

Major vessels of the frontal mouse brain in Allen atlas space

Research white paper | Reanalysis of TubeMap Brain-44R | September 2026 (revised)

This white paper was generated automatically by an AI assistant (Claude, Anthropic) from the lab's analysis code and outputs, under the direction of the lab. It has not been peer reviewed.

Abstract

Whole-brain vascular graphs are dominated by capillaries: in the public TubeMap Brain-44R graph, 95.5% of the centerline samples between estimated Bregma AP +1.0 and +2.0 mm lie on vessels we classify below as small. Drawing every sample, or coloring only the source artery and vein flags, therefore hides the large vessels that matter for anatomy and surgical planning. We instead selected vessels by caliber and continuity: edges with mean estimated radius of at least 7 μm that belong to a connected tree at least 200 μm long. The rule keeps 277,311 of 4,896,278 graph edges (5.7%). Within the frontal slab these major vessels total 657 mm of centerline: 47% carry the artery flag, 27% the vein flag, and 26% carry neither flag, so a label-based display omits about 25% of the large vessels. We present dorsal and lateral surface maps of the whole measured hemisphere and twenty-one 275- μm coronal projections at 50- μm steps, with the capillary bed reduced to a density shading. Candidate identities, including the middle and anterior cerebral arteries, are given as tentative. The data are one specimen and one hemisphere; the maps are anatomical references, not subject-specific surgical maps.

Introduction

Kirst and colleagues combined tissue clearing, light-sheet microscopy, and TubeMap graph reconstruction to map mouse-brain vasculature down to capillaries [1]. The released graph is registered to the Allen Common Coordinate Framework (CCF) [2], so vessel centerlines can be viewed against named regions. An earlier version of this package (still in the repository history) displayed every centerline sample in thin 25- μm coronal slabs, colored by the graph's artery and vein flags. That display had two problems. The unflagged class, 92% of samples and mostly capillaries, filled the image. And the flags did not isolate the large vessels: many flagged segments are small arterioles or venules, and many large segments carry no flag at all.

This revision asks a narrower question: where are the major vessels? We select by caliber rather than by label, keep the flags only as color, and change the geometry of the display. Thicker coronal projections let branching trees read as continuous structures, and surface maps show the pial arteries and veins that a cranial window or implant would encounter.

Results

Surface vessels seen from above

Figure 1 projects every major vessel lying within 100 μm of the dorsal brain surface. Arterial trees enter the dorsal convexity from the midline and from the lateral edge and branch across motor and somatosensory cortex, with veins interleaved. Pale gray segments are large vessels the source graph left unflagged (26% of major-vessel length in the frontal slab).

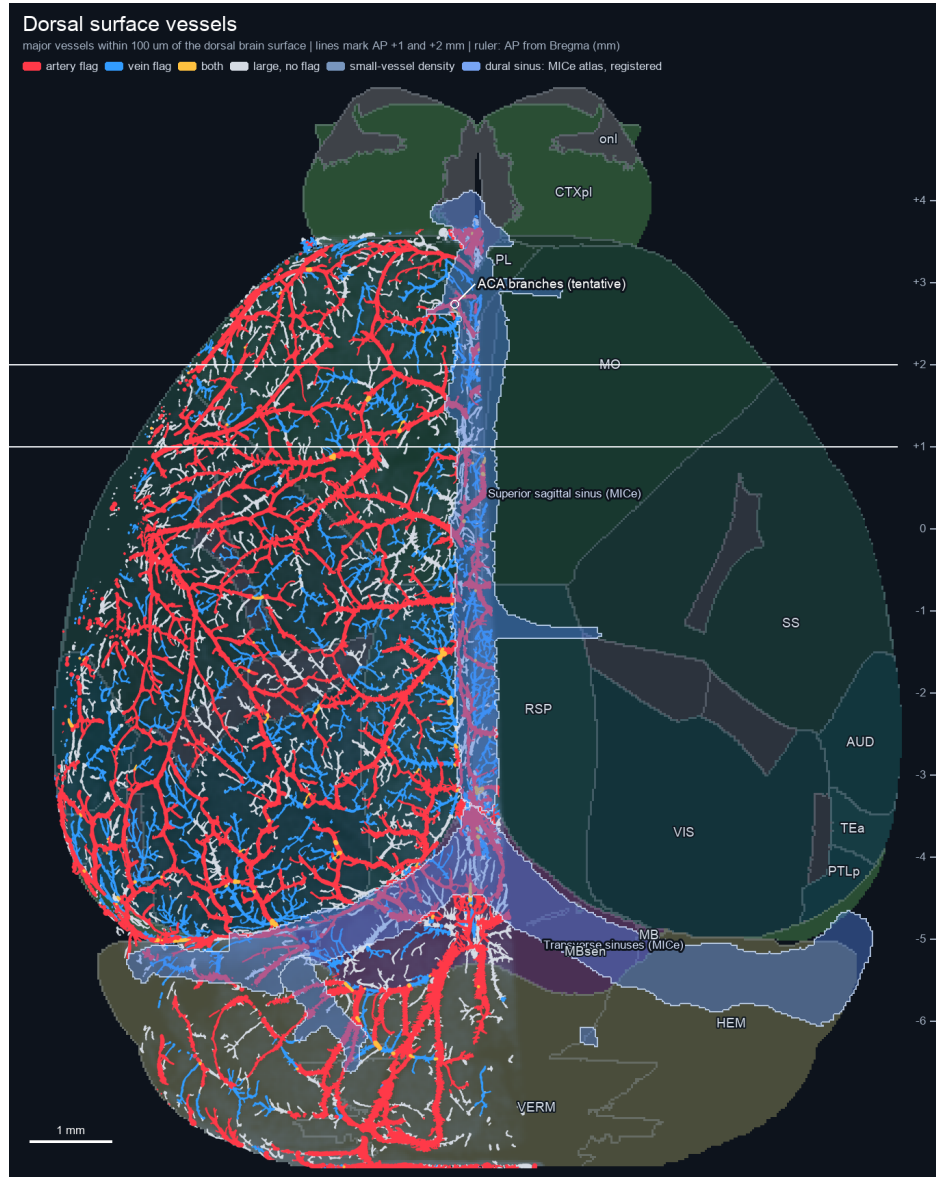


Figure 1. Dorsal surface vessels of the measured hemisphere. Major vessels (mean radius $\geq 7 \mu\text{m}$, tree $\geq 200 \mu\text{m}$) within 100 μm of the dorsal atlas surface, over Allen regions; the opposite hemisphere shows atlas labels only. Horizontal lines bound the AP +1.0 to +2.0 mm coronal series; the ruler gives estimated AP from Bregma. Blue-gray shading is the smoothed density of the remaining small vessels. Labels are tentative identifications. Translucent outlined shapes are dural sinuses from the MICE CBA vasculature atlas registered to the Allen CCF [5]; they are not part of the TubeMap graph. Source: Brain-44R [1, 3].

The lateral surface and the middle cerebral artery

The lateral view (Figure 2) shows the largest arterial trunk on the frontal lateral surface ascending from the rhinal region near estimated AP +0.5 to +1.0 mm and branching dorsally and rostrally over gustatory, insular, and somatosensory cortex. Its position, caliber, and fan-like branching match the middle cerebral artery (MCA). Binning the thickest ($\geq 18 \mu\text{m}$) lateral-surface arteries between AP -1 and +2.5 mm places most of their length at AP +0.75 to +1.0 mm, ventral to mid-height. Rostral to the AP +1 mm line, arteries on the lateral and ventral frontal surface are smaller and more numerous.

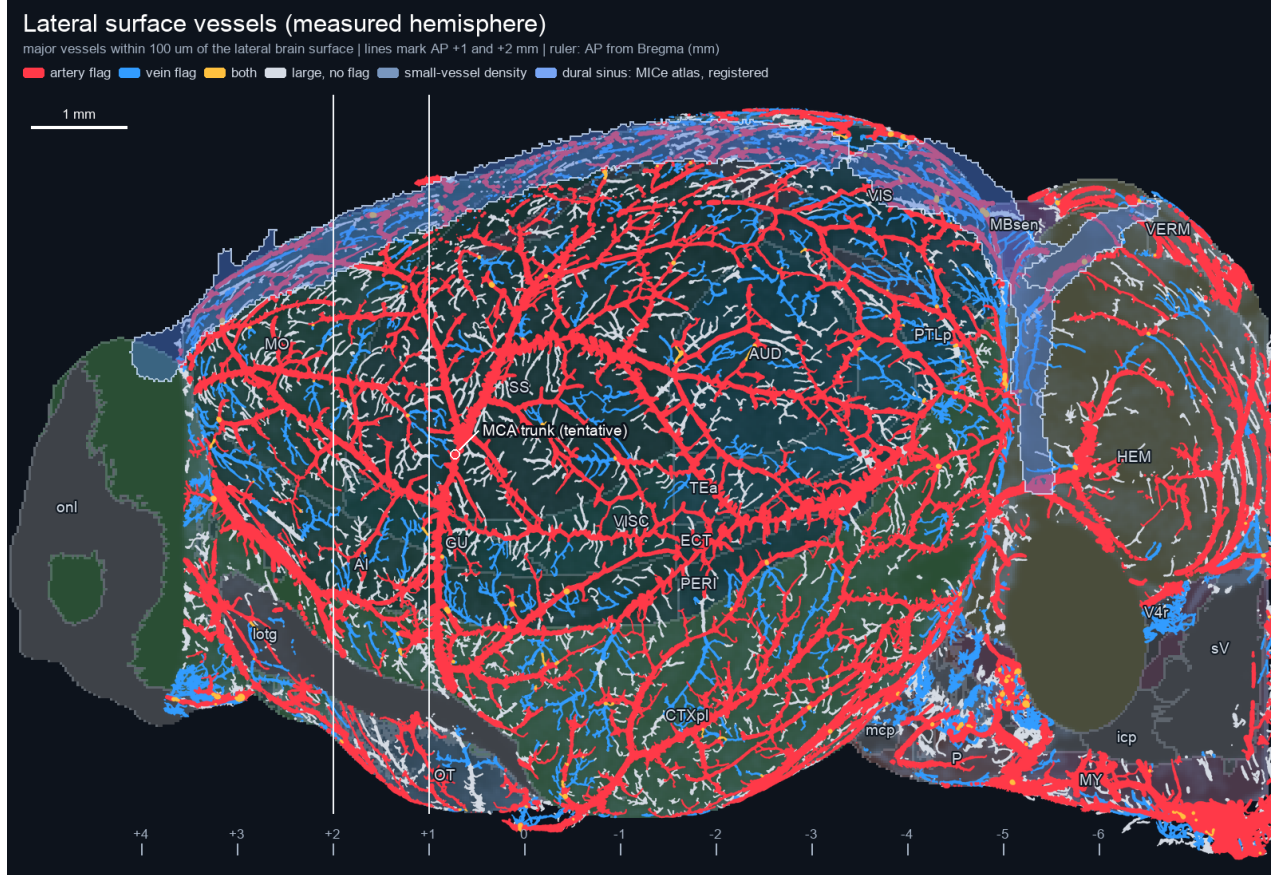


Figure 2. Lateral surface vessels of the measured hemisphere (anterior left). Selection and colors as in Figure 1, projected along the medial-lateral axis. Vertical lines mark AP +2.0 and +1.0 mm. Source: Brain-44R [1, 3].

The surface views also expose a gap in the data: the dural venous sinuses are missing. On the dorsal midline, where the superior sagittal sinus lies, the largest vessel in the graph has an estimated radius of 48 μm , under 100 μm across, and about 80% of the $\geq 20 \mu\text{m}$ samples there carry the artery flag. The sinuses sit within the dura, which is removed with the skull before clearing. To show them, we registered the MICE CBA mouse cerebral vasculature atlas [5], whose sinuses are hand-labeled on micro-CT of a vascular cast, to the Allen CCF (affine then B-spline registration of brain masks; Dice 0.98 for the whole brain, 0.85 for the cerebellum, and 0.65 for the olfactory bulb). We kept each sinus trunk and dropped the painted tributary veins. In that atlas the superior sagittal sinus has a median equal-area diameter of 475 μm (IQR 455-555), and the transverse sinuses 717 μm . After registration the confluence lies at about AP -4.0 mm, close to the typical position of lambda (-4.21 mm [6]). These sinuses come from a different animal and strain (CBA) than the vessels, so treat their position as approximate to a few hundred micrometres.

Coronal projections of major vessels

Each panel projects 275 μm of tissue (eleven 25- μm atlas planes) centered on its AP plane, so neighboring panels overlap and a vessel can appear in several. Major vessels are drawn at their estimated caliber over the central atlas plane, farther vessels first. The capillary-dominated bed is not drawn as vessels; its density appears as blue-gray shading.

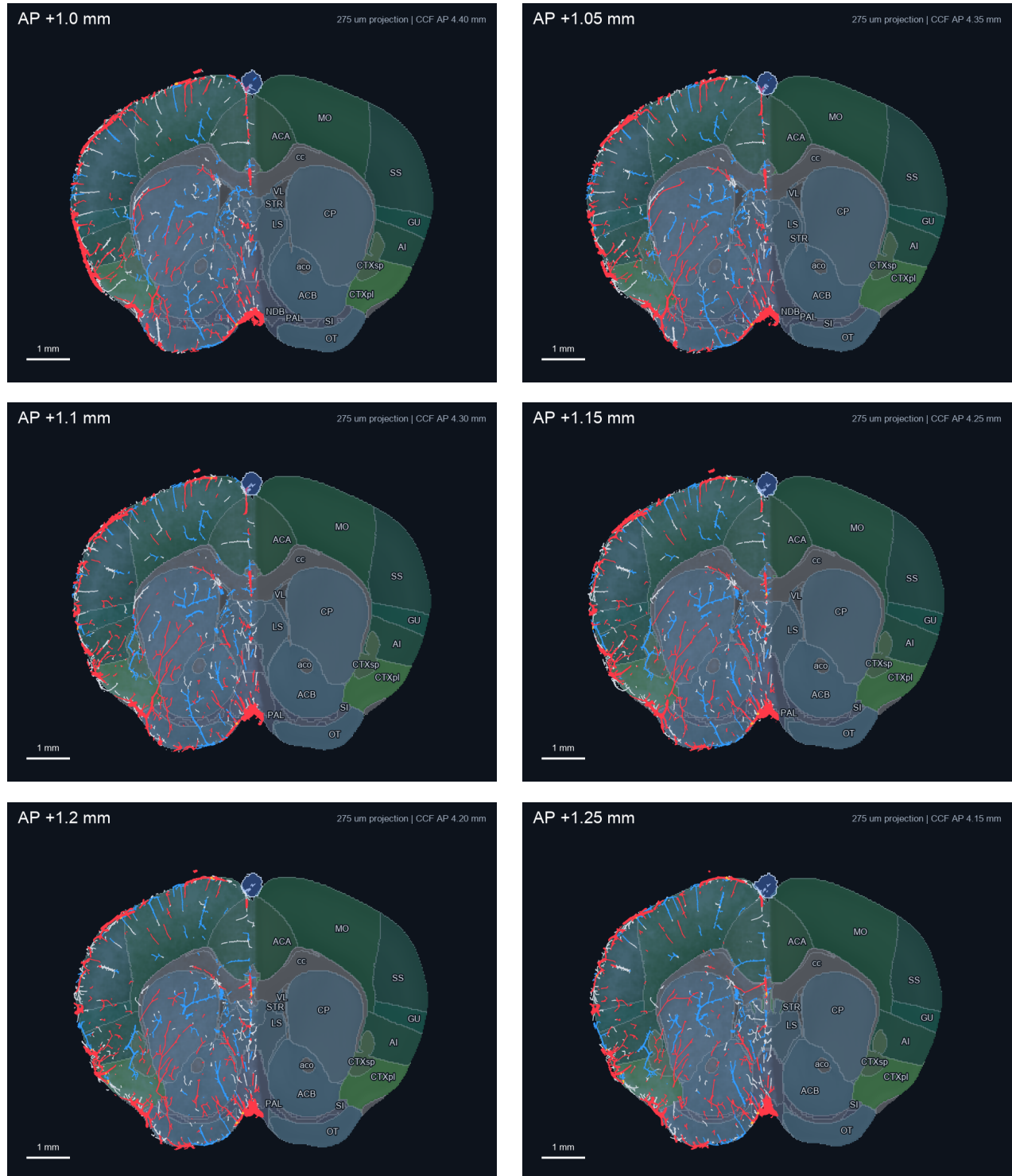


Figure 3. Major vessels from estimated AP +1.0 to +1.25 mm; 275- μm projections at 50- μm spacing. Red: artery flag; blue: vein flag; amber: both; pale gray: large vessel with neither flag. The opposite side shows Allen regions alone. Scale bar: 1 mm. Source: Brain-44R and ClearMap 25- μm atlas [1-3].

Coronal projections, continued

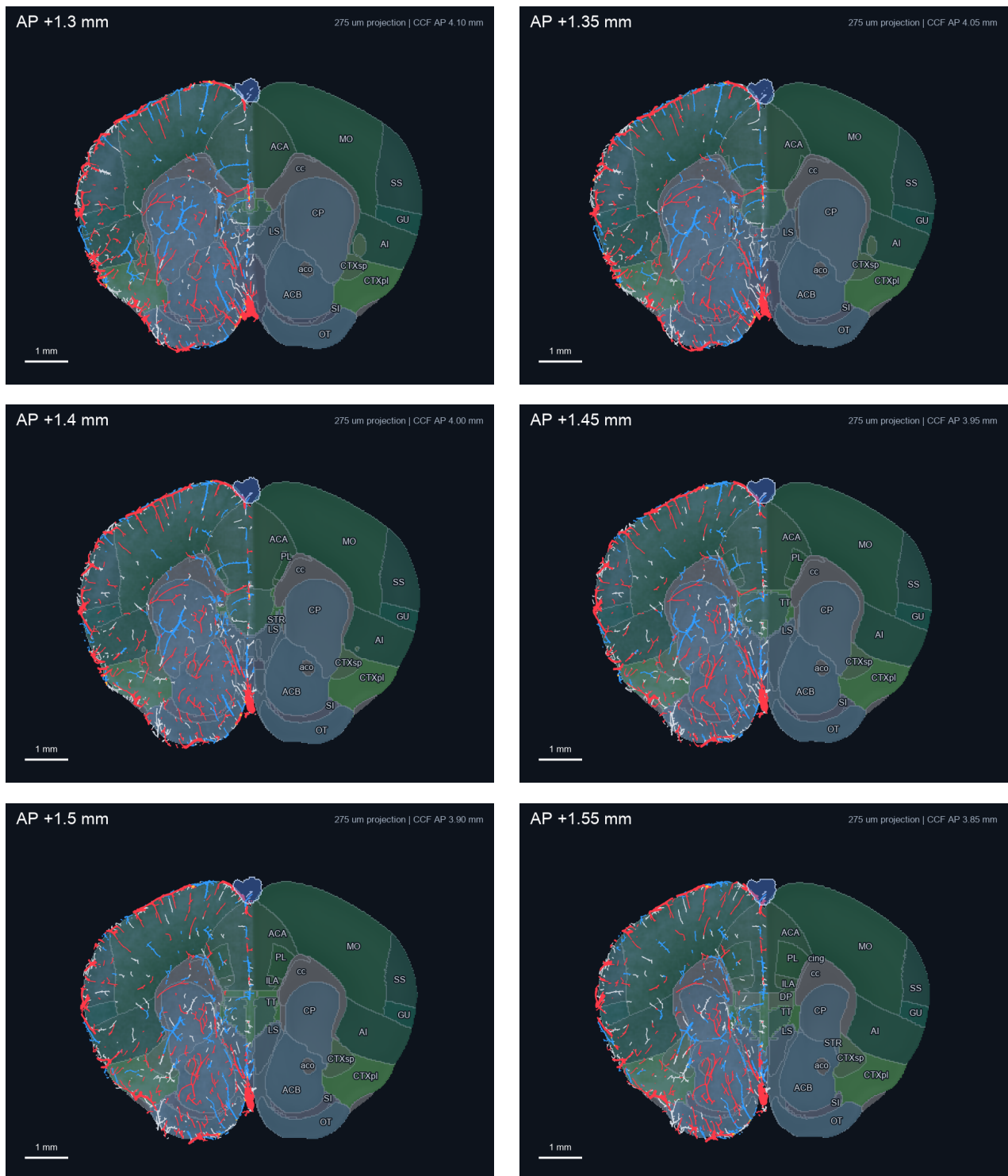


Figure 4. AP +1.30 to +1.55 mm. Pial arteries run along the dorsal and lateral surface; penetrating vessels descend into cortex; deep arteries and veins cross the striatum. Scale bar: 1 mm.

Coronal projections, continued

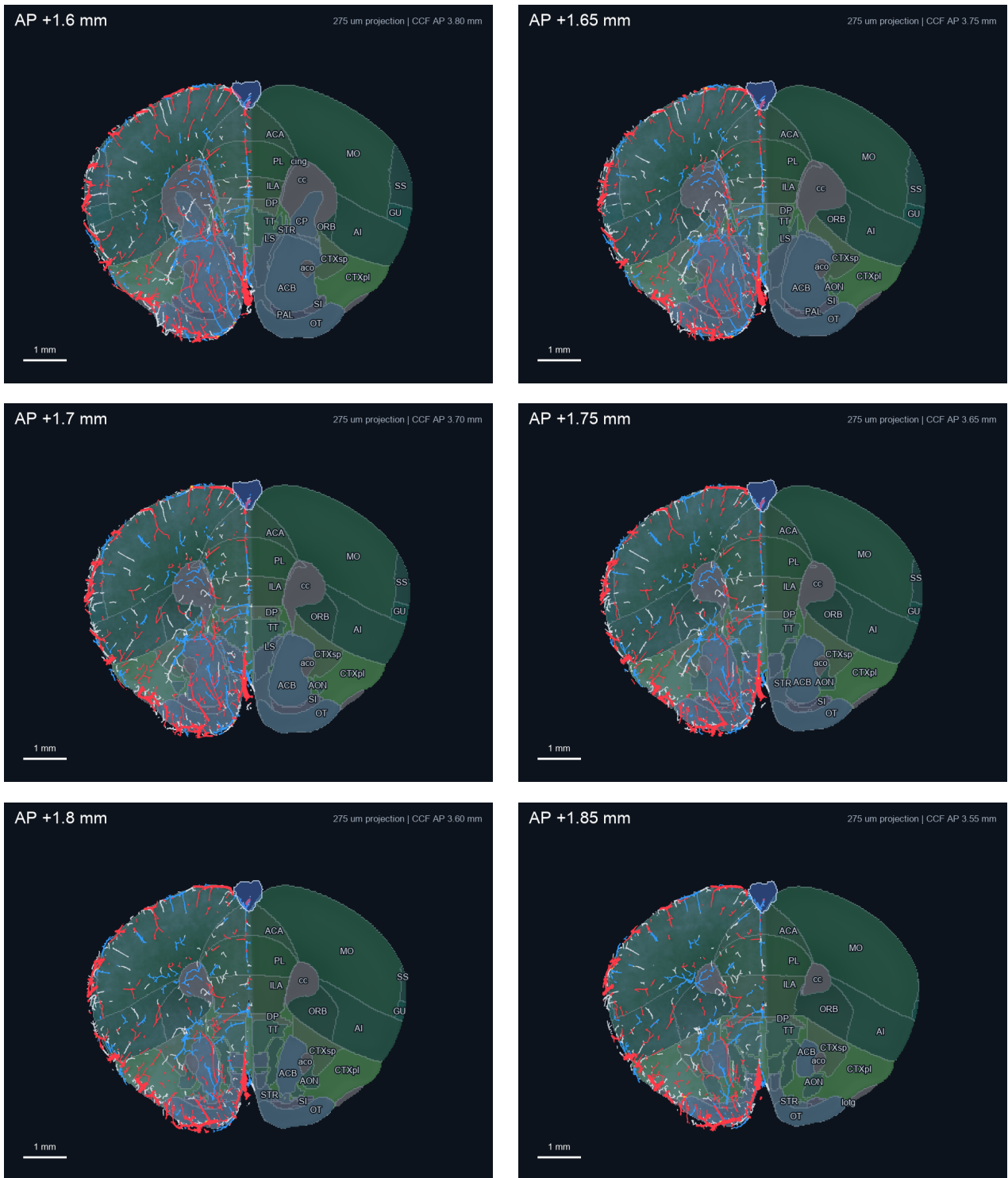


Figure 5. AP +1.60 to +1.85 mm. Toward the frontal pole the striatum narrows and orbital and olfactory regions appear ventrally. Scale bar: 1 mm.

Coronal projections, continued

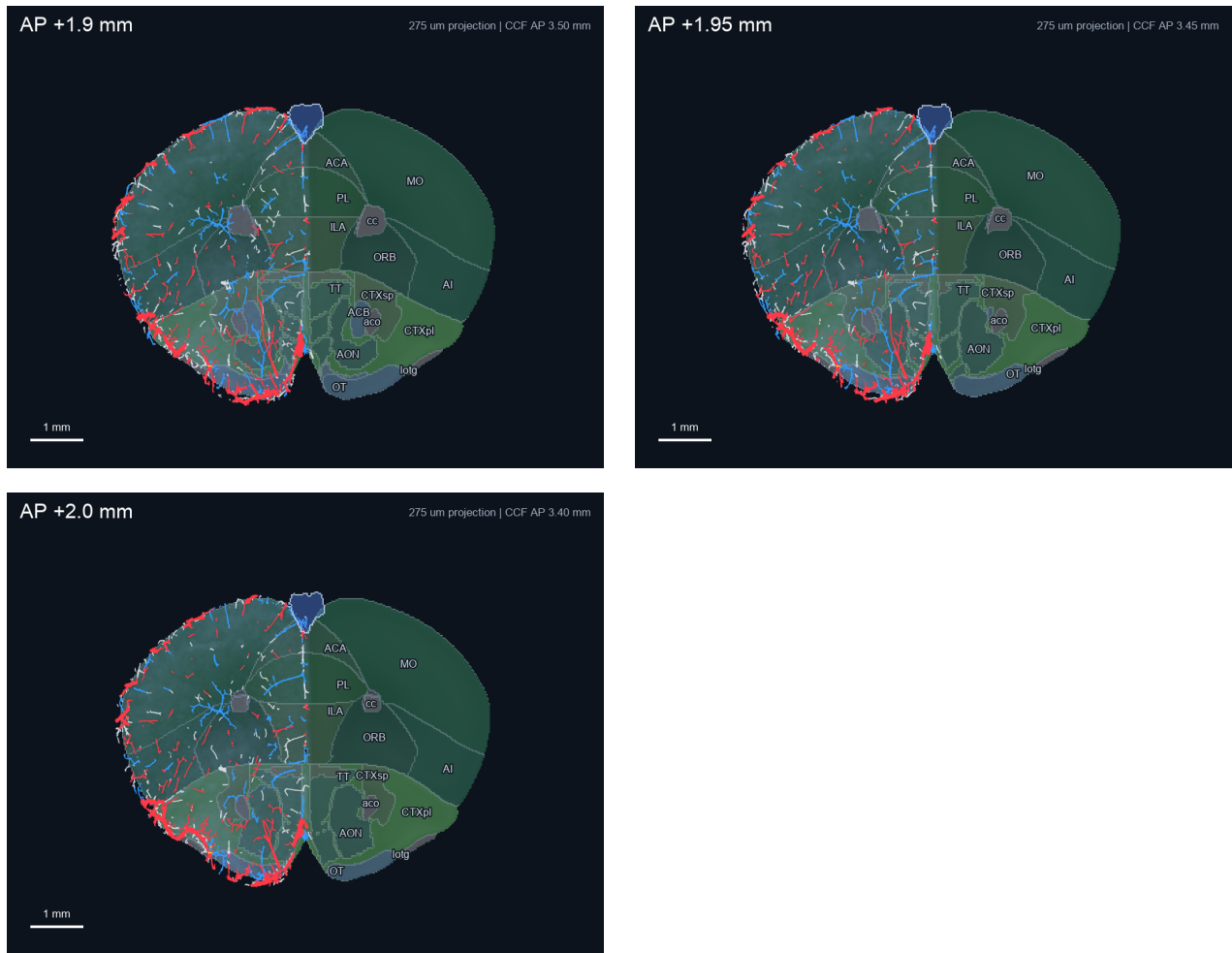


Figure 6. AP +1.90 to +2.00 mm. A high-resolution montage of all twenty-one panels accompanies the paper. Scale bar: 1 mm.

Three large-vessel systems are consistent across the series. Pial arteries cover the dorsal and lateral cortex and give rise to penetrating branches. A large artery runs on the ventral medial surface near the pallidum and olfactory tubercle, most prominent from AP +1.0 to +1.5 mm. Deep arteries and large veins cross the caudoputamen and nucleus accumbens.

Composition of the major-vessel set

Per projection, artery-flagged vessels make up the largest share of major-vessel length, followed by vein-flagged and unflagged large vessels (Figure 7), and the balance is similar across the series. For the whole 1-mm slab, the selected edges carry 269,102 of 5,947,612 centerline samples (4.5%) but 657 mm of connected large-vessel centerline.

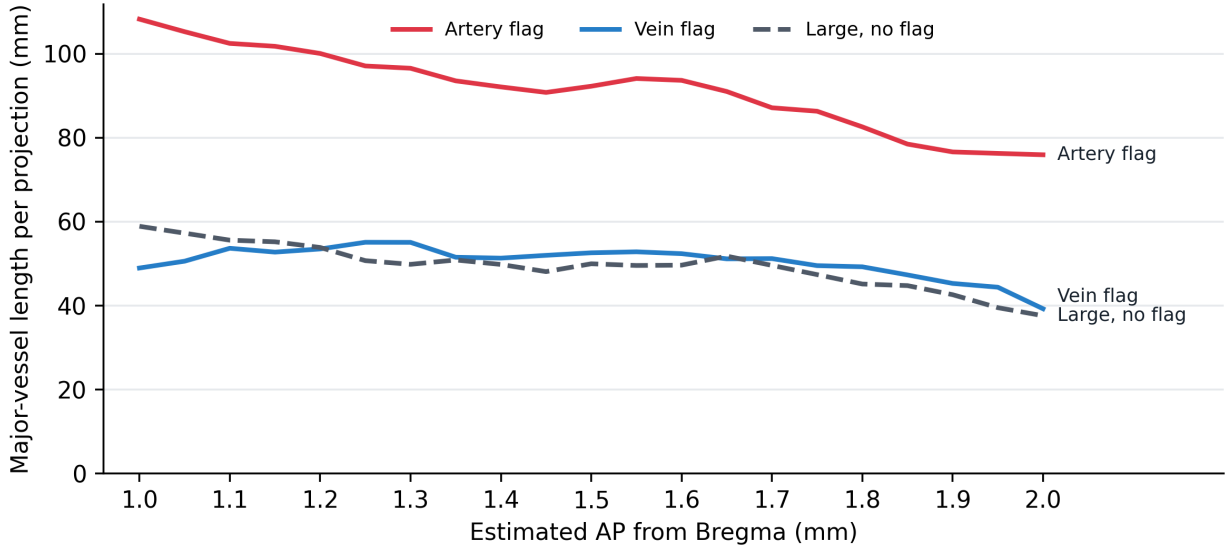


Figure 7. Major-vessel centerline length per 275-um coronal projection, by source flag. Lengths sum whole edges that have at least one sample in the projection, so overlapping projections share edges and the values are not additive across panels. Length depends on graph sampling and on the selection threshold; it is not a measure of vascular density or perfusion.

Why labels alone were not enough

Of all edges carrying the artery flag, 50% pass the caliber rule; for vein-flagged edges the figure is 53%. The rest are smaller arterioles and venules, which a label-based display draws with the same weight as the trunks. Conversely, 79,023 unflagged edges pass the rule. TubeMap stops tracing arterial and venous identity near the brain surface to avoid crossing artifacts [3], which is where many of these unflagged large vessels lie. In the unflagged class as a whole, the median estimated radius is 4.28 μm and 71% of samples are at most 5 μm , so it is dominated by, but not identical to, capillaries.

Candidate vessel identities

Table 2 lists the major vessels that can be named with reasonable confidence from position, caliber, branching, and source flag. None was confirmed against the original fluorescence data or a second specimen; all identities are tentative.

Vessel	Where it appears	Evidence	Confidence
Middle cerebral artery (MCA) trunk and branches	Lateral surface, rising from the rhinal region near AP +0.5 to +1.0 mm; branches over AI, GU, SS, and MO (Figure 2).	Largest frontal lateral-surface artery; ≥ 18 μm segments concentrate at AP +0.75 to +1.0 mm; artery flag; fan-like branching.	Moderate
Anterior cerebral artery (ACA) branches	Dorsal medial surface, arching over the midline near AP +2.5 to +3 mm and spreading over MOs (Figure 1).	Artery-flagged trees entering the dorsal surface from the midline; typical ACA territory.	Moderate
Ventral ACA segment	Ventral medial surface near PAL and OT, AP +1.0 to +1.5 mm (Figures 3-4).	Largest artery in the ventral midline of the coronal projections; artery flag.	Low to moderate
Striatal (lenticulostriate-like) arteries	Entering the caudoputamen from the ventral surface (Figures 3-5).	Artery-flagged deep branches running dorsally through CP.	Low
Large striatal veins	Caudoputamen and nucleus accumbens, AP +1.0 to +2.0 mm.	Vein-flagged, ≥ 14 μm ; about 2.7 mm of such segments inside CP in the slab.	Low to moderate
Superior sagittal sinus	Expected on the dorsal midline.	Not in the TubeMap graph (dura removed before imaging). Shown from the MICE atlas, registered [5].	Other source

Two further systems, the rostral rhinal vein along the rhinal fissure and the olfactory arteries on the ventral frontal surface, are expected in this range. They could not be separated from neighboring vessels with confidence and are not labeled in the figures.

Per-projection results

Table 1. Major-vessel length by coronal projection

AP (mm)	Major edges	Artery (mm)	Vein (mm)	No flag (mm)	Small-vessel share
1.0	5,234	108.3	49.0	58.9	95.7%
1.05	5,064	105.3	50.6	57.3	95.7%
1.1	4,972	102.5	53.7	55.6	95.7%
1.15	5,006	101.8	52.8	55.2	95.6%
1.2	4,941	100.1	53.5	53.9	95.5%
1.25	4,867	97.1	55.1	50.7	95.5%
1.3	4,879	96.6	55.1	49.8	95.5%
1.35	4,838	93.6	51.5	50.9	95.6%
1.4	4,780	92.1	51.3	49.8	95.5%
1.45	4,692	90.8	52.0	48.1	95.5%
1.5	4,855	92.3	52.6	50.0	95.3%
1.55	4,915	94.1	52.8	49.6	95.2%
1.6	4,825	93.7	52.4	49.7	95.2%
1.65	4,732	91.0	51.2	51.8	95.2%
1.7	4,619	87.2	51.2	49.6	95.2%
1.75	4,558	86.3	49.5	47.4	95.2%
1.8	4,406	82.6	49.3	45.2	95.3%
1.85	4,303	78.5	47.3	44.8	95.4%
1.9	4,145	76.6	45.3	42.6	95.5%
1.95	4,033	76.3	44.4	39.5	95.6%
2.0	3,842	76.0	39.3	37.6	95.7%

Small-vessel share is the fraction of all centerline samples in the 275-um projection that lie on edges outside the major set. Values are in the accompanying CSV, together with the projection limits in CCF AP indices.

Methods

Data and extraction

The vascular data are the public TubeMap Brain-44R annotated graph (data_graph.gt) from OSF project sa3x8 [3], associated with Kirst et al. [1]. The graph-tool binary file was parsed directly by `extract_brain44r.py`, which checks that the whole file is consumed. The graph has 3,449,637 vertices, 4,896,278 edges, and 95,040,839 edge-geometry centerline samples. We used atlas-space geometry coordinates and radii, the edge-to-geometry index map, and the Boolean artery and vein edge properties. The extraction reproduces the earlier class audit exactly (5,947,612 samples in the display slab, with identical class counts). The graph's per-sample annotation property does not match the atlas orientation used here, so regions were looked up in the ClearMap 25-um Allen annotation instead.

Coordinates

Atlas geometry coordinates are ordered (DV, AP, ML) in 25-um voxels; the ClearMap annotation TIFF loads as (ML, AP, DV). This mapping was validated previously against atlas dimensions, tissue support, and sampled graph labels. Estimated Bregma AP (mm) = 5.4 - CCF AP (mm), an IBL convention for the Allen atlas [4], with no pitch or specimen-specific correction.

Major-vessel selection

For each edge we averaged the atlas-space radii of its geometry samples and converted to micrometres. Edges with mean radius ≥ 7 um formed a subgraph. Its connected components were measured by summed atlas-space centerline length, and edges in components shorter than 200 um were discarded. This removes isolated thick fragments while keeping continuous trees. TubeMap radii are light-sheet estimates and exceed true lumen radii, so the threshold is relative to this dataset: the 99th percentile of mean radius among unflagged edges is about 9 um, and the median artery- or vein-flagged edge is about 7.6 um. The result, 277,311 edges in 3,416 trees, depends on both parameters, which are arguments to the renderer. The artery and vein flags were not used for selection, only for color.

Methods, continued

Rendering

Coronal panels project major-vessel segments whose sample pairs fall within 137 μm of the panel plane (eleven 25- μm planes). Each segment is drawn as a line of its estimated diameter, with fourfold supersampling. Segments are drawn farther-first within each class, and classes in the order unflagged, vein, artery, both. Surface maps keep samples within 100 μm below the first atlas-brain voxel along the viewing axis (DV for dorsal, ML for lateral). Samples just outside the registered surface are included, so pial vessels are not lost to registration error. The small-vessel bed, meaning all samples not on major edges, is binned on the 25- μm grid, smoothed with a one-voxel Gaussian, normalized to its 98th percentile, and blended into the atlas image inside the brain outline.

Checks and reporting units

Edge counts, centerline samples, and centerline length are distinct units and are reported separately. Samples along one edge are correlated, and overlapping projections share edges. No inferential statistics were run because the analysis uses one specimen. Coordinates, thresholds, colors, and per-projection results are recorded in `vascular_atlas_major_vessel_provenance.json` and the per-projection CSV.

What the display does not establish

The maps do not report flow direction or velocity, true lumen caliber, regional perfusion, registration error for an individual animal, or variation across animals. The caliber rule is a display criterion, not a biological definition of an artery, vein, arteriole, or capillary.

Interpretation and limitations

What changed, and why it matters

Selecting by caliber answers the question the label display could not: the pial arterial trees, the MCA trunk on the lateral surface, the ventral midline artery, and the deep striatal vessels are now visible as continuous structures at their positions relative to Allen regions. Keeping the flags as color shows that about 25% of the large vessels have no source label. Showing capillaries as density keeps their spatial context without letting them fill the image.

Limits

First, the vessels come from a single specimen and one hemisphere. Second, the Allen template is a population reference, and atlas registration can shift vessel positions relative to region boundaries, most of all at the surface. Third, the Bregma conversion is approximate and does not correct for skull pitch. Fourth, the artery and vein flags come from TubeMap's classification and were not revalidated. Fifth, the threshold trades completeness for legibility: medium-caliber vessels near the cut-off can drop out of a tree, and surface vessels with inflated radius estimates can be kept. Sixth, dural sinuses are missing from the graph; the figures show them from a second atlas (MICE, one CBA mouse) registered to the CCF, so their alignment with the TubeMap vessels is approximate. Named identities are tentative (Table 2).

Appropriate applications

The maps suit figure planning, teaching, and choosing regions or approach angles to examine further. They are not a substitute for imaging the vasculature of the animal being operated on. Before implanting or placing a window, surface vessels should be checked in that animal. Region-level quantitative comparisons would need matched specimens, validated class labels, and animals rather than graph samples as replicates.

Conclusion

Filtering the Brain-44R graph by caliber and continuity reduces 4,896,278 edges to 277,311 major vessels that form readable trees. Over estimated AP +1.0 to +2.0 mm, the resulting surface maps and 275-um coronal projections locate the principal arteries and veins of the frontal brain in atlas space, name the likely MCA and ACA systems, and document what the source data omit.

References and data availability

1. Kirst C, Skriabine S, Vieites-Prado A, et al. (2020). Mapping the fine-scale organization and plasticity of the brain vasculature. *Cell* 180:780-795.e25. doi:10.1016/j.cell.2020.01.028.
2. Wang Q, Ding S-L, Li Y, et al. (2020). The Allen Mouse Brain Common Coordinate Framework: a 3D reference atlas. *Cell* 181:936-953.e20. doi:10.1016/j.cell.2020.04.007.
3. TubeMap Brain-44R public example graph and ClearMap atlas resources. Open Science Framework, <https://osf.io/sa3x8/>; ClearMap TubeMap documentation, <https://clearanatomics.github.io/ClearMapDocumentation/v3.1/tubemap.html>. Accessed September 2026.
4. International Brain Laboratory. Working with IBL atlas object: Allen atlas coordinates and reference volumes. https://docs.internationalbrainlab.org/notebooks_external/atlas_working_with_ibllib_atlas.html. Accessed September 2026.
5. Dorr A, Sled JG, Kabani N (2007). Three-dimensional cerebral vasculature of the CBA mouse brain: a magnetic resonance imaging and micro computed tomography study. *NeuroImage* 35:1409-1423. doi:10.1016/j.neuroimage.2006.12.040. Atlas files: Mouse Imaging Centre (MICE), The Centre for Phenogenomics, Toronto.
6. Broersen R, Stuart GJ (2023). In vivo whole-cell recording from morphologically identified mouse superior colliculus neurons. *STAR Protoc* 4:101963. doi:10.1016/j.xpro.2022.101963 (typical bregma-lambda distance 4.21 mm).

Accompanying files

The folder holds the paper, the two surface maps, twenty-one major-vessel coronal projections with a montage, the length chart, a per-projection CSV and provenance JSON for the major-vessel set, and the class audit for the whole slab. The original graph and atlas volumes are available from the cited public sources and are not duplicated here.

To rebuild: `extract_brain44r.py` converts the downloaded graph to NumPy arrays (with `--legacy` for the class audit script); `render_major_vessels.py` renders every major-vessel figure and its provenance; `build_vascular_white_paper.py` rebuilds the chart and this PDF from the saved figures and JSON.