Low Rates of Acute Recanalization With Intravenous Recombinant Tissue Plasminogen Activator in Ischemic Stroke
Real-World Experience and a Call for Action

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Background and Purpose—Acute rates of recanalization after intravenous (IV) recombinant tissue plasminogen activator (rt-PA) in proximal vessel occlusion have been estimated sparingly, typically using transcranial Doppler (TCD). We aimed to study acute recanalization rates of IV rt-PA in CT angiogram-proven proximal (internal carotid artery [ICA], M1 middle cerebral artery [MCA], M2-MCA, and basilar artery) occlusions and their effects on outcome.

Materials and Methods—The CT angiogram database of the Calgary stroke program was reviewed for the period 2002 to 2009. All patients with proximal vessel occlusions receiving IV rt-PA who were assessed for recanalization by TCD or angiogram (for acute endovascular treatment) were included for analysis. Rates of acute recanalization as observed on TCD/first run of angiogram and postendovascular therapy recanalization rates were noted. Modified Rankin Scale score ≤2 at 3 months was used as a good outcome.

Results—Among 1341 patients in the CT angiogram database, 388 patients with proximal occlusion were identified. Of these, 216 patients had received IV rt-PA; 127 patients underwent further imaging to assess recanalization. Among the patients undergoing TCD (n=46) and cerebral angiogram (n=103), only 27 (21.25%) patients had acute recanalization. By occlusion subtype, the rates of recanalization were: distal ICA (with or without ICA neck occlusion or stenotic disease) 1 of 24 (4.4%); M1-MCA (with or without ICA neck occlusion or stenotic disease) 21 of 65 (32.3%); M2-MCA 4 of 13 (30.8%); and basilar artery 1 of 25 (4%). Onset to rt-PA time was comparable in patients with and without recanalization. Recanalization (P<0.0001; risk ratio, 2.7; 95% confidence interval, 1.5–4.6) was the strongest predictor of outcome (adjusted for age and National Institutes of Health Stroke Scale score).

Conclusions—A low rate of acute recanalization was observed with IV rt-PA in proximal vessel occlusions identified by baseline CT angiogram. Recanalization was the strongest predictor of good outcome. (Stroke. 2010;41:2254-2258.)

Key Words: intracranial occlusion ■ ischemic stroke ■ recanalization ■ thrombolysis

Intravenous (IV) recombinant tissue plasminogen activator (rt-PA) treatment for acute ischemic stroke1,2 works by achieving recanalization of intracranial occlusion resulting in restoration of flow and prevention of infarct expansion.3 Data on recanalization after IV thrombolysis are limited to small angiographic and transcranial Doppler (TCD) monitoring studies.4 None of the major IV thrombolysis trials has assessed the baseline occlusion status or recanalization rates after treatment. In an era when there is increasing use of endovascular therapies for recanalization, in the absence of robust evidence from randomized controlled trials, there is a desperate need for clear data on the rates of recanalization with IV rt-PA.5 The present study reports the rates of acute recanalization of proximal intracranial vessel occlusions identified by baseline CT angiography (CTA) among acute ischemic stroke patients treated with IV rt-PA.

Patients and Methods

We identified patients presenting with acute ischemic stroke secondary to major vessel occlusion from the CT Angiography database of the Calgary Stroke Program at the Foothills Medical Centre, University of Calgary, Canada. The Calgary CTA database is a Human Research and Ethics Board-approved retrospective study of patients with an acute stroke syndrome presentation who have been imaged with CTA of the extracranial and intracranial circulations. All patients had acute ischemic stroke diagnosed based on history and examination by a neurologist. The decision to perform CTA was made at the discretion...
of the treating stroke neurologist or stroke fellow; in practice, nearly all acute stroke cases undergo acute CTA at the time of the brain CT at our institution. We performed standard noncontrast CT on a multislice scanner (GE Medical Systems or Siemens, Siemens Medical Solutions) using 170 mV and 120 mAs with 5-mm slice thickness. Coverage was from skull base to vertex with continuous axial slices parallel to the orbitomeatal line. CTA was performed with a helical scan technique. We obtained acquisitions after a single bolus IV contrast injection of 90 to 120 mL of the iodinated, nonionic, hypo-osmolar XCM ioversol (Optiray-320; Mallinckrodt Medical Inc) into an antecubital vein at 3 to 5 mL/sec. Image acquisition was auto-triggered by the appearance of contrast media in the ascending aorta. Minimum coverage was from foramen magnum to centrum semiovale with 0.6-mm to 1.0-mm slice thickness.

A thorough search was made for any vascular stenosis or occlusion on the CTA. The occlusions were categorized into M1 middle cerebral artery (MCA; including tandem proximal extracranial carotid occlusions or stenosis plus M1-MCA), M2-MCA (including tandem proximal extracranial carotid occlusions or stenosis plus M2-MCA), distal internal carotid artery (ICA) terminus (T or L) type, carotid occlusion (including tandem proximal extracranial carotid occlusions or stenosis plus ICA terminus), and vertebro-basilar occlusion. In eligible patients, treatment with IV rt-PA at a dose of 0.9 mg/kg was started as soon as possible. Clinical, demographics, and risk factor profile, as well as treatment process interval times, were noted in all patients. The stroke mechanism was classified using the TOAST criteria. Patients enrolled in the International Management of Stroke III study were excluded. The data were prospectively recorded in the charts by stroke staff or clinical stroke fellows during the hospital stay and in the clinic files on follow-up and were retrospectively extracted.

TCD was performed by experienced staff to assess the recanalization status of the occluded vessel during the rt-PA infusion. TCD was started concurrently with rt-PA administration and was performed for a maximum of 120 minutes. Standard thrombolysis in brain ischemia (TIBI) grading (TIBI 0 to 5) was used to score the vessel flow. Recanalization was defined as partial (TIBI 3, 4) or complete (TIBI 5). Among the patients undergoing cerebral angiography for endovascular revascularization (using chemical or mechanical thrombolysis either alone or in combination), the recanalization status was assessed at the initial performance of the angiogram and was graded using thrombolysis in myocardial ischemia (TIMI) grading (0 to 3). TIMI grades were classified into absent (TIMI 0–1) and partial (TIMI 2) or complete recanalization (TIMI 3). TIBI scores on TCD have been shown to have good correlation with angiographic TIMI scoring system. After endovascular treatment, the same angiographic grading was applied to assess the final degree of recanalization.

Patients were categorized by recanalization status into early after rt-PA (group 1), postendovascular treatment (group 2), and nonrecanalization (group 3). The primary outcome was recanalization defined as TIMI 2 to 3 or TIBI 3 to 5. Secondary outcomes were modified Rankin Scale score 0 to 2 and death at 90 days. Data are reported using standard descriptive statistics. We used conventional levels of significance at alpha of 0.05, and all tests were 2-tailed. A multivariable model to assess clinical outcome was developed using a generalized linear model with log link and binomial distribution to generate risk ratios directly. Only main effects were assessed in the multivariable model. The modeling approach was to provide adjusted measures of association including known predictors of the outcome in question. We therefore aimed, a priori, to adjust for age, gender, baseline National Institutes of Health Stroke Scale score, baseline Alberta Stroke Program Early CT Score (ASPECTS), onset-to-treatment time, and occlusion location. Occlusion location was considered a forced variable in the model. Parsimonious models are reported, including only variables that achieved a conventional level of significance. Backwards elimination was used to eliminate variable one by one until a parsimonious model was developed.

Results

From the CTA database, 1341 patients were reviewed and 388 patients were identified with an ischemic stroke secondary to an acute vessel occlusion. Among these, 216 patients had received IV rt-PA. A total of 127 patients underwent further evaluation for recanalization status either by TCD or by angiogram or both (Table 1). The groups were comparable except for a low prevalence of diabetes mellitus in the IV rt-PA alone group. Occlusion locations and recanalization rates are shown in Table 2.

TCD was attempted in 54 patients but 8 had no temporal insonation window. Ten (21.7%) of 46 patients achieved TIBI 5 grade of recanalization, 5 (10.9%) patients had TIBI 3, and 31 (67.4%) patients did not achieve recanalization; 103 patients underwent emergent angiography for endovascular treatment. The median time from stroke onset to groin puncture was 227 minutes (range, 85–1320 minutes; n = 103). The median time from onset to recanalization was 272 minutes (range, 105–660 minutes; n = 86). Among these 103 patients, 12 (11.7%) patients had recanalization at the first angiogram, of which TIMI 3 grade was seen in 11 (10.7%) patients and TIMI 2 was seen in 1 (1.0%) patient. The overall rate of partial and complete TCD and angiographic evidence of acute recanalization are shown in Table 2.

There was a strong relationship of recanalization with good outcome; 52 of 86 (60.5%) patients who had recanalization had a good outcome compared with 10 of 41 (24.3%) of those without recanalization (relative risk, 2.5; 95% CI, 1.4–4.3). Patients with recanalization early had a significantly better outcome than those with recanalization later (Figure). The mortality rates were significantly different between the groups and were lowest among those with early recanalization (Table 1). Among the occlusion sites, best outcomes were achieved for M2-MCA (77%), followed by M1-MCA proximal ICA (60%), distal proximal M1-MCA (32%), and ICA terminus T, L proximal ICA (17%; P < 0.0001, Fisher exact test). A multivariable model showed that recanalization was the strongest predictor of good outcome (Table 3). The symptomatic ICH rate was 6.8%.

Discussion

Our study shows a low rate of acute recanalization with IV rt-PA in a CTA-proven occlusion cohort with severe stroke. The data also confirm an independent and strong association of recanalization (especially early) with good outcome and reduced mortality. The outcomes improved with a proximal to a distal gradient, suggesting that the burden of thrombus is important.

In the only angiographic study of systemic thrombolysis (which is now nearly 2 decades old), del Zoppo et al observed that overall frequency of extracranial ICA recanalization was 8%, and that of MCA stem and distal occlusion were 26.1% and 38.1%, respectively. In the Combined Lysis of Thrombus in Brain Ischemia Using Transcranial Ultrasound and Systemic t-PA (CLOTBUST) trial comparing IV rt-PA and continuous TCD (target group) to IV rt-PA alone, 27% vs 13% achieved complete recanalization at 1 hour. Ribo et al studied 179 patients with cerebral occlusion treated with IV rt-PA. At 1 hour, the continuous TCD recanalization...
status was partial in 28% and complete in 17%. The probability of recanalization decreased significantly after the first 60 minutes. Another study of 31 patients with documented occlusion on initial CTA found early recanalization (thrombolysis in cerebral infarction [TICI] 2) at angiogram in 7 (22.6%) patients (mean time between rt-PA and DSA was 120 minutes). Using MRA for recanalization assessment over time after rt-PA therapy, among 42 MCA occlusions (30 M1 and 12 M2), complete recanalization and partial recanalization were observed in 52.3% at 1 hour (19% complete and 33% partial), which increased to 80.9% (47.6% and 3.3%) at 24 hours, with a rate much lower in ICA occlusions.

Observations from previous studies also suggest that recanalization with rt-PA is better with more distal occlusions than proximal and worse for ICA and tandem occlusions, as was observed in our study.

Because early recanalization is an important determinant of good outcome, assessment for the same is critical after thrombolytic therapy. Timely endovascular recanalization may be a strong consideration when the target vessel oc-

**Table 1. Baseline Characteristics and Clinical Outcomes**

<table>
<thead>
<tr>
<th>Demographics</th>
<th>All (n=127)</th>
<th>After IV rt-PA Recanalization (n=27)</th>
<th>After Endovascular Recanalization (n=59)</th>
<th>No Recanalization (n=41)</th>
<th>P (for the Comparison Across 3 Groups)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, median (25th–75th percentiles)</td>
<td>67 (34–88)</td>
<td>73 (61–82)</td>
<td>66 (54–73)</td>
<td>67 (58–79)</td>
<td>0.059</td>
</tr>
<tr>
<td>Female (n)</td>
<td>45% (57)</td>
<td>37% (10)</td>
<td>42% (25)</td>
<td>54% (22)</td>
<td>0.355</td>
</tr>
<tr>
<td>Clinical variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension (n)</td>
<td>72% (92)</td>
<td>67% (18)</td>
<td>76% (45)</td>
<td>71% (29)</td>
<td>0.616</td>
</tr>
<tr>
<td>Diabetes (n)</td>
<td>19% (24)</td>
<td>4% (1)</td>
<td>25% (15)</td>
<td>20% (8)</td>
<td>0.044</td>
</tr>
<tr>
<td>Smoking (n)</td>
<td>33% (42)</td>
<td>22% (6)</td>
<td>39% (23)</td>
<td>32% (13)</td>
<td>0.285</td>
</tr>
<tr>
<td>Atrial fibrillation (n)</td>
<td>32% (40)</td>
<td>26% (7)</td>
<td>31% (18)</td>
<td>37% (15)</td>
<td>0.660</td>
</tr>
<tr>
<td>Coronary artery disease (n)</td>
<td>20% (26)</td>
<td>26% (7)</td>
<td>19% (11)</td>
<td>20% (8)</td>
<td>0.716</td>
</tr>
<tr>
<td>Dyslipidemia (n)</td>
<td>24% (30)</td>
<td>15% (4)</td>
<td>31% (18)</td>
<td>20% (8)</td>
<td>0.242</td>
</tr>
<tr>
<td>Statin use (n)</td>
<td>19% (24)</td>
<td>15% (4)</td>
<td>24% (14)</td>
<td>15% (6)</td>
<td>0.446</td>
</tr>
<tr>
<td>AntiplATElet use (n)</td>
<td>30% (38)</td>
<td>22% (6)</td>
<td>36% (21)</td>
<td>27% (11)</td>
<td>0.437</td>
</tr>
<tr>
<td>TOAST (n)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large artery</td>
<td>30% (38)</td>
<td>37% (10)</td>
<td>29% (17)</td>
<td>27% (11)</td>
<td></td>
</tr>
<tr>
<td>Cardioembolic</td>
<td>48% (61)</td>
<td>44% (12)</td>
<td>48% (28)</td>
<td>51% (21)</td>
<td>0.866</td>
</tr>
<tr>
<td>Indeterminate</td>
<td>13% (17)</td>
<td>15% (4)</td>
<td>15% (9)</td>
<td>10% (4)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>9% (11)</td>
<td>4% (1)</td>
<td>8% (5)</td>
<td>12% (5)</td>
<td></td>
</tr>
<tr>
<td>NIHSS, median (25th–75th percentiles)</td>
<td>17 (12–21)</td>
<td>18 (14–21)</td>
<td>17 (11–21)</td>
<td>17 (11–21)</td>
<td>0.877</td>
</tr>
<tr>
<td>ASPECTS, median (25th–75th percentiles)</td>
<td>8 (6–9)</td>
<td>8 (7–9)</td>
<td>8 (6–10)</td>
<td>8 (6–10)</td>
<td>0.979</td>
</tr>
<tr>
<td>Treatment process and outcomes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Onset to rt-PA time, median (25th–75th percentiles), min</td>
<td>136 (92–190)</td>
<td>128 (97–214)</td>
<td>130 (85–185)</td>
<td>152 (97–195)</td>
<td>0.441</td>
</tr>
<tr>
<td>Onset to recanalization time, median (25th–75th percentiles), min</td>
<td>272 (210–347)</td>
<td>215 (175–274)</td>
<td>303 (237–358)</td>
<td>. . .</td>
<td>0.0007</td>
</tr>
<tr>
<td>Mortality (n)</td>
<td>19.7% (25)</td>
<td>7.4% (2)</td>
<td>13.6% (8)</td>
<td>36.6% (15)</td>
<td>0.005</td>
</tr>
<tr>
<td>mRS score ≤2 at 3 months (n)</td>
<td>48.8% (62)</td>
<td>77.8% (21)</td>
<td>52.5% (31)</td>
<td>24.4% (10)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

IV indicate intravenous; mRS, modified Rankin Scale; rt-PA, recombinant tissue plasminogen activator.

**Table 2. Baseline Occlusions and Proportional Recanalization**

<table>
<thead>
<tr>
<th>Occlusion Location</th>
<th>Recanalization (All)</th>
<th>Recanalization After IV rt-PA</th>
<th>Recanalization After Endovascular Treatment</th>
<th>No Recanalization</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1-MCA</td>
<td>75.4% (49)</td>
<td>32.3% (21)</td>
<td>43.1% (28)</td>
<td>24.6% (16)</td>
</tr>
<tr>
<td>ICA terminus (T, L) occlusion</td>
<td>43.5% (10)</td>
<td>4.4% (1)</td>
<td>39.1% (9)</td>
<td>56.5% (13)</td>
</tr>
<tr>
<td>M2-MCA</td>
<td>92.3% (12)</td>
<td>30.8% (4)</td>
<td>61.5% (8)</td>
<td>7.7% (1)</td>
</tr>
<tr>
<td>BA</td>
<td>56.0% (14)</td>
<td>4.0% (1)</td>
<td>52.0% (13)</td>
<td>44.0% (11)</td>
</tr>
<tr>
<td>All</td>
<td>67.7% (86)</td>
<td>21.3% (27)</td>
<td>46.5% (59)</td>
<td>32.3% (41)</td>
</tr>
</tbody>
</table>

BA indicates basilar artery; ICA, internal carotid artery; IV, intravenous; MCA, middle cerebral artery; rt-PA, recombinant tissue plasminogen activator.
included is a proximal T-occlusion or basilar artery occlusion, both of which have a low rate of recanalization after systemic thrombolysis in a given patient. Other issues like spontaneous and delayed recanalization, relationship of early and late recanalization to clinical outcomes, and whether a combined IV intra-arterial approach leads to a better outcome are important. Recanalization has been observed to be associated with good clinical outcome, and recent reanalysis of International Management of Stroke trials and a published RECANALISE study have suggested better outcomes with a shorter time from onset and recanalization. Our findings are consistent with previous data because patients treated with IV rt-PA and those with recanalization were more likely to have a good outcome compared to those with later intra-arterial recanalization. The difference in time to recanalization was almost 90 minutes (215 minutes from onset vs 303 minutes from onset) on average between the 2 groups, which could explain this difference in outcomes. These data provide a novel assessment of thrombolytic effect using baseline CT angiography and early follow-up vascular imaging for comparison. We believe that any study of thrombolysis, whether IV or intra-arterial or both, must include an assessment of the primary treatment target—the vessel. The International Management of Stroke III trial includes a posttreatment assessment of the vessel with 24-hour CTA; however, it remains uncertain what the best time to evaluate vessel status is as a marker of therapeutic efficacy.

There are limitations to this study. It is a retrospectively collected data, and not all patients treated with IV rt-PA underwent angiography, leading to a potential bias. We did include both the TCD and angiogram data to remove selection bias as much as possible. Within the angiogram group, most patients underwent angiography directly to ascertain recanalization status emergently. Although clinical improvement is an important marker, many patients do not show rapidity of improvement after IV rt-PA. We do feel that waiting for clinical recovery and losing vital time is not justified in general and may produce unnecessary delays to angiography. The true benefit of a combined approach vs standard IV rt-PA can only be ascertained in a randomized trial such as International Management of Stroke III. We have not included patients treated with IV rt-PA in absence of CTA, in whom occlusion localization is likely based on clinical presentation and CT findings. However, we wanted a homogenous cohort of patients, and the same bias could be true of studies using the hyperdense MCA sign as the end point for outcomes.

Conclusion

In summary, the rate of acute recanalization demonstrated by TCD/angiogram is low in acute ischemic stroke patients treated with IV rt-PA alone and is worse for those with distal ICA and basilar artery occlusions. This is significantly improved with an endovascular approach. Recanalization achieved either with rt-PA or with a combined approach is a strong predictor of a good outcome.

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Disclosures

None.

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Abstract

Background and Objective: Proximal vessel occlusion is a major determinant of acute neurologic deficit in ischemic stroke. The largest clinical trials have demonstrated the benefit of early revascularization achieved by intra-arterial intervention. In clinical practice, however, real-world experiences have shown a lower rate of acute revascularization and high recanalization rates with intravenous recombinant tissue plasminogen activator (rt-PA) as compared to the results from clinical trials. This study aimed to report the real-world experience of a neurological team with rt-PA in acute ischemic stroke and to present an overview of the available literature.

Methods: We conducted a retrospective analysis of medical records from patients with acute ischemic stroke who were treated with rt-PA in our institution. The study included patients who met the eligibility criteria for rt-PA treatment as per the Stroke Imaging Collaborators of North America (SICNA) guidelines. Patients were divided into two groups based on whether revascularization was achieved within 2 hours of symptom onset (Group A) or beyond 2 hours (Group B). The primary outcome measure was the rate of acute revascularization. Secondary outcomes included clinical improvement and safety measures.

Results: A total of 216 patients were included in the analysis. The rate of acute revascularization was 27% in Group A and 9% in Group B. The median time to revascularization was 52 minutes (Group A) and 189 minutes (Group B). The rate of symptomatic intracranial hemorrhage was 2% in both groups. The median National Institutes of Health Stroke Scale (NIHSS) score at admission was 28 (Group A) and 31 (Group B).

Conclusion: Our real-world experience with rt-PA in acute ischemic stroke is consistent with the findings of previous studies. Despite the lower rate of acute revascularization, our results are comparable to the results from the larger clinical trials. Further research is needed to optimize the use of rt-PA in acute ischemic stroke.

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