

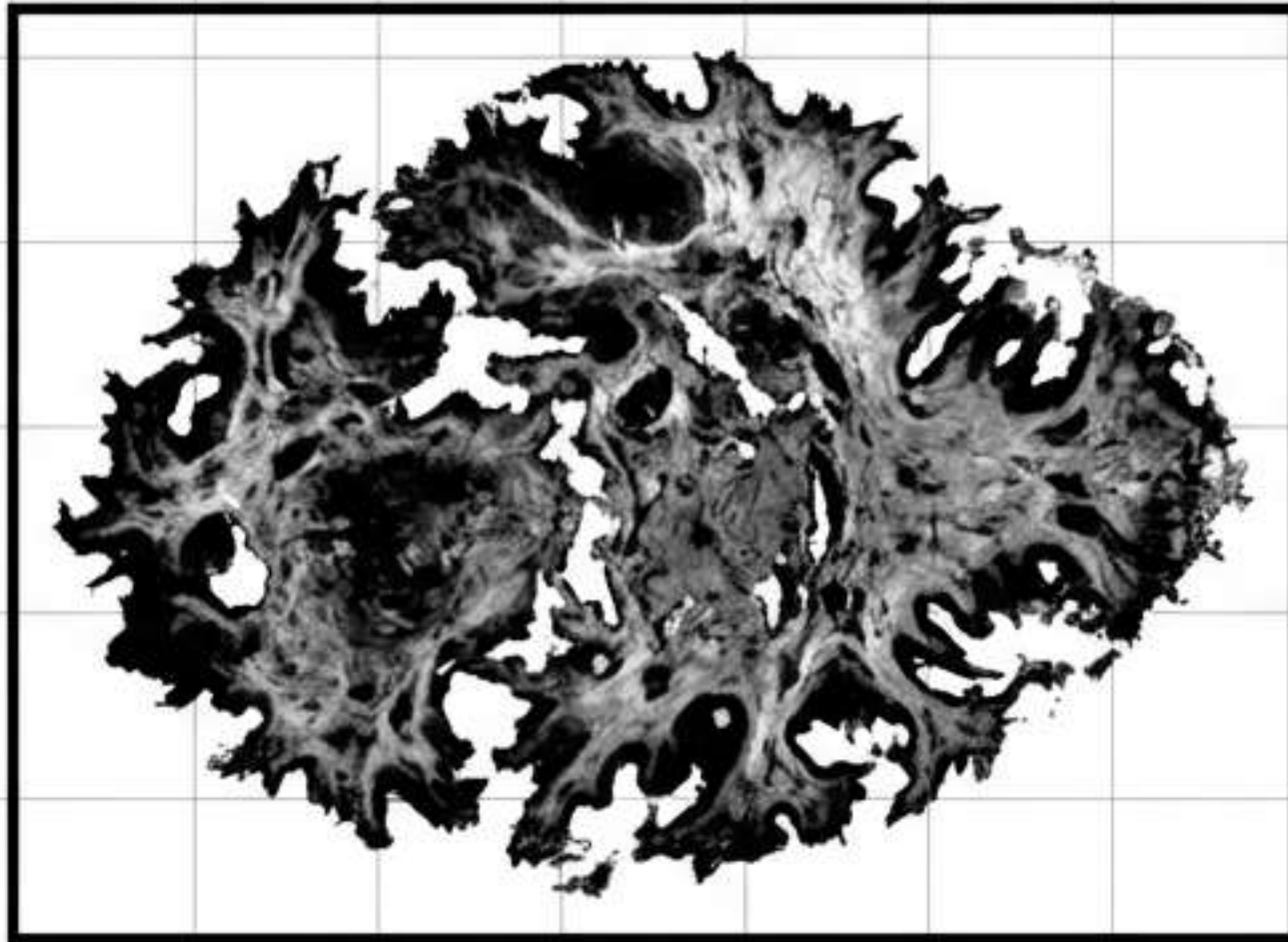
Resolving the PatchGAN Paradox

Architectural Constraints for
Conditional GANs in MRI Brain
Tumor Segmentation

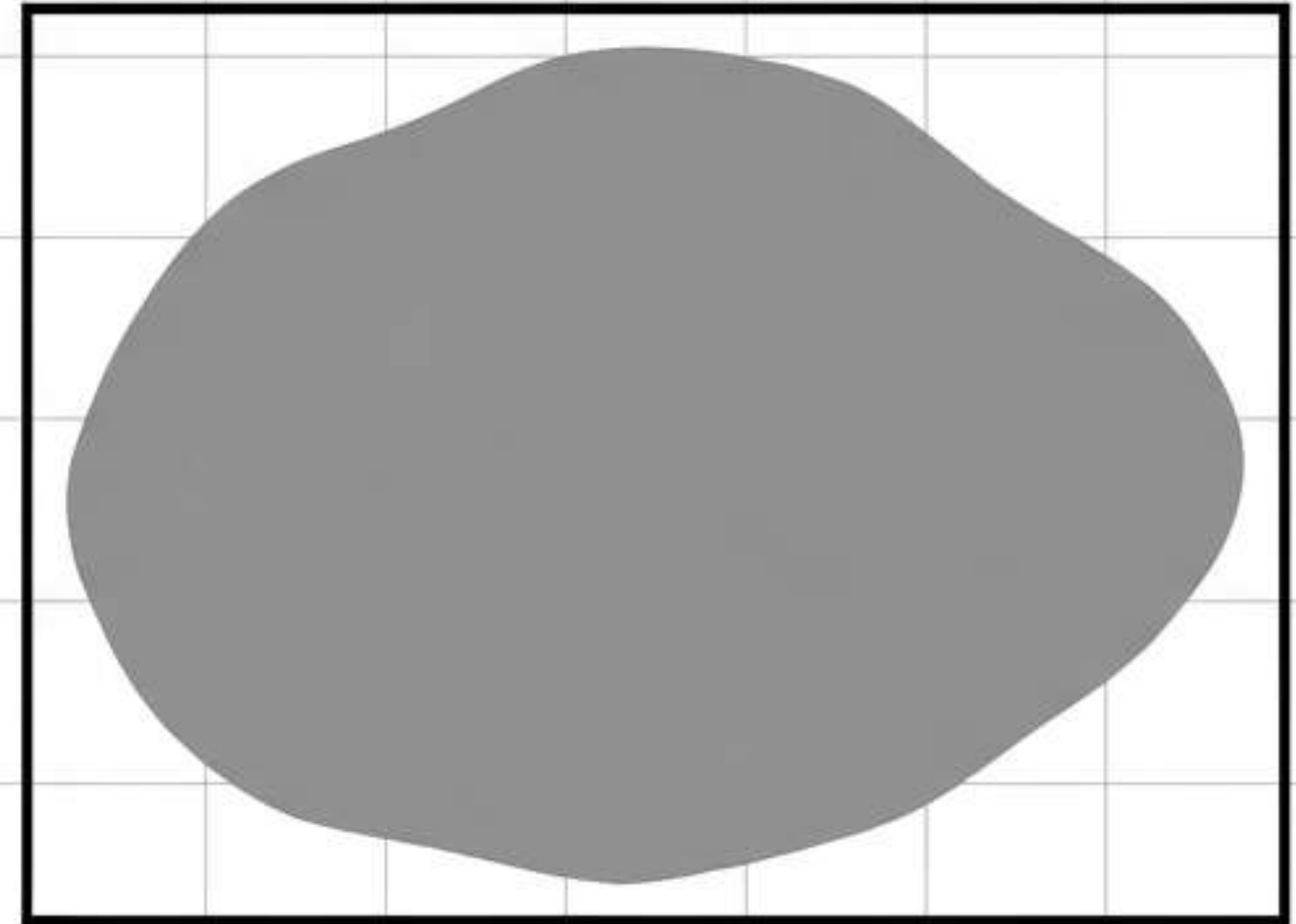
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The U-Net Baseline Trades Anatomical Realism for Mathematical Safety

THE REALITY: MICRO-ANATOMICAL TEXTURE



THE U-NET PREDICTION: OVERLY SMOOTHED BOUNDARY

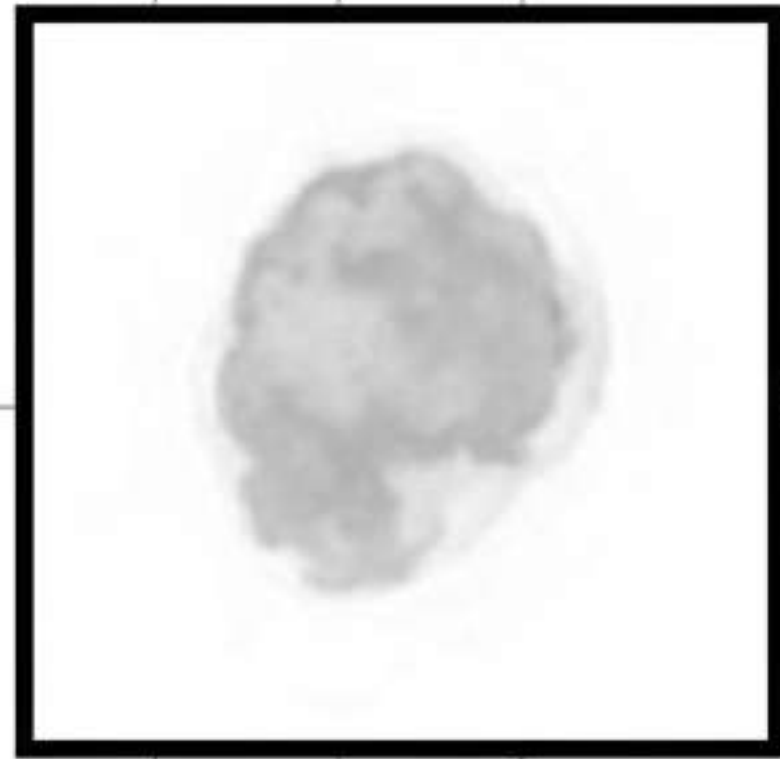


Standard U-Net models trained on pixel-wise loss (Binary Cross-Entropy) predict overly safe, smoothed boundaries.

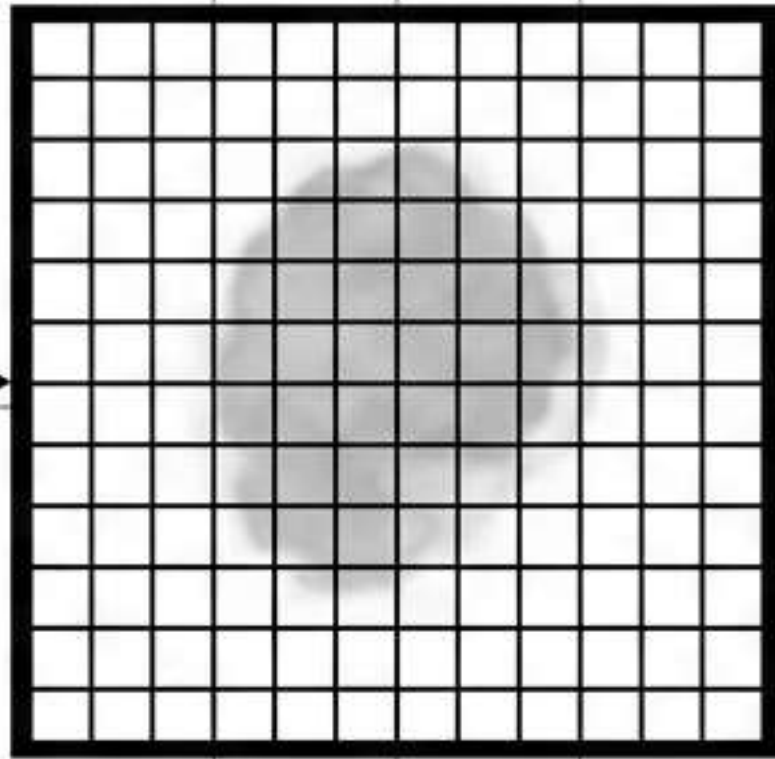
The Bottleneck: They fail to capture high-frequency textures, blurring the critical line between the necrotic core and healthy white matter.

The Goal: Introduce a Conditional GAN with an L1 Segmentation penalty to penalize unrealistic structures.

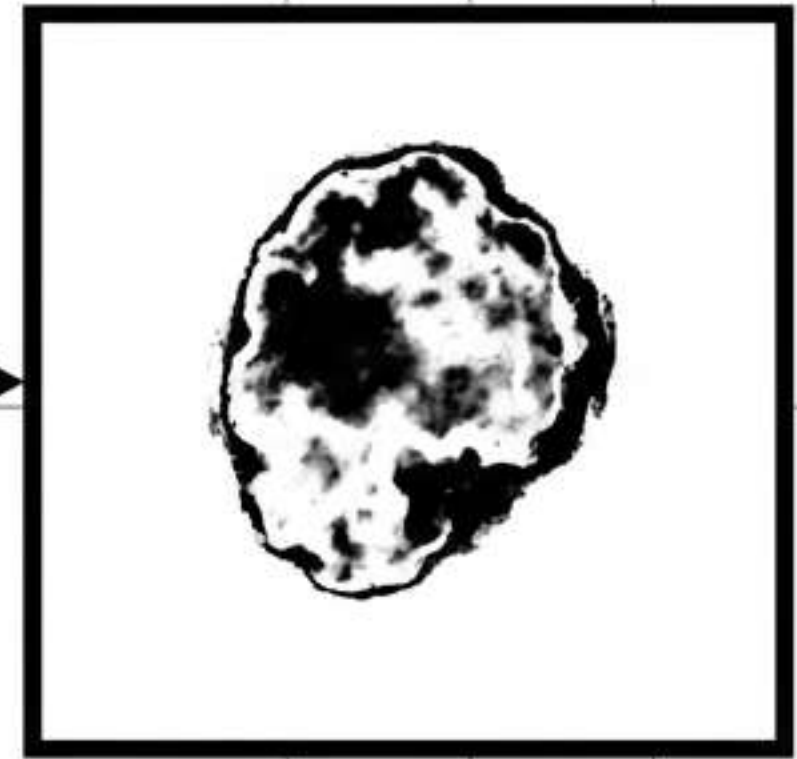
Pre-Processing Catalyst: Forcing Boundary Visibility



Step 1: Raw MRI Slices



Step 2: Tiled Contrast Clipping (CLAHE)



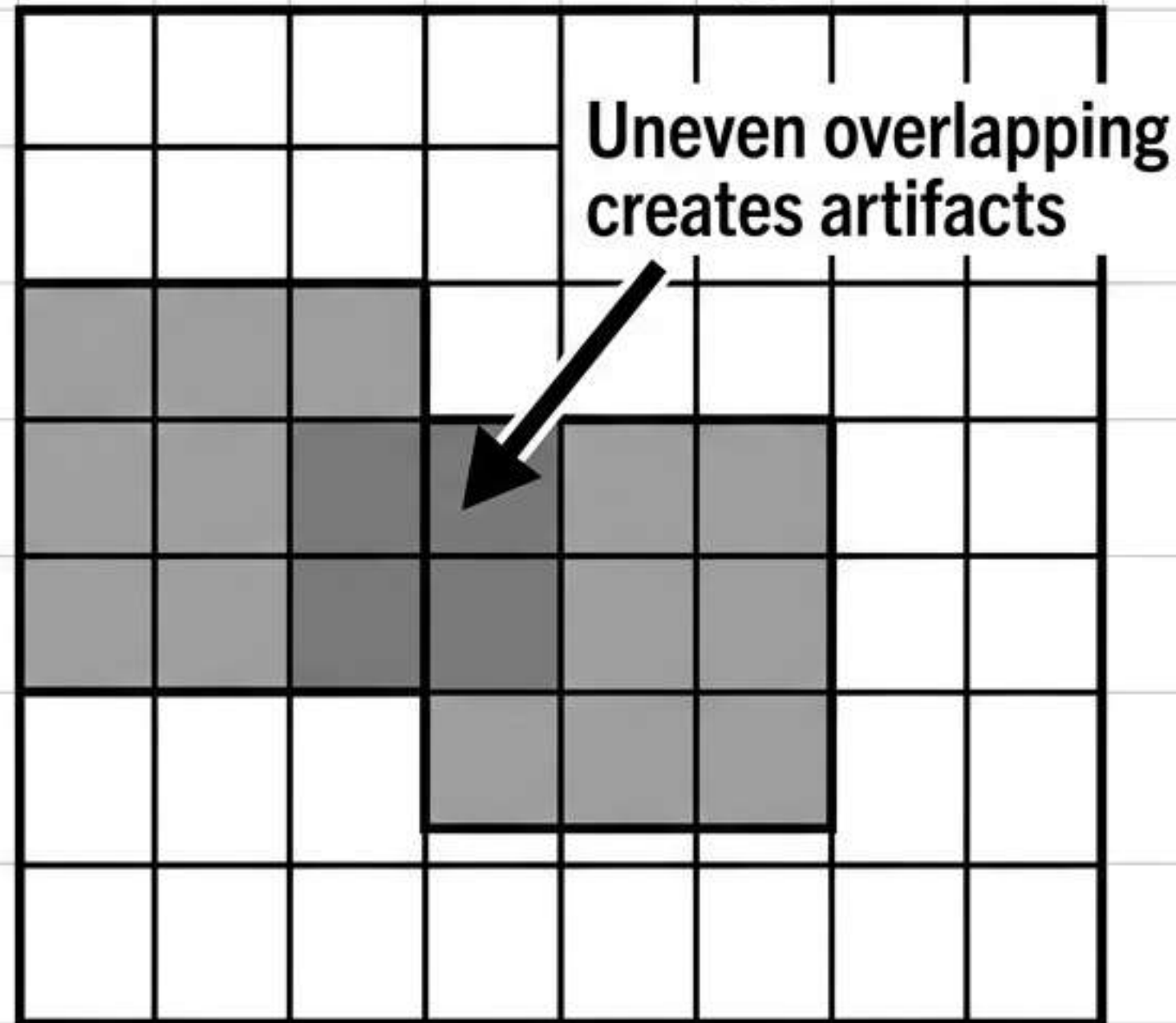
Step 3: Enhanced Boundary Output

Key Insight: Contrast Limited Adaptive Histogram Equalization (CLAHE) mathematically **amplifies low-contrast boundaries** and standardizes tissue intensities. This prevents the Generator from hallucinating structures in poor-contrast regions.

The Artifact Generator: Asymmetrical Receptive Overlap

Model B Configuration

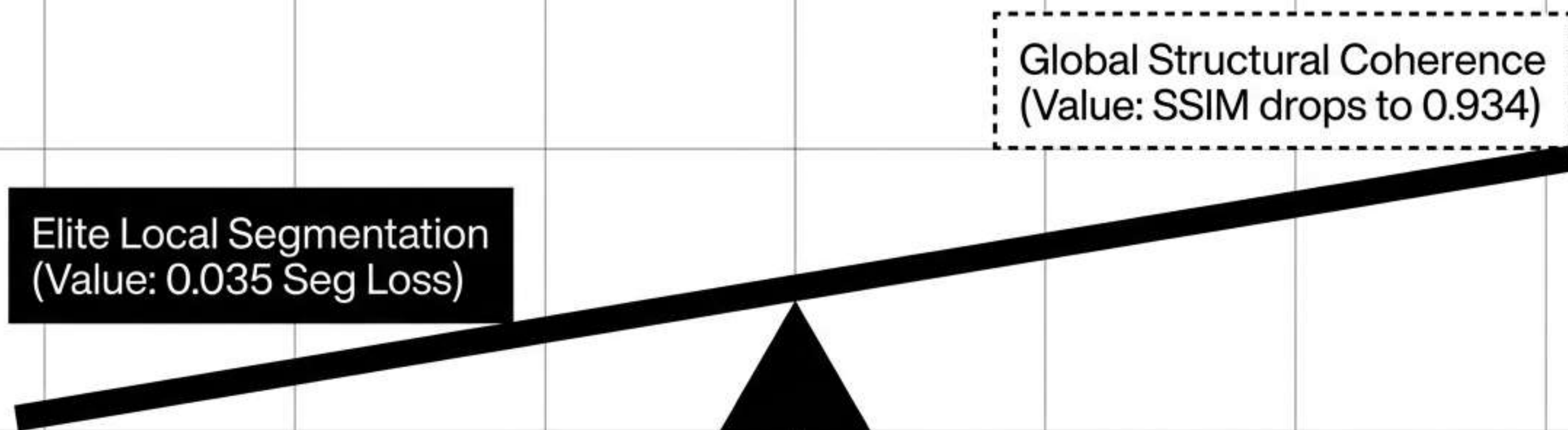
**cGAN with a 3x3
Kernel and a
Stride of 2.**



The Flaw

**An asymmetrical
kernel-to-stride ratio
forces destructive,
high-frequency
checkerboard
artifacts directly
into the predicted
tumor masks.**

The PatchGAN Paradox: When Local Perfection Destroys Global Coherence



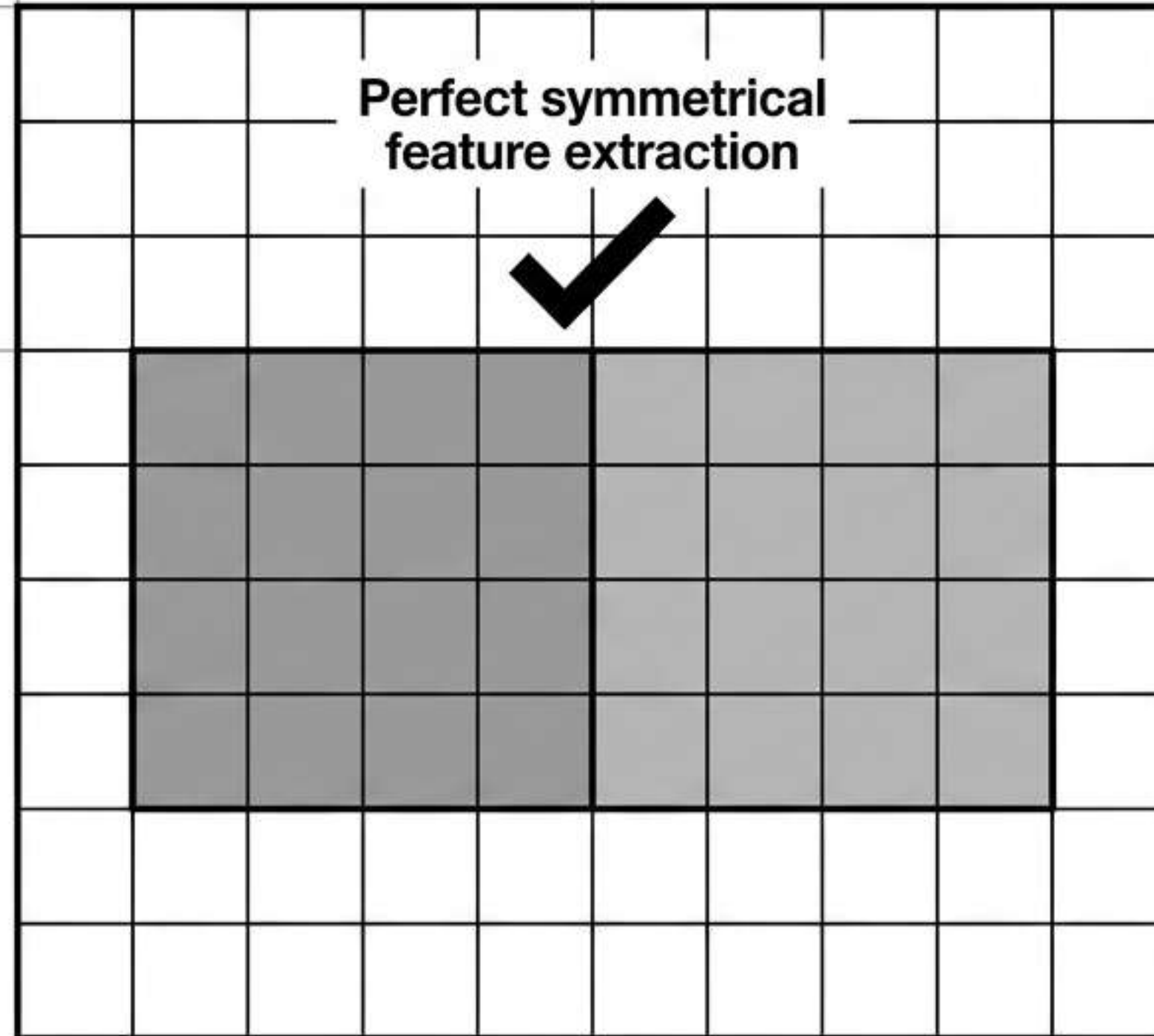
Model C Configuration:
Convolutions locked to a
stride of 1 with 2x2
MaxPooling.

The Paradox: The Discriminator becomes so adept at penalizing local patches that the Generator injects high-frequency micro-textures just to fool it. Hyper-optimization for local texture actively destroys the continuous clinical mask required by radiologists.

The Symmetrical Solution: Achieving the Goldilocks Zone

Model D Configuration

4x4 Kernel, Stride 2.
Outputs a 2D matrix
evaluating a 70x70
overlapping patch.



The Breakthrough

A 4x4 kernel perfectly
divides by a stride of 2,
allowing for
symmetrical feature
extraction without
checkerboard
degradation or sacrificing
global coherence.

Architectural Ablation Study Results

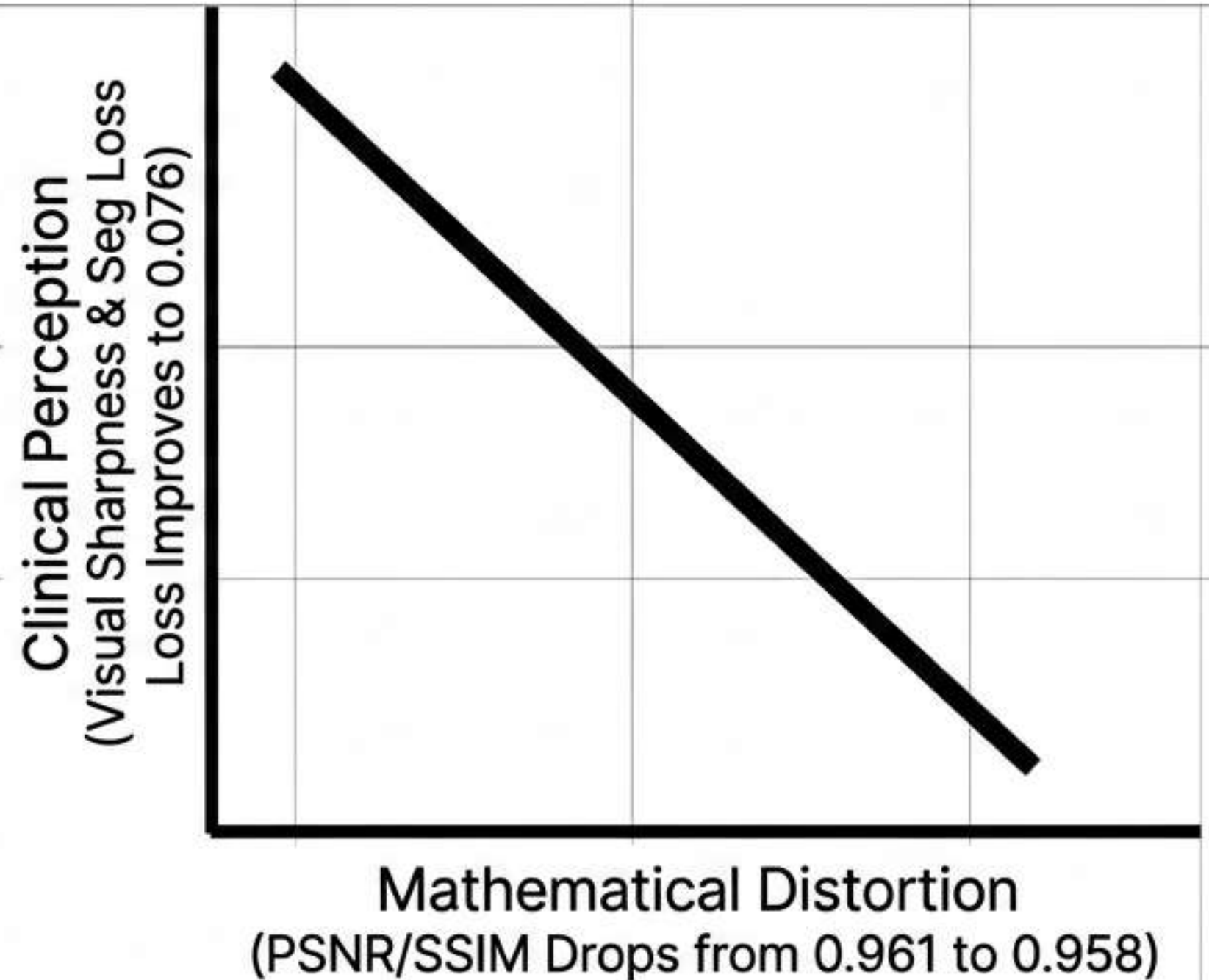
ARCHITECTURE	KERNEL / STRIDE	ARTIFACTS	SEG LOSS	PSNR / SSIM (dB)	VERDICT
Model A (U-Net)	N/A	None	0.140	25.38 / 0.957	Overly Smoothed Baseline
Model B (cGAN)	3x3, Stride 2	Yes (Checkerboard)	0.158	24.63 / 0.951	Structurally Flawed
Model C (cGAN)	3x3, Stride 1	None	0.035	21.61 / 0.934	The PatchGAN Paradox
Model D (Champion)	4x4, Stride 2 (w/ CLAHE)	None	0.076	24.76 / 0.958	Optimal Clinical Balance

Note: Model D prevents checkerboard artifacts, improves Segmentation Loss over the non-enhanced model, and produces highly readable contrast boundaries.

The Perception-Distortion Tradeoff

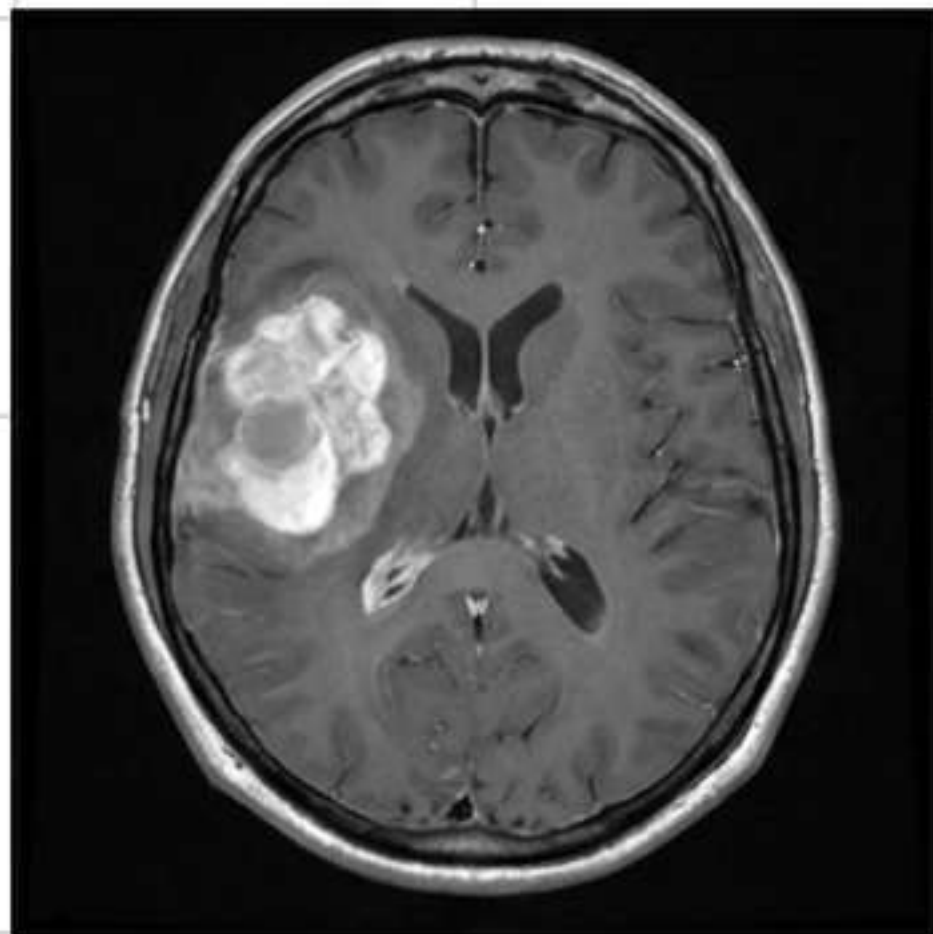
Because CLAHE intentionally forces a stark contrast shift to highlight tumor boundaries, rigid mathematical formulas (PSNR/SSIM) penalize the image, interpreting clinical enhancement as distortion.

The Conclusion: Visual perception and diagnostic clarity in medical imaging supersede strict mathematical distortion metrics. **Worse math equals better medicine.**

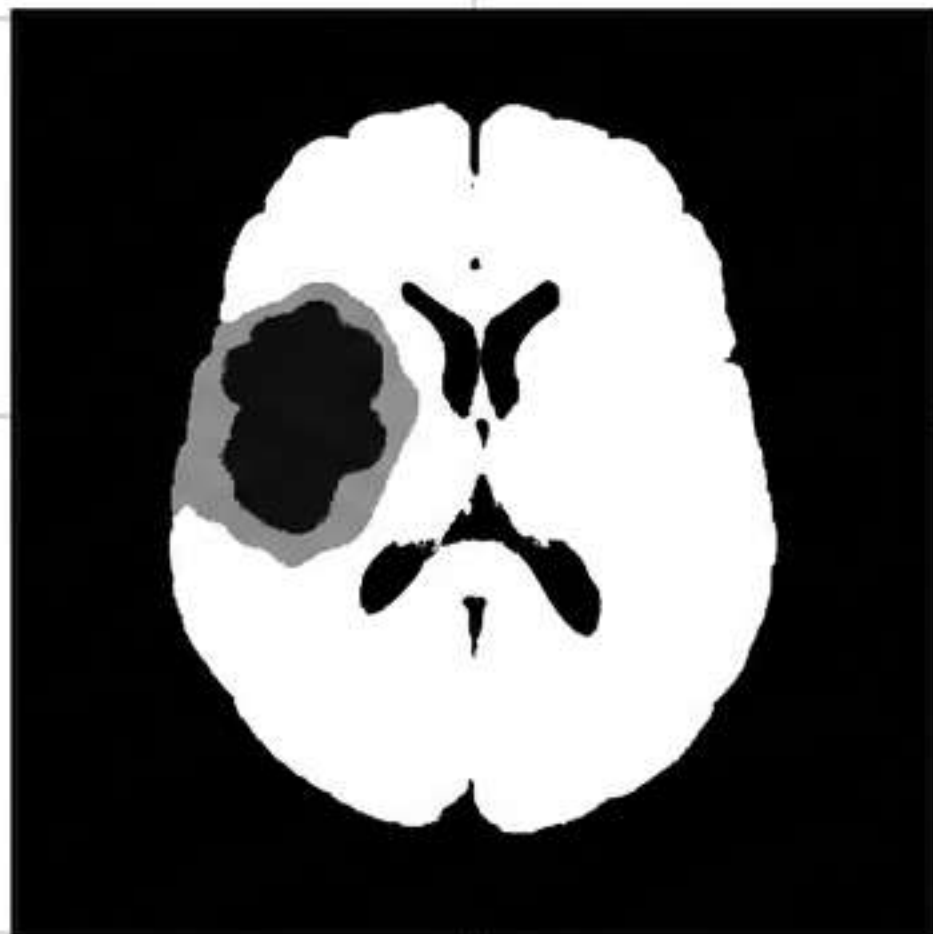


High-Fidelity Anatomical Mapping

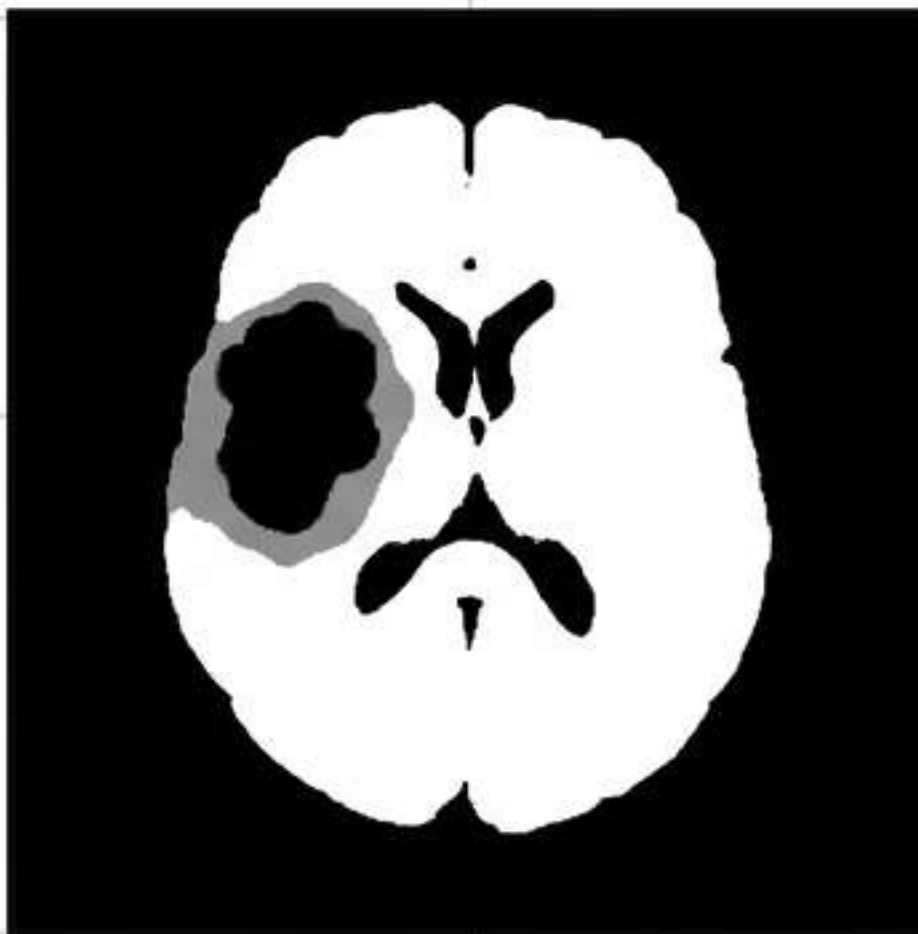
Input MRI



Ground Truth

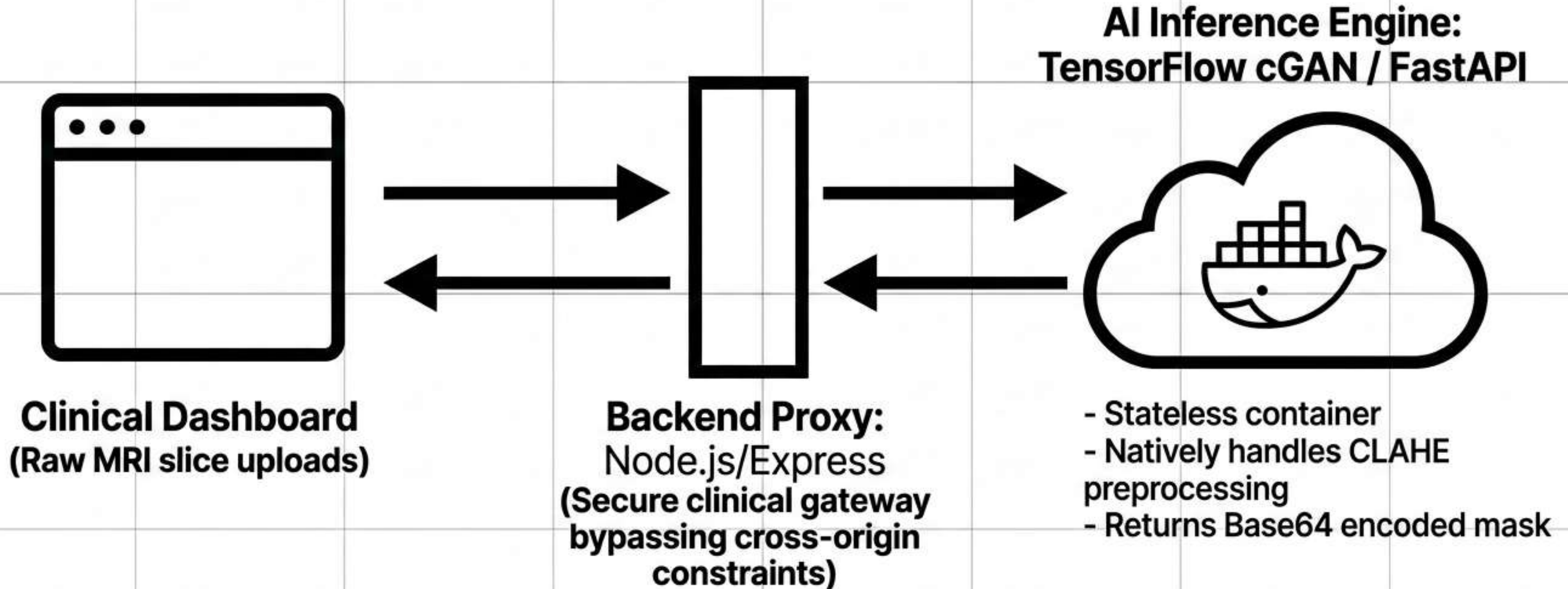


4x4 cGAN Prediction



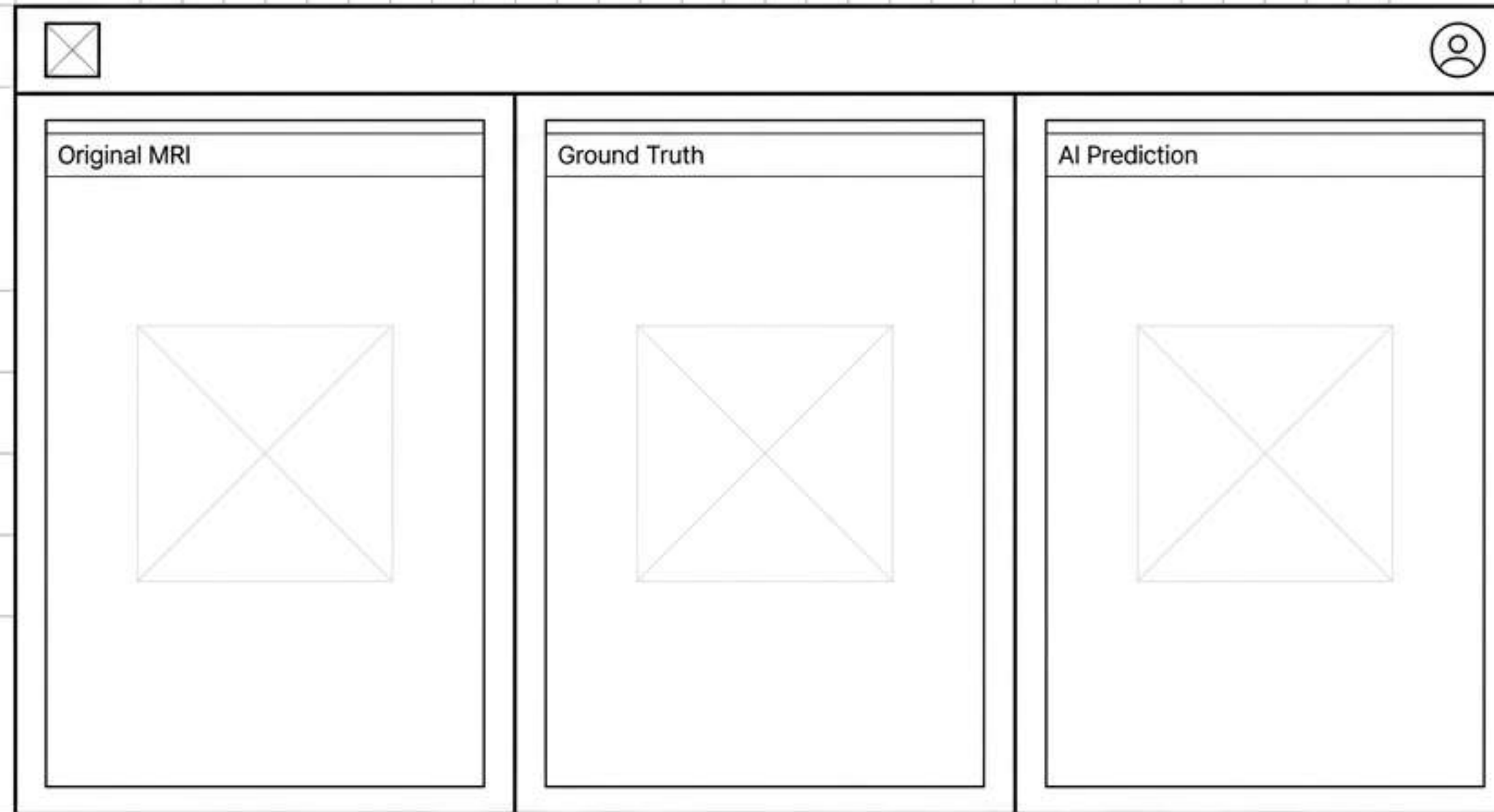
Visual validation of Model D against Ground Truth. The model **successfully** balances **sharp local boundaries** (delineating the necrotic core versus healthy white matter) with **continuous global** structural coherence.

Serverless Microservice Architecture



Built for the **Underserved Middle**: A zero-installation footprint for mid-sized clinical networks priced out of legacy IT contracts.

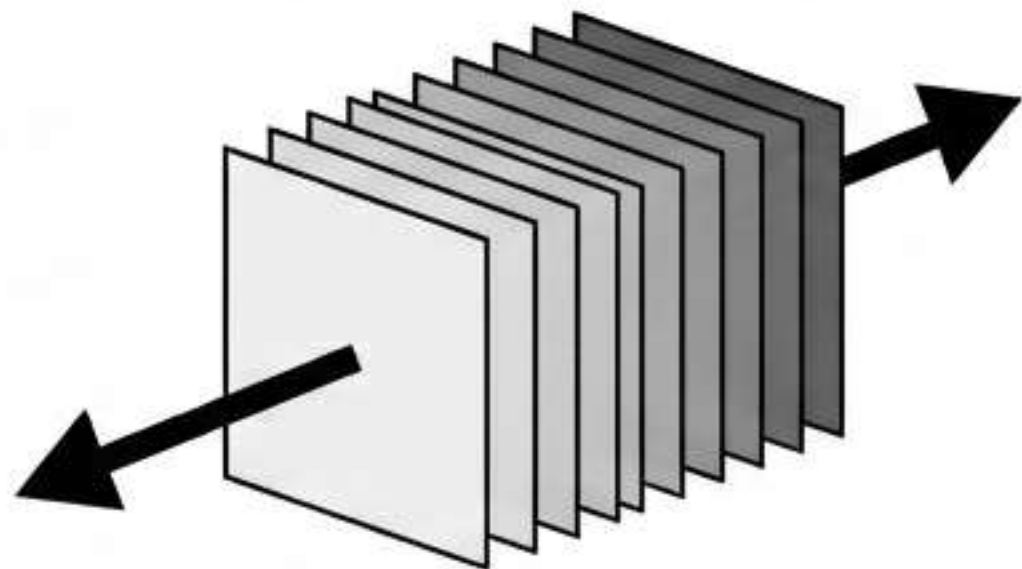
The Second Opinion Diagnostic Gateway



An automated, mathematical Second Opinion deployed instantly via the browser.

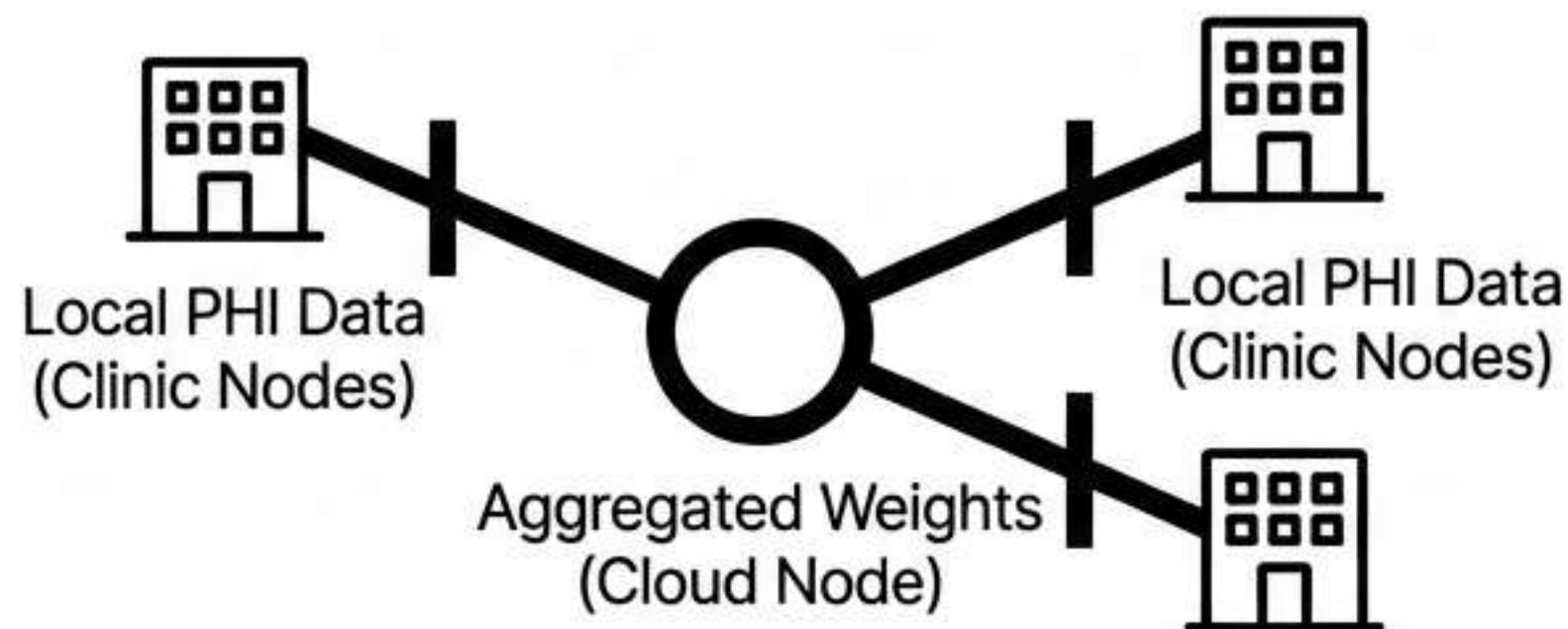
Allows radiologists to immediately perform rapid boundary verification without requiring heavy local computational hardware or installations.

Future Architecture: Scaling to Enterprise



3D Volumetric Segmentation

Processing raw NIfTI volumes in their entirety to penalize structural anomalies across continuous Z-axis slices.



Federated Learning

Aggregating weight updates from independent clinics without transferring sensitive Protected Health Information (PHI) to the cloud.

Goal: Integrating multi-modal capabilities (e.g., bone fracture detection) into a secure, privacy-preserving B2B SaaS platform.