Kidney Stone Composition in Various Country Around the World

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Abstract

To compare urinary stone composition patterns in different populations around the world in relation to the structure of their population, dietary habits, and climate. 1204 adult patients with urolithiasis and stone analysis was included . International websites were searched to obtain data. We observed 710(59%) patients with calcium oxalate, 31(1%) calcium phosphate, 161(13%) mixed calcium oxalate/calcium phosphate, 15(1%) carbapatite, 110(9%) uric acid, 7(<1%) urate, 100(9%) mixed uric acid/ calcium oxalate, 56(5%) struvite and 14(1%) cystine stones. Calcium stones were the most common in all countries (up to 91%) with the highest rates in Canada and China. Oxalate stones were more common than phosphate or mixed phosphate/oxalate stones except Egypt and India. The rate of uric acid stones, being higher in Egypt, India, Pakistan, Iraq, Poland, and Bulgaria. Struvite stones occurred in less than 5% except India (23%) and Pakistan (16%). Cystine stones occurred in 1%. The frequency of different types of urinary stones varies from country to country. Calcium stones are prevalent in all countries. Uric acid stones seems to depend mainly on climatic factors, being higher in countries with desert or tropical climates. Dietary patterns can also lead to an increase it. Struvite stones are decreasing in most countries.

Introduction

Over the past 50 years, the prevalence of urinary calculi continued to increase, both in adults and pediatric population (46). The increase was initially observed in Western countries, but in more recent years the prevalence of kidney stones also tended to increase in many other countries around the world. In the US, the prevalence increased from 3.2% in 1976-80 to 8.8% in 2007-10 [1]. Similar trends have also been observed in Europe and the Far East [2-5]. More recently increased rates of stone prevalence were described in regions [6] where previously the rate of prevalence was lower. Increased prevalence of urinary calculi has been associated with changes of diet and lifestyle and climate modifications and is related to increased prevalence of other non-communicable diseases such as diabetes, hypertension, obesity, and osteoporosis. The effect of these environmental changes overlaps with individual genetic predisposition to stone formation and adds to genetically determined forms of stone disease (cystinuria, primary hyperoxaluria, and other renal tubular defects). The increase in the prevalence of urinary calculi has a significant impact on health systems due to the costs of diagnosing and treating the stones and the loss of working hours due to the disease [7]. The annual cost of kidney stone disease was estimated in the United States at 2.81 billion dollars in 2000 and at 3.79 billion dollars in 2012, after adjustment for inflation to 2014, and it was estimated that with the current trend of population growth and increase in the prevalence of obesity and diabetes it will increase of 1.24 billion dollars by 2030 [8]. The economic burden of the disease is more in Western countries but is increasing in developing countries where the prevalence of kidney stones was lower in the past.

The chemical composition of urinary stones depends on the eating habits and lifestyle of each population, but also on the climatic conditions of the region. The comparison of the patterns of composition of urinary stones in different populations can give information on the pathogenesis of different types of stones.

The patterns of composition of urinary stones has been described in numerous studies from different regions of the world, although most data have been collected in the Western world [9-14].

In Western countries, oxalate and/or calcium phosphate stones are prevalent, while uric acid containing stones are observed in a lower number of cases. In the past, infection stones accounted for up to 15% of all stones but their frequency decreased over time as a result of the more effective and less invasive methods for the treatment of stones and the prevention and the most effective treatment of urinary tract infections. Stones of cystine, dihydroxyadenine and xanthine represent a lower share of all the stones that tends to be constant in all the series as they are caused by genetic defects present in all the populations.

Similar spectra of stone composition are observed in developing countries, although the rate of uric acid and infection stones may vary in different populations depending on diet, climate, and efficiency of health system.

Although several studies evaluated series of urinary stones analyzed with different methods around the world, it is still not available a study comparing the different patterns of stone composition in patients from different countries depending on the gender and age structure of their populations, dietary habits and climatic conditions.

U-merge, an association gathering urologists from all over the world, is the ideal platform for this task. For this reason, the scientific office of U-Merge launched a study to evaluate the results of urinary stone analyses in the countries of its members in order to compare them in relation to the structure of the populations, dietary habits and climatic conditions.

Materials And Methods

U-merge membership is open to academic urologists, nephrologists, other specialists and researchers, who are keen to network and participate in academic activities worldwide. Applicants are evaluated on their record of academic activities in urology and related fields. Currently, U-merge includes members from 66 countries spread across all 5 continents. The Scientific Office of U-merge launched a call among all its members to retrospectively review the results of the stone analysis of patients attending their stone clinics for the treatment of urinary stone.

Participant members were asked to retrospectively review the charts of adult patients (> 18 years) with renal or ureteral stones assessed in previous years until the number of patients needed for the study was accomplished. All the patients for whom the stone analysis was available were considered eligible cases and the informed consent was taken. Duplicate cases have been excluded. No experimental protocols were applied for this study. Sex, age, country, and stone composition of each patient were recorded in an Excel data base. Any method of stone analysis was accepted, but the methodology had to be known and registered. A minimum number of 30 patients per center was required. Stones analyzed by wet chemical were classified as calcium oxalate (CaOx) (unspecified), calcium phosphate (CaP) (unspecified), mixed calcium oxalate/calcium phosphate (CaOx/CaP), struvite, uric acid (UA), mixed uric acid/calcium oxalate (UA/CaOx) and cystine.

Stones analysed by infrared spectroscopy or X-ray **diffractometry** were classified as CaOx dihydrate (> 50%), CaOx monohydrate (> 50%), CaP (> 50%), mixed CaOx/CaP (if CaP > 10%), struvite (>50%), carbonate apatite (50%), UA anhydrous (> 50%), UA dihydrate (> 50%), ammonium urate (> 50%), sodium urate (> 50%), mixed UA/CaOx, cystine.

The pattern of stone composition was expressed as frequency of stone composition, that is the ratio of the number of stones with a given composition by the total number of stones (e.g. number of calcium oxalate stones/ total number of stones). The assessment of prevalence or incidence would require studying a sample of the general population. At present, no epidemiological study ever assessed the prevalence (or incidence) in the general population for a given type of stone composition, because this study would require having the result of the stone analysis in the stone-forming subjects identified in the general population (which in most cases is not available). On the contrary, a rough estimate of the prevalence of a given type of stones can be obtained by multiplying the frequency of the stone composition in a series by the known prevalence of urinary stone disease (in general) in the same country or region. Data of prevalence of urinary calculi in the general population were available for 6 out of 10 countries that participated in the study: Argentina 5.14% [15], Canada 8.2% [16], China 7.0% [6], Southern India 2.6% [17], Italy 7.5% [18], and Pakistan 12% [19].

International institutional statistical websites were searched to obtain data on population structure, dietary habits and climate in the different locations where the series included in the study were collected.

The percentage in the total population by broad age groups (expressed per 100 total population) was obtained by consultation of the World Population Prospects 2019 (United Nations [20].

Mean temperature, precipitation fall and climate classification by Köppen-Geiger system were found on the World Climate website [21].

Mean values of daily dietary energy intake and rates of total energy by carbohydrates, proteins and fats were retrieved by the Food Balance Sheets of Food and Agriculture Organization of the United Nations (FAO) [22].

The Statistical Package for the Social Sciences (SPSS) version 11.5 for Windows was used for statistical analysis. Comparisons were considered to differ significantly if $P < 0.05$.

Descriptive statistics were calculated to describe the participants' demographic. Independent t-tests were used to evaluate differences of age between patients from different countries and between patients with different stone composition. Chi square analysis was used to assess differences in the male to female distribution between patients from different countries and between patients with different stone composition. Differences of the patterns of stone composition of patients from different countries were assessed by chi-square analysis.

Results

Twelve institutions from 10 countries have joined the survey as listed below:

- Acibadem City Clinic Tokuda Hospital, Sofia (Bulgaria)
- City Hospital Pakpattan, Pakpattan (Pakistan)
- Department of Urology, IRCCS Ca' Granda Ospedale Maggiore Policlinico, University of Milan, Milan (Italy)
- CHU de Québec, Laval University, Québec City (Canada)
- Urology Department, Assiut University, Assiut (Egypt)
- Shar Teaching Hospital, Sulaymanyah City (Iraq)
- Private Medical Center Klinika Wisniowa, Zielona Gora (Poland)
- Department of Urology, Renji Hospital,Shanghai Jiaotong University School of Medicine, Shanghai (China)
- Department of Urology and Nephrology, Military Medical Academy, Sofia (Bulgaria)
- Urology Department, Sulaymaniyah Surgical Teaching Hospital, Sulaymaniyah (Iraq)
- Department of Urology, Instituto de Investigaciones Metabólicas, Buenos Aires (Argentina)
- Department of Urology, Kasturba Medical College, Manipal, Karnataka (India)

In total, 1204 renal stone formers (RSFs) were considered (776 males, 428 females) from 10 countries (Argentina, Bulgaria, Canada, China, Egypt, India, Iraq, Italy, Pakistan and Poland).

Stones were analyzed by infrared spectroscopy in most centers (Bulgaria, China, Iraq, Italy, India, and Pakistan), by X-ray diffractometry in one center (Egypt) and by wet chemical analysis in three centers (Argentina, Canada and Poland).

The average age of patients was 49.3 ± 14.4 and the M/F ratio was 1.81. The number, average age and M/F ratio of RSFs from different countries are shown in **Table 1**.The average age of RSFs in Italy and Canada was greater than that of the RSFs of Argentina (p=0.000, Bulgaria (p=0.000 and p=0.001), Egypt (p-0.000), Iraq (p=0.000, and Pakistan (p=0.000). The average age of RSFs in Italy was higher than that of the RSFs in China (p=0.011). The lowest average age was observed in Egypt, Iraq, and Pakistan, where the average age of RSFs was lower than those of RSFs in Canada (p=0.000), Italy (p=0.000) and China (p=0.000, p=0.000 and p=0.001). In Egypt and Iraq, the average age of the RSFs was also lower than in Bulgaria (p=0.001, p=0.002), Poland (p=0.020, p=0.007) and India (p=0.009 and p=0.004).

Table 1. Average age and M/F ratio of renal stone formers (RSFs) from different countries

	ARG	BUL	CAN	CHI	EGY	IND	IRA	ITA	PAK	POL
T n	300	183	50	90	73	35	36	360	44	33
M n %	179 (59%)	122 (67%)	28 (56%)	58 (64%)	57 (78%)	26 (74%)	26 (72%)	226 (63%)	38 (86%)	16 (48%)
F N %	121 (41%)	61 (33%)	22 (44%)	32 (36%)	16 (22%)	9 (26%)	10 (28%)	134 (37%)	6 (14%)	17 (52%)
Age years SD	45±12	48±13	56±14	50±12	40±12	50±12	38±13	56±14	40±8	50±17

ARG = Argentina, BUL = Bulgaria, CAN = Canada, CHI = China, EGY = Egypt, IND = India, IRA = Iraq, ITA = Italy, PAK = Pakistan, POL = Poland

T = Total cases, M = Males, F = Females

N = number

Sig = Age p = 0.000, M/F ratio p = 0.002

In the present series, the mean age of RSFs in different countries averaged about 20 years higher than the average age of the general population (**Fig.1**), but overlapped with the mean age previously reported in other series of patients with kidney stones from the same countries [6, 23-31]

The frequency of the disease was slightly higher in women in Poland (52%), whereas it tended to be higher in men in Canada (56%), Argentina (59%), Italy (63%), China (64%) and Bulgaria (67%). Highest rates in men were observed in Pakistan (86%), Egypt (78%), India (74%) and Iraq (72%).

The spectrum of stone composition by gender and age is shown in **Table 2**. In total, we observed 710 (59%) patients with calcium oxalate, 31 (1%) with calcium phosphate, 161 (13%) with mixed calcium oxalate/calcium phosphate, 15 (1%) with carbapatite, 110 (9%) with uric acid, 7 (< 1 %) with urate (ammonium or sodium), 100 (9%) with mixed with uric acid/ calcium oxalate, 56 (5%) with struvite and 14 (1%) with cystine stones. In the calcium-containing group, calcium oxalate stones accounted for 77% and phosphate or mixed calcium phosphate/calcium oxalate stones for the remaining 23%. The frequency of calcium phosphate or mixed calcium phosphate/ calcium oxalate ranged from 9 to 74%. The great variability depends on the different methods of analyzing stones and reporting the results. In 403 patients with calcium oxalate stones analyzed by infrared spectroscopy, calcium oxalate monohydrate stones (COM) were more frequent than calcium oxalate dehydrate (COD) stones. Frequency of calcium oxalate stones was equal in women and men (58% vs 59%), whereas frequency of uric acid containing stones was lower in women than in men (13% vs 21%) and frequency of calcium phosphate and mixed calcium phosphate/calcium oxalate stones (21% vs 14%) and frequency of struvite stones were higher in women. Frequency of COM stones tended to be higher in men than in women (78 vs 71%) and to increase with age (18-39 =78%, 40-59=80%, > 60%=85%). Frequency of uric acid stones was higher in males and tended to increase with age. The distribution of the different types of stones in RSFs in different countries is described in **Table 3**. Calcium-containing stones were the most common in all countries. Among calcium-containing stones, calcium oxalate stones were more frequent in all countries except in Egypt and India where the frequency of calcium phosphate or mixed calcium phosphate/ calcium oxalate was 74% in Egypt and 53% in India, respectively. Among calcium oxalate stones, the rate of COM stones was 100% in Egypt, 83% in Italy, 81% in Bulgaria, 75% in China, and 69% in Iraq. The rate of uric acid containing stones ranged 4 to 34% in most countries with the highest rates observed in Egypt, India, Poland and Bulgaria. Struvite stones were less than 5% in all countries but India (23%) and Pakistan (16%). Cystine stones were less than 2%.

Table 2. Spectrum of stone composition by gender and age

	Gender		Age Group			
	Males	Females	18-39	40-59	>60	Total
CaOx N (%)	461 (59%)	249 (58%)	200 (59%)	318 (57%)	192 (62%)	710 (59%)
COM N	*223*	*105*	*73*	*136*	*119*	*328*
COD N	*52*	*23*	*20*	*34*	*21*	*75*
CaOx/CaP N (%)	89 (11%)	72 (16%)	46 (13%)	80 (14%)	35 (11%)	161 (13%)
CaP N (%)	18 (2.3%)	13 (3.0%)	12 (3.5%)	14 (2.5%)	5 (1.5%)	31 (3%)
Carbapatite N (%)	4 (0.5%)	11 (2.5%)	5 (1.5%)	8 (1.5%)	2 (0.5%)	15 (1%)
Ca-containing N (%)	572 (74%)	345 (80%)	263 (77%)	420 (76%)	234 (76%)	917 (76%)
UA N (%)	84 (11%)	26 (6%)	22 (6.4%)	49 (8.8%)	39 (12.6%)	110 (9%)
Urate N (%)	4 (0.5%)	3 (0.7%)	0 (0%)	4 (0.5%)	3 (1%)	7 (0.5%)
UA/CaOx N (%)	75 (10%)	25 (6%)	25 (7%)	55 (10%)	20 (6%)	110 (9%)
UA-containing N (%)	163 (21%)	54 (13%)	47 (14%)	108 (19%)	62 (20%)	217 (18%)
Struvite N (%)	33 (4.2%)	23 (5.4%)	23 (7%)	22 (4%)	11 (3.5%)	56 (5%)
Cystine N (%)	8 (1.1%)	6 (1.4%)	8 (2.5%)	4 (0.5%)	2 (0.5%)	14 (1%)
Total N	776	428	341	554	309	1204

N = number

CaOx = calcium oxalate, COM = calcium oxalate monohydrate, COD = calcium oxalate dihydrate, CAP = calcium phosphate, UA = uric acid

Table 3. Spectrum of stone composition in different countries

	ARG	BUL	CAN	CHI	EGY	IND	IRA	ITA	PAK	POL	TOT
CaOx N (%)	239 (80%)	97 (53%)	23 (46%)	65 (72%)	12 (16%)	7 (20%)	16 (44%)	214 (59%)	21 (48%)	16 (49%)	710 (59%)
COM N	-	79	-	49	12		11	178		-	
COD N	-	18	-	16	0		5	36		-	
CaOx/ CaP N (%)	12 (4%)	17 (9%)	11 (22%)	11 (12%)	3 (47%)	8 (23%)	7 (20%)	57 (16%)	0 (0%)	4 (12%)	161 (13%)
CaP N (%)	7 (2%)	0 (0%)	2 (4%)	6 (7%)	0 (0%)	0 (0%)	0 (0%)	14 (4%)	2 (4%)	0 (0%)	31 (3%)
Carbapatite N (%)	0 (0%)	3 (2%)	10 (20%)	0 (0%)	0 (0%)	0 (0%)	2 (5%)	0 (0%)	0 (0%)	0 (0%)	15 (1%)
Ca-containing N (%)	258 (86%)	117 (64%)	46 (92%)	82 (91%)	46 (63%)	15 (43%)	25 (69%)	285 (79%)	23 52%	20 61%	917 (76%)
Ox %	92%	85%	50%	79%	26%	46%	64%	72%	91%	80%	77%
UA pure N (%)	27 (9%)	8 (4.5%)	1 (2%)	5 (5%)	0 (0%)	5 (14%)	8 (22%)	39 (10.5%)	11 (25%)	6 (18%)	110 (9%)
UA urate N (%)	0 (0%)	6 (3.5%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0.5%)	0 (0%)	0 (0%)	7 (1%)
UA/CaOx N (%)	6 (2%)	39 (21%)	1 (2%)	1 (1%)	22 (30%)	7 (20%)	1 (3%)	18 (5%)	0 (0%)	5 (15%)	100 (8%)
UA - containing N (%)	33 (11%)	53 29%	2 (4%)	6 (6%)	22 (30%)	12 (34%)	9 (25%)	58 (16%)	11 (25%)	11 (33%)	217 (18%)
Struvite N (%)	9 (3%)	10 (5.4%)	1 (2%)	2 (3%)	4 (5.5%)	8 (23%)	1 (3%)	12 (3,5%)	8 (18%)	1 (3%)	56 (5%)
Cystine N (%)	0 (0%)	3 (1.6%)	1 (2%)	0 (0%)	1 (1.5%)	0 (0%)	1 (3%)	5 (1.5%)	2 (5%)	1 (3%)	14 (1%)
Total N	300	183	50	90	73	35	36	360	44	33	1204

Argentina = ARG, Bulgaria = BUL, Canada = CAN, China = CHI, Egypt = EGY, India = IND, IRAQ = IRA, Italy = ITA, Pakistan = PAK, Poland = POL

N = number

CaOx = calcium oxalate, COM = calcium oxalate monohydrate, COD = calcium oxalate dihydrate, CAP = calcium phosphate, UA = uric acid

Prevalence of calcium-containing and uric acid-containing stones were estimated for Argentina, Canada, China, India, Italy, and Pakistan (**Table 4**). The highest estimated prevalence for calcium-containing stones was observed in Canada.

Higher values were observed in Italy, China, and Pakistan, lower in Argentina and India.

The highest rate for uric acid-containing stones was observed in Pakistan, while lower values were observed in India and Italy and even lower in Argentina, Canada, and China.

Weight and height of patients were not recorded in the present study, although obesity rates of patients attending to most of the centers participating in the present study are available by another U-merge study (Argentina 17%, Bulgaria 17%, China 2%, India 15%, Iraq 32%, Italy 10%, Pakistan 50%, Poland 22%).

Table 4. Estimated prevalence of calcium- and uric acid-containing stones

	ARG	BUL	CAN	CHI	EGY	IND	IRA	ITA	PAK	POL
Ca-containing Frequency %	86%	64%	92%	91%	63%	43%	69%	79%	52%	61%
Estimated prevalence %	4.42%		7.54%	5.82%		1.11%		5.92%	6.24%	
UA-containing Frequency %	11%	29%	4%	6%	30%	34%	25%	16%	25%	33%
Estimated prevalence %	0.55%		0.32%	0.38%		0.88%		1.2%	3.0%	

Argentina = ARG, Bulgaria = BUL, Canada = CAN, China = CHI, Egypt = EGY, India = IND, IRAQ = IRA, Italy = ITA, Pakistan = PAK, Poland = POL

Ca = calcium, UA = uric acid

Mean temperature, precipitation fall and climate classification as per Köppen-Geiger system in the countries involved in the study are listed in **Table 5**.

Table 5. – Mean temperature, precipitation fall and climate classification in the countries involved in the study

Country	Town	Temperature mean	Precipitation fall	Climate	Köppen-Geiger climate classification system
Argentina	Buenos Aires	16.6 °C.	1005.2 mm	Warm temperate	Cfa
Bulgaria	Sofia	9.9 °C	574.9 mm	Warm temperate	Cfb
Canada	Quebec	4.3 °C.	1142.3 mm	Cold temperate	Dfb
China	Shanghai	15.4 °C.	1144.3 mm	Warm temperate	Cfa
Egypt	Asyut	22.5 °C.	2.3 mm	Hot desert	BWh
India	Karnataka	26.7 °C	4866 mm	Tropical	Am
Pakistan	Pakpattan	24.8 °C	234 mm	Hot desert	BWh
Iraq	Sulaymaniyah	16.2 °C	906 mm.	Warm temperate	Csa
Italy	Milan	11.7 °C	1000.8 mm	Warm temperate	Cfa
Poland	Zielona Gora	8.4 °C	596.9 mm	Warm temperate	Cfb

Mean values of daily dietary energy intake and rates of total energy by carbohydrates, proteins and fats, as well as percentages in the total population > 65 years are shown in **Table 6**.

Table 6. – Dietary energy intake, carbohydrate %, protein %, fats %, and rate of population > 65 years

Country	Energy intake kcal/day	Carbo-hydrate %	Protein %	Fats %	Population Age > 65 years %
Argentina	3000	55	13	32	11.4%
Bulgaria	2760	57	11	32	21.5%
Canada	3530	51	12	37	18.1%
China	2970	61	12	27	12%
Egypt	3160	73	12	15	5.3%
India	2300	71	10	19	6.6%
Pakistan	2250	63	10	27	4.3%
Iraq	-	-	-	-	3.4%
Italy	3660	49	12	39	23.3%
Poland	3400	58	12	30	18.7%

Discussion

In the present study, calcium-containing stones were the most frequent, followed by uric acid-containing stones, while struvite and cystine are less frequent. In accordance to previous reports [32], uric acid containing stones were more frequent in males and in older ages, whereas phosphate stones were more frequent in women.

The average age of RSFs in different countries varies but these differences reflect those that are observable in the general population of their countries, which averaged about 20 years lower. On the other hand, the average age values observed in our series overlapped to those previously reported in other series of patients with kidney stones from the same countries [6, 21-29]

Male to female (M/F) ratio is different in countries, being balanced between men and women or slightly in favor of men in the countries of North America, Europe, South America and China but heavily in favor of men in Egypt, Pakistan, India and Iraq.

This finding confirm the tendency to an increase of stone formation in women of Western countries [32], and more recently of China [6], while in Egypt, Pakistan, India and Iraq the ratio of males to females is still similar to what was observed in Western countries forty years ago [33]. This trend may be explained by the so-called nutrition transition, that is the change in dietary habits across the world with a convergence towards an increased consumption of unhealthy foods that is the cause of the increase in non-communicable diseases in almost all regions of the world in both sexes [34]. Consumption of unhealthy foods is still limited in some regions of North Africa and South Asia that maintain dietary patterns with a lower risk of urinary stones forming. Moreover, in some countries the characteristics of family structure and cultural rules still present a nutritional disadvantage for women [35].

The spectrum of composition of urinary stones is quite variable in different countries. Differences could be attributable to the different characteristics by age and gender of the populations studied, reflecting the distribution by age and gender in the general population of each country. On the other hand, the modality of stone analysis and reporting in the different centers may be a confounding factor [36]. For this reason, the most robust data are those comparing the rates of calcium-containing with those of uric acid containing stones, whereas it is less significant to compare the results of different countries in relation to the specific crystallographic composition, which should be compared between patients whose stones have been analyzed and reported in the same laboratory.

Calcium-containing stones were the most common in most countries with a rate ranging from 52 to 91%. The highest rates of calcium-containing stones were observed in North America, South America, China, and some European countries. In most countries, calcium oxalate stones (in particular COM stones) were the more frequent calcium-containing stones, whereas calcium phosphate and mixed calcium oxalate/calcium phosphate stones were more frequent than pure calcium oxalate stones in some countries such as Egypt and India. This trend is in agreement with previous observation in North America where a tendency has been reported of an increase in oxalate stones and a decrease in phosphate stones during the last two decades [10].

The highest frequency rates of acid uric containing stones were observed in Iraq, Pakistan, India, Egypt and Poland and Bulgaria. In general, uric acid-containing stones should be more frequent in older male patients, but surprisingly in our study the highest rates of uric acid-containing stones were observed in two countries with the lowest mean age, namely Egypt and Iraq. The impact of environmental factors may be decisive, considering that high temperatures and high humidity cause a decrease of urinary volumes and urinary pH values resulting in an increase of urinary uric acid saturation and of the incidence of uric acid stones [37, 38]. In fact, the highest values of uric acid-containing stones were observed in countries with high mean temperatures [21] and tropic or hot desert climates such as Egypt, India, Pakistan and Iraq. Our data confirm previous evidence in the literature showing a high rate of uric acid-containing stones in Pakistan, Egypt, and Iraq [23,24,39]. In the present study, the prevalence of uric acid containing stones was also high in Southern India in accordance with previous reports. In fact, the frequency of uric acid-containing stones was reported as low (< 1%) in North Western India [25,26], but higher in Southern India [17]. This difference can be explained by different regional eating habits: in the Northern and Western regions, a more traditional vegetarian diet is consumed with exclusive consumption of fruit, vegetables and legumes, whereas in the Southern regions the consumption of sweets, snacks and pork meat is common [40]. On the other hand, in our study the lowest rate of uric acid containing stones was observed in Canada, the country with the lowest mean temperature. Intermediate rate values were observed in countries with a temperate climate, such as China and Italy.

In some countries, the high frequency of uric acid-containing stones may be explained by the effect of dietary factors that contribute to the risk of uric acid stone formation [41].

Although in contrast with previous findings showing lower rates of uric acid stones in a series of stones analyzed by infrared spectroscopy [27], the high rate of uric acid stones in Poland may be explained by high obesity rate of the population (45%) and unfavorable dietary patterns [42]. In fact, the adherence to the traditional Polish dietary pattern, characterized by high intake of refined grains, potatoes, sugar and sweets is associated with a higher risk of abdominal obesity and hypertriglyceridemia [43]. Similarly, in Bulgaria the frequency of uric acid-containing stones is associated with an unhealthy nutritional pattern characterized by high consumption of fatty meats and meat products, high-fat milk and a high alcohol intake [44].

The rate of struvite stones is generally lower than described in the past, due to improved health conditions and early diagnosis and treatment of urinary tract infections by urease-producers, although in some countries such as Pakistan and India it still accounts for a quarter of cases.

In some areas of these countries, the diagnosis and treatment of urinary infections is still inadequate and can result in chronic infections and scarring of the urinary tract promoting the formation and growth of staghorn infection stones [45].

Cystine stone rates are similar in all countries, with similar rates than those reported in the literature.

The strength of this study has been to have compared series from different countries according to the same evaluation parameters, but it has some limitations. A limitation was the use of wet-chemical analysis of the stones in 3 out 12 centers that participated in the study. In fact, chemical analysis of the stone has limitations in identifying all the stone components and distinguishing their crystalline forms for which most guidelines recommend analysis by infrared spectroscopy or X-ray diffractometry [36]. Unfortunately, these methods are not available in all centers, so to extend our survey to as many countries as possible, we decided to include also centers where the stones were analyzed with wet chemical analysis. For this reason, data of the stones analyzed in Argentina, Canada and Poland may be less reliable and should be evaluated with caution.

Another possible limitation of this study was the use of frequency rate of the different types of stones as a parameter to compare the pattern of stone composition in different countries. This parameter should be corrected based on the prevalence rate of urinary calculi (all types included) in the population of each country. Unfortunately, we know the rate of prevalence of urinary calculi in the general population only for a limited number of countries.

When we calculated the specific prevalence of different types of stones, we were able to confirm the high prevalence of uric acid stones in Pakistan and, to a lesser extent, in India while we could not calculate prevalence rates of uric acid stones for Iraq, Egypt, Poland and Bulgaria where epidemiological studies were never carried out to assess the prevalence of urinary stones in the general population. The significance of the high frequency rates of uric acid-containing stones in these countries remains uncertain.

In fact, the frequency of a type of stone is not a measure of its prevalence but it is the result of the prevalence of the different types of urinary stones. In other words, a high frequency of uric acid stones may be due to an increase in the prevalence of uric acid stones but, alternatively, to a lower prevalence of other types of stones (e.g. calcium oxalate).

In conclusion, the frequency of different types of urinary stones varies from country to country. Calcium-containing stones are the most frequent in all countries, with frequencies of up to 90%. The frequency of uric acid containing stones seems to depend mainly on climatic factors, being more frequent in warmer countries with desert or tropical climates although dietary patterns can also lead to an increase in the frequency of uric acid containing stones in association with high obesity rates. Struvite stones are decreasing in most countries except India and Pakistan.

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Figures

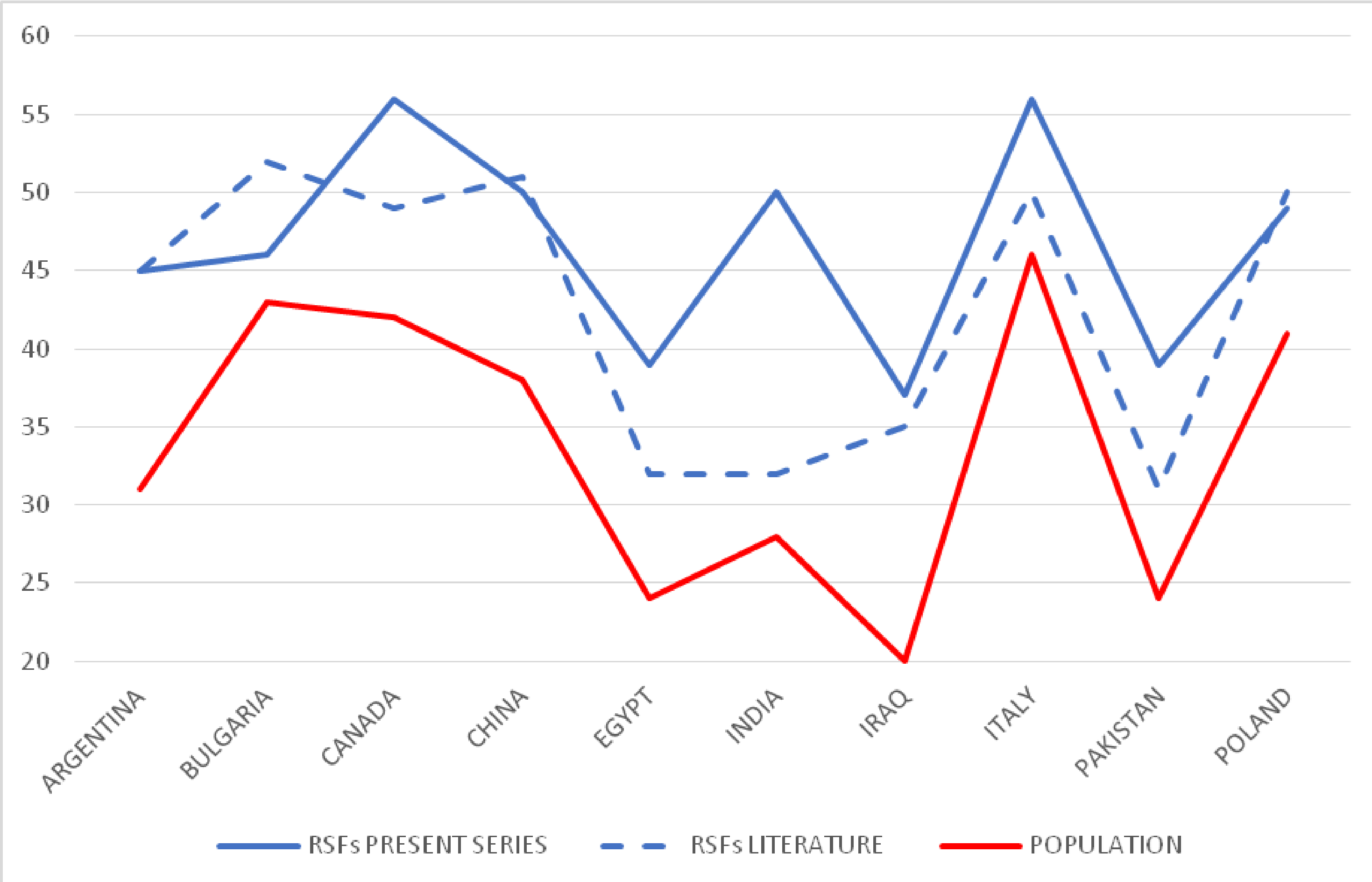

Figure 1

Average age in renal stone formers (RSFs) and general population