Lesion probability mapping in MS patients using a regression network on MR Fingerprinting

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Abstract

Purpose To develop a regression neural network for the reconstruction of lesion probability maps on Magnetic Resonance Fingerprinting using echo-planar imaging (MRF-EPI) in addition to T 1 , T 2 * , NAWM, and GM- probability maps. Methods We performed MRF-EPI measurements in 42 patients with multiple sclerosis and 6 healthy volunteers along two sites. A U-net was trained to reconstruct the denoised and distortion corrected T 1 and T 2 * maps, and to additionally generate NAWM-, GM-, and WM lesion probability maps. Results WM lesions were predicted with a dice coefficient of 0.61±0.09 and a lesion detection rate of 0.85±0.25 for a threshold of 33%. The network jointly enabled accurate T 1 and T 2 * times with relative deviations of 5.2% and 5.1% and average dice coefficients of 0.92±0.04 and 0.91±0.03 for NAWM and GM after binarizing with a threshold of 80%. Conclusion DL is a promising tool for the prediction of lesion probability maps in a fraction of time. These might be of clinical interest for the WM lesion analysis in MS patients.

Full Text

Due to technical limitations, full-text HTML conversion of this manuscript could not be completed. However, the latest manuscript can be downloaded and accessed as a PDF.

Figures

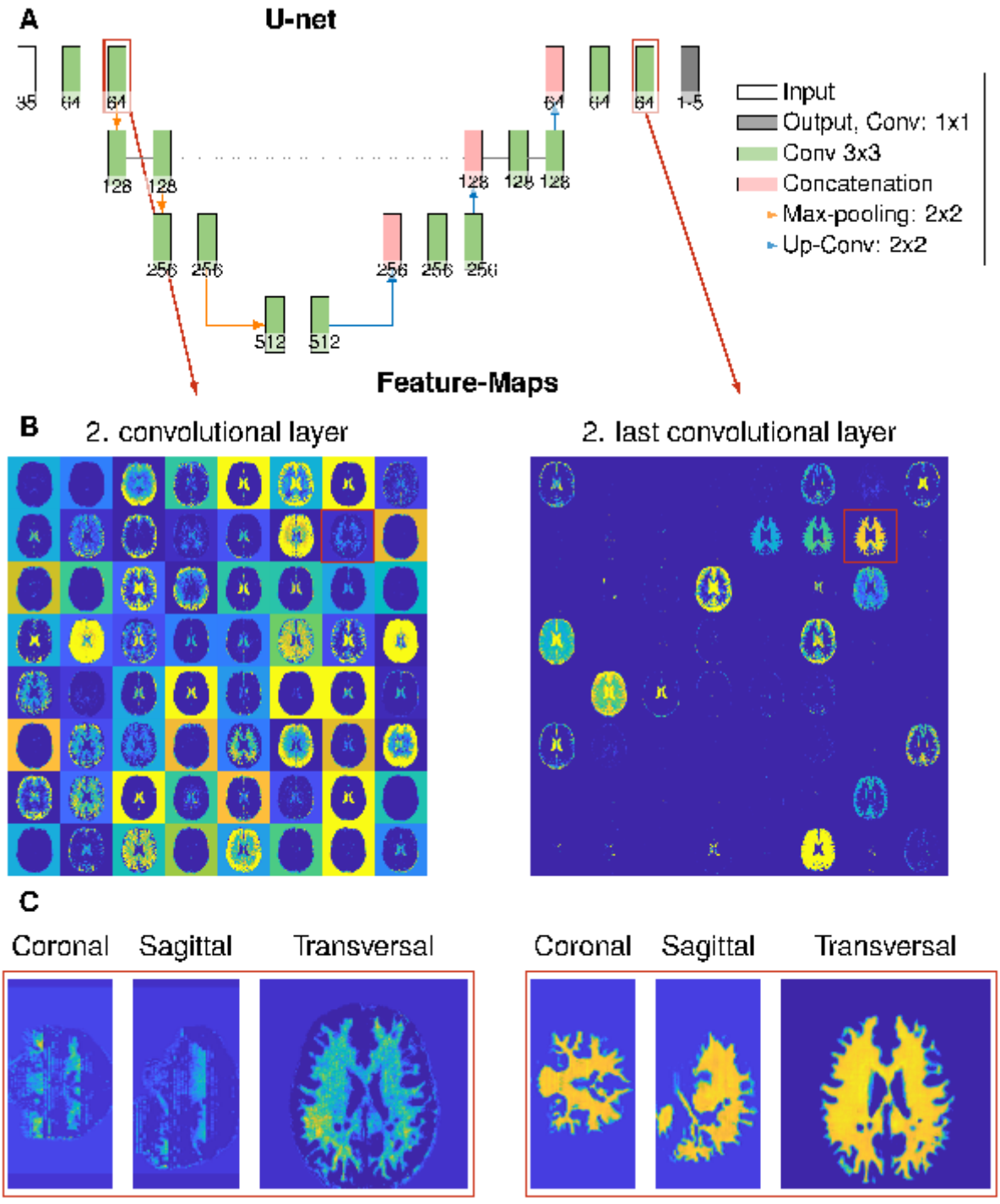

Figure 1

A) Representation of the U-net with an encoder depth of three. B) Feature maps of the second convolutional layer and the second last convolutional layer are depicted. One feature per layer is marked in red and shown below in C). Coronal, sagittal, and transversal slices of the corresponding features maps are shown. The second convolutional layer shows a WM-like feature, which, however, is not homogeneous in all three dimensions. The last convolution layer depicts a homogeneous WM-like feature in all three dimensions. No colorbars were shown because all features are in arbitrary units.

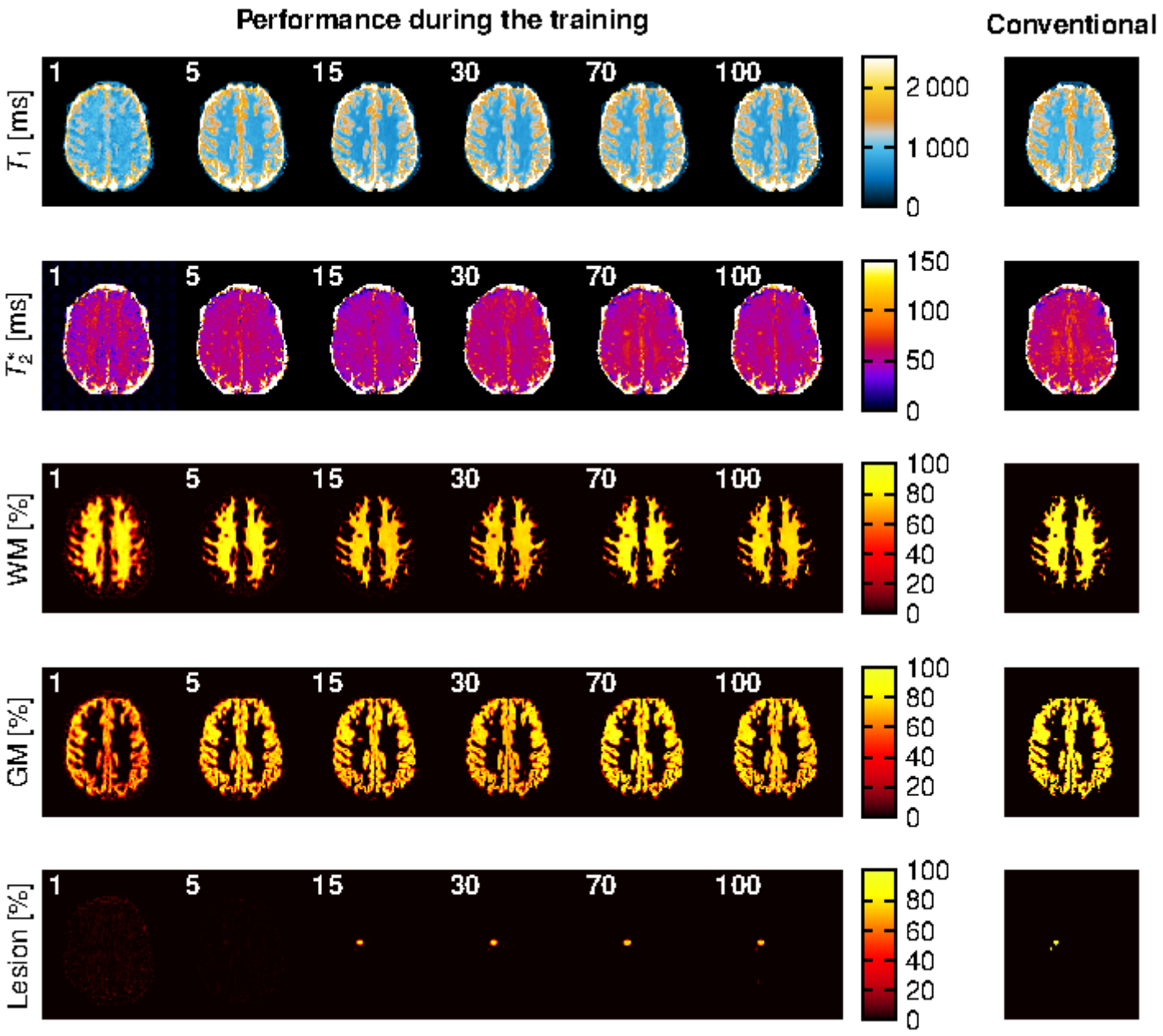

Figure 2

Visualization of the reconstruction during the training. The reconstructed T1, T2∗, NAWM-, GM, and Lesion-probability maps are depicted for 1, 5, 15, 30, 70, and 100 training epochs (white number) and the dictionary matching reference maps are shown on the right side for MSE-5.

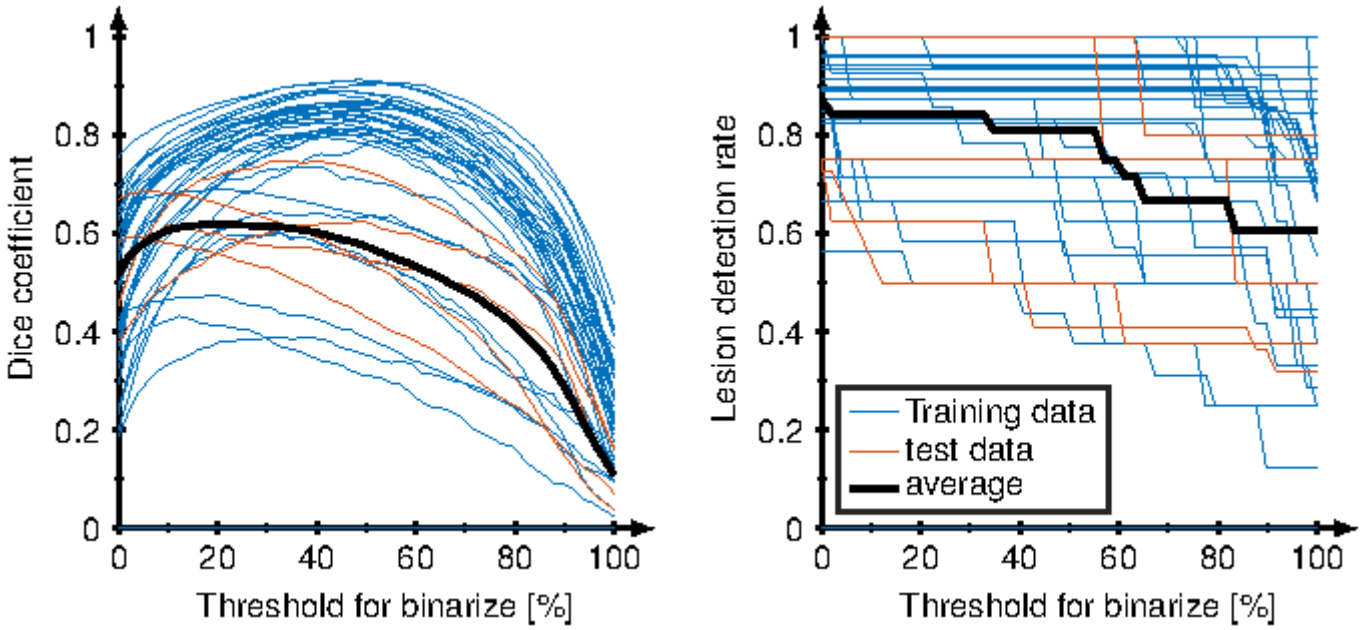

Figure 3

The dice coefficient (left) and the lesion detection rate (right) for all training data (blue) and test data (orange) are shown over the threshold to binarize the lesion probability maps. The black lines depict the average across the test data. A maximum dice coefficient is observed at a threshold of around 50%. The lesion detection rate decreases for an increasing threshold because the background of the lesion probability map is non-zero.

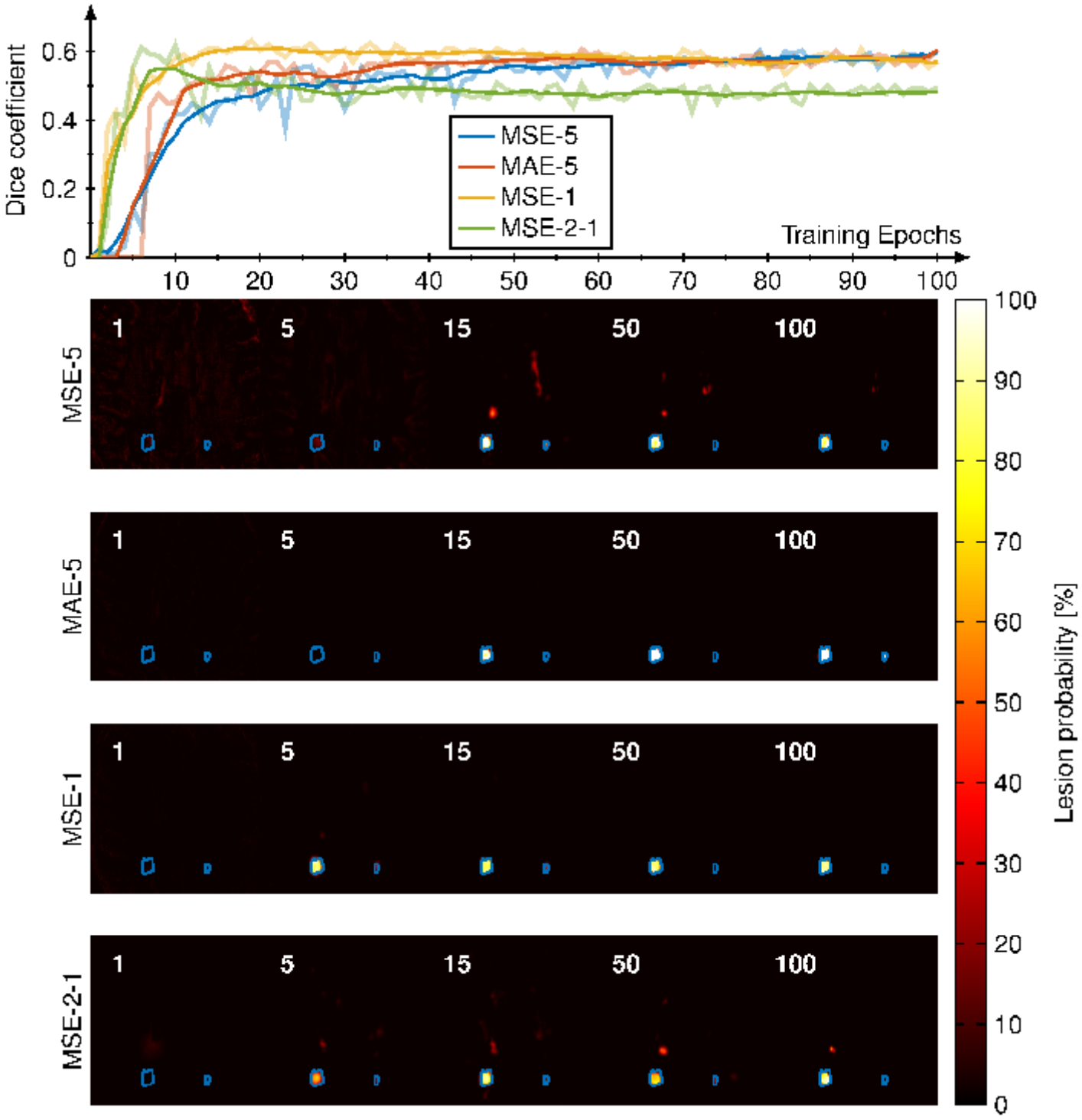

Figure 4

The dice coefficient for three different networks is depicted (five outputs with MSE [MSE-5], five outputs with MAE [MAE-5], only lesions with MSE [MSE-1]) and the reference network with the T1 and T2 $*$ maps as input and lesions as output [MSE-2-1]. The dice coefficient is plotted for all three networks over the training epochs and the smoothed data is shown in the foreground colors. The corresponding lesion probability maps are shown for 1, 5, 15, 50, and 100 epochs below.

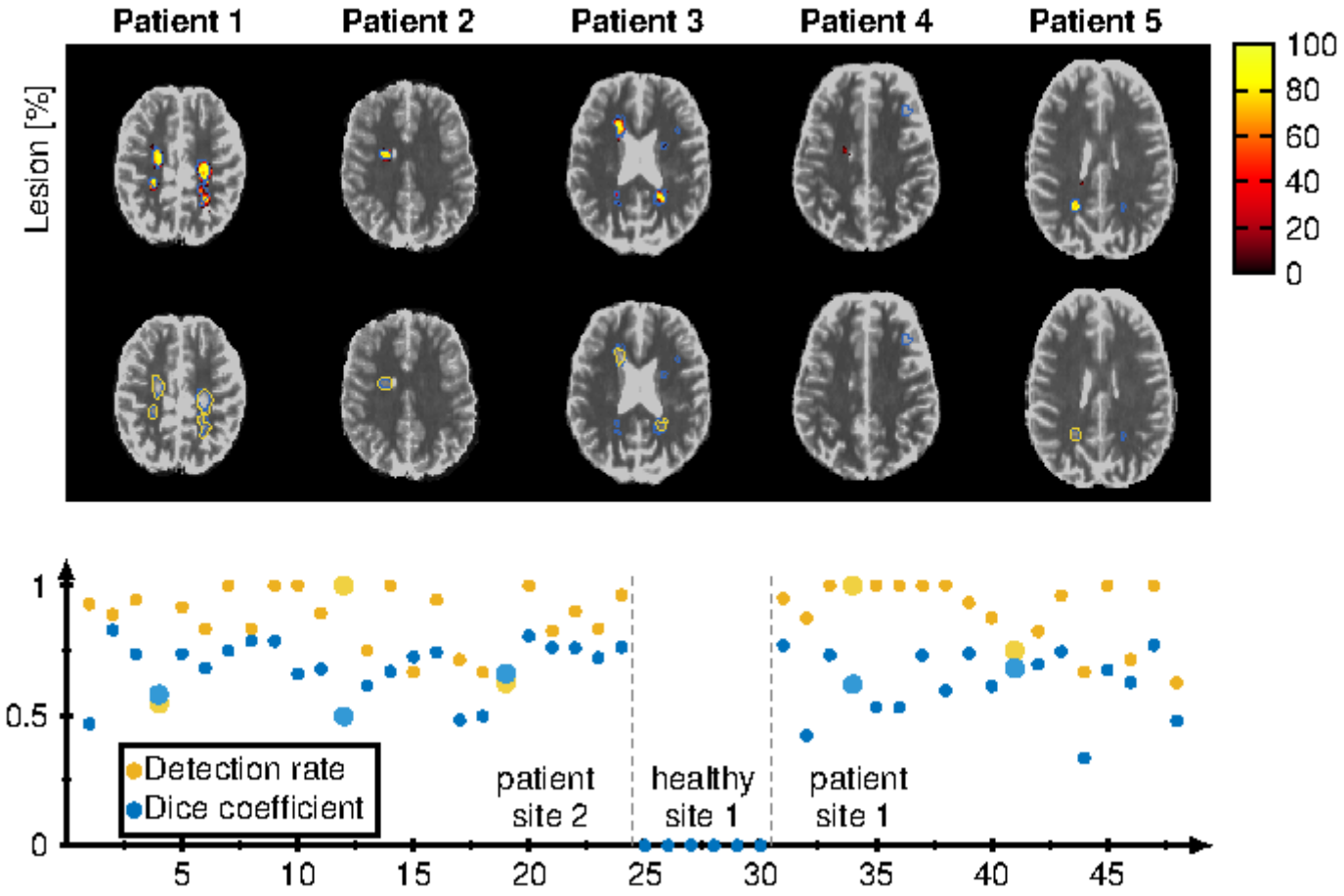

Figure 5

The reconstructed lesions probability maps are overlayed on the magnitude data in color encoding for all five different patients from the test set. Manual annotation is depicted in blue. Below the probability map is binarized and depicted in yellow in addition. The dice coefficient and white matter lesion detection rate is depicted for every patient and healthy subject for both sites. The average lesions detection rate is 0.88 and the average dice coefficient is 0.67 for all patients. The test data is shown in larger marks and brighter color and yields an average lesion detection rate of 0.85 and an average dice coefficient of 0.61 using the MSE-5.

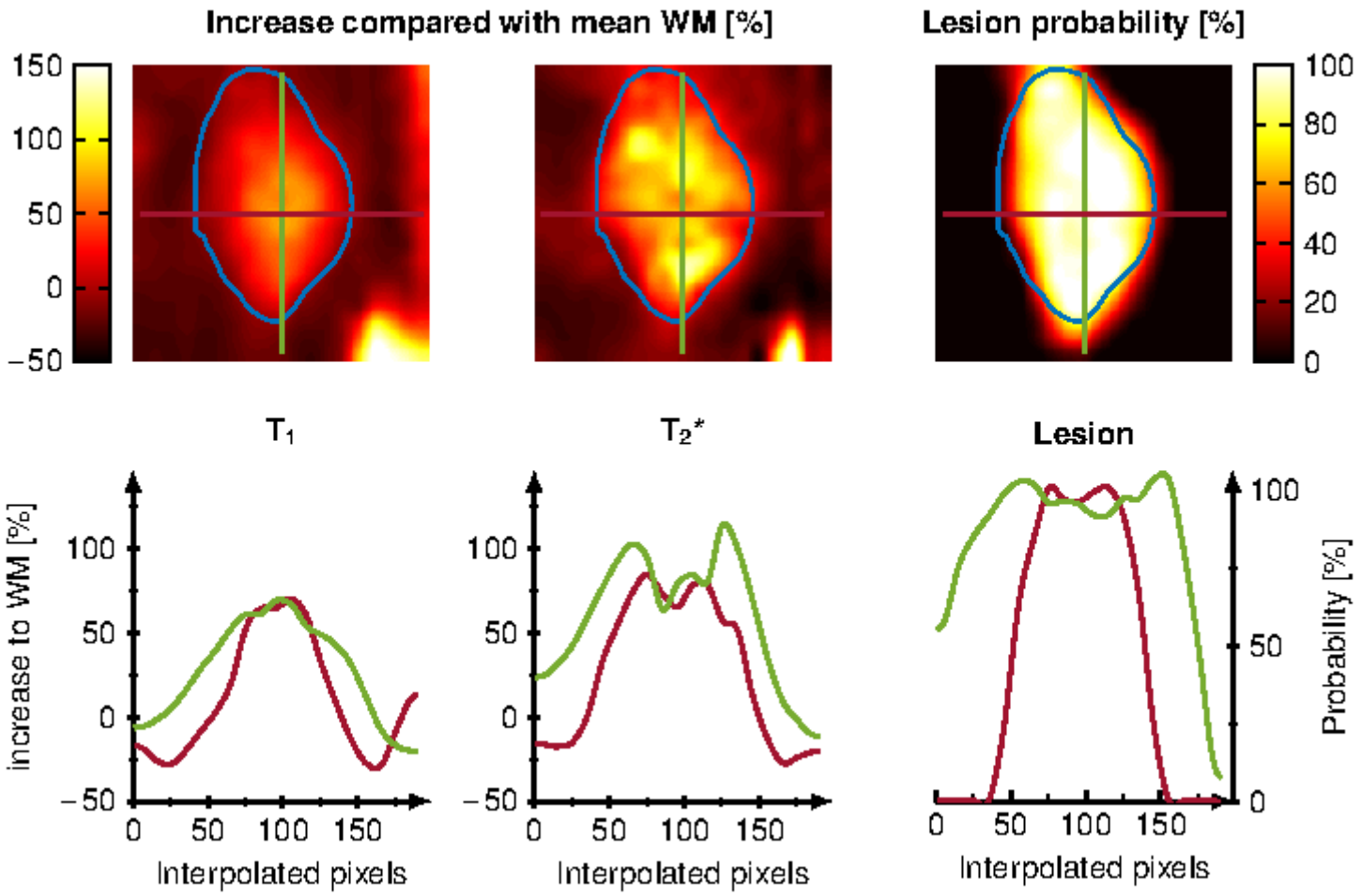

Figure 6

One lesion is depicted in a zoomed-in version with a bilinear interpolation of factor 10. The increase in T1 and T2 ∗ compared with the mean NAWM is color encoded in percentage and the lesion probability generated by the CNN is shown on the right side. The manual annotation is drawn as a blue line. Below the voxel-wise values are depicted for one horizontal (red) and one vertical (green) cut through the lesion.