

Supplementary Materials

Self-Supervised MRI Tissue Segmentation by Discriminative Clustering

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Abstract

In this supplementary material section, we provide (a) higher resolution images and (b) a series of unpublished figures regarding data and the results mentioned in the article “Self-Supervised MRI Tissue Segmentation by Discriminative Clustering”, published in the International Journal of Neural Systems.

1	Methodology flowchart	2
2	Original images	4
3	Summarising results for simulated data	9
4	Illustrative results for simulated data	13
5	Illustrative results for the Grand Challenge training data	18
6	Illustrative results for the Grand Challenge test data	22

1 Methodology flowchart

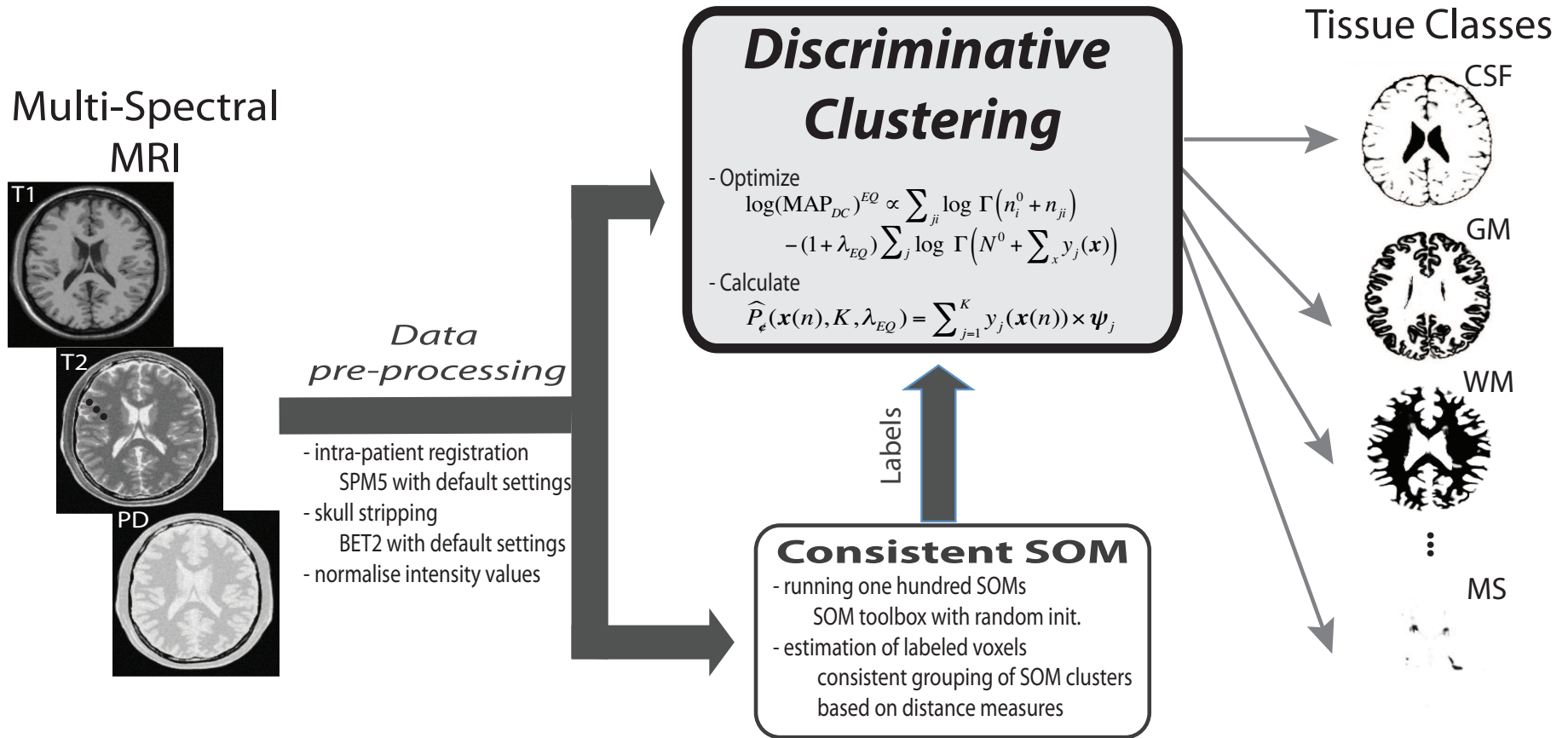


Figure S1: Flowchart of the proposed method. Segmentation is performed by DC on pre-processed multi-spectral MR images, with the help of labels obtained from the analysis of consistency of SOM clustering. **Scaled up version of Figure 1 from main article, with added information.**

2 Original images

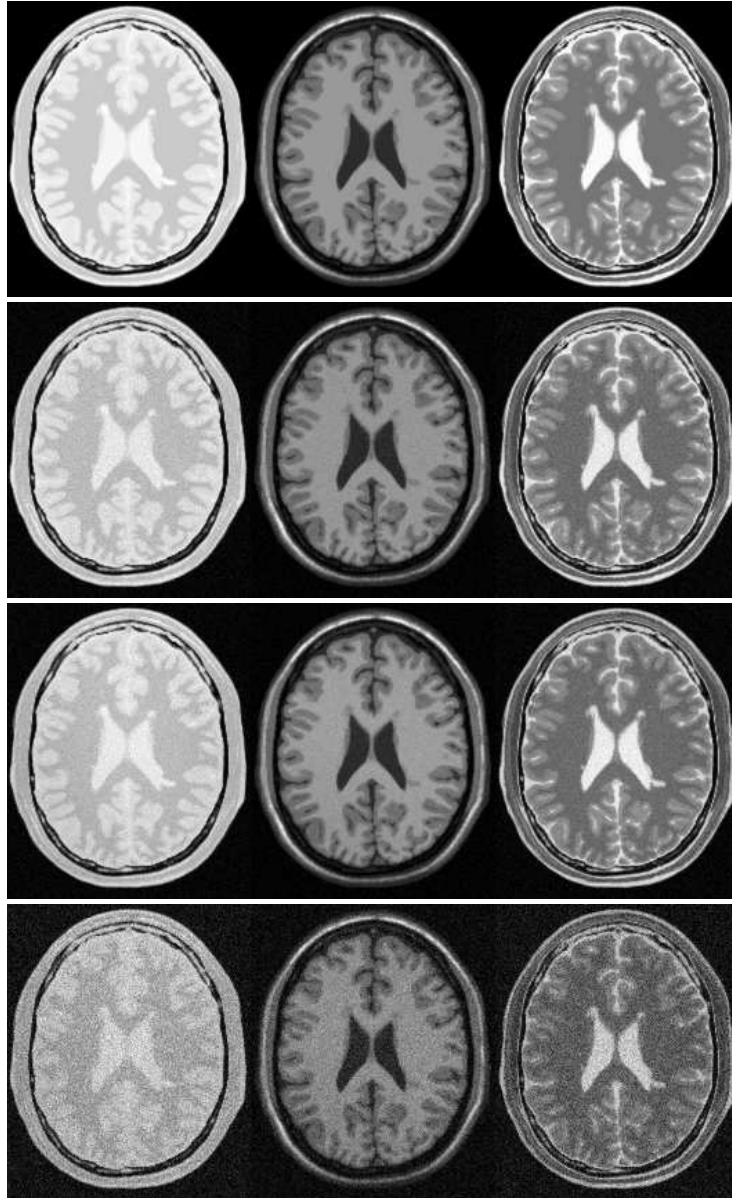
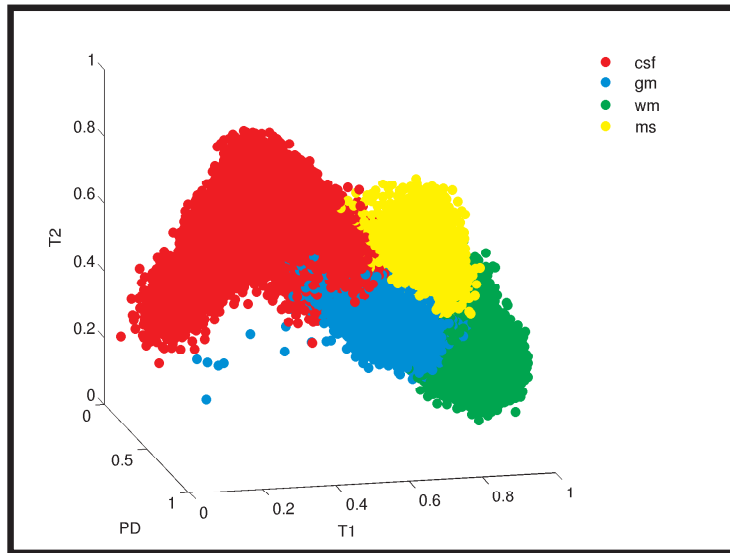
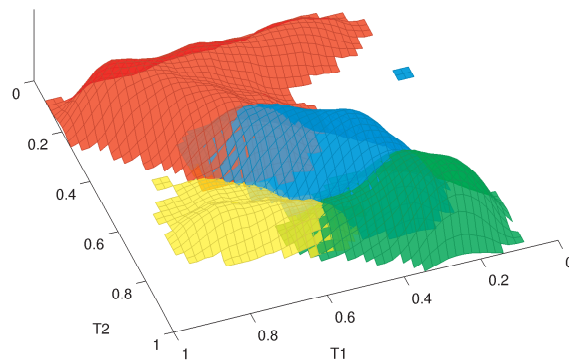


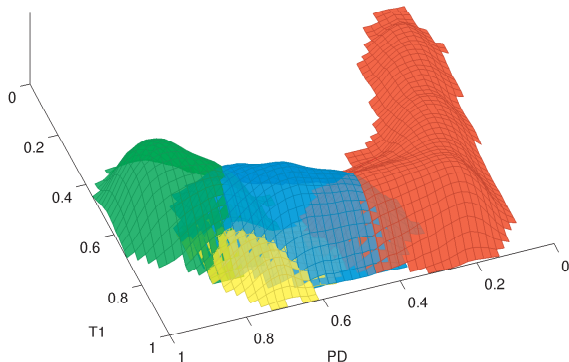
Figure S2: Simulated images with lesion from Brainweb. The sequences, from left to right, are PD, T1 and T2. The lesion has intensity values similar to the other tissues, and is visible around the ventricles. Using T1 as reference, CSF is the darkest tissue, WM the brightest and GM/MS voxels have intensity values in between these two. **Similar to Figure 2 in the main article**, for different sets of noise and homogeneity parameters. From top to bottom: no noise/no inhomogeneity, 3% noise/no inhomogeneity, 3% noise/inhomogeneity, 9% noise/inhomogeneity.



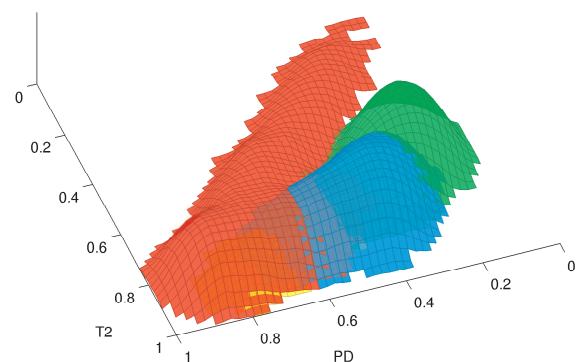
(a) 3D distribution of the gray levels of the different tissues .



(b) T1/T2 intensity distribution histogram.



(c) T1/PD intensity distribution histogram.



(d) T2/PD intensity distribution histogram.

Figure S3: Intensity distribution images for the simulated data with lesion and 3% noise. (a) shows the three-dimensional plot of all the data points in the PD/T1/T2 space. (b)-(d) are projections of the 3D sequence space in a 2D histogram of intensities, where the z-axis is proportional to the number of elements projected to each (x,y) coordinate.

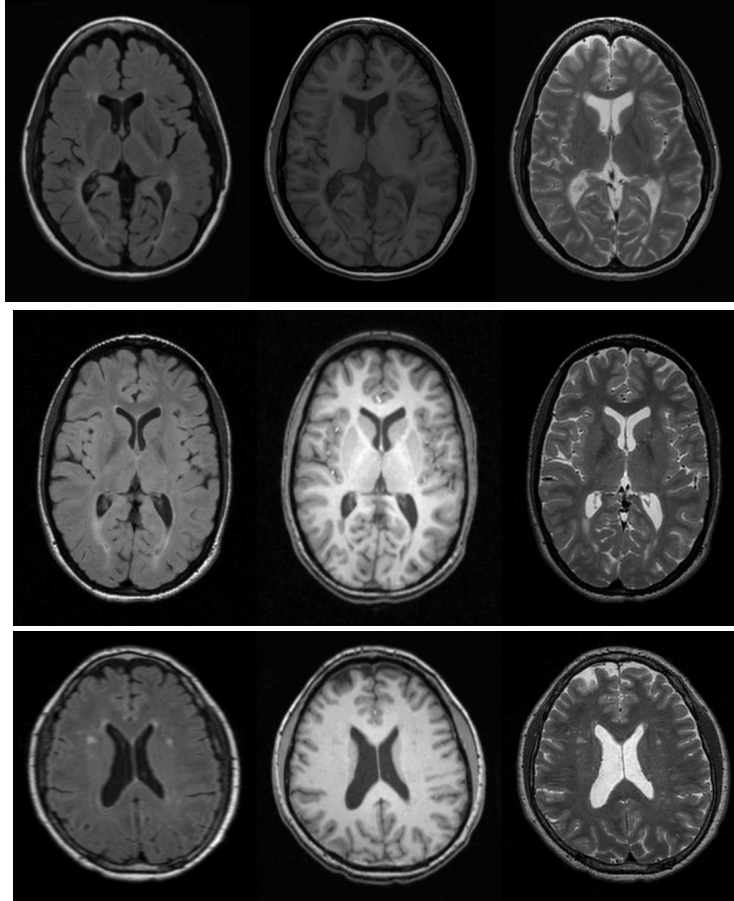


Figure S4: Real images from the 'Grand Challenge II: MS Lesion segmentation' training set. **Similar to Figure 3 from the main article.** The third image corresponds to the same patient shown therein. First and second images are taken from other patients, also from the training set. The sequences, from left to right, are FLAIR, T1 and T2.

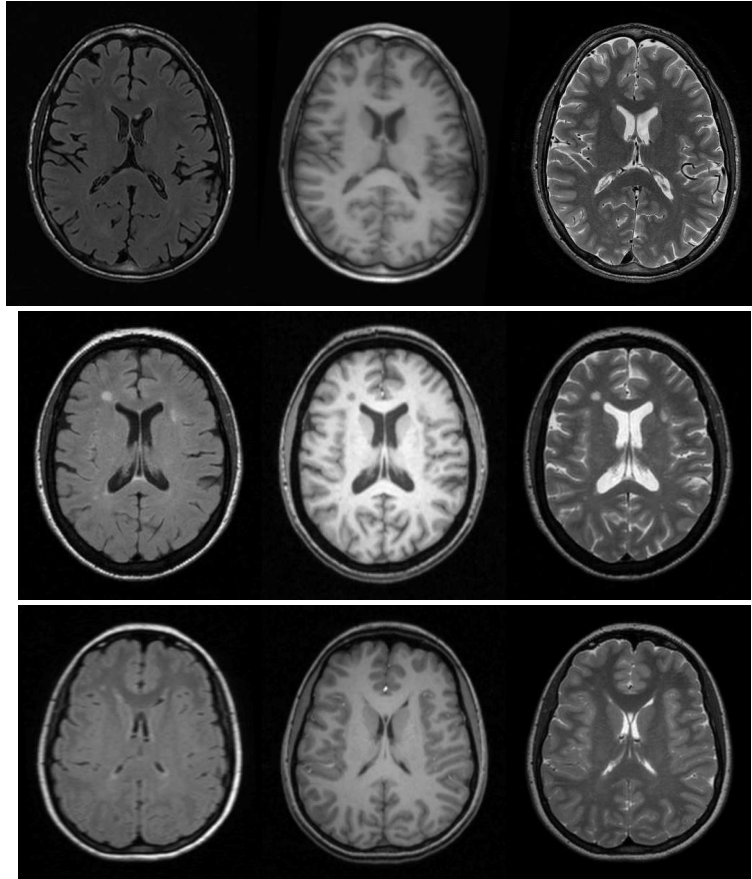


Figure S5: Real images from the 'Grand Challenge II: MS Lesion segmentation' test set. **Similar to Figure 3 from the main article.** The third image corresponds to the same patient shown therein. First and second images are taken from other patients, also from the training set. The sequences, from left to right, are FLAIR, T1 and T2.

3 Summarising results for simulated data

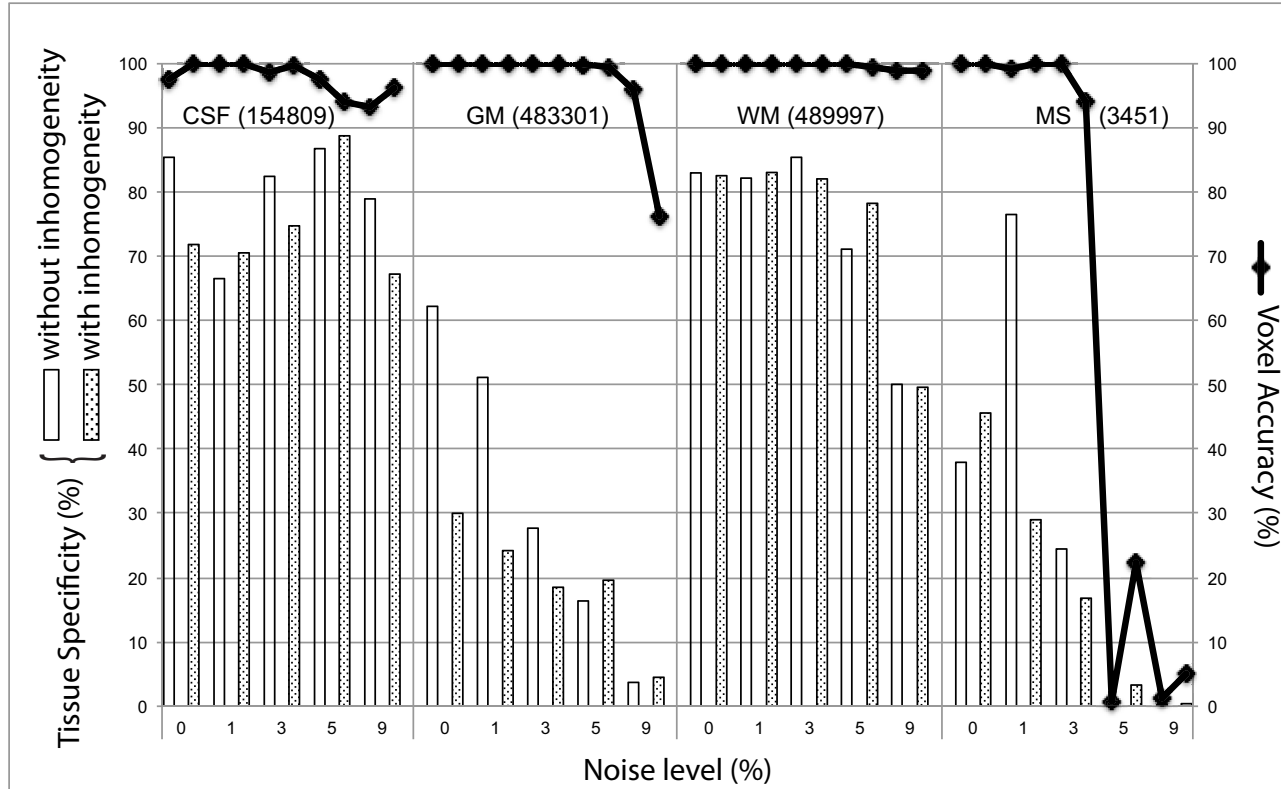


Figure S6: Percentage of LABELLED VOXELS correctly detected (specificity) from the total number of ground truth voxels (in parentheses) for the simulated data-set with different levels of noise, with and without the presence of a 20% inhomogeneity field. In the case of uniform tissues, such as CSF and to some extent white matter, the SOM algorithm performs remarkably well. For MS and GM, results start to deteriorate at higher noise levels. **Scaled up version of Figure 5 from main article.**

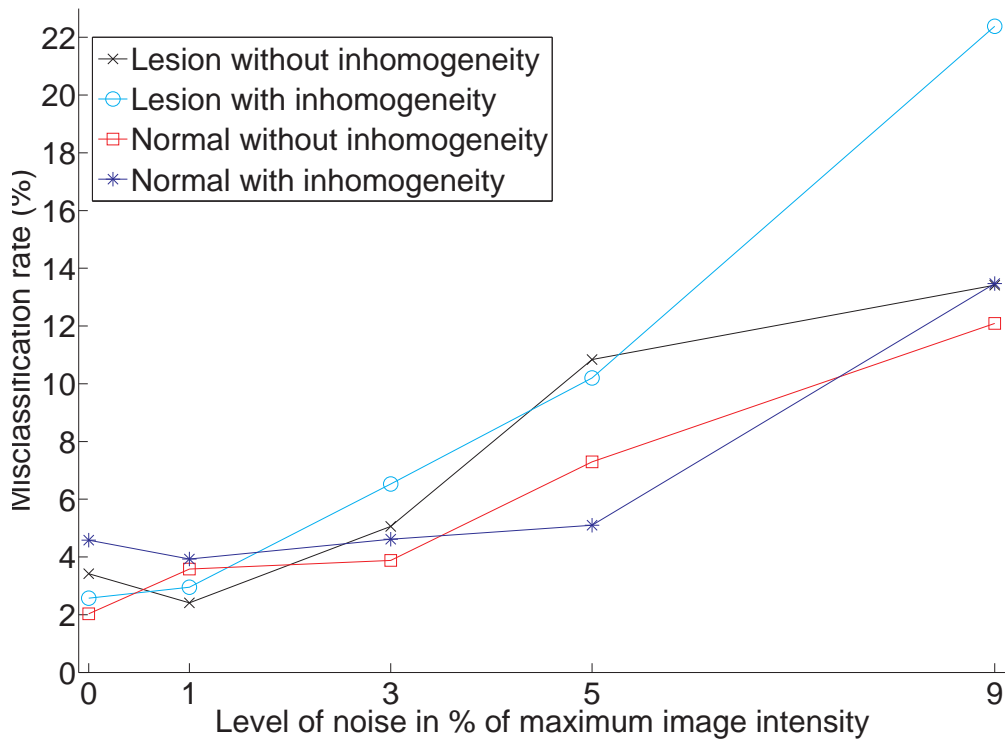


Figure S7: Overall misclassification rates in all simulated sets, calculated as the percentage of wrongly classified voxels in all tissues, as function of the noise level.

Algorithm	CSF κ_d			
	1% noise	3% noise	5% noise	9% noise
Proposed	0.97	0.93	0.93	0.92
Lesion-TOADS [19]	0.90	0.90	0.90	–
Leemput et al. [5]	–	–	–	–
Freifeld et al. [44]	–	–	–	–

Algorithm	GM κ_d			
	1% noise	3% noise	5% noise	9% noise
Proposed	0.98	0.98	0.94	0.86
Lesion-TOADS [19]	0.92	0.91	0.90	–
Leemput et al. [5]	–	–	–	–
Freifeld et al. [44]	–	–	–	–

Algorithm	WM κ_d			
	1% noise	3% noise	5% noise	9% noise
Proposed	0.99	0.99	0.97	0.94
Lesion-TOADS [19]	0.93	0.93	0.92	–
Leemput et al. [5]	–	–	–	–
Freifeld et al. [44]	–	–	–	–

Algorithm	Lesion κ_d			
	1% noise	3% noise	5% noise	9% noise
Proposed	0.85	0.89	0.78	0.45
Lesion-TOADS [19]	0.82	0.81	0.79	–
Leemput et al. [5]	–	0.80	0.73	0.47
Freifeld et al. [44]	–	0.79	0.79	0.76

Table **S1**: DICE score comparison between different algorithms for cerebrospinal fluid (CSF), gray matter (GM), white matter (WM) and MS lesion. **Similar to Table 3 in the main article.**

4 Illustrative results for simulated data

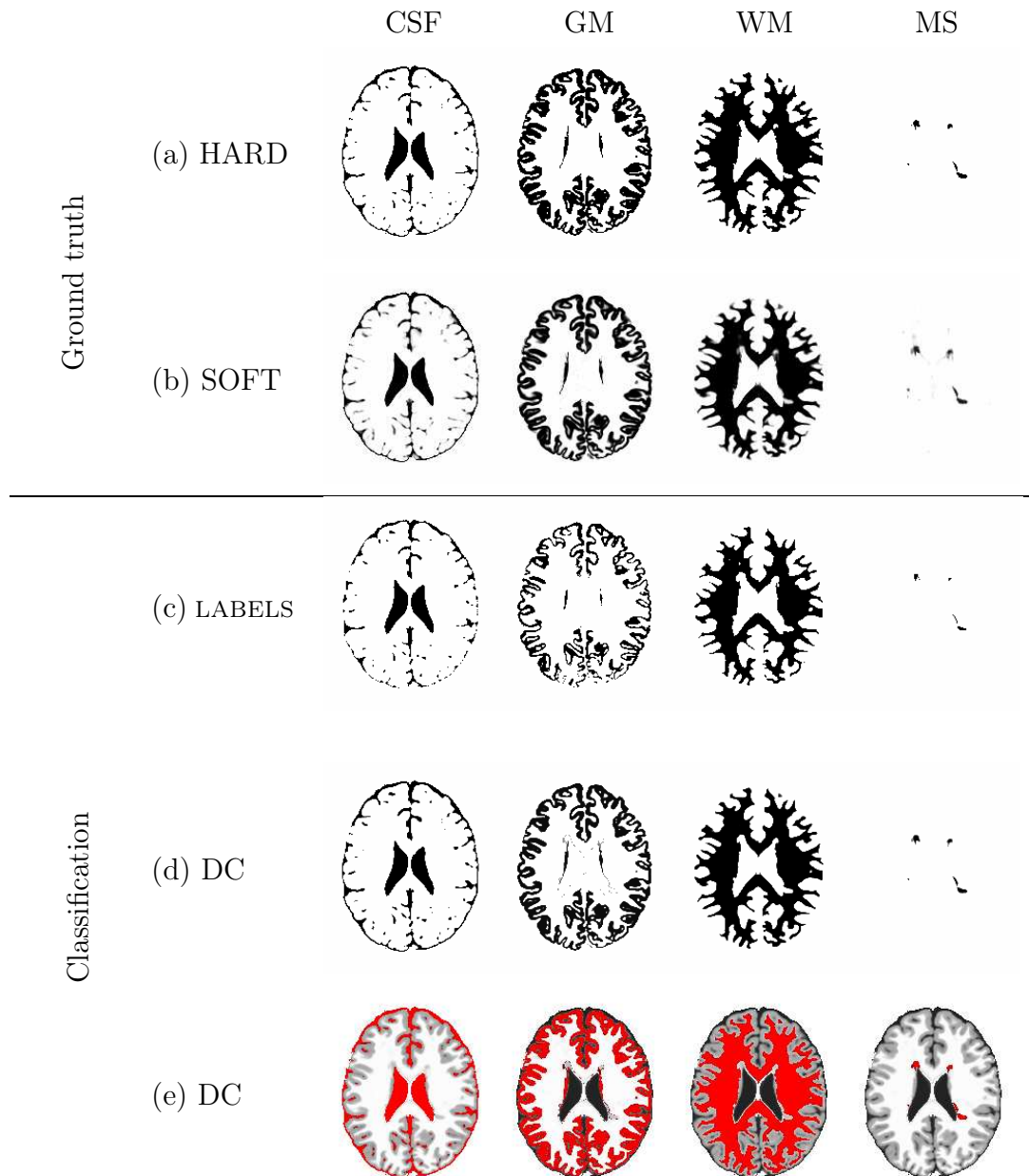


Figure S8: Results for the segmentation using simulated Brainweb data with lesion, *0% noise level and no inhomogeneity*. The first two rows show the ground truth, both with hard (a) and soft (b) class assignments. The LABELLED VOXELS are shown in (c). The DC results (soft segmentation), representing our estimation of PVI, are displayed in the row (d). Row (e) shows the same DC results, overlaying a T1 sequence. The classes shown are CSF, grey matter, white matter and MS lesion, from left to right respectively. **Similar to Figure 4 in the main article**, but for a different noise level.

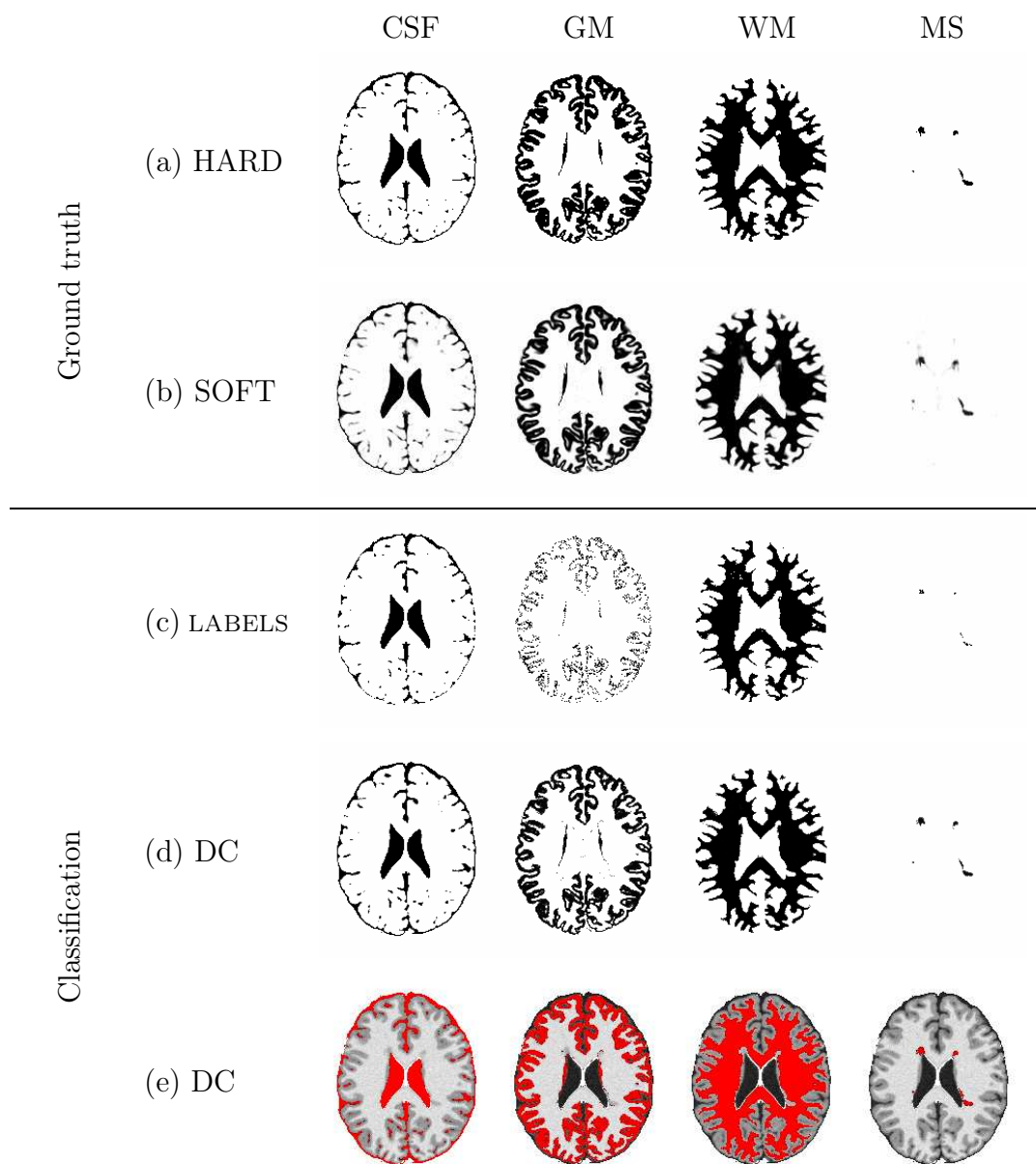


Figure S9: Results for the segmentation using simulated Brainweb data with lesion, *3% noise level and no inhomogeneity*. The first two rows show the ground truth, both with hard (a) and soft (b) class assignments. The LABELLED VOXELS are shown in (c). The DC results (soft segmentation), representing our estimation of PVI, are displayed in the row (d). Row (e) shows the same DC results, overlaying a T1 sequence. The classes shown are CSF, grey matter, white matter and MS lesion, from left to right respectively. **Similar to Figure 4 in the main article.**

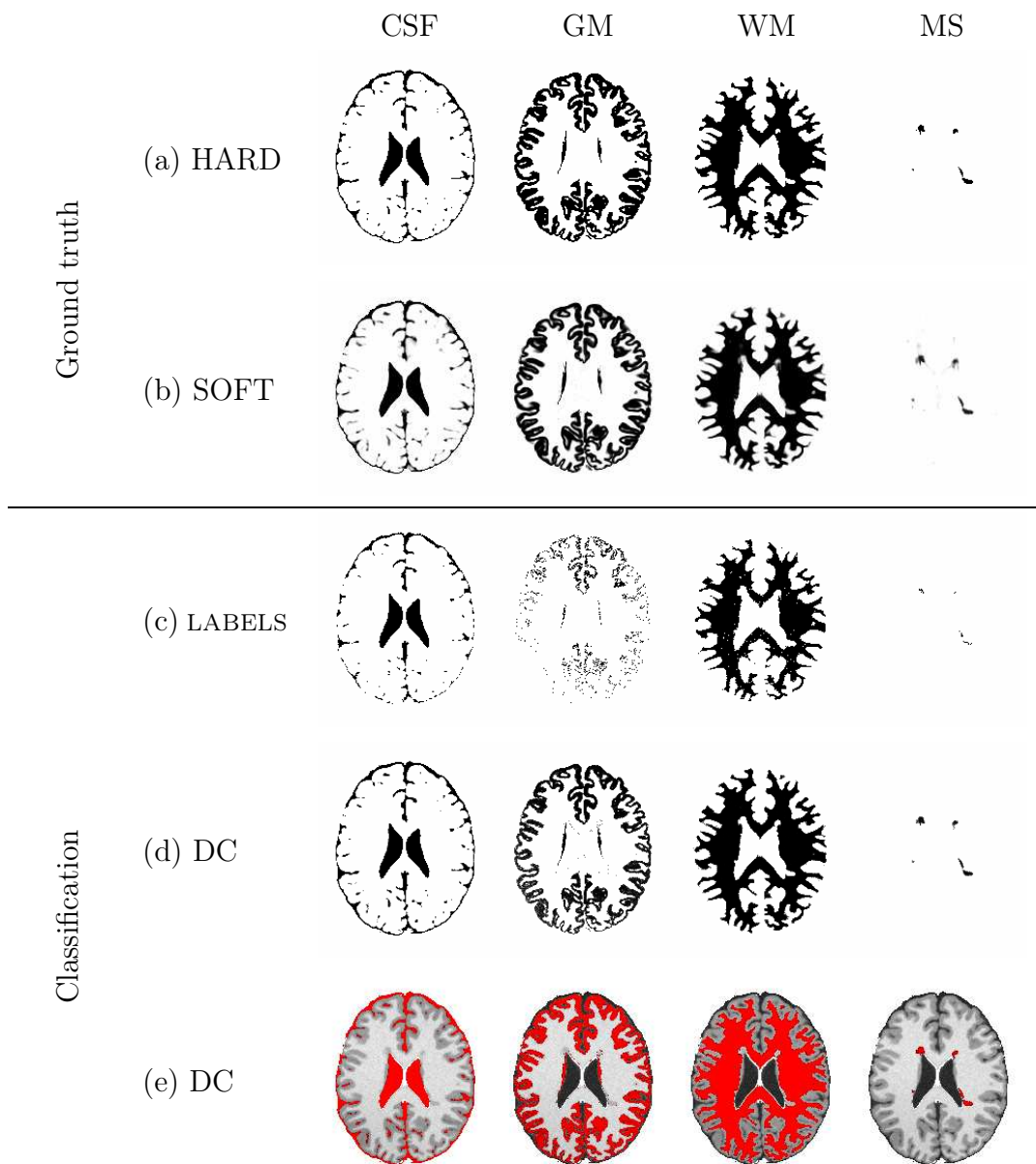


Figure S10: Results for the segmentation using simulated Brainweb data with lesion, *3% noise level and inhomogeneity*. The first two rows show the ground truth, both with hard (a) and soft (b) class assignments. The LABELLED VOXELS are shown in (c). The DC results (soft segmentation), representing our estimation of PVI, are displayed in the row (d). Row (e) shows the same DC results, overlaying a T1 sequence. The classes shown are CSF, grey matter, white matter and MS lesion, from left to right respectively. **Similar to Figure 4 in the main article, but with inhomogeneity.**

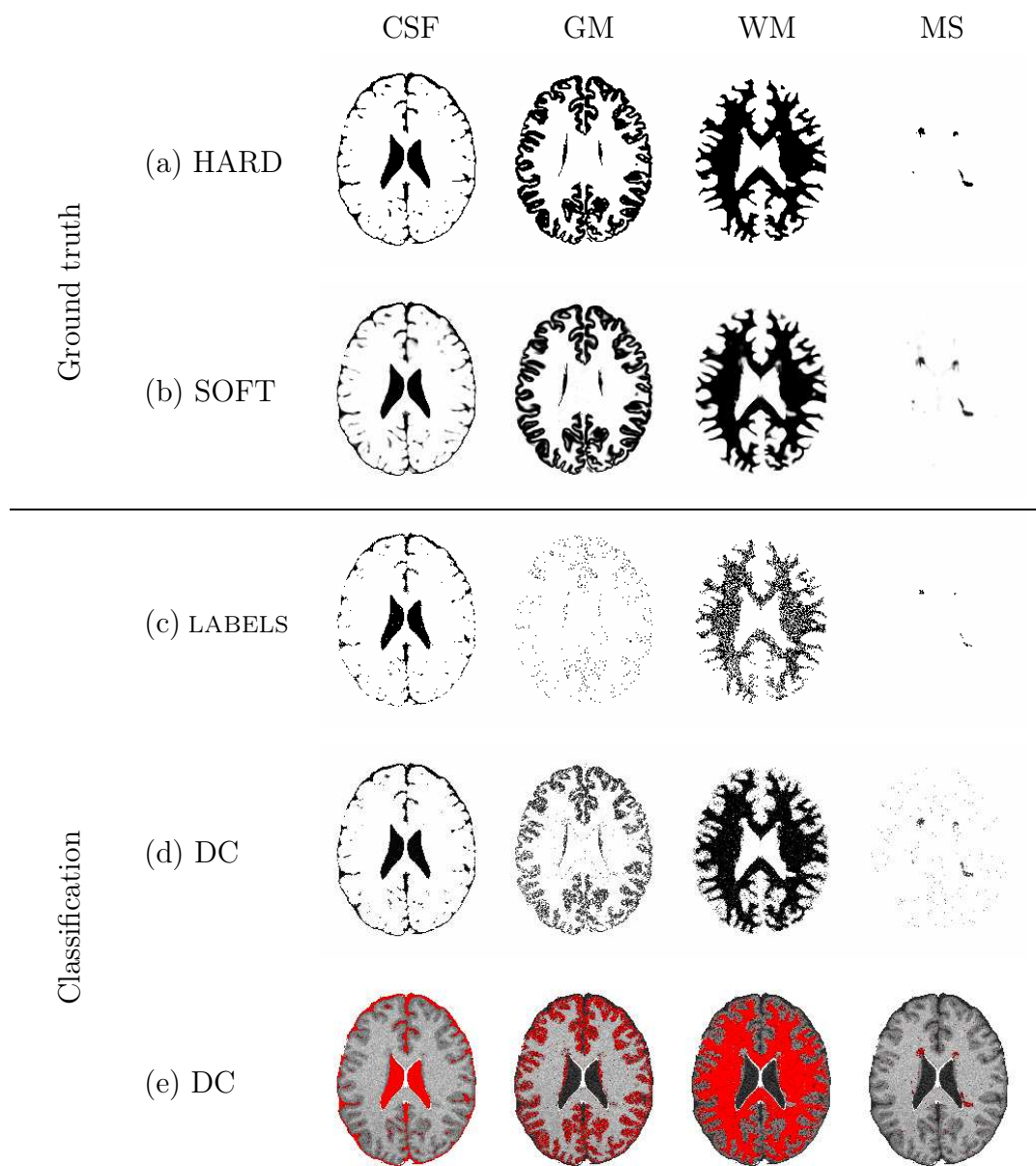


Figure S11: Results for the segmentation using simulated Brainweb data with lesion, *9% noise level and with inhomogeneity*. The first two rows show the ground truth, both with hard (a) and soft (b) class assignments. The LABELLED VOXELS are shown in (c). The DC results (soft segmentation), representing our estimation of PVI, are displayed in the row (d). Row (e) shows the same DC results, overlaying a T1 sequence. The classes shown are CSF, grey matter, white matter and MS lesion, from left to right respectively. **Similar to Figure 4 in the main article**, but for a different noise level and with inhomogeneity.

5 Illustrative results for the Grand Challenge training data

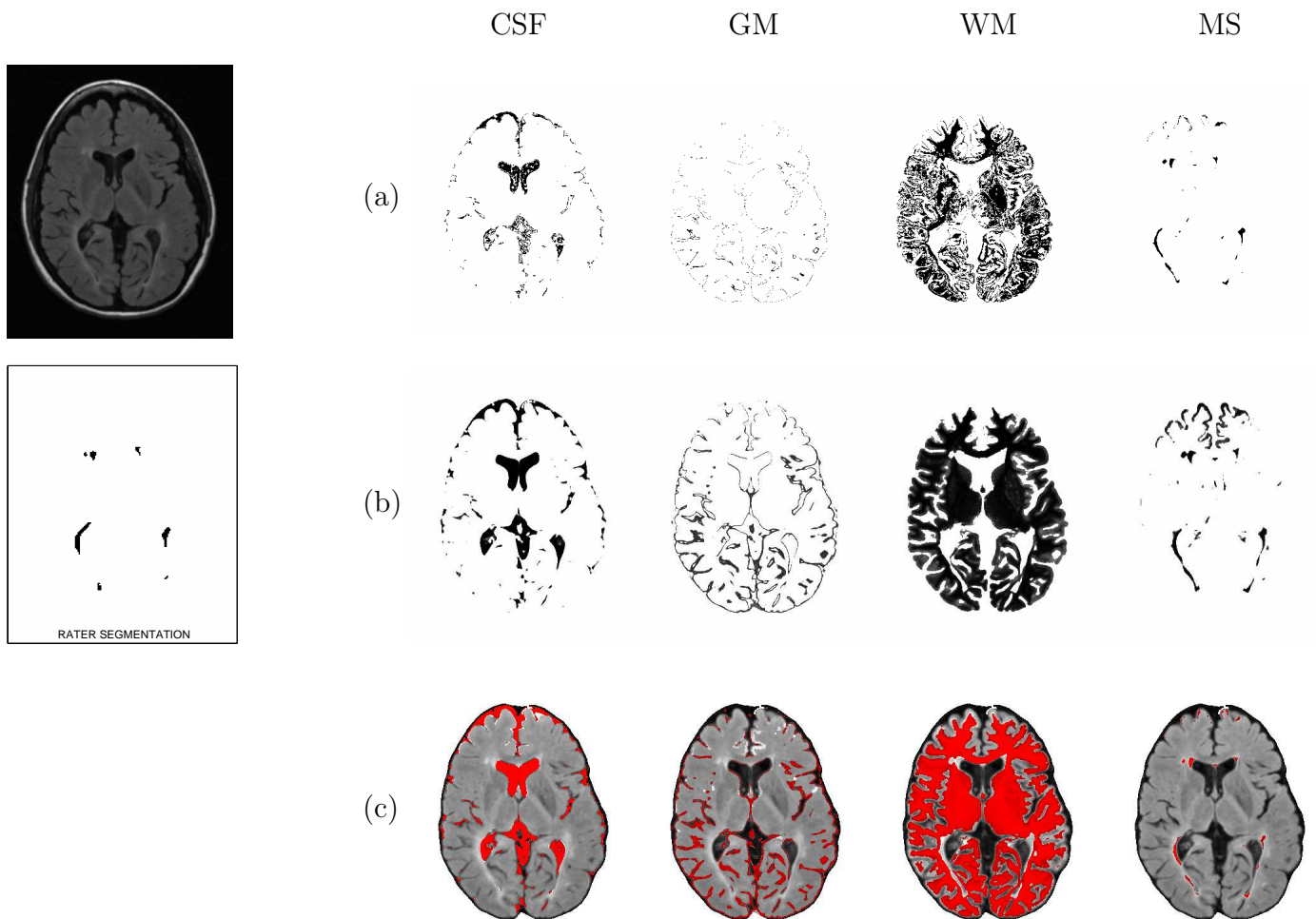


Figure S12: Segmentation results for Case01 of CHB training set from the Grand Challenge data set. The LABELLED VOXELS are shown in (a) and the soft segmentation obtained by DC is displayed in (b) and (c), without and with a FLAIR background. The classes exhibited are CSF, GM, WM and MS, from left to right, respectively. The lesion segmentation, provided by an expert rater, is shown on the left middle frame, while the original FLAIR image is shown on the top left frame. **Similar to Figure 6 in the main article**, for a different training set patient.

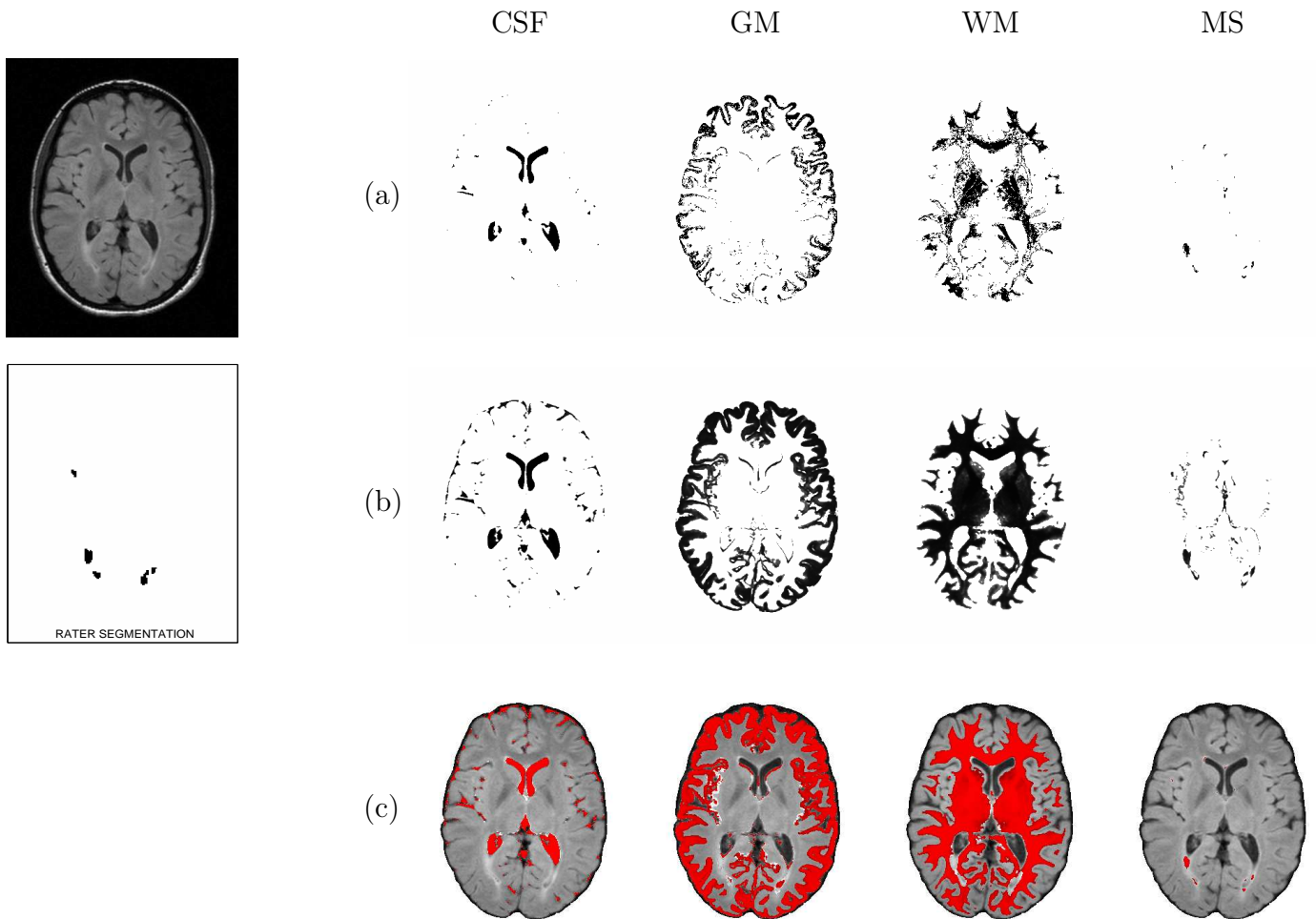


Figure S13: Segmentation results for Case02 of UNC training set from the Grand Challenge data set. The LABELLED VOXELS are shown in (a) and the soft segmentation obtained by DC is displayed in (b) and (c), without and with a FLAIR background. The classes exhibited are CSF, GM, WM and MS, from left to right, respectively. The lesion segmentation, provided by an expert rater, is shown on the left middle frame, while the original FLAIR image is shown on the top left frame. **Similar to Figure 6 in the main article**, for a different training set patient.

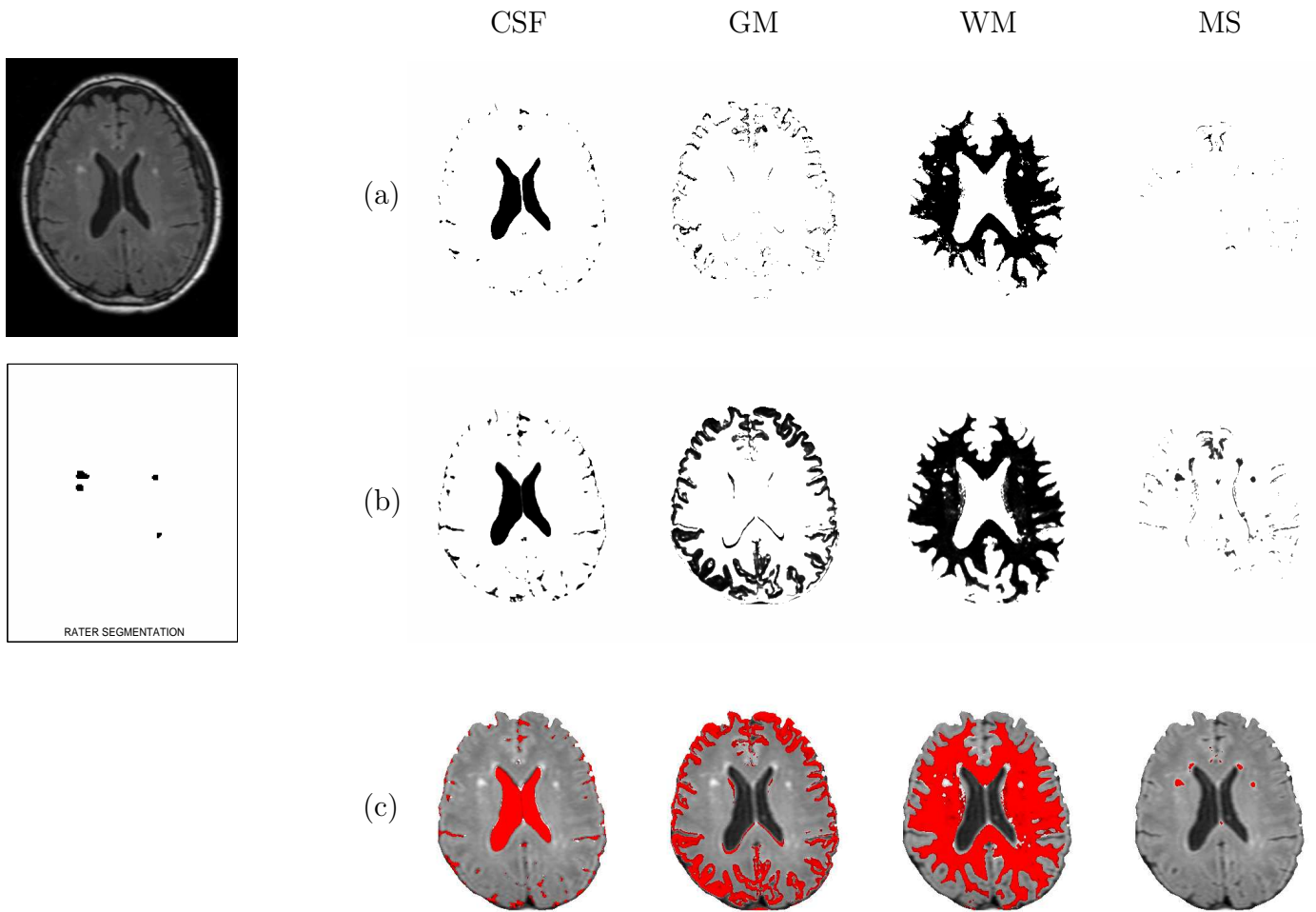


Figure S14: Segmentation results for Case06 of UNC training set from the Grand Challenge data set. The LABELLED VOXELS are shown in (a) and the soft segmentation obtained by DC is displayed in (b) and (c), without and with a FLAIR background. The classes exhibited are CSF, GM, WM and MS, from left to right, respectively. The lesion segmentation, provided by an expert rater, is shown on the left middle frame, while the original FLAIR image is shown on the top left frame. **Same subject as in Figure 6 in the main article.**

6 Illustrative results for the Grand Challenge test data

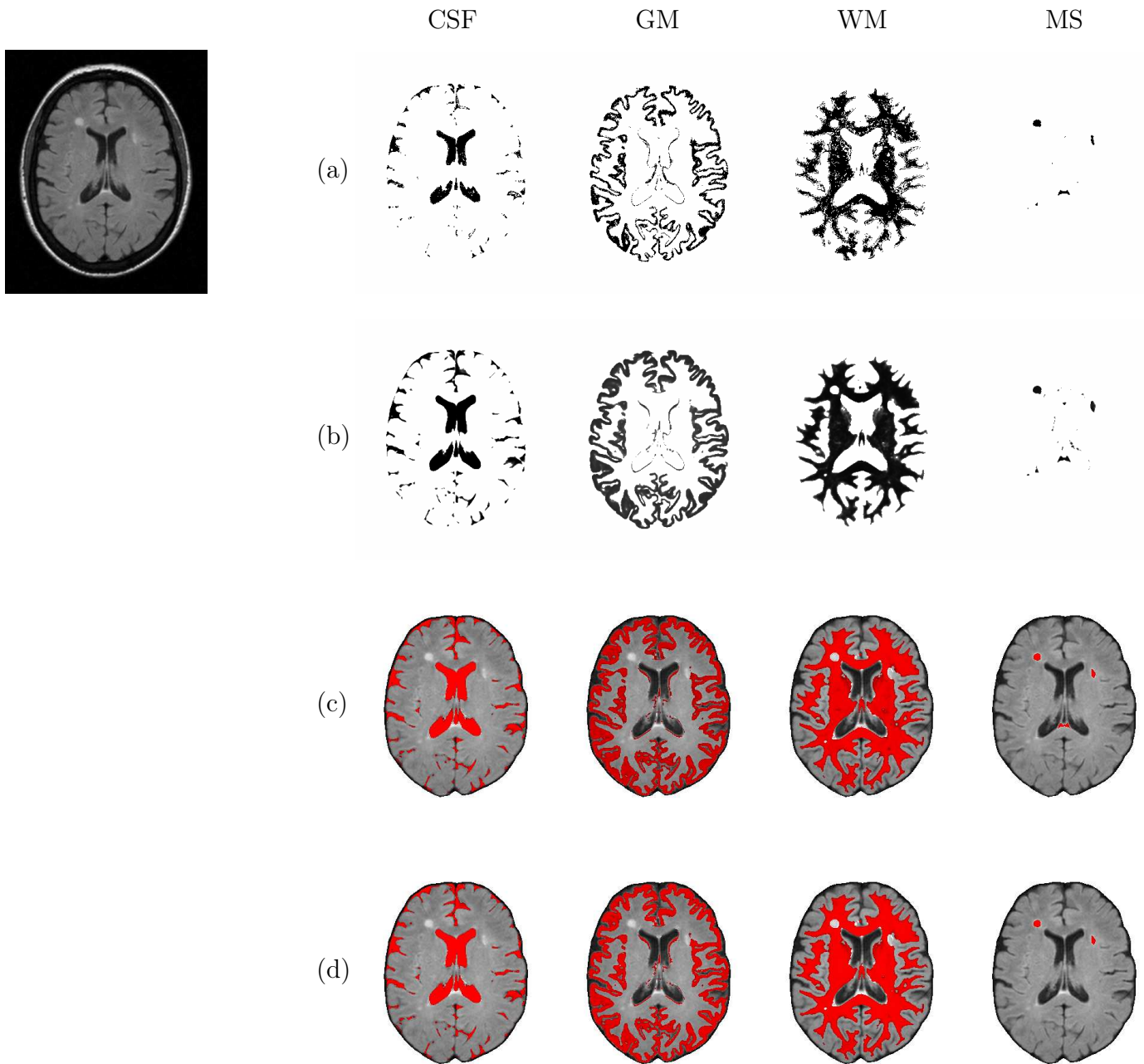


Figure S15: Segmentation results for Case08 of UNC test set from the Grand Challenge data set. The LABELLED VOXELS are shown in (a) and the soft segmentation obtained by DC is displayed in (b) and (c), without and with a FLAIR background. The classes exhibited are CSF, GM, WM and MS, from left to right, respectively. The lesion segmentation, provided by an expert rater, is shown on the left middle frame, while the original FLAIR image is shown on the top left frame. **Similar to Figure 6 in the main article**, for a test set patient and with the segmentation images after using the post-processing prior in row d).

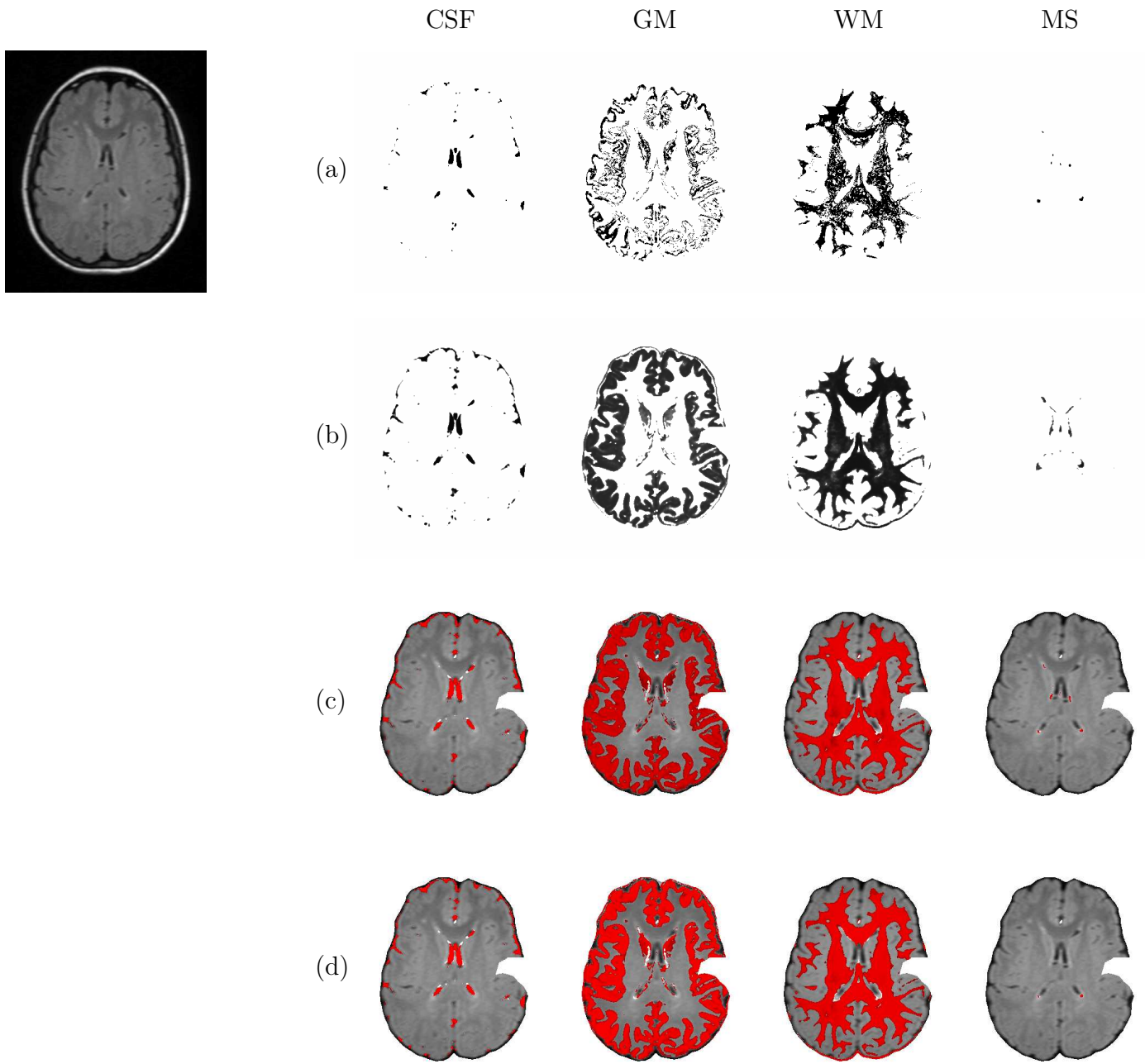


Figure S16: Segmentation results for Case10 of UNC test set from the Grand Challenge data set. The LABELLED VOXELS are shown in (a) and the soft segmentation obtained by DC is displayed in (b) and (c), without and with a FLAIR background. The classes exhibited are CSF, GM, WM and MS, from left to right, respectively. The lesion segmentation, provided by an expert rater, is shown on the left middle frame, while the original FLAIR image is shown on the top left frame. **Similar to Figure 6 in the main article**, for a test set patient and with the segmentation images after using the post-processing prior in row d).

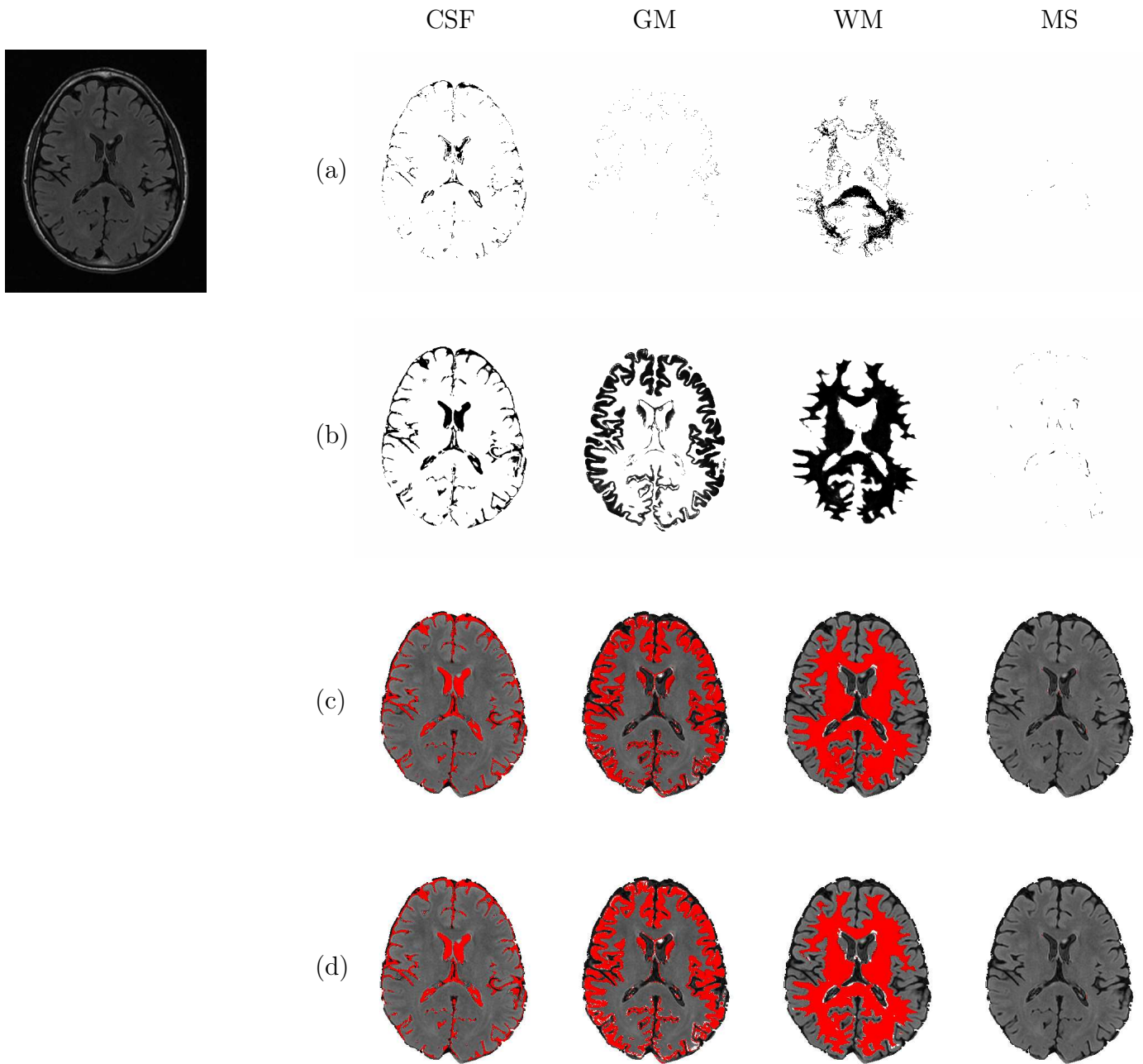


Figure S17: Segmentation results for Case05 of CHB test set from the Grand Challenge data set. The LABELLED VOXELS are shown in (a) and the soft segmentation obtained by DC is displayed in (b) and (c), without and with a FLAIR background. The classes exhibited are CSF, GM, WM and MS, from left to right, respectively. The lesion segmentation, provided by an expert rater, is shown on the left middle frame, while the original FLAIR image is shown on the top left frame. **Similar to Figure 6 in the main article**, for a test set patient and with the segmentation images after using the post-processing prior in row d).