MRI CHARACTERIZATION OF RENAL MASSES USING GADOLINIUM-ENHANCED SUBTRACTION TECHNIQUE: ACCURACY OF A QUANTITATIVE METHODS TO DETECT TUMOR ENHANCEMENT

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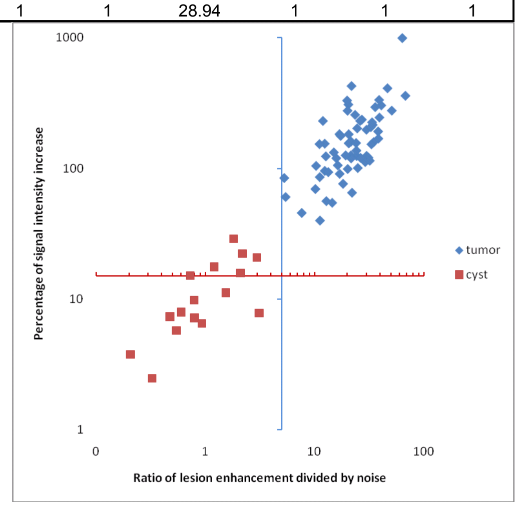
PURPOSE: The most important imaging criterion to differentiate surgical from non-surgical renal masses is the presence of enhancement after intravenous contrast administration, as this indicates vascularity, which is highly predictive of renal neoplasia. Quantitative relative enhancement on the basis of the percentage increase in signal intensity (SI) on contrast enhanced T1-weighted magnetic resonance imaging (CE-MRI) has been shown to distinguish neoplasia from cysts with a threshold of 15% relative enhancement giving a sensitivity of 100% and specificity of greater than 94%.[1] Qualitative evaluation of CE-MRI using magnitude image subtraction (nephrographic phase minus unenhanced) compared to this 15% relative enhancement threshold gave an apparent, but not statistical significant, advantage to image subtraction in sensitivity and specificity for distinguishing renal masses, performing better with lesions with relatively high SI on unenhanced images.[2] The purpose of our study was to evaluate quantitative criteria to diagnose accurately solid enhancing renal tumors with CE-MRI that works with image subtraction and comparing SI measurements between unenhanced and contrast-enhanced images.

MATERIALS AND METHODS: This HIPAA compliant retrospective study was approved by our institutional review board, which waived the informed consent requirement. Analysis was performed on 58 consecutive patients who had 64 renal lesions with enhancement suspicious for carcinoma on CE-MRI with gadolinium-enhanced breath-hold fat-suppressed three-dimensional T1-weighted spoiled gradient echo (3D T1w SPGR) images on a 1.5 Tesla MRI scanner and had histopathologic diagnosis. 25 renal lesions at least 10 mm in size (3 times the size of the largest dimension of the voxel) that were not reported to have suspicious enhancement in these patients also had histopathologic diagnosis. On contrast-enhanced nephrographic phase (NP) images, manually defined regions-of-interests (ROIs) were placed by one investigator in the portion of the enhancing lesion that appeared to have the greatest SI, on the non-enhancing lesions in the location excluding the outer most pixels where there might be volume averaging, and in air along the phase encoding axis outside the patient on the same image as the lesion (noise SI value); the SI value and standard deviation for each ROI were recorded. These ROIs were copied and pasted onto the same section of the unenhanced and magnitude subtraction images. Each lesion SI value was divided by the standard deviation of the noise SI value (SDn) for that sequence to yield a signal-to-noise ratio (SNR) for each lesion on unenhanced, NP and subtraction images. The SNR difference between NP and unenhanced images (ΔSNRnp) and on subtraction images (SNRsub) were calculated. These were compared to a shorthand method commonly used for calculating lesion enhancement (ΔSNRnp_short = [SI lesion NP - SI lesion unenhanced] / SDn NP) and to a percentage enhancement method (%SIΔ = 100 x [SI lesion NP - SI lesion unenhanced] / SI lesion unenhanced) as previously published.[1] As lesion movement occurs between different breatholds, a correction for motion was also made with movement of the kidney borders closest to the lesion measured between the unenhanced and NP images in the superior-inferior, anterior-posterior and right-left directions. If there was movement in any dimension greater than the dimension of the voxel in that direction, then the ROI was moved by the measured amount on the unenhanced images in the dimensions with movement and a new SI value and standard deviation for each moved ROI were recorded. For lesions that moved a second set of calculations (ΔSNRnp, ΔSNRnp_short and %SIΔ) was made; moved calculations could not be made for SNRsub. The data were compiled for each method for all lesions without movement and for those with correction for movement to try to achieve the most accurate result. Using receiver-operating characteristic curve (ROC) analysis, areas under the curve (AUC) for defining solid tumor enhancement for each method and sensitivity, specificity, and accuracy for different thresholds for each method were determined.

RESULTS: At pathologic analysis, all lesions with suspicious enhancement contained solid neoplastic components with 62 of 64 (97%) malignant. All lesions without suspicious enhancement were benign, 24 of 25 lesions simple cysts and one lesion a simple lymphangioma. There were 29 / 89 (33%) lesions with no significant movement (16 / 64 neoplastic lesions and 13 / 25 non-neoplastic lesions) where image subtraction was uncorrupted. The table lists for the different methods the AUC for defining neoplastic enhancement, a threshold to achieve sensitivity of 1 (Threshold 1) with corresponding specificity and accuracy, and a threshold to optimize accuracy (Threshold 2) with the corresponding sensitivity and specificity. There was no statistically significant difference between the methods within each group – all lesions, lesions without movement, lesions with movement correction, and the compiled. Using the previously described 15% relative enhancement threshold for defining neoplastic enhancement with the different groups yielded the following sensitivity, specificity, and accuracy: 1, 0.71, 0.92 for all lesions without correction; 1, 0.77 and 0.90 for lesions without movement; 1, 0.77 and 0.90 for lesions with movement correction; and for the compiled data 1, 0.7 and 0.93. With the compiled data, 6 lesions that would have been classified as neoplastic using the 15% threshold were cysts (Figure).

Variable	Number	AUC	Threshold 1	Sensitivity	Specificity	Accuracy	Threshold 2	Sensitivity	Specificity	Accuracy
Lesions without correction										
ΔSNRnp_short	89	0.979	3	1	0.88	0.97	3	1	0.88	0.97
ΔSNRnp	89	0.969	2	1	0.76	0.93	4	0.98	0.84	0.94
SNRsub	89	0.987	5	1	0.92	0.98	5	1	0.92	0.98
%SIΔ	89	0.989	37	1	0.88	0.97	37	1	0.88	0.97
Lesions without movement										
ΔSNRnp_short	29	1	3	1	1	1	3	1	1	1
ΔSNRnp	29	1	4.51	1	1	1	4.51	1	1	1
SNRsub	29	1	3.49	1	1	1	3.49	1	1	1
%SIΔ	29	1	20.84	1	1	1	20.84	1	1	1
Lesions with movement correction										
ΔSNRnp_short	60	1	3.12	1	1	1	3.12	1	1	1
ΔSNRnp	60	0.997	3.26	1	0.92	0.98	3.26	1	0.92	0.98
%SIΔ	60	1	28.94	1	1	1	28.94	1	1	1
Compiled										
ΔSNRnp_short	89	1	3.12	1	1	1	3.12	1	1	1
ΔSNRnp	89	0.996	3.26	1	0.88	0.97	4.51	0.98	0.96	0.98
%SIΔ	89	1	28.94	1	1	1	28.94	1	1	1



CONCLUSION: When lesion movement does not occur, a simple SNR measurement on subtraction images can separate clearly neoplastic from non-neoplastic enhancement with a threshold value of 3.5 times the SDn completely separating the lesions. A shorthand method commonly used for calculating lesion enhancement and a relative enhancement percentage threshold also completely separated the lesions without movement and with movement correction, though the latter was different from that previously published. Methods using

1 Ho VB, et al. Radiology. 2002;224:695. 2 Hecht EM, et al. Radiology. 2004;232:373.