Texture Analysis of Parameter Maps in Breast MRI

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Target Audience Breast MR Researchers – Physicists and Clinicians

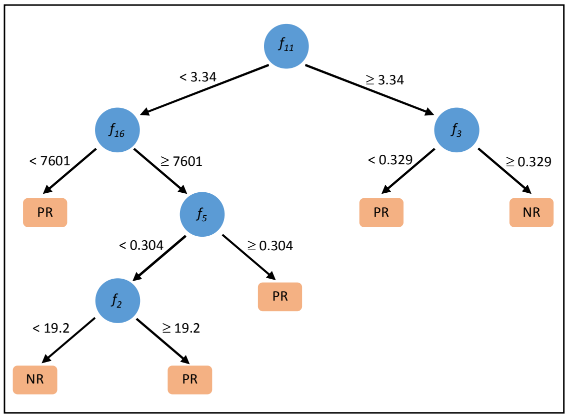
Purpose Texture analysis is an established method of image classification in the non-medical arena. Recently, texture analysis has been used in MRI of the brain, and also in other organs such as the breast for both lesion classification(1) and tumour response prediction(2). Previous work has primarily focused on co-occurrence matrix based texture analysis of either high resolution post-contrast images or DCE data. However, texture analysis of DCE based parameter maps has emerged as a further potential technique to explore lesion heterogeneity(3,4). This work investigates the efficacy of empirical parameter map based texture analysis as a means to predict tumour response to neo-adjuvant chemotherapy in a cohort of breast cancer patients with locally advanced disease.

Methods Data from 98 patients (2 patients with bilateral disease) scanned at 3 Tesla prior to commencing neo-adjuvant chemotherapy 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]) for a minimum of ~4 mins (range 235-447 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. These ROIs were then applied to calculated parameter maps of normalised maximum enhancement, area under the enhancement curve at 1 and 2 mins (AUC1 and AUC2), the initial (uptake) slope gradient and the delayed (washout) slope gradient if present. Parameter map ROI data was then reduced to 16 grey levels via histogram equalisation to ensure adequate counting statistics in subsequent co-occurrence matrices. Co-occurrence matrices were calculated for four directions (0°, 45°, 90°, and 135°) enabling the 14 textural features as defined by Haralick(5) (denoted f_1 to f_{14}) to be determined alongside two further parameters cluster shade (f_{15}) and cluster prominence (f_{16}) as defined by Conners *et al*(6). Finally, texture parameters for the 4 distinct directions were averaged as no directional bias is anticipated. First order statistics (mean, SD, median, min and max) were also determined for each set of parameter maps.

Patients were categorised as either partial responders (>50% reduction) or non-responders (<50% reduction) based on change between pre-treatment MRI longest diameter and post-surgical longest diameter via pathology. Differences between groups were assessed using the non-parametric Mann-Whitney U test with a p value < 0.05 regarded as significant.

Results Response data was available in 89 patients (40 partial responders vs. 49 non-responders). For first order statistics significant differences were noted for AUC1 (mean, SD and median), $p<0.03$, and for delayed phase slope (mean, SD and median), $p<0.05$. Regarding second order statistics no significant differences in textural parameters were noted for maximum enhancement, AUC1, AUC2 and uptake slope gradient. However, 12 out of 16 textural parameters calculated from washout slope gradient demonstrated significant differences between groups, $p<0.048$. Decision tree analysis of the significant washout based texture parameters revealed a classification accuracy of 82% based on 5 parameters (f_2, f_3, f_5, f_{11}, f_{16}), with 73 cases classified correctly, 9 falsely classed as partial responders and 7 falsely classed as non-responders.



Discussion This work has highlighted that differences in texture between groups (based on response) are apparent in DCE based parameter maps prior to the commencement of treatment. These differences are noted for parameter maps based on the gradient of the washout slope with parameters f_2 (contrast), f_3 (correlation), f_5 (inverse difference moment), f_{11} (difference entropy) and f_{16} (cluster prominence) being utilised in a decision tree model based on the CART (classification and regression tree) algorithm. Increased washout, resulting in a higher negative gradient, is related to increased vascularity. Texture analysis assesses ROI heterogeneity, so it appears that the local heterogeneity of washout parameter maps can be used to predict chemotherapeutic response.

Conclusion Texture analysis of parameter maps based on washout slope offers the potential to differentiate those tumours that are more likely to respond to neo-adjuvant chemotherapy.

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