**HyperGAN: A generative adversarial network approach for low-field to high-field super resolution image translation**

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**Introduction:** Portable low-field strength (64mT) MRI scanners promise to increase access to neuroimaging for clinical and research purposes but produce images of lower quality and resolution compared to high field strength scanners. In this study, we developed and evaluated a deep learning method to generate high-field quality brain images from low-field inputs using a paired dataset of multiple sclerosis (MS) patients scanned at 64mT and 3T.

**Methods:** A total of 65 MS patients were scanned on portable 64mT (Hyperfine) and standard 3T scanners (Siemens) at Penn or NIH with T1-weighted, T2-weighted and FLAIR acquisitions at both field strengths. Using 32/65 patients, we trained a generative adversarial network (GAN) architecture for low to high field image super resolution and translation which we termed HyperGAN and consisted of two main parts. The first half of HyperGAN (Figure 1A) consists of 3 pix2pix layers in parallel, each trained on a different orthogonal imaging plane with T1, T2, and FLAIR images as input channels. The second half consists of a 3D patch-based U-Net that combines the parallel outputs from the first half into a cohesive volume (Figure 1B). We used the 33 remaining subjects as out-of-sample test subjects.

**Results:** All presented results reflect out-of-sample test subjects. HyperGAN output images demonstrated visually superior quality than input images (Figure 2A). Quantitatively, HyperGAN outputs had 3.5 times higher peak signal-to-noise ratio (PSNR) than input images across the three different acquisition contrasts (Figure 2B). Measuring thalamic volumes, a clinically relevant MS biomarker, using a state-of-the-art segmentation pipeline (SynthSeg), HyperGAN outperformed another published super resolution algorithm (SynthSR) in producing results approximating 3T (Figure 2C) and correcting undersegmentation seen at 64mT. Total MS lesion volume based on automated segmentation (MiMOSA) was comparable between 64mT, HyperGAN and 3T, but lesions appeared more conspicuous in HyperGAN outputs than original input images (Figure 2D).

**Conclusions:** HyperGAN generates synthetic high-field images that have comparable visual and quantitative quality, regional volumetry, and lesion burden as their paired high-field counterparts.

**Clinical Relevance:** Enhancing portable low-field MRI image quality can boost clinician confidence, leading to wider adoption of these affordable, accessible technologies, benefiting patients who may not have had access to MRI imaging before.

**Figure 1 - Overview of the HyperGAN architecture: Panel A** shows the first half of the architecture which trains a pix2pix model, with T1, T2 and FLAIR as RGB channels, for each orthogonal imaging plane. **Panel B** shows the overall architecture with the patch-based 3D U-net combining the outputs of the first half into a cohesive volume.

**![Graphical user interface

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**Figure 2 – HyperGAN Results:** **Panel A** shows representative coronal slices at 64mT, 3T and after HyperGAN processing, across all three pulse sequences. **Panel B** shows the peak signal-to-noise ratio (PSNR) comparing HyperGAN to 3T (SR-HIFI) and 64mT to 3T (LOFI-HIFI). **Panel C** (left) shows the mean left and right thalamic volumes measured across all test set participants using SynthSeg applied to SynthSR, HyperGAN and 3T data and the corresponding correlations across participants (right). **Panel D.** shows an axial slice with MS lesions (red arrows) at 64mT, 3T and in the HyperGAN output for a single test set participant.

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