Urolithiasis (2023) 51:97
https://doi.org/10.1007/s00240-023-01471-1

RESEARCH

Practices and utility of imaging among urological communities for urolithiasis, observations, and inferences from a targeted survey

Bahadir Sahin[1] · Tarik Emre Sener[1] · Laurian Dragos[2] · Vineet Gauhar[3] · Yiloren Tanidir[4]

Received: 3 May 2023 / Accepted: 17 July 2023

Abstract

To evaluate the general practice among urologists about the use of various radiological imaging and measurement tools, and to compare the different preferences in radiological evaluations between Turkish and European urologists. Our study was designed as a survey study. The survey comprised 22 questions which evaluated the epidemiological information, caseload of participants, general preferences of participants on CT image slice thickness, basic radiologic workup routines prior to surgery, use of special tools and measurements on CT. Data collection was conducted with both an online poll and printed copies. A total of 222 urologists from 23 different countries responded to the survey. The most performed endourologic surgery was semi-rigid URS which was performed more than 25 times/year by 90.1% ($n=200$) of the participants. Although PCNL was performed more commonly by Turkish urologists (39.7%) compared to their European (17.3%) colleagues ($p<0.001$), it was still the least often performed endourological surgery among all participants (31.5%). The stone size evaluation was the most performed measurement performed by the participants. Although the group of surgeons used size measurement tools, there were differences between the two groups. Turkish urologists used size measurement before PCNL (85.7%) as opposed to European urologists who used it mostly before URS (91.4%). Non-contrast CT images for urolithiasis are mainly evaluated by urologists themselves and a considerable number of urologists do not use additional measurement tools in evaluating CT images. Although there are similarities in the knowledge of various radiological tools, there are distinct regional differences.

Keywords Urolithiasis · Computed tomography · Evaluation · Survey · Management

Introduction

Urolithiasis is one of the most frequently encountered conditions in daily urological practice. Although varying with geographical, ethnic, and genetic factors, its prevalence ranges between 10 and 37% [1, 2]. It has also been shown that both prevalence and incidence of urinary system stone disease are globally increasing [3] which makes it even more crucial to choose the easiest, fastest, and reliable diagnostic modality. Furthermore, it has been demonstrated that with increasing incidence, the financial burden of the diagnosis of urolithiasis can result in a 50% increment in overall expenditure in diagnostic procedures [4].

Although most of the urinary stones can be visualized with kidney–ureter–bladder radiography (KUB), the introduction of computerized tomography (CT) has revolutionized the diagnosis process of urolithiasis and has become the gold standard imaging modality for urolithiasis. Non-contrast CT has a sensitivity ranging between 96% and 100% and specificity ranging between 92% and 100% [5]

✉ Yiloren Tanidir
yiloren@yahoo.com

Bahadir Sahin
drbahadirsahin@gmail.com

Tarik Emre Sener
dr.emresener@gmail.com

Laurian Dragos
lauriandragos@yahoo.com

Vineet Gauhar
vineetgaauhaar@gmail.com

1 Department of Urology, Marmara University School of Medicine, Istanbul, Turkey

2 Department of Urology, Cambridge University Hospitals NHS Foundation Trust, Cambridge, UK

3 Department of Urology, Ng Teng Fong General Hospital (NUHS), Singapore, Singapore

4 Department of Urology, Marmara University School of Medicine, Istanbul, Turkey

Published online: 25 July 2023

that renders this imaging modality, the preferred diagnostic option in both emergency and elective cases [6].

Although non-contrast CT is the gold standard diagnostic tool for kidney stones, it has limitations, especially for ureteral stones. It has also been demonstrated that with the use of additional measurement tools such as attenuation in the form of Hounsfield unit (HU) measurement, the diagnostic accuracy can be increased especially in distal ureteral stones [7]. A recent study also demonstrated that although measurements of attenuation or volume can be insufficient alone, deep learning techniques can successfully differentiate stones from extra-urinary calcifications [8].

Basic knowledge about CT or any other imaging modality evaluations is a vital part of the diagnosis of urolithiasis for urologists. In this study, we aimed to evaluate the general practice among urologists about the use of various radiological tools and to compare the different preferences in radiological evaluations between Turkish and European urologists.

Materials and methods

Study design

Our study was designed as a survey study. Data collection was conducted through 2016 with both an online poll and printed copies. Online polls were collected with software which was designed by the authors specifically for this study, based on PHP programming language and MySQL database system. In the case of surveys conducted via printed copies, participants were asked to fill the poll and the sheets were collected afterward.

Survey design

This study was approved by the local ethical committee of Marmara University School of Medicine. The survey comprised 21 questions (Supplementary File 1). The first five were epidemiological and general questions about age, years of experience in the field, and work status. The general workload of participants was evaluated by asking if the respondents perform more than 25 times/year the following stone surgeries; ureterorenoscopy (URS), percutaneous nephrolithotomy (PCNL), and flexible URS.

Four specific questions addressed the general preferences of participants on CT evaluation such as desired slice thickness. Two questions were related to the basic radiologic workup which the participants must have prior to surgery for both renal and ureteral stones. General practice of the participants on the use of special tools and measurements on CT was evaluated with six questions. Two questions about the challenging situations on non-contrast CT evaluation such as stone vs. non-urinary opacity discrimination were asked. The viewing by the tele-medicine tools such as instant messaging applications and radiological software was also asked in two questions.

Furthermore, in addition to originally being prepared in Turkish, the survey was translated into English and French, and participants were asked to fill the survey in the language which they feel themselves most comfortable with. After the creation of the initial questionnaire, survey was conducted on a small group of ten urologists to avoid misunderstandings and unclear questions. After the feedback from the pilot survey, final version of the questionnaire was prepared and reapplied to the pilot study group also. The translation was done by authors and double-checked by a native speaker of each language.

Statistical analysis

Statistical analysis was performed using SPSS software version 22 (IBM Corp, NY, USA). For comparison of nominal variables, the Chi-square test was used for the cases where the values observed in the cells meet the assumptions of the Chi-square test whereas the Fisher test was used for the other cases. For numerical variables, median and standard deviation were given if the variable was normally distributed. For the variables that are not normally distributed, median and interquartile ranges were given. Confidence intervals were set at 95% for all statistical analyses and it was considered significant that p was 0.05 or less.

Results

We have been able to reach 222 urologists worldwide both with online polls and printed copies of surveys. Urologists from Turkey constituted 63.5% ($n=141$) of the participants. Other than Turkey, there were urologists working in 23 different countries all around the world. There were six urologists outside Europe. (Supplementary Table 1) The median participant age was 36 (31–47.5) years. The mean experience of the participants in the field was 12.5 ± 9.5 years. Urology residents were 25.2% ($n=56$) of the total participants (Table 1). Most of the residents in the study were senior residents with at least 3 years of experience in urology (82.1%) There was no statistically significant difference in the baseline parameters of the study, except that residents wanted to see more CUB before kidney stone surgery than urologists (Table 2).

The most performed endourologic surgery was semi-rigid URS which was performed more than 25 times a year by 90.1% ($n=200$) of the participants. Although PCNL was performed more commonly by Turkish urologists (39.7%) compared to their foreign (17.3%) colleagues

Table 1 General characteristics of participants with respect to country

	Turkish participant ($n=141$) *N* (%)	European participant ($n=81$) *N* (%)	*p* value*
Resident			
No	119 (84.4)	47 (58.0)	< 0.001
Yes	22 (15.6)	34 (42.0)	
Hospital type			
Training hospital	32 (27.7)	14 (17.3)	< 0.001
University hospital	42 (29.8)	53 (65.4)	
State hospital	38 (27.0)	10 (12.3)	
Private practice	29 (20.6)	4 (4.9)	
Urology education hospital type			
Training hospital	45 (37.8)	33 (50)	0.073
University hospital	74 (62.2)	33 (50)	

*x^2 test

Table 2 Comparison of preferred basic study parameters between resident and urologist groups

	Residents	Urologists	*p* value*
Would you like to evaluate CT images yourself?			
No	0 (0)	9 (5.5)	0.068
Yes	56 (100)	156 (94.5)	
Desired planes on a CT study			
Monoplanar	8 (14.3)	15 (9.4)	0.305
Tri-planar	48 (85.7)	145 (90.6)	
Prefer to have radiology report before surgery			
No	20 (36.4)	77 (47.5)	0.150
Yes	35 (63.6)	85 (52.5)	
Basic radiological work-up before ureteral stone surgery			
USG	21 (37.5)	46 (27.9)	0.176
Non-Contrast CT	40 (71.4)	130 (78.8)	0.256
KUB	19 (33.9)	44 (26.7)	0.298
IVP	8 (14.3)	22 (13.3)	0.857
Contrast-enhanced CT	11 (19.6)	22 (13.3)	0.252
Basic radiological workup before kidney stone surgery			
USG	14 (25.0)	37 (22.4)	0.693
Non-contrast CT	44 (78.4)	123 (77.0)	0.804
KUB	16 (28.6)	25 (15.2)	0.026
IVP	7 (12.5)	29 (17.6)	0.374
Contrast-enhanced CT	14 (25.0)	39 (23.6)	0.836

*x^2 Test. *USG* ultrasound, *CT* computerized tomography, *IVP* intravenous pyelography, *KUB* kidney–ureter–bladder radiography

($p < 0.001$), it was still the least often performed endourological surgery among all participants (31.5%). More than half of the participants in both groups (58.2–53.1, respectively) performed flexible URS that was not exceeding 25 times in a year ($p = 0.463$).

Most participants stated that they would like to see CT images on the tri-planar (coronal, sagittal, and axial) axis. Our results also showed that compared to foreign urologists, Turkish surgeons would like to evaluate CT images themselves and they do not feel obligated to have a radiology report of the study before surgery (Table 3). The mean value of desired slice thickness in a CT evaluation was 2.9 ± 1.5 and 2.7 ± 1.3 for each group, respectively ($p = 0.434$).

There were some sharp distinctions between two groups of urologists with respect to the desired basic radiological evaluation both before kidney and ureteral stone surgery. The main difference between groups was on the use of contrast enhancement status. For both kidney and ureteral stones, foreign urologists preferred contrast-enhanced CT more whereas their Turkish colleagues preferred to have non-contrast CT (Table 4).

The stone size evaluation was the most performed measurement performed by the participants. Although the group of surgeons used size measurement tools, there were differences between the two groups. Turkish urologists used size measurement before PCNL (85.7%) as supposed to foreign urologists who used it mostly before URS (91.4%). foreign surgeons also seem to use diameter measurement more often at a statistically significant level before PCNL and URS compared to Turkish urologists ($p = 0.005$ and $p < 0.001$, respectively). Axial and coronal sections were the two primarily used sections for the measurement of stone size in both groups.

Measurement of Hounsfield units of the stone was common to both groups for ESWL, PCNL, or URS procedures. Although Turkish urologists seem to use HU measurement more often, this difference was not at a statically significant level ($p = 0.073$). Interestingly even though overall HU

Table 3 Comparison of preferences of CT study between Turkish and European urologists

	Turkish participant ($n=141$) *N* (%)	European participant ($n=81$) *N* (%)	*p* value*
Would you like to evaluate CT images yourself?			
No	2 (1.4)	7 (8.6)	0.009
Yes	139 (98.6)	74 (91.4)	
Desired planes on a CT study			
Monoplanar	14 (10.3)	9 (11.1)	0.850
Tri-planar	122 (89.7)	72 (89.9)	
Prefer to have radiology report before surgery			
No	79 (57.2)	18 (22.5)	< 0.001
Yes	59 (42.8)	62 (77.5)	

*x^2 test, *CT* computerized tomography

Table 4 Comparison of preferred basic radiological workup before the surgery between groups

	Turkish participant ($n=141$) *N* (%)	European participant ($n=81$) *N* (%)	*p* value*
Basic radiological workup before ureteral stone surgery			
USG	36 (25.5)	31 (38.3)	0.047
Non-contrast CT	114 (80.9)	57 (70.4)	0.074
KUB	46 (32.6)	17 (21.0)	0.064
IVP	22 (15.6)	8 (9.9)	0.230
Contrast-enhanced CT	10 (7.1)	23 (28.4)	< 0.001
Basic radiological workup before kidney stone surgery			
USG	28 (19.9)	23 (28.4)	0.145
Non-contrast CT	121 (85.8)	51 (63.0)	< 0.001
KUB	28 (19.9)	13 (16.0)	0.481
IVP	32 (22.7)	4 (4.9)	0.001
Contrast-enhanced CT	19 (13.5)	34 (42.0)	< 0.001

*x^2 Test. *USG* ultrasound, *CT* computerized tomography, *IVP* Intravenous pyelography, *KUB* kidney–ureter–bladder radiography

measurement is more frequently used by Turkish surgeons, foreign urologists seem to use HU more frequently before PCNL and URS procedures ($p<0.001$ and $p=0.013$, respectively). The most frequently used plane for HU measurement was the axial plane for both groups. General practice on HU measurement was similar between the two groups. Although coronal and sagittal planes on a CT is computer generated, nearly 50% of surgeons in both groups stated that they use these planes also for HU measurement (Table 5).

Angles for planning intervention were used by Turkish urologists more often ($p=0.002$) and it was also used more frequently before ESWL (extracorporeal shock wave lithotripsy) by Turkish surgeons ($p<0001$). While all surgeons measure and rely on stone-skin distance measurement, Turkish surgeons preferred it more before PCNL more frequently compared to their foreign colleagues ($p=0.004$). (Table 5).

In challenging CT dilemmas on initial imaging scans, there was a difference between groups regarding their practice and preference for subsequent imaging with Turkish urologists generally asking an IVP (64.5%) whereas foreign urologists mainly relied on the radiology report to distinguish a ureteric stone from other confounding opacities (41.3%). Contrast-enhanced CT was the imaging modality of choice in both groups in case of having a diagnosed simple kidney cyst for further evaluation, although foreign surgeons seem to perform it more frequently ($p<0.001$) (Table 5).

Table 5 Comparison of the answers of Turkish and European urologist

	Turkish participant (n = 141) *N* (%)	European participant (n = 81) *N* (%)	*p* value
Before planning which of the following procedures, do you use Hounsfield unit calculation of a urinary tract stone			
SWL	104 (73.8%)	58 (71.6%)	0.728
PCNL	20 (14.2%)	28 (34.6%)	< 0.001
URS	22 (15.6%)	24 (29.6%)	0.013
None	24 (17.0%)	22 (27.2%)	0.073
Before planning which of the following procedures, do you measure the diameter(s) of a urinary tract stone?			
SWL	120 (85.1%)	72 (88.9%)	0.427
PCNL	99 (70.2%)	74 (91.4%)	0.004
URS	99 (70.2%)	74 (91.4%)	< 0.001
None	2 (1.4%)	4 (4.9%)	0.120
Before planning which of the following procedures, do you use angle measurements?			
SWL	77 (54.6%)	23 (28.4%)	< 0.001
PCNL	71 (50.4%)	40 (49.4%)	0.889
URS	29 (20.6%)	19 (23.5%)	0.615
None	22 (15.6%)	27 (33.3%)	0.002
Before planning which of the following procedures, do you measure skin-to-stone distance?			
SWL	77 (54.6%)	46 (56.8%)	0.753
PCNL	105 (74.5%)	45 (55.6%)	0.004
URS	1 (0.7%)	1 (1.2%)	0.690
None	17 (12.1%)	12 (14.8%)	0.557
Which of the following cross-section(s) do you prefer for calculating Hounsfield unit(s) of a urinary tract stone?			
Transverse sections	111 (78.7%)	67 (82.7%)	0.473
Coronal sections	72 (51.1%)	39 (48.1%)	0.676
Sagittal sections	57 (40.4%)	35 (43.2%)	0.695
All	51 (36.2%)	30 (37.0%)	0.897
Which of the following cross-section(s) do you prefer for measuring the diameter(s) of a urinary tract stone?			
Transverse sections	126 (89.4%)	76 (93.8%)	0.263
Coronal sections	114 (80.9%)	62 (76.5%)	0.446
Sagittal sections	84 (59.6%)	49 (60.5%)	0.893
All	80 (56.7%)	42 (51.9%)	0.481
Which of the following actions do you prefer when you cannot decide if an opacity is a ureteral stone or a phlebolith?			
Order IVP	91 (64.5%)	25 (31.3%)	< 0.001
Perform URS	2 (1.4%)	4 (5.0%)	
Radiology consultation / CT report	37 (26.2%)	33 (41.3%)	
Consult another urologist	1 (0.7%)	4 (5.0%)	
Use special measurement tools of the digital imaging modalities	1 (0.7%)	7 (8.8%)	
Use special measurement tools of the digital imaging modalities	9 (6.4%)	7 (8.8%)	

Table 5 (continued)

	Turkish participant (n = 141) *N* (%)	European participant (n = 81) *N* (%)	*p* value
Which of the following modalities would you like to have as an additional imaging modality if you encounter a simple renal cyst while evaluating the CT scan for urinary tract stones?			
Contrast-enhanced CT	48 (34.0%)	48 (59.3%)	< 0.001
MRI	16 (11.3%)	13 (16.0%)	0.317
Urinary US	47 (33.3%)	20 (24.7%)	0.224
None	0 (0)	0 (0)	–

Discussion

Urolithiasis is a common diagnosis in the emergency department and non-contrast CT is the first imaging modality of choice in case of a suspected urinary stone for flank pain in the emergency setting [9]. A recent study has shown that among specialties that order abdominal imaging, urology ranks second and the specialty that orders abdominopelvic CT, it comes third [10]. As urologists rely more on CT, basic knowledge of CT evaluation becomes more crucial for urologists. Apart from initial diagnosis, CT is also a powerful tool for treatment planning, follow-up, characterization of stone fragility, and composition [11].

Our results showed that there are significant differences between Turkish and European urologists in terms of preoperative radiological evaluations. Similar to our results, Otite et al. demonstrated that the radiological approach to acute flank pain was quite different between urologists from the United Kingdom and the rest of Europe [12]. They also demonstrated that this difference was mainly the result of the clinicians' familiarity with the radiological technique. The familiarity might also be the main reason for the difference between the Turkish and foreign urologists' choices in our study.

Stone size is one of the key components in the decision-making process of urolithiasis treatment. Especially for renal and proximal ureter stones, treatment of choice is mainly determined by stone size [6, 13, 14]. Our results also confirmed that nearly all (97.3%) urologists use stone size measurement at some point in their daily practice. Although the total size evaluation rate was very high, the stone size assessment ratios before ESWL, PCNL, and URS procedures were 85.1%, 74.5%, and 69.5%, respectively. The lower ratios for individual procedures were mainly because of the lack of using stone measurement in Turkish urologists compared to foreigns. In a survey study on the stone size measurement in urolithiasis, it has been reported that nearly 50% of urologists try to guess stone size instead of measuring the actual size in CT images [15]. Contrary to this report, our results indicated that regardless of the country, most urologists measure the size of the stone using the CT evaluation tools. Since that report is fairly old, it is clear that with the advancements in imaging and viewing technologies, urologists are now more accustomed to measuring the size of the stone.

The relationship between mean stone density and ESWL success rate is well defined by many studies [4, 16]. Even though this is a well-established knowledge, our study showed that nearly 27% of urologists all around the world choose to neglect this information. Also, the surgeon's country of residence does not seem to have any effect on this matter since there were no statistically significant differences between Turkish and foreign urologists in our study. Along with mean stone density, stone to skin distance is also a well-known predictor for ESWL success rate [4, 16] and our study also demonstrated that nearly half (44.6%) of urologist all around the world does not measure this before they decide to perform ESWL for their patients. Additionally, although being one of the strongest predictors of stone clearance after the ESWL in lower pole stones [17], infundibulopelvic angle measurement was used by only 54.6% of Turkish urologists and even less (28.4%) among European urologists.

Stone density is not only an important predictor for ESWL success but also one of the five components of the S.T.O.N.E. Nephrolithometry score can be used as a predictor for PCNL treatment success and perioperative complication rate [18]. Our study showed that only 21.6% of the urologists worldwide use HU measurement before deciding for PCNL. Although foreign surgeons use HU significantly more than their Turkish colleagues before PCNL, even 65.4% do not use this tool before surgery. The other two determinants of the S.T.O.N.E. nephrolithometry score which are stone size and tract length also seemed to be ignored by some urologists according to our study. Before PCNL, nearly one out of five urologists does not measure the size of a stone (19.8%) and around one-third of urologists (34.4%) does not measure stone to skin distance. Since these different measurements can guide the urologists to better understand the stone burden, success rate, and possible postoperative complications, they can be recommended to be used in a way to ameliorate the outcomes, but unfortunately, many urologists, especially those from Turkey, do not use these useful measurement tools very often.

Recently stone density measurement has also been shown to be an effective tool to differentiate distally located ureteral stones from extra-urinary opacities, although there are reports suggesting otherwise [7, 8]. In addition to this, for proximal ureteral stones, HU measurement may aid to choose between URS and ESWL options in certain cases. Despite these potential benefits, only 20.6% of the participants in our study stated that they find it useful to measure HU before deciding for URS. However, in the pre-URS

evaluation, it was determined that even the stone size measurement, which was found to be the most used among the tools in our study, was used less frequently, especially by Turkish surgeons.

Our study has some limitations; although we managed to reach a considerable number of participants, foreign urologists were limited in number compared to Turkish respondents. Also, there were more residents in foreign urologists which can be thought to cause some differences between groups, but subgroup analysis of our study demonstrated that there was no statistically significant difference between urology residents and urology specialists on most of the evaluated subjects. So, the effect of having more residents in one group was negligible. In addition, as in all survey studies, the differences in the way participants perceive the questions and the problems that may arise from misunderstanding are also valid for our study. To overcome this, we tried to keep the questions and options as simple as possible. In addition, after the questionnaire was first prepared, it was applied to a small group of about ten people, and details that could cause misunderstandings in the questions and options were corrected.

Conclusion

Urologists managing stones prefer to evaluate the non-contrast CT images themselves irrespective of radiological reporting with similar practice patterns in both Turkey and foreign countries. Self-evaluation of the CT images may be common in Turkey because there is no requirement to wait for a radiological report before moving forward with an elective care plan. This rule also applies in emergency cases. While the use of additional measurement tools while evaluating the CT images may help in both diagnosis and determination of treatment success rates by providing objective data, there is still a considerable number of urologists who do not use these tools. There are still many different practice patterns in the daily use of these tools. This also could be a contributing factor for the different treatment outcomes in different areas of practice.

Knowledge about the use of advanced measurement tools in non-contrast CT evaluation can help to increase success rates and decrease complication rates, therefore should be encouraged in daily urological practice.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00240-023-01471-1.

Acknowledgements None.

Author contributions Authors whose names appear on the submission have contributed sufficiently to the scientific work and, therefore, share collective responsibility and accountability for the results. BS—protocol/project development, data collection and management, data analysis and manuscript writing. TES—protocol/project development, data collection, and manuscript writing. LD—data collection and manuscript writing. VG—data collection and manuscript writing and editing. YT—protocol/project development, data collection and management, data analysis and manuscript writing and editing.

Funding No funding was received to assist with the preparation of this manuscript.

Data availability Data available within the article or its supplementary materials.

Declarations

Conflict of ınterest The authors declare no confict of interest that relates to the content of this work.

Ethical approval No formal ethical approval was necessary to conduct the study.

References

1. Curhan GC (2007) Epidemiology of stone disease. Urol Clin North Am 34(3):287–293. https://doi.org/10.1016/j.ucl.2007.04.003
2. Stamatelou KK, Francis ME, Jones CA, Nyberg LM, Curhan GC (2003) Time trends in reported prevalence of kidney stones in the United States: 1976–1994. Kidney Int 63(5):1817–1823. https://doi.org/10.1046/j.1523-1755.2003.00917.x
3. Romero V, Akpinar H, Assimos DG (2010) Kidney stones: a global picture of prevalence, incidence, and associated risk factors. Rev Urol 12(2–3):e86-96
4. Pearle MS, Calhoun EA, Curhan GC, Diseases U (2005) Urologic diseases in America project: urolithiasis. J Urol 173(3):848–857. https://doi.org/10.1097/01.ju.0000152082.14384.d7
5. Memarsadeghi M, Heinz-Peer G, Helbich TH, Schaefer-Prokop C, Kramer G, Scharitzer M, Prokop M (2005) Unenhanced multi-detector row CT in patients suspected of having urinary stone disease: effect of section width on diagnosis. Radiology 235(2):530–536. https://doi.org/10.1148/radiol.2352040448
6. Turk C, Petrik A, Sarica K, Seitz C, Skolarikos A, Straub M, Knoll T (2016) EAU guidelines on interventional treatment for urolithiasis. Eur Urol 69(3):475–482. https://doi.org/10.1016/j.eururo.2015.07.041
7. Tanidir Y, Sahan A, Asutay MK, Sener TE, Talibzade F, Garayev A, Tinay I, Sekerci CA, Simsek F (2017) Differentiation of ureteral stones and phleboliths using Hounsfield units on computerized tomography: a new method without observer bias. Urolithiasis 45(3):323–328. https://doi.org/10.1007/s00240-016-0918-1
8. Jendeberg J, Thunberg P, Lidén M (2021) Differentiation of distal ureteral stones and pelvic phleboliths using a convolutional neural network. Urolithiasis 49(1):41–49. https://doi.org/10.1007/s00240-020-01180-z
9. Botsikas D, Hansen C, Stefanelli S, Becker CD, Montet X (2014) Urinary stone detection and characterisation with dual-energy CT urography after furosemide intravenous injection: preliminary results. Eur Radiol 24(3):709–714. https://doi.org/10.1007/s00330-013-3033-5
10. Rosenkrantz AB, Ayoola A, Duszak R Jr (2017) Abdominal imaging ordering patterns by referring provider specialty. Abdom Radiol (NY) 42(9):2363–2368. https://doi.org/10.1007/s00261-017-1121-8

11. Andrabi Y, Patino M, Das CJ, Eisner B, Sahani DV, Kambadakone A (2015) Advances in CT imaging for urolithiasis. Indian J Urol 31(3):185–193. https://doi.org/10.4103/0970-1591.156924
12. Otite U, Parkin J, Waymont B, Inglis JA, Philp NH (2005) Investigation of acute flank pain: how do practices of UK and Irish urologists compare with those of transatlantic and continental European colleagues? J Endourol 19(8):959–963. https://doi.org/10.1089/end.2005.19.959
13. Eisner BH, McQuaid JW, Hyams E, Matlaga BR (2011) Nephrolithiasis: what surgeons need to know. AJR Am J Roentgenol 196(6):1274–1278. https://doi.org/10.2214/AJR.11.6434
14. Preminger GM, Assimos DG, Lingeman JE, Nakada SY, Pearle MS, Wolf JS (2005) AUA guideline on management of staghorn calculi: diagnosis and treatment recommendations. J Urol 173(6):1991–2000. https://doi.org/10.1097/01.ju.0000161171.67806.2a
15. Kampa RJ, Ghani KR, Wahed S, Patel U, Anson KM (2005) Size matters: a survey of how urinary-tract stones are measured in the UK. J Endourol 19(7):856–860. https://doi.org/10.1089/end.2005.19.856
16. Weld KJ, Montiglio C, Morris MS, Bush AC, Cespedes RD (2007) Shock wave lithotripsy success for renal stones based on patient and stone computed tomography characteristics. Urology 70(6):1043–1046. https://doi.org/10.1016/j.urology.2007.07.074
17. Poulakis V, Dahm P, Witzsch U, de Vries R, Remplik J, Becht E (2003) Prediction of lower pole stone clearance after shock wave lithotripsy using an artificial neural network. J Urol 169(4):1250–1256. https://doi.org/10.1097/01.ju.0000055624.65386.b9
18. Okhunov Z, Friedlander JI, George AK, Duty BD, Moreira DM, Srinivasan AK, Hillelsohn J, Smith AD, Okeke Z (2013) S.T.O.N.E. nephrolithometry: novel surgical classification system for kidney calculi. Urology 81(6):1154–1159. https://doi.org/10.1016/j.urology.2012.10.083