation and identify risk factors involved in the encrustation process.

PATIENTS AND METHODS

This study was approved by the Ethics Review Board of the First Affiliated Hospital of Guangzhou Medical University, Guangzhou, China. Informed consent was obtained from all individual patients included in the study. All double-J stents were obtained from patients who had been subject to stent removal at the First Affiliated Hospital of Guangzhou Medical University.

From July 2016 to June 2017, a total of 372 patients with the removal of double-J stents that had been part of their clinical treatment were recruited prospectively. All of the double-J stents were made of a material with a variety of medical applications, polyurethane, the most common polymeric biomaterial used in modern double-J stents[14]. The baseline characteristics included age, gender, body mass index (BMI), frequent stone former, presence or absence of hydronephrosis, chronic kidney disease (CKD), preoperative urinary tract infection, stone location, stone free status, ureteral and/or ureteropelvic junction strictures, double-J stent caliber, indwelling time, stone and the encrustation composition. The variables were analyzed in a logistic regression model, with the aim to find factors associated with the development of encrustation. To further elucidate the importance of the duration of stent treatment, the indwelling time was sub-grouped into four intervals: ≤ 14 days, >14 days to 1 month, >1 month to ≤ 2 months and >2 months. Generally, patients with indwelling time of double-J stent longer than 1 month were related to the ureteral stricture, ureteral injury or the delay of double-J stent removal with patients' personal reason.

Patients eligible for inclusion in the present study were those who were planned for removal of 5Fr or 6Fr double-J stents inserted because of urolithiasis and/or ureteral/ureteropelvic junction strictures after nephroscope, ureteroscopy, laparoscope or open surgery. Computed Tomography (CT) scanning was used for the diagnosis of urinary stones. Ureteral and/or ureteropelvic junction strictures were diagnosed with intravenous pyelography (IVP), CT urography or ureteroscopy. The exclusion criteria were as follows: 1) a serious medical history of blood disease, family history of hereditary diseases, and other unusual conditions; 2) anatomical malformations including scoliosis, ectopic kidney, horseshoe kidney and polycystic kidney; 3) patients planned for urinary diversion or renal transplantation; 4) the stent was displaced. Moreover, only the data from the initial stent episode were included in case the same patient had been subject to repeated stent treatment.

Patients with severe stone disease (frequent stone formers) were defined by frequent recurrence of stone after treatment or by stone surgery more than three times. The definition of CKD is described as the presence of kidney damage (usually defined as urinary albumin excretion of ≥ 30 mg/day or equivalent) or decreased kidney function (detected as estimated glomerular filtration rate (eGFR) < 60 mL/min/1.73m^2) for three or more months, irrespective of the cause. Chronic kidney disease epidemiology collaboration (CKD-EPI) creatinine equation was used for the evaluation of the estimated glomerular filtration rate (eGFR)[15]. All patients were examined with plain film of kidney-ureter-bladder (KUB) and urinary ultrasound imaging before extraction of the stent. Patients were considered stone-free when no residual stones were detected in CT, KUB or urinary ultrasound examinations before extraction of the double-J stents. Hydronephrosis was evaluated by a CT examination or ultrasonography, defined by dilatation of the renal pelvis or calices to a diameter exceeding 10mm according to the modification of the Grignon Grade system[16]. Preoperative urinary tract infection was defined as a mid-stream sample of urine indicating bacterial growth ≥ 10^5 cfu/mL, or with a high level of leukocytes (sensitivity threshold: 104 leukocytes/mm3) or nitrites in the urine test strips, or with a positive urinary culture[17-18]. Presence of encrustation

Table 3. Factors associated with the development of double-J stent encrustation of kidney.

Index	Kidney Univariate OR	95% CI	*P* value	Multivariable OR	95% CI	*P* value
Age	1.002	0.985-1.018	0.854			
Gender	0.841	0.543-1.304	0.439			
BMI	1.003	0.946-1.062	0.929			
Frequent stone former	0.857	0.560-1.311	0.477			
Hydronephrosis	1.094	0.682-1.755	0.710			
Chronic renal insufficiency	0.372	0.217-0.638	< 0.001	0.339	0.194-0.593	< 0.001
Preoperative urinary tract infection	0.900	0.583-1.388	0.632			
Stone location	1.085	0.817-1.441	0.573			
Stone free status	0.997	0.644-1.545	0.990			
Ureteral and/or ureteropelvic junction stricture	1.497	0.816-2.746	0.192			
Double-J stent caliber	1.313	0.855-2.018	0.214			
Indwelling time						
≤14 days			< 0.001			< 0.001
>14 days to 1 month	3.229	1.621-6.433	0.001	3.366	1.669-6.788	0.001
>1 month to ≤2 months	4.503	2.285-8.873	< 0.001	5.006	2.499-10.026	< 0.001
>2 months	5.835	1.819-18.716	0.003	5.691	1.747-18.540	0.004
Stone composition	1.011	0.870-1.174	0.889			

Table 4. Factors associated with the development of double-J stent encrustation of bladder.

Index	Bladder Univariate OR	95% CI	*p* value	Multivariable OR	95% CI	*p* value
Age	1.000	0.982-1.018	0.969			
Gender	0.846	0.522-1.372	0.499			
BMI	1.007	0.945-1.073	0.831			
Frequent stone former	0.701	0.438-1.124	0.141			
Hydronephrosis	1.502	0.907-2.487	0.114			
Chronic renal insufficiency	0.392	0.225-0.684	0.001	0.383	0.217-0.675	0.001
Preoperative urinary tract infection	1.002	0.621-1.615	0.994			
Stone location	0.808	0.599-1.090	0.162			
Stone free status	1.144	0.709-1.844	0.581			
Ureteral and/or ureteropelvic junction stricture	2.156	1.018-4.569	0.045			
Double-J stent caliber	1.350	0.844-2.160	0.211			
Indwelling time						
≤14 days			0.025			0.021
>14 days to 1 month	2.080	1.039-4.161	0.039	2.128	1.051-4.308	0.036
>1 month to ≤ 2 months	2.399	1.220-4.717	0.011	2.580	1.294-5.146	0.007
> 2 months	6.786	1.417-32.485	0.017	6.546	1.351-31.706	0.020
Stone composition	1.018	0.861-1.204	0.835			

was considered when visible chemical and mineralogical deposits covered the surface or lumen of the renal and vesical coils (approximately 6-8cm at each end of the stent). Their chemical composition was analyzed by infrared spectroscopy (Thermo Scientific Nicolet iS5). Under sterile conditions, the double-J stents were removed cystoscopically with an alligator forceps under local anesthesia. Stent fragments were dried by heating at 70ºC for 12 hours and then cooled at room temperature. Subsequently, approximately 1mg of the dried encrustation sample scraped from stent was evenly mixed with 200mg of potassium bromide, powdered, compressed into a small tablet, and finally scanned by Fourier transform infrared spectroscopy[19,20]. According to the major chemical component that was recorded, the composition was classified as follows: calcium oxalate monohydrate, calcium oxalate dihydrate, ammonium magnesium phosphate, uric acid and carbonate apatite. In view of the rarity of cystine, ammonium urate, calcium phosphate, xanthine and 2,8-dihydroxyadenine, these constituents were referred to "other composition". The composition of the stone was compared with the composition of encrustation at the renal and vesical coils of the stent.

Statistical Analysis

The SPSS software version 16.0 was used to perform the statistical analysis. The significance level was defined as p-values less than 0.05. Continuous variables were presented as means ± standard deviation (SD). Categorical variables were expressed as frequency and percentage. McNemar test was used for group comparison. Bowker's test of symmetry was used to compare the composition of urinary stones and double-J stent encrustation. Unconditional logistic regression was used and expressed as odds ratios (OR) and 95% confidence intervals (95% CI) to identify independent factors associated with the formation of stent encrustation. Variables with p-values less than 0.1 in univariate analysis were regarded as important factors, and they were further examined in the multivariable analysis.

RESULTS

A total of 372 double-J stents were collected prospectively and included in this study. Patients' demographics and the characteristics of patients with or without encrustation were listed in Table 1. The mean age of patients was 50.4 ± 13.1 years. There were 228 males (61.3%) and 144 females (38.7%) with a male to female ratio of 1.60:1. The most common stone constituent was calcium oxalate monohydrate (58.8%).

There were 77 stents without any encrustation. A total of 277 stents were encrusted with vesical coil and 239 stents had encrustation in the renal coil. The encrusted rate of vesical coils (74.5%) was significantly higher than that in the renal coil (64.2%) when analyzed with the McNemar method ($P < 0.001$) (**Table 2**).

Figure 1 and Figure 2 show the comparison between the composition of stone and encrustation. Only those patients with analysis of stone and encrustation simultaneously were included. A comparison with Bowker's test of symmetry didn't demonstrate any significant difference about the chemical composition between stone and double-J stent encrustation in both of renal (178 patients, $P = 0.086$) and vesical (201 patients, $P = 0.072$) coils. This result means that the composition of double-J stent encrustation was more likely to be the same as that of the stone.

A regression analysis model was established to analyze the potential variables that were related to the formation of double-J stent encrustation (**Table 3 and Table 4**). The parameters including age, gender, body mass index (BMI), frequent stone former, hydronephrosis, preoperative urinary tract infection, stone location, stone free status, ureteral and/or ureteropelvic junction stricture, double-J stent caliber and stone composition had no effect on the formation of encrusted double-J stents when analyzed in the logistic regression model. The only predictive risk factor for development of stent encrustation was the indwelling time for both renal ($P < 0.001$) and vesical ($P = 0.021$) coils. Interestingly, CKD patient was shown to be less risk for development of encrustation of renal (OR 0.339, 95% CI: 0.194-0.593, $P < 0.001$) and vesical (OR 0.383, 95% CI: 0.217-0.675, $P = 0.001$) coils.

DISCUSSION

Identification of the characteristics of double-J stent encrustation and search for related factors are of importance for the prevention and treatment of encrustation. Observations in this study indicated that the vesical coil was more prone to encrustation than the renal coil. The only risk factor for the formation of encrustation was the time that stent had been indwelling in the collecting system. CKD was found to associate with less double-J stent encrustation. This series of measurements provide the first report on a reduced risk of stent encrustation in patients with CKD.

In this study, the vesical coil was observed to have a higher rate of encrustation than the renal coil. The underlying cause is probably attributable to the storage function of urine in the bladder, with increased exposure time of the stent to urine. Furthermore, Sighinolfi et al. reported that urinary tract infection was related to encrustation of vesical coils[6]. Lower urinary tract infection is more common than upper urinary tract infection, which might provide another explanation for the fact that vesical coils have a higher rate of encrustation than renal coils. However, in our series, preoperative urinary tract infection did not affect the encrustation of double-J stent in the regression model. It was a shortcoming that the current research lacks data of postoperative urinary tract infection, which might be more persuasive to explain the connection between urinary tract infection and double-J stent encrustation.

Rouprêt et al. recorded a 71.4% correlation between stent encrustation and stone composition and concluded that analysis of the chemical composition of encrustation could be a possible method for conclusions on stone composition in the case of a stone has not been acquired for analysis[21]. Similar findings were also described by Bariol and colleagues[22]. In our series, the Bowker's test of symmetry conducted to authenticate the chemical composition of double-J stent encrustations was more likely to be the same as that of the urinary stone, which means the prevention strategy for stone composition is also useful for the prevention of encrustations of double-J stent. Rouprêt et al. indicated that there was no significant difference in the composition of encrustation at the ends of the stent[21]. Moreover, our series presented that calcium oxalate monohydrate was found to be the most common stone or encrustation component. Calcium oxalate monohydrate is mainly associated with hyperoxaluric states[23]. It can also come from the crystalline conversion of calcium oxalate dihydrate, thus, be initiated by transient hypercalciuria[24,25]. Venkatesan and colleagues blamed the encrustation of calcium oxalate to a consequence of its poor solubility[26].

After adjustment of all statistically significant variables from the univariate analysis, the multivariable logistic regression model indicated that indwelling time was the only predictive risk factor associated with encrusted double-J stents in both renal and vesical coils. The same phenomenon was also described by Sancaktutar and Eisenberg et al.[27,28]. The rate of chemical and mineralogical encrustation increases with the indwelling time. Sighinolfi et al. have mentioned that urolithiasis patients, especially in frequent stone formers, were related to the burden of renal coil encrustation[6]. However, urinary tract infection and patient's aging were the risk variables contributing to the higher degrees of vesical coil encrustation. This phenomenon was related to a bladder outlet dysfunction.

In this series, patient with CKD was associated with less risk of double-J stent encrustation for both renal and vesical coils. There is reason to convince that CKD as a special physiological status being against the formation of kidney stones. Craver and colleagues conducted a cross-sectional study for the analysis of mineral metabolism alterations in CKD[29]. A total of 1836 patients were included and classified into stages 1-5. Results indicated that there is an associated fall in urine calcium excretion when GFR declines. It is well recognized that urine calcium is one of the most important critical risk factors for stone formation[23,30]. Marangella et al. investigated in 171 patients with chronic renal insufficiency, presented that multiple changes in renal pathophysiology were connected to the onset of renal insufficiency, which result in a sharp decrease in the urine saturation with respect to calcium salts[31]. These changes account for the decrease in the stone recurrence rate in the impaired GFR patients. Also, the reduction in urine calcium excretion in patients with CKD seems to contribute to the less double-J stent encrustation.

There are several shortcomings inherent in the design of this study to which attention should be paid. Firstly, lack of data of postoperative urinary tract infection, bacteriuria, medication therapy, daily water intake and diet, did not enable us to exactly elucidate the possible impact of infection, medication therapy, daily water intake and diet on encrustation. Secondly, stent characteristics were heterogeneous both in terms of brand and length. Finally, without the degree of quality of encrustation, hindering us to further understand the relationship of encrustation and indwelling time.

CONCLUSIONS

In this series, the chemical composition of double-J stent encrustation was more likely to be the same as that of the urinary stone, which means the prevention strategy for stone composition is also useful for the prevention of encrustation of double-J stent. The results showed that CKD patient had less risk on development of encrustation. Indwelling time was the only predictive risk factor for development of double-J stent encrustation. The observations provides a basis for further considerations on the prevention and treatment of patients with double-J stent encrustation.

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REFERENCES

1. Zimskind PD, Fetter TR, Wilkerson JL. Clinical use of long-term indwelling silicone rubber ureteral splints inserted cystoscopically. J Urol. 1967;97:840-4
2. Finney RP. Experience with new double J ureteral catheter stent. J Urol. 1978;120:678-81.
3. Borboroglu PG, Kane CJ. Current management of severely encrusted ureteral stents with a large associated stone burden. J Urol. 2000;164:648-50.
4. Fiuk J, Bao Y, Calleary JG, Schwartz BF, Denstedt JD. The use of internal stents in chronic ureteral obstruction. J Urol.2015;193:1092-100.
5. Lange D, Bidnur S, Hoag N, Chew BH.

Ureteral stent-associated complications--where we are and where we are going. Nat Rev Urol. 2015;12:17-25.

6. Sighinolfi MC, Sighinolfi GP, Galli E, et al. Chemical and Mineralogical Analysis of Ureteral Stent Encrustation and Associated Risk Factors. Urology. 2015;86:703-6.
7. Kartal IG, Baylan B, Gok A, et al. The Association of Encrustation and Ureteral Stent Indwelling Time in Urolithiasis and KUB Grading System. Urol J. 2018;17;15:323-328.
8. Venkatesan N, Shroff S, Jeyachandran K, Doble M. Effect of uropathogens on in vitro encrustation of polyurethane double J double-J stents. Urol Res. 2011;39:29-37.
9. Buhmann MT, Abt D, Nolte O, et al. Encrustations on ureteral stents from patients without urinary tract infection reveal distinct urotypes and a low bacterial load. Microbiome. 2019;7:60.
10. Arkusz K, Pasik K, Halinski A, Halinski A. Surface analysis of ureteral stent before and after implantation in the bodies of child patients. Urolithiasis. 2021;49:83-92.
11. Jacobsen SM, Shirtliff ME. Proteus mirabilisbiofilms and catheter-associated urinary tract infections. Virulence. 2011;2:460–465.
12. Arkusz K, Krasicka-Cydzik E. The effect of phosphates and fluorides, included in TiO2 nanotube layers, on the performance of hydrogen peroxide detection. Arch Metall Mater. 2018;63:765–772
13. Pais VM Jr, Chew B, Shaw O, et al. Percutaneous nephrolithotomy for removal of encrusted double-J stents: a multicenter study. J Endourol. 2014;28:1188-91.
14. Chew BH, Denstedt JD. Technology insight: novel double-J stent materials and designs. Nat Clin Pract Urol. 2004;1:44-48.
15. Levey AS, Stevens LA, Schmid CH, et al. A new equation to estimate glomerular filtration rate. Ann Intern Med. 2009;150:604-12.
16. Grignon A, Filion R, Filiatrault D, et al. Urinary tract dilation in utero: classification and clinical applications. Radiology. 2014;160:645-647.
17. Caron F, Galperine T, Flateau C, et al. Practice guidelines for the management of adult community-acquired urinary tract infections. Med Mal Infect. 2018;48:327-358.
18. Freifeld Y, Goldin D, Khalili L, et al. Does the use of ureteral stents with extraction strings increase urinary infection rates? Int Urol Nephrol. 2017;49:763-767.
19. Liu Y, Yasheng A, Chen K, et al. Difference in urinary stone composition between Uyghur and Han children with urolithiasis. Urolithiasis. 2017;45:435-440.
20. Huang J, Tusong H, Batuer A, Tuerxun A, Tiselius HG, Wu W. High prevalence of pediatric urinary tract stones in Xinjiang Uyghur. Urolithiasis. 2019;47:265-272.
21. Rouprêt M, Daudon M, Hupertan V, Gattegno B, Thibault P, Traxer O. Can double-J stent encrustation analysis predict urinary stone composition? Urology. 2005;66:246-51.
22. Bariol S, Farebrother T, Ruthven S, MacNeil F. Comparison of urinary stone and stent encrustation: biochemical analysis. J Endourol. 2003;17:741-3.
23. Daudon M, Doré JC, Jungers P, Lacour B. Changes in stone composition according to age and gender of patients: a multivariate epidemiological approach. Urol Res. 2004;32:241-7.
24. Berg W, Lange P, Bothor C, Rössler D. Submicroscopic investigations on calcium oxalate stone genesis. Eur Urol. 1979;5:136-43.
25. Schubert G, Brien G. Crystallographic investigations of urinary calcium oxalate calculi. Int Urol Nephrol. 1981;13: 249
26. Venkatesan N, Shroff S, Jeyachandran K, Doble M. Effect of uropathogens on in vitro encrustation of polyurethane double J double-J stents. Urol Res. 2011;39:29-37.
27. Sancaktutar AA, Tepeler A, Söylemez H, et al. A solution for medical and legal problems arising from forgotten double-J stents: initial results from a reminder short message service (SMS). Urol Res. 2012;40:253-8.
28. Eisenberg ML, Lee KL, Stoller ML. Endoscopic management of retained renal foreign bodies. Urology. 2012;73:1189-94.
29. Craver L, Marco MP, Martínez I, et al. Mineral metabolism parameters throughout chronic kidney disease stages 1-5--achievement of K/DOQI target ranges. Nephrol Dial Transplant. 2007;22:1171-6.
30. Curhan GC, Willett WC, Speizer FE, Stampfer MJ. Twenty-four-hour urine chemistries and the risk of kidney stones among women and men. Kidney Int. 2007;59:2290-8.
31. Marangella M, Bruno M, Cosseddu D, et al. Prevalence of chronic renal insufficiency in the course of idiopathic recurrent calcium stone disease: risk factors and patterns of progression. Nephron. 1990;54:302-6.