Comparison of Morpholgical Estimates in Lesion Discrimination

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Introduction Whilst it is well known that MR imaging of the breast has high sensitivity the reported specificity has varied greatly. This is probably due to a number of factors including the overlapping characteristics of some benign and malignant lesions, and the limited number of experienced radiologists available. The BI-RADS lexicon [1] is an attempt to standardise breast MR reporting, but this system is still open to individual interpretation. Quantitative analysis of the appropriate parameters is an alternative more objective strategy. A large body of work now exists on pharmacokinetic modelling and recent work has demonstrated the potential use of texture analysis [2]. However, there is little evidence in the literature of systematic analysis of different measures of lesion shape. It has been reported that interobserver agreement on lesion shape is often only moderate when the subjective descriptors advocated by BI-RADS are used [3]. This work seeks to redress the balance by examining the usefulness of various shape based parameters in breast lesion discrimination. As well as the more traditional shape descriptors (circularity, complexity, elongatedness, and convexity) the efficacy of two-dimensional moments, which have been successfully used as a descriptor set for matching [4], are explored.

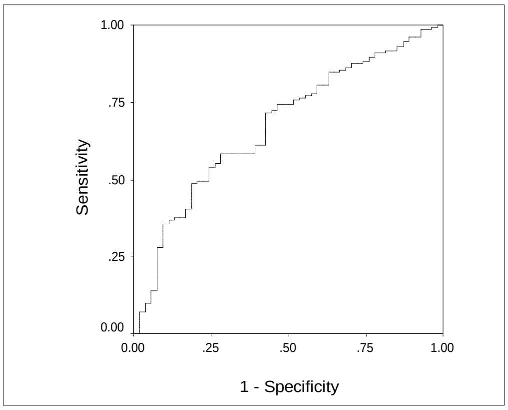
Methods All imaging was performed using a GE Signa Echo-Speed 1.5 T scanner and a dedicated breast coil. After contrast enhanced imaging high-resolution fat suppressed images were obtained using a 3D FSPGR sequence. Data from 198 lesions (54 benign, 144 malignant) was analysed. Regions of interest (ROIs) were drawn by an experienced radiologist and lesion size varied from 44 to 21619 pixels (median 1802 pixels). The following morphological parameters were then calculated – circularity (defined as the normalised standard deviation of the distances of the border points from the centre of mass), complexity (defined as perimeter squared over region area), elongatedness (region area over thickness squared), and convexity (the difference in area between an ROI and its convex hull). The central moments were also calculated according to the formula:

$$\mu_{ij} = \frac{\sum_x \sum_y (x-\mu_x)^i (y-\mu_y)^j f(x,y)}{\sum_x \sum_y f(x,y)}$$

where μ_{ij} is the ijth moment, f(x,y) is the image intensity at the ROI co-ordinate point (x, y), and μ_x and μ_y are the x and y components of the mean respectively. In a manner akin to Fourier analysis an infinite number of central moments would completely describe the shape of the ROI. Finally, Hu invariant moments [5], of order 3 or less (labelled ϕ_1 to ϕ_7), are calculated to ensure invariance under rotation, translation, reflection, and scaling. Statistical comparisons were then implemented using either a student unpaired t-test or the non-parametric equivalent where appropriate. Receiver operating characteristic (ROC) curves were calculated to determine which single parameter offered the best diagnostic accuracy.

Results The table below details the results obtained (mean±SD are quoted for normally distributed data and median values for non-normally distributed data). Significant differences were noted for circularity, complexity, elongatedness and the first four Hu invariant moments. The best individual parameters were circularity and the first invariant moment ϕ_1 (ROC curve shown above) both of which gave a diagnostic accuracy of 0.68. However, it is clear from these results that all parameters show significant overlap between benign and malignant lesions and are therefore not suitable for use as stand-alone diagnostic indicators.

	Benign Lesions	*Malignant Lesions*	*P-Value*	*Diagnostic Accuracy*
Circularity	0.31±0.10	0.25±0.10	<0.0001	0.68±0.04
Complexity	27.4	22.0	0.027	0.60±0.05
Convexity (%)	77.3±14.1	81.2±13.1	0.067	0.59±0.05
Elongatedness	0.75	0.60	0.001	0.66±0.05
ϕ_1	0.22	0.19	<0.0002	0.68±0.04
ϕ_2 (×10)	0.12	0.05	0.003	0.64±0.04
ϕ_3 (×100)	0.15	0.08	0.004	0.63±0.04
ϕ_4 (×1000)	0.16	0.04	0.001	0.66±0.04



Discussion The diagnostic efficacy of various shape parameters has been explored. Although no individual parameter offered clinically acceptable diagnostic accuracy these results show that shape parameters may be useful as inputs into quantitative pattern recognition tools such as neural networks. Incorporating some form of automated or semi-automated segmentation tool may aid ROI generation especially for lesions with a high degree of spiculation wherein greater contributions could be expected from the higher order moments. Two-dimensional Hu invariant moments appear to offer an alternative strategy for assessing shape and have an equivalent diagnostic accuracy to a traditional circularity measure. The advantage of two-dimensional moments is their invariance under region transformation, since parameters such as circularity, complexity, and elongatedness calculated from digital data are known to be prone to scaling problems [6].

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