MAPPING COLLATERAL IMPACTS: REGIONAL SPARING IN ACUTE ISCHEMIC STROKE

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BACKGROUND

IMPACT OF COLLATERALS ON INFARCT

- Hypoperfusion of downstream tissue during ischemic stroke can be mitigated by recruitment of secondary circulation pathways [1-3].
- In acute ischemic stroke (AIS), collateral circulation is correlated with improved clinical outcome, reduced mortality and decreased size of final infarct (FI) [1-3].
- The efficacy of collaterals, however, is dependent on the anatomy of pathways, recruitment rate and recanalization [1, 2].

PURPOSE

1. Depict regional tissue salvage in patients with (C+) or without (C-) collateral circulation.
2. Examine the impact of occlusion location and recanalization status (R- vs R+) on the efficacy of collaterals.

METHODS

PATIENTS

- 349 patients with acute ischemic stroke 2003 -2013.
- Acute stroke protocol and 5-7 day follow-up MRI.
- Collateral score was calculated from baseline CT Angiography; scores 0,1 assigned collateral negative; 2,3 to collateral positive.
- Occlusion was also identified using CTA; internal carotid artery (ICA) occlusions were separated from middle cerebral artery (M1).

INFARCT PROBABILITY MAPS

- FI was manually traced from follow up images; tracings were spatially normalized to MNI space (SPM8, Wellcome Institute, UCL).
- Normalized tracings were averaged based on collateral status, recanalization status, and occlusion location (MATLAB 2012b).
- Averaged maps were compared voxel-wise while controlling for recanalization status and occlusion location.

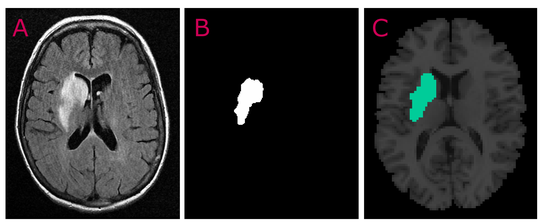

Figure 1. Image processing steps used in creating FI probability maps: A) Raw FLAIR image; B) Binary mask from tracing of A; C) Transformed mask in MNI standardized brain space.

STATISTICAL ANALYSIS

- Group probability maps were used to generate sparing maps, depicting the relative reduction in FI given collaterals as in:

$$Sparing = \frac{(PI_{C-}) - (PI_{C+})}{(PI_{C-})}$$

- A voxel-wise z-score was calculated in each comparison and used to mask insignificant (z < 1.96) voxels.
- The volume of FI in each patient (FIV) was also calculated as the sun of nonzero voxels in the spatially normalized tracings.
- FIV was also compared based on collateral status for each group.

RESULTS

BASELINE CHARACTERISTICS

- FIV was strongly correlated with negative patient outcome as measured by 90-day mRS, while recanalization, collateral score, CBS and M1 occlusion were each correlated with improved outcome ($p < 0.0001$).
- Distribution of FI (Figure 1) was consistent with literature with greater propensity to FI in basal ganglia regions [4].

FINAL INFARCT VOLUME

- Significant salvage of tissues was observed in all volumetric comparisons (Table 1) demonstrating the benefit of collateral recruitment.
- Collateral impact was greater in patients who did not recanalize, and in patients who presented with occlusions in the M1 or distal vessels.

REGIONAL SPARING

- Spatial modeling has quantified and visually demonstrated the scale and distribution of tissue sparing accounted for by collaterals (Figure 3).
- A greater propensity to peripheral sparing and central infarction is demonstrated, consistent with theoretical accounts of collateral pathophysiological mechanisms [1,2].

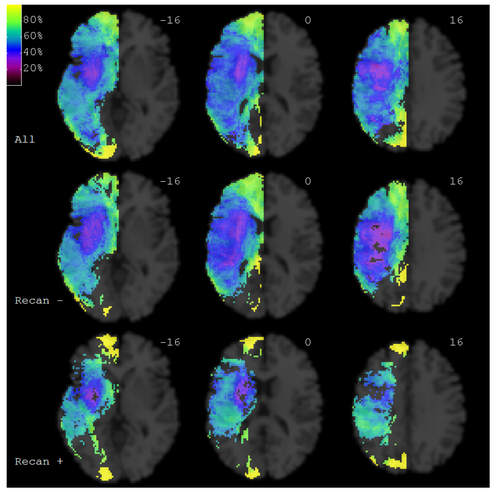

Figure 3. Voxel-wise relative sparing due to collaterals based on average FI tracings; voxels show the percent reduction in probability of infarction given collaterals. Only voxels reaching a significant z-score (≥ 1.96) are displayed. Numeric indices denote slice distance (mm) from MNI-space origin.
TOP: Sparing map for all patients irrespective of recanalization status
MIDDLE: Sparing in non-recanalizing patients
BOTTOM: Sparing in recanalization-positive patients

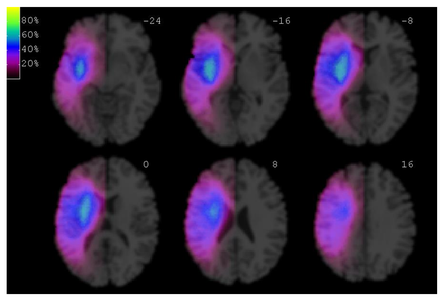

Figure 2. Distribution of infarction in the total patient cohort (N = 349). Colour-mapped intensities represent the probability of infarction based on population proportions, after mirroring left-sided strokes onto the right side.

Table 1. Median FIV (cc); Wilcoxon rank-sum unpaired tests compare C+ to C– groups for each of R+ and R-. In all comparisons, collaterals contributed to reductions in FIV.

	Occ	C	N	Volume (cc)	p
R–	ICA	–	24	324	0.023
		+	40	175	
	M1	–	22	203	<0.001
		+	61	61	
	ALL	–	46	258	<0.001
		+	101	83	
R+	ICA	–	10	224	0.010
		+	35	81	
	M1	–	14	100	<0.001
		+	144	34	
	ALL	–	24	133	<0.001
		+	179	36	

DISCUSSION

CLINICAL ANATOMY

- In the absence of recanalization, the deep and peripheral M1 distribution salvage presumably reflects the greater availability of collateral pathways at the level of the circle of Willis and peripheral watershed regions (Figure 4).
- Patients with ICA occlusion, however, profit primarily in the distal border regions of the M1 territories likely due to watershed zone retrograde collateral pathways through the anterior and posterior cerebral arteries (ACA, PCA)

SIGNIFICANCE

- Acute penumbral tissues may survive without recanalization if sufficient collaterals are recruited, particularly in distal tissues.
- Conversely, central infarction is little affected by collaterals

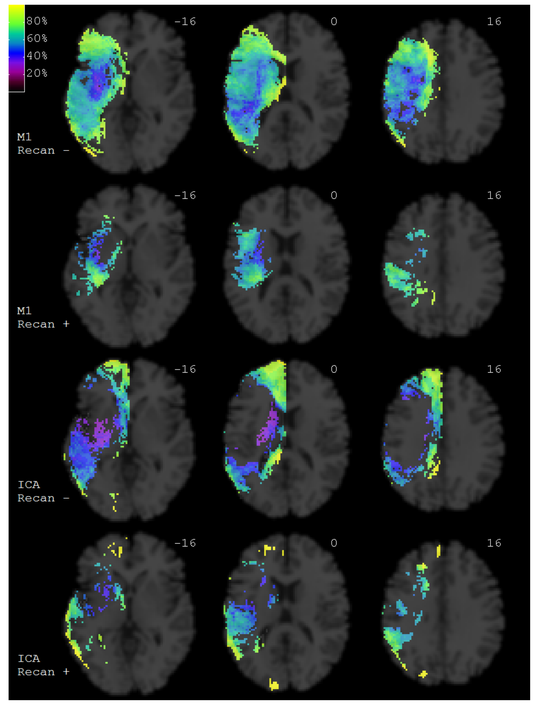

Figure 4. Relative sparing maps due to collaterals for patients grouped by occlusion location and recanalization status. Numeric indices denote slice distance (mm) from MNI-space origin.
TOP: Significant sparing in the proximal and peripheral M1 territory due to recruitment of circle of Willis and border-region collateral pathways. Marked reduction in volume and extent of infarcted tissue in the presence of collaterals
BOTTOM: Smaller overall infarction with marked peripheral sparing may be attributable to leptomeningeal or extracranial anastomoses.

REFERENCES & ACKNOWLEDGEMENTS

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