A Novel Collateral Imaging method Derived from Time-Resolved Dynamic Contrast-Enhanced Magnetic Resonance Angiography in Acute Ischemic Stroke

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BACKGROUNDS & PURPOSES

- Assessment of the collateral status has been emphasized for appropriate treatment decisions in patients with acute ischemic stroke (AIS).
- Multiphase collateral flow map derived from dynamic susceptibility contrast-enhanced MR perfusion (DSC-MRP) provides prognostic value in AIS with a major artery occlusion.
- Dynamic contrast-enhanced MRA (DCE-MRA) is also an angiographic imaging method and, like DSC-MRP, detects intracranial dynamic signals according to the flow of MR contrast media.

➤ To introduce the new multiphase collateral imaging method, named 'mMRA Collateral map', using the dynamic signals of DCE-MRA.
➤ To evaluate whether these new collateral maps can be used to predict outcomes in patients with AIS due to major artery occlusion.

RESULTS

- 101 AIS episodes in 100 pts(38 F, 63 M), Mean age: 70.6±10.9 year
- IA-Thrombectomy (EVT) : 54 cases in 53 pts
- Inter-observer reliabilities for collateral scoring of both maps
  ✓ Weighted κ = 0.964 for DCE-MRA Collateral map
  ✓ Weighted κ = 0.956 for DSC-MRP Collateral map

Table 1. Univariate predictors of clinical outcome after ischemic stroke (Total 101 AIS episodes in 100 pts)

Predictor	Poor Outcome (N=49)	Good Outcome (N=52)	p
Age	73.6 ± 11.7	64.7 ± 12.4	< 0.001
Male sex	30 (61.2%)	33 (63.5%)	0.8166
Initial NIHSS	15.0 ± 5.0	9.0 ± 6.0	< 0.001
IAT	24 (49.0%)	30 (57.7%)	0.3809
IV-tPA	29 (59.2%)	31 (59.6%)	0.9648
HTN	35 (71.4%)	27 (51.9%)	0.0461
DM	17 (34.7%)	11 (21.2%)	0.1317
Dyslipidemia	9 (18.4%)	13 (25.0%)	0.4211
A-fib	19 (38.8%)	17 (32.7%)	0.5239
Smoking	8 (16.3%)	12 (23.1%)	0.3968
Alcohol	12 (24.5%)	18 (34.6%)	0.2675
Prev. Stroke Hx.	4 (8.2%)	10 (19.2%)	0.1174
IHD Hx.	8 (16.3%)	9 (17.3%)	0.8952
Onset to Door time	104.2 ± 115.8	130.9 ± 115.0	0.2470
MAC score			< 0.0001
0	13 (26.5%)	0 (0.0%)	
1	8 (16.3%)	2 (3.8%)	
2	12 (24.5%)	9 (17.3%)	
3	13 (26.5%)	17 (32.7%)	
4	2 (4.1%)	11 (21.2%)	
5	1 (2.0%)	13 (25.0%)	

Table 2. Multivariate predictors of good clinical outcome after ischemic stroke

Predictor	Odds ratio	95% Confidence interval	P
Age	0.93	0.88-0.97	0.002
HTN	0.75	0.27-2.05	0.570
Initial NIHSS	0.86	0.78-0.95	0.002
MAC score			
0			
1	2.37	0.39-14.37	0.348
2	2.86	0.42-18.74	0.280
3	14.19	1.84-109.66	0.011
4	27.11	2.78-264.79	0.005
5	23.85	1.28-443.82	0.033

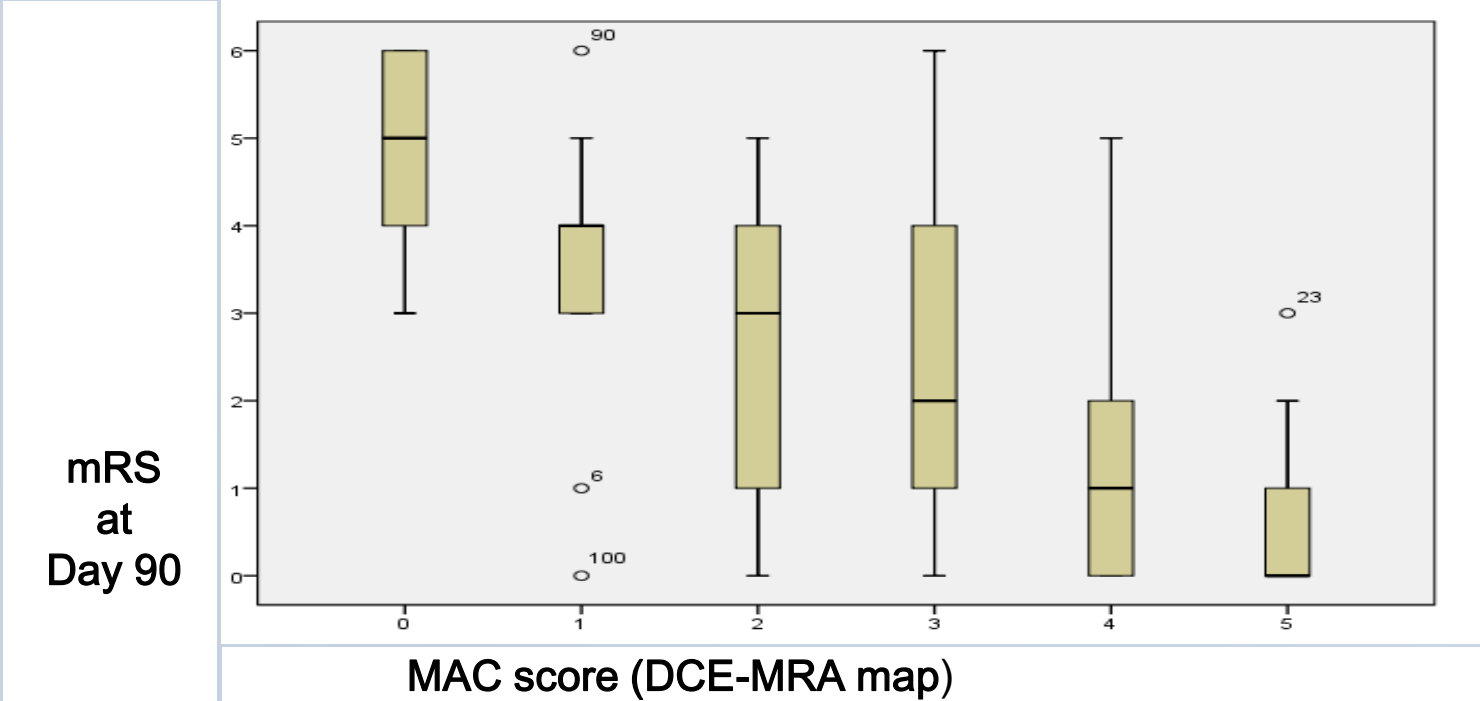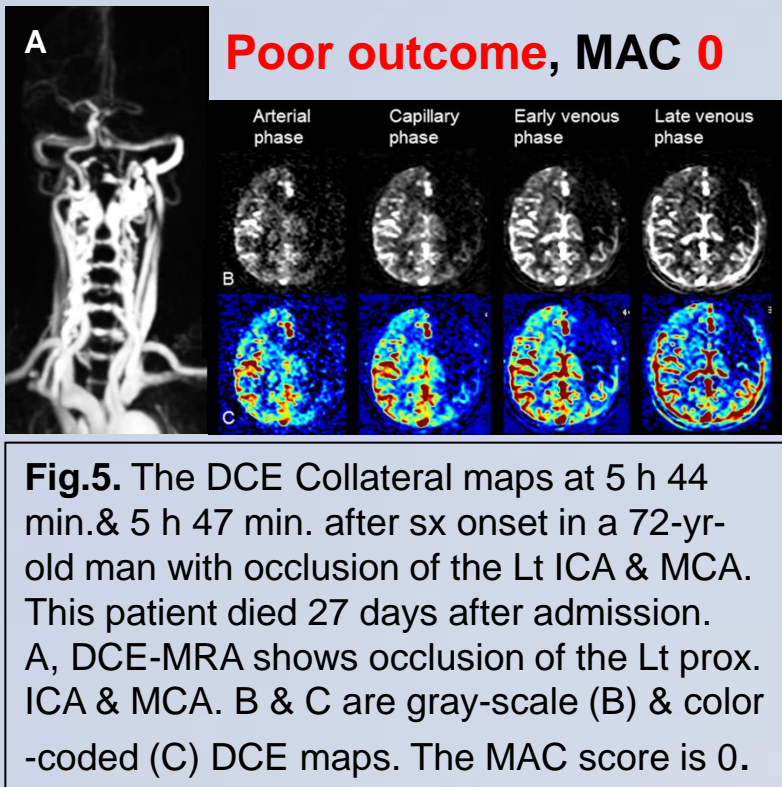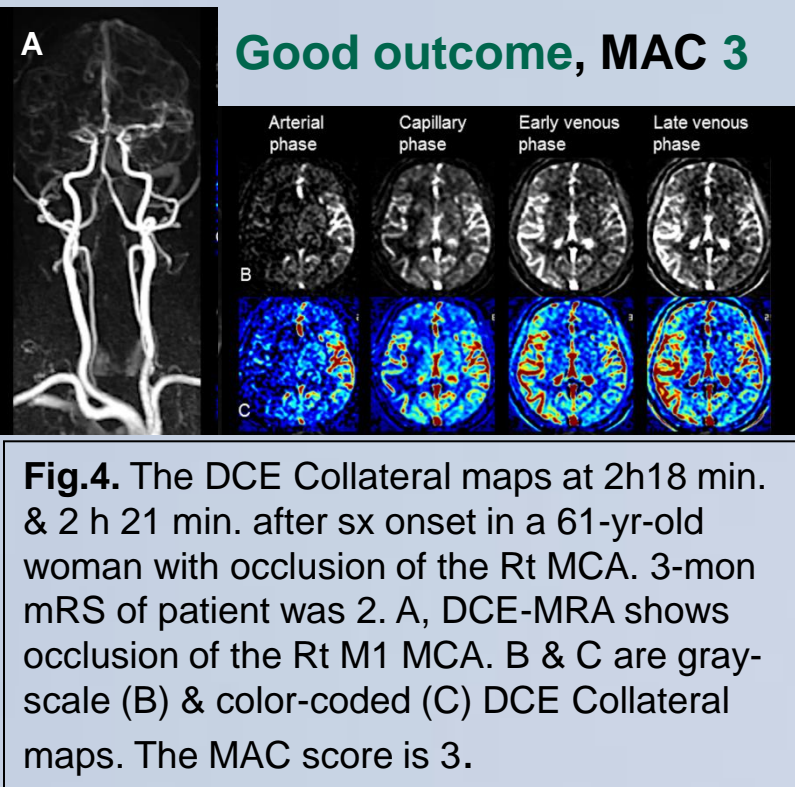**Fig.3**. The correlation of collateral grade (MAC score) and 3- month clinical outcome after acute ischemic stroke.

Good outcome, MAC 3

Fig.4. The DCE Collateral maps at 2h18 min. & 2 h 21 min. after sx onset in a 61-yr-old woman with occlusion of the Rt MCA. 3-mon mRS of patient was 2. A, DCE-MRA shows occlusion of the Rt M1 MCA. B & C are gray-scale (B) & color-coded (C) DCE Collateral maps. The MAC score is 3.

Poor outcome, MAC 0

Fig.5. The DCE Collateral maps at 5 h 44 min.& 5 h 47 min. after sx onset in a 72-yr-old man with occlusion of the Lt ICA & MCA. This patient died 27 days after admission. A, DCE-MRA shows occlusion of the Lt prox. ICA & MCA. B & C are gray-scale (B) & color-coded (C) DCE maps. The MAC score is 0.

METHODS

- MRI data of patients with AIS from a prospectively maintained registry
- 3-T Magnetom Skyra MRI system
- Generation of collateral imaging from the 4D-MRA data
  - Data processing by use of dedicated software running in MATLAB
- Nov. 2015 ~ Jul. 2017 at two university medical centers
- Inclusion criteria
  - patients who presented symptoms consistent with AIS within 8 hours of symptom onset
  - patients older than 18 years
  - patients who underwent a brain MRI, including DWI, DSCMRP, and DCE-MRA, at admission
  - patients with occlusion or severe stenosis (≥ 70%) of the unilateral ICA and/or M1 segment of the MCA (M1 MCA) and the associated symptoms.
- Good outcome : mRS of ≤ 2, or an mRS equal to the pre-stroke mRS if the pre-stroke mRS was > 2 at day 90.
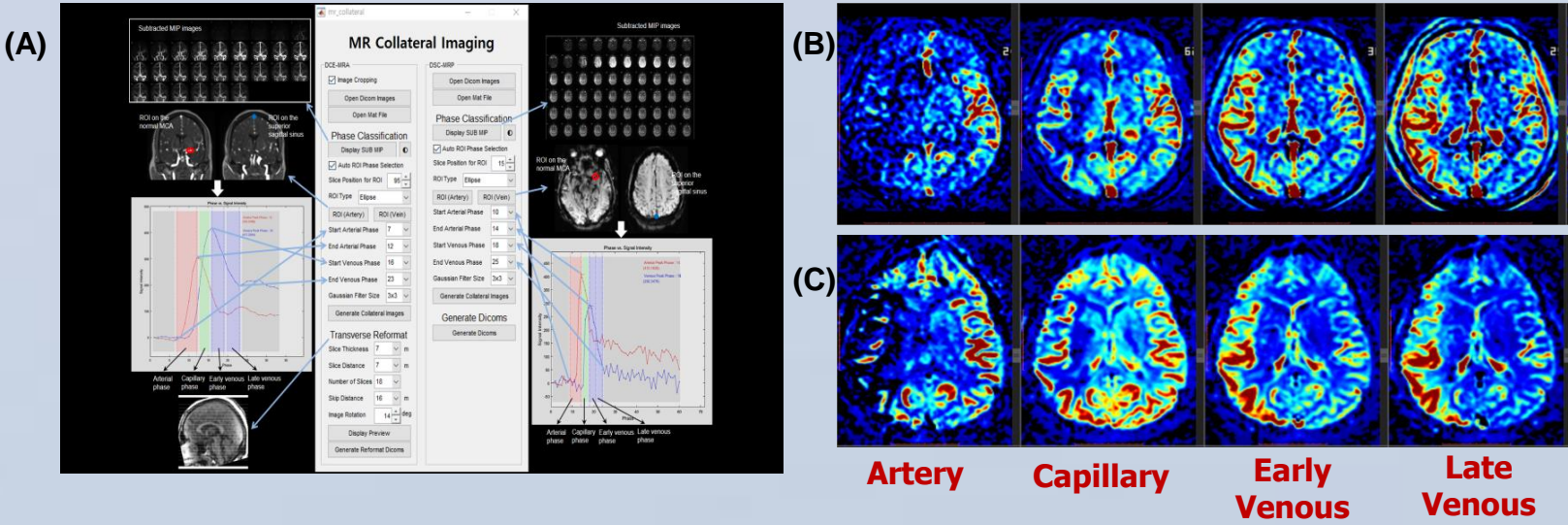
Artery   Capillary   Early Venous   Late Venous

Fig.1. Sequential post-processing steps by use of MATLAB-based program (A). The DCE-MRA (B) & DSC-MRP (C) Collateral maps consisted early, mid, & late phases divided by reference time point represented the midpoint of the mid phase on signal intensity-time curve. The three phases were correlated with arterial, capillary, & venous phases of DSA respectively.

5=Excellent
No or *small collateral defect in ischemic territory on Capillary phase regardless collateral status on Arterial phase

4=Good
Collateral defect ≤ ½ of ischemic territory on Capillary phase + no or small collateral defect on Early Venous phase

3=Intermediate~Good
1. Collateral defect ≤ ½ of ischemic territory on Capillary phase + Collateral defect ≤ ½ on Early Venous phase
2. Collateral defect > ½ of ischemic territory on Capillary phase + no or small Collateral defect on Early Venous phase

2=Intermediate~Poor
Collateral defect > ½ of ischemic territory on Capillary phase + Collateral defect ≤ ½ on Early Venous phase

1=Poor
Collateral defect > ½ of ischemic territory on Early Venous phase + Collateral defect ≤ ½ on Late Venous phase

0=Very poor
Collateral defect > ½ of ischemic territory on Late Venous phase

<Phase>   Artery   Capillary   Early Venous   Late Venous
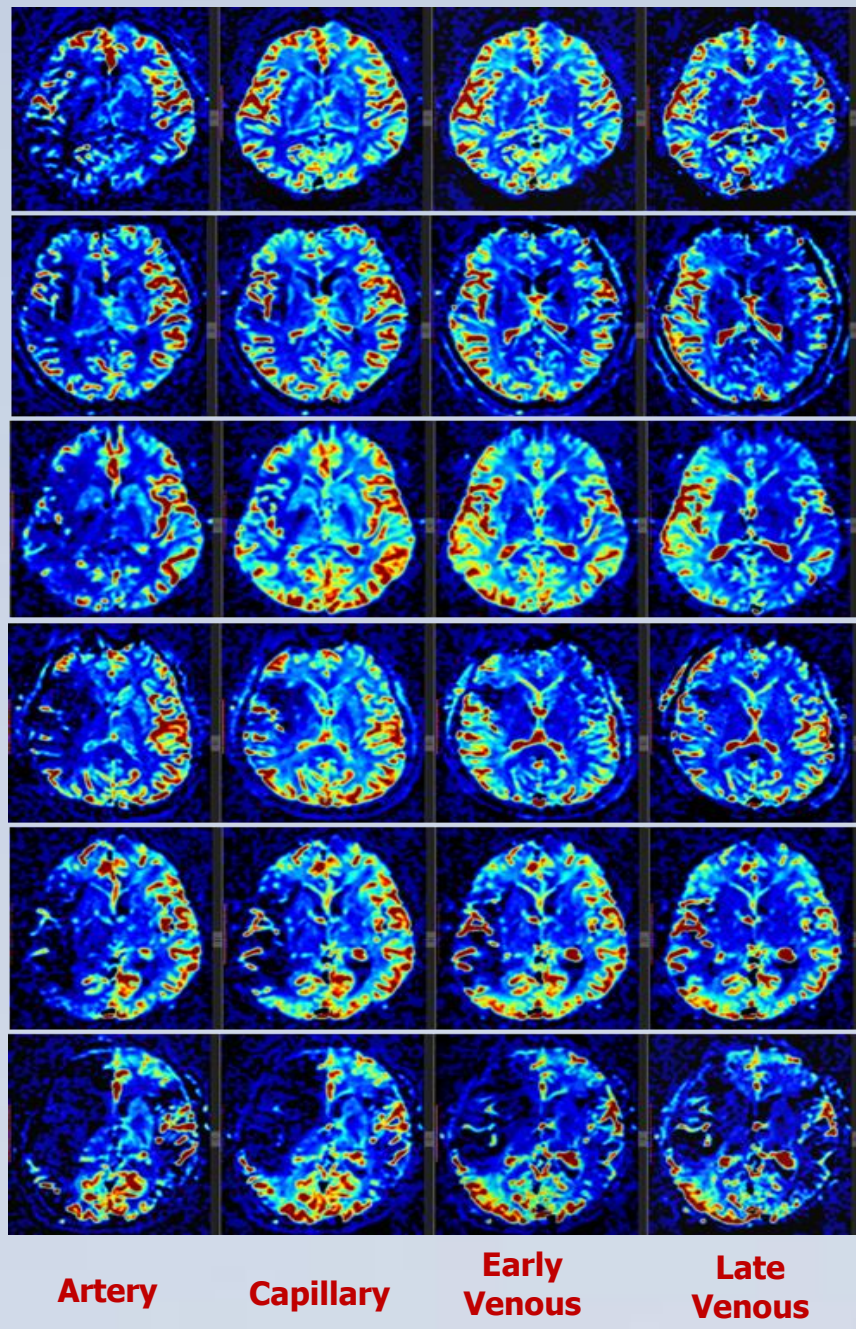
Fig.2. Collateral flow map-based grading system with a 6-point scale (Magnetic resonance Acute ischemic stroke Collateral, MAC score). It represent the collateral-perfusion status & severity of ischemia in the MCA territory by comparison with the unaffected cerebral hemisphere.

CONCLUSIONS

- Multiphase collateral imaging derived from time-resolved MRA can be used as a predictor of clinical outcome in patients with AIS.
- The DCE-MRA collateral map may result in simplification of the acute stroke MRI protocol (composed of DWI, SWI, & 4D-MRA) & shortening the imaging time (<10 min.) with minimal amount of the contrast media.
- Future validation of the clinical usefulness of DCE-MRA collateral map and large clinical studies are needed.

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