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ORIGINAL ARTICLE

Perceptions of dietary factors promoting and preventing nephrolithiasis: a cross-sectional survey

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Abstract

Objective To assess knowledge of both promoting and preventive dietary factors on nephrolithiasis in a diverse patient population. Precipitating factors of kidney stone disease include diet, lifestyle, socioeconomic status, and race/ethnicity. However, patient awareness of these influences is poorly described.

Materials and methods A 24-question survey, assessing intake-related risk factors for stone disease, was administered prospectively to 1018 patients. Responses were summarized with frequency and percent. Statistical comparisons were made using a propensity scoring method in order to account for potential confounding variables. Propensity scores were stratified into quintiles. Further analysis with multiple imputation was performed to account for any missing data in the survey. The results of the propensity-adjusted log-binomial regression model are presented as prevalence ratios (PRs) and 95% confidence intervals (CIs).

Results Respondents demonstrated limited knowledge of nutrient factors that influence stone development. However, most study participants (70.3%) reported a willingness to make lifestyle changes aimed at lowering their risk for stone disease. Respondents reporting previous nephrolithiasis education were less likely to report that diet had no effect on kidney stone formation (PR = 0.795, 95% CI 0.65, 0.96, $p = 0.01$) The type of physician who counseled the respondent had no association with patient knowledge for stone disease (PR = 0.83, 95% CI 0.63, 1.10, $p = 0.2$).

Conclusions Knowledge of diet-related risk factors for nephrolithiasis is limited among this population. Respondents who received prior education appeared to maintain the knowledge of dietary risk for nephrolithiasis. Participants also expressed a willingness to make requisite dietary changes if that information is provided. Given that most stone formers experience a recurrence, these findings highlight the need for more comprehensive patient education strategies on the modifiable risk factors for nephrolithiasis.

Keywords Nephrolithiasis · Knowledge · Dietary · Perceptions · Promoting · Survey

Introduction

Each year, in the United States, urinary tract stones account for more than one million medical appointments and over 300,000 visits to emergency rooms [1]. The cost burden of urolithiasis is substantial—an estimated $10 billion is spent on urological stone disease annually [2–4]. The need for prevention is thus vital, and prevention programs aimed at minimizing modifiable risk factors are clearly warranted.

The association of nephrolithiasis with a typical western diet—high in salt, animal protein, sugar-sweetened beverages, and fructose—is well documented [4–9]. Thus, behavior changes aimed at reducing the probable dietary contributors to nephrolithiasis offer focal points during patient

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counseling [10]. Nutrition education may serve as a therapeutic strategy for prevention and risk reduction of kidney stones and, therefore, is included in the clinical guidelines of the American Urological Association (AUA) and European Association of Urology (EAU) [10, 11]. Limited studies, however, provide data on patient awareness of dietary risk factors for stone disease.

This study gleaned patient knowledge of dietary risk factors leading to kidney stone formation and patient awareness of preventive measures. Our primary objective was to estimate the association of prior education about kidney stone risk factors with present knowledge about diet as a risk factor. Our secondary objective was to estimate the association between prior education from a urologist vs. a primary care provider (PCP) with present knowledge about diet as a risk factor. Lastly, we assessed participant knowledge of avenues to prevent kidney stone formation. Results of this study may help direct future efforts for patient education and counseling of stone disease and offer insights into updates to the AUA and EAU clinical guideline for urolithiasis.

Materials and methods

Patients

This was a cross-sectional study. Across 1 year (November 2014–November 2015), the questionnaire was administered in different three urology clinics in the NY city area. All patients ≥ 18 years of age were eligible for this study, regardless of gender or ethnicity and regardless if they have urolithiasis history. Questionnaires were administered in consecutive fashion at the three urology clinics. Patients < 18 years of age, those whose primary language was not either English, Spanish, Mandarin, or Russian, or those who did not wish to participate were excluded, with an overall response rate of 95.8%. All patients who met the above criteria attending the urology clinic were given the survey questionnaire for completion. No flyers were used for advertisement and each patient was allowed to complete the survey once.

Measures

A 24-question, non-validated survey evaluating patient knowledge of the dietary nephrolithiasis risk factors was created (Online Appendix). The survey was modeled after the Evaluation of Psychometric Properties of the Chronic Kidney Disease–Mineral Bone Disease–Knowledge and Behavior (CKD–MBD–KB) Questionnaire [11]. The CKD–MBD–KB is a validated instrument, tested for validity and reliability with a urology patient population [11]. The structure of the questions included in this study's survey instrument mirrors that of the CKD–MBD–KB; the content was modified to focus on risk factors for nephrolithiasis. With the goal of developing an easy-to-read survey tool (7th grade reading level), the study questionnaire was also evaluated using the Flesch–Kincaid Grade Level test. Lastly, the survey was translated into Spanish, Mandarin, and Russian by certified translators.

Statistical analysis

To estimate the association of prior education about kidney stone risk factors with present knowledge about diet as a risk factor, while adjusting for potential confounding variables, we used a propensity scoring method. To calculate the propensity score, we fit a logistic regression model predicting prior education on stones with covariates considered a priori confounders, including gender, age, race/ethnicity, educational attainment, annual income, health insurance, history of diabetes, hyperlipidemia, hypertension, heart disease, kidney disease, asthma, lung disease, kidney stones, and other medical condition. The logistic regression model was used to score each participant and scores were stratified into quintiles. We examined the distribution of propensity scores for common support between exposure groups and dropped any quintiles that contained less than ten observations in either the exposed or unexposed groups. We then fit a log-binomial regression model with knowledge of diet being a risk factor as the response, and prior education about stones and quintiles of the propensity score as covariates. Adjusting for quintiles of the propensity score is similar to creating a propensity-matched sample and is estimated to account for 90% of confounding by observed variables [12]. We present the results of the propensity-adjusted log-binomial regression model as adjusted prevalence ratios (PRs) and 95% confidence intervals (CIs).

We additionally estimated the association between prior education from a urologist vs. a primary care provider (PCP) with present knowledge about diet as a risk factor, among the subset of patients who reported receiving prior education about stones. We estimated a separate propensity score for this model, in which we decided a priori to include gender, history of stones, kidney disease, other comorbidities, as well as race/ethnicity, education, annual income, and health insurance, with some categories combined to address low cell counts and increase stability. Patients in this subset were then scored and propensity values were stratified into quintiles, with any quintiles containing less than five observations in either exposure group being dropped. We then fit another propensity-adjusted log binomial model regression knowledge of diet as a risk factor on prior education from a urologist vs. PCP, with results presented as PRs and 95% CIs.

We hypothesized that history of stones would be a potential effect measure modifier for the association between education about stones and knowledge of diet as a risk factor. Therefore, we also fit the same propensity-adjusted model specified above with the interaction term for history of stones by and education about stones. In the case that this interaction term had $p < 0.05$, we additionally present adjusted PRs separately for patients with and without history of stones. Because all survey questions were voluntary, several observations were missing in our sample for prior education on stones ($n = 42$), race/ethnicity ($n = 24$), health insurance status ($n = 63$), history of stones ($n = 11.8$), as well as other demographic variables, and many of the diet questions (n range 56–134). To assess whether data missing at random may have impacted our results, we imputed ten datasets with five iterations each using random forest classifiers with all demographics, comorbidities, and risk factor knowledge variables included as predictors. We again fit all models to the ten imputed datasets and pooled results, with pooled standard errors calculated according to Rubin's rules [13].

All statistical analyses were conducted in R software version 3.4.2 [14] with multiple imputation using the 'mice' package [15]. All statistical tests were two sided with significance determined at $\alpha < 0.05$.

Results

The questionnaire was completed by 1018 respondents. Table 1 shows the demographics of the study respondents. Most of the respondents were males (69.6%, $n = 709$) between 60 and 79 years (47.5%, $n = 484$). The majority self-identified as Hispanic descent (41.1%, $n = 418$). Two-hundred and eighty-four (27.9%) of the participants disclosed a prior history of stone disease. Overall, 212 (21.7%) surveyors reported being educated on stone disease, and of those individuals, the majority ($n = 79$, 12.4%) were educated by a urologist. Differences in annual income, age, respondent race, and education level were not significant between those patients with and without a history of kidney stone.

Respondents' perceptions regarding dietary intake and promoting factors of stone disease are shown in Table 2. Overall, most participants reported either that diet did not influence stone formation ($n = 371$, 36%) or that they did not know diet influences stone formation ($n = 393$, 39%). Of note, approximately 31% of surveyors reported that water intake decreased kidney stone development, and nearly 43% answered that timing of water intake had no bearing on stone formation. Only 25% of respondents reported that salt increased stone formation, and approximately 13% reported that meat increased stone formation. Furthermore, regardless of the beverage questioned about, at least 66% of surveyors believed that the type of fluid consumption would have no effect on stone formation (i.e., beer, water, juice, tea, alcohol, lemonade, coffee). Nearly two-thirds (59%) of total respondents answered they would be ready to make dietary modifications to decrease their risk of kidney stone formation. These findings were consistent after adjusting for missing data using multiple imputation (Table 2).

In crude analysis, individuals with prior education on kidney stone development were less likely to believe that diet had no effect on kidney stone development [PR = 0.71, 95% confidence interval (CI) 0.63, 0.80, $p < 0.001$]. Among participants reporting prior education, compared to participants who received education from a primary care physician, participants who were educated by a urologist were less likely to believe that diet had no effect on kidney stone development (PR = 0.75, 95% CI 0.56, 0.97, $p = 0.032$).

In propensity score analysis for prior education about stones, quintile one contained only one observation for participants who reported having prior education; therefore, this quintile (146 observations) was dropped from analysis (Table 3). After adjustment using a propensity score for gender, age, race/ethnicity, education, annual income, health insurance, kidney disease, history stones, and other comorbidities, participants with prior education on stones were still less likely to believe that diet had no effect on kidney stone development (PR = 0.80, 95% CI 0.66, 0.97, $p = 0.01$, Table 4). Following multiple imputation, the association between prior education on kidney stones and belief that diet affects kidney stone development was similar to complete case analysis where patients with prior education on stones were less likely to believe that diet had no effect on kidney stone development (PR = 0.80, 95% CI 0.70, 0.92, $p = 0.002$, Table 4).

The interaction term for history of stones by education about stones was significant ($p < 0.001$) in the propensity-adjusted model, providing evidence that the association between education about stones and knowledge of diet as a risk factor was different for patients with and without history. Specifically, the association was stronger among patients with stone history (PR 0.61 95% CI 0.48–0.79 $p < 0.001$) and absent among patients without stone history (PR 1.12, 95% CI 0.98–1.28, $p = 0.095$). Following multiple imputation, the interaction term was still significant ($p = 0.048$) and prior education was negatively associated with lack of knowledge of diet as a risk factor among patients with prior history of stones (PR = 0.61, 95 CI 0.47, 0.78, $p < 0.001$). However, among patients without prior history of stones, prior education was weakly positively associated with lack of knowledge of diet as a risk factor (PR = 1.14, 95 CI 1.02, 1.27, $p = 0.026$).

In propensity score analysis for prior education from a urologist vs. a primary care provider, quintile five contained only three observations for participants reporting prior education from a primary care provider or other

Table 1 Demographics of participants (stratified by prior nephrolithiasis education)

	n (%) Overall	*n* (%) No or IDK	*n* (%) Yes	*n* (%) *p*
N	1018	764	212	
Gender				0.103
Male	709 (69.6)	542 (70.9)	138 (65.1)	
Female	304 (29.9)	217 (28.4)	74 (34.9)	
NA	5 (0.5)	5 (0.7)	0 (0.0)	
Age*				0.080
< 40	188 (18.5)	127 (16.6)	51 (24.1)	
40–59	332 (32.6)	253 (33.1)	64 (30.2)	
60+	484 (47.5)	374 (49.0)	93 (43.9)	
NA	14 (1.4)	10 (1.3)	4 (1.9)	
Race/ethnicity				0.844
White	189 (18.6)	138 (18.1)	42 (19.8)	
Asian or Pacific Islander	164 (16.1)	123 (16.1)	30 (14.2)	
Black/African American	168 (16.5)	129 (16.9)	32 (15.1)	
Hispanic	418 (41.1)	316 (41.4)	94 (44.3)	
American Indian/Alaskan Native	55 (5.4)	40 (5.2)	11 (5.2)	
NA	24 (2.4)	18 (2.4)	3 (1.4)	
Race/ethnicity*				0.746
White	189 (18.6)	138 (18.1)	42 (19.8)	
Black/African American	168 (16.5)	129 (16.9)	32 (15.1)	
Hispanic	418 (41.1)	316 (41.4)	94 (44.3)	
Other	219 (21.5)	163 (21.3)	41 (19.3)	
NA	24 (2.4)	18 (2.4)	3 (1.4)	
Education				0.638
Primary	126 (12.4)	95 (12.4)	29 (13.7)	
HS graduate	476 (46.8)	354 (46.3)	101 (47.6)	
College graduate	288 (28.3)	216 (28.3)	61 (28.8)	
Graduate school	113 (11.1)	86 (11.3)	20 (9.4)	
NA	15 (1.5)	13 (1.7)	1 (0.5)	
Education*				0.367
HS or less	602 (59.1)	449 (58.8)	130 (61.3)	
College graduate or above	401 (39.4)	302 (39.5)	81 (38.2)	
NA	15 (1.5)	13 (1.7)	1 (0.5)	
Annual income*				0.080
< 25K	510 (50.1)	369 (48.3)	120 (56.6)	
26–60K	254 (25.0)	198 (25.9)	50 (23.6)	
61K+	254 (25.0)	197 (25.8)	42 (19.8)	
Health insurance				0.029
Medicaid	337 (33.1)	238 (31.2)	89 (42.0)	
Medicare	302 (29.7)	236 (30.9)	50 (23.6)	
Private Insurance	280 (27.5)	217 (28.4)	52 (24.5)	
None	36 (3.5)	26 (3.4)	10 (4.7)	
NA	63 (6.2)	47 (6.2)	11 (5.2)	
Health insurance*				0.013
Medicaid or uninsured	373 (36.6)	264 (34.6)	99 (46.7)	
Medicare	302 (29.7)	236 (30.9)	50 (23.6)	
Private insurance	280 (27.5)	217 (28.4)	52 (24.5)	
NA	63 (6.2)	47 (6.2)	11 (5.2)	
Health conditions				
Diabetes	222 (21.8)	166 (21.7)	49 (23.1)	0.736

Table 1 (continued)

	n (%) Overall	*n* (%) No or IDK	*n* (%) Yes	*n* (%) *p*
Hyperlipidemia	276 (27.1)	210 (27.5)	54 (25.5)	0.619
Hypertension	410 (40.3)	315 (41.2)	78 (36.8)	0.277
Heart disease	87 (8.5)	68 (8.9)	17 (8.0)	0.791
Kidney disease	136 (13.4)	90 (11.8)	37 (17.5)	0.040
Asthma	93 (9.1)	64 (8.4)	24 (11.3)	0.235
Lung disease	20 (2.0)	10 (1.3)	8 (3.8)	0.038
Other comorbid condition*	620 (60.9)	461 (60.3)	134 (63.2)	0.498
Other medical conditions				0.003
No	895 (87.9)	680 (89.0)	176 (83.0)	
Yes	121 (11.9)	84 (11.0)	34 (16.0)	
NA	2 (0.2)	0 (0.0)	2 (0.9)	
History of stones				< 0.001
No	614 (60.3)	557 (72.9)	50 (23.6)	
Yes	284 (27.9)	117 (15.3)	146 (68.9)	
NA	120 (11.8)	90 (11.8)	16 (7.5)	
Prior education on stones				NaN
No or IDK	764 (75.0)	764 (100.0)	0 (0.0)	
Yes	212 (20.8)	0 (0.0)	212 (100.0)	
NA	42 (4.1)	0 (0.0)	0 (0.0)	
Prior education by provider				< 0.001
PCP	50 (4.9)	0 (0.0)	50 (23.6)	
Urologist	126 (12.4)	0 (0.0)	126 (59.4)	
Other	29 (2.8)	0 (0.0)	29 (13.7)	
NA	813 (79.9)	764 (100.0)	7 (3.3)	
Prior education by urologist				< 0.001
PCP/other	79 (7.8)	0 (0.0)	79 (37.3)	
Urologist	126 (12.4)	0 (0.0)	126 (59.4)	
NA	813 (79.9)	764 (100.0)	7 (3.3)	

IDK I do not know, *NaN* not a number

*Reduced/data categories collapsed for analysis

provider; therefore, this quintile (36 observations) was dropped from the analysis (Table 3). After adjusting using a propensity score for gender, age, race/ethnicity, education, annual income, health insurance, kidney disease, history of stones, and other comorbidities, the type of physician who counseled the respondent had no association with patient knowledge for stone disease (PR = 0.83, 95% CI 0.63, 1.10, $p = 0.2$). Adjusted results for this association following multiple imputation were similar to complete case analysis (PR = 0.85, 95% CI 0.66, 1.08, $p = 0.185$).

Comment

In our analysis, we found that participants who were previously exposed to stone disease education were less likely to state that diet had no influence on stone formation, suggesting that diet education is retained by patients. Furthermore, among patients who did receive education, the type of provider from whom the education was received (PCP vs. urologist) did not appear to impact knowledge of diet as a risk factor (PR = 0.83, 95% CI 0.63, 1.10, $p = 0.2$), suggesting that urologists and PCPs are equally effective at educating their patients in this area. Overall, patient knowledge regarding dietary factors that promote and/or inhibit stone formation was low, regardless of urolithiasis history.

Approximately 1 in 11 people will be diagnosed with a kidney stone in their lifetime [16] with lifetime prevalence up to 15% [17]. Stone disease has a substantial impact on the individual, healthcare system, and society. For individuals, stone disease is more likely to occur during a period of high work productivity; therefore, in addition to the medical expenses, there are costs associated with lost wages and likely quality of life issues [18]. Given the high prevalence and cost of kidney stone disease, patient education on potential lifestyle influences is paramount.

Table 2 Patient perception regarding dietary intake

	Diet knowledge (n = 1018) n (%)	Multiple imputation n (%)		Diet knowledge (n = 1018) n (%)	Multiple imputation n (%)
Foods			Water		
No	371 (36.4)	371 (36.4)	No	901 (88.5)	979 (96.2)
Yes	254 (25.0)	254 (25.0)	Yes	38 (3.7)	39 (3.8)
I don't know	393 (38.6)	393 (38.6)	NA	79 (7.8)	–
Meat			Water, intake		
No effect	131 (12.9)	136 (13.3)	No effect	159 (15.6)	173 (17.0)
Increases risk	135 (13.3)	140 (13.7)	Increases risk	31 (3.0)	32 (3.2)
Decreases risk	20 (2.0)	20 (2.0)	Decreases risk	319 (31.3)	349(34.3)
I don't know	617 (60.6)	722 (70.9)	I don't know	393 (38.6)	463 (45.5)
NA	115 (11.3)	–	NA	116 (11.4)	–
Dairy			Water, timing		
Don't limit	177 (17.4)	186 (18.3)	No	436 (42.8)	493 (48.5)
Should limit	135 (13.3)	141 (13.9)	Yes	166 (16.3)	180 (17.6)
I don't know	580 (57.0)	690 (67.8)	I don't know	306 (30.1)	345 (33.9)
NA	126 (12.4)	–	NA	110 (10.8)	–
Nuts			Alcohol		
I don't know	683 (67.1)	794 (78.0)	No	674 (66.2)	720 (70.7)
Increases risk	69 (6.8)	71 (6.9)	Yes	288 (28.3)	298 (29.3)
Decreases risk	145 (14.2)	154 (15.1)	NA	56 (5.5)	–
NA	121 (11.9)	–	Beer		
Fruits and vegetables			No	742 (72.9)	793 (77.9)
No effect	182 (17.9)	194 (19.0)	Yes	219 (21.5)	225 (22.1)
Increases risk	87 (8.5)	90 (8.8)	NA	57 (5.6)	–
Decreases risk	105 (10.3)	109 (10.7)	Coffee		
I don't know	525 (51.6)	625 (61.4)	No	760 (74.7)	819 (80.5)
NA	119 (11.7)	–	Yes	191 (18.8)	199 (19.5)
Salt			NA	67 (6.6)	–
No effect	103 (10.1)	107 (10.5)	Tea		
Increases risk	255 (25.0)	276 (27.1)	No	866 (85.1)	937 (92.1)
Decreases risk	31 (3.0)	32 (3.2)	Yes	79 (7.8)	81 (7.9)
I don't know	503 (49.4)	603 (59.2)	NA	73 (7.2)	–
NA	126 (12.4)	–	Lemonade		
Overeating			No	895 (87.9)	965 (94.8)
I don't know	668 (65.6)	792 (77.8)	Yes	52 (5.1)	53 (5.2)
Increases risk	140 (13.8)	146 (14.3)	NA	71 (7.0)	–
Decreases risk	76 (7.5)	80 (7.9)	Juice		
NA	134 (13.2)	–	No	870 (85.5)	938 (92.2)
Readiness to change			Yes	78 (7.7)	80 (7.8)
No	97 (9.5)	102(10.0)	NA	70 (6.9)	–
Yes	598 (58.7)	715 (70.3)			
Maybe	108 (10.6)	118 (11.6)			
Depends on food	78 (7.7)	84 (8.2)			
NA	137 (13.5)	–			

Prevention of initial and recurrent stone formation involves identifying modifiable risk factors and initiating measures to address them. Thus, evaluating patients' awareness of risk factors that promote stone disease is a key step in a preventive program. In this cross-sectional survey, self-reported understanding of stone disease dietary risk factors among those without a previous history of nephrolithiasis was found to be low. Moreover, this study identifies gaps

Table 3 Propensity quintiles stratified by exposure variables, to assess common support

	Prior education about stones		Prior education provider	
	No or IDK	Yes	PCP/other	Urologist
Total	764 (78.3%)	212 (21.7%)	79 (38.5%)	126 (61.5%)
Propensity*quintile (%)				
Quintile 1	145 (25.9%)	1 (0.6%)	25 (36.8%)	9 (8.6%)
Quintile 2	137 (24.5%)	10 (6.4%)	16 (23.5%)	17 (16.2%)
Quintile 3	132 (23.6%)	14 (9.0%)	18 (26.5%)	17 (16.2%)
Quintile 4	103 (18.4%)	38 (24.4%)	6 (8.8%)	29 (27.6%)
Quintile 5	43 (7.7%)	93 (59.6%)	3 (4.4%)	33 (31.4%)

Quintiles with less than five observations in either exposure group were dropped from the analysis for that exposure

*Propensity score including gender, age, race/ethnicity, education, annual income, health insurance, kidney disease, history stones, and other comorbidities. Quintile 1 was dropped from analysis of prior education about stones, and quintile 5 was dropped from analysis of prior education provider, due to having less than five observations

in understanding about potential dietary influencers among middle age and older individuals. For example, our findings highlight the need for risk factor education on adequate hydration—inadequate fluid intake reduces both urine output and flow, thereby encouraging stone formation [19, 20]: the value of fresh fruits and vegetables in reducing the odds of developing nephrolithiasis; [4, 6, 21, 22] and excessive protein consumption [8]. In addition, the majority of survey respondents (84.16%) were not aware of the association between overeating and increased risk for stone disease. As overeating leads to obesity, an additional topic regarding risk reduction is thus the hormonal changes that occur with obesity that may increase the risk for nephrolithiasis and the importance of maintaining a normal body weight to help reduce risk [4, 23].

Supplement Figure 1 provides a summary of the recommended dietary interventions included in the AUA and EAU clinical guidelines for nephrolithiasis [10]. Specific guidelines vary based on individual biochemical indicators, e.g., hypercalciuria, hypocitraturia, hyperuricosuria, hypernatriuria, hyperoxaluria, or low pH [10, 20]. Additional dietary recommendations draw on individual parameters gleaned from the 24-h urinary excretion test [24]. Given that dietary alterations differ based on the composition of the stone and individual laboratory findings, the lack of awareness among this cohort regarding dietary recommendations for specific comestibles is not surprising. However, there are certain dietary considerations (e.g., fluid consumption) that are generally valuable for reducing risk for development of all types of kidney stones.

Most of the respondents reported they would make the necessary changes in lifestyle to lower their risks, underscoring the significance of providing comprehensive patient education. These findings highlight both the importance of patient education across both prior stone formers and non-stone formers, as well as the need for a more extensive approach to help promote long-term behavioral change among high-risk populations. Several potential strategies for raising awareness of stone-related risk factors have been proposed including, increasing individual education by engaging Registered Dietitian Nutritionists (RDNs) [10, 24–29], sponsoring group appointments for stone patients [30], employing e-tools for sending regular reminders about the importance of preventive lifestyle choices, hosting community events [18, 29], and implementing initiatives on a national scale. Engagement of RDNs in medical nutrition therapy and community education events has been found to

Table 4 Crude, adjusted, and multiply imputed association between education about stones, education provider, and answering 'No' or 'I don't know' to the question on whether diet affects kidney stones (vs. 'Yes')

	Crude			Adjusted*			Adjusted* w/multiple imputation		
	PR	95% CI	*p* value	PR	95% CI	*p* value	PR	95% CI	*p* value
Prior education about stones									
No	1.00	Reference		1.00	Reference		1.00	Reference	
Yes	0.71	0.63–0.80	< 0.001	0.80	0.65–0.96	0.010	0.80	0.70–0.92	0.001
Prior education provider									
Primary care physician	1.00	Reference		1.00	Reference		1.00	Reference	
Urologist	0.75	0.56–0.97	0.032	0.83	0.63–1.10	0.199	0.85	0.66–1.08	0.185

PR prevalence ratio, *CI* confidence interval

*Adjusted for gender, age, race/ethnicity, education, annual income, health insurance, kidney disease, history stones, and/or other comorbidities using quintiles of a propensity score. Adjusted association for prior education about stones dropped 146 observations because quintile 1 contained fewer than five observations in the exposed group, and the adjusted association for education provider dropped 36 observations because quintile five contained fewer than five observations in the primary care physician group offer a cost-effective approach for other kidney conditions. Future studies are needed to determine strategies for improving patient compliance with these dietary modifications.

The findings of this study may ultimately aid in the design of an effective program aimed at the prevention of stone formation, including informing all patients of their risk of an initial stone as well as their significant risk of forming a recurrent stone; ensuring that all patients receive counseling on preventive strategies from their urologists, nephrologists, or RDNs; encouraging patients to be proactive in modifiable behavior changes of stone promoting risk factors; and tailoring counseling to a patient's specific level of barrier's. This study may also highlight the benefit to having an educator that can provide expert education regarding dietary modification and stone disease.

Several limitations of this study warrant consideration. Of note, our cohort was largely compromised of older, male patients. When compared to the literature, kidney stone formation has been associated with an increased risk in males compared to females, although the gap in gender for kidney stone disease is closing. Furthermore, the cohort demonstrated a large population of Hispanics (41.4%), with Caucasians representing a minority of patients (18.6%). Historically, kidney stone disease has demonstrated an increased prevalence amongst white individuals. This finding is likely secondary to the urban area where our urology clinics are located. Furthermore, it is important to recognize that not all kidney stone formation is in fact related to diet. It is well known throughout the literature that diet does not contribute to all kidney stone formation, although it is widely accepted that diet does play a significant role [4, 9].

This study is also limited by its observational design and may be subject to confounding. However, we addressed this limitation by including many potential confounders in the analysis via adjustment for quintiles of a propensity score, a method estimated to reduce 90% of the bias due to measured confounding [12]. That said, we are unable to rule out the effect of unmeasured confounders. Our study was limited by missing data in the outcome and covariates, which may not have been missing completely at random. We addressed this limitation by conducting a pooled analysis of multiply imputed datasets. Results from multiple imputation were very similar to complete case analysis, indicating that any data with missingness dependent on observed covariates were unlikely to bias the results. Additionally, study findings are based on self-report data and are thus susceptible to social desirability bias. However, if such a bias occurred, a higher rate of patient knowledge and education would be expected. Our study is limited by being a convenience sample–patients were recruited at only two academic centers, meaning that our results may not be generalizable to patients in other settings. Additionally, participants were volunteers and may, therefore, be more knowledgeable and/or healthier than the general population [30]. The study employed a non-validated questionnaire; we were unable to locate a validated questionnaire surveying patient's knowledge on the promoting factors of stone disease. This gives rise to the opportunity for our survey to be validated in future studies.

Despite these limitations, this is the largest known prospective analysis of perceptions of nephrolithiasis promoting factors and preventive measures. Thereby, this study provides new insights into opportunities for educating patients on stone disease.

Conclusions

Knowledge of diet-related risk factors for nephrolithiasis is limited among this population. Respondents who received prior education appeared to maintain the knowledge of dietary risk for nephrolithiasis. Participants also expressed a willingness to make requisite dietary changes if that information is provided. Given that most stone formers experience a recurrence, these findings highlight the need for more comprehensive patient education strategies on the modifiable risk factors for nephrolithiasis.

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Compliance with ethical standards

Conflict of interest Marc Bjurlin served on a speakers' bureau for Blue Earth Diagnostics and Ultimate Medical Academy. James Wysock disclsoures: Endocare Inc: paid speaker/consultatn. Fortec Medical, Inc.: paid speaker. Genomic Health Inc.: consultant (went to dinner). Intuitive Surgical Inc: consultant (went to dinner). Precision Biopsy, Inc.: consultant. Sonacare, Inc.: consultant/dinner/travel. Tolmar Pharmaceuticals, Inc.: consultant. Boston Scientific: consultant as well (dinner). United Medical Systems (paid speaker). No other authors have disclosures/conflicts of interest.

Institutional review board statement This study was reviewed and approved by our institution review board.

Informed consent Patients were not required to give informed consent to the study as it was a voluntary survey. Our institutional board deems the study exempt.

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