Ghost Infarct Core and admission CT perfusion: redefining neuroimaging role in acute ischemic stroke

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INTRODUCTION

- Early arterial recanalization is one of the most important goals to address in the management of acute ischemic stroke
- However, an inadequate selection of a patient to reperfusion therapy may deprive some patients from treatment or offer futile treatment to others. Determining the size of infarct extent is crucial to elect patients for reperfusion therapies.
- Computed tomography (CT) perfusion (CTP) based on cerebral blood volume (CBV) may overestimate infarct core on admission and consequently include **ghost infarct core (GIC)** in a definitive lesional area.
- Our **goal** is to **confirm** and **better characterize GIC phenomenon** using CTP- cerebral blood flow (CBF) as the reference parameter to determine infarct core.

METHODS

We performed a retrospective (from January 2014 to June 2017), single-center analysis of consecutive patients who received EVT due to proximal middle cerebral artery (M1-MCA) or terminal internal carotid artery (TICA) occlusions or tandem extracranial/intracranial occlusion.

Imaging protocol

The CTP images were sent to RAPID® software in order to quantify Ischemic core (CBF-core) as the area with >70% reduction in CBF (rCBF<0.3) in comparison to the mean CBF of normally perfused brain parenchyma.

Time from symptom onset to CTP and to recanalization was recorded.

Final infarct volume was measured on follow-up imaging at 24 hours on non-contrast cerebral tomography by a vascular neurologist using the (A×B×C)/2 formula. **Ghost Infarct Core (GIC)** was defined and considered **when initial core volume minus final infarct volume > 10 mL**.

Outcomes

Primary outcome: to determine the prevalence of GIC.

Secondary outcomes: time from symptom onset to CTP, from CTP to recanalization, from symptom onset to recanalization, time to CTP and to recanalization, recanalization rate, mRS ≤2 at 90 days, hemorrhagic transformation and in-hospital death.

Statistical significance for intergroup differences was assessed by Pearson χ² test or Fisher exact test for categorical variables and by Mann-Whitney U test for continuous variables.

A probability value of ≤0.05 was considered significant for all tests.

RESULTS

- 123 patients** were included, baseline characteristics are shown in **Table I**:

Variable	All Patients n=123	GIC>10 mL n=20	No GIC n=103	p value
Sex (female/male)	77/46	13/7	64/39	0.80
Age (years), median (IQR)	78 (67-83)	77 (64-83)	78 (68-83)	0.69
Previous mRS ≤ 2 (%)	99.20%	100%	99%	0.66
NIHSS admission, median (IQR)	18 (13-20)	19 (16-21)	17 (12-20)	0.26
Symptom onset to CTP, minutes, median (IQR)	188 (67-288)	107 (50-227)	193 (76-294)	0.10
Time from CTP to recanalization, minutes, median (IQR)	56 (40-84)	42 (33-78)	63 (42-85)	0.13
Symptom onset to recanalization, minutes, median (IQR)	241 (142-352)	150 (105-291)	255 (163-367)	0.05
Time to CTP < 259 min (%)	69%	85%	65.60%	0.09
Time to recanalization < 302 min (%)	63.30%	84%	58.90%	0.04
Recanalization rate (TICI 2b, 2c or 3) (%)	82.90%	90%	81.60%	0.36

- A ROC curve analysis showed a cut-off point of **302 minutes** in time to recanalization (S: 41,1%, E: 84,2%) to be associated with the presence of GIC.
- A *logistic regression* adjusting for time to recanalization < 302 minutes and CBF-core found both time to recanalization <302 min (OR 4.598, 95% CI 1.143 to 18.495, p=0.032) and initial infarct volume (OR 1.01, 95% CI 1.001 to 1.019, p=0.032) as independent predictors of GIC.

- Imaging characteristics and outcomes are shown in **Table II**:

Variable	All Patients n=123	GIC>10 mL n=20	No GIC n=103	p value
CT ASPECTS admission, median (IQR)	9 (8-10)	9 (7-10)	9 (8-10)	0.90
IV tPA pretreatment (%)	43.40%	55%	41.20%	0.25
Occlusion location				
MCA-M1 (%)	80.40%	80%	80.60%	
Terminal ICA (%)	16.30%	15.00%	16.50%	
Tandem ICA/MCA (%)	3.30%	5.00%	2.90%	
TOAST				
Atherothrombotic (%)	2.40%	5%	1.90%	
Cardioembolic (%)	71.50%	85%	68.90%	
Undetermined (%)	20.30%	5%	23.30%	
Other determined (dissections)	5.70%	5%	5.80%	
CBF-core, mL, median (IQR)	8 (0-35)	38 (26-59)	6 (0-27)	0.00
Final infarct volume, mL, median (IQR)	12 (1-67)	6 (1-13)	15 (1-80)	0.05
Infarct growth mL, median (IQR)	3.56 (-5-34)	-27 (-48.4- -14)	7 (0-50)	0.00

- From those patients with **complete recanalization (n=102)**, 18 patients (17,6%) presented GIC.
 - ✓ **GIC** was associated with time to recanalization (150 (117-267) vs 245 (165-365); p=0.04)
 - ✓ *ROC curve analysis*: time from **symptom onset to CTP < 259 min** (time to CTP < 259:GIC=23.2% vs time to CTP > 259: GIC=6.7%; p=0.05) tended to be associated with presence of GIC.
 - ✓ Time from **onset to recanalization < 302 min** (time to recanalization < 302 min: GIC=24.6% vs time to recanalization > 302 min: GIC = 6.5%; p=0.03) is associated with presence of GIC.
- Favorable **outcome at 90 days** was achieved in 45 patients (36.8%) with a non statistical trend favoring GIC patients (52.60% Vs 31.10%: p=0.1).

DISCUSSION

- Our results reinforce the notion that GIC is time dependent.
- We found a cut-off of approximately 4.5 hours to imaging and 5 hours to recanalization as independent predictors of GIC in CBF < 30%.
- Initial ASPECTS-CTP lesion may overestimate the final infarct, since GIC patients have shorter time from symptom onset to CTP, from CTP to reperfusion and higher rates of recanalization. An example is shown in **Figure 1**:

Figure 1: Admission CT (A), admission CTP with CBF <30% (B), initial and post-revascularization angiography (C) and 72 hour CT (D) of a 70 year old male that presented to the Emergency Department with signs and symptoms of a **right total anterior circulation infarct**. NIHSS at admission: 19. **Brain CT:** blurred outlines of right lentiform nucleus. **Angio-CT:** occlusion of right internal carotid artery and initial portion (M1) of right CMA. **CTP:** infarct core of 143 mL based on CBF<30%. The patient underwent endovascular treatment with successful **TICI 2b** at first pass. Time from symptom onset to CT was 107 minutes and to recanalization was 153 minutes. After the procedure, NIHSS: 14. At 5th day, NIHSS: 5. Follow up CT at day 3: very limited infarct. At 3 months, mRS was 2

- Despite showing significantly larger “presumed” initial infarct core volume, patients with GIC had experienced significantly higher rates of favorable outcome mRS at 90 days.

CONCLUSION

- CTP CBF < 30% may overestimate infarct core volume, especially in patients imaged in the very early time window and with fast complete reperfusion. Therefore, CTP-CBF technique may exclude patients who would benefit from endovascular treatment.

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