Displaying parametric data from DCE-MRI investigations of breast cancer: how to present complex data.

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Introduction. Dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI) of the breast provides an effective clinical tool for early diagnosis of breast cancer. It has been shown by the UK multi-centre screening trial of MRI in women at genetic risk of breast cancer (MARIBS) [1] as well as by other similar trials conducted concurrently that MRI is more sensitive than X-ray mammography (XRM) for detecting breast cancer in pre-menopausal high risk women. Assessment of lesion's uptake kinetics using DCE-MRI involves evaluation of relative extent of enhancement due to contrast agent during the initial phase of about 2 min following the administration, along with analysis of the shape of kinetic uptake curve [2]. It has been shown [3] that the uptake curve's shape, which is usually classified using three patterns as follows: washout, plateau or persistent enhancement, can aid in distinguishing between benign and malignant lesions. There is an increasing need to combine dynamic functional data with morphology leading to a need to evaluate the merits of different approaches. In this work we compare five different methods of creating colour-encoded kinetics maps where saturation of the colours is modulated by the extent of contrast enhancement during the initial phase.

Materials and Methods. All the methods were applied to DCE-MRI measurements of 10 patients acquired at the same medical centre using a Siemens 1.5T Vision scanner. The MR imaging protocol [1] was T1w fast spoiled gradient echo sequence with coronal acquisition plane, spatial resolution 1.33x1.33x2.5 mm. Two reference volumes were acquired before administration of contrast medium and five after the intravenous bolus injection of Gd-DTPA at 0.2 mmol/kg body weight with the temporal resolution 90s. All patients were symptomatic with pathologically confirmed lesions. Shapes of uptake curves were classified using three temporal points [4] for each voxel extracted from pre-contrast and two post-contrast volumes: 180s and 450s. Colour-encoded kinetic maps were computed assigning to each voxel one of the three hues, as follows: RED – to voxel displaying washout pattern, BLUE – to voxel displaying persistent enhancement and GREEN – to voxel displaying plateau. Subtracted 2nd post-contrast image (180s) was used to modulate the resulted kinetic map using the following five methods (Fig. 1).

(a) Fusion of the kinetic map with the subtracted image using a transparency factor $\alpha = 0.8$ (Fig. 1a): $F = C.(1-\alpha) + S.\alpha$ (Symbols: F = fused image, C = colour-encoded kinetic map, S = subtracted image, all the mathematical operations are assumed voxel-wise.) Different transparency factors in the range $0.6 < \alpha < 1.0$ were evaluated using a sub-set of two cases and $\alpha = 0.8$ was found to be optimal.

(b) Intensity modulation (Fig. 1b): $F = C\,.\,I$, where I is the subtracted image normalized to the maximum, $I = S / \max(S)$

(c) Saturation modulation (Fig. 1c): $F = b + (C - b).I$, the method changing saturation of colours of the kinetic map in a way that as value of the normalized subtracted image I approaches zero, the voxel's colour becomes indistinguishable from the constant background value b

(d) Method similar to (c) using unsubtracted reference image R as a background (Fig. 1d): $F = R + (C - R).I$

(e) Method similar to (c) and (d) using subtracted image as a background (Fig 1e): $F = S + (C - S).I$

The methods were scored basing on human perception by two independent observers. The observers gave scores 0, 1 or 2 for each of the five following attributes: (1) contrast between enhancing tissue and background; (2) completeness of details; (3) goodness of colours (how colours reflect kinetics); (4) prominence of lesion; (5) visual correlation between intensity of colours and extent of enhancement (i.e. subtracted image). Thus the range of the final score combining all the factors was 0 to 10.

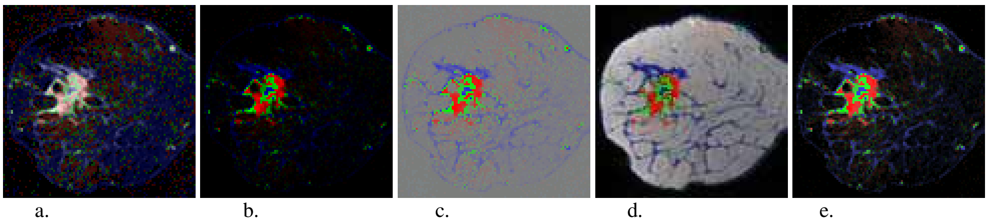

Fig. 1: Example of all the five approaches applied to the same data.

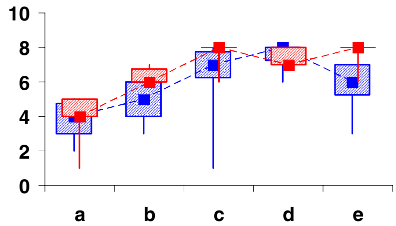

Fig. 2:
Box and whisker plot showing range of the scorings distribution, median (inner box) and inter-quartile distance (outer box); one plot for each method, different colours for different observers.

Results and Discussion. Comparison of the scorings provided by different observers yielded poor agreement (k = 0.28), however in general the observers agreed on ranking the methods based on saturation modulation above the approach based on fusion using semi-transparency (Fig. 2). The limitation of the fusion method (a) is that saturation of colours is not well balanced with the extent of enhancement, and as a result the region of the lesion appears not colour-saturated comparing to the tissues displaying slow enhancement, like fat. This leads to increased noise in the image and difficulties in interpreting of the lesion's kinetic characteristics. Increasing transparency factor above the value $\alpha = 0.8$ results in a loss of colour of the important regions, while reducing this factor results in increasing noise and decreasing of contrast between fat and enhancing tissue. The saturation modulation approach (c) displays good contrast between enhancing tissue and fat, and produces a well-balanced relation between saturation of colours and extent of enhancement. The same approach using unsubtracted image as a background (d) adds extra information about anatomical details. The other two approaches (b, e) produce images with a dark background resulting in poor visibility of anatomical details.

Conclusions. Although the study has not shown statistical significance of agreement between the observers, the methods based on saturation modulation approach (c, d, e) produce images of superior quality comparing to other approaches evaluated (a, b). Future work will involve application of the described approaches to more data along with revision of the scoring scheme to include more detailed criteria on each of the scoring factors. Latter is important to avoid possible cause of discrepancies between the observers due to misinterpretation of the scoring factors.

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