ORIGINAL RESEARCH

# Trevo 2000: Results of a Large Real-World Registry for Stent Retriever for Acute Ischemic Stroke

Mandy J. Binning, MD; Bruno Bartolini, MD; Blaise Baxter, MD; Ronald Budzik, MD; Joey English, MD; Rishi Gupta, MD; Hirad Hedayat, MD; Antonin Krajina, MD; David Liebeskind, MD; Raul G. Nogueira, MD; Ryan Shields, MSc; Erol Veznedaroglu, MD

***Background*—**Recent randomized controlled trials show benefit of thrombectomy for large vessel occlusion in stroke. Real-world data aid in assessing reproducibility of outcomes outside of clinical trials. The Trevo Retriever Registry is a multicenter, international, prospective study designed to assess outcomes in a large cohort of patients.

***Methods and Results*—**The Trevo Registry is a prospective database of patients with large vessel occlusion treated with the Trevo device as the first device. The primary end point is revascularization based on modified Thrombolysis in Cerebral Infarction score and secondary end points include 90-day modified Rankin Scale, 90-day mortality, neurological deterioration at 24 hours, and device/procedure related adverse events. Year 2008 patients were enrolled at 76 centers in 12 countries. Median admission National Institutes of Health Stroke Scale was 16 (interquartile range, 11–20). Occlusion sites were internal carotid artery (17.8%), middle cerebral artery (73.5%), posterior circulation (7.1%), and distal vascular locations (1.6%). A modified Thrombolysis in Cerebral Infarction 2b or 3 was achieved in 92.8% (95% CI, 91.6, 93.9) of procedures, with 55.3% (95% CI, 53.1, 57.5) of patients achieving modified Rankin Scale ≤2 at 3 months. Patients meeting revised 2015 American Heart Association criteria for thrombectomy had a 59.7% (95% CI, 56.0; 63.4) modified Rankin Scale 0 to 2 at 3 months, whereas 51.4% treated outside of American Heart Association criteria had modified Rankin Scale 0 to 2. 51.4% (95% CI, 49.6, 55.4). Symptomatic intracranial hemorrhage rate was 1.7% (95% CI, 1.2, 2.4).

***Conclusions*—**The Trevo Retriever Registry represents real-world data with stent retriever. The registry demonstrates similar reperfusion rates and outcomes in the community compared with rigorous centrally adjudicated clinical trials. Future subgroup analysis of this cohort will assist in identifying areas of future research.

***Clinical Trial Registration*—**URL: https://www.clinicaltrials.gov. Unique identifier: NCT02040259. **(*J Am Heart Assoc*. 2018;7: e010867. DOI: 10.1161/JAHA.118.010867.)**

**Key Words:** endovascular treatment • stroke, ischemic • thrombectomy

Stroke is the second-leading cause of death after ischemic heart disease and causes 9% of all deaths globally. In the United States, it is the fifth-most common cause of death, with ≈795 000 strokes occurring per year. Up to 87% of strokes are ischemic in nature and secondary to embolic or thrombotic etiologies.[1] Intravenous thrombolysis with tissue plasminogen activator has traditionally been the first line of treatment in patients presenting within 4.5 hours of onset of stroke symptoms. However, recent multicenter, randomized, controlled trials have demonstrated that selected patients with large vessel arterial occlusions are found to have higher recanalization rates and better outcomes when intravenous thrombolysis with tissue plasminogen activator is used in conjunction with mechanical thrombectomy (MT).[2–7]

The Trevo stent retriever (Stryker Neurovascular) is a third-generation mechanical thrombectomy device used to incorporate and remove arterial thrombus in patients. The Trevo device was found to be superior to the Merci device in a randomized controlled trial, the Trevo 2 trial.[8] The Trevo

*From the Department of Neurosciences, Drexel Neurosciences Institute, Philadelphia, PA (M.J.B., H.H., E.V.); Department of Interventional Radiology, La Pitié Salpétrière, Paris, France (B. Bartolini); Department of Radiology, Erlanger Hospital, Chattanooga, TN (B. Baxter); Department of Interventional Neuroradiology, Riverside Methodist Hospital/Ohio Health Research Institute, Columbus, OH (R.B.); Department of Neurology, California Pacific Medical Center, San Francisco, CA (J.E.); Department of Neurosciences, Wellstar Health System, Atlanta, GA (R.G.); Department of Radiology, University Hospital Hradec Kralove, Czech Republic (A.K.); Department of Neurology, UCLA, Los Angeles, CA (D.L.); Department of Neurology, Grady Memorial Hospital, Atlanta, GA (R.G.N.); Department of Neurovascular Intervention, Stryker Neurovascular, Fremont, CA (R.S.).*

**Correspondence to:** Erol Veznedaroglu, MD, Drexel Neurosciences Institute, N Broad St, 7th Floor, Philadelphia, PA 19102. E-mail: evez@gnineuro.org

Received September 8, 2018; accepted October 31, 2018.

## Clinical Perspective

### What Is New?

- The Trevo Retriever Registry is a large, multicenter, international prospective study showing the real-world usage of stent retriever technology before, during, and after randomized trials for thrombectomy in an extended time window.
- The Trevo Retriever Registry shows similar outcomes in terms of revascularization and clinical outcomes to those achieved in randomized clinical trials.

### What Are the Clinical Implications?

- In the real-world, operators are performing thrombectomy outside of guidelines to help patients with distal occlusions, posterior circulation occlusions, and extended time frames with good results.

device was also the most frequent device utilized in the MR CLEAN (Multicenter Randomized Clinical Trial of Endovascular Treatment for Acute. Ischemic Stroke in the Netherlands) randomized clinical trial, which established the clear superiority of thrombectomy over medical treatment alone within 6 hours of symptoms onset.[2] Trevo was also the only device allowed in the DAWN (Diffusion Weighted Imaging [DWI] or Computerized Tomography Perfusion [CTP] Assessment With Clinical Mismatch in the Triage of Wake Up and Late Presenting Strokes Undergoing Neurointervention) trial, which showed a large benefit for thrombectomy in properly selected patients treated within the 6- to 24-hour time window.[9] However, enrollment criteria were clearly defined in these trials. The Trevo Retriever Registry is a prospective, real-world registry that captured data from sites that performed thrombectomy based on their local protocols. This cohort represents the largest data set on patients undergoing MT with a stent retriever as the first-line device.

## Materials and Methods

The registry was approved by the institutional review board at each site with enrolled patients or their designee providing written informed consent within 7 days of the procedure. The Trevo Retriever Registry, funded by Stryker Neurovascular, was designed and led by a steering committee including academic investigators and representatives of the sponsor. Site investigators gathered the data using the case report forms while the sponsor performed database monitoring and maintenance. The academic authors had unrestricted access to the data, performed the data analysis with the primary and the independent study statisticians, and attest to the integrity of the trial and the completeness and accuracy of the reported data. The data, analytical methods, and study materials can be made available to other researchers for purposes of reproducing the results or replicating the procedure. Because of the sensitive nature of the data collected for this study, requests to access the data set from qualified researchers trained in human subject confidentiality protocols may be sent to Stryker Neurovascular at ryan.shields@stryker.com.

The Trevo Retriever Registry is an international, multicenter, prospective, open-label, registry of patients who underwent MT for large vessel occlusion (LVO) with the Trevo stent retriever as the initial device. The registry was designed to capture data on 2000 patients at 76 sites in 12 countries. Pretreatment imaging and other entry criteria were based on the protocols at each individual center. Each site was encouraged to consecutively enroll patients in whom the Trevo device was used as first-line therapy. Patients could not be enrolled if they were in a confounding clinical trial or another device was used as the first-line treatment. Enrollment in the registry began November 11, 2013 and ended May 1, 2017. The registry protocol was amended March 26, 2015 to include central adjudication imaging core lab to provide additional data validation and integrity to site-reported data and included 1599 of the 2008 patients. Retrospective image collection was prohibited per protocol. Each site had data-monitoring visits by the sponsor as well as an independent clinical research organization in order to enhance data integrity.

Baseline demographic information, pretreatment modified Rankin Scale (mRS), adverse events, discharge National Institutes of Health Stroke Scale (NIHSS), and 90-day mRS were collected by the sites. The mRS was obtained in person or by telephone by a certified examiner at each site. A central imaging core lab adjudicated the site of vessel occlusion, pre- and post-treatment modified Thrombolysis in Cerebral Infarction (mTICI) score, pretreatment Alberta Stroke Program Early CT Score, and post-treatment imaging for hemorrhagic complications. The primary end point was final angiographic revascularization success as graded by the mTICI score. Secondary end points include neurological deterioration at 24 hours as defined by a 4-point or greater increase in NIHSS, device- and procedure-related adverse events, 90-day mRS, and 90-day mortality.

All subjects in whom informed consent was obtained and in whom the Trevo Retriever was deployed through the microcatheter was considered enrolled in the intention-to-treat analysis. If a patient's 90-day mRS was not available, the last available mRS from either discharge or day 30 was carried forward for purposes of analysis. No imputation was performed for missing data on the mTICI.

## Statistical Analysis

Patient baseline characteristics and procedural data were analyzed and represented using frequency, mean, SD, and

median. In comparing 2 groups, the *t* test or Wilcoxon sum test was utilized for continuous variables and Fisher's exact test for dichotomous variables. Clopper–Pearson CIs were constructed for inferences of key outcomes. Uni- and multivariate logistic regression was performed on the intention-to-treat cohort to identify predictors of good outcome. Stepwise selection using score chi-squre statistics. *P* value for enter is 0.05, and *P* value for stay is 0.05. In patients with missing 90-day mRS, last observation carried forward was utilized. These analyses were performed with SAS software (version 9.4; SAS Institute Inc, Cary, NC).

## Results

A total 2008 patients were enrolled during the enrollment period from 76 centers internationally. Of the 2008 subjects that became the intention-to-treat population, 1365 (68%) were enrolled in the United States whereas 643 (32%) were enrolled at international sites: Canada, Czech Republic, France, Germany, Hungary, Italy, Korea, Singapore, Spain, Switzerland, and Thailand. Mean age of this cohort was 68.3±14.4 years (range, 19–99). Table 1 summarizes baseline demographic information and pretreatment imaging and clinical characteristics.

Mean presenting NIHSS was 15.5±6.8, and the median was 16 (interquartile range, 11–20). One thousand forty-one (52.3%) patients received intravenous thrombolysis with tissue plasminogen activator before intervention, and the median baseline Alberta Stroke Program Early CT Score was 8 (interquartile range, 7–9). Baseline imaging used to select patients for treatment was a computed tomography (CT) angiography and/or CT perfusion in 69.8% of patients (1398 of 2002), magnetic resonance imaging of the brain in 13.4% (269 of 2002), and noncontrast CT only in 16.7% (335 of 2002). The vast majority of patients had a baseline mRS of 0 to 1 (85.6%). Table 2 summarizes angiographic and procedural variables for the patient cohort. Most patients had clots located in the proximal middle cerebral artery distribution, with 1096 (54.7%) in the M1 and 375 (18.7%) in the M2. The occlusion site was the intracranial internal carotid artery in 356 patients (17.8%). One hundred forty-three patients (7.1%) had thrombus located in the vertebrobasilar circulation (including vertebral artery, basilar artery, and posterior cerebral arteries), with the remaining occlusions involving the anterior cerebral artery (0.5%) and the more-distal middle cerebral artery branches (1%).

Mean procedure duration time was 59.0±36.7 minutes (range, 8–286). Type of anesthesia was split between conscious sedation in 977 (48.7%) patients and general anesthesia in 870 (43.3%) whereas in 8% local or no anesthesia was reported.

A balloon guide catheter was used with the first pass in 50.6% of patients (1004 of 1983) whereas an intermediate guide catheter was used in 48% of patients (952 of 1983). The Trevo 4×20 or 4×30 was the first device used in 68.4% (1341 of 1960) of patients whereas the 6×25 and 3×20 were used in 17.3% (340 of 1960) and 14.2% (279 of 1960), respectively. Mean number of passes with any thrombectomy device, including Trevo, was 2.0±1.4 (range, 1–12). Mean number of passes with the Trevo device was 1.7±1.0 (range, 1–10). Distal emboli were observed in 374 of 2002 (18.7%), with 46 of 1997 (2.3%) having emboli to new vascular territories.

Table 3 summarizes the safety outcomes and hemorrhagic complications related to the procedure. Access-site complications requiring surgical treatment or blood transfusion occurred in 0.3% (6 of 2008; 95% CI, 0.1, 0.7). A total of 9 device malfunctions were reported in the Trevo Retriever Registry over the course of the study. None of the reported device malfunctions were associated with an adverse event.

The overall mortality rate within 48 hours of procedure was 0.6% (12 of 2008; 95% CI, 0.3, 1.1). Neurological deterioration within 48 hours postprocedure occurred in 4.8% (97 of 2008; 95% CI, 3.9, 5.9) patients, and 2.4% (49 of 2008; 95% CI, 1.8, 3.2) of procedures reported a procedure- or device-related adverse event. Symptomatic intracranial hemorrhage, as defined by ECASS III (European Cooperative Acute

**Table 1.** Baseline Patient Characteristics

| Characteristic | Intention to Treat (n=2008) |
|---|---|
| Age, y (mean±SD) | 68±14 |
| Sex: female | 51.8% (1041/2008) |
| Atrial fibrillation | 36.1% (722/2000) |
| Diabetes mellitus | 23.8% (477/2002) |
| Coronary artery disease | 22.2% (443/1999) |
| Congestive heart failure | 14.2% (285/2002) |
| Baseline glucose >150 mg/dL | 24% (446/1859) |
| Prestroke mRS | |
| 0 | 70.9% (1372/1972) |
| 1 | 14.7% (290/1972) |
| 2 | 7.6% (151/1972) |
| 3 | 4.1% (80/1972) |
| 4 | 2.1% (42/1972) |
| 5 | 0.5% (10/1972) |
| Baseline NIHSS (mean±SD) | 15.5±6.8 (1991) |
| IV t-PA delivered | 52.3% (1041/1990) |
| Pretreatment ASPECTS (core lab adjudicated)* | |
| 0 to 5 | 13.4% (176/1309) |
| 6 to 10 | 86.6% (1133/1309) |

ASPECTS indicates Alberta Stroke Program Early CT Score; IV, intravenous; mRS, modified Rankin Scale; NIHSS, National Institutes of Health Stroke Scale; t-PA, tissue plasminogen activator.
*Imaging Corelab implemented after protocol AB. Data not available for AA subjects.

**Table 2.** Procedural Characteristics

| | ITT (n=2008) |
|---|---|
| Time to arterial puncture (hours)* | |
| Mean±SD | 7.1±9.5 (1992) |
| 0 to 3 | 24% (478/1992) |
| 3 to 6 | 44.1% (879/1992) |
| 6 to 8 | 9.6% (191/1992) |
| >8 | 22.3% (444/1992) |
| Procedure time (min) | |
| Mean±SD | 59.0±36.7 (1996) |
| Range | 278 (8–286) |
| Anesthesia | |
| General anesthesia | 43.3% (870/2008) |
| Conscious sedation | 48.7% (977/2008) |
| Other | 8% (161/2008) |
| Clot hemisphere location | |
| Right | 45.4% (912/2008) |
| Left | 49.2% (987/2008) |
| Basilar | 5.4% (109/2008) |
| Clot location | |
| Vertebrobasilar | 7.1% (143/2002) |
| ACA-A1 | 0.1% (3/2002) |
| A2 | 0.4% (8/2002) |
| ICA | 17.8% (356/2002) |
| MCA-M1 | 54.7% (1096/2002) |
| M2 | 18.7% (375/2002) |
| M3 | 1% (21/2002) |
| Suspected stroke etiology | |
| Cardioembolic | 56% (1122/2004) |
| Large artery atherosclerosis | 9.6% (193/2004) |
| Cryptogenic | 27.6% (554/2004) |
| Other determined etiology | 6.7% (135/2004) |
| No. passes of Trevo retriever(s) | |
| Mean±SD | 1.7±1.0 (2002) |
| Range (Min–Max) | 9 (1–10) |
| No. of passes of all thrombectomy device(s) | |
| Mean±SD | 2.0±1.4 (2004) |
| Range (Min–Max) | 11 (1–12) |

ACA indicates anterior cerebral artery; ICA, internal carotid artery; ITT, intent to treat; MCA, middle cerebral artery.
*Time last seen normal to arterial puncture.

**Table 3.** Safety Outcomes

| | ITT (n=2008) |
|---|---|
| Vessel dissection | 0.6% (13/2008) [95% CI, 0.3, 1.1] |
| Vessel perforation | 0.6% (13/2008) [95% CI, 0.3, 1.1] |
| In vivo breakage | 0% (1/2008) [95% CI, 0.0, 0.3] |
| Access-site complication requiring surgical treatment or blood transfusion | 0.3% (6/2008) [95% CI, 0.1, 0.7] |
| Emboli to new territory | 2.3% (46/1997) [95% CI, 1.7, 3.1] |
| Neurological deterioration within 48 hours | 4.8% (97/2008) [95% CI, 3.9, 5.9] |
| Procedure- or device-related SAEs within 48 h | 2.4% (49/2008) [95% CI, 1.8, 3.2] |
| Symptomatic ICH (ECASS III definition) within 48 hours | 1.7% (34/2008) [95% CI, 1.1, 2.4] |
| 48-hour all-cause mortality | 0.6% (12/2008) [95% CI, 0.3, 1.1] |
| 90-d all-cause mortality | 13.9% (280/2008) [95% CI, 12.5, 15.5] |

Numbers reflect counts of patients, as opposed to counts of events. ECASS III indicates European Cooperative Acute Stroke Study III; ICH, intracranial hemorrhage; ITT, intention to treat; SAE, serious adverse event.

Stroke Study III) criteria, occurred in 1.7% (34 of 2008; 95% CI, 1.2, 2.4) of patients.

The primary end point of the study (site-reported reperfusion success defined by mTICI score ≥2b was achieved in 92.8% (1863 of 2008; 95% CI, 91.6, 93.9) of patients, with mTICI 2b or mTICI 3 in 36.4% and 56.4%, respectively. Incomplete reperfusion grade 2a was achieved in 4.7% (94 of 2008; 95% CI, 3.8, 5.7) of patients and minimal-to-no reperfusion TICI 0 to 1 in 2.5% (51 of 2008; 95% CI, 1.9, 3.3) of patients. For available imaging, distribution for centrally adjudicated mTICI was: mTICI 0 to 1: was 3.3% (52 of 1599; 95% CI, 2.4, 4.2); grade 2a: 15.1% (242 of 1599; 95% CI, 13.4, 17.0); grade 2b: 67.5% (1080 of 1599; 95% CI, 65.2, 69.8); and grade 3: 14.1% (225 of 1599; 95% CI, 14.1, 15.9). The breakdown for discharge location was as follows: home with or without home care (36.7% [699 of 1903 patients]); inpatient rehabilitation (31.7% [602 of 1903 patients]); and nursing home (7.5% [143 of 1903 patients]).

The secondary end point of the study was 90-day clinical outcomes with a good clinical outcome defined as mRS 0 to 2, which was achieved in 55.3% (1104 of 1997; 95% CI, 53.1, 57.5) of patients. Excellent outcome (mRS 0–1) was achieved in 40.7% (814 of 1997; 95% CI, 38.6, 43.0). Ninety-day mortality was 14.0% (280 of 2008; 95% CI, 12.5, 15.5) of patients.

In univariate analysis, many baseline characteristics were correlated with good outcome. Once adjusting in a multivariate analysis (Table 4), significant predictors of good outcome (90-day mRS 0–2) included age (crude odds ratio [cOR], 0.97; 95% CI, 0.95, 0.98) per year, diabetes mellitus (cOR, 0.55;

**Table 4.** Adjusted Odds Ratios, mRS 0 to 2 Compared With mRS 3 to 6

| | Odds Ratio | Coefficient | SE | *P* Value |
|---|---|---|---|---|
| 1-y increment in age | 0.97 [0.95–0.98] | −0.04 | 0.01 | <0.001 |
| Diabetes mellitus | 0.55 [0.38–0.81] | −0.59 | 0.20 | 0.002 |
| Preprocedure mRS | 0.45 [0.36–0.55] | −0.81 | 0.11 | <0.001 |
| Preprocedure NIHSS (per point increment) | 0.92 [0.90–0.94] | −0.08 | 0.01 | <0.001 |
| Baseline ASPECTS | 1.22 [1.11–1.34] | 0.20 | 0.05 | <0.001 |
| Procedure time, min | 0.99 [0.99–0.99] | −0.01 | 0.00 | <0.001 |
| 10-unit increment in glucose, mg/dL | 0.97 [0.95–1.00] | −0.03 | 0.01 | 0.032 |

Stepwise selection using score chi-square statistics. *P* value for enter is 0.05, and *P* value for stay is 0.05. ASPECTS indicates Alberta Stroke Program Early CT Score; mRS, modified Rankin Scale; NIHSS, National Institutes of Health Stroke Scale.

95% CI, 0.38, 0.81), prestroke NIHSS (cOR, 0.92; 95% CI, 0.90, 0.94) baseline Alberta Stroke Program Early CT Score (cOR, 1.22; 95% CI, 1.11, 1.34), baseline blood glucose (cOR, 0.97; 95% CI, 0.95, 1.00), and procedure time (cOR, 0.99; 95% CI, 0.99, 0.99).

Age >80 years was a negative predictor of outcome. Admission NIHSS was significantly higher in the octogenarian cohort (15 versus 17.3; $P<0.001$). Significantly fewer octogenarians were discharged to home (36.6 versus 16.4%; $P<0.001$). The 90-day mortality was significantly higher in the ≥80 group (27.2% versus 9.6%; $P<0.001$). Good outcomes were noted in 62.2% of <80-year-old patients versus 33.7% in ≥80-year-olds ($P<0.001$). Excellent outcomes were only observed in 23.3% of octogenarians versus 46.5% ($P<0.001$) in the younger group.

The real-world data provided the opportunity to evaluate a substantial number of patients treated per American Heart Association (AHA) guidelines, but also those outside the guidelines. Table 5 compares patients who were treated based on AHA guidelines in comparison with outside of the guideline patients. This variable could not be derived in 102 patients, typically because the time last seen well was not reported. There were no differences in TICI 2b/3 reperfusion between the 2 groups (92.8% versus 92.1%; $P=0.595$), but the 90-day mRS 0 to 2 was significantly higher in the AHA group compared with the non-AHA (59.7% versus 52.5%; $P=0.002$), respectively.

**Table 5.** Clinical Assessment and Efficacy Outcomes, Stratified by AHA/Non-AHA

| | Non-AHA (n=1192) | AHA (n=711) | *P* Value |
|---|---|---|---|
| Preprocedure NIHSS | | | |
| Mean±SD | 14.9±7.4 (1192) | 16.7±5.5 (711) | <0.001* |
| Median (Q1–Q3) | 15 (9–20) | 17 (13–20) | |
| Range (Min–Max) | 40 (0–40) | 31 (6–37) | |
| Prestroke mRS | | | |
| 0 | 64.3% (766/1192) | 81.6% (580/711) | <0.001* |
| 1 | 12.7% (151/1192) | 18.4% (131/711) | |
| 2 | 12.3% (147/1192) | 0% (0/711) | |
| 3 | 6.4% (76/1192) | 0% (0/711) | |
| 4 | 3.5% (42/1192) | 0% (0/711) | |
| 5 | 0.8% (10/1192) | 0% (0/711) | |
| Postprocedure modified TICI ≥2b | 92.8% (1106/1192) | 92.1% (655/711) | 0.595† |
| 90-day mRS 0 to 2 | 52.5% (623/1186) | 59.7% (422/707) | 0.002† |
| 90-day mRS | | | |
| 0 | 20.1% (238/1186) | 23.9% (169/707) | <0.001* |
| 1 | 18.9% (224/1186) | 20.2% (143/707) | |
| 2 | 13.6% (161/1186) | 15.6% (110/707) | |
| 3 | 12.1% (144/1186) | 14% (99/707) | |
| 4 | 13% (154/1186) | 13.7% (97/707) | |
| 5 | 5.1% (61/1186) | 3.7% (26/707) | |
| 6 | 17.2% (204/1186) | 8.9% (63/707) | |

AHA indicates American Heart Association; mRS, modified Rankin Scale; NIHSS, National Institutes of Health Stroke Scale; TICI, Thrombolysis in Cerebral Infarction.
*Wilcoxon rank-sum test.
†Fisher's exact test.

## Discussion

Recent randomized controlled trials, demonstrated that MT in addition to best medical treatment (including intravenous thrombolysis with tissue plasminogen activator, if applicable) was superior to best medical treatment alone when applied in properly selected patients.[2–6] Previous trials predominantly enrolled patients with anterior LVO up to 6 hours from symptom onset and found substantial clinical benefit in early neurological recovery and long-term functional outcomes.[2–6] The HERMES (Highly Effective Reperfusion Evaluated in Multiple Endovascular Stroke Trials) collaborators performed a meta-analysis of the first 5 randomized MT trials utilizing stent retrievers, and found that the number of patients needed to treat to positively impact 1 patient was only 2.6.[7] Based on these results, the AHA published guidelines that supported the use of MT for patients with LVO of the M1 middle cerebral artery or internal carotid artery terminus if treated under 6 hours with an Alberta Stroke Program Early CT Score ≥6 as level of evidence IA.[10]

The Trevo Registry provides real-world data on the results of MT in the community allowing for comparisons to recent randomized clinical trials. The results demonstrate that MT is being performed safely and with similar outcomes and reperfusion rates. Overall, 55.3% of patients achieved an mRS of 0 to 2 at 90 days with a mTICI 2b/3 reperfusion rate of 92.8%. The symptomatic hemorrhage rate was in line with recent studies at 1.7% and an overall mortality rate of 14%. The therapy was being offered more broadly than the AHA guidelines, with 62.6% of patients treated outside of the 2015 guidelines. The Trevo Stent-Retriever Acute Stroke (TRACK) Registry[11] retrospectively evaluated self-reported data in 634 patients who underwent MT with the Trevo device. The investigators found 90-day mRS≤2 of 54.3% in patients meeting AHA guidelines and 47.9% in all comers.[11]

In the TREVO Registry, we found that a 90-day mRS of 0 to 2 was 59.7% in patients treated within the AHA guideline versus 52.5% outside of the guidelines. Although, early in enrollment, there were concerns for the absence of level 1 data in treating patients beyond 6 hours, local institutions adopted protocols to treat patients based on imaging as opposed to time based on previous studies showing that similar outcomes can be achieved to patients treated under 8 hours.[12–14] Similarly, there is an absence of data showing the efficacy of MT for posterior circulation LVO, but given that devastating outcomes occur in untreated occlusion nearly 80% of the time,[15] many centers perform thrombectomy routinely for this condition. Recent data show that MT for basilar artery occlusions can achieve a good neurological recovery in up to 38% of patients.[16,17] In the current cohort, there were 143 posterior circulation strokes treated with MT, of which 74 (51.8%) had an mRS of 0 to 2 at 90 days. This improvement in rates of good outcome relative to other published literature is likely reflective of the previous retrospective studies including use of older-generation technologies, such as the Merci device, in their case series.

It is important to note that this registry was completed, and collected, before publication of the DEFUSE 3 (Endovascular Therapy Following Imaging Evaluation for Ischemic Stroke) and DAWN trials,[9,18] that demonstrated efficacy of MT in patients treated up to 16 and 24 hours, respectively, with advanced imaging (CT perfusion or magnetic resonance imaging). In this cohort, 69.3% of patients underwent a CT angiography and/or CT perfusion study before MT. This supports that, in the community, patients were being selected based on protocols for later-presenting stroke victims. Patients treated beyond 6 hours in this registry had a 90-day mRS of 0 to 2 of 51.3%. This is in line with what was reported in the DAWN and DEFUSE 3 studies.

There are significant limitations to our analysis. First, this is a single-arm registry without a control arm, but represents a large cohort of stent-retriever patients collected in the real world. Second, patients undergoing thrombectomy were not consecutively collected at each institution. Given there were ongoing clinical trials and competitive device registries during this time period, it would not have been feasible to achieve consecutive patient data. Third, consent was obtained within 7 days of the procedure, and there is a potential for bias of not enrolling patients with less-than-desirable outcomes attributed to having to approach families after the procedure. Fourth, 3-month mRS was reported by local sites or investigators; this evaluation could have resulted in a higher rate of patients with a good or excellent clinical outcome. Last, there were missing imaging data points. However, the fact that our results are within the same range of the HERMES pooled analysis, with similar rates of mortality (14% versus 15.3%) and independent outcomes (55.7% versus 46%) at 90 days despite a slightly lower stroke severity (median baseline NIHSS 15.5 versus 17), helps minimize the concerns of selection bias, which are inherent to the design of any registry. Moreover, the Trevo registry had a centralized core lab for review of angio- and radiographic imaging in order to reduce the bias for reperfusion and hemorrhagic complication outcomes.

## Summary

The Trevo Retriever Registry is a large, prospective, real-world registry of MT for patients with acute ischemic stroke harboring an LVO. Outcome data suggest that the results from clinical trials can be reproduced in the real world for stroke over a wide range of occlusion sites, stroke severity, time of onset, and patient comorbidities.

## Sources of Funding

The Trevo Registry was funded by Stryker Neurovascular.

## Author Contributions

Mandy Binning, MD, prepared the manuscript. Bartolini, MD, is a Trevo Registry steering committee member and approved of the manuscript. Baxter, MD, is a Trevo Registry steering committee member and approved the manuscript. Budzik, MD, approved the manuscript and is co-primary investigator (PI) of the Trevo Retriever Registry. English, MD, approved the manuscript and is a member of the Trevo Registry steering committee. Gupta is a member of the Trevo Retriever Steering Committee and assisted with the content of the manuscript. Hedayat, MD, assisted with manuscript preparation. Krajina, MD, is a member of the Trevo Registry steering committee and has approved the manuscript. Dr Liebeskind is Trevo Registry steering committee member and has approved the manuscript. Nogueira, MD, is on

the Trevo Registry steering committee and has assisted with and approved the manuscript. Shields, MSc, assisted with statistics and data reporting. Veznedaroglu, MD, is co-PI and has approved the manuscript.

## Disclosures

Dr Bartolini, is a consultant and on the advisory board of Stryker. Dr Baxter receives consulting fees and fees for serving on a speakers' bureau from Penumbra and consulting fees from Stryker, Medtronic, Route 92 Medical, and Pulsar and holding US Patent 9526863 on devices and methods for perfusion therapy, licensed to Neuronal Protection System. Dr English is a consultant for and on the advisory board of Penumbra and Medtronic and a consultant for Stryker. Dr Gupta has ownership interest in and receives royalties from UpToDate. He is a consultant/advisory board member of Stryker Neurovascular, Medtronic, and Rapid Medical. He is also serving as an associate editor of the *Journal of Neurointerventional Surgery*, *Journal of Neuroimaging*, and *Interventional Neurology*. Dr Krajina is a consultant for and on the advisory board of Stryker. Dr Liebeskind is a consultant for and on the advisory board of Medtronic (Imaging Core Lab) and a consultant for Stryker Neurovascular (Imaging Core Lab). Dr Nogueira has the following disclosures: Stryker (PI: Trevo-2 PI/DAWN Trials), Covidien (SWIFT/SWIFT-PRIME Steering Committee, STAR Trial Core-Lab), and Penumbra (3-D Trial Executive Committee). Mr Shields is employed by Stryker. Dr Veznedaroglu is a consultant for and on the advisory board of Stryker, is a Penumbra patent holder and scientific advisor, is a Trice scientific advisory board consultant, and holds an Mizuho patent. The remaining authors have no disclosures to report.

## References


1. Benjamin EJ, Blaha MJ, Chiuve SE, Cushman M, Das SR, Deo R, de Ferranti SD, Floyd J, Fornage M, Gillespie C, Isasi CR, Jimenez MC, Jordan LC, Judd SE, Lackland D, Lichtman JH, Lisabeth L, Liu S, Longenecker CT, Mackey RH, Matsushita K, Mozaffarian D, Mussolino ME, Nasir K, Neumar RW, Palaniappan L, Pandey DK, Thiagarajan RR, Reeves MJ, Ritchey M, Rodriquez CJ, Roth GA, Rosamond WD, Sasson C, Towfighi A, Tsao CW, Turner MB, Virani SS, Voeks JH, Willey JZ, Wilkins JT, Wu JH, Alger HM, Wong SS, Muntner P; American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Heart disease and stroke statistics—2017 update: a report from the American Heart Association. *Circulation*. 2017;135:e146–e603.
2. Berkhemer OA, Fransen PS, Beumer D, van den Berg LA, Lingsma HF, Yoo AJ, Schonewille WJ, Vos JA, Nederkoorn PJ, Wermer MJ, van Walderveen MA, Staals J, Hofmeijer J, van Oostaven JA, Lychlama à Nijeholt GJ, Boiten J, Brouwer PA, Emmer BJ, de Bruijn SF, van Dijk LC, Kappelle LJ, Lo RH, van Dijk EJ, de Vries J, de Kort PL, van Rooij WJ, van den Berg JS, van Hasselt BA, Aerden LA, Dallinga RJ, Visser MC, Bot JC, Vroomen PC, Eshghi O, Schreuder TH, Hejjboer RJ, Keizer K, Tielbeek AV, den Hertog HM, Gerrits DG, van den Berg-Vos RM, Karas GB, Steyerberg EW, Flach HZMarquering HA, Sprengers ME, Jenniskens SF, Beenen LF, van den Berg R, Koudstaal PJ, van Zwam WH, Roos YB, van der Lugt A, van Oostenbrugge RJ, Majoie CB, Dippel DW; MR CLEAN Investigators. A randomized trial for intraarterial treatment for acute ischemic stroke. *N Engl J Med*. 2015; 372:11–20.
3. Goyal M, Demchuk AM, Menon BK, Eesa M, Rempel JL, Thornton J, Roy D, Jovin TG, Willinsky RA, Sapkota BL, Dowlatshahi D, Frei DF, Kamal NR, Montanera WJ, Poppe AY, Rychborst KJ, Silver FL, Shuaib A, Tampieri D, Williams D, Bang OY, Baxter BW, Burns PA, Choe H, Heo JH, Holmstedt CA, Jankowitz B, Kelly M, Linares G, Mandzia JL, Shankar J, Sohn SI, Swartz RH, Barber PA, Coutts SB, Smith EE, Morrish WF, Weill A, Subramniam S, Mitha AP, Wong JH, Lowerison MW, Saiobi TT, Hill MD; ESCAPE Trial Investigators. Randomized assessment of rapid endovascular treatment of ischemic stroke. *N Engl J Med*. 2015;372:1019–1030.
4. Campbell BC, Mitchell PJ, Kleinig TJ, Dewey HM, Churilov L, Yassi N, Yan B, Dowling RJ, Parsons MW, Oxley TJ, Wu TY, Brooks M, Simpson MA, Miteff F, Levi CR, Krause M, Harrington TJ, Faulder KC, Steinfort BS, Priglinger M, Ang T, Scroop R, Barber PA, McGuinness B, Wijeratne T, Phan TG, Chong W, Chandra RV, Bladin CF, Badve M, Rice H, de Villiers L, Ma H, Desmond PM, Donnan GA, Davis SM; EXTEND-IA Investigators. Endovascular therapy for ischemic stroke with perfusion-imaging selection. *N Engl J Med*. 2015;372:1009–1018.
5. Jovin TG, Chamorro A, Cobo E, de Miquel MA, Molina CA, Rovira A, San Roman L, Serena J, Abilleira S, Ribo M, Millan M, Urra X, Cardona P, Lopez-Cancio E, Tomasello A, Castano C, Blasco J, Aja L, Dorado L, Quesada H, Rubiera M, Hernandez-Perez M, Goyal M, Demchuk AM, von Kummer R, Gallofre M, Davalos A; REVASCAT Trial Investigators. Thrombectomy within 8 hours after symptom onset in ischemic stroke. *N Engl J Med*. 2015;372:2296–2306.
6. Saver JL, Goyal M, Bonafe A, Diener H, Levy EI, Pereira VM, Albers GW, Cognard C, Cohen DJ, Hacke W, Jansen O, Jovin TG, Mattle HP, Nogueira RG, Siddiqui AH, Yavagal DR, Baxter BW, Devlin TG, Lopes DK, Reddy VK, du Mesnil de Rochemont R, Singer OC, Jahan R; SWIFT PRIME Investigators. Stent-retriever thrombectomy after intravenous t-PA vs. t-PA alone in stroke. *N Engl J Med*. 2015;372:2285–2295.
7. Goyal M, Menon BK, van Zwam WH, Dippel DW, Mitchell PJ, Demchuk AM, Davalos A, Majoie CB, van der Lugt A, de Miquel MA, Donnan GA, Roos YB, Bonafe A, Jahan R, Diener HC, van den Berg LA, Levy EI, Berkhemer OA, Pereira VM, Rempel J, Millan M, Davis SM, Roy D, Thornton J, Roman LS, Ribo M, Beumer D, Stouch B, Brown S, Campbell BC, van Oostenbrugge RJ, Saver JL, Hill MD, Jovin TG; HERMES collaborators. Endovascular thrombectomy after large-vessel ischemic stroke: a meta-analysis of individual patient data from five randomised trials. *Lancet*. 2016;387:1723–1731.
8. Nogueira RG, Lutsep HL, Gupta R, Jovin TG, Albers GW, Walker GA, Liebeskind DS, Smith WS; TREVO 2 Trialists. Trevo versus Merci retrievers for thrombectomy revascularization of large vessel occlusions in acute ischaemic stroke (TREVO 2): a randomised trial. *Lancet*. 2012;380:1231–1240.
9. Nogueira RG, Jadhav AP, Haussen DC, Bonafe A, Budzik RF, Bhuva P, Yavagal DR, Ribo M, Cognard C, Hanel RA, Sila CA, Hassan AE, Millan M, Levy EI, Mitchell P, Chen M, English JD, Shah QA, Silver FL, Pereira VM, Mehta BP, Baxter BW, Abraham MG, Cardona P, Veznedaroglu E, Hellinger FR, Feng L, Kirmani JF, Lopes DK, Jankowitz BT, Frankel MR, Costalat V, Vora NA, Yoo AJ, Malik AM, Furlan AJ, Rubiera M, Aghaebrahim A, Olivot JM, Tekle WG, Shields R, Graves T, Lewis RJ, Smith WS, Liebeskind DS, Saver JL, Jovin TG; DAWN Trial Investigators. Thrombectomy 6 to 24 hours after stroke with a mismatch between deficit and infarct. *N Engl J Med*. 2018;378:11–21.
10. Powers WJ, Derdeyn CP, Biller J, Coffey CS, Hoh BL, Jauch EC, Johnston KC, Johnston SC, Khalessi AA, Kidwell CS, Meschia JF, Ovbiagele B, Yavagal DR; American Heart Association Stroke Council. 2015 American Heart Association/American Stroke Association Focused Update of the 2013 Guidelines for the Early Management of Patients with Acute Ischemic Stroke Regarding Endovascular Treatment: A Guideline for Healthcare Professionals From the American Heart Association/American Stroke Association. *Stroke*. 2015;46:3020–3035.
11. Zaidat OO, Castonguay AC, Nogueira RG, Haussen DC, English JD, Satti SR, Chen J, Farid H, Borders C, Veznedaroglu E, Binning MJ, Purj A, Vora NA, Budzik RF, Dabus G, Linfante I, Janardhan V, Alshekhlee A, Abraham MG, Edgell R, Tagi MA, Khoury RE, Mokin M, Majjhoo AQ, Kabbani MR, Froehler MT, Finch I, Ansari SA, Novakovic R, Nguyen TN. TREVO stent-retriever mechanical thrombectomy for acute ischemic stroke secondary to large vessel occlusion registry. *J Neurointerv Surg*. 2018;10:516–524.
12. Jovin TG, Liebeskind DS, Gupta R, Rymer M, Rai A, Zaidat OO, Abou-Chebl A, Baxter B, Levy EI, Barreto A, Nogueira RG. Imaging-based endovascular therapy for acute ischemic stroke due to proximal intracranial anterior circulation occlusion treated beyond 8 hours from last seen well: retrospective multicenter analysis of 237 consecutive patients. *Stroke*. 2011;42:2206–2211.
13. Aghaebrahim A, Leiva-Salinas C, Jadhav AP, Jankowitz B, Zaidi S, Jumaa M, Urra X, Amorim E, Zhu G, Giurgiutiu DV, Horey A, Reddy V, Hammer M, Wechsler L, Wintermark M, Jovin T. Outcomes after endovascular treatment for anterior circulation stroke presenting as wake-up strokes are not different than witnessed onset beyond 8 hours. *J Neurointerv Surg*. 2015;7:875–880.
14. Mokin M, Kan P, Sivakanthan S, Veznedaroglu E, Binning MJ, Liebman KM, Jethwa PR, Turner RD IV, Turk AS, Natarajan SK, Siddiqui AH, Levy EI. Endovascular therapy of wake-up strokes in the modern era of stent retriever thrombectomy. *J Neurointerv Surg*. 2016;8:240–243.
15. Schonewille WH, Wijman CA, Michel P, Rueckert CM, Weimar C, Mattle HP, Engelter ST, Tanne D, Muir KW, Molina CA, Thijs V, Audebert H, Pfefferkorn T,

Szabo K, Lindsberg PJ, de Freitas G, Kappelle LJ, Algra A; BASICS study group. Treatment and outcomes of acute basilar artery occlusion in the Basilar Artery International Cooperation Study (BASICS): a prospective registry study. *Lancet Neurol*. 2009;8:724–730.

16. Bouslama M, Haussen DC, Aghaebrahim A, Grossberg JA, Walker G, Rangaraju S, Horev A, Frankel MR, Nogueira RG, Jovin TG, Jadhav AP. Predictors of good outcome after endovascular therapy for vertebrobasilar occlusion stroke. *Stroke*. 2017;48:3252–3257.

17. Mokin M, Sonig A, Sivakanthan S, Ren Z, Elijovich L, Arthur A, Goyal N, Kan P, Duckworth E, Veznedaroglu E, Binning MJ, Liebman KM, Rao V, Turner RD IV, Turk AS, Baxter BW, Dabus G, Linfante I, Snyder KV, Levy EI, Siddiqui AH. Clinical and procedural predictors of outcomes from the endovascular treatment of posterior circulation strokes. *Stroke*. 2016; 47:782–788.

18. Albers GW, Marks MP, Kemp S, Christensen S, Tsai JP, Ortega-Gutierrez S, McTaggart RA, Torbey MT, Kim-Tenser M, Leslie-Mazwi T, Sarraj A, Kasner SE, Ansari SA, Yeatts SD, Hamilton S, Mlynash M, Heit JJ, Zaharchuk G, Kim S, Carrozzella J, Palesch YY, Demchuk AM, Bammer R, Lavori PW, Broderick JP, Lansberg MG; DEFUSE 3 Investigators. Thrombectomy for stroke at 6 to 16 hours with selection by perfusion imaging. *N Engl J Med*. 2018;378: 708–718.