MRI Analysis of Bone Metastasis: Shape-Related Exclusion Criteria

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Introduction and Thesis: The shape of a lesion is a key parameter that indicates its growth pattern, and in certain situations helps differentiate benign from malignant histology. Decades of effort characterizing malignant and benign tumors have resulted in many sophisticated categorization schemes utilizing assessment of contours, size, location, density, and countless other features. Within the MRI field, the differentiation of malignant versus benign tumors has most commonly been attempted using signal and contrast enhancement characteristics. The ability of MRI and newer CT-scanners to provide exquisite delineation of tumors has also provided investigators with a highly valuable tool for evaluation of a tumor's contour features and internal architecture (Ref 1). However, the overall shape of the lesion is only rarely considered as a specific criterion in any of these assessment systems, and when used they are frequently included only within complex analysis tools (Ref 2). We demonstrate that assessment of the tumor shape via simple measurements on standard MRI exams provide data of potentially high value, for clinical assessment of metastatic disease of the bone. Our approach makes use of the fact that most malignancies will grow in a centrifugal fashion if no significant barrier is encountered, and under these anatomic circumstances, when a high degree of lesion eccentricity is detected, the diagnosis of malignancy can be excluded as a consideration.

Methods and Results: Standard intermediate resolution T1 and T2-weighted transaxial and sagittal MR-images were used as the assessment tool, an exam very commonly used for detection of metastatic disease of the spine. The thoracic and upper lumbar spine vertebral bodies were chosen as a clinically relevant site and nearly symmetric (cubic) background morphology. MR-Images were 3-4mm slice thickness and approximately 1.2mm pixel in-plane resolution. T1 or T2 images that best depicted the tumor were used for measurement of diameters in all three orthogonal planes (by R.M.K.). Lesions with associated compression fractures or other distortion were not assessed. 28 lesions were analyzed, ranging in size from 5mm to 32mm in greatest dimension. Seven lesions averaged less than 10mm in diameter. The number of millimeters of tumor contact with adjacent cortex was documented for each lesion. Three categories were designated, lesions without any contact on adjacent cortex, those with 7mm or less contact, and those greater than 7mm cortical interface. Eccentricity ratios were determined by taking the longest tumor length and dividing by the short axis length. The averages and ranges for each group were analyzed. Results are listed in Table 1.

(Table 1.)	LESION POSITION VS CORTEX BARRIER		
Lesion Eccentricity	**No Cortical Contact n=6**	**Minor Contact** (=/<7mm) **n=8**	**Major Contact** (8-20mm) **n=14**
Avg	1.19	1.18	1.44
Range	1.0 – 1.33	1.08 – 1.43	1.0 – 2.13

Where metastasis had minor contact with adjacent vertebral cortex, or none (n=14) the degree of eccentricity averaged less than 1.2, (none >1.4) whereas in lesions where growth in at least one direction was impeded (n=14), morphology became elongated in a higher percent, with an average of 1.44 eccentricity and with nearly half of lesions at or exceeding a 3:2 ratio (1.5 eccentricity). When these two groups are compared, the difference in their eccentricity is clearly significant (0.0027 p-value with t-test).

Discussion: We hypothesize that nearly all metastatic tumors will maintain a nearly spherical morphology, in the absence of major contact on cortical barriers at the perimeter of the vertebral body. This pattern is clear to nearly all observers, in both theory and reality, but to what degree is this true? We sought to determine if there are measurement parameters that will allow exclusion of metastasis as a serious consideration. The evidence that there is easily obtainable data to make use of this truth is "proven" in a reverse fashion in this initial study. The lesions whose growth was not impeded by major anatomic barriers, invariably maintained a roughly spherical shape. Bone metastasis only became eccentric when they impacted cortical barriers over a significant percentage of their perimeter. Thus, when the image-interpreter encounters a centrally located obviously eccentric lesion, the diagnosis of metastatic malignancy can essentially be excluded. The optimal eccentricity ratio to use as a "cut-off" in this determination requires evaluation of a greater number of lesions than accomplished in this limited study. We currently suggest a ratio of 1.5 as reliable true negative discriminator. The most common false positive vertebral marrow "lesion" that these criteria will likely help eliminate, is simply prominent hematopoietic marrow mixed with fatty marrow elements (as relatively few benign neoplasms of the vertebrae, are commonly elongated). However, we further hypothesize that this growth pattern will be similar in all bones; whenever metastatic tumors have no, or only limited contact, on adjacent cortex, they will maintain a roughly spherical shape. A larger number of benign lesions (neoplasms and other mass-like conditions) are commonly found in long and flat bones, making these morphologic criteria more clinically useful. Examples where noticeable elongation may occur include red-marrow "islands", infarcts, infection, stress reaction/fractures, enchondromas, fibrous dysplasia, hemangiomas, and fibroxanthomas. Although our diagnostic approach is not applicable in a significant number of clinical situations, this shape criterion is a valuable tool to have available; it is always useful to be able to confidently state that the lesion in question is not consistent with metastatic disease.

Conclusions:

1. Bone metastasis will maintain a nearly spherical shape whenever their growth is unimpeded by adjacent cortices.
2. Unimpeded bone lesions of indeterminate histology, which have > 1.5 eccentricity ratio, are very unlikely to represent metastasis.
3. Use of these easily obtained morphologic data helps provide diagnostic confidence and avoid unnecessary inclusion of metastasis as a reasonable differential consideration ("cannot exclude metastatic disease") in radiologic MRI exam reports.

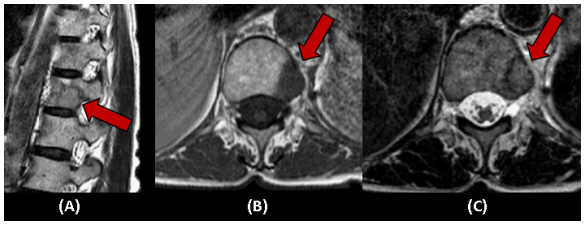

Figure 1. Note in the sagittal image (A) that the metastatic tumor (arrow) grows in a centrifugal manner, creating a circular pattern in superior and anterior directions where it is unimpeded by cortical bone. On axial T1 (B) and T2 (C) images, growth in the left lateral direction is initially prevented by the major cortical barrier, causing a nearly 2:1 ratio of antero-posterior elongation of the lesion.

References: (1) Chun YS, et al. *JAMA* 2009;302:2338-44.
(2) Evangelic I, et al. *Magnetic Resonance in Medicine* 62:1609–1618 (2009)