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 revascularization 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.¹ 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 neuroangioradiologists 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=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.² In patients with symptoms lasting >4.5 hours (n=19), the
presence of mismatch was also required (online-only Data Supple-
ment; http://stroke.ahajournals.org). All procedures were carried out
without general anesthesia except in 3 patients with extreme agita-
tion 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 H11349 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 previ-
ous studies of endovascular therapy.5–10 and argue that the
systematic use of advanced brain imaging seems to contribute
to a better selection of the candidates to receive reperfusion
therapies.2 In addition, 95% of our cases were done without
intubation during the procedure, which may also have af-
ected outcome. The main limitations of the study were the

<table>
<thead>
<tr>
<th>Table 1. Main Characteristics of the Study Population</th>
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<tbody>
<tr>
<td>N=60</td>
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<tr>
<td>Age, y, mean (SD)</td>
</tr>
<tr>
<td>Male, no. (%)</td>
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<tr>
<td>Hypertension, no. (%)</td>
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<td>Diabetes, no. (%)</td>
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<tr>
<td>Atrial fibrillation, no. (%)</td>
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<tr>
<td>Baseline NIHSS, median (IQR)</td>
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<tr>
<td>Previous intravenous tPA, no. (%)</td>
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<td>Site of intracranial occlusion, no. (%)</td>
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<tr>
<td>Carotid T</td>
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<tr>
<td>Proximal M1</td>
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<tr>
<td>Distal M1</td>
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<tr>
<td>M2</td>
</tr>
<tr>
<td>Basilar artery</td>
</tr>
<tr>
<td>Proximal internal carotid stenosis &gt;70%</td>
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</tbody>
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NIHSS indicates National Institutes of Health Stroke Scale; IQR, interquartile range; tPA, tissue-type plasminogen activator.

<table>
<thead>
<tr>
<th>Table 2. Comparison of Outcome Variables of Reperfusion Studies in Stroke</th>
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<tbody>
<tr>
<td>Study</td>
</tr>
<tr>
<td>PROACT II</td>
</tr>
<tr>
<td>IMS-II</td>
</tr>
<tr>
<td>Pooling data intravenous tPA trials &lt;6 hours</td>
</tr>
<tr>
<td>Multi MERCI, Smith et al, 2008</td>
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<tr>
<td>Penumbra PST, 2009</td>
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<tr>
<td>Solitaire, Castaño et al, 2010</td>
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<tr>
<td>Solitaire, Miteff et al, 2011</td>
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<tr>
<td>Revive, Rohde et al, 2011</td>
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</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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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 $\geq$ 4ml 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 < 4ml; Malignant profile: reduced CBV $\geq$ 40ml. “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


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

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

Background and Objectives: We report our single-center experience of cerebral artery thrombectomy with the TREVO device in 60 patients with acute ischemic stroke. We evaluated the safety and efficacy of this new stent-retriever in patients with confirmed large-artery occlusion and a normal/low-grade susceptibility-weighted imaging (SWI) sign, without contraindications for intravenous thrombolysis, at 90±240 min after symptom onset.

Methods: We included 60 patients with acute ischemic stroke with large-artery occlusion (54 patients in the anterior circulation and 6 in the posterior circulation). They were treated with the TREVO device and/or additional reperfusion therapies as needed. We evaluated functional outcomes using the modified Rankin scale and clinical outcomes using the National Institutes of Health Stroke Scale (NIHSS).

Results: The median NIHSS score at admission was 18 (12-22). The median time from symptom onset to groin puncture was 210 (173-296) min. Of the 60 patients, 44 (73.3%) achieved successful recanalization with the TREVO device alone, while 52 (86.7%) achieved successful recanalization with additional reperfusion therapies. The median procedure time was 80 (45-114) min. The overall 30-day mortality rate was 17.5% (11 of 60). The median mRS score at 30 days was 1 (1-2).

Conclusions: Thrombectomy with the TREVO device is a safe and effective method for the treatment of acute ischemic stroke. The results of our single-center study support further evaluation in a multi-center, randomized clinical trial.

Table 2: Comparison of Outcomes in Additional Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Stroke 2012:43:1657-1659</th>
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<tbody>
<tr>
<td>PROCT II</td>
<td>121</td>
</tr>
<tr>
<td>IMS-II</td>
<td>55</td>
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<tr>
<td>t-PA injection</td>
<td>1,391</td>
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<tr>
<td>Multi MERCI</td>
<td>164</td>
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<td>Smith et al,</td>
<td>19</td>
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<td>Smith et al,</td>
<td>55</td>
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<tr>
<td>2008</td>
<td>10</td>
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<tr>
<td>Penumbra PST,</td>
<td>125</td>
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<td>2009</td>
<td>17</td>
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<tr>
<td>Solitaire,</td>
<td>20</td>
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<td>Castano et al,</td>
<td>19</td>
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<td>2010</td>
<td>11</td>
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<td>Solitaire,</td>
<td>26</td>
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<td>Miteff et al,</td>
<td>96</td>
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<td>2011</td>
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<td>30</td>
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