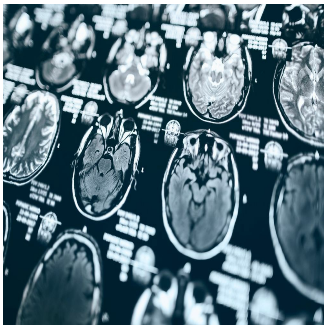
Accelerated 3D FLAIR with Deep Learning



Three-dimensional fluid-attenuated inversion recovery (3D FLAIR) MRI is essential in the diagnosis and monitoring of demyelinating diseases such as multiple sclerosis. However, its adoption in routine clinical practice has been hindered by long acquisition times. Conventional acceleration techniques, while improving efficiency, often compromise image quality. A recent clinical study evaluated a physics-informed deep learning (DL) reconstruction approach for ultrafast 3D FLAIR MRI, comparing it to the state-of-the-art Wave-CAIPI technique. The results suggest that DL-based 3D FLAIR imaging not only shortens scan time but also enhances image quality, while maintaining diagnostic reliability and quantitative consistency.

Deep Learning Reconstruction with Physics-Informed Architecture

The study introduced a novel two-step deep learning-based reconstruction method incorporating an unrolled variational network and a super-resolution algorithm. This architecture integrates MRI physics directly into the network design. Unlike image-domain approaches that rely solely on convolutional neural network filtering, the unrolled network iteratively refines images by alternating between regularisation and data consistency steps. This method handles undersampled k-space data more effectively, supporting greater acceleration with less image degradation. The approach was embedded into the scanner pipeline, allowing for prospective use during image reconstruction.

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Participants underwent brain MRI scans on a 3-T system using both Wave-CAIPI and DL-based 3D FLAIR protocols. The DL protocol employed a 6-fold Cartesian undersampling scheme, while the Wave-CAIPI method used a more established aliasing approach. Both maintained equivalent resolution at $1 \times 1 \times 1$ mm^3, but the DL-FLAIR protocol achieved this in significantly less time—1 minute 53 seconds compared to 2 minutes 50 seconds for Wave-CAIPI. This improvement in speed did not compromise image fidelity; rather, it enabled enhanced anatomical detail and lesion visibility.

Qualitative and Quantitative Validation

In total, 88 participants were included in the final analysis, with the majority undergoing imaging for suspected or confirmed multiple sclerosis. Four neuroradiologists assessed the images using standardised criteria, including image quality, lesion conspicuity, anatomical detail and artifacts. DL-FLAIR significantly outperformed Wave-CAIPI across all qualitative measures. For example, 97.4% of DL-FLAIR images were rated good or excellent in image quality compared to 85.7% for Wave-CAIPI. Improvements were especially notable in lesion conspicuity across periventricular, cortical and infratentorial regions.

Quantitative assessments supported these findings. Lesion count and volume derived from DL-FLAIR showed high intraclass correlation with Wave-CAIPI results, with coefficients of 0.95 and 0.98 respectively. DL-FLAIR also demonstrated superior signal-to-noise and contrast-to-noise ratios. Brain structure volumes, including white matter, cortical grey matter, subcortical grey matter and cerebrospinal fluid, showed excellent agreement across both imaging techniques. This confirmed the DL method’s reliability for volumetric analyses, which are increasingly critical in both diagnosis and longitudinal monitoring of neurological conditions.

Interchangeability and Clinical Implications

An essential aspect of clinical adoption for new imaging methods is their interchangeability with established protocols. The study employed the individual equivalence index (IEI) to assess whether DL-FLAIR could reliably substitute Wave-CAIPI. The IEI results indicated that DL-FLAIR achieved acceptable equivalence for lesion volume and count in more than 96% of cases. Brain region volumes also met the threshold for interchangeability, further validating the method’s diagnostic compatibility.

The implications for clinical practice are significant. DL-FLAIR not only reduces scan time by 30%, potentially improving patient comfort and scanner throughput, but also provides enhanced diagnostic clarity. The uniform voxel resolution aids multi-planar assessments and meets guideline-recommended standards for multiple sclerosis evaluation. Additionally, the use of Cartesian undersampling and physics-informed learning supports broader integration across scanner models and institutions, reducing reliance on complex hardware or proprietary acceleration techniques.

The study confirmed that deep learning reconstruction using physics-informed unrolled networks can surpass current state-of-the-art techniques in 3D FLAIR brain MRI. DL-FLAIR delivers higher image quality, greater lesion conspicuity and improved noise characteristics while achieving faster acquisition times. Its demonstrated interchangeability with Wave-CAIPI validates it as a clinically viable alternative. As demand for efficient, high-quality neuroimaging grows, DL-FLAIR offers a powerful tool for improving diagnostic workflows in neurological care.

Source: Radiology Advances

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