Endovascular stroke therapy: a single-center retrospective review

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Object. Endovascular treatment of acute ischemic stroke delivers direct therapy at the site of an occluded cerebral artery and can be employed beyond the 3–4.5-hour window limit set for intravenous recombinant tissue plasminogen activator. In this paper, the authors report their experience with various endovascular therapies in acute ischemic stroke.

Methods. The authors conducted a retrospective review of their clinical database for acute ischemic stroke in large-vessel cerebral territories that underwent endovascular treatment between May 2005 and February 2009. Endovascular treatment was defined as pharmacological and/or mechanical intervention, angioplasty, stenting, or a combination of these methods. Admission National Institutes of Health Stroke Scale and the modified Rankin Scale scores were recorded. Thrombolysis in Myocardial Infarction (TIMI) scores of 0, 1, 2A, 2B, and 3 were used to define recanalization.

Results. Forty procedures were performed in 39 patients, with 1 patient having sequential bilateral strokes. Nine patients were lost to follow-up after discharge. Strokes in the carotid artery circulation occurred in 82.5% of cases, and those in the vertebral-basilar territory occurred in 17.5%. The Merci device was used in 22 (55%) of 40 procedures, and the Penumbra device in 9 (22.5%) of 40. Angioplasty was performed in 15 (37.5%) of 40 procedures, and intraarterial recombinant tissue plasminogen activator was administered in 23 (57.5%) of 40 procedures. In 23 (57.5%) of 40 cases, multiple recanalization methods were used. The recanalization rate for all methods was 60%. The recanalization rate from TIMI Score 0/1 occlusions was 71.4% (20 of 28). An estimated modified Rankin Scale score of ≤ 2 was obtained in 11 (36.7%) of 30 cases. The overall mortality rate was 26.7% (8 of 30). Intracerebral hemorrhage at 24 hours postprocedure was noted in 17 (42.5%) of 40 cases, 3 (7.5%) of which were symptomatic. The recanalization rate for all methods was 60%. The recanalization rate from TIMI Score 0/1 occlusions was 71.4% (20 of 28). An estimated modified Rankin Scale score of ≤ 2 was obtained in 11 (36.7%) of 30 cases. The overall mortality rate was 26.7% (8 of 30). Intracerebral hemorrhage at 24 hours postprocedure was noted in 17 (42.5%) of 40 cases, 3 (7.5%) of which were symptomatic.

Conclusions. The authors’ institution performs endovascular stroke treatment with a safety and efficacy profile comparable to those of other major endovascular stroke therapy studies. Recanalization was associated with an improved clinical outcome. Protocols to maximize efficient triage of patients and better documentation of stroke treatments can assist in further studies. (DOI: 10.3171/2011.3.FOCUS10267)

Key Words • stroke • endovascular • mechanical • ischemic • pharmacological • stenting

Previous studies have established the efficacy of intravenous rt-PA to reduce overall disability when administered within 3–4.5 hours of an acute ischemic stroke.8,12,22 Although rt-PA is the only FDA-approved medical therapy currently available for acute ischemic stroke, it is surprisingly underutilized. It is estimated that less than 2%–5% of patients receive this treatment in most countries, primarily due to delayed admission and the inherent “automatic” exclusion of several patient populations such as the postoperative patient.2,23 Furthermore, rt-PA has limited efficacy in achieving recanalization in proximal vessel occlusions.19

The endovascular management of acute ischemic stroke circumvents some of these shortfalls because this therapy has proven effective up to 6 hours after the stroke10 and has demonstrated improvement in recanalization rates.5,10,15,20,24,26,27 Currently a Class I B level of evidence indication is the use of intraarterial thrombolysis in selected patients with major stroke of 6-hour duration due to an occlusion of the middle cerebral artery.21
Current endovascular therapies include local pharmacological infusions (usually of a fibrinolytic such as rt-PA), ultrasound-augmented fibrinolysis, and mechanical manipulation by guide wire, snare, angioplasty balloon, stent, and dedicated clot retrieval systems such as the Merci or Penumbra device. The greatest risks of these therapies are vessel damage, thrombus migration, and possible delays in treatment due to a patient’s need for a specialized stroke center. In addition, the potential benefit of reperfusion decreases with delayed treatment, and there is a corresponding increase in the risk of symptomatic cerebral hemorrhage. Recent evidence suggests that carefully selected patients, chosen based on perfusion imaging, may receive the maximum benefit from intervention.

Northwestern Memorial Hospital, located in the center of Chicago, is a comprehensive stroke center that treated approximately 60 TIA and 242 ischemic strokes in 2008. The purpose of this study is 2-fold: 1) to assess Northwestern Memorial Hospital’s experience in this field as a formal institutional review and 2) to compare our data with major publications.

Methods

Computerized records were reviewed and analyzed for 39 consecutive patients treated between May 2005 and February 2009. All participants provided written and informed consent for release of their clinical data using an institutional review board–approved, Health Insurance Portability and Accountability Act–compliant protocol. Included cases involved strokes of all large-vessel territories that were treated acutely by endovascular methods. Excluded cases were those having central retinal artery occlusions, cerebral venous thrombosis, intracranial angioplasty, stenting done for subacute to chronic cerebral occlusions, cerebral venous thrombosis, intracranial aneurysm, any extracranial procedure that did not also include intracranial therapy, and coagulopathies or low platelets.

The data obtained from the medical records included demographic information, vascular risk factors, and medication use. Data also recorded included presenting NIHSS score, ischemic territory, endovascular method, interval between stroke onset and anesthesia prior to endovascular intervention, pre- and postoperative TIMI score, hospital discharge location, mRS score at most recent follow-up, and all-cause mortality.

Initial blood pressures on admission to NMH were recorded. Data were also collected from the neurology resident examination note in all cases as well as an emergency department nurse’s triage note, an emergency department paramedic examination note, or an intensive care unit vital sign flow sheet if available for review. However, NIHSS scores were recorded exclusively from the neurology resident notes. If an NIHSS score was not available or was not consistent with the concomitant reported examination, it was estimated using validated methods.

The TIMI score was obtained using a scale described by the IMS-II authors from an ad hoc scale (TIMI scores of 0/1, 2AB, and 3).15 Contrary to previous studies, we chose to report TIMI scores pertaining to the effect on cerebral perfusion as a whole rather than reporting a TIMI score specific to the occluded vessel. A TIMI score of 0/1 was reserved for stump occlusions of the ICA, M1, or basilar system. For example, an M1 superior branch occlusion would be reported as a TIMI score of 2A should the MCA territory be perfused by less than 50%. Improvement after intraarterial treatment to a TIMI score of 2B would be achieved if the MCA territory perfusion improved to greater than 50%. A TIMI score of 3 was reserved for revascularization that included perfusion to all M1 and M1 cortical vessels.

Using the TIMI 2AB classification system, the posterior circulation was scored in a novel way. For instance, a TIMI score of 2A referred to perfusion to the top of the basilar artery and at least one of the PCA branches, whereas a TIMI score of 2B indicated flow involving the basilar tip and both PCA branches. Recanalization was defined as an improvement in grade from TIMI 0/1 to at least a 2A or a TIMI 2A to at least a 2B. The mRS score was recorded as an estimate after reviewing the electronic records of outpatient follow-up visits or readmission notes.

Unless indicated, administration of antiplatelet and anticoagulant agents was prohibited for 24 hours postintervention. Medical management and acute poststroke care after the procedure were consistent with American Stroke Association guidelines. A CT scan was obtained 24 hours after the procedure to rule out the presence of ICH. An ICH was classified using definitions of hemorrhagic infarction Types 1 and 2 and parenchymal hematoma Types 1 and 2. Progress notes (clinical notes) were reviewed to determine whether ICH was symptomatic. If the notes did not clearly state the impact of ICH clinically, the ICH was assumed to be symptomatic.

Results

At NMH, a total of 40 endovascular procedures were performed in 39 patients for acute large-vessel ischemic stroke between May 2005 and February 2009. One patient suffered a recurrent stroke requiring endovascular intervention for both instances. Nine patients were lost to follow-up after being discharged from the hospital. Table 1 summarizes patient baseline characteristics. Table 2 includes information about the NIHSS scores, locations of vascular occlusions, revascularization rate, and clinical outcomes. The mean baseline NIHSS score was 16.7 (median 15, range 5–36) (Table 2). The estimated median interval from stroke onset to anesthesia prior to endovascular stroke therapy was 265.5 minutes. Overall, 82.5% of the strokes were confined to the anterior circulation. The majority were M1 and M1 occlusions (47.5%), whereas 25% of patients had ICA or carotid-T occlusions. Only 10% of the occlusions were localized to M2.

Endovascular therapies varied, and in most treatment cases more than one modality was applied. The Merci device was used in 22 (55%) of 40 procedures and the Penumbra device in 9 (22.5%) of 40. Angioplasty was performed...
Endovascular stroke therapy

TABLE 1: Summary of baseline characteristics*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Median Age (yrs)‡</th>
<th>Female (%)‡</th>
<th>Current Smoker (%)‡</th>
<th>Index BP (systolic/diastolic)‡</th>
<th>Prior Aspirin/Plavix (%)‡</th>
<th>Prior AC (%)‡</th>
<th>Median INR‡</th>
<th>Known A Fib (%)‡</th>
<th>Known DM (%)‡</th>
<th>Known HL (%)‡</th>
<th>TIA/CVA†</th>
<th>Cardiac Disease†</th>
<th>Renal Disease†</th>
<th>Past Malignancy†</th>
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<td></td>
<td>15.4</td>
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</table>

* A Fib = atrial fibrillation; AC = anticoagulation; BP = blood pressure; CVA = cerebrovascular accident; DM = diabetes mellitus; HL = hyperlipidemia; INR = International Normalized Ratio.
† Determined in 39 patients.
‡ Determined in 40 procedures.

in 15 (37.5%) of 40 procedures, and intraarterial rt-PA was administered in 23 procedures (57.5%). In 23 cases (57.5%), multiple recanalization methods were used. Three patients required stents (2 with a Neuroform and 1 with a Wingspan stent). Two stents were deployed intracranially, whereas the third was deployed at the carotid bifurcation.

The estimated mRS score was available in all surviving patients, except for 9 lost to follow-up; therefore, analysis was confined to 30 patients (Fig. 1 upper). In this group, the mean age was 64.8 years, and the mean and median NIHSS scores were 17.4 and 15.5, respectively. The follow-up period ranged from 1 to 37 months. Outcome in 11 (36.7%) of 30 patients was reflected by the mRS score 0–2. In 4 patients, lack of information in the outpatient records precluded an accurate rating of the mRS outcome, which presented a challenge in determining whether the mRS score rating was 2 or 3. For analysis’ sake, the mRS score was assumed to be 3. The overall mortality rate was 26.7% (8 of 30 patients). Five patients died during the initial stroke while being admitted, and 3 died after discharge from the hospital. Of these patients, 1 died of sepsis 2 months after discharge, another was placed in hospice 6 weeks later, and 1 was placed in hospice 2 years later.

To better compare our results to outcomes in major clinical trials, we performed subgroup analysis to compute 3-month outcomes (Fig. 1 lower). Of the 39 patients, 9 were lost to follow-up and because 6 were followed up for less than 3 months, their data were excluded from the analysis. For this remaining subgroup of 24, the mean age was 63.1 years, while the mean and median NIHSS scores were 18.45 and 17, respectively. Good outcome was achieved in 37.5% of patients (9 of 24), whereas the overall mortality rate was 29.1% (7 of 24 patients).

Hospital discharge locations were available for all 39 patients: 5 (12.8%) went home, 22 (56.4%) went to acute inpatient rehabilitation, 1 (2.6%) to long-term acute care, 1 (2.6%) to an in-network hospital, 5 (12.8%) to subacute nursing care, and 5 (12.8%) died while in the hospital.

TABLE 2: Summary of perioperative data*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Median NIHSS Score†</th>
<th>Circulation of the ICH</th>
<th>Segment/Artery of Occlusion</th>
<th>Revascularization Rate†</th>
<th>Index TIMI Score 0/1 Cases‡</th>
<th>Revascularization Rate in TIMI Score 0/1 Cases†</th>
<th>mRS Score ≤2§</th>
<th>Mortality Rate§</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Anterior†</td>
<td>Posterior†</td>
<td>ICA, Carotid†</td>
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<td></td>
<td></td>
<td>M1/M2†</td>
<td>M1†</td>
<td></td>
<td>60</td>
<td>70</td>
<td>71.4</td>
<td>36.7</td>
</tr>
<tr>
<td>% of pts</td>
<td>15</td>
<td>82.5</td>
<td>17.5</td>
<td>47.5</td>
<td>10</td>
<td>25</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* All values are presented as percentages except NIHSS scores. Abbreviations: pts = patients; SICH = symptomatic ICH.
† Determined in 40 patients.
‡ Determined in 28 patients.
§ Determined in 30 patients.
In 17 patients (42.5%), 24-hour CT scanning revealed ICH; 3 patients (7.5%) were symptomatic (Table 2). Of these 3 patients, 1 developed ICH and SAH after intra-venous rt-PA. In this patient, endovascular methods were palliative to decrease clot burden, and subsequently, the patient underwent surgical evacuation of the hematoma and died during the index hospitalization (Fig. 2A). The second patient suffered an intraprocedural perforation, underwent decompressive craniectomy, and was lost to follow-up (Fig. 2B). The third patient suffered a contralateral parenchymal hematoma Type 2 ICH after a skull base carotid stenting procedure was performed for acute stroke. Prior to the emergence of the ICH, postprocedure MR imaging revealed an interval development of a new infarction contralateral to the original stroke. This patient was also lost to follow-up (Fig. 2C).

Overall, 3 (7.5%) of 40 patients had definite procedure-related SAH. One had a concomitant ICH and was discussed in the previous paragraph. The other 2 patients had asymptomatic SAH. An mRS score of 4 was estimated in 1 patient at 2-month follow-up, and an mRS score of 0 was estimated in the other patient at 4-month follow-up.

**Discussion**

In our population overall, 36.7% of the patients had an outcome represented by an mRS score of ≤2 at various follow-up times; 37.5% of the patients had an outcome represented by an mRS score of ≤2 at the 3-month follow-up. These results exceed the outcomes of the Penumbra Phase 2 trial,7 (25.0%) and the MERCI Trial,27 but they are similar to those reported in the Multi MERCI trial (36.0%).26 Of note, our mRS ≤2 rate was less favorable than those of PROACT II (40.0%),10 MELT (Middle Cerebral Artery Embolism Local Fibrinolytic Intervention Trial [49.1%]),25 and IMS-II (46.0%),15 all of which disallowed direct mechanical means of thrombolysis.24 Patients with successful revascularization tended to have better outcomes, as measured by an mRS score ≤2, than those without revascularization. Outcome reflected by an mRS score of ≤2 was achieved in 47.4% of the patients with revascularization, which exceeded the outcome in the Penumbra trial (29%),7 and was comparable to rates in the MERCI (46.0%),27 Multi MERCI (49.1%),26 and IMS-II (45.6%)15 trials. The overall mortality rate in our study was 26.7%, and the 3-month mortality rate was 29.1%. On the one hand, this rate is consistent with that in the PROACT II Trial (25.0%) but is exceeded by the rates reported by MERCI/Multi MERCI (43.5% and 34.0%, respectively) and Penumbra (32.8%)25 investigators. On the other hand, the mortality rate was lower in the IMS-I/IMS-II14,15 (16.0%) and MELT studies (5.3%). The encouraging mortality rate seen in the latter trial may be attributed to a lower baseline NIHSS score of 14. Based on the location of the target vessels, the highest mortality rate in our cas-

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**TABLE 3: Outcome in patients with and without successful recanalization**

<table>
<thead>
<tr>
<th>Index TIMI Score &amp; Outcome</th>
<th>Percentage of Patients*</th>
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<tr>
<td></td>
<td>w/ Recanalization</td>
</tr>
<tr>
<td>all TIMI scores</td>
<td></td>
</tr>
<tr>
<td>mRS score ≤2</td>
<td>47.4</td>
</tr>
<tr>
<td>mortality rate</td>
<td>26.3</td>
</tr>
<tr>
<td>w/ TIMI scores 0/1</td>
<td></td>
</tr>
<tr>
<td>mRS score ≤2</td>
<td>43.7</td>
</tr>
<tr>
<td>mortality rate</td>
<td>25.0</td>
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</tbody>
</table>

* Four patients in the revascularized group and 1 patient in the nonrevascularized group were lost to follow-up.
A series was associated with the MCA (62.5% [5 of 8]) and the basilar artery (37.5% [3 of 8]). A literature review indicated expected mortality rates ranged from 27% to 78% for the MCA and nearly 90% in the basilar artery. Although our data set is limited, it is worth noting that the mortality rate for basilar artery occlusion was less than half (42.8% [3 of 7]) in our case series.

Seventeen patients (42.5%) were found to have ICH on 24-hour postoperative CT scans; 3 patients (7.5%) were symptomatic. This rate has been exceeded by all major endovascular trials to date except for the IMS-I (6.3%). The definition of symptomatic ICH varies across the stroke studies: NINDS (National Institute of Neurological Disorders and Stroke) defined symptomatic ICH as any neurological decline as a result of ICH, whereas the ECASS (European and Australian Cooperative Stroke Study) II, ECASS III, PROACT II, MERCI, Multi MERCI, and Penumbra trials defined it as a 4-point increase or higher on the NIHSS. In our study, the impact of ICH on clinical status was determined by review of the clinical notes.

Acute stent procedures were performed in 3 patients. Inclusion of these procedures makes our study unique in that previous studies excluded patients with arterial stenosis because it prevented safe passage of a microcatheter. Stenting was not designed to be performed in MERCI, Multi MERCI, or Penumbra trials. A case example of a supraclinoid dissection treated with stent placement is shown in Fig. 3. Additionally, unlike other intraarterial trials, we included patients with tandem stenosis as long as the extracranial carotid artery was successfully revascularized, which occurred in 10 (25%) of the 40 procedures. Thus, our patients had a mixture of cardioembolic and atherosclerotic occlusions for the treatment of tandem stenosis and an artery-to-artery embolus.

As mentioned earlier, our methods also differ by the definition we used for TIMI revascularization. To our knowledge, all major prior endovascular trials commented on TIMI scores in reference to effect on target vessel treated. In PROACT II, the investigators defined successful recanalization as TIMI Score 2 flow in at least one of the M segments when treating a more proximal target. Our series included 4 patients with M occlusions. Such patients were excluded from comparable studies. At baseline, these patients had a TIMI score of 2B, and revascularization was not achieved. Excluding those patients from analysis reduces the percentage of nonrevascularized cases with good outcome (mRS score ≤2) to 11.1%, which likely reflects the generally better outcomes in patients with occlusions relative to proximal occlusions.

Our institution is capable of undertaking diffusion/perfusion imaging; however, quantifiable measurement of mismatch is pending. As noted in the DEFUSE (Diffusion and Perfusion Imaging Evaluation for Understanding Stroke Evolution) study and subsequent analysis, perfusion-weighted imaging can greatly help in selecting the most appropriate patients for intervention. In our series, perfusion-weighted imaging was used in 25 (62.5%) of 40 cases, and we determined that there was a mismatch in 17 (68%) of these 25 patients. Unfortunately, a large proportion of our patients lost to follow-up were in this category, precluding any meaningful analysis.
The other 15 patients, who did not undergo perfusion imaging, were selected for endovascular therapy based on several factors and findings including elapsed intravenous treatment window, clinical decision making, noninvasive angiography, flow void interpretation from MR imaging, or dense artery signs on head CT scanning. There was only one use of combined intravenous plasminogen activator therapy with intraarterial therapy, and this clinical outcome is described in Fig. 2A.

This study is limited by its retrospective nature and by the fact that it is a single-center study. Another limitation in our review is estimation of mRS score from follow-up clinic or readmission notes. To our knowledge, there are no standardized or validated methods for obtaining such mRS scores. To minimize our overestimation of outcome, the 4 patients to whom an mRS score between 2 or 3 could not be reliably assigned due to ambiguous documentation were assumed to be in the higher grade. This approach to assigning values resulted in an overall mRS < 2 rate of 36.7%. Finally, our endovascular therapies varied, and in most treatment cases different endovascular modalities or devices were applied. While our approach resembles most practices at stroke centers, it is not easily comparable to prior studies, in which one treatment modality was used at a time.

Conclusions

Our center is performing endovascular stroke therapy with a safety and efficacy profile that is consistent with other major endovascular studies. To successfully continue with future analysis, we have established a registry of endovascular cases with standardized medical history forms, follow-up scales, and standardized follow-up.

Disclosure

Dr. Bernstein reports a financial relationship with Boehringer Ingelheim.

Author contributions to the study and manuscript preparation include the following: Conception and design: Bendok, Day, Hurley, Alberts, Bernstein, Dabus, Shaibani. Acquisition of data: Bendok, Day, Hurley, Dabus, Shaibani. Analysis and interpretation of data: Bendok, Day, Hurley, Alberts, Bernstein, Dabus, Shaibani. Drafting the article: Bendok, Day, Chmayaissi, Rahme. Critically revising the article: Bendok, Chmayaissi. Reviewed final version of the manuscript and approved it for submission: all authors. Statistical analysis: Day, Hurley. Study supervision: Bendok, Day, Alberts.

References


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