Can AI Safely Restore Low-Quality CT/CTA Scans to Improve Brain Aneurysm Detection?

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Abstract

Intracranial aneurysms can cause severe disability or death if they rupture, which is why it is so important to precisely, accurately, and immediately detect them. Computed Tomography Angiography (CTA) and Computed Tomography (CT) scans are widely used around the world for meeting these criteria. However, low dose, noise, blur, motion, and reconstruction artifacts can weaken subtle vascular signals, especially in smaller aneurysms, making them weaker to detect. Most other methods of scan unblurring can improve visual quality or standard image metrics. However, a cleaner-looking scan does not always correlate to a better or safer scan. When a system overshoots, it can actually lead to worse detection results.

This study asks a key question of whether AI can improve degraded CTA while keeping harmful edits low. With real life limitations, I addressed the lack of clinical and medical-grade data by generating realistic scan degradations from relatively clean CT/CTA images and train a model to proceed with limited, cautious corrections to ensure the most medically beneficial restorations. Results in my first training data has been very encouraging. Tested with 50 CT/CTA out-of-distribution results, this method achieved great mean target gains and stable, positive results. This system created stable outcomes consistently against multiple testing methods, and these results can confidently tell us how this model is able to generate good enhancements consistently.

Introduction

CT and CTA scans are used widely around the world for evaluation of intracranial aneurysms, as they have the benefits of being quick, accessible, and practical (Thompson et al., 2015; Levinson et al., 2023). However, their diagnostic value can vary and heavily depends on the quality of the scan, such as blurring or noise. These issues could cause smaller aneurysms to be hidden and make early detection difficult (Din et al., 2023; Yang et al., 2021). In clinical scans, unlike photography, aggressive enhancements are unacceptable. A method that may add too much detail or blur and remove subtle anatomy does much more harm than good. Therefore, this study aims not to make these files prettier, but to improve these files clinical diagnostic value at the requirement of causing the least harmful edits possible (Bizjak & Špiclin, 2023; Joo, 2025).

This brings up an important and practical question: if a scan file's quality is limited, can AI assist in repairing these scans so that the detection for intracranial aneurysms can be improved, and at the same time, ensure no overcorrection on the scan?

Literature Review

Previous research shows, CT/CTA scans have great value for intracranial aneurysm detections, but when image quality decreases, or when the lesions are extremely small and structures are subtle, the diagnostic ability of these scans would decrease greatly (Din et al., 2023; Heit et al., 2022; Hu et al., 2024). At the same time, AI denoising and enhancement methods have grown exponentially, with many researchers have reported improvements in PSNR, SSIM, and Scan File Visual Quality (Chen, Li, Zhou, & Li, 2024; Koetzier et al., 2023; Kulathilake et al., 2023).

However, two issues remain within completed research. Firstly, it is incredibly rare and difficult for researchers to obtain perfectly matching scan files in both degraded and truly clear conditions. This makes standard supervised restoration training difficult to proceed (Chen et al., 2017; Kulathilake et al., 2023). Second, many researchers automatically assume a higher score or image metrics correlates to higher medical value. In the context of intracranial aneurysm imaging, this assumption is weak. An overcorrected or aggressively sharpened region in the scan may perform better on benchmark scores, but it distorts the vessel boundaries that truly matter in the clinical setting (Bijzak & Špicilin, 2023; Koetzier et al., 2023; Joo, 2025). Therefore, this study focuses on a much more clinically relevant question, which is the ability for AI to enhance these images to improve in a clinical setting, without overcorrecting them and causing harm.

Methodology

To address issues for the absence of real paired training data, I chose to manually create degraded scans. Starting with relatively clean CT/CTA images, I proceeded with inputs that reflect real clinical degradations. This includes blurring, motion artifact, and other methods. These degradations were done to approximate realistic image quality reductions, so that we can train models with artificially degraded files. The model restores the center slice while reading the previous, current, and next slice of these CT scans, allowing it to use context under 2.5D processing instead of 3D. This allows the model to make cautious corrections on top of the original scan, rather than generating a new file.

Evaluation was performed at four levels. At the first level, a Clinical Rescue Matrix measured the results after this system and compared the restored scans with the degraded images and the baseline filters. Then, at the second level, a Monte Carlo stability test repeated restoration under multiple random degradation seeds to determine if the method we used remained net positive across these random conditions. In the third level, an anatomical overlap analysis examined where the truly meaningful edits occurred, allowing tests to see if the model was modifying relevant regions or smoothing the entire image. Finally, at the fourth level, external low-dose testing examined whether the method could transfer beyond the synthetic training setting.

Conclusion

This study shifts the question from "Can AI make CTA look clearer?" to a clinically meaningful question. With our results, anatomical overlap analysis showed that meaningful edits were concentrated mainly in the brain and skull, while most unrelated structures showed negligible or no meaningful change. These findings suggest that the method behaves less like a global smoothing filter and more like a targeted, cautious restoration approach.

The true value for this project is present in both its relevance and its maturity. It addresses a real clinical issue, and uses a method suited to the limitations of existing solutions and bypasses them with my own methods. While larger external datasets, blinded radiologist review, and further expansions are still needed for this to be truly applied in real life clinical situations, the next steps are now clear and realistic. For a student research project, that is precisely what makes this work stand out: it is not just an interesting idea, but a study with credible evidence, strong potential, and a genuine path toward real-world impact.

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