Al-Kindy College Medical Journal (KCMJ)

Commentary

A Cautionary Perspective on Artificial Intelligence and Novel Imaging Technologies in Patient Selection for Retrograde Intrarenal Surgery

Samir Muter[1,2*], Noorulhuda Al-Ani[3]

[1] Macquarie University, Faculty of Medicine and Health Sciences. Sydney. Australia
[2] College of Medicine, University of Baghdad, Baghdad, Iraq
[3] Northwest health, Tasmania. Australia
* Corresponding author's email: samir.muter@yahoo.com

Article history:
Received 6 May 2025
Accepted 16 June 2025
Available online 1 August 2025

https://doi.org/10.47723/e4j95114

Keywords: Retrograde renal surgery; Dual Energy CT; 3-dimensional Reconstruction; Radiomics

ABSTRACT

The advancement of retrograde intrarenal surgery (RIRS) has been accompanied by the evolution of many promising tools that aim at improving patient selection and predicting surgery outcomes in terms of stone fragmentation and expected complications. The incorporation of artificial intelligence (AI) into the advanced imaging technologies such as dual-energy CT scan (DECT), three-dimensional (3D) reconstruction, and radiomics resulted in a number of clinical tools and algorithms forwarded to surgeons to use in their daily practice.
This commentary critically examines these clinical algorithms, highlighting the absence of prospective validation, the potential for overreliance, and the possible limitations of their clinical applicability. AI-driven predictive models often rely on retrospective, uniform datasets taken from a single center, with evident interpretability concerns. Similarly, DECT and 3D reconstructions might provide detailed information about the anatomy of the renal collecting system and stone composition, but they do not account for real-time surgical dynamics. Radiomics, in the other hand, provides excellent insights into stone behavior, but their reproducibility and clinical relevance are still to be tested.
The take-home message of this commentary is that conventional CT metrics—such as stone size and density—continue to outperform novel techniques in reliability and accessibility, and the adoption of emerging technologies in RIRS must be cautious, ethically sound, and evidence-based, reinforcing the primacy of clinical judgment in urologic care.

Retrograde intrarenal surgery (RIRS) has quickly become the first-line therapy for renal stones, especially stones smaller than 20 mm in size. As the ureteroscopy and laser technologies have improved, patient outcomes have also improved dramatically. However, the new frontier in RIRS looks like it is preoperative precision – who are the patients most likely to gain, with the least risk and best stone clearance?

AI algorithms and sophisticated imaging techniques, including dual-energy CT (DECT) and three-dimensional (3D) reconstructions, are driving this ambition [1,2]. Although these new technologies present exciting opportunities, surgeons contend that their clinical implementation at present is premature. Without robust, prospective validation, over-credence in these technologies poses the danger of injecting a misleading sense of objectivity into nuanced, personalized surgical decision making.

AI and Predictive Algorithms: Promise Meets Prematurity

Artificial intelligence (AI) has been utilized to improve diagnosis and management in medicine in general [3]. In urology and stone disease in specific, AI models (especially machine learning classifiers) have been built to forecast stone-free rates, complication risks, and procedural complexity in RIRS [4]. These models frequently include information from electronic patient records, imaging characteristics, and operative details to produce predictive probabilities. Investigations similar to those of Aminsharifi et al. and Pérez-Fentes et al. have reported predictive accuracy greater than 85% using support vector machines and logistic regression model trained on retrospective data [5,6].

In spite of this, these tools still carry substantial limitations when it comes to their clinical applicability as most of them use single-center datasets with minimal demographic and anatomical diversity [7]. In addition, many models are complex, making it difficult for clinicians to understand the way a certain prediction was made [8]. RIRS requires intraoperative judgment that considers stone migration, renal anatomy, infundibular angles, and laser dynamics, so a "black-box" risk prediction model cannot be relied upon to make the final treatment decision. Until these algorithms are prospectively validated across multiple centers, they should be considered experimental tools only, not clinical decision aids.

Dual-Energy CT: Sophisticated Imaging with Limited Clinical Leverage

Among the advantages of dual energy CT are its ability to distinguish stone composition based on attenuation differences at varying energy levels, particularly between calcium oxalate and calcium phosphate stones [9,10]. DECT can provide an accurate estimate of effective atomic number and iodine content that can be effectively related to stone response to shockwave lithotripsy and laser fragmentation, this in turn will help the treating clinician choosing the appropriate, high yield modality of treatment.

In real life, this is not the situation because mixed-composition stones make the majority of stones. These mixed-composition stones do not show a predictable attenuation pattern that can be related to a specific type of stone or fragmentation response [11,12]. Furthermore, the scene is more complicated when taking into consideration the technical variabilities in terms of the manufacturer, software used, and the tube current modulation [13]. To summarize, DECT at present can provide valuable information to take into consideration when making decisions on stone treatment but cannot be relied on in dictating patient selection for RIRS.

3D Reconstruction: Intuitive Planning or Unnecessary Complexity?

When exploring how 3D reconstruction might improve RIRS planning, researchers are building on successes seen in PCNL procedures. Just as detailed 3D kidney maps-showing calyces, stone locations, and infundibular dimensions-are created from CT scans using specialized software [14], some teams are testing "virtual RIRS" simulations to help surgeons rehearse maneuvers and predict challenges before stepping into the operating theaters [15]. But here's the catch: while these models look impressive, there's little proof they actually boost surgery success rates or save time [16]. Unlike PCNL, where choosing the skin access point is half the procedure, RIRS relies largely on the surgeon's real-time adaptability and the scope's flexibility. Moreover, static 3D images cannot simulate breathing patterns, patient positioning, or fluid dynamics during live surgery, all of which can detriment the best made plan [17]. Until well-designed studies confirm their practical value, 3D reconstruction images remain more of a "nice-to-have" than essential tools for RIRS.

Radiomics and AI-Augmented CT Interpretation: A Double-Edged Sword

Imagine if CT scans could tell surgeons not just where kidney stones are, but how easily they will fragment with laser. That's the promise of radiomics, a smart imaging analysis that looks beyond basic shapes to decode texture patterns of renal stones. Early studies suggest these "digital fingerprints" (characteristics like stone roughness, density variations, and internal complexity) might predict which stones will fragment quickly and which will need more laser time or energy [18]. Studies by Xiang et al. and Lyu et al. have even linked radiomic features to stone composition, and potentially stone fragmentation efficiency [19,20].

Radiomics however, share most of the limitations of other AI tools. The accuracy of feature extraction is highly dependent on the precise definition of the region of interest and the quality of the imaging data, raising concerns regarding reproducibility across different CT scanners and imaging protocols [21]. Furthermore, the lack of interpretability of radiomic signatures and the absence of prospective clinical trials limit the current applicability of these findings in routine clinical practice. Consequently, similar to dual-energy CT (DECT) and 3-D reconstruction techniques, radiomics remains primarily a research tool rather than a validated clinical instrument.

Revisiting Basic Imaging Metrics: A Cautionary Contrast

A comparison between advanced imaging modalities and established, conventional parameters underscore the enduring clinical value of the latter. In many studies, renal stone density measured in Hounsfield units (HU) on non-contrast CT was identified as a robust predictor of shock wave lithotripsy (SWL) outcomes, with stones exhibiting HU values below 800 demonstrating a significantly higher likelihood of successful fragmentation under shockwave therapy [22,23]. This observation is corroborated by multiple independent investigations, which consistently report that lower HU values are associated with improved SWL efficacy, whereas stones exceeding 1000 HU are linked to higher rates of treatment failure and the need for alternative interventions [23,24].

Although these researches focused on SWL, these findings highlight a broader principle: fundamental CT-derived metrics, when interpreted within the appropriate clinical context, can serve as powerful predictors of treatment outcomes. In the context of retrograde intrarenal surgery (RIRS), stone volume and density-whether assessed manually or through automated volumetric analysis-remain among the most reliable predictors of operative duration and surgical success [25]. Prior to the widespread adoption of advanced imaging technologies or artificial intelligence-driven platforms, it is imperative that the urologists ensure these foundational parameters are fully standardized, readily accessible, and rigorously validated in clinical practice.

The Ethical and Economic Imperative for Validation

Integrating advanced technologies such as dual-energy CT (DECT), three-dimensional (3D) reconstruction, and AI-based predictive tools into everyday clinical practice brings with it important ethical and financial considerations. Without thorough validation, these innovations risk widening disparities in healthcare access, particularly for patients in resource-limited settings, as the costs and infrastructure required may not be universally available [26]. Additionally, reliance on proprietary software and hardware introduces further challenges, including concerns about transparency, data ownership, and the accountability of algorithms-issues that are not yet sufficiently addressed in the current urologic literature [27,28].

The medical field has previously witnessed enthusiasm for new technologies that, despite their initial promise, ultimately failed to deliver on their expectations. For example, the introduction of robot-assisted surgical systems and fusion biopsy platforms generated significant excitement, yet subsequent experience revealed that, in the absence of robust validation, such innovations can lead to inappropriate use, inefficient allocation of resources, or even diagnostic errors[29]. As the adoption of AI and advanced imaging in RIRS accelerates, it is crucial that the lessons of the past guide current practice. Ensuring that new technologies are rigorously evaluated before widespread implementation will help prevent repeating cycles of overpromising and underdelivering and will safeguard both patient outcomes and healthcare equity.

Conclusion: Precision Demands Prudence

The ongoing evolution of retrograde intrarenal surgery (RIRS) increasingly depends on precise patient selection, which remains central to optimizing outcomes. While technological advances such as dual-energy computed tomography (DECT), three-dimensional (3D) reconstruction, and artificial intelligence (AI)-driven analytics are impressive, it is essential to distinguish between what is technologically feasible and what is clinically necessary. Current guidelines and expert consensus emphasize that, in the absence of robust evidence from prospective, multicenter trials demonstrating clear benefits-such as improved stone-free rates, reduced complications, or enhanced procedural efficiency-these advanced tools should be regarded primarily as investigational rather than standard of care.

The potential pitfalls of premature adoption are not theoretical. Over-reliance on unvalidated technologies risks shifting clinical decision-making away from individualized, bedside assessment toward algorithm-driven abstraction. This may undermine the nuanced judgment required in patient care, as precision unsupported by strong evidence can be misleading. Until these innovations are validated through rigorous, outcome-focused studies, they should be viewed as adjuncts to, rather than replacements for, clinical expertise and judgment.

Funding

This research did not receive any specific fund.

Conflict of Interest

Authors declare no conflict of interest.

ORCID

Samir Muter 0000-0002-3744-2887
Noorulhuda Al-Ani 0009-0000-3338-2162

References

[1] Candela L, Keller EX, Pietropaolo A, Esperto F, Juliebø-Jones P, Emiliani E, De Coninck V, Tailly T, Talso M, Tonyali S, Sener ET, Hameed BMZ, Tzelves L, Mykoniatis I, Tsaturyan A, Salonia A, Ventimiglia E. New Technologies in Endourology and Laser Lithotripsy: The Need for Evidence in Comprehensive Clinical Settings. J Clin Med. 2023 Sep 1;12(17):5709. https://doi.org/10.3390/jcm12175709

[2] Joanne Dale, Rajan T. Gupta, Daniele Marin, Michael Lipkin, and Glenn Preminger imaging advances in urolithiasis. Journal of Endourology 2017 31:7, 623-629. https://doi.org/10.1089/end.2016.0695

[3] Hameed EK, Al-Ameri LT. Artificial Intelligence: The Gateway to Better Medical Diagnosis. Al-Kindy Col. Med. J. 2024;20(1):1-3. https://doi.org/10.47723/w1ymg293

[4] Lee HY, Tung YH, Elises JC, Wang YC, Gauhar V, Cho SY. Machine learning-based prediction of stone-free rate after retrograde intrarenal surgery for lower pole renal stones. World J Urol. 2025 Jul 12;43(1):433. https://doi.org/10.1007/s00345-025-05762-7

[5] Huang Y, Li K, Yang W, Li Z, Liu C, Lai C et al (2022) A scoring system for optimal selection of endoscopic treatment for 1-2 cm lower pole renal calculi. Urol J 19(5):356–362. https://doi.org/10.22037/uj.v19i05.7195

[6] Doyle, Patrick & Gong, Wu & Hsi, Ryan & Kavoussi, Nicholas. (2023). Machine Learning Models to Predict Kidney Stone Recurrence Using 24 Hour Urine Testing and Electronic Health Record-Derived Features. Research square. https://doi.org/10.21203/rs.3.rs-3107998/v1

[7] Topol, E.J. High-performance medicine: the convergence of human and artificial intelligence. Nat Med 25, 44–56 (2019). https://doi.org/10.1038/s41591-018-0300-7

[8] Rajpurkar P, Chen E, Banerjee O, Topol EJ. AI in health and medicine. Nat Med. 2022 Jan;28(1):31-38. https://doi.org/10.1038/s41591-021-01614-0

[9] Graser A, Johnson TR, Bader M, Staehler M, Haseke N, Nikolaou K, Reiser MF, Stief CG, Becker CR. Dual energy CT characterization of urinary calculi: initial in vitro and clinical experience. Invest Radiol. 2008 Feb;43(2):112-9. https://doi.org/10.1097/RLI.0b013e318157a144

[10] Chaytor RJ, Rajbabu K, Jones PA, McKnight L. Determining the composition of urinary tract calculi using stone-targeted dual-energy CT: evaluation of a low-dose scanning protocol in a clinical environment. Br J Radiol. 2016 Nov;89(1067):20160408. https://doi.org/10.1259/bjr.20160408

[11] Meng X, Sun X, Cong R, Qi L, Wang Z, et al. Characterization of Mixed Urinary Stone Compositions with Dual-Source Dual-Energy Computed Tomography in Vivo Compared to Infrared Spectroscopy.I J Radiol.2021;18(3):e114717. https://doi.org/10.5812/iranjradiol.114717

[12] Sheikhi M, Sina S, Karimipourfard M. Dual-energy Computed Tomography (DECT) Scan for Determination of Renal Stone Composition: A Phantom Study.I J Radiol.2023;20(3):e134455. https://doi.org/10.5812/iranjradiol-134455

[13] Anushri Parakh, Simon Lennartz, Chansik An, Prabhakar Rajiah, Benjamin M. Yeh, Frank J. Simeone, Dushyant V. Sahani, and Avinash R. Kambadakone. Dual-Energy CT Images: Pearsl and Pitfalls. RadioGraphics 2021 41:1, 98-119. https://doi.org/10.1148/rg.2021200102

[14] Finch W, Johnston R, Shaida N, Winterbottom A, Wiseman O. Measuring stone volume - three-dimensional software reconstruction or an ellipsoid algebra formula? BJU Int. 2014 Apr;113(4):610-4. https://doi.org/10.1111/bju.12456

[15] EZER M, AYDOĞAN TB, TZELVES L, SKOLARIKOS A, USLU M, SARICA K, HURİ E. Evaluation and validation of 3D-printed anatomical urinary system model and virtual reality RIRS simulators in RIRS training: a comparative study. Turk J Med Sci. 2025 Jun 5;55(3):733–42. https://doi.org/10.55730/1300-0144.6022

[16] Hameed BMZ, Pietropaolo A, Naik N, Noronha C, Juliebø-Jones P, Mykoniatis I, Esperto F, Shah M, Ibrahim S, Shetty DK, Karimi H, Sharma D, Rai BP, Chlosta P, Somani BK. Role of three dimensional (3D) printing in endourology: An update from EAU young academic urologists (YAU) urolithiasis and endourology working group. Front Surg. 2022 Aug 12;9:862348. https://doi.org/10.3389/fsurg.2022.862348

[17] Meyer-Szary J, Luis MS, Mikulski S, Patel A, Schulz F, Tretiakow D, Fercho J, Jaguszewska K, Frankiewicz M, Pawłowska E, Targoński R, Szarpak Ł, Dądela K, Sabiniewicz R, Kwiatkowska J. The Role of 3D Printing in Planning Complex Medical Procedures and Training of Medical Professionals-Cross-Sectional Multispecialty Review. Int J Environ Res Public Health. 2022 Mar 11;19(6):3331. https://doi.org/10.3390/ijerph19063331

[18] Philippe Lambin, Emmanuel Rios-Velazquez, Ralph Leijenaar, Sara Carvalho, Ruud G.P.M. van Stiphout, Patrick Granton, Catharina M.L. Zegers, Robert Gillies, Ronald Boellard, André Dekker, Hugo J.W.L. Aerts, Radiomics: Extracting more information from medical images using advanced feature analysis, European Journal of Cancer,Volume 48, Issue 4, 2012, 441-446, https://doi.org/10.1016/j.ejca.2011.11.036

[19] Pranovich A.A., Karmazanovsky G.G., Sirota E.S., Firsov M.A., Simonov P.A., Junker A.I., Dzhatdoeva M.K., Khubiev D.A. Radiomics in Urolithiasis: a Systematic Review of Current Applications, Limitations and Future Directions // Annals of the Russian Academy of Medical Sciences. - 2024. - Vol. 79. - N. 5. - P. 393-405. https://doi.org/10.15690/vramn17953

[20] Cui HW, Devlies W, Ravenscroft S, Heers H, Freidin AJ, Cleveland RO, Ganeshan B, Turney BW. CT Texture Analysis of Ex Vivo Renal Stones Predicts Ease of Fragmentation with Shockwave Lithotripsy. J Endourol. 2017 Jul;31(7):694-700. https://doi.org/10.1089/end.2017.0084

[21] Traverso A, Wee L, Dekker A, Gillies R. Repeatability and Reproducibility of Radiomic Features: A Systematic Review. Int J Radiat Oncol Biol Phys. 2018 Nov 15;102(4):1143-1158. https://doi.org/10.1016/j.ijrobp.2018.05.053

[22] Muter S, et al. Renal Stone Density on Native CT scan as a predictor of treatment outcomes in shockwave lithotripsy. J Med Life. 2022;15(12):1579–84. https://doi.org/10.25122/jml-2022-0153

[23] Abdelaziz H, Elabiad Y, Aderrouj I, Janane A, Ghadouane M, Ameur A, Abbar M. The usefulness of stone density and patient stoutness in predicting extracorporeal shock wave efficiency: Results in a North African ethnic group. Can Urol Assoc J. 2014 Jul;8(7-8):E567-9. https://doi.org/10.5489/cuaj.1849

[24] Garg M, Johnson H, Lee SM, Rai BP, Somani B, Philip J. Role of Hounsfield Unit in Predicting Outcomes of Shock Wave Lithotripsy for Renal Calculi: Outcomes of a Systematic Review. Curr Urol Rep. 2023 Apr;24(4):173-185. https://doi.org/10.1007/s11934-023-01145-w

[25] Raj K K, Adiga K P, Chandni Clara D'souza R, et al. (July 01, 2024) Assessment of Factors Responsible for Stone-Free Status After Retrograde Intrarenal Surgery. Cureus 16(7): e63627. https://doi.org/10.7759/cureus.63627

[26] d'Elia A, Gabbay M, Rodgers S, Kierans C, Jones E, Durrani I, Thomas A, Frith L. Artificial intelligence and health inequities in primary care: a systematic scoping review and framework. Fam Med Community Health. 2022 Nov;10(Suppl 1):e001670. https://doi.org/10.1136/fmch-2022-001670

[27] Beltramin, Diva & Lamas, Eugenia & Bousquet, Cédric. (2022). Ethical Issues in the Utilization of Black Boxes for Artificial Intelligence in Medicine. https://doi.org/10.3233/SHTI220709

[28] Obermeyer Z, Powers B, Vogeli C, Mullainathan S. Dissecting racial bias in an algorithm used to manage the health of populations. Science. 2019 Oct 25;366(6464):447-453. https://doi.org/10.1126/science.aax2342

[29] Crettenand F, Stritt K, Grilo N, Lucca I. Urologie : ce qui a changé en 2024 [Urology: what's new in 2024]. Rev Med Suisse. 2025 Jan 15;21(900-1):81-84. French. https://doi.org/10.53738/REVMED.2025.21.900-1.81

To cite this article:
Muter S, Al-Ani N. A Cautionary Perspective on Artificial Intelligence and Novel Imaging Technologies in Patient Selection for Retrograde Intrarenal Surgery. Al-Kindy Col. Med. J. 2025;21(2):161-4. https://doi.org/10.47723/e4j95114