A dual-phase kinetic volume rendering approach to present 3D T1-weighted DCE-MRI data of the breast on 2D images combining morphology and kinetic characteristics.

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Introduction. Interpretation of 3D T1w Dynamic Contrast Enhanced MRI (DCE-MRI) of the breast combines assessment of morphology and kinetic characteristics. The latter involves two major factors: the extent of relative enhancement during the initial uptake phase of about 2 min and the type of uptake kinetics, which is defined by the shape of the relative intensity-time curve (uptake curve) as one of the following: persistent enhancement, washout, or plateau (equivocal) [1]. One of the problems associated with interpreting DCE-MRI of the breast are false-positives produced by blood vessels that usually possess strong relative enhancement and often display contrast agent uptake kinetics similar to many malignant lesions. Maximum Intensity Projection (MIP) is a method of volume rendering, which is commonly used to visualize shape of enhancing anatomical structures. On MIP images one can readily recognise the blood vessels due to their characteristic pipe-like tubular shape. The same is much more difficult to do when analysing volume data as a stack of slices. The MIP that is produced using single volume subtracted or fat-suppressed images accounts for the extent of enhancement at the time of acquisition of the input volume, but does not produce further information on tissues' kinetics. In this work we propose a method to extend capabilities of MIPs beyond shape visualization by fusing morphology with colour-encoded information describing the type of tissue contrast uptake kinetics, thus implying a way to extract information from four-dimensional dynamic dataset to a 2D parametric image combining both morphology and kinetic characteristics.

Materials and Methods. The method consists of the following steps. Firstly, all the voxels in the imaged volume are classified basing on the shape of their uptake curves into two classes: voxels containing the tissue in the phase of washout/plateau and therefore possessing fast uptake kinetic and voxels containing the tissue in the phase of persistent enhancement thus possessing slow uptake kinetics. In this work the classification is performed using the Computational Fat Suppression algorithm [2,3] classifying the shape of the uptake curves using the whole range of acquired temporal points. (However, other approaches can be used.) Secondly, a subtracted image corresponding to the time of initial enhancement is selected, and maximum intensity projections are computed independently for each class (i.e. using the voxels of one of the classes at a time) producing two independent MIPs of the tissues with fast uptake kinetics and slow uptake kinetics (Fig. 1a-b). Next, the two resultant MIPs are merged together into a combined intensity image choosing between the voxels of the two images in a voxel-by-voxel manner applying one of the following two combination rules:

(1) Taking the maximal value of the two MIPs thus producing a combined intensity image similar to a "traditional" MIP (Fig. 1c).

(2) Taking a voxel from the MIP of fast uptake kinetics tissue if its value exceeds an adjustable threshold, or otherwise a voxel of the MIP of slow uptake kinetics tissue.

For each voxel in the resultant combined intensity image, the information of the image of its origin is stored in the colour-encoded map containing the value RED if the voxel in the current lattice location came from the MIP of the fast uptake tissue, or BLUE otherwise (the hues are subject to customizable selection). Finally, the combined intensity image and the map are fused together into a kinetic volume rendered image (Fig. 1d-e). Thus the colour intensity of the kinetic volume rendered image is modulated by the extent of enhancement as defined by the combined intensity image.

The method was applied to the measurements from 8 patients from the symptomatic (n=6) and screening (n=2) cohorts of UK multicentre MRI breast screening trial MARIBS [4], 6 with malignant lesions and 2 with benign lesions (all confirmed pathologically). Two reference and five post-contrast 3D T1w images were acquired in each case using a 1.5T Siemens scanner with a temporal resolution of 90 sec. The contrast agent was Gd-DTPA at 0.2 mmol/kg body weight administered intravenously as a bolus. A second post-contrast subtracted image (180s) was used as an input for computing MIPs of fast and slow uptake kinetics tissues.

Results and Discussion. In all the cases a good balance between intensity of colour and extent of enhancement was observed. Using the combination rule (1) the method produces a kinetic volume rendering that is morphologically similar to the "traditional" MIP and enhances it by kinetic information. Using the combination rule (2) allows in-depth interrogation of the tissues' morphology by interactive adjustment of the threshold defining the fractions of voxels from each class, and thus compensating for the effect when an anatomical structure is partially obstructed by the tissue of another class.

Conclusions. The method allows rapid overview of the breast volume with improved appreciation of the anatomy combined with colour-encoded intensity-modulated functional information. Producing a number of renderings from different view angles one can assess the 3D shape of a lesion detected. The method can be used in addition to the existing methods – subtracted imaging, and 2D colour encoded maps of contrast agent uptake kinetics (like e.g. 3TP maps [5]). The method can be readily extended to visualize more than two kinetic phases, e.g. persistent, washout and plateau.

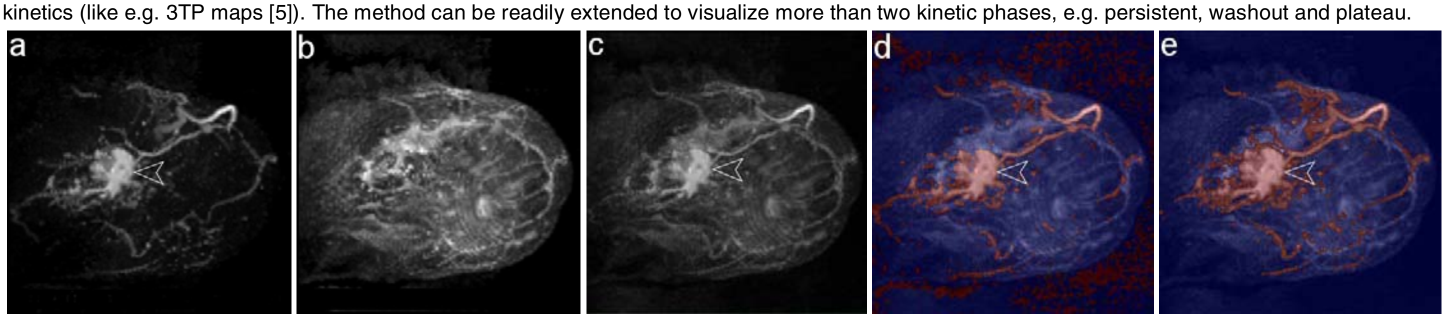

Fig. 1. Example of dual-phase kinetic volume rendering. Pathology: invasive ductal carcinoma, grade II (lesion is shown by the arrow). **(a, b)** MIPs of correspondingly fast and slow uptake kinetic tissues; **(c)** "traditional" MIP; **(d)** Kinetic volume rendering image produced using the combination rule (1); **(e)** Kinetic volume rendering image produced using the combination rule (2)

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