Abstract #00541 ISMRM ABSTRACT

Improving Multicontrast Arterial Centerline Alignment Between TOF and SNAP MRI Using Landmark-Based Affine Transformations

Primary: Analysis Methods - Software Tools 〉 **Secondary:** Cardiovascular - Vascular and Vessel Wall 〉 **Presentation:** PowerPitch Oral, Digital Poster, Traditional Poster
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Impact

Our automated TOF-to-SNAP MRA conversion tool replicates manual modeling accuracy in minutes, eliminating hours of labor. It enables visualization of arteries often omitted in SNAP images, allowing faster, more complete vascular centerlines and improving efficiency and accessibility in cerebrovascular research.

Synopsis

Motivation: Multicontrast MRA supports vascular disease diagnosis and blood flow analysis, often requiring arterial centerlines. Generating separate centerlines for each contrast is time-consuming, so creating one and registering it to another is preferred. This study registers TOF and SNAP centerlines, which capture the same anatomy but differ in artery visibility and scale, reducing effort.

Goals: Develop a user-friendly tool that converts TOF centerlines to SNAP centerlines efficiently.

Approach: We began with simple scaling using TOF and SNAP landmarks, expanded to multi-dimensional scaling, and applied an affine transformation using three arterial landmarks along cardinal axes.

Results: The tool performs rapid conversions with accurate centerline registration.

Introduction

Accurate reconstruction of intracranial artery centerlines is crucial for studying cerebrovascular morphology and hemodynamics. Time-of-Flight (TOF) MRI provides high spatial resolution and clear visualization of small arteries, while SNAP (Simultaneous Non-contrast Angiography and intraPlaque hemorrhage) MRI offers improved vessel wall contrast and tissue characterization[1–2]. However, generating separate artery centerlines for each contrast is time-consuming, often exceeding three hours per scan. SNAP frequently omits smaller or distal arteries, producing incomplete centerlines.

To address these challenges, we developed an automated pipeline that converts TOF-derived artery centerlines into SNAP images using five shared vascular landmarks (basilar artery [BA], left/right A1, left/right M1), as illustrated in *Figure 1*. These anatomical fiducials are easily identified on both contrasts (*Figure 3*), supporting consistent geometric registration. The proposed pipeline produces complete SNAP centerlines in minutes (*Figure 4*), enabling rapid, accurate, and consistent multicontrast vascular analysis. The approach provides a scalable method for studies requiring precise centerline registration across contrasts.

Methods

Development of the Conversion Algorithm

Five vascular landmarks were selected at consistent anatomical fiducials on both TOF and SNAP MRAs, including the basilar artery (BA), left and right A1, and left and right M1 segments (*Figure 3*). The initial linear transformation anchored at the BA produced acceptable accuracy locally but poor distal alignment. Adding the four anterior circulation landmarks provided distributed references across both anterior and posterior regions, improving overall stability and spatial fidelity. Landmarks were manually identified based on anatomical consistency, ensuring reproducibility across subjects.

A nonlinear mapping was tested to account for curvature variation, but it introduced spatial distortions. The final affine model incorporated translation, rotation, scaling, and shear, balancing global alignment with geometric realism. Alignment accuracy was visually evaluated by comparing transformed TOF centerlines with manually traced SNAP centerlines from normal subjects. Representative examples of accurate alignment are shown in *Figure 4*, and minor misalignments are presented in *Figure 5*.

Application Design

A user interface was developed in Python using Tkinter. Inputs include TOF artery centerlines, TOF and SNAP landmarks, and optionally corresponding MRA volumes. Nibabel was used to read volume dimensions and orientation, ensuring proper coordinate mapping between modalities. Points outside SNAP bounds were automatically removed. The pipeline outputs a YAML-formatted SNAP artery centerline compatible with VesselVoyager for visualization and morphometric analysis[3] (*Figure 2*).

Results

The affine registration achieved robust and anatomically consistent alignment between TOF and SNAP MRAs. Central arteries, including the BA and proximal segments of A1 and M1, showed high spatial overlap with SNAP vascular structures. The generated centerlines followed the true SNAP vessel trajectories closely, as demonstrated in *Figure 4*. Distal or branching arteries occasionally showed small positional offsets, typically near curved M2 and M3 regions or where SNAP contrast was weak (*Figure 5*). Despite these localized errors, the overall morphology and topology of the converted centerlines were preserved. Processing time for each subject was reduced from approximately 3 hours of manual tracing to under 5 minutes using the automated pipeline.

Discussion

The proposed TOF-to-SNAP pipeline provides an efficient, reproducible approach for generating SNAP artery centerlines without manual reconstruction. The affine model balances simplicity and anatomical accuracy by distributing geometric control points across the anterior and posterior circulations. Nonlinear

registration produced distortions and was unsuitable for thin distal vessels, confirming that affine modeling provides optimal stability. Minor misalignments primarily correspond to variations in curvature or contrast, as shown in *Figure 5*, which may need manual corrections in those regions. Overall, the method greatly reduces workload while maintaining high geometric accuracy.

Conclusion & Future Work

We developed an automated TOF-to-SNAP artery centerline conversion pipeline using an affine transformation. The method preserves anatomical accuracy, reduces manual workload from hours to minutes, and performs robustly in typical vascular anatomies. Although anatomical variability can reduce precision in some cases, overall geometry and continuity remain reliable.

Future developments will focus on refining alignment in distal and branching arteries. Local curvature-based corrections and regional nonlinear adjustments will be implemented to reduce residual deviations visible in *Figure 5*. Expanded validation across larger and more diverse subject datasets will assess reproducibility and generalizability. Integration with computational flow analysis tools will further extend the pipeline's application in multicontrast cerebrovascular studies, facilitating combined assessment of structure, hemodynamics, and vessel wall properties.

This pipeline represents a scalable, practical advancement in vascular modeling, bridging TOF and SNAP reconstructions to enable faster, more complete, and accurate multicontrast cerebrovascular studies.

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References

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Figures and Tables

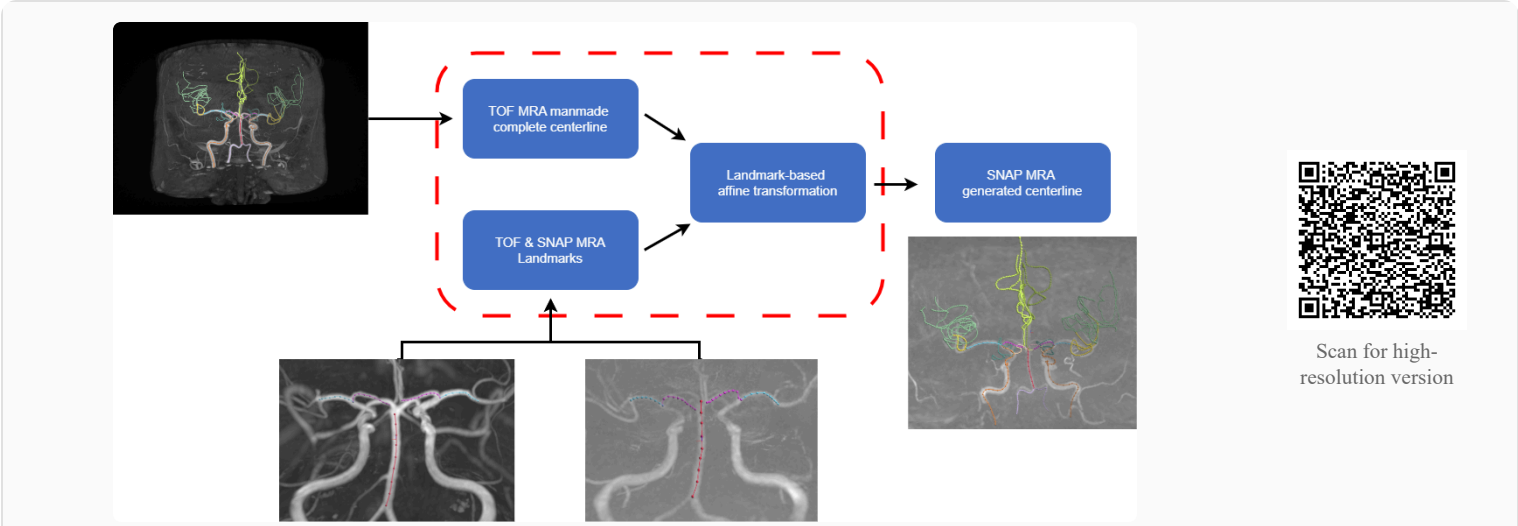

Figure 1: Flowchart of the TOF-to-SNAP MRA centerline conversion process

The diagram illustrates the steps used to generate the SNAP MRA centerline from a manually created TOF MRA model using a landmark-based affine transformation defined by the basilar artery (BA), left and right A1, and left and right M1 arterial landmarks.

Animated Figure 2

This figure contains animation/video content. To view the animation, scan the QR code with your mobile device or visit the online version of this abstract.

Figure 2: Demonstration of the TOF to SNAP converter app

The figure shows the process of converting a TOF centerline to a SNAP-aligned centerline using the desktop app. Users select the TOF centerline file and the TOF and SNAP reference landmarks. Optional trimming can be applied to remove portions of the centerline that exceed the SNAP MRA scan boundaries. The final generated centerline is displayed after applying the transformation.

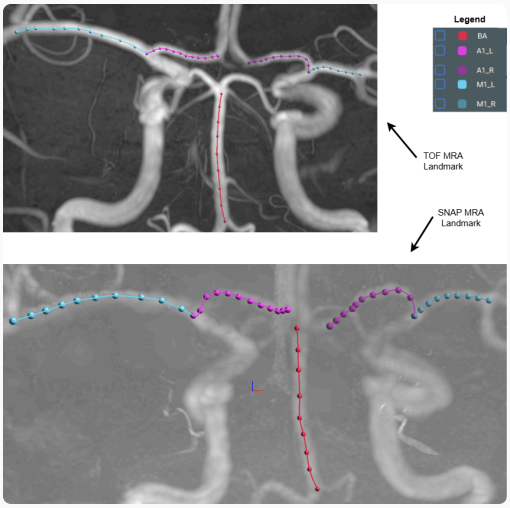

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Figure 3: Landmark Identification for TOF-to-SNAP Centerline Conversion

Basilar artery (BA), left and right A1 arteries, and left and right M1 arteries. TOF and SNAP MRA landmarks are shown with color-coded centerlines to illustrate simple, rapid identification for centerline registration.

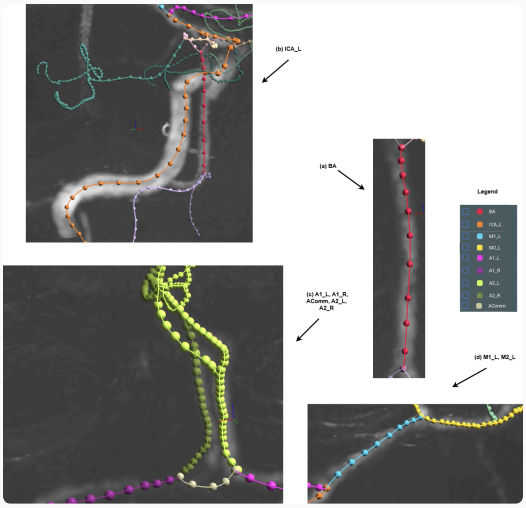

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Figure 4: Examples of automatically generated SNAP centerlines aligned with corresponding SNAP MRA images

Shown are representative segments: (a) basilar artery (BA), (b) left internal carotid artery (ICA_L), (c) anterior circulation arteries (A1_L, A1_R, AComm, A2_L, A2_R), and (d) middle cerebral artery segments (M1_L, M2_L), demonstrating accurate alignment across primary and secondary vessels.

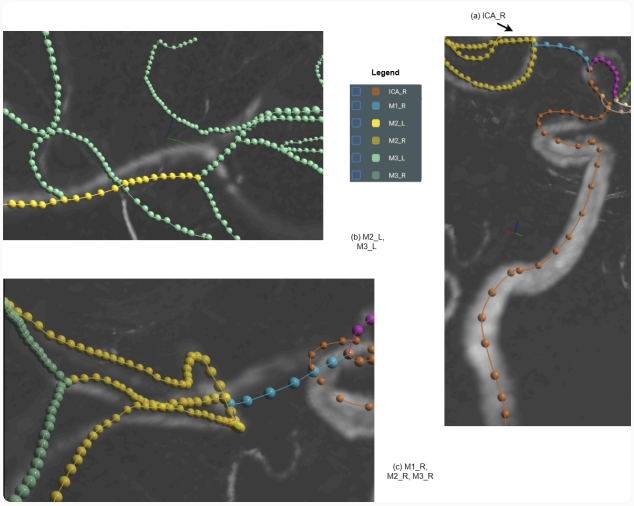

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Figure 5: Examples of minor misalignment in automatically generated SNAP centerlines

Shown are representative regions: (a) right internal carotid artery (ICA_R), (b) left middle cerebral branches (M2_L, M3_L), and (c) right middle cerebral branches (M1_R, M2_R, M3_R). Slight deviations occur in highly tortuous or distal arteries, where local curvature and vessel variability increase alignment difficulty.