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Advances in Urology: A Comprehensive Literature Review on Urolithiasis Management and Innovations

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Introduction. Urolithiasis is a prevalent condition, affecting approximately 12% of the global population at some point in their lives, with higher incidence rates reported in industrialized nations. This condition poses significant health challenges worldwide due to its recurrence and the associated healthcare burden. Recent innovations in imaging, minimally invasive techniques, and pharmacotherapy have revolutionized the field. This review aims to explore recent updates and innovations in the management of urolithiasis, from diagnosis to therapy.
Methods. A systematic search using predefined keywords in multiple databases was done. Peer-reviewed articles, clinical trials, meta-analyses, and systematic reviews focused on urolithiasis management, diagnostic techniques, therapeutic innovations, and preventive strategies were analyzed. Articles from January 2015—December 2023 were included, reviewed for its eligibility, and extracted.
Results. Emerging pharmacological agents (eg. empagliflozin, thiosulfate) offer new avenues for prevention and recurrence reduction, particularly for patients with recurrent urolithiasis, although not as primary therapy. Additionally, the integration of artificial intelligence and machine learning is beginning to play a role in predicting stone recurrence and optimizing treatment plans.
Conclusion. This review highlights the importance of a personalized, patient-centered approach in managing urolithiasis, emphasizing the need for ongoing research and clinical trials to further refine these innovations.

Keywords: artificial intelligence, disease management, urinary stone disease, urolithiasis

Introduction

Urolithiasis is a global health issue occurring when calculi form in the urinary tract. The management of urolithiasis has changed overtime following the present day technology and surgical surgical procedures and understanding the pathological mechanisms. An estimated 10-15% people worldwide will experience urolithiasis sometime in their lifetime [1-2]. The widespread and increasing urolithiasis prevalence requires a multifaceted solution. . If left untreated, urolithiasis may predisposes individuals to recurrent urinary tract infections [3].

Current research shows that conservative treatment measures such as extracorporeal shock wave lithotripsy (ESWL), minimally invasive surgeries like ureteroscopy (URS), and percutaneous nephrolithotomy (PCNL) are preferred in the management of kidney stones [4-5]. The European Association of Urology (EAU) guidelines advise to distinguish the treatment strategy by taking into account the characteristics of the stones, the patient's preference, and the capabilities of the healthcare provider, to yield better outcomes, shorter recovery periods, and higher safety levels [6-8].

In terms of surgical management, the application of laser technology has become a significant importance. Laser lithotripsy, especially with the enhanced use of high-power lasers, has brought significant advancement in the management of urolithiasis due to its increased stone fragmentation rate and less risk of procedural complications [9-10]. The International Alliance of Urolithiasis (IAU) Guidelines are optimizing the use of laser technology in diverse settings, which is essential for developing best practices and enhancing the quality of surgery [11]. Furthermore, the application of artificial intelligence (AI) in urology has demonstrated the potential in improving the care of urolithiasis. The AI-enhanced imaging and predictive analysis helps in the proper categorization of stones, more effective operation planning, increasing the success rate and patients' satisfaction, and lowering the relapse rate [12-13]. This review aims to explore recent updates and innovations in the management of urolithiasis, from diagnosis to therapy.

Materials and Method

This literature review was conducted by systematically searching multiple electronic databases, including PubMed, Science Direct, and Web of Science, to identify relevant studies on urolithiasis management and innovations. The search terms used were combinations of keywords such as "urolithiasis," "urinary stone disease," "minimally invasive surgery," "laser lithotripsy," "artificial intelligence in urology," and "diagnostic advances." The search was limited to articles published between January 2015 and December 2023 to ensure the inclusion of the most recent advancements. Additionally, manual searches of reference lists from key articles were performed to identify further relevant studies.

The inclusion criteria comprised peer-reviewed articles, clinical trials, meta-analyses, and systematic reviews focused on urolithiasis management, diagnostic techniques, therapeutic innovations, and preventive strategies. Studies not written in English, case reports with fewer than 10 participants, and articles lacking full-text availability were excluded. The initial search yielded a broad range of articles, which were then screened based on titles and abstracts. Full-text articles were reviewed for eligibility, and data were extracted based on relevance to the research objectives.

Result

Pathophysiology on Urolithiasis

The key factor in kidney stone formation is the condition called "urinary supersaturation" where the concentration of stone-forming substances is higher than their solubility in the urine. This supersaturation results in nucleation, the formation of the first stone crystals [14-15]. Calcium oxalate stones are the most common type of kidney stones found in clinical practice, representing around 80% of overall cases [16-17]. Calcium oxalate crystallization is distinctive by the pH and the ionic strength of urine, which also define the inhibition or promotion of crystallization [17-18]. For example, the low urinary pH favors the formation of uric acid stones, whereas the high urine pH promotes the formation of struvite stones [17,19]. Conditions such as hypercalciuria, hyperoxaluria, and hypocitraturia are commonly observed in patients with stone formation [20-21].

Other important factors that contribute to the development of urolithiasis include the high consumption of sodium, animal protein and oxalate containing foods. On the other hand, drinking more water and adopting a healthy diet, such as by consuming more fruits and vegetables, are useful to dilute and minimize the amount of stone forming chemicals in the urine [22-23]. Comorbid conditions such as obesity, diabetes mellitus, and metabolic syndrome have also been important contributors to urolithiasis. These conditions can change the composition of urine and facilitate stone formation through insulin resistance and renal action on electrolytes [2,24].

Metabolic syndrome, characterized by obesity, insulin resistance, hypertension, and dyslipidemia, has emerged as a significant contributor to the pathogenesis of urolithiasis. Insulin resistance, a hallmark of metabolic syndrome, alters renal tubular handling of electrolytes, leading to an increased urinary excretion of calcium, oxalate, and uric acid, which were key components of kidney stones. Additionally, the chronic low-grade inflammation associated with obesity promotes oxidative stress, which further disrupts urinary solute balance and crystal formation. Studies have shown that obese individuals often exhibit lower urinary pH, favoring the precipitation of uric acid stones. These metabolic disturbances create a supporting environment for stone formation. Thus, explaining the higher prevalence of urolithiasis in patients with metabolic syndrome compared to the general population [25-27].

There are also certain important genetic concerns involved in the development of urolithiasis. Some of the primary metabolic disorders that include cystinuria and primary hyperoxaluria put people at higher risk of recurrent stone formation due to the lack of renal amino acid and oxalate handling [28-29]. Polymorphisms in genes regulating urinary solute transporters (e.g., CLDN14) and inhibitors of crystallization (e.g., OPN) further modulate individual susceptibility to stone disease [30-32]. Thus, family history is a risk factor of urolithiasis.

Diagnostic Advances in Urolithiasis

Non-contrast computed tomography (NCCT) remains the best imaging technique for diagnosis of urolithiasis due to its sensitivity and specificity of 95% to 100% [33-35]. NCCT exhibits certain advantages over other methods as it does not rely on contrast media, hence reduces the time required to perform the test while providing satisfactory results in the detection of urinary stones of various sizes and compositions [33]. The high sampling rate and the possibility to visualize the entire urinary tract make NCCT irreplaceable in acute conditions, particularly in case of renal colic [34]. The use of low-dose CT protocols has also emerged in recent studies as concerns regarding the total radiation of multiple imaging scans received by a patient started rising [34,36]. Ultrasound (US) is widely used for most diagnostic purposes as it does not interfere with ionizing radiation and is preferred for specific age and groups of patients, such as pregnant women and children. Though ultrasound is useful for defining large stones and evaluating the severity of hydronephrosis, it may have limited sensitivity for small stones, leading to missed diagnoses [37-38]. Thus is used as first-line imaging in suspected renal disease by the European Association of Urology (EAU) guidelines [37,39]. The integration of ultrasound with other imaging techniques such as NCCT can improve the specificity of diagnosis and offer a comprehensive assessment of the urinary tract [37].

Dual-energy computed tomography (DECT) has recently been identified as one of the most significant improvements in the imaging of urolithiasis. DECT enables classification of stones based on the chemical composition, and increases the probability to detect uric acid stones which might not be seen on plain NCCT [40-41]. The use of AI to diagnose urolithiasis is certainly a promising innovation to improve the patient treatments approaches.While machine learning (e.g., CNN-based models) achieve >90% accuracy in stone detection on CT scan, current limitations include dependency on high-quality training datasets and poor generalizability across diverse populations. Key challenges such as ethical concerns about data privacy, model interpretability, and integration cost into the existing hospital workflows must be addressed before widespread adoption. AI-driven 3D reconstruction technology is also under development, enabling clinicians to visualize stones in three-dimensional detail and more accurately assess stone size, shape, and anatomical location. In addition, the use of AI-based software has the potential to improve the assessment of the ultrasound images based on the feedforward and feedback mechanisms, leading to an increased degree of accuracy of diagnostic interpretation. These innovations are paving the way for a future where AI may not only streamline diagnostics but also facilitate surgical planning and predict recurrence risk with unprecedented precision [42-45].

Molecular diagnostics and biochemical assays have also been developed in recent years. The urinary indole-reacted calcium oxalate crystallization index (iCOCI) appears to provide a promising means of distinguishing between calcium oxalate stone formers and non-stone formers, demonstrating high sensitivity and specificity. This diagnostic tool could enhance existing imaging techniques by revealing the metabolic factors associated with stone development [46]. Furthermore, ongoing research is examining the potential of non-invasive outpatient diagnostics through hyperspectral imaging techniques in the context of urinary stone disease. This method may also allow for the detection of spectral signatures in urine, identifying stone-forming agents, which indicates that the conditions can be diagnosed earlier and consequently treated before further progression [47].

Therapeutic Interventions for Urolithiasis

Minimally invasive procedures have become the cornerstone of urolithiasis management, offering effective treatment options with reduced morbidity. Percutaneous nephrolithotomy (PCNL) remains a preferred method for large or complex kidney stones. Recent studies have demonstrated the feasibility of PCNL in challenging anatomical situations, such as ectopic kidneys, with high stone-free rates and minimal complications [48-49]. This technique has a high success rate but is associated with greater morbidity compared to other minimally invasive options [50]. Ureteroscopy (URS) is a minimally invasive option that allows for direct visualization and removal of stones from the urinary tract. URS is particularly effective for stones located in the distal ureter and can be performed with or without laser lithotripsy for fragmentation [51]. The success rates for URS are high, and it is often preferred for larger stones or those that are not amenable to ESWL [52]. The introduction of the holmium:yttrium-aluminum-garnet (Ho:YAG) laser has revolutionized the treatment of urolithiasis. This laser is recognized as the most efficient for lithotripsy, as the studies have demonstrated its ability to fragment stones of all types, especially calcium oxalate and struvite [53-54]. Recent studies have demonstrated that the Ho:YAG laser has shown to have high stone free rates (SFRs) with low rates of complications in ureteroscopy and percutaneous nephrolithotomy (PCNL), thus making it a preferred choice [54].

A relatively new laser model is the thulium fiber laser (TFL). TFL offers advantages such as reducing thermal damage to the surrounding tissues and improving stone fragmentation efficiency compared to traditional Ho:YAG laser. A meta-analysis comparing TFL and Ho:YAG laser lithotripsy has found that TFL may result in shorter operative time and lower rate of postoperative complications, suggesting its potential as a superior alternative [55] (Table 1). The advances in laser technology have opened up new possibilities in performing laser lithotripsy, where the fiber bundle laser steering system has been enhanced to deliver lasers at precise and difficult sites in human anatomy[56].

Table 1. Comparison of laser technologies in urolithiasis

Parameter	Ho:YAG Laser	Thulium Fiber Laser (TFL)
Stone Types	All (esp. calcium oxalate)	Uric acid, cystine
Penetration Depth	0.5–1.0 mm	0.2–0.4 mm
Operative Time	Moderate	Shorter
Cost	Moderate	High
Best For	Large/hard stones	Small/soft stones

Retrograde Intrarenal Surgery (RIRS) has emerged as a valuable alternative for the treatment of kidney stones, especially in patients who might be unable to handle more invasive procedures. RIRS utilizes a flexible ureteroscope to access the kidney through the ureter, allowing a direct visualization and treatment of intrarenal stones without the need of skin incision. This technique is particularly effective for small to moderate stones and offers high stone-free rates (SFRs) with minimal postoperative discomfort. When combined with advanced laser technologies, RIRS has shown impressive outcomes with fewer complications, making it a preferred choice for patients with stones in anatomically challenging locations or those with underlying comorbidities [57].

Laparoscopic procedures provide another minimally invasive option for treating urolithiasis, particularly where other techniques, such as PCNL and RIRS, are unsuitable for complex and large stones. Laparoscopic pyelolithotomy and ureterolithotomy allow for the removal of stones through small incisions, reducing both recovery time and postoperative pain. While laparoscopic methods generally require more technical expertise, they are associated with lower morbidity and fewer complications than traditional open surgery. Laparoscopy is often reserved for cases with impacted or recurrent stones, or when associated anatomical abnormalities are present, providing both diagnostic and therapeutic advantages in a single procedure [6].

Open surgery, once the mainstay of urolithiasis management, has shown a significant decline due to the advent of minimally invasive techniques that offer comparable or superior outcomes with fewer complications. Although rarely indicated today, open surgery may still be considered in cases with extremely large or complex stone burdens, anatomical abnormalities that preclude other techniques, or recurrent stones after multiple failed minimally invasive attempts. However, open surgery is associated with higher morbidity, prolonged recovery, and greater risk of postoperative complications, which has led to its relegation to a last-resort option in urolithiasis management [58].

Pharmacologic intervention remains an important part of, not only the therapy, but also the prophylaxis of urolithiasis. Medical expulsive therapy (MET) using alpha-blockers, such as tamsulosin and silodosin, has shown to facilitate the passage of ureteral stones by relaxing smooth muscle in the ureter [59]. Recent studies also review the use of sodium-glucose cotransporter 2 (SGLT2) inhibitors, such as empagliflozin, regarding its altering supersaturation states and further stone formation rate [60]. Studies have indicated that certain plant extracts, such as those from Cymbopogon proximus and Enhydra fluctuans, exhibit antiurolithic properties by inhibiting calcium oxalate [61-62]. Probiotics and other natural remedies are also being investigated for their potential role in preventing stone formation and recurrence [63-64]. Moreover, researchers are exploring the utilization of nanoparticles for photothermal therapy to eliminate bacteria associated with kidney stones, which may reduce the risk of infection and subsequent stone formation [64].

Economic Burden and Patient-Reported Outcomes of Urolithiasis Management

The management of urolithiasis imposes a significant economic burden on healthcare systems worldwide, driven by high treatment costs, recurrent hospitalizations, and loss of productivity. Surgical interventions are associated with substantial expenses, particularly for complex or recurrent cases. In industrialized nations, where the prevalence of urolithiasis is rising, the annual healthcare expenditure for stone-related treatments has increased markedly. For example, studies estimate that the United States spends billions annually on urolithiasis care, with the costs further amplified by postoperative complications and the need for repeating procedures. The economic impact is even more pronounced in low-resource settings, where limited access to advanced technologies and trained specialists exacerbate disparities in care [65–67].

Indirect costs, such as missed workdays and reduced productivity experienced by the patients and their helper, further burden the patients and society. Recurrent stone formation often requires multiple interventions, leading to prolonged recovery period and long-term disability. Preventive measures, including dietary modification and pharmacotherapy, offer cost-saving potential but are underutilized due to gaps in patient education and adherence. Addressing these economic challenges necessitates a shift toward value-based care, emphasizing early diagnosis, minimally invasive treatments, and personalized prevention strategies to reduce both direct and indirect costs associated with urolithiasis [65,68].

Patient-reported outcomes (PROs) and quality of life (QoL) measures are critical for evaluating the holistic impact of urolithiasis and its treatments. Acute episodes of renal colic and recurrent stone events are associated with severe pain, anxiety, and diminished physical functioning, significantly impairing patients' daily lives. Studies have shown that the patient often reported lower scores in mental health, vitality, and social functioning compared to the general population, thus interventions should address not only stone clearance but also psychosocial well-being. Emerging evidence highlights the role of minimally invasive techniques in improving PROs. For instance, ureteroscopy with laser lithotripsy has been linked to shorter recovery times and fewer complications, leading to faster resumption of normal activities. However, disparities persist in QoL outcomes based on treatment modality, stone burden, and socioeconomic factors. Integrating QoL metrics into clinical decision-making can enhance treatment adherence and satisfaction. This integration ultimately serves to connect technological advancements with the actual experiences of patients undergoing management for urolithiasis [69-71].

Conclusion

Over the years, urolithiasis management has developed almost hand in hand with technology improvement, surgical techniques, and pathological discoveries. Integration of AI in diagnosis and treatment protocol determination has also enhanced treatment results. An understanding of the chemistry involved in stone formation, dietary requirements, and genetic factors are important in preventing the formation of the kidney stones.

Future research should prioritize: (1) longitudinal studies on AI-assisted diagnostics to validate real-world efficacy, (2) randomized trials comparing TFL vs. Ho:YAG lasers in complex stone anatomies, and (3) development of targeted pharmacotherapies for genetic subtypes (e.g., cystinuria). Collaborative efforts between urologists, data scientists, and geneticists are essential to translate innovations into practice.

Conflict of interest

The authors declare no conflict of interest.

References

[1] Li S, Huang X, Liu J, Yue S, Hou X, Hu L, et al. Trends in the Incidence and DALYs of Urolithiasis From 1990 to 2019: Results From the Global Burden of Disease Study 2019. *Front Public Health*. 2022 Mar 4;10:825541. doi: 10.3389/fpubh.2022.825541

[2] Xu JZ, Sun JX, Miao LT, Zhang SH, Wang WJ, Liu CQ, et al. Interconnections between urolithiasis and oral health: a cross-sectional and bidirectional Mendelian randomization study. *Front Med (Lausanne)*. 2023 Apr 26;10:1174502. doi: 10.3389/fmed.2023.1174502

[3] Budaya T, Rohman M, Ardhino A, Dhani F. The Association Between Urinary Tract Stones and The Incidence of Urinary Tract

Infections. *Brawijaya J Urol*. 2024;5(1):1–4. doi: 10.11594/bjurology.2024.005.01.1

[4] Sulaksono T, Syahrir S, Palinrungi MA. Profile of urinary tract stone in Makassar, Indonesia. *Int J Res Med Sci*. 2019 Nov 27;7(12):4758-61. doi: 10.18203/2320-6012.ijrms20195552

[5] Turney BW, Demaire C, Klöcker S, Woodward E, Sommerfeld HJ, Traxer O. An analysis of stone management over the decade before the COVID-19 pandemic in Germany, France and England. *BJU Int*. 2023 Aug;132(2):196-201. doi: 10.1111/bju.16018

[6] Cassell A, Jalloh M, Ndoye M, Mbodji M, Gaye O, Thiam NM, et al. Surgical management of urolithiasis of the upper tract – current trend of endourology in africa. *Research and Reports in Urology*. 2020 Jul 6;12:225-238. doi: 10.2147/RRU.S257669

[7] Güven S, Sönmez MG, Somani BK, Gözen AS, Sarica K, Rivas JG, et al. Current management of renal colic across Europe and its compliance to the European Association of Urology Guidelines on Urolithiasis: a survey from the European Section of Uro-technology, European Section of Urolithiasis, Young Academic Urologists study groups. *Cent Eur J Urol*. 2022;75(2):182-90. doi: 10.5173/ceju.2022.0046

[8] Singh A, Shah M, Zeeshan Hameed BM. Guideline Based Algorithmic Approach for the Management of Renal and Ureteric Calculi. In: Nephrolithiasis - From Bench to Bedside. *Intech Open*. 2023. doi: 10.5772/intechopen.101013

[9] Enrique Corona-Montes V, Júarez-Cataneo V, Eduardo Sánchez-Núñez J. Perspective Chapter: Clinical Indications for the Use of Laser in Urolithiasis. In: Lithotripsy - Novel Technologies, Innovations and Contemporary Applications. *Intech Open*. 2023 Nov 7. doi: 10.5772/intechopen.1002712

[10] Nazim SM. Advancements in Shock Wave Lithotripsy: Pushing Boundaries with Innovative Technology and Techniques. In: Lithotripsy - Novel Technologies, Innovations and Contemporary Applications. *Intech Open*. 2023 Dec 15. doi: 10.5772/intechopen.1003654

[11] Zeng G, Traxer O, Zhong W, Osther P, Pearle MS, Preminger GM, et al. International Alliance of Urolithiasis guideline on retrograde intrarenal surgery. *BJU Int*. 2023 Feb;131(2):153-164. doi: 10.1111/bju.15836

[12] Zeng G, Zhu W. Urolithiasis: From pathogenesis to management (part one). *Asian J Urol*. 2023 Jul;10(3):213-214. doi: 10.1016/j.ajur.2023.03.001

[13] Tzelves L, Berdempes M, Mourmouris P, Mitsogiannis I, Skolarikos A. Optimal Delivery of Follow-Up Care for the Prevention of Stone Recurrence in Urolithiasis Patients: Improving Outcomes. *Res Rep Urol*. 2022 Apr 19;14:141-148. doi: 10.2147/RRU.S277498

[14] Chen T, Qian B, Zou J, Luo P, Zou J, Li W, Chen Q, Zheng L. Oxalate as a potent promoter of kidney stone formation. *Front Med (Lausanne)*. 2023 Jun 5;10:1159616. doi: 10.3389/fmed.2023

[15] Wang Z, Zhang Y, Zhang J, Deng Q, Liang H. Recent advances on the mechanisms of kidney stone formation (Review). *Int J Mol Med*. 2021 Aug;48(2):149. doi: 10.3892/ijmm.2021.4982

[16] Liu L, Lin C, Li X, Cheng Y, Wang R, Luo C, Zhao X, Jiang Z. Protective Effect of Alkaline Mineral Water on Calcium Oxalate-Induced Kidney Injury in Mice. *Evid Based Complement Alternat Med*. 2023 Oct 25;2023:4559802. doi: 10.1155/2023/4559802

[17] Kachkoul R, Touimi GB, Mouhri GEl, Habbani R El, Lahrichi A. Pathophysiological aspects of renal stone formation and stone types. *Notulae Scientia Biologicae*. 2023 Mar 17;15(1):11462. doi: 10.55779/nsb15111462

[18] Alelign T, Petros B. Kidney Stone Disease: An Update on Current Concepts. *Adv Urol*. 2018 Feb 4;2018:3068365. doi: 10.1155/2018/3068365

[19] Strakosha R, Monga M, Wong MY. The relevance of Randall's plaques. *Indian J Urol*. 2014 Jan;30(1):49-54. doi: 10.4103/0970-1591.124207

[20] Letavernier E, Daudon M. Vitamin D, Hypercalciuria and Kidney Stones. *Nutrients*. 2018 Mar 17;10(3):366. doi: 10.3390/nu10030366

[21] Alexander RT. Kidney stones, hypercalciuria, and recent insights into proximal tubule calcium reabsorption. *Curr Opin Nephrol Hypertens*. 2023 Jul 1;32(4):359-365. doi: 10.1097/MNH.0000000000000892

[22] Sadeghi-Bojd S, Naghshizadian R, Mazaheri M, Ghane Sharbaf F, Assadi F. Efficacy of Probiotic Prophylaxis After The First Febrile Urinary Tract Infection in Children With Normal Urinary Tracts. *J Pediatric Infect Dis Soc*. 2020 Jul 13;9(3):305-310. doi: 10.1093/jpids/piz025

[23] Maalej B, Louati H, Abid H, Zitouni H, Weli M, Ali Zghal M, et al. Pediatric Urolithiasis in Children: Diagnosis and Management. *Med*

Surg Urol. 2017;06(04). doi: 10.4172/2168-9857.1000196
[24] Perumal KR, Chua RHB, Teh GC, Lei CCM. Prevalence of urolithiasis in Sarawak and associated risk factors: An ultrasonography-based cross-sectional study. *BJUI Compass*. 2022 Apr 20;4(1):74-80. doi: 10.1002/bco2.152
[25] Chang CW, Ke HL, Lee JI, Lee YC, Jhan JH, Wang HS, et al. Metabolic Syndrome Increases the Risk of Kidney Stone Disease: A Cross-Sectional and Longitudinal Cohort Study. *J Pers Med*. 2021 Nov 6;11(11):1154. doi: 10.3390/jpm11111154
[26] Kadlec AO, Greco K, Fridirici ZC, Hart ST, Vellos T, Turk TM. Metabolic syndrome and urinary stone composition: what factors matter most? *Urology*. 2012 Oct;80(4):805-10. doi: 10.1016/j.urology.2012.05.011
[27] Ramaswamy K, Shah O. Metabolic syndrome and nephrolithiasis. *Transl Androl Urol*. 2014 Sep;3(3):285-95. doi: 10.3978/j.issn.2223-4683.2014.06.03
[28] Bhat D, Shankar R, Shenoy RD, Rai S. Cystine Urolithiasis in Early Childhood. Indian *J Clin Biochem*. 2019 Jul;34(3):361-362. doi: 10.1007/s12291-018-0783-5
[29] Marco BB, Haid B, Radford A, Knoll T, Sultan S, Spinoit AF, et al. Guideline Adherence of Paediatric Urolithiasis: An EAU Members' Survey and Expert Panel Roundtable Discussion. *Children (Basel)*. 2022 Apr 2;9(4):504. doi: 10.3390/children9040504
[30] Elshamaa MF, Fadel FI, Kamel S, Farouk H, Alahmady M, Ramadan Y. Genetic polymorphisms in CLDN14 (rs219780) and ALP (rs1256328) genes are associated with risk of nephrolithiasis in Egyptian children. *Turk J Urol*. 2021 Jan;47(1):73-80. doi: 10.5152/tud.2020.20141
[31] Arcidiacono T, Simonini M, Lanzani C, Citterio L, Salvi E, Barlassina C, et al. Claudin-14 Gene Polymorphisms and Urine Calcium Excretion. *Clin J Am Soc Nephrol*. 2018 Oct 8;13(10):1542-1549. doi: 10.2215/CJN.01770218
[32] Spasiano A, Letavernier E, Ferraro PM, Unwin RJ, Gambaro G. Kidney Stone Biology: insights from Genetics. *Nephrol Dial Transplant*. 2025 May 15:gfaf062. doi: 10.1093/ndt/gfaf062
[33] Smith T, Blach O, Baker S, Newman L, Guest K, Symes A. Virtual stone clinic – the future of stone management? *Journal of Clinical Urology*. 2018; 2018(5):361-367. doi: 10.1177/2051415818757933
[34] Firas Salim Daoud Karomy. The Role of Low Dose CT in Diagnosis of Uretric Stones. *Med Leg Updat*. 2021;21(4):123-130. doi: 10.37506/mlu.v21i4.3116
[35] Raza M, Ghazanfar S, Mahrukh F, Altuf L, Shah L. Diagnostic Accuracy of Non-Contrast Computed Tomography in Identification of Renal Calculi in Suspected Patients with Negative Intravenous Pyelogram. *JHRR*. 2024 May 31;4(2):1078-82. doi: 10.61919/jhrr.v4i2.882
[36] Soliman AA, Sakr LK. Evaluation of the accuracy of low dose CT in the detection of urolithiasis in comparison to standard dose CT. *Al-Azhar Int Med J*. 2020;1(2):209-14. doi: 10.21608/aimj.2020.22462.1082
[37] Bozan Ö, Danacıoğlu YO, İslam MM. The approach of emergency physicians to patients with acute renal colic. *Yeni Üroloji Derg*. 2022;17(1). doi: 10.33719/yud.2022;17-1-1016256
[38] Al-Beltagi M, Saeed NK, Bediwy AS, Elbeltagi R, Hasan S, Hamza MB. Renal calcification in children with renal tubular acidosis: What a paediatrician should know. *World J Clin Pediatr*. 2023 Dec 9;12(5):295-309. doi: 10.5409/wjcp.v12.i5.295
[39] Nuswantoro Y, Anggraini E. The Systematic Review Of Radiologic Imaging In Suspected Renal Colic. *J Adv Res Med Heal Sci*. 2024;10(1).
[40] Magistro G, Bregenhorn P, Krauß B, Nörenberg D, D'Anastasi M, Graser A, et al. Optimized management of urolithiasis by coloured stent-stone contrast using dual-energy computed tomography (DECT). *BMC Urol*. 2019 Apr 30;19(1):29. doi: 10.1186/s12894-019-0459-3
[41] Armiñana A, Montón-Gómez C, Puig-Chilet A, Infante-Fuenzalida T, Fontenla-Martínez C, Torres-Espallardó I, et al. Spectral CT and Hounsfield Units: basis for correct interpretation. *An RANM*. 2023;140(2):102-113. doi: 10.32440/ar.2023.140.02.rev01
[42] Yang B, Veneziano D, Somani BK. Artificial intelligence in the diagnosis, treatment and prevention of urinary stones. *Curr Opin Urol*. 2020 Nov;30(6):782-787. doi: 10.1097/MOU.0000000000000820
[43] Liang X, Du M, Chen Z. Artificial intelligence-aided ultrasound in renal diseases: a systematic review. *Quant Imaging Med Surg*.

2023 Jun 1;13(6):3988-4001. doi: 10.21037/qims-22-1428

[44] Xing Z, Zhu Z, Jiang Z, Zhao J, Chen Q, Xing W, Pan L, Zeng Y, Liu A, Ding J. Automatic Urinary Stone Detection System for Abdominal Non-Enhanced CT Images Reduces the Burden on Radiologists. *J Imaging Inform Med*. 2024 Apr;37(2):444-454. doi: 10.1007/s10278-023-00946-2

[45] Li D, Xiao C, Liu Y, Chen Z, Hassan H, Su L, et al. Deep Segmentation Networks for Segmenting Kidneys and Detecting Kidney Stones in Unenhanced Abdominal CT Images. *Diagnostics (Basel)*. 2022 Jul 23;12(8):1788. doi: 10.3390/diagnostics12081788

[46] More-Krong P, Tubsaeng P, Madared N, Srisa-Art M, Insin N, Leeladee P, et al. Clinical validation of urinary indole-reacted calcium oxalate crystallization index (iCOCI) test for diagnosing calcium oxalate urolithiasis. *Sci Rep*. 2020 May 20;10(1):8334. doi: 10.1038/s41598-020-65244-1

[47] Sun X, Zhou S, Zhang Y, Ma C, Hu Y, Tian S, et al. Simultaneous Detection of Citric Acid and Oxalic Acid Based on Dual Spectrum and Biomimetic Peroxidase for Urolithiasis Screening with a Fully Automatic Urine Analyzer. *Small*. 2024 Mar;20(9):e2304941. doi: 10.1002/smll.202304941

[48] Wang C, Jin L, Zhao X, Li G, Xue B. Minimally invasive treatment of an ectopic kidney stone: a case report and literature review. *J Int Med Res*. 2019 Sep;47(9):4544-4550. doi: 10.1177/0300060519865845

[49] Hossain TMS, Islam SN. Mini Percutaneous Nephrolithotomy in Ectopic Lumber Kidney: A Case Report. *Bangladesh J Urol*. 2023;25(2): 122-125. doi: 10.3329/bju.v25i2.68591

[50] Zheng J, Zhang J, Cai J, Yao Y, Lu S, Wu Z, et al. Development of a radiomics model to discriminate ammonium urate stones from uric acid stones in vivo: A remedy for the diagnostic pitfall of dual-energy computed tomography. *Chin Med J (Engl)*. 2024 May 5;137(9):1095-1104. doi: 10.1097/CM9.0000000000002866

[51] Şahin MF, Ozman O, Cakir H, Cinar O, Akgul M, Basatac C, et al. Retrograde Intrarenal Surgery Learning Curves of Urology Residents Supervised by an Experienced Endourologist: An RIRSearch Study. *Urol Int*. 2023;107(9):877-885. doi: 10.1159/000531517

[52] Kumar A, Sharma A. Phytochemical Screening, Acute Toxicity and Evaluation of in vitro Antiurolithaitic Activity of Ethanolic and Methanolic Root and Leaf Extracts of Acalypha indica Linn. *J Young Pharm*. 2024;16(2):223–8. doi: 10.5530/jyp.2024.16.29

[53] Moriyama MT, Tachibana H, Sugimoto Y. The Characteristics of the Behavior of Impact Energy and Treatment for Urolithiasis by Holmium:YAG Laser. *Nippon Laser Igakkaishi*. 2019;40(1):7-13. doi: 10.2530/jslsm.jslsm-40_0006

[54] Guler AG, Karakaya AE, Dogan AB, Kandur Y. Our Results For Rigid Ureteroscopy And Laser Lithotripsy In Pediatric Age Group. *Kırıkkale Üniversitesi Tıp Fakültesi Derg*. 2021;23(2):338-42. doi: 10.24938/kutfd.915946

[55] Chua ME, Bobrowski A, Ahmad I, Kim JK, Silangcruz JM, Rickard M, et al. Thulium fibre laser vs holmium: yttrium-aluminium-garnet laser lithotripsy for urolithiasis: meta-analysis of clinical studies. *BJU Int*. 2023 Apr;131(4):383-394. doi: 10.1111/bju.15921

[56] Miyoshi Y, Nishimura T, Shimojo Y, Okayama K, Awazu K. Endoscopic image-guided laser treatment system based on fiber bundle laser steering. *Sci Rep*. 2023 Feb 28;13(1):2921. doi: 10.1038/s41598-023-29392-4.

[57] Inoue T, Okada S, Hamamoto S, Fujisawa M. Retrograde intrarenal surgery: Past, present, and future. *Investig Clin Urol*. 2021 Mar;62(2):121-135. doi: 10.4111/icu.20200526

[58] Akram M, Jahrreiss V, Skolarikos A, Geraghty R, Tzelves L, Emilliani E, et al. Urological Guidelines for Kidney Stones: Overview and Comprehensive Update. *J Clin Med*. 2024 Feb 16;13(4):1114. doi: 10.3390/jcm13041114

[59] Jung H Do, Cho KS, Jun DY, Jeong JY, Moon YJ, Chung DY, et al. Silodosin versus Tamsulosin for Medical Expulsive Therapy of Ureteral Stones: An Updated Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Medicina (Kaunas)*. 2022 Dec 6;58(12):1794. doi: 10.3390/medicina58121794

[60] Schietzel S, Bally L, Cereghetti G, Faller N, Moor MB, Vogt B, et al. Impact of the SGLT2 inhibitor empagliflozin on urinary supersaturations in kidney stone formers (SWEETSTONE trial): protocol for a randomised, double-blind, placebo-controlled cross-over trial. *BMJ Open*. 2022 Mar

14;12(3):e059073. doi: 10.1136/bmjopen-2021-059073

[61] Young MJ, Pang KH, Elmussarah M, Hughes PF, Browning AJ, Symons SJ. Acute extracorporeal shockwave lithotripsy for ureteric stones - 7-years' experience from a busy district general hospital. *BJU Int*. 2022 Nov;130(5):655-661. doi: 10.1111/bju.15820

[62] Chattaraj B, Nandi A, Das A, Sharma A, Dey YN, Kumar D, et al. Inhibitory activity of Enhydra fluctuans Lour. on calcium oxalate crystallisation through in silico and in vitro studies. *Front Pharmacol*. 2023 Jan 20;13:982419. doi: 10.3389/fphar.2022.982419

[63] Arya AA, Kumar SK, Suryavanshi AS, Kain DK. Biosynthesis of Metallic Nanoparticles from Medicinal Plants: A Review. *J Nanosci Technol*. 2019;5(5):827-31. doi: 10.30799/jnst.277.19050502

[64] Klein I, Sarkar S, Gutierrez-Aceves J, Levi N. Photothermal nanoparticles for ablation of bacteria associated with kidney stones. *Int J Hyperthermia*. 2021;38(1):760-770. doi: 10.1080/02656736.2021.1916099

[65] Hyams ES, Matlaga BR. Economic impact of urinary stones. *Transl Androl Urol*. 2014 Sep;3(3):278-83. doi: 10.3978/j.issn.2223-4683.2014.07.02

[66] Kirkali Z, Rasooly R, Star RA, Rodgers GP. Urinary Stone Disease: Progress, Status, and Needs. *Urology*. 2015 Oct;86(4):651-3. doi: 10.1016/j.urology.2015.07.006

[67] Clark JY, Thompson IM, Optenberg SA. Economic impact of urolithiasis in the United States. *J Urol*. 1995 Dec;154(6):2020-4

[68] Pozdzik A, Grillo V, Sakhaee K. Gaps in kidney stone disease management: From clinical theory to patient reality. *Urolithiasis*. 2024;52(1):1–9. doi: 10.1007/s00240-024-01563-6

[69] Lee KS, Yoo TK, Liao L, Wang J, Chuang YC, Liu SP, Chu R, Sumarsono B. Association of lower urinary tract symptoms and OAB severity with quality of life and mental health in China, Taiwan and South Korea: results from a cross-sectional, population-based study. *BMC Urol*. 2017 Nov 21;17(1):108. doi: 10.1186/s12894-017-0294-3

[70] Modersitzki F, Goldfarb DS, Goldstein RL, Sur RL, Penniston KL. Assessment of health-related quality of life in patients with cystinuria on tiopronin therapy. *Urolithiasis*. 2020 Aug;48(4):313-320. doi: 10.1007/s00240-019-01174-6

[71] Ryan JR, Nguyen MH, Linscott JA, Nowicki SW, James E, Jumper BM, et al. Ureteroscopy with thulium fiber laser lithotripsy results in shorter operating times and large cost savings. *World J Urol*. 2022 Aug;40(8):2077-82. doi: 10.1007/s00345-022-04037-9