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Variation in Radiologic and Urologic Computed Tomography Interpretation of Urinary Tract Stone Burden: Results from ReSKU

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ABSTRACT

Objective: To compare the measured stone burden recorded between urologists and radiologists, and examine how these differences could potentially impact stone management. As current urologic stone surgery guideline recommendations are based on stone size, accurate stone measurements are crucial to direct appropriate treatment. This study investigated the discrepant interpretation that often exists between urologic surgeons and radiologists' estimation of patient urinary stone burden.

Materials and Methods: From November 2015 through August 2016, new patients prospectively enrolled into the Registry for Stones of the Kidney and Ureter (ReSKU™) were included if they had computed tomography images available and an accompanying official radiologic report at the time of their urologist provider visit. Stone number and aggregate stone size were compared between the urologic interpretation and the corresponding radiologic reports.

Results: Of 219 patients who met inclusion criteria, concordance between urologic and radiologic assessment of aggregate stone size was higher for single stone sizing (63%) compared to multiple stones (32%). Statistical significance was found in comparing the mean difference in aggregate stone size for single and multiple stones ($p<0.01$). Over 33% of stone-containing renal units had a radiologic report with an unclear size estimation or size discrepancy that could lead to non-guideline-driven surgical management.

Conclusions: Significant variation exists between urologic and radiologic computed tomography interpretations of stone burden. Urologists should personally review patient imaging when considering stone surgical management. A standardized method for measuring and reporting stone parameters is needed among urologists and radiologists.

INTRODUCTION

One in 11 people in the United States are affected by urolithiasis and disease prevalence is on the rise.[1] American Urological Association (AUA) Guidelines provide specific size thresholds to help guide appropriate surgical options for kidney stones.[2,3] As a result, surgical decision-making for nephrolithiasis relies on an accurate assessment of stone burden. While urologists are trained and board examined to independently review radiologic studies for patient care,[4] how this interpretation compares with official radiologic reports remains unknown.

In addition, while health care legislation is still evolving, quality is a major component of the Affordable Care Act (ACA) and the Medicare Access & CHIP Reauthorization Act of 2015 (MACRA).[5,6] For urinary stone disease, an accurate estimation of a patient's stone burden represents an essential starting point for any discussion on the quality of care provided.[7] Currently there is no standardized reporting methodology used by practicing radiologists and urologists to ensure that imaging reports and preoperative documentation accurately reflect total stone number, volume, location, and potential case complexity.

Ideally, a consensus could be reached between the urologic and radiologic communities as to how stone burden can be quantified in an accurate and reproducible manner. To these ends, the aim of this study was to utilize a high quality, prospective kidney stone registry to investigate the concordance in stone burden estimation by urologists compared to radiologists.

MATERIALS AND METHODS

Study Participants

From November 2015 through August 2016, consecutive new patients presenting to the University of California San Francisco (UCSF) Urology Clinic for urinary stone disease management were prospectively enrolled into the Registry for Stones of the Kidney and Ureter (ReSKU™). The methodology and organization of this kidney stone registry has been previously described.[8] All subjects enrolled into ReSKU™ provide written consent and the study has been approved by the Committee on Human Research (Protocol 14-14533). ReSKU™ clinical information is managed using REDCap electronic data capture tools hosted at this institution.[9]

Inclusion Criteria

Subjects were included only if there was an available computed tomography (CT) scan of the abdomen/pelvis as part of their initial evaluation that had both a urologist's interpretation as well as an official radiologic report. If a subject had multiple CT scans completed, only the scan obtained just prior to the initial urologic evaluation was included for review.

CT Radiologic Report Characteristics and Interpretation

The official radiologic reports for these ReSKU™ subjects were obtained, scanned into REDCap for quality control, and individually reviewed by an attending urologist and one urologic trainee (DT and DI), blinded to the urologist interpretation. The following characteristics from each CT radiologic report were recorded: study date, location, indication, radiation dose index volume (CTDIvol), radiation dose length product (DLP), and use of intravenous contrast. Patient effective dose was based on multiplying the DLP by an accepted standard conversion factor (*k* = 0.015 mSv/mGy-cm for a CT of the abdomen/pelvis).[10] If present in the report, the following stone characteristics were recorded: stone number, laterality and location within each kidney and ureter, aggregate size, dimensions, and reference to stone Hounsfield units (HU). Additionally, the use of descriptive phrases such as 'punctate stones,' 'multiple calcifications,' and 'multiple stones the largest of which measures…' was recorded.

<u>Urologic CT Interpretation</u>

Imaging data including date, total stone number, location, burden, and degree of hydronephrosis are prospectively recorded into ReSKU™ based on the interpretation of the primary urologist personally viewing the images. As a UCSF institutional practice, this is performed at the time of the patient encounter by the urology attending or fellow to be performing the surgery, prior to viewing any radiologic report. For this study, 2 urology attending physicians and 4 fellows (all of whom were endourology specialty-trained) performed all CT interpretations. The standardized method is to zoom in using a bone window on the stone, with electronic calipers utilized in both axial and coronal views to determine the maximum linear dimension of each stone. For multiple stones, individual stone measurements are summed for an aggregate stone size.

<u>Comparing Urologic and Radiologic Interpretation of Stone Characteristics</u>

For each subject, right and left upper urinary tract units were evaluated separately. A distinction was made between whether a single stone versus multiple stones were reported. Only renal units in which a stone was described by either the urologist or radiologist were included for review. Stone number was defined as the total number of stones identified in a renal unit. Aggregate stone size was defined as the sum of the largest diameters for all stones identified in each renal unit. Concordance in stone number was defined as agreement on the number of stones reported between the urologic read and radiologic report. Aggregate stone size was considered concordant when the urologic aggregate stone size was within 2mm of the radiologic report.

For both stone number and aggregate stone size, a radiologic report was designated as “unclear” when no data were provided on either the number of stones or aggregate stone size. In instances where no aggregate stone size was noted but the statement ‘the largest of which measures…’ was used, the largest stone measurement provided was considered to represent the radiologic aggregate stone size.

Size thresholds mentioned in American Urological Association (AUA) Guidelines for stone management ($\leq$10mm, >10mm to <20mm, and $\geq$20mm) were referenced to compare how differences in urologic and radiologic reported aggregate stone size could impact surgical management.[2,3]

Blinded Radiologist Interpretation

To further evaluate the potential discrepancy between urologic and radiologic interpretation, an additional blinded radiologist (ZJW) was asked to review a randomized sample of the cohort and provide total stone number and aggregate stone size based on axial and coronal views. Concordance was similarly defined, with exact stone number and aggregate stone size within 2mm representing concordance.

Statistical Analyses

Statistical analyses were performed using STATA software (version 14.2, StataCorp, College Station, Texas). Because aggregate stone size was not normally distributed, data were summarized using medians and interquartile ranges. The median difference between radiologic and urologic aggregate stone size was compared using a Wilcoxon rank-sum (Mann-Whitney) test, with $\alpha = 0.01$ and the null hypothesis of the difference being equal to 0. Two-way scatter plots and bar plots were used to illustrate graphically the variability and magnitude of disparity in the aggregate stone size assessments reported by urologists and radiologists. Kappa interrater agreement was performed to determine how the independent radiologic read compared to the urologic read for stone number and aggregate stone size.

RESULTS

Of 371 subjects enrolled in ReSKU™ between October 2015 and September 2016, 219 met inclusion criteria, with 303 renal units available for analyses after exclusions. Table 1 provides information on patient demographics and characteristics of the CT reports. In nearly 65% of patients the indication for imaging was stone-related, consistent with 65% of the cohort having a non-contrast CT scan performed. Over half of the radiologic reads were from outside institutions representing an aggregate of 71 unique radiology centers. The majority of radiologic reports (68%) denoted stone size in only one dimension, with two and three dimensions reported in 18% and 7% respectively. Hounsfield units were noted in less than 3% of reports.

The radiation dose noted within these radiologic reports was highly variable. For the non-contrast CT scans reviewed, DLP and CTDIvol were reported in > 95% of the reports. For these single-phase CT scans, only 8% had a calculated effective dose < 4mSv and would be considered a low dose CT study.[11]

The number of stones and the aggregate stone size was unclear in the radiologic report in 102/303 (34%) and 47/303 (16%) respectively. For aggregate stone size, the concordance between urologic and radiologic reads was 63% if a single stone was present, compared to only 32% if multiple stones were present. Over 40% of renal units either had an unclear radiologic report or an extreme (>10mm) aggregate stone size difference (supplemental figure).

Of the 256 renal units available to be compared between urologic and radiologic interpretation, the median differences in aggregate stone size for single and multiple stones are shown in Table 2, along with their interquartile ranges. The null hypothesis of no difference between the two measurements was rejected (p=0.01); we observed a median difference of 4 mm in aggregate stone size when multiple stones were present. The variability in the aggregate size measurements made on the same patients by a radiologist and a urologist are illustrated in Figures 1a (single stone) and 1b (multiple stones). While there was relatively good consistency between urologic and radiologic estimates for a single stone, a much higher variability was observed when a patient had multiple stones.

Reports of radiologic and urologic stone burden often fell into different size categories, as referenced by the AUA Guidelines size thresholds (Table 3). Over 33% of stone-containing renal units had a corresponding radiologic report with nondescript language or a stone size discrepancy that could lead to non-guideline-driven surgical management if a urologist were to rely solely on the radiologic report. Discordance between urologic interpretations and radiologic reports occurred for both small and large stones. In an equal percentage of cases (7%), the urology read was $\leq$10mm or $\geq$20mm and the corresponding radiology report was unclear. Of the 21 cases in which the urology read was <10mm and the radiology report was unclear, 12 of the renal units (>50%) had a urologic read describing a stone burden that was 4mm or more.

A blinded independent radiologic review of images demonstrated a high level of agreement with the urologic interpretation for both stone number and aggregate stone size. Kappa inter-rater agreement demonstrated 79% and 74% agreement for stone number and aggregate size respectively, both of which were statistically significant ($p < 0.01$).

DISCUSSION

To our knowledge, this study is the first to examine the difference between urologic and radiologic interpretation of stone number and size on clinical CT scans. The concordance in aggregate stone size between urologic and radiologic reads was only 32% when multiple stones were present. Statistically significant discrepancies in the aggregate stone size reported by urologists and radiologists occurred in the setting of solitary and multiple stones. While the small size discrepancy for single stones is unlikely to have any clinically significant implications, for patients with multiple stones the degree of discordance could lead to suboptimal surgical decisions. In this study, over 33% of renal units would have been classified into a different AUA guideline stone size category based solely on utilization of the size provided by the radiology report. This significant discrepancy was reinforced by a blinded radiologist reviewing a randomized sample of cases and demonstrating statistically significant Kappa interrater agreement with the urologic interpretation.

Urologists in practice are often faced with relying on the radiologic report when patients arrive to office visits without accessible images for review. Despite best practice radiologic guidelines for how to measure and report stone burden[11], the results of this study demonstrate that the amount of detail provided within the radiologic report can vary. With the recent passage of MACRA, urologists may soon face a shift from the established fee-for-service model of reimbursement to a new pay for performance model.[6] For the treatment of nephrolithiasis, operative success might one day be defined by the efficiency with which total stone burden is reduced.[7] As such, it is crucial that a uniform and accurate assessment of total stone burden be established, otherwise discrepancies may arise in the reported quality and complexity of care provided.

In this study, CT was used for stone burden estimation given that this imaging modality is accepted as the gold standard for identifying urinary tract calculi.[12] Very few low dose scans were included in this study, therefore the quality of the images was unlikely to have impacted the accuracy of the radiologic reports. Previous studies have demonstrated that urologists are capable of accurately interpreting and assessing stone burden on CT scans.[13] Moreover, high patient satisfaction has been reported when the urologist personally shows these images to the patient.[14] While it is unknown how many providers currently rely solely on radiologic reports to assess stone burden, the results of this study reinforce the importance of practicing urologists viewing the images for themselves.

Previous comparisons between urologic and radiologic reads have relied on surveys of radiologic impressions/interpretations instead of what descriptions are actually placed in the official medical record. Kampa et al. used a questionnaire-based survey and found a significant difference in accuracy among radiologists for the estimation of an 11mm stone. They also referenced the practice of ‘guestimation’ that involves relying on personal assessment versus using electronic measuring aids. Interestingly, 31% of surveyed urologists stated that they based the size estimate of stones on the radiology report.[15]

Our findings prompt further discussion on potential reasons for discrepancies between urologic and radiologic imaging interpretation. Maximum stone diameter has traditionally served as the basis for AUA treatment guidelines.[2,3] The American College of Radiology has published ACR Appropriateness Criteria® for when urinary stones are suspected, stating that "because urologic management is based on maximal stone diameter, stone measurements should be provided in the coronal and axial plane."[11] While stones have classically been reported in the axial view,[16] for all of the urologic reads in ReSKU™ both axial and coronal views are reviewed prior to determining each stone's maximum diameter. Previous studies have shown that the coronal view can detect a greater number of stones, more accurately estimate stone size, and require significantly less time for interpretation.[17,18] Kadihasanoglu et al. recently found that the coronal diameter was reported by the reading radiologist in only 17% of 150 patients.[19] This study also demonstrated that the largest stone diameter was found in the coronal rather than axial plane in 75% of cases, with only the coronal diameter significantly associated with stone passage on multivariable analysis.[19] Exactly how many radiologic reports in the current study relied on the axial view alone remains unknown; however, with only 25% of patients having two or more stone dimensions reported, the underreporting of coronal stone size is a possible explanation for the size discrepancy found in this study.

Other possible explanations for the size interpretation discrepancy could be that many radiologists either are simply not aware of the level of detail needed by urologists for stone reporting, or perhaps lack the time/incentive to characterize the entire amount of stone present. In this study, the radiologist who performed the blinded interpretation was asked to use both axial and coronal views to describe stone number and aggregate stone size. As a result of this independent radiologist being given the same instructions that we provide to our urologic trainees in terms of CT interpretation, a high level of agreement was seen between these re-reads and urologic interpretations. Similar to how a standardized Bosniak classification exists to help guide surgical intervention for renal cysts,[20] better communication between the urologic and radiologic communities would help so that the information needed to direct a urologic surgical decision is routinely noted in the radiological report.

The results of this study emphasize the need for an improved method for accurately reporting stone burden. While stone volume on CT can be estimated by measuring stones in three dimensions, this is rarely done in practice and in the current analysis, only 7% of radiologic reports contained this information. One could infer that this is likely secondary to the time involved in measuring a stone in three dimensions. Recent work has shown that rather than largest stone diameter, more sophisticated tools can automatically provide total stone volume.[21] With future development, such tools may also include stone number, density, and other clinical characteristics. A standardized application of this technology would help to eliminate some of the time, subjectivity, and variability related to the interpretation of stone burden.

Limitations of this study include the relatively small number of urologists (6) that interpreted the imaging as part of ReSKU™. The use of the size mentioned in the "multiple stones, largest of which measures" phrase of the radiologic report could also be considered a limitation since this size represented the aggregate stone size for this analysis. However, as this was the most descriptive information provided in these radiologic reports, this approach reflects what a urologist in practice would have available to make surgical decisions. Finally, the inclusion of contrast CT scans might represent a potential limitation. Patients referred for urolithiasis often have already received a contrast CT scan that was ordered for an alternative differential diagnosis. We believe most urologists would use these scans to assess stone burden rather than order another non-contrast CT scan, therefore their inclusion in this study was intentional and reflects the reality of urologic practice. Moreover, previous studies have shown that contrast does not interfere with the detection of renal stones > 3mm.[22]

Despite these limitations, there are several strengths to this study. The prospective nature of ReSKU™ allowed for the capture of all urologic interpretations at the clinical encounter, resulting in a high quality of data input without a retrospective influence. This has the advantage of eliminating recall bias and improving the quality of the data reported. Next, given the large region from which patients are referred to the high-volume UCSF Urology stone clinic, there were official radiologic reports from 71 unique centers. As not every CT is read by the same radiologist at each institution, the number of different radiologic interpretations in this study was likely even higher - suggesting that this cohort offers a strong sampling of different radiologists in the reporting of urinary stones. Finally, a blinded radiologic review was included and helped to provide an independent interpretation with interrater agreement.

CONCLUSIONS

There is significant discordance between urologists and radiologists in the reporting of stone burden in patients with urolithiasis. Relying solely on the radiologic report could potentially lead to inappropriate surgical management based on guideline size thresholds; therefore, practicing urologists should review patient images themselves before making surgical decisions. Continuing collaboration is needed between radiologic and urologic specialties to define an accurate, standardized, and reproducible method for viewing, measuring, and reporting detailed parameters related to stone size and total stone burden.

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Figure Legends

Figure 1 Scatter Plots of Urologic and Radiologic Aggregate Stone Size

Supplemental Figure Categories of Urologic and Radiologic Stone Size Variation

Aggregate stone size differences by magnitude of disparity.

Table 1 Patient Demographics and CT Report Characteristics (n=219)

Mean Age (years, mean ± SD)	55 ± 15
BMI (kg/m^2 ± SD)	28.6 ± 8.3
Gender (n, % total)	
Male	121 (55%)
Female	98 (45%)
Radiology Facility (n, % total)	
UCSF	105 (48%)
Community Imaging Center	109 (50%)
Non-UCSF Academic Imaging Center	5 (2%)
Number of Unique Radiology Institutions	71
Type of CT performed (n, % total)	
Non-contrast	143 (65%)
Contrast	35 (16%)
Non-contrast + Contrast (CT Urogram)	41 (19%)
Effective Dose (mSv) of non-contrast CT scans	
Low dose (<4 mSv)	12
Non-low dose (>4 mSv)	125
Unavailable	6
Indication for CT (n, % total)	
Stone (flank pain, nephrolithiasis, renal colic, stone, urolithiasis)	142 (65%)
Hematuria (gross or microscopic)	19 (9%)
Abdominal Pain	37 (17%)
Recurrent UTI	16 (7%)
Other	5 (2%)
Radiology read descriptors (n, % total)	
'punctate stones'	26 (12%)
'multiple calcifications'	9 (4%)
'multiple stones, largest of which measures'	64 (29%)
Stone Dimensions reported (n, % total)	
None	15* (7%)
Diameter	149 (68%)
Area	39 (18%)
Volume	16** (7%)
Hounsfield units (HU) reported (n, % total)	6 (2.7%)

*Of 15 patients where no stone dimension was provided, 8/15 (53%) were read as staghorn calculus

**Of 16 patients where 3 dimensions were reported, 6/16 (37%) were labeled as staghorn calculi.

Table 2 Median Difference between Urologic and Radiologic Aggregate Stone Size

Stone Group	Number of renal units	Median	(IQR)	p
Solitary	121	1	(0, 3)	<0.01*
Multiple	135	4	(1, 13)	
Total	256	2	(2, 6)	

*Two-sample Wilcoxon rank-sum test demonstrated p <0.01

Table 3 Discrepancies in urologic interpretation vs radiologic report of aggregate stone size based on AUA Guidelines size thresholds

Stone-containing renal units (n=303)	Urologic Interpretation ≤ 10mm	Urologic Interpretation > 10mm, < 20mm	Urologic Interpretation ≥ 20mm
Radiologic Report ≤ 10mm	137 (45%)	24 (8%)	11 (4%)
Radiologic Report > 10mm, < 20mm	5 (2%)	25 (8%)	13 (4%)
Radiologic Report ≥ 20mm	0 (0%)	2 (<1%)	39 (13%)
Radiologic Report unclear	21 (7%)	5 (2%)	21 (7%)

Shaded boxes = size discrepancy or unclear report, total = 102 (34%)
White boxes = size concordance, total = 201 (66%)