Seasonal Variation in the Frequency of Presentation with Acute Ureteral Colic and Its Association with Meteorologic Factors

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Abstract

Introduction: A seasonal variation in the frequency of acute stone presentations has been observed in studies from the United States, Africa, and Asia. The increased incidence of acute stone presentations during periods of warm weather has been attributed to both the dehydrating effect of elevated temperatures and the vitamin D related increase in calciuria during periods of increased sunshine. The aim of this study is to establish whether the association between various meteorologic parameters and the frequency of acute stone presentations also exists in a European climate.

Methods: All computed tomography kidneys, ureters and bladder scans performed by Emergency Departments within the Dublin Midland Hospital Group between June 2017 and September 2018 were identified from the national radiologic database. The date of scan in addition to stone parameters (site, size, and side) was recorded. These data were then correlated with weather recordings obtained from the Irish meteorologic office.

Results: A total of 2441 patients were investigated for suspected renal colic during the study period of which 781 were confirmed to have ureteral stones. An increased frequency of acute stone presentations was observed during the summer months of both years (June, July, and August). Unexpectedly, the heat wave of summer 2018 was not associated with an increased frequency of nephrolithiasis compared with summer 2017.

Conclusion: There is an increased frequency of acute nephrolithiasis during the summer months in Ireland. Health care services should be tailored to expect an increase in service needs during these periods of increased activity.

Keywords: urolithiasis, meteorologic factors, ureteral colic

Introduction

A SEASONAL VARIATION in the frequency of acute urinary calculi presentations has been observed across a number of climates. Studies from the United States, Africa, and Asia found an increased frequency of stone presentations in periods of warm weather with a corresponding decrease in presentations observed in colder seasons.^{1–3} This increased incidence has been attributed to both the dehydrating effect of elevated temperatures on urinary volume and the vitamin D related increase in calciuria during periods of increased sunshine and sun exposure.⁴ Periods of elevated temperatures have also been associated with an increase in urinary calcium excretion, further contributing to stone formation.⁵ The prevalence of urolithiasis has been increasing over a number of decades. This has been attributed, in part, to global

warming.⁶ The aim of this study was to investigate the association between various meteorologic parameters and the frequency of urolithiasis in a temperate Northern European cohort. We also sought to evaluate whether there was a demographic variation in different ages and gender.

Methods

All computed tomography kidneys, ureters and bladder (CTKUB) scans performed for the investigation of acute ureteral colic within the Dublin Midland Hospital Group between 1st June 2017 and 30th September 2018 were identified using the Health Service Executive National Integrated Medical Imaging System. Patients who had scans performed in an elective or semielective setting were not included in the analysis. The date of scan, patient age, and

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gender were collected. The presence of a ureteral calculus and calculus parameters were recorded. All patients with a ureteral calculus identified on imaging were included in final analysis. Data were obtained from the Irish meteorologic office detailing weather recordings for the same time period. Collected data were tabulated using Microsoft Excel (Microsoft Office 2010) to facilitate interpretation. Results were imported to IBM SPSS Statistics 25 (IBM Corp., Armonk, NY) for statistical analysis. Figures are quoted as mean $\pm$ standard deviation where applicable. Pearson's correlation coefficients and Poisson regression models were used to identify the effect of maximum daily temperature, mean daily pressure, daily rainfall, and potential evapotranspiration (PE) on the frequency of stone presentations. PE was analyzed independently to maximum temperature due to their interdependence. A p -value of <0.05 was considered statistically significant. Ethical approval was granted by the office of clinical audit.

Results

The Dublin Midlands Hospital Group provides elective and emergency care to a population of $\sim 800,000$ people across seven clinical sites. Standard protocol within the hospital group is to perform CT/KUB in all suspected cases of acute ureteral colic. There were 2467 CT/KUBs performed for suspected renal colic during the study period of which 794 had confirmed ureteral stones. Almost three quarters of the cohort were male (72.3%, 574/794). Median age was 44 ± 14 years. There was a peak increase in the frequency of presentations during the summer months (June, July, and August) of both years (Fig. 1). The mean frequency of presentations during summer months was 18%–42% more than the overall mean frequency of presentations. The heat wave in Summer 2018 did not result in a corresponding spike in presentations compared to Summer 2017.

Poisson regression models showed that the frequency of presentations was significantly related to maximum daily temperature ($p < 0.001$) and mean pressure ($p = 0.026$) but not daily rainfall ($p = 0.139$). The model also showed that for each 1°C increase in maximum temperature the frequency of presentations with ureteral colic increased by 2.3% (95% confidence interval [CI] 1–3.6). In the same model, the number of presentations increased by 0.2% (95% CI 0.06–0.33) for each 1 hPa increase in daily pressure. When PE was substituted for temperature in the model, it was also significantly associated with the number of presentations ($p \leq 0.001$). PE was highly predictive of presentation frequency with a 1 mm increase in PE predicting a 12% increase in presentations (95% CI 6–19).

The incidence of presentations with ureteral colic also had significant associations between maximum daily temperature, mean daily pressure, and PE across gender, age, and stone size (Table 1). Males appeared to be more affected by changes in temperature and PE than females. For each 1°C increase in temperature, the number of males and females presenting with ureteral colic increased by 2.7% and 1%, respectively (Table 1). For each 1 mm increase in PE, the number of males and females presenting with ureteral colic increased by 16% and 3.3%, respectively (Table 1). People over 65 years also appeared to be more affected by changes in temperature than those under 65 years. For each 1°C increase

in temperature, the number of those under 65 years and over 65 years presenting with ureteral colic increased by 2.1% and 3.7%, respectively (Table 1). For each 1 mm increase in PE, the number of those under 65 years and over 65 years presenting with ureteral colic increased by 12% and 15%, respectively (Table 1).

Discussion

For climatologic and meteorologic purposes, Ireland experiences four distinct seasonal changes, each consisting of a 3 month period: December to February (Winter), March to May (Spring), June to August (Summer), and September to November (Autumn). This common grouping is observed in many countries in the middle and northern latitudes. The seasonal variation in stone presentation has been previously described for warmer climates.^{1–3} Boscolo-Berto and colleagues¹ reported an association between the onset of renal colic and exposure to hot and dry weather. They found that there was an increase in the frequency of patients presenting with renal colic during periods of warm dry weather, particularly when temperatures rose above 27°C and relative humidity fell below 45%. There are a number of mechanisms proposed to explain the increase in frequency noted in times of elevated temperatures. Inadequate fluid intake, excessive sweating, dehydration, and the subsequent formation of concentrated urine are thought to play a key role in this process.⁵ Excessive exposure to sunshine results in the increased production of vitamin D, which is converted to 1,25-dihydroxy-vitamin D in kidneys and can promote calcium absorption in the gut.⁷ Our data show a significant increase in number of stone presentations in warmer months.

Brikowski and colleagues⁸ suggested that an unanticipated side effect of global warming will be a northern expansion of the current kidney stone belt in South-eastern United States. This is a region in the United States where stone incidence has been shown to be significantly higher compared with the general public.⁸ They report that this expansion will result in a 25% potential increase in current costs associated with the investigation and treatment of acute urinary calculi presentations. This would have significant implications for future service provision of urologic resources. It is anticipated that by the end of the century, average daily temperatures in Ireland will increase by 3.4°C and the intensity and duration of heat waves are also set to increase.⁹ The summer of 2018 produced a heat wave affecting many parts of Ireland. Temperature conditions in June to August 2018 were hotter and drier compared with the same months in 2017. However, the increase in temperature observed in summer 2018 compared to summer 2017 did not correlate with a significantly increased number of stone presentations over this time period. It is possible that the temperature difference seen in June to August 2018 compared with June to August 2017 was not large enough to produce a statistically significant effect.

We observed that for each increase of 1 hPa in air pressure, there was a corresponding increase in presentations of 0.2%. This positive correlation between air pressure and stone presentations has not previously been shown. We hypothesize that increases in atmospheric pressure may lower the saturation point of stone forming solutes in the urine.¹⁰ However limited data exist to support this hypothesis, and further studies are required to explain our observation. Our

FIG. 1. (a) Mean maximum daily temperatures by month. (b) Mean maximum daily potential evapotranspiration by month. (c) Frequency of ureteral stones by month.

TABLE 1. PRESENTATION OF URETERAL COLIC COMPARED BY GENDER, AGE, AND STONE SIZE

	Frequency (% total)	% change for incr. of 1°C (95% CI)	p-Value	% change for incr. of 1 hPa (95% CI)	p-Value	% change for incr. of 1 mm (95% CI)	p-Value
Gender							
Male	574/794 (72.3%)	2.7% (1.2–4.3)	0.001	0.9% (0–2)	0.066	16% (8–24)	0.001
Female	220/794 (27.7%)	1% (–2 to 3.5)	0.37	1% (–1 to 2.6)	0.17	3.3% (–8 to 15)	0.55
Age							
<65	722/794 (91%)	2.1% (0.8–3.5)	0.002	1% (0.2–1.9)	0.022	12% (5–19)	0.001
>65	72/794 (9%)	3.7% (–1 to 8)	0.074	0.3% (–3 to 2.7)	0.836	15% (–3 to 37)	0.1
Stone size							
<4 mm	400/794 (50.4%)	2.1% (0.3–4)	0.02	0.8% (–1 to 2)	0.172	11% (3–21)	0.006
>4 mm	394 (49.6%)	2.6% (0.8–4.5)	0.005	1.2% (0–2.4)	0.05	13% (4–22)	0.003

CI = confidence interval.

study findings differ from Fujita which found a significant increase in the frequency of stone presentations in days of decreased air pressure.²

PE is the water flux under nonlimiting soil water conditions.^{11,12} It is a measure of the ability of the atmosphere to remove water from the surface through the processes of evaporation and transpiration assuming that there is no limit to the supply of water. It is influenced indirectly by a combination of other climatic factors such as sunshine, temperature, and wind speed. PE was highly predictive of presentation frequency in our study. This increase was observed across gender age and stone size. This association has not previously been described. We hypothesize that this increase in frequency of stone presentations is linked to a dehydrating effect exerted on the body as a result of the atmospheric abilities to extract water by evaporation and transpiration. However, given the degree of significance observed, further studies to investigate the mechanisms to explain this increase in frequency are required.

Our study found that men are more likely than women to develop ureteral calculi and appeared to be more susceptible to changes in temperature and PE. This mimics the trend observed worldwide.⁵ One explanation for this is the different dietary habits observed across genders. Men are more likely to consume red meat, which leads to acidification of urine and subsequent stone formation.¹² Testosterone is also reported to promote stone formation due to the suppression of osteopontin expression in the kidney and subsequent increase in urinary oxalate excretion.¹³ It increases hepatic levels of glycolic acid oxidase, which is an enzyme involved in the metabolic pathway for urinary oxalate synthesis. Conversely, estrogen inhibits stone formation by increasing osteopontin expression in the kidney and decreasing urinary oxalate excretion.^{13,14}

People over 65 years also appeared to be more affected by changes in temperature than those under 65 years. This finding has also been observed in other studies.¹⁵ Due to the increased morbidity of accompanying diseases, older people are more susceptible to dehydration than younger people, especially during periods of warm weather.¹⁶ It is well recognized that the concentration of stone-forming salts exceeds their saturation point in the urine during periods of dehydration resulting in the development of calciuria, oxaluria, and subsequent stone formation.¹⁷

Our study was limited by the fact that it only included patients who presented to hospital with renal colic. It does not

take into account individuals who may have spontaneously passed stones without seeking medical attention. Therefore, the frequency of renal colic may have been underestimated in this study. This is an observational study and does not evaluate the effect of meteorologic factors on the pathogenesis or rate of stone formation. Neither does it explain the precise mechanism by which these factors influence the frequency of acute stone presentations.

Conclusion

Our study found that the seasonal variation in stone presentations seen in warmer climates also applies to more temperate climates like Ireland. Patients should be reminded to increase their fluid intake in warm weather. Climate change and predicted increases in global temperatures may cause an increase in the number of patients presenting to emergency departments with acute ureteral colic in the future.¹⁸ This will have implications on the provision of services both for therapeutic management and the need for implementation of primary care prevention strategies. Health care services should be tailored to expect an increase in service needs during these periods of increased activity.

Authors' Contributions

E.C.R.: Data collection, article writing; E.J.R.: Data collection, data analysis, article writing/editing; L.C.Y.: Data collection; and R.P.M.: Protocol/project development, article writing/editing.

Author Disclosure Statement

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Abbreviations Used

CI = confidence interval
 CTKUB = computed tomography kidneys,
 ureters and bladder
 PE = potential evapotranspiration