The Capabilities and Limitations of Clinical MRI Sequences for Detecting Kidney Stones. A Retrospective Study

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INTRODUCTION: Common, often painful, and frequently recurrent, kidney stones are increasing in incidence and associated with high health care costs. Computed Tomography (CT) has become the modality of choice for kidney stone imaging with 90-100% sensitivity, but with the drawback of radiation exposure. Despite the successes of MRI for anatomical and functional imaging of the kidneys, its role in renal stone imaging has traditionally been limited. Using conventional MRI pulse sequences, stones appear as nonspecific signal voids, easily overlooked or confused with other structures or artifacts. In this work, we conducted a retrospective study to document the performance of currently available clinical MRI techniques for detecting kidney stones, and, in addition, to determine the characteristics of successfully detected stones when compared with undetected stones.

METHODS: A list of patients treated at our institution between 2009 and 2012 who underwent both abdominal/pelvic CT and MRI exams within 30 days were obtained. The CT reports of the patients in the list were reviewed to identify those diagnosed with kidney stones. Patients who passed stones or had them extracted during the period between the CT and MR scanning were excluded. A total of 160 patients were identified with an interval between the CT and MR examinations of 11±9 days. CT examinations were performed using a standard renal stone imaging protocol. MRI imaging included breath-hold T2 weighted imaging using a single-shot approach (HASTE). The cases were reviewed by two radiologists (80 cases each), who were blinded to the patients' diagnoses. The study protocol (Figure 1) consisted of four steps: 1) Review the MRI images and then answer Question 1 (Q1): Were you able to identify any stone(s) on the MRI images? 2) Review the CT images and then answer Question 2 (Q2): Are there stone(s) visible on the CT images? 3) Take a second look at the MRI images. Now that you know where the stones are on the CT images, can you identify them on the MRI images (Q3)? 4) If you answered yes to question #3, would you in retrospect have called these stones (Q4)?

RESULTS: Figure 2 shows representative CT and MRI images of stones both detected and missed on the MRI images. Figure 1 shows the results of each stage of the study protocol, and the stones characteristics based on stone visibility on the CT and MRI images (true/false positive and negative ratios are also provided based on first MRI reading). There was significant ($P<0.001$) difference between the size of the stones successfully identified during the initial MRI reading and those that were not (Q1). For the stones identified by both modalities, there was no significant ($P = 0.451$) difference between the stone size determined by CT (8±5 mm) and MRI (8±4 mm). After reviewing the CT images and then reading the MRI images for a second time (Q3), 12 stones (11%) of those originally unidentified on the MRI images were successfully identified. There was a significant ($P = 0.001$) difference between the size of the stones that were successfully identified on the 2nd MRI reading versus those that were still unidentifiable. Regarding the 32 stones that were originally identified on the 1st MRI reading, the review of the CT images resulted in exclusion of 9 (28%) of them as artifacts. There was a difference, but not a significant one ($P = 0.05$), between the size of the stones that were excluded and those whose existence on the MRI images was confirmed after reviewing the CT images. For the 35 stones that were identified on the MRI images and confirmed by CT, the reviewers reported that they would have called 26 (74%) of them in retrospect (Q4). A comparison of reviewer performance is shown in Table 1.

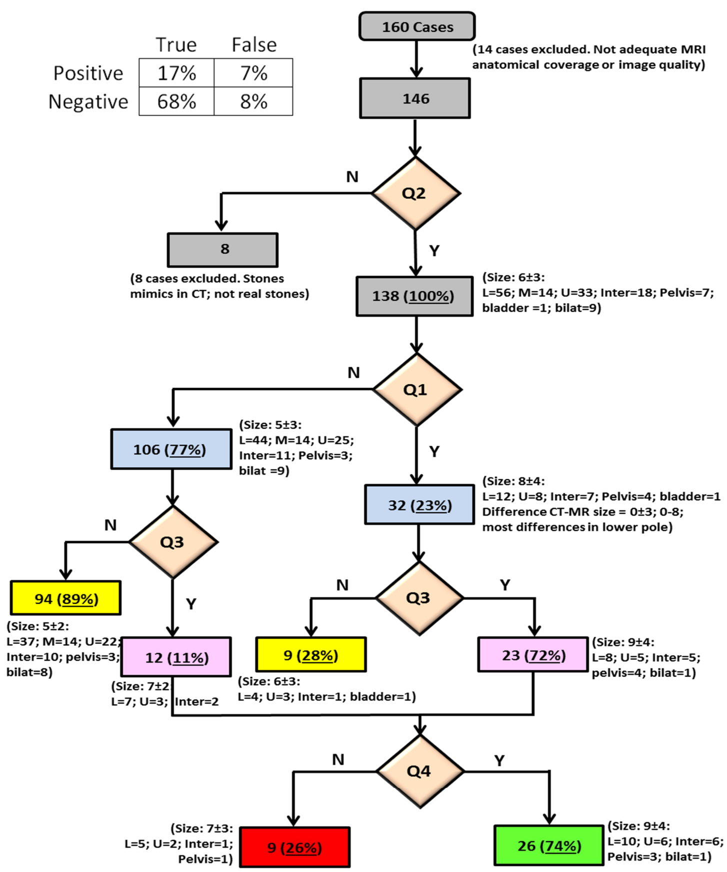

Fig 1. Study design and Results. L, M, U = lower, medium, and upper poles.

DISCUSSION AND CONCLUSION: Conventional clinical MRI scans allow for detecting about one-fifth of the kidney stones. The stone size (8 mm threshold) and background contrast (e.g. from urine) are major factors for determining its visibility in MRI. The stones detected are on average 60% larger than the undetected ones, with significant difference in the stone size between the two groups. Location-wise, significantly more stones are detected in the pelvis and bladder. Knowing the stone location from the CT images does not result in a statistically significant increase in recognition of previously unidentified stones on the MRI images (11% of the missed stones were identified). However, 28% of stones thought to be present on MRI were not confirmed by CT. These results suggest that false positive MRI findings may be more of a problem than false negative results, and this perhaps due to the non-specific nature of signal void foci on T2-weighted images. The reviewers' capability of calling three quarters of the identified stones in retrospect without help from the CT images reflects the different nature of stone-to-tissue contrast in the CT and MRI images. In summary, MRI has the potential for imaging kidney stones, especially medium-to-large ones with sufficient background contrast. Further study, using newly developed techniques, is underway and promises to improve the ability of MRI to detect kidney stones, which may be useful in vulnerable groups for whom CT scanning with its attendant radiation exposure may not be recommended.

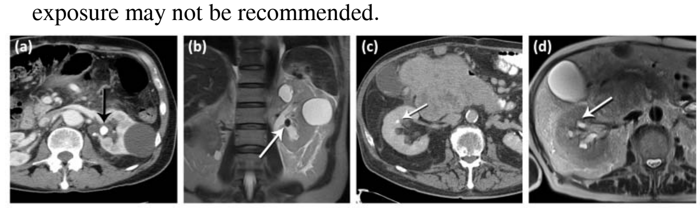

Fig 2. CT (a,c), and the corresponding MRI (b,d) images of two cases. (a,b) Enhanced axial CT demonstrates a large stone in the left renal pelvis (arrow), which was detected as hypointense (arrow) in the coronal HASTE MRI image against the backdrop of hyperintense urine. (c,d) Contrast-enhanced CT performed for tumor staging reveals a stone in a right renal interpolar calyx (arrow), which was not detected in the same calyx on the axial MRI HASTE image.

Table 1. Comparison of the results from both reviewers.

	#	Sex	Age (y.o.)	Size (mm)	Q1-NO (size)	Q1-YES (size)	Q3-NO (size)	Q3-YES (size)	Q4-NO (size)	Q4-YES (size)
Expert 1	64	38 m; 26 f	62±12;32-87	6±3;2-18	73% (5±3;2-12)	27% (8±4;3-18)	73% (5±3;2-12)	27% (9±3;4-18)	18% (8±4;4-12)	82% (9±3;4-18)
Expert 2	74	46 m; 28 f	[illegible]	6±3;1-19	80% (5±2;1-15)	20% (8±4;3-19)	76% (5±2;1-15)	24% (8±4;3-19)	33% (6±2;3-9)	67% (9±4;5-19)