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ORIGINAL PAPER

Association of body mass index and urine pH in patients with urolithiasis

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Abstract Increase in body size increases the risk of renal stone formation. The mechanism explaining this relationship remains unclear. Urine pH is one of the important factors for urinary stone formation. The purpose of this study was to determine whether there is an association between urine pH and body mass index (BMI) in patients with urolithiasis. Medical charts review that included 342 urinary stone formers (248 men and 94 women). Data obtained included patient sex, age, BMI, urine pH at diagnosis, and stone composition. The patients were classified as normal weight ($18.5 \leq \text{BMI} < 24$), overweight ($24 \leq \text{BMI} < 27$), or obese ($\text{BMI} \geq 27$). The mean urine pH of the normal body weight, overweight, and obese groups was 6.25, 6.14, and 6.00, respectively ($P < 0.05$). Urine pH is inversely related to BMI among patients with urolithiasis. Among patients with urolithiasis, higher BMI will have lower urine pH. This may explain why obesity is associated with an increased risk of nephrolithiasis. Weight loss should be explored as a potential treatment to prevent kidney stone formation. The prevention of urinary stone disease gives clinicians an additional reason to encourage weight reduction through diet.

Keywords Body mass index (BMI) · Urine pH · Urolithiasis · Obesity

Introduction

Urolithiasis is a major cause of morbidity. The lifetime prevalence rate of symptomatic urolithiasis is approximately 5–10% in the general population and there is male predominance [1, 2]. The etiology of urinary stone disease is multifactorial and not completely understood [3, 4]. The prevalence of urinary stone disease is increasing in the United States as well as in other countries [1, 5], in parallel with the escalating rate of obesity in many nations [6, 7]. The prevalence and incidence of stone disease have been reported to be associated with body weight and body mass index (BMI) [8–10]. In Taiwan, the prevalence of overweight and obesity in the general population was 25.8 and 16.8%, respectively [11]. Identification of common, modifiable risk factors for urinary stones may result in new approaches to treatment and prevention.

The correlation among urinary stone disease, body weight, and urinary pH is unclear. Based on the above observations, we sought to determine whether there is an association between BMI and urine pH in patients with urolithiasis.

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Methods

We retrospectively reviewed data from patients with urolithiasis from December 2005 to January 2007. The data included patient sex, age, BMI, urine pH at diagnosis, and stone composition. Body mass index (BMI) was calculated as weight in kilograms divided by the square of the height in meters. BMI cutoffs were adopted as suggested by the Department of Health in Taiwan including normal ($18.5 \leq BMI < 24$), overweight ($24 \leq BMI < 27$) and obese ($BMI \geq 27$) categories. The composition of stones was analyzed by using infrared spectrophotometry. Before stone removal, three spot urine samples were collected from the patients. Urine samples were analyzed by using an automated urine test strip analyzer, the Aution Max AX 4280 (Arkray Inc., Kyoto, Japan), which uses strips (Aution sticks-10EA, Arkray Inc., Kyoto, Japan) able to measure ten urinary parameters. The mean urine pH was calculated from the three spot urine samples.

Urine pH was compared among BMI and stone composition groups with one-way ANOVA. The differences in BMI, urinary pH and stone composition between men and women were analyzed by means of Pearson's chi-square test or Student's *t* test. Statistical significance was defined as two-tailed *P* less than 0.05. Statistical analysis was performed with SPSS version 12.0.

Results

Data from 342 patients, 248 men (72.5%) and 94 women (27.5%), were analyzed (Table 1). The mean age of the patients was 54.2 years and the mean BMI was 25.8 kg/m^2. There were 85 (24.9%) patients who were normal weight, 135 (39.5%) who were overweight, and 122 (35.7%) who were obese. The stone composition was calcium oxalate (CaOx) in 110 (32.2%) patients, calcium phosphate (CaP) in 35 (10.2%), uric acid (UA) in 32 (9.4%), and combined calcium oxalate and calcium phosphate in 165 (48.2%). The differences in BMI, urinary pH and stone composition between men and women were listed in Table 2. Male stone formers had significantly higher BMI and lower urine pH than females. Female stone formers had higher proportion of CaOx and CaP stones and lower proportion of mixed and UA stones than males.

Urine pH displayed a stepwise decrease with increasing BMI (Fig. 1). The mean urine pH of the normal weight, overweight, and obese patients was 6.25, 6.14, and 6.00, respectively, which was a statistically significant difference among the groups ($P = 0.021$). Urine pH is inversely related to BMI among patients with urolithiasis. In addition, the mean urine pH of the CaP, mixed composition, CaOx, and UA stone groups was 6.46, 6.23, 6.01, and 5.5, respectively, which also was a statistically significant difference among the groups ($P < 0.001$). The proportion of obesity in the CaP, mixed composition, CaOx, and UA stone groups was 34.3, 38.7, 42.7, and 53.1%, respectively. The UA stone formers had significantly higher proportion of obesity than other stone formers ($P = 0.012$).

Table 1 Characteristics of the study population

	N (%)
Patient number	342 (100)
Gender	
Male	248 (72.5)
Female	94 (27.5)
Age (mean ± SD, years)	54.2 ± 12.4
BMI (mean ± SD, kg/m^2)	25.8 ± 3.5
Normal weight ($18 \leq BMI < 24$)	85 (24.9)
Overweight ($24 \leq BMI < 27$)	135 (39.5)
Obese ($BMI \geq 27$)	122 (35.7)
Stone composition	
Calcium oxalate (CaOx)	110 (32.2)
Calcium phosphate (CaP)	35 (10.2)
Combined CaOx and CaP	165 (48.2)
Uric acid (UA)	32 (9.4)

Table 2 The different characteristics between male and female stone formers

	Male	Female	*P* value
Patient number	248	94	
Age (mean ± SD, years)	54.2 ± 12.3	54.1 ± 12.5	0.96
BMI (%)			
<24 kg/m^2	54 (25.9)	31 (33.0)	0.032*
≥24 kg/m^2	197 (79.4)	63 (67.0)	
Urine pH (mean ± SD)	6.06 ± 0.63	6.30 ± 0.63	0.002**
Stone composition (%)			
Calcium oxalate (CaOx)	13 (5.2)	22 (23.4)	<0.001*
Calcium phosphate (CaP)	115 (46.4)	50 (53.2)	
Combined CaOx and CaP	95 (38.3)	15 (16.0)	
Uric acid (UA)	25 (10.1)	7 (7.4)	

* Statistically significant (Pearson's chi-square test)

** Statistically significant (Student's *t* test)

Discussion

Increase of body size increases the risk of renal stone formation. The mechanism that explains this relationship is still unclear. Urine pH is one of the important factors for urinary stone formation. The purpose of our study was to investigate whether there is an association between urine

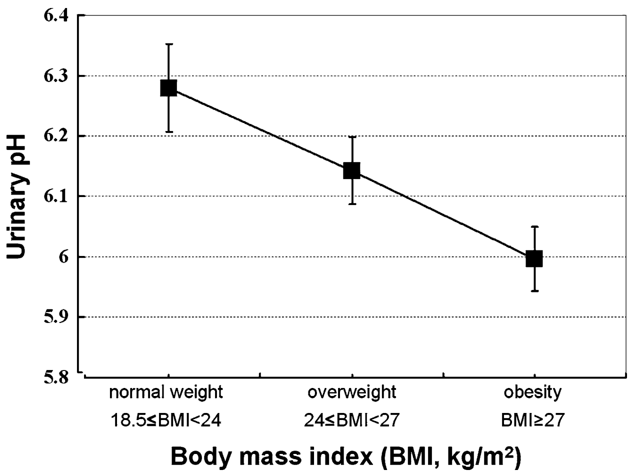

Fig. 1 Correlation between urine pH and body mass index. *Vertical bars* indicate mean ± SE

pH and BMI in patients with urolithiasis. We found that urine pH significantly decreases with increasing BMI. Studies of several groups of individuals with nephrolithiasis have also demonstrated that higher weight is associated with lower urine pH [12, 13].

The reasons for a progressive decline in urine pH with increasing BMI in patients with urolithiasis are uncertain. Hyperinsulinemia or insulin resistance is one of the possible reasons. Overweight or obese people have a higher incidence of diabetes mellitus which is correlated with hyperinsulinemia or insulin resistance. Insulin is known to stimulate the synthesis of ammonia and sodium–hydrogen exchange in the renal tubule which mediates ammonium excretion in urine [14, 15]. Insulin resistance may manifest in the kidney as a defect in ammonium production and the ability to excrete acid, and thus affect urine pH [16]. Recent data have confirmed that insulin resistance in humans is associated with lower urine pH [17]. Hyperinsulinemia could also lead to decreased urinary citrate and increased urinary excretion of calcium, uric acid, and oxalate, which are important risk factors for calcium nephrolithiasis [17].

Another possible reason is gouty diathesis and increasing urinary uric acid excretion. Overweight or obesity are associated with an increased risk of gouty diathesis which often results in increased urine uric acid excretion, an acidific urine environment, and uric acid stone formation. Epidemiologic studies have also shown that type 2 diabetes is significantly associated with an increased risk of uric acid stone formation in comparison to stone formation without diabetes [18, 19]. Men who weighed more than 120 kg had a urinary concentration of uric acid 13% greater than men who weighed less than 100 kg [13]. Moreover, the prevalence of gout was 30% in overweight and obese men compared with 18% in normal weight men. Similar findings were observed in women [9]. Increased urinary uric acid excretion not only affects uric acid stone formation but also is a risk factor for calcium oxalate stone formation, since calcium oxalate stones may also develop by heterogeneous nucleation of calcium oxalate by uric acid [20, 21].

In conclusion, our study showed that urine pH is inversely related to body mass index among patients with urolithiasis. Therefore, patients with higher BMI will have lower urine pH. This may explain why obesity is associated with an increased risk of nephrolithiasis. Weight loss should be explored as a potential treatment to prevent kidney stone formation. The prevention of urinary stone disease gives clinicians an additional reason to encourage weight reduction through diet.

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