Conditional Hybrid GAN for Class-Specific 2D Brain MRI Synthesis Using a CNN-Vision Transformer Discriminator

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PURPOSE

Limited availability of labeled brain MRI, particularly for less common tumor subtypes, constrains development of neuroimaging AI tools. Traditional CNN-only GAN discriminators emphasize local texture but fail to enforce long-range anatomic consistency. We develop a class-conditional GAN that improves global anatomic realism by combining convolutional and transformer-based discrimination with progressive transfer learning.

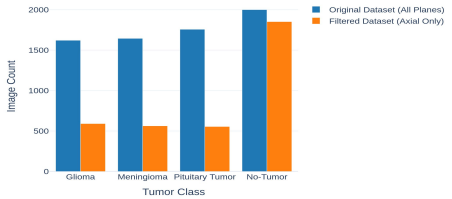
METHODS

Architecture: Conditional Hybrid-cGAN with dual-branch discriminator: spectrally normalized CNN (local texture) + pretrained ViT-Base/16 (global context).

Training: ViT layers progressively unfrozen based on validation metric plateaus to stabilize dynamics.

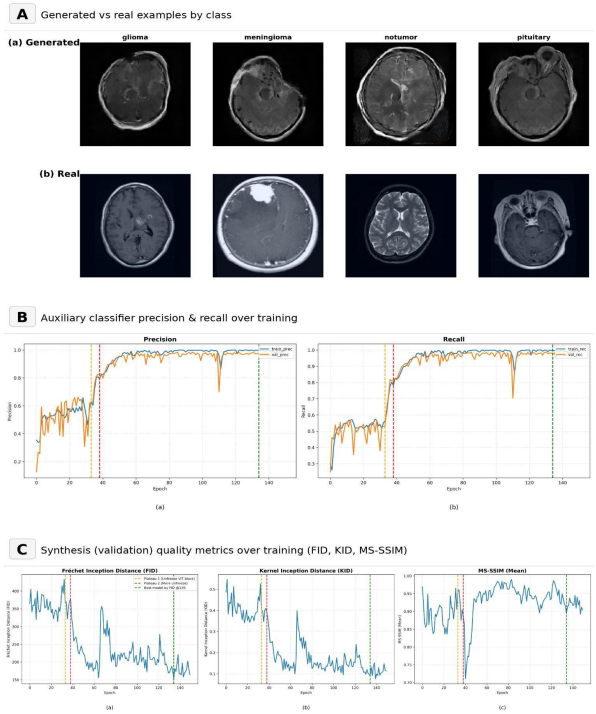
Dataset: 3,561 axial 2D slices, four-class public brain MRI (glioma, meningioma, pituitary, no-tumor)1, split 70/15/15.

Evaluation: FID, KID, MS-SSIM for synthesis quality; auxiliary tumor classifier for class-specific fidelity.



RESULTS

Progressive ViT unfreezing produced stepwise improvements across all synthesis quality metrics:



KEY TEST SET METRICS

149.8	0.086	0.906
FID	KID	MS-SSIM
(↓ better)	(↓ better)	(↑ better)

CONCLUSIONS

- A hybrid CNN-ViT discriminator with metric-guided progressive unfreezing improves training stability and global anatomic coherence in class-conditional brain MRI synthesis.
- Validation FID decreased from >380 to 153; KID from ~0.34 to 0.09; MS-SSIM stable (~0.90).
- Macro-averaged precision and recall remained stable, indicating preserved class-conditional structure without mode collapse.
- Supports potential synthetic data generation for neuroimaging AI in low-data or restricted-sharing clinical settings.

REFERENCES

1. Nickparvar M. Brain Tumor MRI Dataset. Kaggle; 2021. https://doi.org/10.34740/kaggle/dsv/14832123