Elastic Registration Based Neonatal Brain Segmentation

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Introduction

Premature born infants carry a high risk for impaired neurodevelopment. Early identification of patients at risk for neurodevelopmental disabilities may lead to intervention programs improving longterm outcome. Disabilities may be predicted by volume measurement of different brain structures. Accurate volumetric neonatal methods already exist, however might be improved. Since head shapes of preterm infant at term equivalent age vary due to deformation of the skull because of prone position often necessary for their respiratory problems. Differences in head size and shape might influence the quality of the segmentation. This paper presents a major improvement on our existing method[1], that minimizes the influence of these diffences. The new method performs segmentation on the T1-weighted and T2-weighted image of the brain structures unmyelinated white matter (UWM), cortical gray matter (GM), basal ganglia and thalamus (BG), and cerebro-spinal fluid (CSF), ventricles (VENT), brainstem (BS), cerebellum (CB), and myelinated white matter (MWM) simultaneously. The method is fully automatic, and based on the K-Nearest Neighbor (KNN) classification technique using multi-spectral information. The improvement concerns correction of the feature space, performed by elastic registration.

Methods

The algorithm uses two types of regular MRI-scans: 3D-T1 and T2. MR images acquired at term age of seven newborn children were included in this study. All patients were manually segmented into the eight tissue types: UWM, GM, BG, CSF, MWM, VENT, BS and CB. These manual segmentations were used for training of the method and considered as gold standard. Three preprocessing steps were performed on the data: (1) rigid registration[2] (intra patient); (2) generation of a brain mask by the BET-tool[3]. Voxels were classified by KNN-classification based on a probabilistic segmentation method[4]. The procedure generated eight probabilistic segmentations (probability maps), indicating per voxel the probability of being one of the tissue classes. Each patient was segmented using the training data composed from the manual segmentations of the six other segmentations (leave-one-out). Two types of features were applied: (1) voxel intensity values of the 3D-T1 and the T2 scans, (2) spatial features: coordinates x, y and z. Before classification the learning samples were corrected into the feature space of the classified patient. This was performed by elastic registration of the training data to the classified patient[2]. All features were consequently scaled to a mean of 0 and a variance of 1 to create a proper metric for distance measurement inside the feature space. After KNN-classification thresholds were applied to the probability maps, resulting in binary segmentations. Evaluation was performed by comparison of the binary segmentations with the manual segmentations. The sensitivity, specificity, and Dice similarity index (SI) over the binary segmentations were calculated. The SI is defined by:

$$\mathrm{SI} = \frac{2 \times (Ref \cap Seg)}{Ref + Seg}$$

with: Ref: the area of the reference (gold standard), Seg: the segmentation area.

Results

Figure 1 shows T2 images of one patient with the classification results. Examples were taken from different slices, such that all structures are shown. Table 1 presents the sensitivity, specificity and SI of the binary segmentations.

Discussion

KNN-classification provides a powerful technique for probabilistic segmentation of brain tissue in neonatal MRI. The proposed method substantially improves the segmentation, giving significantly higher values on the similarity measures. The proposed method can be applied for segmentation of eight different tissue types simultaneously, resulting in high sensitivity, specificity, and SI for CSF, GM, BS, UWM, VENT, CB, and BG. Finally, the method is based on the information from only two routine diagnostic MR scans, and is therefore suitable for large and longitudinal population studies involving neonatal brain analysis.

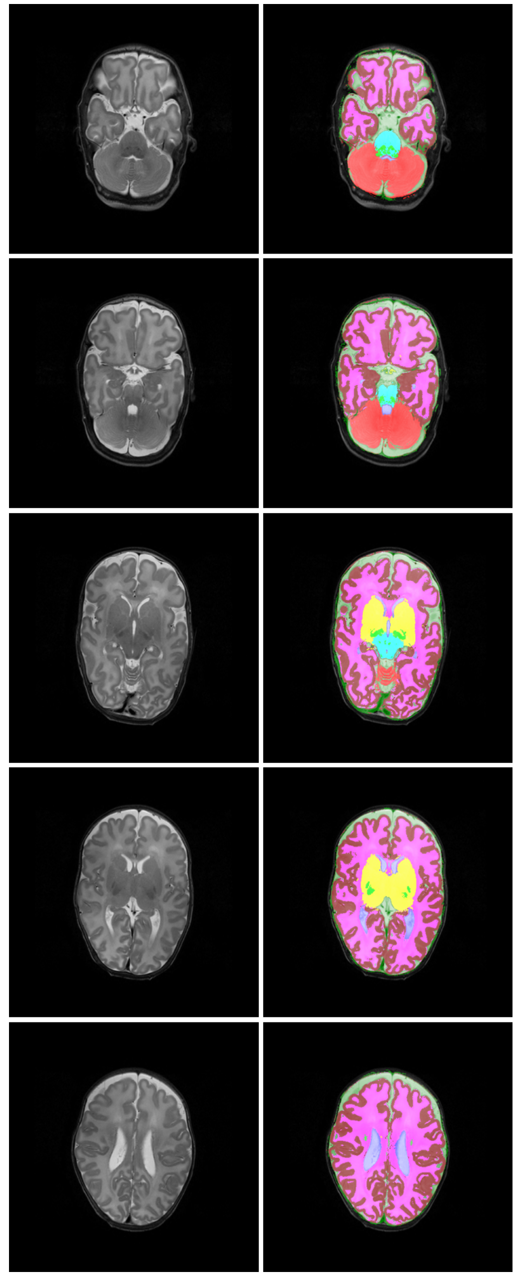

Figure 1: T2-weighted MRI and segmentation of eight tissue types in different regions of the neonatal brain.

Table 1. Similarity measures of the segmentations of eight tissue types

Tissue type	Sensitivity	Specificity	Dice SI	Tissue type	Sensitivity	Specificity	Dice SI
CB	0.918	0.996	0.924	BS	0.878	0.998	0.857
BG	0.915	0.997	0.920	VENT	0.847	0.998	0.856
UWM	0.898	0.954	0.898	CSF	0.765	0.970	0.801
GM	0.908	0.940	0.882	MWM	0.665	0.998	0.623

Ref: [1]P Anbeek et al. ISMRM (2009), [2]M Staring et al. Phys Med Biol. 52: 6879-92 (2007); [3]SM Smith. Hum Brain Mapp. 17: 143-55 (2002); [4]P Anbeek et al. Pedriatr Res. 63: 158-63 (2008)