Predictive Factors for Achieving the Recommended AUA Daily Urine Production in Patients With Nephrolithiasis

Kimberly Tay, MD; Anojan Navaratnam, MBBS, FRACS; Sean McAdams, MD; Mira Keddis, MD; Matthew Neville, MS; and Mitchell R. Humphreys, MD

Abstract

Objective: To identify factors that predict kidney stone patient's ability to produce 2.5 L urine volume per day on metabolic evaluation.

Patients and Methods: In a retrospective chart review, the first analysis evaluated *initial* 24-hour urine collections with respect to those who achieved or did not achieve a urine volume of 2.5 L/day. The second analysis evaluated those who achieved or did not achieve a daily urine volume of 2.5 L on their *subsequent* collection. Several variables were assessed.

Results: Patients' initial collections (n=1100) that achieved 2.5 L/day (n=274) were of younger age and had a higher body mass index, increased urine sodium, phosphorus, calcium levels, increased protein catabolic rate, and decreased supersaturation of calcium oxalate. In the second analysis (n=273), decreased supersaturation of calcium oxalate, increased urine urea nitrogen level, and increased protein catabolic rate were observed in subsequent collections with a urine volume of 2.5 L/day or more. Patients with a diagnosis of hyponatremia were less likely to achieve 2.5 L/day urine volume. Collection date, other comorbidities, and diuretic use were not associated with achieving 2.5 L/day urine volume. Patients' mean creatinine per kilogram for all study cohorts were within the range of adequate collection.

Conclusion: Predictive factors for a urine volume of 2.5 L/day or more include increased fluid intake, higher salt and animal protein diet, elevated body mass index, and male sex. Patients with these factors may require interventions other than hydration recommendations to optimize their prevention of future kidney.

 ■ Mayo Clin Proc Inn Qual Out 2019;3(2):141-148

According to the National Health and Nutrition Examination Survey, 1 in 11 Americans will experience a kidney stone event, whether it be incidental or symptomatic. The 10-year recurrence rate in first-time stone formers is 50%.[1] Recurrent episodes and subsequent treatment(s) can cause significant morbidities and distress through missed work and reduced quality of life. The treatment of kidney stone disease was estimated to exceed 10 billion US dollars annually.[2] Thus, the impetus is on clinicians to identify modifiable factors to prevent future stone events.

The American Urological Association (AUA) recommends that repeat and initial stone formers complete 24-hour urine collections for metabolic evaluation to better assess risk factors and monitor treatment progress.[3-5] Nephrolithiasis has a complex pathogenesis influenced by metabolism, genetics, pharmacotherapy, and systemic conditions.[3] Low urine volumes have been associated with an increased prevalence of kidney stone disease in large cohort studies.[6] A key to reducing recurrence risk is achieving adequate daily urine volume.[3] It has been found that increasing urine volume can reduce the 5-year stone recurrence rate from 27% to 12.1%.[7]

Twenty-four-hour urine collections can be used to identify and tailor treatment for

From the Department of Urology (K.T., A.N., S.M., M.K., M.H.) and Department of Biostatistics (M.N.), Mayo Clinic, Phoenix, AZ.

patients at risk of recurrent kidney stone formation. There is potential to reduce overtreatment due to nonspecific "generalized" advice to patients who may not need specific interventions to prevent recurrence based on their individual physiology, which may change over time. Although studies have used 24-hour urine collections to look at the importance of urine volume in stone recurrence, little has been published about factors that might predict patient's ability to achieve the AUA's recommended daily urine volume. This study aims to identify factors that may predict patient's ability to achieve 2.5 L urine a day in a large cohort of metabolically evaluated kidney stone formers.

PATIENTS AND METHODS

After obtaining institutional review board approval, a retrospective chart review was performed using a database from the Mayo Clinic's stone clinic in Arizona that contained 3500 twenty-four-hour urine collections from January 1, 2007 to May 31, 2017. The initial metabolic evaluation of urine included patients who underwent 2 consecutive 24-hour urine collections (henceforth referred to as the "initial collection") and were then followed with a subsequent single 24-hour urine collection (henceforth referred to as the "subsequent collection"). Parameters for the 2 initial collections were averaged for each patient. The subsequent collection was taken 6 weeks to 1.5 years after the initial collection, depending on the clinical scenario. Collections were excluded if any data were missing.

The first analysis evaluated and compared the following variables: age, sex, body mass index (BMI; calculated as the weight in kilograms divided by the height in meters squared (kg/m^2)), diuretic use, comorbidities related to fluid restriction (hyponatremia, cirrhosis, and heart failure), and day of the week the collection was performed with respect to those who achieved or did not achieve a daily urine volume of 2.5 L on their *initial* collection. The first cohort included 1100 patients.

The second analysis evaluated and compared the same variables with respect to those who achieved or did not achieve a daily urine volume of 2.5 L on their *subsequent* collection despite stone clinic recommendations. To be included in the second analysis, patients needed a subsequent collection (as defined above) and an average daily urine volume of less than 2.5 L on their *initial* collection. This second cohort involved 273 patients.

Creatinine per kilogram (Cr24/Kg) was evaluated in all collections to determine whether patients undercollected or overcollected. Inadequate collections were less than 15 mg/kg in women and 18 mg/kg in men. Excess urine collections were more than 20 mg/kg in men and women. These are the recommended values to determine inadequate or excess urine collection.[8-10]

To detect differences between the urine output groups, categorical variables were analyzed using the chi-square test and continuous variables were analyzed using the nonparametric Kruskal-Wallis test. Analyses were performed using SAS version 9.4 of the SAS System for UNIX (SAS Institute). Data were then reported as mean ± SD.

RESULTS

Initial Collection

In the first analysis, 1100 patients had their initial 24-hour collections analyzed. There were 274 initial collections that achieved at least 2.5 L/day output as compared with 826 that did not. Table 1 depicts each variable that was evaluated with respect to achieving 2.5 L/day urine on the initial collection. Stone formers with a higher BMI (28.7±6.8 kg/m^2) were more likely to achieve the 2.5 L/day goal than were those with lower BMI (27.7±6.3 kg/m^2) (P=.025). Patients with increased urine sodium (203.7±90.3 mmol/dL), phosphorus (1±0.3 g/d), calcium (256.0±135.5 mg/d), urea nitrogen (12.7±4.2 g/d) levels and protein catabolic rate (1.1±0.3 g/kg per day) were more likely to achieve the 2.5 L/day goal (P<.0001). In addition, patients who achieved 2.5 L/day urine volume on their initial collection had decreased supersaturation of calcium oxalate (SSCaOx) (4.6±2.4) (P<.0001), likely reflective of their increased urine production. Collections were not more likely to be performed on a weekend. Younger age was found to be associated with 2.5 L/day urine volume, whereas diuretic use and comorbidities

TABLE 1. Variables Associated With Achieving 2.5 L/day Urine Volume on the Initial Collection[a,b]

Variable	Urine volume: <2.5 L on the initial collection (n=826)	Urine volume: ≥2.5 L on the initial collection (n=274)	*P* value
Sex (n=1100)			.013[c]
Female (n=448)	354/826 (42.9)	94/274 (34.3)	
Male (n=652)	472/826 (57.1)	180/274 (65.7)	
Age (y)	58.2±15.1	56.7±13.3	.016[c]
BMI (kg/m^2)	27.7±6.3	28.7±6.8	.025[c]
Urine dietary factors (n=1100)			
Urine sodium level (mmol/dL)	151±68.5	203.7±90.3	<.0001[c]
Urine phosphorus level (g/d)	0.9±0.3	1.0±0.3	<.0001[c]
Urine calcium level (mg/d)	196.0±110.4	256.0±135.5	<.0001[c]
SSCaOx	7.6±3.5	4.6±2.4	<.0001[c]
UUN level (g/d)	10.0±4.0	12.7±4.2	<.0001[c]
PCR (g/kg per day)	1.0±0.3	1.1±0.3	<.0001[c]
Comorbidities requiring fluid restriction (n=1046)			
Heart failure	26/782 (3.3)	7/264 (2.7)	.59
Hyponatremia	32/782 (4.1)	17/264 (6.4)	.12
Cirrhosis	13/782 (1.7)	3/264 (1.1)	.55
Medications at presentation (n=1043)			
Hydrochlorothiazide	28/781 (3.6)	7/262 (2.7)	.48
Chlorthalidone	235/781 (30.1)	85/262 (32.5)	.47
Indapamide	8/781 (1.0)	3/262 (1.1)	.87
Amiloride	9/781 (1.2)	4/262 (1.5)	.64
Furosemide	26/781 (3.3)	4/262 (1.5)	.13
Bumetanide	0/781 (0)	1/262 (0.4)	.084
Torsemide	1/781 (0.1)	2/262 (0.8)	.097
Potassium citrate	113/781 (14.5)	33/262 (12.6)	.45
Sodium bicarbonate	3/781 (0.4)	1/262 (0.4)	>.99
Collection day			.36
Sunday	227/826 (27.5)	77/274 (28.1)	
Monday	165/826 (20.0)	60/274 (21.9)	
Tuesday	141/826 (17.1)	38/274 (13.9)	
Wednesday	112/826 (13.6)	48/274 (17.5)	
Thursday	103/826 (12.5)	34/274 (12.4)	
Friday	50/826 (6.1)	12/274 (4.4)	
Saturday	28/826 (3.4)	5/274 (1.8)	
Weekday vs weekend			.77
Weekday	571/826 (69.1)	192/274 (70.1)	
Weekend	255/826 (30.9)	82/274 (29.9)	

[a]BMI = body mass index; PCR = protein catabolic rate; SSCaOx = supersaturation of calcium oxalate; UUN = urine urea nitrogen.
[b]Data are presented as mean ± SD or as number/total number (percentage).
[c]Any *P* value less than .05.

requiring fluid restriction were not associated with the ability to achieve the recommended daily urine volume on the initial collection. Day of collection did not seem to influence the successful volume results, and most consecutive urine collections were done on Sunday and Monday in both groups. In terms of adequate urine collection, the mean Cr24/Kg for both cohorts were above the minimum required (15 mg/kg for women and 18 mg/kg for men) (Table 2).

Subsequent Collection

Analysis of subsequent urine collections included 273 patients. Patients who achieved the goal urine volume on their subsequent

TABLE 2. Creatinine per Kilogram (Cr24/Kg) on the Initial Collection[a]

Variable	Urine volume: <2.5 L on the initial collection	Urine volume: ≥2.5 L on the initial collection	*P* value
Men	20.0±4.7	22.1±4.6	<.0001[b]
Women	16.8±4.6	18.4±4.5	.0020[b]

[a]Data are presented as mean ± SD.
[b]Any *P* value less than .05.

collection achieved higher urine volumes on their initial collection than did patients who did not achieve the goal (1.9±0.4 L vs 1.5±0.5 L; *P*<.0001). Table 3 summarizes the results for these patients. Patients who initially had higher urine sodium (168.0 mmol/dL vs 147.2 mmol/dL *P*=.025) and calcium (223.3 mg/d vs 185.9 mg/d; *P*=.0016) levels were more likely to achieve the goal urine volume on their subsequent collection. There was no difference in the mean change in either of these parameters (*P*=.16). There was no difference in change in urine calcium level between the 2 groups; however, patients who achieved 2.5 L/day urine volume on their subsequent collection had decreased SSCaOx (7.0 vs 3.1) as compared with those who did not (8.0 to 6.6) (*P*<.0001), as would be expected.

There was an increase in mean urine urea nitrogen level (11.9±4.1 g/d) and protein catabolic rate (1.1±0.2 g/kg per day) in the subsequent collections of those who achieved the goal urine volume (*P*<.0001). Patients with a documented history of hyponatremia (sodium concentration <135 mmol/L) were less likely to achieve the goal urine volume on their subsequent collection (5.8% vs 0%; *P*=.0119).

The day of the week did not seem to influence the ability to produce 2.5 L/day, and both cohorts were more likely to complete urine collections during weekdays. Age, sex, diuretic use, and socioeconomic factors such as employment or Medicare status were also not found to have a significant effect on daily urine volume of subsequent collections.

The mean Cr24/Kg for men and women in both cohorts were above the minimum for adequate urine collection (15 mg/kg for women and 18 mg/kg for men) (Table 4).

DISCUSSION

This study analyzed a large data set of 24-hour metabolic urine collections for urinary stone disease, aiming to determine factors that predict success in achieving the AUA's recommended urine volume of 2.5 L/day to reduce the risk of stone recurrence. The first analysis assessed initial urine collections of patients who did not receive any formal evaluation or counseling before urine collection at our institution. This was followed by a second analysis of the subsequent urine collection in those who failed to initially obtain 2.5 L/day urine output.

Overall, men were more likely to achieve a urine volume of 2.5 L/day or more on their initial collection. This finding is consistent with multiple studies.[8,11] When adherence rates of components of nephrolithiasis prevention therapy were evaluated, van Drongelen et al[11] reported that men were more compliant with high fluid intake, but noncompliant with a specific diet. In addition, women had lower adherence with medication and high fluid intake. This study also revealed that women were less likely to achieve goal urine volumes on their initial and subsequent collections. A possible explanation for this is that women may undercollect because of anatomical and mechanical constraints when providing urine collections.[12] Given the mean age of patients in this study (56-60 years) and the high rate of incontinence in this demographic (22.4%-24.7%), this may have contributed to the observed differences.[13,14] However, based on the parameters for undercollection, the average urine volume of collections in all study groups were more than 15 mg/kg for women and 18 mg/kg for men. Although urine collections may have been adequate, these results and the aforementioned studies emphasize the importance of considering sex-specific advice with regard to fluid modification in stone formers.

Patients with a higher BMI were associated with increased initial urine volume in this study population, which is consistent with previous studies. One hypothesis is that these patients have a higher oral intake of food and drink contributing to higher urine volume,

TABLE 3. Variables Associated With Achieving 2.5 L/d Urine Volume on the Subsequent Collection[a,b]

Variable	Urine volume: <2.5 L on the subsequent collection (n=165)	Urine volume: ≥2.5 L on the subsequent collection (n=108)	*P* value
Sex (n=273)			.67
Female (n=118)	73/165 (44.2)	45/108 (41.7)	
Male (n=155)	92/165 (55.8)	63/108 (58.3)	
Age (y)	60.8±14.4	59.4±14.4	.40
BMI (kg/m^2)			
Initial collections	27.5±6.2	28.0±6.1	.45
Subsequent collection	27.2±6.3	28.4±6.1	.12
Change	−0.2±2.3	0.0±1.5	.93
Insurance			.69
Medicare	79/156 (50.6)	51/106 (48.1)	
Not Medicare	77/156 (49.4)	55/106 (51.9)	
Urine volume			
Initial collections	1.5±0.5	1.9±0.4	<.0001[c]
Subsequent collection	1.7±0.5	3.3±0.5	<.0001[c]
Change	0.3±0.5	1.4±0.6	<.0001[c]
Urine dietary factors			
Urine sodium level (mmol/dL)			
Initial collections	147.2±54.4	168.0±66.3	.025[c]
Subsequent collection	159.5±67.7	191.2±80.1	.0026[c]
Change	12.3±58.2	23.2±67.2	.16
Urine phosphorus level (g/d)			
Initial collections	0.8±0.3	0.9±0.3	.052
Subsequent collection	0.8±0.3	0.9±0.3	.22
Change	0.0±0.3	0.0±0.3	.28
Urine calcium level (mg/d)			
Initial collections	185.9±99.1	223.3±102.3	.0016[c]
Subsequent collection	173.0±96.8	197.2±112.0	.15
Change	−12.9±78.0	−26.1±98.0	.1806
SSCaOx			
Initial collections	8.0±3.3	7.0±2.7	.012[c]
Subsequent collection	6.6±3.2	3.1±1.5	<.0001[c]
Change	−1.4±3.5	−3.9±2.4	<.0001[c]
UUN level (g/d)			
Initial collections	9.4±3.3	11.0±4.0	.0055[c]
Subsequent collection	9.9±3.8	11.9±4.1	<.0001[c]
Change	0.5±2.6	1.0±3.3	.079
PCR (g/kg per day)			
Initial collections	0.9±0.2	1.0±0.3	.0016[c]
Subsequent collections	1.0±0.3	1.1±0.2	<.0001[c]
Change	0.1±0.2	0.1±0.3	.43
Comorbidities (n=262)			
Heart failure	6/156 (3.8)	4/106 (3.8)	.98
Hyponatremia	9/156 (5.8)	0/106 (0)	<.05[c]
Cirrhosis	3/156 (1.9)	3/106 (2.8)	.63
Medications at presentation (n=262)			
Hydrochlorothiazide	7/156 (4.5)	2/106 (1.9)	.26
Chlorthalidone	48/156 (30.8)	44/106 (41.5)	.074
Indapamide	3/156 (1.9)	1/106 (0.9)	.53
Amiloride	4/156 (2.6)	2/106 (1.9)	.72

Continued on next page

TABLE 3. Continued

Variable	Urine volume: <2.5 L on the subsequent collection (n=165)	Urine volume: ≥2.5 L on the subsequent collection (n=108)	*P* value
Medications at presentation (n=262), continued			
Furosemide	5/156 (3.2)	2/106 (1.9)	.52
Bumetanide	0/156 (0)	1/106 (0.9)	.22
Torsemide	1/156 (0.6)	0/106 (0)	.41
Potassium citrate	31/156 (19.9)	31/106 (29.2)	.080
Sodium bicarbonate	1/156 (0.6)	0/106 (0)	.41
Collection day			.59
Sunday	13/165 (7.9)	6/108 (5.6)	
Monday	48/165 (29.1)	34/108 (31.5)	
Tuesday	30/165 (18.2)	22/108 (20.4)	
Wednesday	25/165 (15.2)	16/108 (14.8)	
Thursday	26/165 (15.8)	12/108 (11.1)	
Friday	20/165 (12.1)	12/108 (11.1)	
Saturday	3/165 (1.8)	6/108 (5.6)	
Weekday vs weekend			.71
Weekday	149/165 (90.3)	96/108 (88.9)	
Weekend	16/165 (9.7)	12/108 (11.1)	

[a]BMI = body mass index; PCR = protein catabolic rate; SSCaOx = supersaturation of calcium oxalate; UUN = urine urea nitrogen.
[b]Data are presented as mean ± SD or as number/total number (percentage).
[c]Any *P* value less than .05.

which could explain the high urine volume on the initial presentation to the clinic.[15] It may also be that increasing BMI is associated with increasing urine metabolite levels (increased urine sodium, oxalate, calcium, and uric acid levels as well as decreased pH) in both men and women, leading to increased urine osmolality and subsequently higher urine volume.[16-19] This increased urine osmolality is likely due to the resting anabolic state of obesity, resulting from an indulgent diet, especially with increased uptake in sodium and animal protein.[20,21] As such, this increased urine osmolality leads to an obligatory increase in thirst, allowing adequate water loss to excrete excess solutes.[22]

Patients who achieved 2.5 L/day urine volume on either initial or subsequent collections had increased urine sodium, calcium, urea nitrogen levels; increased protein catabolic rate;

TABLE 4. Creatinine per Kilogram (Cr24/Kg) on the Subsequent Collection[a]

Variable	Urine volume: <2.5 L on the subsequent collection	Urine volume: ≥2.5 L on the subsequent collection	*P* value
Men			
Initial collection	18.7±4.0	20.5±4.6	.021[b]
Subsequent collection	19.8±4.5	21.0±4.8	.13
Change	1.2±2.8	0.5±3.5	.52
Women			
Initial collection	16±4.4	16.8±4.7	.66
Subsequent collection	17.0±4.6	18.1±5.3	.38
Change	0.9±3.5	1.4±3.0	.77

[a]Data are presented as mean ± SD.
[b]Any *P* value less than .05.

and decreased SSCaOx. The association of high urine volume with increased urine metabolite levels, especially sodium, may be explained by a change in the physiological osmotic trigger for thirst, resulting in increased fluid and salt intake to maintain serum osmolality. Although increased urine volume was associated with high urine osmolality, SSCaOx significantly decreased with patients who achieved at least 2.5 L/day urine volume, thus decreasing the risk of stone recurrence. After 5 years, Borghi et al[7] found that stone formers treated with increased fluid intake—to a goal urine volume of 2 L/day—had a significant decrease in SSCaOx and lower incidence of stone episodes than did those not treated with increased fluid intake recommendations.

Those with an initial urine volume of less than 2.5 L/day had their subsequent collection analyzed to assess for improvement. Almost 60% of the cohort was unable to achieve goal urine volume, despite receiving education and follow-up in the clinic. Of note, the stone clinic has extensive experience counseling patients with regard to urine volume, as the authors have recommended a goal urine production of at least 2.5 L/day before incorporation into AUA guidelines. The failure to achieve urine volume recommendations could be due to poor adherence, which van Drongelen et al[11] found to be a major factor in efficacy failure of increasing urine volume, eating specific diets, and taking medications. They noted that adherence rates were based on patients' knowledge about their therapy. They also suggested that adherence increases in those who have required more treatments or had more stone-related symptoms, leading to more frequent follow-up visits. This could indicate that patients with a higher risk profile—identified in stone clinic—may be more compliant with and/or motivated to adhere to their treatment regimen. Furthermore, evidence exists in the literature suggesting that patients have difficulty sustaining short-term changes over the long-term.[23,24]

Upon initial collections, a younger age (56.7 years vs 58.2 years; $P<.05$) was found to be associated with 2.5 L/day urine volume. The study by Khambati et al[8] had similar results, in which patients older than 58 years were less likely to be compliant with increased fluid intake and increased urine volume. They attribute this to the increased prevalence of bladder outlet obstruction, overactive bladder, and cardiovascular comorbidities that may worsen in the setting of increased fluid intake. In addition, the elderly population experiences reduction in thirst even in the setting of dehydration and physiological changes in fluid and electrolyte homeostasis, affecting their fluid intake as well as excretion.[25] Therefore, age may serve as a barrier to achieving 2.5 L/day urine volume.

There were several limitations of this study. Patients had a relatively short follow-up after modification of fluid intake; however, this allowed us the most complete data set. Furthermore, only the immediate subsequent visit after the initial collection was included. With expanded analysis to look at every subsequent urine collection, further improvements may have been seen for patients compliant with stone clinic follow-up. Stone episodes and surgical interventions for stone disease between urine collections were not incorporated into this analysis. It is also acknowledged that urine collections provide just a snapshot of a patient's metabolism on that day. We did not conduct any surveys to ask patients whether their urine collections reflected their usual fluid and dietary habits or if they changed for the test. Future research can trend patients' subsequent urine volumes to see if they improve over a longer span of time with continued follow-up in a stone clinic. The clinical effect of these fluid intake modifications on stone recurrence rates in the study cohort was not assessed. Although it is widely known that increasing fluid intake decreases risk of kidney stones, it is possible that in the cohort who achieved 2.5 L/day urine volume, there were still stone recurrences because stone formation is multifactorial.[7] Height and weight were self-reported, possibly making BMI values inaccurate.

CONCLUSION

Low urine volume was the most common modifiable risk factor in this study population. Men and patients with elevated BMI were more likely to achieve 2.5 L/day urine volume. Although increased urine volume led to an increased excretion of urine metabolites, SSCaOx significantly decreased in patients who achieved 2.5 L/day urine volume, which has been proven to decrease the risk of stone recurrence. Overall, predictive factors for adequate urine volume include increased fluid intake, higher salt and animal protein diet, elevated BMI, and male sex. Patients with these factors may require other interventions or recommendations besides just increase fluid intake, whereas patients without the positive predictive factors may benefit from more intensive fluid interventions to achieve 2.5 L/day urine production.

Abbreviations and Acronyms: **AUA** = American Urological Association; **BMI** = body mass index; **Cr24/Kg** = creatinine per kilogram; **SSCaOx** = supersaturation of calcium oxalate

Potential Competing Interests: Dr Humphreys has received consultancy fees and grants from Boston Scientific (outside the submitted work). The other authors report no competing interests.

Correspondence: Address to Mitchell Humphreys, MD, Department of Urology, Mayo Clinic, 5777 E Mayo Blvd, Phoenix, AZ 85054 (Humphreys.mitchell@mayo.edu).

REFERENCES

1. Scales CD Jr, Smith AC, Hanley JM, Saigal CS. Urologic Diseases in America Project. Prevalence of kidney stones in the United States. *Eur Urol*. 2012;62(1):160-165.
2. Litwin MS, Saigal CS. Table 14-47: Economic impact of urologic disease. In: Litwin MS, Saigal CS, eds. *Urologic Diseases in America*. Washington, DC: National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health, Public Health Service, US Dept of Health and Human Services; 2012:486. NIH publication 12-7865.
3. Pearle MS, Goldfarb DS, Assimos DG, et al; American Urological Association. Medical management of kidney stones: AUA guideline. *J Urol*. 2014;192(2):316-324.
4. Parks JH, Coward M, Coe FL. Correspondence between stone composition and urine supersaturation in nephrolithiasis. *Kidney Int*. 1997;51(3):894-900.
5. Asplin J, Parks J, Lingeman J, et al. Supersaturation and stone composition in a network of dispersed treatment sites. *J Urol*. 1998;159(6):1821-1825.
6. 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*. 2001;59(6):2290-2298.
7. Borghi L, Meschi T, Amato F, Briganti A, Novarini A, Giannini A. Urinary volume, water and recurrences in idiopathic calcium nephrolithiasis: a 5-year randomized prospective study. *J Urol*. 1996;155(3):839-843.
8. Khambati A, Matulewicz RS, Perry KT, Nadler RB. Factors associated with compliance to increased fluid intake and urine volume following dietary counseling in first-time kidney stone patients. *J Endourol*. 2017;31(6):605-610.
9. Sawyer MD, Dietrich MS, Pickens RB, Herrell SD, Miller NL. Adequate or not? A comparison of 24-hour urine studies for renal stone prevention by creatinine to weight ratio. *J Endourol*. 2013;27(3):366-369.
10. Semins MJ, Matlaga BR. Medical evaluation and management of urolithiasis. *Ther Adv Urol*. 2010;2(1):3-9.
11. van Drongelen J, Kiemeney LA, Debruyne FM, de la Rosette JJ. Impact of urometabolic evaluation on prevention of urolithiasis: a retrospective study. *Urology*. 1998;52(3):384-391.
12. McGuire BB, Bhanji Y, Sharma V, et al. Predicting patients with inadequate 24- or 48-hour urine collections at time of metabolic stone evaluation. *J Endourol*. 2015;29(6):730-735.
13. Al-Mukhtar Othman J, Åkervall S, Milsom I, Gyhagen M. Urinary incontinence in nulliparous women aged 25-64 years: a national survey. *Am J Obstet Gynecol*. 2017;216(2):149.e1-149.e11.
14. Wu JM, Vaughan CP, Goode PS, et al. Prevalence and trends of symptomatic pelvic floor disorders in U.S. women. *Obstet Gynecol*. 2014;123(1):141-148.
15. Ekeruo WO, Tan YH, Young MD, et al. Metabolic risk factors and the impact of medical therapy on the management of nephrolithiasis in obese patients. *J Urol*. 2004;172(1):159-163.
16. Eisner BH, Eisenberg ML, Stoller ML. Relationship between body mass index and quantitative 24-hour urine chemistries in patients with nephrolithiasis. *Urology*. 2010;75(6):1289-1293.
17. Lee SC, Kim YJ, Kim TH, Yun SJ, Lee NK, Kim WJ. Impact of obesity in patients with urolithiasis and its prognostic usefulness in stone recurrence. *J Urol*. 2008;179(2):570-574.
18. Powell CR, Stoller ML, Schwartz BF, et al. Impact of body weight on urinary electrolytes in urinary stone formers [published correction appears in *Urology*. 2000;56(2):352]. *Urology*. 2000;55(6):825-830.
19. Sarica K, Altay B, Erturhan S. Effect of being overweight on stone-forming risk factors. *Urology*. 2008;71(5):771-774.
20. Curhan GC, Willett WC, Rimm EB, Speizer FE, Stampfer MJ. Body size and risk of kidney stones. *J Am Soc Nephrol*. 1998; 9(9):1645-1652.
21. Taylor EN, Curhan GC. Body size and 24-hour urine composition. *Am J Kidney Dis*. 2006;48(6):905-915.
22. Choi HY, Park HC, Ha SK. High water intake and progression of chronic kidney diseases. *Electrolyte Blood Press*. 2015;13(2):46-51.
23. Martin LR, Williams SL, Haskard KB, Dimatteo MR. The challenge of patient adherence. *Ther Clin Risk Manag*. 2005;1(3): 189-199.
24. Sanz EJ. Patient adherence to medical treatment regimens: bridging the gap between behavioral science and biomedicine. *BMJ*. 2005;330(7500):1155.
25. Rolls BJ, Phillips PA. Aging and disturbances of thirst and fluid balance. *Nutr Rev*. 1990;48(3):137-144.