Early Loss of Immediate Reperfusion While Stent Retriever in Place Predicts Successful Final Reperfusion in Acute Ischemic Stroke Patients

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Background and Purpose—Degree of stent retriever engagement with target thrombi may be reflected by (1) immediate reperfusion (IR) on first deployment, indicating displacement of clot toward the vessel wall, and (2) by early loss of IR (ELOIR), indicating penetration of retriever struts through the thrombus. The relation of these early findings to final reperfusion and clinical outcomes has not been well delineated.

Methods—We investigated IR and ELOIR in patients undergoing stent retriever mechanical thrombectomy at an academic medical center between March 2012 and June 2014.

Results—Among 56 patients, IR itself was not associated with final successful reperfusion, which occurred in 66.7% of IR patients and 71.4% of non-IR patients (P=0.999). However, ELOIR was associated with a higher rate of final successful reperfusion (92% versus 44%; P=0.046). Patients with ELOIR had a higher nominal rate of final favorable outcome (42% versus 22%; P=0.64).

Conclusions—ELOIR during the embedding period after deployment of stent retrievers is associated with successful final reperfusion, likely because of greater thrombus engagement with the stent retriever. ELOIR may be a useful finding to guide duration of embedding time in clinical practice and design of novel stent retrievers.

Key Words: angiography • reperfusion • stent • stroke • thrombectomy

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stroke center. Eligibility criteria for this study were (1) acute cerebral ischemia, (2) treatment with a stent retriever (Solitaire, Covidien, Irvine, CA; or Trevo, Stryker Neurovascular, Mountain View, CA), and (3) acquisition of a digital subtraction angiogram on stent retriever deployment, permitting evaluation for presence or absence of IR. The patients who only had fluoroscopic assessment for IR after the stent retriever deployment were excluded. Demographic and clinical data collected on all patients are summarized in Table 1.

**Assessment of Immediate Reperfusion**

Immediately after deployment of the stent retriever, a digital subtraction angiogram was performed to evaluate for the presence or absence of IR. Any visualization of the distal branches beyond the occlusive lesion immediately after the deployment of the stent retriever was defined as IR. After an embedding time of 5 minutes, a second control digital subtraction angiogram was obtained. For patients with IR, the finding of the additional control digital subtraction angiogram was classified into 3 groups: (1) complete loss of reperfusion without visualization of the distal branches (Figure [A] and [B]), (2) partial loss of reperfusion with diminished visualization of the distal branches (Figure [C] and [D]), and (3) persistent reperfusion with no change compared with the first control angiogram performed immediately after the stent retriever deployment. In this small cohort study, patients with complete and with partial early loss of reperfusion were combined into single ELOIR group situations.

**Reperfusion**

Reperfusion was measured according to thrombolysis in cerebral infarction reperfusion parameters. Successful reperfusion was defined as achieving a thrombolysis in cerebral infarction score of $\geq 2b$, as documented on the angiogram at the end of the stent retriever procedure before the use of any rescue therapy.

**Statistical Analysis**

Statistical analyzes were performed using the Statistical Package for the Social Sciences (SPSS), version 22.0 (SPSS Inc, Chicago, IL). Fisher exact or $\chi^2$ tests (2-sided) were used for categorical variables and the Mann–Whitney U test for continuous variables. A $P$ value of $<0.05$ was considered significant.

**Results**

During the study period, 205 patients underwent revascularization treatment for acute ischemic stroke, among whom 56 had an immediate digital subtraction angiography performed upon stent deployment, meeting eligibility criteria for this study. Demographic and baseline characteristics for these 56 patients are shown in Table 1. Mean age was 69.6 years ($SD\pm15.2$), 33 (59%) were female, and mean National Institutes of Health Stroke Scale score was 18 ($SD\pm8.7$; interquartile range 13.0–22.3). Intravenous tissue-type plasminogen activator was
administered before endovascular mechanical revascularization procedure in 34 patients (60.7%). The site of the target occlusion was the intracranial internal carotid artery in 20 (35.7%), M1 middle cerebral artery in 27 (48.2%), M2 middle cerebral artery in 4 (7.1%), and posterior circulation in 5 (8.9%) patients.

Solitaire stent retrievers only were used in 78.6% of patients, Trevo only in 14.3%, and both in 7.1%. In this series, the thrombolysis in cerebral infarction ≥2b revascularization rate after stent retriever interventions was 67.9%. Rescue therapies after stent retriever, such as intra-arterial tissue-type plasminogen activator and thrombus aspiration, were used in 16.1% of patients. Average stent retriever attempts in this cohort were 2.1 times.

IR was observed in 42 patients (75.0%) after the deployment of stent retriever. Demographic and clinical characteristics did not substantially differ between patients with and without IR (Table 1). The frequency of final successful reperfusion did not differ between IR patients (28/42 [66.7%]) and non-IR patients (10/14 [71.4%], P=0.999; Table 2). Control digital subtraction angiography to identify the persistence of IR or ELOIR after 5-minutes embedding time was performed in 21 patients (Table 2). ELOIR was found in 12 patients (57%), including complete loss in 6 and partial loss in 6 patients. Patients with ELOIR had a higher rate of successful final reperfusion (11/12, 92%) than patients without ELOIR (4/9, 44%; P=0.046; Table 2).

**Discussion**

IR upon device deployment and ELOIR are unique effects associated with use of the current stent retrievers. We found that ELOIR was associated with a higher rate of final successful reperfusion, but the presence of IR itself had no correlation with final successful reperfusion. Without a proper understanding of the clot capturing mechanism of stent retrievers, it may be counterintuitive that ELOIR, including complete reocclusion, is a good sign for ultimate success of the endovascular thrombectomy procedure. We propose that ELOIR occurs when the stent retriever successfully carves into the thrombus in the target occlusive lesion and the thrombus is captured in the stent cavity. The extensive engagement of the thrombus in the stent retriever indicated by ELOIR reduces the possibility of slippage and fragmentation of the captured thrombus and leads to the higher chance of successful reperfusion.

**Table 2. Analysis of Immediate Reperfusion and Its Early Loss**

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Final Successful Reperfusion</th>
<th>Favorable Outcome</th>
<th>Mortality</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(+) (−) OR (95% CI)</td>
<td>(+) (−) OR (95% CI)</td>
<td>(+) (−) OR (95% CI)</td>
<td></td>
</tr>
<tr>
<td>Immediate Reperfusion</td>
<td></td>
<td>(+) 42 28 14 0.80 (0.21−3.01)</td>
<td>0.999</td>
<td>15 27 0.74 (0.22−2.54)</td>
<td>0.752</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(−) 14 10 4</td>
<td></td>
<td>6 8</td>
<td></td>
</tr>
<tr>
<td>Early loss of Immediate</td>
<td></td>
<td>(+) 12 11 1 2.50 (0.36−17.5)</td>
<td>0.046</td>
<td>5 7 2.50 (0.36−17.5)</td>
<td>0.642</td>
</tr>
<tr>
<td>Reperfusion</td>
<td></td>
<td>(−) 9 4 5</td>
<td></td>
<td>2 7</td>
<td></td>
</tr>
</tbody>
</table>

CI indicates confidence interval; and OR, odds ratio.

**Figure.** Group 1, complete flow stasis. This shows immediate flow restoration of middle cerebral artery (MCA) branches (A). After the embedding time, the distal branches of MCA were not visualized at all (B). Group 2, diminished visualization. The distal branches of MCA diminishes blood flow visualization (D) compared with the angiogram before embedding (C).
Composition of the thrombus is one factor that can determine the level of thrombus engagement. Liebeskind et al observed marked heterogeneity both in pathology and composition of the retrieved thrombi. This heterogeneity may explain why 3 discrete ELOIR groups were observed in this study (Figure). Stent retrievers are unlikely to expand deep into relatively firm occlusive lesions, and as a result, IR will be sustained in these patients (Group 3: No ELOIR). In contrast, stent retrievers are likely to expand deeply through and to more fully capture soft thrombi within the stent cavity with ELOIR (Group 1: Complete ELOIR). When stent retrievers are placed within intermediate firmness thrombi, the ELOIR effect is intermediate in degree as a result of partial engagement of the clot (Group 2: Partial ELOIR).

Studies to date have not systematically varied the embedding time in acute ischemic stroke patients, and it is uncertain how long an embedding time after deployment is optimal. The best embedding time is likely to vary with patient-specific and device-specific factors; the radial force and structure of the stent retriever, curvature, and diameter of the occlusive lesion; and composition of the thrombus. In our series, more than half (56%) of Group 3 (No ELOIR) patients did not accomplish successful reperfusion. It is possible that a longer embedding time in those cases would have helped with better thrombus engagement. However, the downside of longer embedding time is that it extends the total procedure time and may delay in achieving the final effective recanalization. Because the large prospective stent retriever trials showed substantial clinical benefit with 5-minutes embedding time, the results of the present study are exploratory and do not directly support a procedural strategy to wait much longer than 5 minutes until ELOIR is observed. This observation may be useful to optimize the embedding time particularly when a new stent retriever is introduced to the clinical practice. Stent retriever itself would be important. Wenger et al compared the relation between the stent design and the thrombus capture with the artificial models. They documented the difference of the thrombus capture caused by the stent design. Therefore, ELOIR may be a useful finding to design of novel stent retrievers.

The number of this study was relatively small, and thus, larger prospective studies are required to confirm this phenomenon.

Conclusions

This study found that ELOIR after the 5-minute embedding period after deployment of stent retrievers was associated with successful reperfusion. ELOIR may be an angiographic sign of adequate thrombus engagement with the stent retriever.

Disclosures

Dr Duckwiler is a Scientific Advisor for Blockade Medical, Asahi Intec, and Medtronic. Dr Tateshima is a Scientific Advisor for Medtronic, Stryker, PulserVascular, Lazarus Effect, Blockade Medical, and Century Medical Inc. Dr Jahan is a Scientific Advisor for Medtronic, and Medina Medical. Dr Liebeskind is a consultant for Stryker and Covidien. Dr Saver is a scientific advisor for Medtronic/Covidien, Stryker, and Neuravi. The other authors report no conflicts.

References

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