Texture Analysis using Run Length Matrices in MRI of Breast Cancer

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Target Audience Breast MR researchers – Physicists and Clinicians

Purpose Texture analysis is an established method of image classification in the non-medical arena. Recently, texture analysis has been used in MRI of the brain, and also in other organs such as the breast for both lesion classification(1) and tumour response prediction(2). Many methods of texture analysis have been developed including transform (e.g. Fourier and wavelet analysis) and statistical methods. Statistical methods are more widely utilised due to computational ease and their tendency to achieve a higher level of discrimination than other methods(3). The most commonly utilised statistical method is based on co-occurrence matrices which contain information regarding image intensities of adjacent pixels. However, run length matrices, which contain information regarding the length of pixel runs of similar intensity, are also widely used outside medicine. This work investigates the relationships between run length matrix derived parameters with clinical variables such as grade in a group of breast cancer patients scanned prior to neoadjuvant chemotherapy for locally advanced disease.

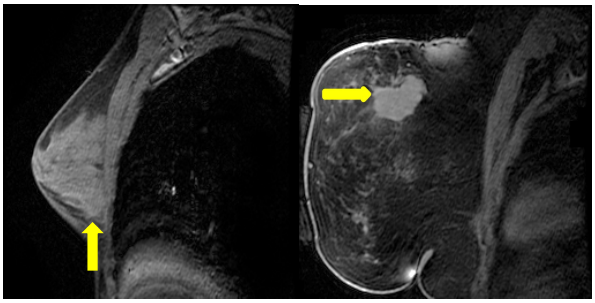
Methods Data from 98 patients (2 patients with bilateral disease) scanned at 3 Tesla was retrospectively analysed. 3D dynamic contrast-enhanced images were obtained using VIBRANT (flip angle 10°, TR 4.1 ms, TE 1.6 ms, receiver bandwidth ±41.7 kHz, FOV 22×22 cm, matrix 220×160, slice thickness/gap 4/-2 mm, Δt 33.6 [range 23.5 – 44.6 s]). After acquisition, malignant tissue ROIs were generated semi-automatically for all appropriate slices using seed points and Otsu thresholding on the early arterial phase data. After data reduction to 3 bits (8 grey levels) run length matrices were calculated in four directions (0°, 45°, 90°, and 135°) for run lengths between 2 and 10 pixels on pre-contrast images and 1, 2, 3, 4, and 5 minutes post-contrast images. From these matrices 5 distinct texture parameters were calculated as:

$$SRE = \frac{1}{n}\sum_g\sum_r \frac{p(g,r)}{r^2} \quad LRE = \frac{1}{n}\sum_g\sum_r r^2 p(g,r) \quad GLNU = \frac{1}{n}\sum_g\left(\sum_r p(g,r)\right)^2 \quad RLNU = \frac{1}{n}\sum_r\left(\sum_g p(g,r)\right)^2 \quad IF = \left(\sum_g\sum_r p(g,r)\right)/\left(\sum_g\sum_r rp(g,r)\right)$$

where *n* is the sum of the run length matrix, *g* is the grey level index, *r* is the run length index and *p(g,r)* is the run length probability. Patient groups were determined based on pre-treatment biopsy grade, nodal status and hormone receptor status. Differences between groups were determined using the Student *t*-test or non-parametric equivalent as appropriate.

Results Pre-treatment biopsy grade was available for 93 cases, with 38 low grade (I/II) lesions compared with 55 high grade (III) lesions. Interestingly, significant differences were noted (see table) for 4 of the 5 texture parameters both pre-contrast and 5 minutes post-contrast administration (when a significant amount of washout will have occurred). Example images for a low grade and high grade lesion are shown below along with the pre-contrast run length parameters. No differences between low grade and high grade tumours were observed at peak contrast. No significant differences were noted between node negative (45 cases) and node positive (46 cases) lesions or between triple negative (ER-, PR- HER2-) (22 cases) and non-triple negative (72 cases) for all time points.

	median value [minimum-maximum]		
Param. (Time)	Grade I or II	Grade III	*p* value
SRE (Pre)	**0.177 [0.151 – 0.208]**	**0.170 [0.140 – 0.195]**	**0.010**
LRE (Pre)	**9.49 [5.91 – 14.19]**	**10.40 [7.24 – 15.95]**	**0.018**
GLNU (Pre)	**2390 [65 – 31927]**	**3994 [236 – 45397]**	**0.043**
RLNU (Pre)	5214 [176 – 64908]	7461 [754 – 87315]	0.096
IF (Pre)	**0.355 [0.301 – 0.426]**	**0.341 [0.283 – 0.395]**	**0.011**
SRE (5min)	**0.168 [0.142 – 0.199]**	**0.171 [0.119 – 0.191]**	**0.016**
LRE (5min)	**9.81 [6.82 – 15.21]**	**10.48 [7.71 – 21.51]**	**0.018**
GLNU (5min)	**2537 [158 – 32703]**	**3504 [319 – 54363]**	**0.034**
RLNU (5 min)	**4639 [232 – 65705]**	**8146 [882 – 89874]**	**0.016**
IF (5 min)	0.339 [0.289 – 0.404]	0.341 [0.245 – 0.386]	0.563



Grade II lesion *Grade III lesion*

Discussion Significant differences were noted between low grade and high grade lesions with high grade lesions having a smaller fraction of the ROI represented by runs of length 2 or longer possibly reflecting their increased heterogeneity. Surprisingly, the addition of contrast seems to obscure these differences. Reducing the data to only 8 grey levels increases the number of runs present in the data whilst probably reducing discriminatory power. Future work will concentrate on optimising the run length matrix calculation, including the optimal degree of grey level decimation, and applying this methodology to tumour response prediction.

(1) P Gibbs and LW Turnbull (2003) *Magnetic Resonance in Medicine* 50:92-98. (2) A Ahmed *et al* (2013) *Journal of Magnetic Resonance Imaging* 38:89-101. (3) G Castellano *et al* (2004) *Clinical Radiology* 59:1061-1069.