

# Angiographic Blush after Mechanical Thrombectomy is Associated with Hemorrhagic Transformation of Ischemic Stroke

Setareh Salehi Omran, MD,\* Srikanth Reddy Boddu MD,†

Aaron M. Gusdon, MD,\* Benjamin Kummer, MD,\* Hadiyah Baradaran, MD,‡

Praneil Patel, MD,‡ Iván Díaz, PhD,§ Babak B. Navi, MD, MS,\* || Ajay Gupta, MD,‡

Hooman Kamel, MD,\* || and Athos Patsalides, MD, MPH†

*Background and Purpose:* Risk factors for hemorrhagic transformation of ischemic stroke after mechanical thrombectomy (MT) are not well established. We conducted a study to determine if prominent angiographic cerebral vascularity following recanalization with thrombectomy (angiographic blush) is associated with hemorrhagic transformation. *Methods:* Using the Cornell Acute Stroke Academic Registry, we identified stroke patients who had thrombectomy and achieved recanalization of anterior circulation large-vessel occlusion between 2012 and 2015. The exposure variable was presence of angiographic blush after recanalization, defined as capillary blush with or without early venous drainage. The primary outcome was volume of hemorrhagic transformation on brain imaging after thrombectomy, as determined by semiautomated volumetric analysis on computed tomography or magnetic resonance imaging among those adjudicated to have hemorrhagic conversion by neuroradiology investigators blinded to angiography results. Using a doubly robust estimator with propensity scores and outcome regression adjusting for demographics and known risk factors for hemorrhagic transformation, we evaluated whether angiographic blush after recanalization is associated with an increased volume of hemorrhagic transformation. *Results:* Among 48 eligible patients, 31 (64.6%) had angiographic blush and 26 (54.2%) had radiographic hemorrhagic transformation (mean volume, 7.6 ml). Patients with angiographic blush averaged lower thrombolysis in cerebral infarction scores and more often received intravenous thrombolysis. In adjusted analysis, angiographic blush was associated with an increased volume of hemorrhagic transformation: mean volume, 10.3 ml (95% CI, 3.7-16.9 ml) with blush versus 1.8 ml (95% Confidence Interval (CI), 0.1-3.4 ml) without ( $P = .01$ ). *Conclusions:* Presence of angiographic blush after MT was independently associated with the volume of hemorrhagic transformation.

**Key Words:** Angiography—thrombectomy—brain infarction—hemorrhage

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From the \*Department of Neurology, Weill Cornell Medicine, New York, NY; †Department of Neurological Surgery, Weill Cornell Medicine, New York, NY; ‡Department of Radiology, Division of Neuroradiology, Weill Cornell Medicine, New York, NY; §Division of Biostatistics and Epidemiology, Weill Cornell Medicine, New York, NY; and || Feil Family Brain and Mind Research Institute, Weill Cornell Medicine, New York, NY.

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Address correspondence to Setareh Salehi Omran, MD, Department of Neurology, Weill Cornell Medicine, Clinical and Translational Neuroscience Unit, 407 East 61st Street, New York, NY, 10065. E-mail: [sso2002@nyp.org](mailto:sso2002@nyp.org)  
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## Introduction

Randomized trials have established mechanical thrombectomy (MT) with stent-retrievers as the standard treatment for acute ischemic stroke from proximal large-vessel cerebral artery occlusion.<sup>1</sup> However, these procedures are not without risk, which occurs in about 5%-6% of patients following treatment.<sup>2,3</sup> Symptomatic intracranial hemorrhage after stroke is associated with worse long-term functional outcomes and increased mortality.<sup>4,5</sup> Unlike with intravenous thrombolysis, predictors of hemorrhagic transformation after MT are not well established. Some possible risk factors include history of diabetes or atrial fibrillation, higher degree of initial stroke severity, use of intravenous thrombolysis, delays in arterial puncture, lower pretreatment Alberta Stroke Program Early CT Score (ASPECTS) scores, and incomplete recanalization.<sup>6-9</sup> Apart from clinical information and reperfusion grading schemes, there is limited data on angiographic markers of hemorrhagic transformation.

Prominent brain vascularity in the form of capillary blush with or without arteriovenous shunting and early venous drainage (so called *angiographic blush*) can be seen on angiography after acute recanalization of cerebral artery occlusion with MT. The clinical relevance of angiographic blush is uncertain but some data suggest that it is a biomarker for endothelial damage and blood brain barrier disruption, and that it might predict hemorrhagic transformation after recanalization therapy, as well as resultant poor outcomes.<sup>10-13</sup> Identifying a novel angiographic marker might aid in preventing hemorrhagic transformation and clinical deterioration in susceptible patients through various means, including aggressive postMT blood pressure control. In this study, we investigated the association between angiographic blush after MT and the volume of postprocedural hemorrhagic transformation. Our hypothesis was that angiographic blush would be associated with an increased volume of hemorrhagic transformation independent of confounding factors.

## Methods

### *Study Design and Population*

The data that support the findings of this study are available from the corresponding author upon request. We used data from the prospective Cornell Acute Stroke Academic Registry, which comprises patients with acute stroke at New York-Presbyterian Hospital/Weill Cornell Medical Center, a tertiary-care teaching hospital and designated comprehensive stroke center with around-the-clock endovascular capability. For this study, we included all ischemic stroke patients who received MT with stent-retriever devices for anterior circulation proximal cerebral artery occlusion (e.g., intracranial internal carotid artery or M1 segment of the middle cerebral artery) within

6 hours of stroke onset between January 1, 2012 and December 31, 2015. Patients were excluded if they had MT beyond 6 hours, received intra-arterial thrombolysis without MT, or did not have recanalization of the occluded site. This study was approved by the Weill Cornell Medicine Institutional Review Board, which waived the requirement for informed consent due to minimal risk to subjects.

### *Measurements*

The Cornell Acute Stroke Academic Registry includes prospectively collected information on demographic, clinical, treatment, and outcome data. For this analysis, a neurologist reviewed patients' electronic medical records and ascertained the following additional data: blood pressure on arrival to the emergency room, the anatomical site of the intracranial large-vessel occlusion, the type of MT device used, time from symptom onset until groin puncture, and recanalization time.

We retrospectively ascertained the following imaging parameters: the ASPECTS score on the initial computed tomography (CT), the postprocedure modified Thrombolysis in Cerebral Infarction (TICI) score, the presence and quantification of angiographic blush following MT, and the presence and degree of hemorrhage on postthrombectomy CT and magnetic resonance imaging (MRI).<sup>14,15</sup> The TICI score was obtained retrospectively from the operative notes written by the interventionalist. ASPECTS score was ascertained using double adjudication by two neuroradiologists (H.B., P.P) blinded to clinical outcome, with disagreements being resolved by a third, independent neuroradiology attending (A.G.). Angiographic blush was interpreted by two attending interventional neuroradiologists (S.B., A.P.) in consensus, who were blinded to the patient risk factors and clinical outcome. The final degree of angiographic blush was expressed as a score deemed acceptable by both interventional neuroradiologists. We adapted a three-tiered grading system used in previous studies for interpretation of severity of angiographic blush: normal vascularity, presence of capillary blush, and capillary blush with arteriovenous shunting and early venous drainage (Fig 1).<sup>12</sup> Similar to previous studies, we defined capillary blush as prolonged contrast enhancement, and arteriovenous shunting and early venous drainage as the premature depiction of the venous system with drainage into the Vein of Galen after injection of the contrast medium. The severity of angiographic blush was determined on the angiographic series obtained immediately after recanalization.

All data variables were predefined prior to data abstraction using a data dictionary that underwent several revisions based on investigator feedback.

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