Prediction of Recanalization Trumps Prediction of Tissue Fate
The Penumbra: A Dual-edged Sword

Guangming Zhu, MD, PhD; Patrik Michel, MD; Amin Aghaebrahim, MD; James T. Patrie, MS; Wenjun Xin, MS; Ashraf Eskandari, NP; Weiwei Zhang, MD, PhD; Max Wintermark, MD

Background and Purpose—To determine whether infarct core or penumbra is the more significant predictor of outcome in acute ischemic stroke, and whether the results are affected by the statistical method used.

Methods—Clinical and imaging data were collected in 165 patients with acute ischemic stroke. We reviewed the noncontrast head computed tomography (CT) to determine the Alberta Score Program Early CT score and assess for hyperdense middle cerebral artery. We reviewed CT-angiogram for site of occlusion and collateral flow score. From perfusion-CT, we calculated the volumes of infarct core and ischemic penumbra. Recanalization status was assessed on early follow-up imaging. Clinical data included age, several time points, National Institutes of Health Stroke Scale at admission, treatment type, and modified Rankin score at 90 days. Two multivariate regression analyses were conducted to determine which variables predicted outcome best. In the first analysis, we did not include recanalization status among the potential predicting variables. In the second, we included recanalization status and its interaction between perfusion-CT variables.

Results—Among the 165 study patients, 76 had a good outcome (modified Rankin score ≤2) and 89 had a poor outcome (modified Rankin score ≥2). In our first analysis, the most important predictors were age (P<0.001) and National Institutes of Health Stroke Scale at admission (P=0.001). The imaging variables were not important predictors of outcome (P>0.05). In the second analysis, when the recanalization status and its interaction with perfusion-CT variables were included, recanalization status and perfusion-CT penumbra volume became the significant predictors (P<0.001).

Conclusions—Imaging prediction of tissue fate, more specifically imaging of the ischemic penumbra, matters only if recanalization can also be predicted. (Stroke. 2013;44:1014-1019.)

Key Words: infarct core ■ outcome ■ penumbra ■ recanalization ■ stroke

In a patient with an acute ischemic stroke (AIS), multimodal imaging can not only rapidly provide information about vessel patency status but also provide information about infarct core and tissue at risk (the ischemic penumbra). The role of the penumbral information, its prognostic value in terms of clinical outcome, and its impact on treatment decision are still debated. More specifically, contradictory results have been reported in the literature regarding whether the infarct core, or the ischemic penumbra, matters most in the prediction of outcome.

Two perfusion computed tomography (PCT)-based studies demonstrated that the volume of the infarct core was a more significant determinant of clinical outcome compared with the penumbra or total perfusion deficit.1,2 Another study using significant determinant of clinical outcome compared with demonstrated that the volume of the infarct core was a more significant determinant of clinical outcome compared with.

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The goal of our study was to determine which one of the infarct core or penumbra information was the more significant predictor of outcome in a large registry of patients with AIS, and to determine whether the results of this analysis are affected by the statistical method used.

Material and Methods

Study Patients
The clinical and imaging data presented in this study belong to a repository that has previously been described (Zhu G, Michel P, Aghaebrahim A, Patrie JT, Xin W, Eskandari A, Zhang W, Wintermark M. CT Work-Up of Patients Suspected of Acute Ischemic Stroke: Perfusion-CT Adds Value Compared to Clinical Evaluation, Noncontrast Head CT and CT-Angiogram in Terms of Predicting Outcome [submitted for publication]). Collection, analysis, and publication of data from the repository were approved by the respective institutional review boards of the contributing institutions.

We retrospectively identified in this registry all consecutive patients with suspected hemispheric stroke, who met the following inclusion criteria: (1) AIS resulting from M1 and/or internal carotid artery (ICA) occlusion and without intracranial hemorrhage; (2) completion of a stroke CT work-up at admission, including noncontrast head CT (NCT), PCT, and computed tomography angiogram (CTA), within 12 hours of symptom onset; and (3) completion of recanalization imaging (CTA, MR-angiography, or digital subtraction angiography) between 1 and 48 hours. Exclusion criteria included the following: (1) age <18 years and (2) no available admission, recanalization, and follow-up imaging (CT and MR).

We recorded the following demographic and clinical variables: age, sex, National Institutes of Health Stroke Scale at admission, time from symptom onset to recanalization imaging, type of reperfusion therapy (if any), time from symptom onset to baseline imaging, time from symptom onset to reperfusion therapy, and modified Rankin Score (mRS) at 90 days. Death was coded as mRS of 6.

PCT and CTA Image Acquisition
PCT studies were obtained on 16- and 64-slice CT scanners. Each PCT study involved successive gantry rotations performed in cine mode during intravenous administration of 1 or 2 boluses of 40 to 50 mL of iodinated contrast material at an injection rate of 4 to 5 mL/s. First-pass PCT acquisition ranged from 50 to 70 seconds, with a sampling interval of either 1 or 2 seconds. Total PCT coverage ranged from 20 to 80 mm. Acquisition parameters were 80 kVp and 100 to 200 mAs.

The CTA studies of the cervical and intracranial arteries were obtained with an image acquisition protocol as follows: helical mode: 0.5 to 0.8 second gantry rotation; pitch: 1 to 1.375:1; slice thickness: 0.625 to 1.25 mm; reconstruction interval: 0.5 to 1 mm; and acquisition parameters: 120 kVp/200 to 300 mAs. A caudocranial scanning direction was selected covering the midchest to the vertex of the brain.

Image Processing and Interpretation
The NCT studies were assessed for the Alberta Score Program Early CT Score (ASPECTS) and the presence or absence of a hyperdense middle cerebral artery sign. The head and neck CTA images were reviewed for the site and severity of arterial occlusion, the degree of collateral circulation, and the North American Symptomatic Carotid Endarterectomy Trial (or NASCET) degree of cervical ICA stenosis. The sites of occlusion were recorded as ICA only, M1 only, or both. The severity of arterial occlusion was scored using a modified version of the thrombosis in myocardial ischemia score: 0 = complete occlusion, 1 = severe stenosis, 2 = mild or moderate stenosis, and 3 = normal. Recanalization imaging (CTA or MRA or digital subtraction angiography) was reviewed for a second thrombolysis in myocardial ischemia measurement. Recanalization was defined as an improvement in the thrombosis in myocardial ischemia score from baseline to recanalization of ≥2 points. Absence of collateral flow to the ischemic territory was graded as 0, whereas collateral flow in <50%, >50%, and 100% of the vessels filling in the ischemic territory was graded as 1, 2, or 3, respectively; a score of 4 was added for individuals with >100% filling of the ischemic bed when compared with the normal side.

The PCT data were analyzed using Philips Brain Perfusion software version 4.5.2 (Philips Medical Systems, Cleveland, OH). This software relies on a volume principle. The software applies a curve fitting by least mean squares to obtain mathematical descriptions of the time–density curves for each pixel. The volumes of PCT infarct and PCT penumbra, automatically measured by the software as the areas of mean transit time >145% of the contralateral side values and cerebral blood volume <2.0 mL/100 g or >2.0 mL/100 g, respectively, were recorded.

Statistical Analyses

Descriptive Statistics
Continuous scaled data (eg, age, PCT infarct, PCT penumbra) were summarized by the mean±SD of the measurement distribution. Frequency data (eg, sex) were summarized by counts and percentages.

Multivariate Statistical Analyses

Multivariate logistic regression was used to determine whether clinical outcome (90-day mRS) was associated with a priori established sets of imaging and clinical work-up variables. The dependent variable in the multivariate logistic regression analyses was a binary variable assigned the value 1 if the patient had a good clinical outcome (ie, 90-day mRS ≤2) and was assigned the value 0 if the patient had a poor clinical outcome (ie, 90-day mRS >2).

Multivariate Logistic Regression Models
Two multivariate logistic regression models were constructed. The first multivariate logistic regression model (model 1) was constructed with age, sex, time from symptom onset to baseline imaging, NIHSS at admission, ASPECTS, hyperdense middle cerebral artery sign, collateral flow, site of occlusion, PCT infarct, PCT penumbra, PCT spatial coverage, and type of treatment as predictor variables. The second multivariate logistic regression model (model 2) was constructed with the same set of predictor variables as model 1. Additionally, model 2 included an indicator variable for recanalization and a set of interactions, which allowed the relationships between clinical outcome (ie, good or poor) and collateral flow, PCT penumbra, and type of treatment to be conditional on recanalization.

Model 1 Hypothesis Testing
The central focus of the hypothesis testing procedure was not to assess the relative importance of each imaging/clinical work-up variable with regard to predicting clinical outcome (ie, 90-day mRS ≤2, vs 90-day mRS >2), but to assess the relative importance of the different pieces of information extracted from the acute imaging and clinical work-ups with regard to predicting clinical outcome. More specifically, as part of the hypothesis testing procedure, the vascular patency variables (NCT hyperdense middle artery sign hyperdense middle cerebral artery sign, CTA site of occlusion) were evaluated as a unit, the infarct core variables (NCT ASPECTS, PCT infarct, and PCT spatial coverage) were evaluated as a unit, and the penumbra variables (CTA collateral flow, PCT penumbra, PCT spatial coverage) were evaluated as a unit. The clinical variables, such as sex, time from symptom onset to baseline imaging, and NIHSS at admission, were also evaluated as a unit, and type of treatment was evaluated as a separate entity (Table 1). Each hypothesis test was conducted by way of a likelihood ratio χ² test that compared the goodness of the fit of the full model (ie, model 1) with the goodness of the fit of the reduced model, which excluded the variable set of interest (eg, vascular patency variables). The null hypothesis rejection criterion was based on a P≤0.05 decision rule. If the null hypothesis was rejected, then additional likelihood ratio χ² tests were conducted to determine
which variables within the imaging/clinical work-up variable unit were uniquely associated with clinical outcome. A P ≤ 0.05 criterion was used as the null hypothesis rejection rule.

### Table 2. Patient Characteristics Based on 90-day mRS Outcome Dichotimization

<table>
<thead>
<tr>
<th>Variables</th>
<th>Patients With 90-day mRS 0–2 (n=76)</th>
<th>Patients With 90-day mRS &gt;2 (n=89)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>61.4±14.1</td>
<td>68.8±13.1</td>
</tr>
<tr>
<td>Female, %</td>
<td>51.3 (39/76)</td>
<td>48.3 (43/89)</td>
</tr>
<tr>
<td>Time from symptom onset to baseline imaging, h</td>
<td>8.4±11.5</td>
<td>5.3±5.2</td>
</tr>
<tr>
<td>Time from symptom onset to reperfusion therapy, h</td>
<td>9.9±5.0</td>
<td>7.1±3.8</td>
</tr>
<tr>
<td>Time from symptom onset to recanalization imaging, h</td>
<td>11.8±8.0</td>
<td>13.4±10.8</td>
</tr>
<tr>
<td>Admission NIHSS (mean±SD)</td>
<td>13.5±5.2</td>
<td>17.0±4.9</td>
</tr>
<tr>
<td>ASPECTS (mean±SD)</td>
<td>8.0±1.6</td>
<td>7.9±1.9</td>
</tr>
<tr>
<td>Hyperdense middle cerebral artery CT sign</td>
<td>Yes</td>
<td>67.1% (51/76)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>32.9% (25/76)</td>
</tr>
<tr>
<td>Site of occlusion</td>
<td>ICA</td>
<td>7.9% (6/76)</td>
</tr>
<tr>
<td></td>
<td>M1</td>
<td>75.0% (57/76)</td>
</tr>
<tr>
<td></td>
<td>ICA+M1</td>
<td>17.1% (13/76)</td>
</tr>
<tr>
<td>Collateral flow</td>
<td>2.1±0.9</td>
<td>1.9±0.9</td>
</tr>
<tr>
<td>PCT infarct, mL</td>
<td>33.4±39.6</td>
<td>54.1±50.4</td>
</tr>
<tr>
<td>PCT Penumbra, mL</td>
<td>50.2±29.4</td>
<td>44.7±37.4</td>
</tr>
<tr>
<td>PCT Coverage, mm</td>
<td>20</td>
<td>69.7% (53/76)</td>
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<tr>
<td></td>
<td>40</td>
<td>17.1% (13/76)</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>13.2% (10/76)</td>
</tr>
<tr>
<td>Treatment type</td>
<td>None</td>
<td>11.9% (9/76)</td>
</tr>
<tr>
<td></td>
<td>Endovascular</td>
<td>53.9% (41/76)</td>
</tr>
<tr>
<td></td>
<td>IV thrombolysis</td>
<td>14.5% (11/76)</td>
</tr>
<tr>
<td></td>
<td>Both</td>
<td>19.7% (15/76)</td>
</tr>
<tr>
<td>Recanalization</td>
<td>Yes</td>
<td>81.6% (62/76)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>18.4% (14/76)</td>
</tr>
</tbody>
</table>

ASPECTS indicates Alberta Score Program Early Computed Tomography score; CTA, computed tomography angiogram; NIHSS, National Institutes of Health Stroke Scale; and PCT, perfusion computed tomography.

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### Results

#### Study Patients and Clinical Characteristics

Of the 165 study patients, 76 (46.1%) had good outcome with a 90-day mRS from 0 to 2; 89 (53.9%) had a poor outcome with a 90-day mRS >2 (Table 2).

In the group with good outcome, 39 patients (51.3%) were female. Mean±SD age was 61.4±14.1 years (range 26–90). Mean±SD time from symptom to baseline imaging was 8.4±11.5 hours. Mean±SD time from onset to reperfusion therapy was 9.9±5.4 hours. Mean±SD time from onset to recanalization imaging was 11.8±8.0 hours. Mean±SD NIHSS was 13.5±5.2 (range 2–24). Mean±SD ASPECTS score was 8.0±1.6. Of 76 patients, 51 (67.1%) had a hyperdense middle cerebral artery CT sign; 6 (7.9%) had ICA occlusion, 57 (75.5%) had M1 occlusion, and 13 (17.1%) had both. The mean±SD collateral flow score was 2.1±0.9. Mean±SD volume of PCT infarct was 33.4±39.6 mL. Mean±SD volume of PCT penumbra was 50.2±29.4 mL. Nine patients (11.9%) did not receive reperfusion therapy; 41 (53.9%) received endovascular therapy; 11 (14.5%) patients received IV thrombolysis; and 33 patients (20%) received both IA and IV therapy. Sixty-two patients (81.6%) demonstrated recanalization.
In the group with poor outcome, 43 patients (48.3%) were female. Mean±SD age was 68.8±13.1 years (range 18–95). Mean±SD time from symptom to baseline imaging was 5.3±5.2 hours. Mean±SD time from onset to reperfusion therapy was 7.1±3.8 hours. Mean±SD time from onset to recanalization imaging was 13.4±10.8 hours. Mean±SD NIHSS was 17.0±4.9 (4–31). Mean±SD ASPECTS score was 7.9±1.9. Fifty-eight patients (65.2%) had a hyperdense middle cerebral artery CT sign. Eight of 89 patients (9.0%) had ICA occlusion, 59 (66.3%) had M1 occlusion, and 22 (24.7%) had both. Mean±SD collateral flow score was 1.9±0.9. Mean±SD volume of PCT infarct was 44.7±37.4 mL, and mean±SD volume of PCT penumbra was 54.1±50.4 mL. Fifteen patients (16.9%) did not receive reperfusion therapy; 37 (47.3%) received endovascular therapy; 19 patients (21.3%) received IV thrombolysis; and 18 (20.2%) patients received both IA and IV therapy. Only 50 patients (56.2%) demonstrated recanalization.

**Multivariate Logistic Regression Model 1 Without Recanalization Status**

With regard to the multivariate logistic regression analysis that did not include recanalization information (Table 3), the only subset of the regression predictor variables that was determined to be important in predicting clinical outcome (ie, 90-day mRS ≤2 vs 90-day mRS >2) was the clinical data (P<0.001). The infarct core, the tissue at risk, the site of occlusion and collateral status, and the type of treatment were not important in terms of predicting clinical outcome (Table 3). Among the set of clinical data, patient age and NIHSS at admission were both independent predictors of clinical outcome (P<0.001 and P=0.001, respectively), and both were inversely related to good clinical outcome.

**Multivariate Logistic Regression Model 2 With Recanalization Status**

With regard to the multivariate logistic regression analysis that did include recanalization information (Table 4), the significant predictors of clinical outcome were the clinical data (P<0.001), the tissue at risk (P=0.020), and the treatment and recanalization subset (P=0.001). Neither the infarct core (P=0.219) nor the site of occlusion and collateral status (P=0.155) were important predictors of clinical outcome. The most important predictors of clinical outcome were recanalization status (P<0.001) and PCT penumbra volume (P=0.001), which had a differential impact on clinical outcome through its interaction with recanalization (P<0.001). Significant clinical variables included age and NIHSS at admission (P<0.001 and P=0.004, respectively).

Overall, the additional predictive information about clinical outcome provided by the recanalization information and the interaction of this information with the infarct core and the penumbra information was highly significant (P<0.001) (Table 4).

Adjusted odds ratios, based on the multivariate logistic regression parameter estimates, suggested that in the presence of recanalization, a large PCT penumbra volume was predictive of a favorable outcome (odds ratio, 1.18; 95% confidence interval, 1.06–1.31; P=0.003). In the absence of recanalization, a large PCT penumbra volume was predictive of a poor outcome (odds ratio, 1.06; 95% confidence interval, 0.97–1.16; P=0.212).
Penumbral imaging has heralded a lot of hope in terms of shifting the treatment paradigm for AIS patients from a “time is brain” approach to a “penumbra is brain” or “imaging is brain” approach.9–11 However, recently, the clinical relevance of the penumbral information has been questioned, and some have proposed the infarct core volume as the only clinical relevant factor to decide whether AIS patients should be treated. In our study, we focused our attention on one single large population of patients, and we performed 2 separate analyses on the same patient population, matching the analyses typically reported by the proponents of the infarct core and by the proponents of the penumbra as the relevant clinical factors for acute stroke treatment decisions.

Our first analysis did not take into account recanalization because the recanalization information is not known at admission, when a treatment decision needs to be made. In this analysis, we found that the predictors of functional outcome include clinical data, including age and NIHSS, at admission. This is in agreement with what is reported in the literature.12,13 We were surprised not to find infarct core size as one of the significant predictors of outcome in this first analysis. Indeed, most studies have found that a large infarct volume, superior to 70 or 100 mL, is a predictor of poor outcome, independently of the penumbra being small or large and independently of recanalization.3,4 These studies used diffusion-weighted MR imaging to assess infarct core volume. In our study, the reason why we did not find infarct core to be a significant predictor of outcome may be related to the NCT ASPECTS score to be too crude and insensitive assessment of the infarct core volume,14 and to the limited coverage of PCT adversely affecting the measurement of the infarct core volume.

The main issue with the interaction between recanalization and the ischemic penumbra is that the recanalization information is not known at the time of making a treatment decision. Recanalization rates tend to be high with IA endovascular therapy17 but they are more variable with IV tissue plasminogen activator.18 Finally, recanalization can happen spontaneously in the absence of treatment.19 As a result, when comparing an IA or IV treatment with a placebo in a clinical trial, the mere presence of penumbra will not necessarily hallmark a better outcome, except if a higher recanalization rate is observed in the treatment arm compared with the placebo arm. This may explain the mitigated and sometime contradictory results of the penumbra imaging-based clinical trials.20,21

### Table 4. Prediction of Clinical Outcome With Recanalization Information

<table>
<thead>
<tr>
<th>Variables</th>
<th>Clinical data</th>
<th>Infarct core</th>
<th>Vascular information</th>
<th>Treatment and effect</th>
<th>All Interactions</th>
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<tbody>
<tr>
<td></td>
<td>Age</td>
<td>ASPECTS</td>
<td>Collateral flow</td>
<td>Treatment type</td>
<td></td>
</tr>
<tr>
<td></td>
<td>25.07</td>
<td>5.75</td>
<td>15.30</td>
<td>20.51</td>
<td>12.84</td>
</tr>
<tr>
<td></td>
<td>&lt;0.001</td>
<td>0.219</td>
<td>0.020</td>
<td>0.001</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NIHSS</td>
<td>PCT Infarct</td>
<td>PCT Penumbra</td>
<td>Recanalization</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8.47</td>
<td>13.27</td>
<td>4.64</td>
<td>2.20</td>
<td>19.82</td>
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<tr>
<td></td>
<td>0.004</td>
<td>0.001</td>
<td>0.098</td>
<td>0.332</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Time to Baseline</td>
<td>Coverage</td>
<td>Treatment × Recanalization</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.21</td>
<td>4.64</td>
<td>0.30</td>
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<tr>
<td></td>
<td>0.136</td>
<td>0.098</td>
<td>0.580</td>
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<td></td>
<td>6</td>
<td>5</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Vascular</td>
<td>Treatment × Recanalization</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Collateral Flow × Recanalization</td>
<td>12.04</td>
<td>&lt;0.001</td>
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<tr>
<td></td>
<td></td>
<td>PCT P × Recanalization</td>
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<td>&lt;0.001</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Treatment × Recanalization</td>
<td>1.17</td>
<td>0.279</td>
<td></td>
</tr>
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</table>

ASPECTS indicates Alberta Score Program Early Computed Tomography score; HMCAS, hyperdense middle cerebral artery sign; LR, likelihood ratio; NIHSS, National Institutes of Health Stroke Scale; and PCT, perfusion computed tomography.

### Discussion

Penumbral imaging has heralded a lot of hope in terms of shifting the treatment paradigm for AIS patients from a “time is brain” approach to a “penumbra is brain” or “imaging is brain” approach.9–11 However, recently, the clinical relevance of the penumbral information has been questioned, and some have proposed the infarct core volume as the only clinical relevant factor to decide whether AIS patients should be treated.

In our study, we focused our attention on one single large population of patients, and we performed 2 separate analyses on the same patient population, matching the analyses typically reported by the proponents of the infarct core and by the proponents of the penumbra as the relevant clinical factors for acute stroke treatment decisions.

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We were surprised not to find infarct core size as one of the significant predictors of outcome in this first analysis. Indeed, most studies have found that a large infarct volume, superior to 70 or 100 mL, is a predictor of poor outcome, independently of the penumbra being small or large and independently of recanalization.3,4 These studies used diffusion-weighted MR imaging to assess infarct core volume. In our study, the reason why we did not find infarct core to be a significant predictor of outcome may be related to the NCT ASPECTS score to be too crude and insensitive assessment of the infarct core volume,14 and to the limited coverage of PCT adversely affecting the measurement of the infarct core volume.

The penumbra information became meaningful only when the recanalization information was included in the statistical model, reflecting the ambiguous predictive value of the penumbra. The penumbra could hallmark either a favorable outcome, in the setting of recanalization, or a negative outcome, in the absence of recanalization. In the absence of recanalization, the large penumbra will grow into a large final infarct and be associated with poor prognosis—an observation in agreement with those in the DEFUSE, DEFUSE 2, and EPITHET trials.5,15,16

The main issue with the interaction between recanalization and the ischemic penumbra is that the recanalization information is not known at the time of making a treatment decision. Recanalization rates tend to be high with IA endovascular therapy17 but they are more variable with IV tissue plasminogen activator.18 Finally, recanalization can happen spontaneously in the absence of treatment.19 As a result, when comparing an IA or IV treatment with a placebo in a clinical trial, the mere presence of penumbra will not necessarily hallmark a better outcome, except if a higher recanalization rate is observed in the treatment arm compared with the placebo arm. This may explain the mitigated and sometime contradictory results of the penumbra imaging-based clinical trials.20,21
A last element to consider that we did not address in our study is how much penumbra is necessary to warrant treatment. This has been addressed in previous studies, and various results have been reported. Clinical trials typically used a 20% mismatch to select patients for treatment. However, there are reports suggesting that a mismatch of 2.6 would be more optimal. Finally, others think that the volume of tissue at risk does not matter as much as its eloquence.

In summary, our study demonstrates that different predictors of outcome emerge in the exact same data sets, depending on whether recanalization is included in the analysis. Penumbral information has little predictive value in and by itself becomes significant only if recanalization status is known (which is not the case at the time of making a treatment decision) or can be predicted. Further studies are needed that combine prediction of recanalization with prediction of tissue fate.

Disclosures
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References
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