Application of Mammographic Shape Factors to Breast MRI

E. Van Uytven[1], H. Alto[2], and L. Ryner[1]
[1]National Research Council Institute for Biodiagnostics, Winnipeg, Manitoba, Canada, [2]National Research Council Institute for Biodiagnostics (West), Calgary, Alberta, Canada

Introduction: Breast MR has recently gained a boost in popularity with the American Cancer Society recommending breast MR for screening of high-risk women [1]. When evaluating suspicious breast MR images, a radiologist will typically focus on two main areas: morphology and contrast kinetics. Some authors have suggested that morphological appearance is superior to kinetic behaviour in diagnostic accuracy [2]. Malignant tumours typically present rough, spiculated, or micro-lobulated contours while benign lesions are more likely to present smooth, round, or oval contours. Many shape factors have been developed in the field of mammography [3]. However, in breast MR radiologists typically assign qualitative descriptors only to an area of enhanced intensity, such as 'indistinct margins' or 'high-density mass'. Here we present preliminary work in adaptation and application of several mammographic shape factors to breast MR in an effort to evaluate tumor morphology statistically and improve breast MR specificity.

Methods: In a preliminary study on a 1.5T GE scanner, anonymized, *in vivo,* Gadolinium-enhanced, dynamic image sets were collected. Dynamic, contrast enhanced breast imaging parameters: TR/TE – 9/4ms, 45˚ flip, IR fat suppression, 512x256x32 matrix resulted in a temporal resolution of 90s. Six time points were obtained. Each patient data set contained one mass which was later confirmed to be a carcinoma. Contours were generated automatically using mass thresholding from the transverse 2D slice bisecting each tumour. The contours and associated images were processed in MATLAB® (Mathworks, Natick, Massachusetts) to generate shape factors. These shape factors are 1) spiculation index – measures the degree of spiculation in the boundary, ranges between 0 (circle) and 1 (heavily spiculated), 2) Acutance – measures the edge strength or diffusion of a tumor or mass into the surrounding areas of the image, where 0 is a total lack of contrast and 1 is contrast gradient similar to a step function, 3) Fourier factor – a weighted sum of the 2D Fourier frequency components of a boundary, 4) Fractal Dimension, and 5) Compactness – a measure of the ratio of area to perimeter, between 0 (a circle) and 1 (a contour with a finite area but infinite perimeter length).

Table 1. Shape Factors

Shape Factor	Tumor Type: Benign	Tumor Type: Malignant	
Spiculation Index	0.18	0.46	0.39
Acutance	0.75	0.64	0.61
Fourier Factor	0.74	0.56	0.33
Fractal Dimension	0.98	1.07	1.10
Compactness	0.25	0.71	0.79

Results: Shape factors were calculated and compared to shape factors calculated from a previously obtained benign mass contour. The mass contour obtained from one patient is shown in Figure 1 below. Figure 1a illustrates detection of tumour spicules which are used in the calculation of spiculation index. Acutance is calculated from a weighted average of intensity gradients along the tumour boundary (Figure 1b). Figure 1c shows a data collapse of the number of boxes *n(r)* required to cover the contour of the tumour shown in figure 1a for different box sizes *r*. The fractal dimension is the slope of a linear fit to the plot. Fourier factor and compactness were calculated from the 2D Fourier transform and measured length and perimeter, respectively (not illustrated). The results are shown in Table 1.

Discussion: Malignant tumours exhibit an increased spiculation index due to the presence of sharp protrusions from the main tumor body as can be seen in Fig. 1a in red and green. The acutance of malignant tumors is lower than that of benign masses, implying the edges of malignancies are fuzzier and less defined than those of benign masses. This is consistent with mammographic findings. Calculation of Fourier factor gave inconclusive results, possibly due to the lower resolution of MR images when compared to mammography. Fractal dimension and compactness followed the predictions of mammography, where malignant tumours in breast MR exhibited boundaries longer and rougher for the same area than those of benign tumors. Based on these promising results, we are currently undertaking a more extensive patient study to evaluate the potential of these shape factors to improve the specificity of breast MR.

Acknowledgements: The authors would like to thank Iain Kirkpatrick for supplying breast imaging data sets.

References:
1. Saslow D. et al, 2007, CA Cancer J Clin 57:75-89.
2. Goto M. et al, 2007, J. Mag. Reson. Im. 25:104-112.
3. Guliato D. et al, 2008, IEEE Trans. Biomed. Eng., 55:14-20.

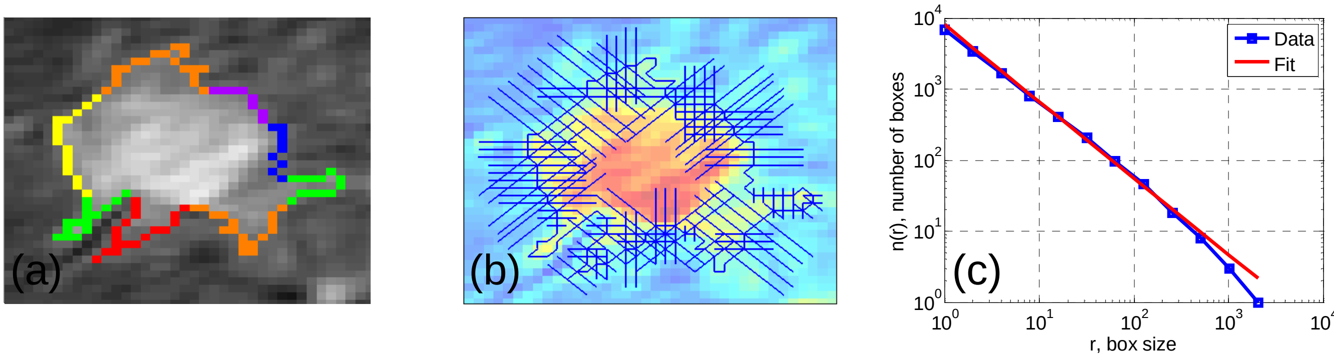

Figure 1. (a) Spiculation index calculation involves detection of individual spicules. (b) Acutance calculation involves drawing lines normal to the tumor boundary and calculation of the contrast gradient along each line. (c) The data collapse of the number of boxes *n(r)* required to cover the contour for different box sizes *r*. The slope of the fit (red) is the fractal dimension.