Original Article

Compositional analysis of urinary stones in Eastern India: Insights from a comprehensive analysis of 1231 Stone Samples

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ABSTRACT:

***Objective*:** Urinary stones are a prevalent medical condition entailing considerable health and financial implications. Studying patients with diverse stone types is crucial for optimizing treatment and preventive measures. The primary goal of this study was to investigate the correlations between patient demographics and the characteristics of urinary stones with its recurrence rate in eastern Indian population.

***Patient and methods*:** In an Eastern Indian tertiary care centre, 1231 cases of urinary stone patients who were admitted for elective stone removal from January 2015 to November 2022 were recruited. Patient data, including demographic information, clinical records, dietary habits, water intake, geographical location, and stone recurrence history were collected. A thorough analysis was conducted to elucidate the associations between the patient characteristics and urinary stone composition and its recurrence.

Result: The study revealed a higher occurrence of urinary stones in men, mainly calcium oxalate stones. Individuals aged 31-40 exhibited the highest prevalence of pure, two-component, and three-component stones. Kidneys were the most commonly affected, patients often accompanied by flank pain and a history of tobacco use. There was a significant correlation between stone recurrence and dietary habits, along with water intake.

***Conclusion*:** Calcium oxalate was the predominant component in urinary stones observed within the Eastern Indian population, and it was noted that the early middle age group exhibited the highest incidence of stone formation. Furthermore, instances of stone recurrence were found to be associated with various factors, such as age, gender, dietary habits, and water intake.

Keywords: Urinary Stone, Stone analysis, Stone composition, Urinary stone recurrence

Introduction

The escalating global incidence of urinary stone cases has emerged as a significant public health concern with profound socioeconomic implications [1]. Lifestyle factors, notably elevated consumption of proteins, salt, and fructose, alongside environmental influences, collectively contribute to the surge in stone formation [2,3].

Kidney stones, comprising a diverse array of over 100 chemical components, are influenced by a myriad of factors, encompassing abnormalities in urine biochemistry, anatomical variations, genetic predisposition, and various syndromes [4]. Innovative treatment modalities such as Extracorporeal Shock Wave Lithotripsy (ESWL) and Percutaneous Nephrolithotomy (PCNL) have revolutionized urinary stone management, ushering in an era of enhanced efficacy and reduced surgical complexity [5,6]. Advancements like flexible or semi-rigid ureteroscopy and Transurethral or percutaneous cystolithotripsy have further streamlined procedures, minimizing the need for invasive surgeries and lowering associated morbidity [6,7,8].

Despite these strides in surgical intervention, the imperative to address the root causes of urinary stone disease remains paramount, as current procedures predominantly focus on removal rather than prevention of recurrence [9]. Stone composition analysis emerges as a crucial tool in this pursuit, facilitating precise patient-specific treatment and potentially curbing the risk of relapse. Recognizing its significance, the European Association of Urology (EAU) mandates stone analysis as an integral step in the diagnostic process [10].

Given India's distinction as the home to the world's largest population, the prevalence of stone disease exhibits noteworthy variations influenced by factors like climate, dietary choices, and groundwater quality [11,12]. Consequently, this study endeavors to conduct a comprehensive compositional analysis of stones in patients across different age groups, presenting at our hospital. The overarching goal is to unravel the intricate patterns of stone formation, shedding light on the nuances of urinary stone disease within the context of this diverse and populous nation.

Patient and methods

In this prospective study, 1231 patients diagnosed with urolithiasis at a tertiary hospital in eastern India between January 2015 and December 2021 were enrolled. The study was subject to review and approval by an Independent Institutional Ethics Committee prior to study commencement. Following informed consent, patients underwent surgical intervention for either primary or recurrent urolithiasis, during which urinary stones were systematically collected and subsequently sent to the laboratory for comprehensive analysis.

Patient-specific data including clinical details, demographic information, stone localization, recurrence history, and stone composition reports were meticulously documented. To investigate potential variations in stone composition across distinct age cohorts, patients were stratified into age groups: 1-10 years, 11-20 years, 21-30 years, 31-40 years, 41-50 years, 51-60 years, 61-70 years, 71-80 years, and 81-90 years.

Post-surgical retrieval, the collected stones underwent a meticulous cleansing process using distilled water to eliminate any residual blood or tissue, ensuring the integrity of subsequent analyses. Subsequently, the stones were carefully dried using filter paper in preparation for compositional analysis utilizing Fourier Transform Infrared spectroscopy (FTIR). This analytical technique facilitated a detailed examination of the chemical constituents of the urinary stones, contributing valuable insights into the compositional analysis of urolithiasis across different age groups within our study cohort.

Statistical Analysis

In the present study, statistical analyses were conducted using IBM SPSS Version 21. Descriptive statistics, comprising means, proportions, and percentages, were employed to compute the results. The significance of the study's outcome variables was evaluated using Chi-square tests. A significance level of $p < 0.05$ was deemed as indicative of statistical significance.

Results

This study conducted a comprehensive examination of 1231 stone samples obtained from patients, comprising 876 from males and 355 from females. The average age of the entire cohort was approximately 39 years, with males averaging 38.59 years and females 40.47 years. The study systematically categorized patients into various age groups spanning from 1 to 90 years.

A statistically significant difference in the number of stones was evident across different age groups ($P = 0.000$). The findings revealed that the highest incidence of urinary stones occurred in patients aged 31 to 40 years, while the age groups of 1 to 10 and 81 to 90 years exhibited the lowest incidence.

The predominant symptoms reported by most patients in the study were flank pain, followed by hematuria. Among the types of stones encountered, kidney stones were the most prevalent, followed by bladder and ureteric stones. Notably, a substantial proportion of patients with

urinary stones were tobacco users, with a slightly higher representation compared to those without any known addiction, as shown in Table 1.

Table 1- Analysis of urinary stone composition in relation to different patient characteristics

Factors	Number of Patients (n=1231)		
	Overall	Male (%)	Female (%)
Total Number		876 (71.2)	355 (28.8)
Mean Age (Yrs)	39.13	38.59	40.47
Age group	**n (%)**		
1-10	35 (2.8)	25 (2.01)	10 (0.81)
11-20	51 (4.1)	38 (3.08)	13 (1.05)
21-30	286 (23.2)	210 (17.1)	76 (6.1)
31-40	343 (27.9)	251 (20.4)	92 (7.4)
41-50	244 (19.8)	165 (13.4)	79 (6.4)
51-60	171 (13.9)	110 (8.9)	61 (5.0)
61-70	88 (7.1)	65 (5.3)	23 (1.9)
71-80	09 (0.7)	08 (0.6)	1 (0.1)
81-90	04 (0.3)	04 (0.3)	00
Chief complaints			
Haematuria	288 (23.3)	210 (17.0)	78 (6.33)
Flank Pain	593 (48.1)	421 (34.2)	172 (13.9)
Fever	105 (8.52)	73 (5.93)	32 (2.59)
Infection	148 (12)	104 (8.44)	44 (3.57)
Combinations of above	45 (3.65)	32 (2.59)	13 (1.05)
Non symptomatic	52 (4.22)	36 (2.92)	16 (1.29)
Stone Location			
Kidney	922 (74.9)	652 (53)	270 (21.9)
Bladder	92 (7.5)	75 (6.1)	17 (1.4)
Ureter	217 (17.6)	147 (11.9)	70 (5.7)

Addiction	
Tobacco	522 (42.4)
Alcohol	89 (7.22)
Tobacco+ Alcohol	164 (13.3)
No addiction	456 (37.0)

In the context of the scrutinized stones, singular-component pure stones comprised 5.77% of the total, with two-component stones emerging as the most prevalent at 86.5%. Three-component stones represented 7.71% of the overall composition. Among single-component stones, ammonium hydrogen urate stones exhibited the highest prevalence, constituting 1.79% of the total. In the realm of two-component stones, the predominant composition was Calcium oxalate (MH) and Calcium oxalate (DH) at 62.8%. Within three-component stones, the combination of Calcium oxalate (MH), Calcium oxalate (DH), and Carbonate apatite was the most frequently observed, accounting for 5.93% of the total, as delineated in Table-2.

Table 2- Distribution of urinary stones based on their composition (pure, two-component, and three-component).

Stone composition	Number (n)	Percentage (%)
Pure stone		
Calcium oxalate (Monohydrate)	11	0.89
Carbonate Apatite	04	0.32
Struvite*	01	0.08
Ammonium Hydrogen Urate	22	1.79
Uric Acid	15	1.21
Cystine	17	1.38
Xanthine	01	0.08
	71	**5.77**
Two component stone		
Calcium oxalate (MH)**+ Calcium oxalate (DH)***	773	62.8
Calcium oxalate (MH) + Struvite	02	0.16

Calcium oxalate (MH)+ Carbonate Apatite	10	0.81
Calcium oxalate (MH)+ Uric Acid	12	0.97
Carbonate Apatite +Struvite	05	0.40
Calcium oxalate (MH)+ +Xanthine	15	1.21
Calcium oxalate (DH)+Struvite	01	0.08
Calcium oxalate (DH)+ Carbonate Apatite	234	19.0
Calcium oxalate (DH)+Cystine	10	0.81
Calcium oxalate (MH)+Cystine	01	0.08
Ammonium Hydrogen Urate + Uric acid	01	0.08
Calcium oxalate (MH) + Ammonium Hydrogen Urate	01	0.08
	1065	**86.5**
Three component stone		
Calcium oxalate (MH)+ Calcium oxalate (DH)+ Carbonate Apatite	73	5.93
Ammonium Hydrogen Urate + Calcium Hydrogen Phosphate + Magnesium Hydrogen Phosphate	01	0.08
Ammonium Hydrogen Urate + Uric acid + Cystine	01	0.08
Calcium oxalate (DH)+ Struvite + Uric acid	01	0.08
Calcium oxalate (MH)+ + Carbonate Apatite + Struvite	19	1.54
	95	**7.71**
*Struvite= Magnesium Ammonium Phosphate ** Calcium oxalate (MH) = Calcium oxalate monohydrate *** Calcium oxalate (DH)= Calcium oxalate dihydrate		

In the context of stone removal procedures, Percutaneous Nephrolithotomy (PCNL) was as the most commonly used procedure in 905 (73.5%) cases. Following this, Ureteroscopy 238 (19.3%), Cystolitholapaxy/Laser Cystolitholapaxy 81 (6.58%), and Pyelolithotomy 7 (0.6%) were the other procedures.

Stone composition patterns across age groups

During an analysis based on incidences of pure stone, two component stone and three component stone in different age groups.

1.A

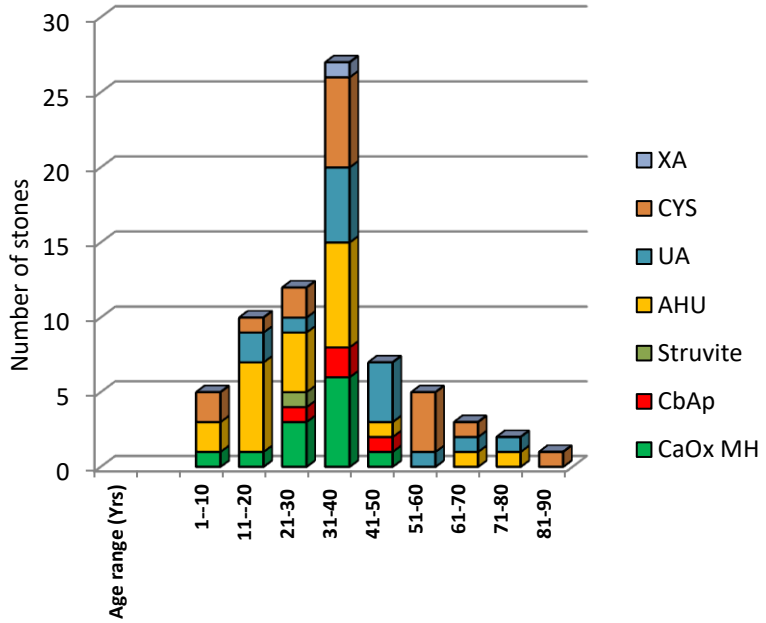

Figure 1.A: Distribution of pure stones in different age group

1.B

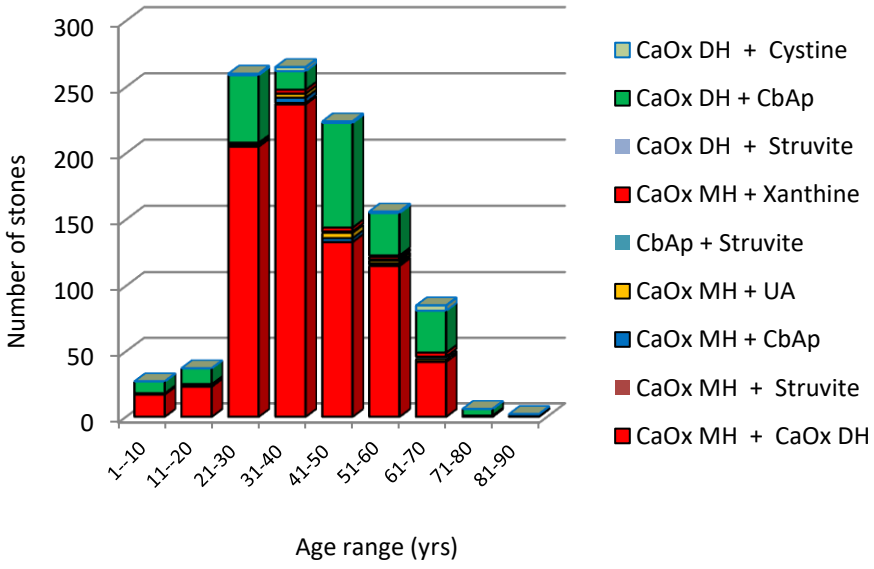

Figure 1B: Distribution of stones with two components in different age group

1.C

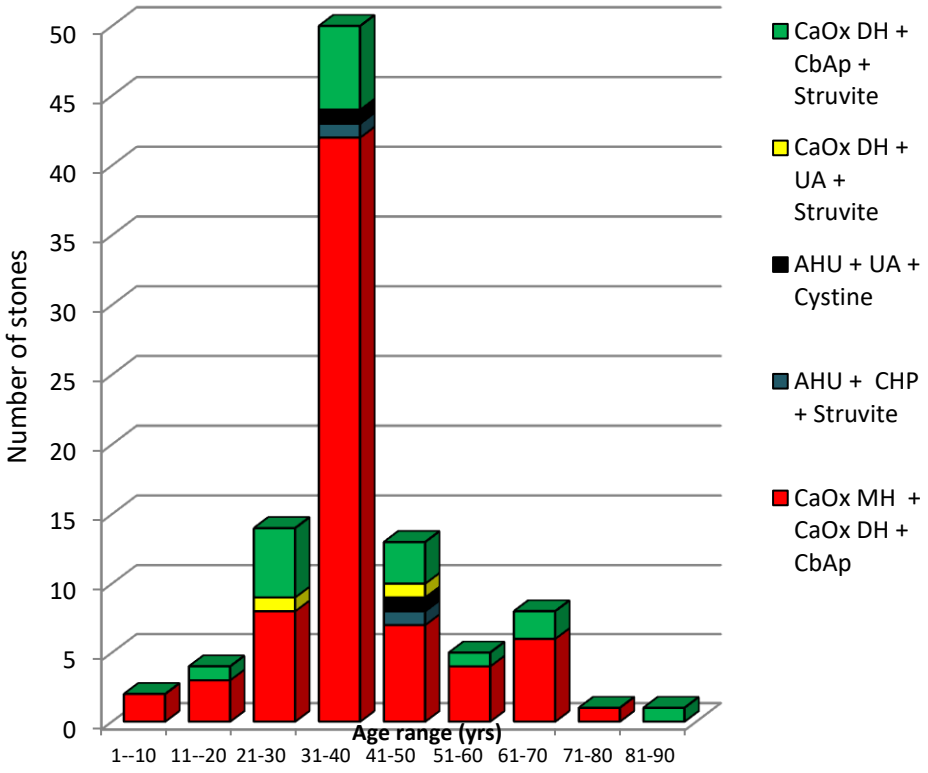

Figure 1C: Distribution of three component stones in different age group

***CaOx MH= Calcium oxalate Monohydrate, CaOx DH= Calcium Oxalate Dihydrate, CbAp= Carbonate Apatite, Struvite= Magnesium Ammonium Phosphate Hexahydrate, AHU= Ammonium Hydrogen Urate, UA= Uric Acid, CHP= Calcium Hydrogen Phosphate XA= Xanthine, CYS= Cystine,

Most of the pure stone were found in 31-40 year age group, and the leading pure component was Ammonium hydrogen urate, similarly two and three component stone were also observed maximum in this age group. then the cases starts declining and found least in the age group of 71-80 and 81-90 as illustrated in Figure 1.A, 1.B, 1.C.

Urinary Stone Recurrence Analysis

The study involved observing 1231 patients with urinary stones, and a subset of 530 individuals underwent follow-up. Among this subgroup, 57 patients experienced a recurrence of stones. The analysis did not reveal any significant correlation between stone recurrence and factors such as stone composition, location within the urinary tract, or the patient's gender.

However, a robust correlation was evident between stone recurrence and the dietary habits and water intake patterns of the patients.

Specifically, individuals adhering to a diet low in oxalate-rich vegetarian foods and maintaining adequate hydration demonstrated a significantly lower likelihood of experiencing stone recurrence. Remarkably, recurrence rates were highest among patients aged 21-30 and 31-40, while individuals in the age groups of 1-10 and 61-90 exhibited the lowest recurrence rates. These findings suggest that young adults and those in their thirties have a higher susceptibility to stone recurrence compared to children, early seniors, and elderly individuals, as detailed in Table 3.

Table 3- Urinary stone recurrence analysis with reference to different factors.

Age Range	**1-10**	**11-20**	**21-30**	**31-40**	**41-50**	**51-60**	**61-70**	**71-80**	**81-90**	**Significance**
	n (%)									(p)
Recurrence cases*	01(1.7)	06(10.5)	21(36.8)	16(28.0)	10(17.5)	01(1.7)	02(3.5)	00(0)	00(0)	
Low oxalate veg diet	01(1.7)	01(1.7)	02(3.5)	02(3.5)	01(1.7)	00(0)	00(0)	00(0)	00(0)	**0.001**
High oxalate veg diet	00(0)	01(1.7)	04(7.0)	02(3.5)	04(7.0)	00(0)	02(3.5)	00(0)	00(0)	
Non-Veg diet	00(0)	04(7.0)	15(26.3)	12(21.0)	05(8.7)	01(1.7)	00(0)	00(0)	00(0)	
Good water intake**	00(0)	01(1.7)	05(8.7)	07(12.2)	03(5.2)	00(0)	01(1.7)	00(0)	00(0)	**0.001**
Less Water intake***	01(1.7)	05(8.7)	16(28.0)	09(15.7)	07(12.2)	01(1.7)	01(1.7)	00(0)	00(0)	
Stone location										
Kidney	01(1.7	03(5.2)	05(8.7)	02(3.5)	03(5.2)	06(10.5	02(3.5	00(0)	00(0)	0.091

	)					)	)			
Bladder	01(1.7)	03(5.2)	02(3.5)	03(5.2)	01(1.7)	00(0)	04(7.0)	00(0)	00(0)	
Ureter	00(0)	02(3.5)	01(1.7)	02(3.5)	04(7.0)	01(1.7)	00(0)	00(0)	00(0)	
Gender										
Male	01(1.7)	04(7.0)	05(8.7)	05(8.7)	0(10.5)	03(5.2)	04(7.0)	01(1.7)	02(3.5)	0.001
Female	02(3.5)	04(7.0)	03(5.2)	02(3.5)	02(3.5)	04(7.0)	02(3.5)	05(8.7)	02(3.5)	

***Total 57 cases of recurrence from 530 follow up.**

**** Good water intake= > upto 4 lit water/day, ***Less water intake= < 2 lit water/day**

Discussion

Urinary stone disease represents a substantial public health challenge, posing a risk of progression of many urological diseases including kidney failure in some cases. The prevalence of urinary stone formation exhibits regional disparities, ranging from 5-9% in Europe, 1-5% in Asia, 10-15% in the US, and peaking at 20-25% in the Middle East.[13]

Consistent with Jindal et al.'s study, our findings affirm a mean patient age of 38.5 years for males and 40.4 years for females, reinforcing the male predominance in urinary stone cases.[14] Large-scale investigations, exemplified by Knoll T et al.'s cohort study, underscore the predominance of calcium oxalate stones, closely followed by uric acid stones.[15] Ansari MS et al.'s study, involving 1050 renal stones from North Delhi, further validates these findings, identifying calcium oxalate in a staggering 93.04% of patients.[16] Similar outcomes are echoed in studies conducted by Tanthanuch M et al. and Rahman A et al., all designating calcium oxalate as the most prevailing stone type.[17-18]

Within the scope of our study, calcium oxalate emerged as the predominant stone type, followed by carbonate apatite stones, along with a spectrum of other stone components, including uric acid, magnesium ammonium phosphate hexahydrate, calcium hydrogen phosphate, xanthine, and cysteine. This detailed insight into stone composition assumes paramount significance, guiding the selection of appropriate stone therapy. For instance,

extracorporeal shock wave lithotripsy demonstrates enhanced efficacy in disintegrating calcium oxalate dihydrate and struvite stones, as opposed to cysteine-rich stones.[19]

In certain instances, a precise evaluation of stone composition can reveal an underlying metabolic disorder, exemplified by the association of magnesium ammonium phosphate stones with chronic urinary tract infections caused by urea-producing bacteria.[20] When scrutinizing frequently encountered urinary stones, the diagnostic significance of their composition becomes imperative. These stones often have a combination of calcium oxalate and calcium phosphate.[21] Remarkably, calcium phosphate stones exhibit stronger correlations with renal tubular acidosis and primary hyperparathyroidism, distinguishing them from calcium oxalate stones. In contrast, uric acid stones are predominantly associated with conditions characterized by gout.[22]

Moreover, the prevalence of urinary stones typically rises with age, reaching its peak around 60-70 years, after which cases tend to decline.[23,24] In an intriguing pattern, stones formed by children aged 1-10 exhibit the highest prevalence of ammonium hydrogen urate, suggesting a distinct predilection within this age group.[25]

Throughout this investigation, a discernible trend in the incidence of urinary stones within the general population became evident. This incidence initiates an ascent within the age group of 11 to 20 years, ultimately reaching its zenith in the age range of 31 to 40 years. Subsequently, there is a noticeable decline in the age group of 61 to 70 years. Our study further substantiates that urinary stones predominantly affect the kidney, followed by the ureter and bladder, aligning with the observations of Chand RB et al., where 75.08% of stones in their study population were renal stones, 13.62% were ureteric stones, and 1.74% were bladder stones.[26]Among the male population, the age group of 31 to 40 exhibited the highest incidence of kidney stones, while their female counterparts displayed a lower rate. Conversely, bladder stones were more prevalent in males within this age bracket, whereas for females, the highest number of bladder stones was noted in the age range of 21 to 30 years. Ureteric stones were most frequently observed in the 21–30-year-old age group among males compared to females.

Regarding stone composition, the majority of stones analyzed possessed two components, followed by those with three or more components, with pure stones being the least common. Kidney stones were the most prevalent among those received, leading to the primary utilization of Percutaneous Nephrolithotomy for their removal. Among combination stones, Calcium oxalate (MH) and Calcium oxalate (DH) were the most frequent, while uric acid stones emerged as the predominant pure component.

Dietary therapy presents a promising avenue for mitigating the recurrence of urinary stones and enhancing patients' quality of life. In the Indian context, dietary compositions are characterized by a significant proportion of proteins and carbohydrates compared to other developing countries. This dietary habit has been identified as a major driver of urinary stone disease prevalence in India. Therefore, elevating awareness about this health concern and implementing optimal dietary interventions can effectively curtail hospitalization costs and enhance overall adherence to preventive measures. Consequently, dietary factors are widely recognized as one of the primary risk factors contributing to urinary stone development.[27]

Consuming substantial amounts of non-vegetarian foods and partaking in a diet rich in oxalate-laden vegetarian options, such as spinach, beets, peanuts, and sweet potatoes, while concurrently failing to maintain adequate hydration, contributes to the genesis of stones. This dietary pattern notably facilitates the formation of calcium oxalate stones [28]. Furthermore, we observed that patients with a history of urinary stone recurrence were more inclined towards non-vegetarian, oxalate-rich dietary choices and exhibited reduced water intake.

Conclusions

The study highlights that in Eastern Indian population the age group most susceptible to urinary stone formation falls within the age group of 21-40 years, urinary stone incidence peaked among those aged 31 to 40, with lower rates in the 1 to 10 and 81 to 90 age groups. Key symptoms were flank pain and hematuria, with kidney stones being the most common, followed by bladder and ureteric stones. Notably, a significant proportion of stone patients were tobacco users.

Analysis identified two-component stones as the most prevalent, with uric acid and calcium oxalate as primary components. Percutaneous Nephrolithotomy (PCNL) was the preferred removal procedure. Maintaining a low oxalate diet and good hydration were crucial in reducing stone recurrences. Recurrence rates for urinary stones were highest in young adults and individuals in their thirties, with the lowest rates observed in children and patients aged 61 to 90. A thorough understanding of urolithiasis composition within specific populations can significantly enhance the assessment, treatment, and prevention of urinary stone occurrence and recurrence. Notably, the incidences and compositional analysis of urinary stones in the eastern Indian population have not been reported previously. Consequently, the findings of this study can serve as a valuable resource for broader research efforts, facilitating comprehensive comparative analyses of urinary stone composition across various regions of India, its subcontinents, and across the globe.

DECLARATIONS

Ethics approval and consent to participate

Ethical approval was obtained from the institutional review board (IRB).

Consent for publication

Consent of publication was obtained directly from patient of legal age.

Availability of data and materials

All data generated or analyzed during this study are included in this published article.

Competing interests

The authors declare that they have no competing interests.

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Author contributions

All authors have read and approved the manuscript. PK and SA proposed the study concept and design.

SA, PP, SS and HM acquired the data.

PK, SA, HM and PP drafted the manuscript.

PK and SS critically revised the manuscript.

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