ORIGINAL PAPER

UROLITHIASIS

The clinical utility of urolithiasis morphology assessment for perioperative stone composition determination

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Citation: Tomczak W, Grunwald K, Molik K, et al. The clinical utility of urolithiasis morphology assessment for perioperative stone composition determination. Cent European J Urol. 2025; doi: 10.5173/ceju.2025.0162

Article history
Submitted: Jul. 13, 2025
Accepted: Jul. 27, 2025
Published online: Aug. 31, 2025

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Introduction Urolithiasis is a highly prevalent disease influenced by a wide range of factors multifactorial etiology results in the formation of urinary stones with diverse mineral compositions. Accurate identification of stone constituents is crucial for effective prevention of recurrence. Gold-standard methods for stone analysis are not always readily available in clinical practice. To address this, Daudon proposed a morphological classification system aimed at identifying stone types based on their surface characteristics. However, existing literature reports suboptimal accuracy of this method, largely due to technical limitations of endoscopic equipment. The primary objective of this study was to evaluate the reliability of morphological assessment in predicting stone mineral composition. Secondary aims included the identification of factors contributing to the consistently poor accuracy reported in previous studies.

Material and methods An online quiz consisting of 20 single-choice questions was developed, each accompanied by a high-resolution image of a urinary stone and five predefined answer options. The reference stone composition for each image was determined using Fourier-transform infrared spectroscopy. Participants' performance was evaluated based on the percentage of correct responses per individual and per question. The results of specialists and residents were compared using the two-proportion Z-test, with statistical significance set at $p < 0.05$.

Results A total of 779 responses were collected, with an overall accuracy rate of 33.7%. The most commonly selected answers were respectively oxalates, phosphates, uric acid, cystine, and infectious stones. Subgroup analysis revealed accuracy rates of 36% among attending physicians and 32% among residents, with no statistically significant difference. Notably, two participants achieved a perfect score (100%), supporting the internal validity of the test.

Conclusions Detailed analysis revealed a wide distribution of scores, ranging from participants with only one correct response to those who completed the quiz with full accuracy. These results suggest that the consistently low diagnostic accuracy reported in the literature is more likely due to limited familiarity and lack of experience with the morphological classification, rather than inherent shortcomings of the system itself. The findings highlight the need for comprehensive endourology training programs focused on improving stone morphology recognition skills.

Key Words: urolithiasis ‹› stone morphology ‹› stone composition ‹› kidney stones

INTRODUCTION

Kidney stones have affected humans since the dawn of time. Moreover, the global burden of this condition has been consistently rising for at least 30 years [1, 2]. According to available data, urolithiasis prevalence ranges from 1% to 20% and depends on factors such as diet, climate, genetics, but also on comorbidities and corresponding treatment strategies [3-7]. Equally diverse as the causative factors are the numerous constituents that compose kidney stones. Their identification is essential as the initial step of targeted diagnostics and metabolic prevention of recurrence. This is particularly important since urolithiasis not only negatively affects patients' quality of life [8] but also significantly increases the likelihood of renal failure development with each recurrence [9, 10]. Daudon et al. described in detail morphological features of distinct kidney stone constituents allowing for their recognition [11]. This study provides a "manual" highlighting key features to observe, which in theory should allow users to correctly distinguish the crystalline components of the stone. Nevertheless, several studies evaluating *in vivo* endourological images using Daudon classification have reported unsatisfactory results [12–14]. These can potentially be attributed to several factors, including poor intraoperative image quality, inexperience with the classification, or its limited utility. This study assessed the ability of urologists, at different stages of their careers, to identify and differentiate between the stone types based on high resolution *ex vivo* images and investigated the factors responsible for the consistently poor results reported in the literature.

MATERIAL AND METHODS

Survey preparation

Authors created an online quiz to test the ability to recognise the stone composition based on their morphological features. It was designed to consist of 20 questions with an identical structure: an instruction – "Based on the presented photo, please select the most probable chemical composition of the stone", a photo, and five predetermined answers – Calcium Oxalates, Uric Acid, Calcium Phosphates, Cystine, Infectious Stone respectively. Detailed crystal forms were deliberately not included in the answers as not all can be distinguished by morphology, rendering the correct completion of the survey impossible. Additionally, accurate determination of any of the aforementioned five answers is sufficient to set the course of diagnostic and therapeutic measures. Lastly, a test format was preferred over open-ended responses, as the latter could result in answers at varying levels of specificity, complicating statistical analysis and potentially distorting the study's overall findings. Attending urologists and residents from a regional medical network were invited to participate. Invitations were sent electronically, and participation was voluntary. Informed consent was obtained from all subjects. Among the invited participants, 83% took part in the study.

Obtaining and selecting photographs

Photographs were taken of material obtained intraoperatively from patients who underwent endoscopic treatment for urolithiasis at one of the European centres of excellence in urology. As standard, whenever possible, stones are collected for analysis of their chemical composition using the Fourier transform infrared spectroscopy (FTIR). If undecisive result occur, X-ray diffraction is performed. Prior to analysis, each stone was carefully photographed. Although the majority of urinary calculi exhibit mixed chemical composition, the images selected for inclusion in the study were carefully chosen to visually represent a single component in each case. This approach ensured consistency in image-based evaluation in accordance with the predefined response categories.

Statistical analyses

The results for each respondent and each item were calculated as the percentage of correct answers. A subgroup analysis was performed to compare accuracy between specialists and residents. Questions with the highest and lowest percentage of correct answers were identified. The most frequently selected answers were analysed both collectively and for each question separately. Groups of respondents were compared using the two proportions Z-test. The significance threshold was set at $p = 0.05$.

Data availability statement

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

Bioethical standards

This study received approval from the Wroclaw Medical University Bioethics Committee (approval number KB 610/2024) and was carried out in full compliance with the principles outlined in the Declaration of Helsinki.

RESULTS

Seven hundred and seventy-nine records have been collected. Due to technical inconsistencies, one question was excluded from the analysis.
Of the provided answers 33.7% were correct. The most commonly selected stone compositions were respectively oxalates, phosphates, uric acid, cystine, and infectious stones (Figure 1).
The subgroup analysis revealed the response accuracy of 36.2% among attending physicians and 32.8% across residents (Figure 2). The respondents comprised 56% endourologists and 44% residents interested in this subspecialty.
Notably, the differences in overall accuracy between groups were not statistically significant ($p > 0.05$). To complement the picture, the results for each question are presented in Figure 3. Furthermore, supplementary file 1 contains the original quiz, the distribution of answers for each question, and the answer key.
An in-depth analysis of individual respondents' results shows that 2 out of 41 respondents achieved 100% accuracy, both being residents. The third highest result (95%) was obtained by a specialist. On the other side, the two worst results were also recorded among residents. Remarkably, these two lowest-scoring respondents identified only one stone composition correctly.
The obtained data was also analysed in terms of the recognition rate for each stone type (Figure 4). The highest recognition rate of 37.5% was observed for calcium oxalate followed by cystine stones, with 35% correct responses. The most challenging stones to identify were infectious and uric acid stones, with 29.4% correct responses each.

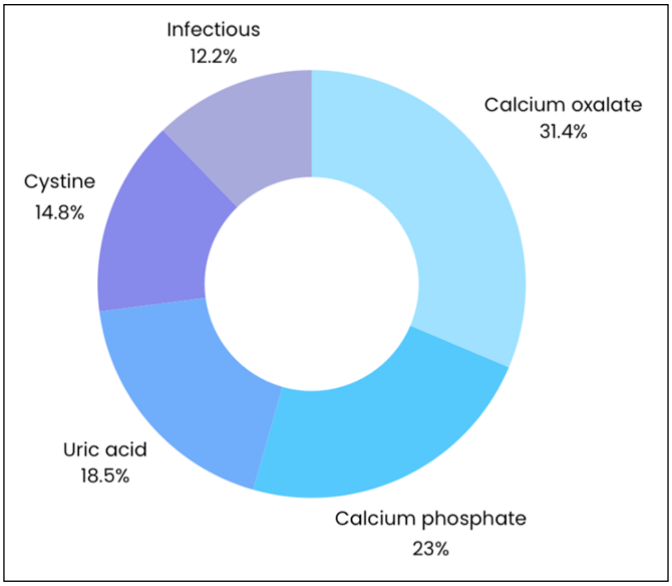

Figure 1. *Distribution of selected answers.*

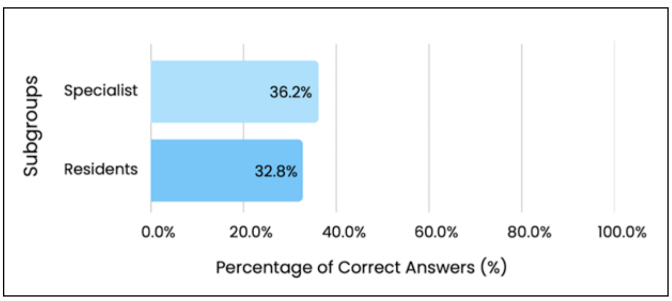

Figure 2. *Responses accuracy by a subgroup.*

DISCUSSION

Determination of stones chemical composition is essential for effective urolithiasis metaphylaxis. Reliable analysis not only determines the direction of subsequent diagnostic measures but also creates a certain range of metabolic disorders that predis-

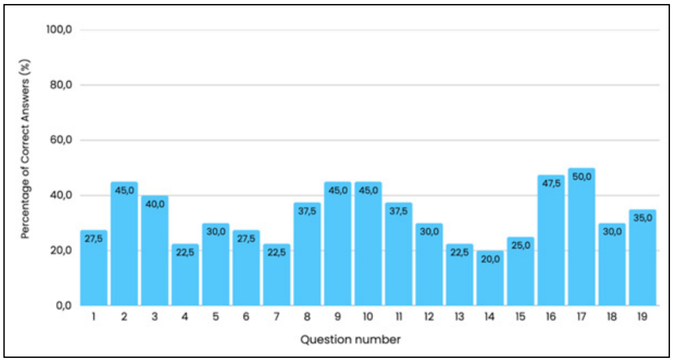

Figure 3. *Percentage of correct answers per question.*

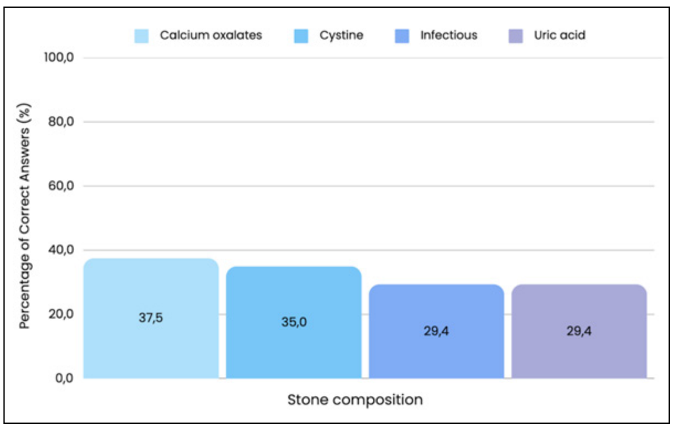

Figure 4. *Recognition rate by a stone composition.*

pose to stone formation [15]. Unfortunately, this evaluation is rarely performed. Moreover, when it is carried out, it is often limited to chemical analysis, which is both inaccurate and not recommended by scientific societies [15, 16]. In order to aid urologists involved in the treatment process but without necessary resources, scientists proposed classification systems that enable stone type identification based purely on morphology [11, 17].

To the best of our knowledge, this is the first study to assess the clinical utility of this tool using high-resolution *ex vivo* images obtained from routinely collected material. These images were compiled into a quiz and presented to multiple urologists. While similar studies have been conducted using intraoperative endoscopic images, they have yielded unsatisfactory results [12–14]. Prior research has attributed these limitations to low endoscopic image quality often further compromised by intraoperative conditions or to insufficient proficiency in Daudon's classification among operators. The objective of this study was to evaluate the clinical applicability of this tool and to elucidate the factors contributing to the poor outcomes observed in previous investigations.

In our cohort, only 33.7% of the responses were correct, marginally exceeding what would be expected from random guessing. Moreover, no statistically significant difference was observed between specialists and residents. These findings align with previous studies conducted using intraoperatively acquired images. This suggests that the quality of the endoscopic *in vivo* images is unlikely to be the primary limiting factor. Instead, the results suggest that limited proficiency in the aforementioned classification among urologists plays a significant role.

It should be emphasized that included photos do not reflect well known distribution of stone types. However, we consider it as a strength of this study. As illustrated in Figure 1, nearly 80% of the responses assumed calcium containing stones. Therefore, inclusion of more "calcium containing" images would artificially skew the results, failing to accurately reflect respondents' ability to identify stone composition. This issue was evident in the SEGUR2 study, where overall diagnostic performance was suboptimal [12]. However, the accuracy in identifying calcium oxalate stones was comparatively higher. During the survey preparation no image selection was applied, instead we incorporated adequate photos from 20 consecutive samples. However, given that our institution is a tertiary care centre handling complex cases, stones composed of rare components are observed more frequently.

During the interpretation of results, concerns were raised regarding the potential difficulty of the survey. However, we believe that the inclusion of predefined, ready-to-choose answers constituted a significant simplification. The negative influence of the images was mitigated by using high quality images only. Uniform level of difficulty was confirmed by the consistently poor performance across all questions (Figure 3.). Finally, the fact that two respondents answered all questions correctly supports the test's validity in accurately assessing participants' stone composition recognition skills.

Beyond morphology, various other factors contribute to the clinical assessment of kidney stone composition. For instance, low Hounsfield units on imaging combined with the subjective perception of "softness" during lithotripsy, raise suspicion of uric acid stones [18]. Similarly, the presence of a sulphuric odour, characteristic stone surface reflex, and white bubbles released during lithotripsy suggest cystine stones [19]. Considering these factors, the results would likely improve. On the other hand, the mixed composition adds an additional level of complexity, particularly for less experienced endourologists.

A limitation of our study is the sample size. Addressing this potential constraint, we developed the test to be completed in under three minutes to facilitate participation. Despite the relatively small number of respondents, the test was undertaken by doctors genuinely interested in assessing their skills. Participation was entirely voluntary, without external pressure or encouragement, to ensure the integrity of the results and avoid responses influenced by disengagement or lack of motivation

CONCLUSIONS

Urolithiasis is a condition treated in nearly every urology department. Reliable stone composition analysis is essential for effective prevention of its recurrence. However, reference laboratory methods are available only in selected tertiary centres. To support clinicians lacking access to advanced diagnostics, morphological classification manuals have been developed. Unfortunately, numerous studies suggest their limited clinical utility. In this study, specialists and residents evaluated high-resolution stone images to identify composition based on morphology. Notwithstanding overall unsatisfactory results, detailed analysis revealed a wide variability in responses, ranging from a single correct answer to fully accurate completion of the survey. These results suggest that poor outcomes reported in the literature are primarily due to inexperience with the classification, underscoring the need for comprehensive endourology training programs.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

FUNDING

This research received no external funding.

ETHICS APPROVAL STATEMENT

The study was approved by Wroclaw Medical University Bioethics Committee (approval number KB 610/2024).

References

1. Qian X, Wan J, Xu J, et al. Epidemiological Trends of Urolithiasis at the Global, Regional, and National Levels: A Population-Based Study. Int J Clin Pract. 2022; 2022: 6807203.
2. Sorokin I, Mamoulakis C, Miyazawa K, Rodgers A, Talati J, Lotan Y. Epidemiology of stone disease across the world. World J Urol. 2017; 35: 1301-1320.
3. Chang CW, Ke HL, Lee JI, et al. Metabolic Syndrome Increases the Risk of Kidney Stone Disease: A Cross-Sectional and Longitudinal Cohort Study. J Pers Med. 2021; 11: 1154.
4. Siener R, Glatz S, Nicolay C, Hesse A. The role of overweight and obesity in calcium oxalate stone formation. Obes Res. 2004; 12: 106-113.
5. Dell'Orto VG, Belotti EA, Goeggel-Simonetti B, et al. Metabolic disturbances and renal stone promotion on treatment with topiramate: a systematic review. Br J Clin Pharmacol. 2014; 77: 958-964.
6. Geraghty RM, Proietti S, Traxer O, Archer M, Somani BK. Worldwide Impact of Warmer Seasons on the Incidence of Renal Colic and Kidney Stone Disease: Evidence from a Systematic Review of Literature. J Endourol. 2017; 31: 729-735.
7. Tomczak W, Krajewski W, Grunwald K, et al. A cross-language analysis of urolithiasis patient online materials: Assessment across 24 European languages. Cent European J Urol. 2025; 78: 221-227.
8. Tomczak W, Krajewski W, Chorbińska J, et al. Polish validation of the wisconsin stone quality of life questionnaire (POL-WISQoL). World J Urol. 2024; 42: 590.
9. Alexander RT, Hemmelgarn BR, Wiebe N, et al. Kidney stones and kidney function loss: a cohort study. BMJ. 2012; 345: e5287.
10. Sigurjonsdottir VK, Runolfsdottir HL, Indridason OS, Palsson R, Edvardsson VO. Impact of nephrolithiasis on kidney function. BMC Nephrol. 2015; 16: 149.
11. Daudon M, Dessombz A, Frochot V, et al. Comprehensive morpho-constitutional analysis of urinary stones improves etiological diagnosis and therapeutic strategy of nephrolithiasis. Comptes Rendus Chimie. 2016; 19: 1470-1491.
12. Sampogna G, Basic D, Geavlete P, et al. Endoscopic identification of urinary stone composition: A study of South Eastern Group for Urolithiasis Research (SEGUR 2). Identificación endoscópica de la composición de los cálculos urinarios: un estudio del Southeastern Group for Lithiasis Research (SEGUR 2). Actas Urol Esp (Engl Ed). 2021; 45: 154-159.
13. Rodriguez-Alvarez JS, Khooblall P, Brar H, et al. Endoscopic Stone Composition Identification: Is Accuracy Improved by Stone Appearance During Laser Lithotripsy?. Urology. 2023; 182: 67-72.
14. Henderickx MMEL, Stoots SJM, De Bruin DM, et al. How Reliable Is Endoscopic Stone Recognition? A Comparison Between Visual Stone Identification and Formal Stone Analysis. J Endourol. 2022; 36: 1362-1370.
15. Daudon M, Bader CA, Jungers P. Urinary calculi: review of classification methods and correlations with etiology. Scanning Microsc. 1993; 7: 1081-1106
16. EAU Guidelines. Edn. presented at the EAU Annual Congress Paris 2024.
17. Grases F, Costa-Bauzá A, Ramis M, Montesinos V, Conte A. Simple classification of renal calculi closely related to their micromorphology and etiology. Clin Chim Acta. 2002; 322: 29-36.
18. Gallioli A, De Lorenzis E, Boeri L, et al. Clinical utility of computed tomography Hounsfield characterization for percutaneous nephrolithotomy: a cross-sectional study. BMC Urol. 2017; 17: 104.
19. Kılınç MT, Özkent MS, Göger YE. Observation and comparison of gas formation during holmium:YAG laser lithotripsy of cystine, uric acid, and calcium oxalate stones: a chromatographic and electron microscopic analysis. Urolithiasis. 2024; 52: 23. ■