Automated whole brain segmentation of T2w MRI brain scans of rats exposed to organophosphates using a U-Net neural network

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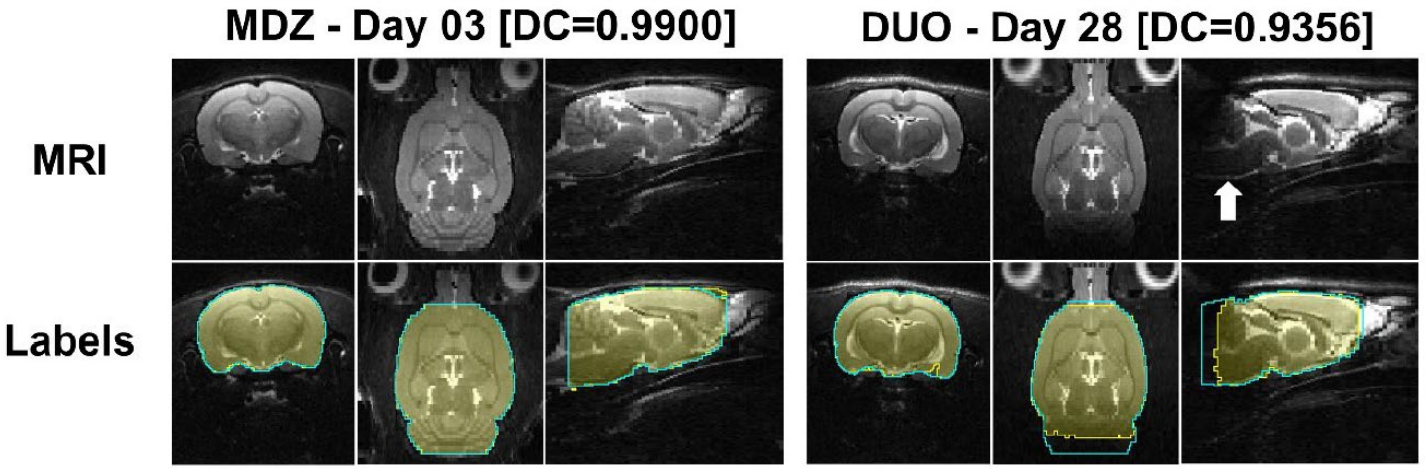
Introduction: Whole brain delineation (WBD) is a common technique used in neuroimaging analysis to remove non-brain signals from brain measures of interest and improve the accuracy of automated co-registration techniques. However, current WBD methods perform poorly on images that show large deformations due to neuropathology, like from organophosphate intoxication (OPI). The 2D U-Net convolutional neural network (CNN) has shown promise for brain MRI segmentation in multiple species. We optimized and evaluated a 2D U-Net CNN for WBD on MRI brain scans from an OPI rat model.

Methods: The CNN had a modified 2D U-Net architecture. We optimized the training parameters and data augmentation functions to improve training accuracy. Our data consisted of T2-weighted MRI brain scans (n=120 scans, voxel size: 125x125x500µm, matrix size: 280x200x59, acquired on a Bruker BioSpec 7T scanner, phased array coil) and matching manually segmented WBD labels. Scans were of adult Sprague Dawley rats from an OPI (diisopropylfluorophosphate (DFP)) study that compared novel therapies (midazolam (MDZ), allopregnanolone (ALO), and MDZ and ALO (DUO)) to untreated, DFP-exposed animals (DFP) and vehicle controls (VEH) across three timepoints (3-, 7-, and 28-days post-OPI). The training and test datasets consisted of 100 scans (DFP=23, MDZ=23, ALO=21, DUO=21, VEH=12) and 20 scans (DFP=4, MDZ=4, ALO=4, DUO=4, VEH=4). MRI scans were preprocessed: N4ITK bias correction, center-cropping (to [200x200x59]), and down sampling (to [128x128x59]). To evaluate CNN performance, Dice coefficients (DC) were calculated between CNN-generated labels and manual segmentations.

Results and Conclusion: The CNN-generated labels achieved a DC (median[range]) of 0.9836[0.9356-0.9900] across all scans, indicating excellent segmentation accuracy. The training runtime was 30 minutes, while application runtime is ~10 seconds/scan. We conclude that a 2D U-Net CNN provided a fully automated, efficient, and accurate segmentation approach. Future research will include examining the applicability of this WBD CNN on other preclinical disease and animal models.



Comparison of scans segmented manually and with the 2D U-Net CNN. **First row**: three orthogonal views of the MRI image of each scan. **Second row:** both manual and CNN labels overlaid on the anatomical scan. The cyan line is the manual segmentation outline, while the yellow region is the CNN output label. The MZD Day 03 scan achieved the highest DC, while the DUO Day 28 scan achieved the lowest DC. The white arrow shows signal loss in the cerebellum that contributes to lower segmentation accuracy.