Single-Center Experience of Cerebral Artery Thrombectomy Using the TREVO Device in 60 Patients With Acute Ischemic Stroke

Luis San Román, MD; Victor Obach, MD; Jordi Blasco, MD; Juan Macho, MD; Antonio Lopez, MD; Xabier Urra, MD, PhD; Alejandro Tomasello, MD; Alvaro Cervera, MD, PhD; Sergio Amaro, MD, PhD; Joan Perandreu, MD; Jordi Branera, MD; Sebastián Capurro, MD; Laura Oleaga, MD; Angel Chamorro, MD, PhD

Background and Purpose—We sought to explore the safety and efficacy of the new TREVO stent-like retriever in consecutive patients with acute stroke.

Methods—We conducted a prospective, single-center study of 60 patients (mean age, 71.3 years; male 47%) with stroke lasting <8 hours in the anterior circulation (n=54) or <12 hours in the vertebrobasilar circulation (n=6) treated if CT perfusion/CT angiography confirmed a large artery occlusion, ruled out a malignant profile, or showed target mismatch if symptoms >4.5 hours. Successful recanalization (Thrombolysis In Cerebral Infarction 2b–3), good outcome (modified Rankin Scale score 0–2) and mortality at Day 90, device-related complications, and symptomatic hemorrhage (parenchymal hematoma Type 1 or parenchymal hematoma Type 2 and National Institutes of Health Stroke Scale score increment ≥4 points) were prospectively assessed.

Results—Median (interquartile range) National Institutes of Health Stroke Scale score on admission was 18 (12–22). The median (interquartile range) time from stroke onset to groin puncture was 210 (173–296) minutes. Successful recanalization was obtained in 44 (73.3%) of the cases when only the TREVO device was used and in 52 (86.7%) when other devices or additional intra-arterial tissue-type plasminogen activator were also required. The median time (interquartile range) of the procedure was 80 (45–114) minutes. Good outcome was achieved in 27 (45%) of the patients and the mortality rate was 28.3%. Seven patients (11.7%) presented a symptomatic intracranial hemorrhage. No other major complications were detected.

Conclusions—The TREVO device was reasonably safe and effective in patients with severe stroke. These results support further investigation of the TREVO device in multicentric registries and randomized clinical trials. (Stroke. 2012;43:00-00.)

Key Words: acute ischemic stroke ■ endovascular treatment

The clinical efficacy of endovascular treatment in acute ischemic stroke has not been proven in randomized clinical trials. Meanwhile, several neurothrombectomy devices have shown widely varying rates of successful recanalization and/or harmful effects. This study reports the first consecutive large series of patients with acute stroke treated with the new TREVO stent-like retriever (Figure).

Methods

From January to December 2010, 60 consecutive patients with acute stroke were treated by board-certified neuroangiologists using the TREVO stent-like retriever (Concentric Medical Inc, Mountain View, CA) as the unique device (n=49) or followed afterward by other devices (Solitaire, n=5; Merci, n=3; and Solitaire and Merci, n=3) or intra-arterial recombinant tissue-type plasminogen activator (n=1) because the TREVO device was unable to reopen the occluded vessel.

Clinical criteria included strokes lasting <8 hours in the anterior circulation or <12 hours in the vertebrobasilar circulation. Thirty-three patients (55%) received intravenous recombinant tissue-type plasminogen activator. All study participants had a CT perfusion/CT angiography that confirmed an artery occlusion proximal to M2, or a basilar occlusion, and ruled out a malignant profile as previously reported. In patients with symptoms lasting >4.5 hours (n=19), the
presence of mismatch was also required (online-only Data Supplement; http://stroke.ahajournals.org). All procedures were carried out without general anesthesia except in 3 patients with extreme agitation or hemodynamic and respiratory function instability.

**Outcome Measures**

Successful recanalization was defined as a Thrombolysis In Cerebral Infarction score of 2b or 3. Good clinical outcome was defined as a modified Rankin Scale score 2 at Day 90. Treatment-related complications were prospectively assessed and serious bleeding was defined as parenchymal hematomas Type I or Type II on CT scan associated with at least 4 points increase in the National Institutes of Health Stroke Scale score at 36 hours of treatment. Mortality at Day 90 was also registered.

**Results**

The main characteristics of the population are shown in Table 1. The median (interquartile range) time from stroke onset to arterial puncture was 210 (173–296) minutes and 302 (243–391) minutes from stroke onset to successful recanalization, which was achieved in 73.3% of patients treated only with the TREVO. Thrombolysis In Cerebral Infarction 2b to 3 and Thrombolysis In Cerebral Infarction 2 to 3 were reached by 86.7% and 93% of patients, respectively, when additional devices or intraarterial tissue-type plasminogen activator were required. The median (interquartile range) time of the procedure (groin puncture to recanalization) was 80 (45–114) minutes.

Median (interquartile range) National Institutes of Health Stroke Scale score at baseline was 18 (12–22). Good outcome was achieved by 27 (45%) patients; there were 17 (28%) deaths, 7 (12%) serious bleedings, 1 carotid dissection before the TREVO device was deployed, and 1 symptomatic distal embolization that was clinically resolved at discharge. The main outcome measures of previous reperfusion studies are shown in Table 2.

**Discussion**

To our knowledge, this is the first large prospective study reporting the main clinical effects of the TREVO device administered to consecutive patients with acute stroke treated according to predefined clinical and radiological criteria. The current study found a successful recanalization rate of 73.3% and that 45% of the treated patients had reached a good outcome at 3 months despite the high severity of stroke on admission (median National Institutes of Health Stroke Scale score of 18) and the protracted time delay to recanalization (5 hours). These encouraging results compare well with previous studies of endovascular therapy and argue that the systematic use of advanced brain imaging seems to contribute to a better selection of the candidates to receive reperfusion therapies. In addition, 95% of our cases were done without intubation during the procedure, which may also have affected outcome. The main limitations of the study were the

**Table 1. Main Characteristics of the Study Population**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>N=60</th>
<th>Age, y, mean (SD)</th>
<th>Male, no. (%)</th>
<th>Hypertension, no. (%)</th>
<th>Diabetes, no. (%)</th>
<th>Atrial fibrillation, no. (%)</th>
<th>Baseline NIHSS, median (IQR)</th>
<th>Previous intravenous tPA, no. (%)</th>
<th>Site of intracranial occlusion, no. (%)</th>
<th>Carotid T</th>
<th>Proximal M1</th>
<th>Distal M1</th>
<th>M2</th>
<th>Basilar artery</th>
<th>Proximal internal carotid stenosis &gt;70%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>71.2 (12.4)</td>
<td>28 (46.7)</td>
<td>40 (66.7)</td>
<td>16 (26.7)</td>
<td>20 (33.3)</td>
<td>18 (12–22)</td>
<td>33 (55.0)</td>
<td>33 (55.0)</td>
<td>13 (21.6%)</td>
<td>20 (35.0%)</td>
<td>10 (16.7%)</td>
<td>11 (18.3%)</td>
<td>6 (10.0)</td>
<td>11 (18.3)</td>
</tr>
</tbody>
</table>

NIHSS indicates National Institutes of Health Stroke Scale; IQR, interquartile range; tPA, tissue-type plasminogen activator.

**Table 2. Comparison of Outcome Variables of Reperfusion Studies in Stroke**

<table>
<thead>
<tr>
<th>Study</th>
<th>NIHSS Basal</th>
<th>TICI 2–3 (%)</th>
<th>SICH (%)</th>
<th>Mortality 90 D (%)</th>
<th>mRS 2 90 D (%)</th>
</tr>
</thead>
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<tr>
<td>PROACT II</td>
<td>121</td>
<td>17</td>
<td>66</td>
<td>10</td>
<td>25</td>
</tr>
<tr>
<td>IMS-II</td>
<td>55</td>
<td>19</td>
<td>60</td>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>Pooling data intravenous tPA trials &lt;6 hours</td>
<td>1391</td>
<td>11</td>
<td>9</td>
<td>13</td>
<td>49</td>
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<tr>
<td>Multi MERCI, Smith et al, 2008</td>
<td>164</td>
<td>19</td>
<td>55</td>
<td>10</td>
<td>34</td>
</tr>
<tr>
<td>Penumbra PST, 2009</td>
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<td>Solitaire, Mitoff et al, 2011</td>
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<td>10</td>
<td>19</td>
<td>42</td>
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<tr>
<td>Revive, Rohde et al, 2011</td>
<td>10</td>
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<td>100</td>
<td>20</td>
<td>30</td>
</tr>
</tbody>
</table>

NIHSS indicates National Institutes of Health Stroke Scale; TICI, Thrombolysis In Cerebral Infarction; SICH, symptomatic intracranial hemorrhage; mRS, modified Rankin Scale; PROACT, Pro-Urokinase (r-proUK) for Acute Cerebral Thromboembolism; IMS, Interventional Management of Stroke; tPA, tissue-type plasminogen activator; MERCI, Mechanical Embolus Removal in Cerebral Ischemia; Penumbra PST, Penumbra Pivotal Stroke Trial.
lack of randomization and inclusion of a control group and that additional devices were used in 11 patients in which the TREVO device was unable to reanalyze the occluded vessel. However, these results may be of help to design future randomized studies of the TREVO device in acute stroke.

Conclusions
The TREVO device was reasonably safe and effective in patients with severe stroke managed according to predefined clinical criteria and assisted by the use of advanced brain imaging in the treatment decisions, although 18.3% of the patients may require the use of additional devices for successful recanalization. The value of this new device deserves further formal investigation in larger multicentric registries and randomized clinical trials.

Sources of Funding
Multimodal CT-assisted thrombolysis and systematic access to ET were possible through a pilot program granted by the Servei Català de Salut (Health Department of Catalonia, Catalonia, Spain).

Disclosures
Drs Blasco and Macho have received honoraria from Concentric Medical Inc, Montain View, CA, for invited conferences.

References
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Data Supplement (unedited) at:
http://stroke.ahajournals.org/content/suppl/2012/03/22/STROKEAHA.111.640011.DC1
http://stroke.ahajournals.org/content/suppl/2013/10/02/STROKEAHA.111.640011.DC2

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SUPPLEMENTAL MATERIAL

Title: Single center experience of intracerebral artery thrombectomy using TREVO device in 60 patients with acute ischemic stroke.

Supplemental Methods

Reperfusion protocol

In October 2008, we were qualified as a CSC implying that CT, CT perfusion /CT Angiology (CTP/CTA) and endovascular treatment (ET) were systematically available at stroke admission. Since then, patients are treated with thrombolytic therapy within 4.5 h of stroke onset. CTP/CTA was performed after alteplase therapy had been infused for 40 minutes and if CTP/CTA disclosed proximal occlusions and ruled out a Malignant profile ET was initiated if angiographic confirmed a large vessel occlusion, in the internal carotid, middle cerebral M1 and/or M2 segments, basilar or vertebral arteries, and P1 or P2 posterior cerebral segments.

In patients admitted > 4.5 h of stroke onset (n=13), or in wake-up strokes (n=6), CTP and CTA were performed before treatment onset and the patients were considered eligible to receive ET when a target mismatch and a proximal occlusion were present and there was not a malignant profile. Age is not considered an exclusion criterion for intravenous tPA and ET is indicated in patients under 85 years old.

All the patients are admitted to our stroke Unit. Daily NIHSS evaluation is performed by neurologist specialized in stroke with current NIHSS certification.
and modified Rankin scale is assessed at 3 months by programmed visit or telephone contact.

Follow-up CT scan is performed within 24h after thrombolysis or when clinical worsening of at least 4 points in the NIHSS score occurred.

**Brain imaging**

CT scanning was obtained on a 64-row scanner. For CTP, serial CT was performed with a rapid bolus injection of contrast material and four adjacent 7.2mm thick sections were obtained per second for 40 seconds. Anatomic coverage was adjusted to the level of the basal ganglia when anterior circulation infarct was suspected, parallel and superior to the orbital roof. In posterior circulation infarct, the anatomical imaging reference used to position the dynamic perfusion studies was the internal auditory canal. CTA with maximum intensity projection (MIP) was used to assess location of the occlusion and cerebral blood volume (CBV), cerebral blood flow (CBF) and time to peak (TTP) maps were calculated using a commercially available semi-automated perfusion analysis software (Siemens) based on the maximum slope model of perfusion. Maximum slope of the time attenuation curves (TAC) were used to calculate CBF, and CBV values were calculated from the maximum enhancement ratio. Infarct core was segmented based on a CBV threshold of 0.6 relative to the contralateral white matter,\(^1\) and ischemic penumbra was segmented based on a TTP threshold of 6 seconds for identification of critically hypoperfused tissue.\(^2\)

Infarct core was visually demonstrated on CBV color maps and ischemic penumbra on TTP color maps based on the color scale. Infarct core and tissue
at risk volumes were calculated by two independent readers (LO and SC) not involved in the acute care of the patients, with the summation area technique, manually drawing the area of core infarct on each of the parametric CBV images, and the hypoperfused tissue on the TTP images, respectively. The volume of penumbra was calculated as the total volume of TTP abnormality minus the reduced CBV volume and the percentage of mismatch was calculated according to the formula \((TTP - CBV)/TTP\). We defined several imaging patterns similar to those reported in previous MRI studies, but we redefined the criteria according to the smaller brain volume covered by CTP as follows: Target mismatch: Abnormal TTP \(\geq 4\) ml and abnormal \((TTP - CBV)/TTP \geq 50\%\); No target mismatch: Abnormal \((TTP - CBV)/TTP < 50\%\) (small lesion profile excluded); Small lesion: reduced CBV and abnormal TTP volumes both < 4 ml; Malignant profile: reduced CBV \(\geq 40\) ml. “Malignant profile corresponds to abnormal CBV area extending more than 1/3 of the middle cerebral artery territory.

In patients with basilar artery occlusions lasting >4.5 hour, magnetic resonance with DWI was used to rule out patients with severe ADC map abnormalities.

**Device and revascularisation procedure**

The study was approved by the local ethics committee and informed written consent was obtained from the patients or their relatives.
TREVO stent like retriever (Concentric Medical Inc Montain View, Ca.), is a new non-detachable self-expanding stent specifically designed for the removal of intracranial artery thrombi. It has an optimized cell geometry for consistent integration of the clot, very similar to other stent retrievers but with a flexible, tapered core wire without a closed basket at the distal end. A platinum coil at the distal end allows a better fluoroscopic visualization. This soft radiopaque tip achieves an atraumatic deployment. The device has also a hydrophilic coating to reduce friction during placement and retrieval. The diameter and length available ranged from 3 to 4 mm and 20 mm respectively.

All procedures were performed on a biplane angiography machine (Siemens Axiom Artis, Siemens Healthcare, Erlangen, Germany), without general anesthetic except in 3 specific cases (5%) of extreme agitation or hemodynamic and respiratory function instability.

An 8F femoral guiding catheter with distal balloon for temporary flow occlusion was used whenever possible, otherwise a conventional 6F guiding catheter was used. In particularly tortuous vessels a 4.3 to 5.2 F coaxial distal access catheter was used. A 0.014-inch microwire was used to advance along the artery until a 0.18 micro catheter could be located distally to the thrombus. The TREVO was placed at the site of the thrombus, maintaining it open for at least 3 minutes. We always used continuous aspiration from the guider catheter and flow arrest in the cases where the balloon was used while the device was being removed. Unfractionated heparin was administrated in continuous perfusion at 500 unit/hour and was stopped at the end of the procedure.

A maximum of three attempts were done with Trevo, achieving a total
revascularization rate of 76%. In those cases in which Trevo was not able to reopen the vessel, Solitaire and/or Merci were used, again with a total number of three attempts with each of them. In our protocol, we never use GP2b3a antagonists.

If the patient had a tandem occlusion of the proximal ICA, then angioplasty and stenting followed by distal mechanical thrombectomy were performed in the ICA. Eight hundred milligrams of lysine salicilate is administered previous to stent deployment followed by 300 mg of clopidogrel orally as early as possible.
Supplemental references


急性虚血性脳卒中患者60例に対してTREVOデバイスを用いた脳動脈血栓除去術の単一施設での経験

Single-Center Experience of Cerebral Artery Thrombectomy Using the TREVO Device in 60 Patients With Acute Ischemic Stroke

Luis San Román, MD1; Victor Obach, MD1; Jordi Blasco, MD1; Juan Macho, MD1; Antonio Lopez, MD1; Xabier Urra, MD, PhD1; Alejandro Tomasello, MD2; Alvaro Cervera, MD, PhD1; Sergio Amaro, MD, PhD1; Joan Perandreu, MD1; Jordi Branera, MD3; Sebastián Capurro, MD1; Laura Oleaga, MD1; Angel Chamorro, MD, PhD1

1 Functional Unit of Cerebrovascular Diseases, Hospital Clínica of Barcelona, Barcelona, Spain; 2 Radiology Service, Hospital Sant Pau, Barcelona, Spain; 3 Radiology Service Hospital Parc Taulí, Barcelona, Spain.

背景および目的：連続した急性脳卒中患者において、新しいTREVOステント状リトリバーの安全性と有効性を検討した。

方法：脳卒中の持続時間が前方循環において8時間未満（54例）または椎骨脳底動脈循環において12時間未満（6例）で、CT灌流/CT血管造影で大動脈閉塞のあることが確認され、悪性プロフィールが否定され、また症状が4.5時間以上持続している場合には標的のミスマッチ現象が認められた患者60例（平均年齢71.3歳、男性47%）を対象として、前向き単一施設試験を実施した。再開通の成功（Thrombolysis In Cerebral Infarctionスコア2b-3）、好ましい転帰（改変Rankin尺度スコア0～2）および90日目の死亡率、デバイス関連の合併症および症候性出血（実質内血腫1型または実質内血腫2型およびNIHSSスコア≧4ポイントの上昇）を前向きに評価した。

結果：入院時のNIHSSスコアの中央値（四分位範囲）は18（12〜22）であった。脳卒中発症から至適穿刺までの時間の中央値（四分位範囲）は210（173〜296）分であった。再開通が成功したのは、TREVOデバイスのみを使用した症例で44例（73.3%）、他のデバイスまたは補助的な動脈内組織プロテーゼ活性化因子も必要とした症例で52例（86.7%）であった。処置に要した時間の中央値（四分位範囲）は80（45〜114）分であった。良好な転帰は27例（45%）の患者で達成され、死亡率は28.3%であった。患者7例（11.7%）が、症候性頭蓋内出血を発症した。それ以外には重大な合併症は認められなかった。

結論：TREVOデバイスは重症脳卒中患者に対し適度に安全かつ有効である。これらの結果は、多施設共同登録研究および無作為臨床試験においてTREVOデバイスをさらに評価することを支持している。

Stroke 2012; 43: 1657-1659

表2 脳卒中患者を対象とした再灌流試験における転帰変数の比較

<table>
<thead>
<tr>
<th>試験</th>
<th>NIHSSベースライン</th>
<th>TICI 2〜3 (%)</th>
<th>SICH (%)</th>
<th>死亡率 90日 (%)</th>
<th>mRS &lt; 2 90日 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROCT II</td>
<td>121</td>
<td>17</td>
<td>66</td>
<td>10</td>
<td>25</td>
</tr>
<tr>
<td>IMS-II</td>
<td>55</td>
<td>19</td>
<td>60</td>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>t-PA静注試験の6時間未満</td>
<td>1,391</td>
<td>11</td>
<td>60</td>
<td>10</td>
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<tr>
<td>Multi MERCI, Smith et al, 2008年</td>
<td>164</td>
<td>19</td>
<td>55</td>
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<tr>
<td>Penumbra PST, 2009年</td>
<td>125</td>
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<td>10</td>
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NIHSS:米国国立衛生研究所脳卒中スケール, TICI:Thrombolysis In Cerebral Infarction Scale, SICH:症候性頭蓋内出血, mRS:改変Rankin尺度, PROACT, Pro-Urokinase (r-proUK) for Acute Cerebral Thromboembolism試験, IMS:Interventional Management of Stroke試験, t-PA,組織プロテーゼ活性化因子, MERCI:Mechanical Embolus Removal in Cerebral Ischemia試験, Penumbra PST:Penumbra Pivotal Stroke Trial.