Stent-Retriever Thrombectomy after Intravenous t-PA vs. t-PA Alone in Stroke


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*A complete list of investigators in the Solitaire with the Intention for Thrombectomy as Primary Endovascular Treatment (SWIFT PRIME) trial is provided in the Supplementary Appendix, available at NEJM.org.

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ABSTRACT

BACKGROUND

Among patients with acute ischemic stroke due to occlusions in the proximal anterior intracranial circulation, less than 40% regain functional independence when treated with intravenous tissue plasminogen activator (t-PA) alone. Thrombectomy with the use of a stent retriever, in addition to intravenous t-PA, increases reperfusion rates and may improve long-term functional outcome.

METHODS

We randomly assigned eligible patients with stroke who were receiving or had received intravenous t-PA to continue with t-PA alone (control group) or to undergo endovascular thrombectomy with the use of a stent retriever within 6 hours after symptom onset (intervention group). Patients had confirmed occlusions in the proximal anterior intracranial circulation and an absence of large ischemic-core lesions. The primary outcome was the severity of global disability at 90 days, as assessed by means of the modified Rankin scale (with scores ranging from 0 [no symptoms] to 6 [death]).

RESULTS

The study was stopped early because of efficacy. At 39 centers, 196 patients underwent randomization (98 patients in each group). In the intervention group, the median time from qualifying imaging to groin puncture was 57 minutes, and the rate of substantial reperfusion at the end of the procedure was 88%. Thrombectomy with the stent retriever plus intravenous t-PA reduced disability at 90 days over the entire range of scores on the modified Rankin scale (P<0.001). The rate of functional independence (modified Rankin scale score, 0 to 2) was higher in the intervention group than in the control group (60% vs. 35%, P<0.001). There were no significant between-group differences in 90-day mortality (9% vs. 12%, P=0.50) or symptomatic intracranial hemorrhage (0% vs. 3%, P=0.12).

CONCLUSIONS

In patients receiving intravenous t-PA for acute ischemic stroke due to occlusions in the proximal anterior intracranial circulation, thrombectomy with a stent retriever within 6 hours after onset improved functional outcomes at 90 days. (Funded by Covidien; SWIFT PRIME ClinicalTrials.gov number, NCT01657461.)
I
NTRAVENOUS TISSUE PLASMINOGEN ACTI-
vator (t-PA) administered within 4.5 hours
after the onset of acute ischemic stroke im-
proves outcomes.1-3 However, intravenous t-PA
has multiple constraints, including unresponsiveness
of large thrombi to rapid enzymatic digestion, a
narrow time window for administration, and the
risk of cerebral and systemic hemorrhage. Among
patients with occlusions of the intracranial internal
carotid artery or the first segment of the
middle cerebral artery (or both), intravenous t-PA
alone. Three initial trials of endovascular ther-
pies did not show a benefit for thrombectomy
over intravenous t-PA or supportive medical care,
but they were limited by the use of intraarterial
delivery of t-PA or the use of early-generation de-
vices with modest reperfusion efficacy (or both),
the failure of two trials to use vessel imaging to
confirm the presence of an appropriate target oc-
clusion, and the slow initiation of endovascular
intervention.8-10

The Solitaire revascularization device (Covidien)
is a self-expanding stent used to retrieve thrombi
and restore blood flow. In multicenter registries
and one randomized trial, this stent retriever,
as compared with early-generation mechanical
thrombectomy devices, was associated with faster
and more frequent reperfusion, reduced intracra-
nal hemorrhage, and improved disability
outcome.11-15

We performed the Solitaire with the Intention
for Thrombectomy as Primary Endovascular Treat-
ment (SWIFT PRIME) trial to establish the effi-
cacy and safety of rapid neurovascular throm-
bectomy with the stent retriever in conjunction
with intravenous t-PA versus intravenous t-PA alone
in patients with acute ischemic stroke. This trial
was among several contemporaneous trials
launched worldwide to test new-generation stra-
gies for mechanical thrombectomy.16-18 Our
trial was conducted in multiple countries and
health systems as a registration trial capable of
supporting expansion of regulatory labeling. We
used a uniform device procedure in the interven-
tion group and tested intracranial neurovascular
thrombectomy alone rather than in combination
with cervical stenting.

METHODS

TRIAL DESIGN
In this international, multicenter, prospective,
randomized, open clinical trial, we compared in-
travenous t-PA followed by neurovascular throm-
bectomy with the use of a stent retriever with
intravenous t-PA alone in patients with acute is-
chemic stroke. All the patients had confirmed oc-
closure of the intracranial internal carotid artery,
the first segment of the middle cerebral artery, or
both on vessel imaging and an absence of large
ischemic-core lesions. Patients were randomly
assigned in a 1:1 ratio to one of two treatment
groups: intravenous t-PA plus stent retriever (in-
tervention group) or intravenous t-PA alone (con-
trol group). Using a minimization algorithm,
we balanced the numbers of patients in the two
treatment groups with respect to four factors:
investigational site, baseline severity according
to the National Institutes of Health Stroke Scale
(NIHSS) score (<17 vs. >17, on a scale of 0 to 42,
with higher scores indicating greater severity), age
(<70 years vs. ≥70 years), and occlusion location
(middle cerebral artery vs. internal carotid artery).

Details of the study design have been pub-
lished previously.19 The study was conducted and
reported with fidelity to the study protocol, avail-
able with the full text of this article at NEJM.org.
(An overview of the study procedure is provided
in Fig. S1 in the Supplementary Appendix, avail-
able at NEJM.org.)

The trial was approved by the institutional
review board at each site. Enrolled patients pro-
vided written informed consent, or at select sites,
there was an exception from explicit informed
consent in emergency circumstances.

The trial was funded by Covidien and designed
and led by a steering committee that included
academic investigators and representatives of the
sponsor. The site investigators gathered the data,
with monitoring and database maintenance per-
formed by the sponsor. The first and subsequent
drafts of the manuscript were written by the
first and second authors, incorporating input
from all the authors. The academic authors had
unrestricted access to the data, performed the
data analysis with the primary and the independ-
ent study statisticians, and attest to the integ-
ity of the trial and the completeness and accu-
racy of the reported data. The trial was monitored
by an independent data and safety monitoring
board.
PATIENTS AND PARTICIPATING CENTERS

The study was performed at 39 centers in the United States and Europe. All study centers were required to have performed at least 40 mechanical-thrombectomy procedures, including at least 20 procedures with the Solitaire stent retriever, annually. Entry criteria selected patients who had acute ischemic stroke with moderate-to-severe neurologic deficits; had imaging-confirmed occlusion of the intracranial internal carotid artery, the first segment of the middle cerebral artery, or both; met the imaging eligibility requirements; were receiving or had received intravenous t-PA; and were able to undergo initiation of endovascular treatment within 6 hours after the time that they were last known to be well before the onset of acute stroke symptoms. Qualifying imaging had to be performed at a study hospital; imaging was repeated for patients who were transferred from outside hospitals. Detailed study inclusion and exclusion criteria are provided in Table S1 in the Supplementary Appendix.

To identify patients with salvageable tissue, at trial launch the entry criteria regarding imaging selection required patients to have a target-mismatch penumbral profile, with a small core of tissue that was likely to be irreversibly injured and a large region of hypoperfused tissue that was likely to be salvageable. Penumbral imaging analysis was performed with the use of RAPID (iSchemaView), an operator-independent image-processing system. After the enrollment of the first 71 patients, these criteria were revised to use a small-to-moderate core-infarct strategy (Table S1 in the Supplementary Appendix) to accommodate study sites with limited perfusion-imaging capability and to ensure accelerated treatment delivery. Study sites with advanced imaging capability were still encouraged to obtain penumbral imaging and to exclude patients who did not meet the target-mismatch profile.

INTERVENTION

In the intervention group, neurovascular thrombectomy was performed with the use of the Solitaire FR (Flow Restoration) or Solitaire 2 device. Concomitant stenting of the cervical internal carotid artery was not permitted, although angioplasty could be performed to permit intracranial access.

A studywide continuous quality-improvement program emphasized the speed and quality of the neurointerventional workflow, including rapid patient transfer to the neuroangiography suite and procedure performance. The study target for the time from qualifying imaging to groin puncture was within 70 minutes.

OUTCOME MEASURES

The primary study-outcome measure was disability at 90 days, as assessed by means of the modified Rankin scale, a global measure of disability on a seven-level scale, with scores ranging from 0 (no symptoms) to 6 (death) (Fig. 1). (Details on the use of this scale are provided in the Supplementary Appendix.)

Secondary clinical efficacy outcomes were the rate of death at 90 days, the rate of functional independence (modified Rankin scale score, ≤2) at 90 days, and the change in the NIHSS score at 27 hours after randomization. The technical efficacy outcomes regarding revascularization were substantial reperfusion, as assessed by means of catheter angiography in the intervention group and defined as a modified Thrombolysis in Ce-
rebral Infarction score of 2b (50 to 99% reperfu-
sion) or 3 (complete reperfusion)\textsuperscript{21}; and successful
reperfusion at 27 hours in the two study groups, which
was defined as reperfusion of 90% or
more of the initial perfusion-lesion volume, as
assessed by means of perfusion imaging (com-
puted tomography [CT] or magnetic resonance
imaging [MRI]) at 27 hours after randomiza-
tion. Prespecified safety outcomes were all seri-
uous adverse events through study completion and
symptomatic intracranial hemorrhage at 27 hours
after randomization.

**CLINICAL AND RADIOLOGIC ASSESSMENT**

Clinical assessments were performed at baseline,
27 hours after randomization, 7 to 10 days (or at
discharge if earlier), 30 days, and 90 days. Clinical
evaluations included the score on the modi-
fied Rankin scale for assessing global disability
and the NIHSS score for assessing neurologic
deficit. Entry and outcome neurovascular images
were assessed in a blinded manner by staff at the
core imaging laboratories (iSchemaView for pen-
umbral and volumetric imaging and Synarc for
parenchymal and angiographic imaging).

<p>| Table 1. Demographic and Clinical Characteristics of the Patients.\textsuperscript{a} |
|----------------|----------------|----------------|
| <strong>Characteristic</strong> | <strong>Intravenous t-PA Alone (N = 98)</strong> | <strong>Stent Retriever plus Intravenous t-PA (N = 98)</strong> |
| <strong>Age — yr</strong> | 66.3±11.3 | 65.0±12.5 |
| <strong>Male sex — no./total no. (%)</strong> | 45/96 (47) | 54/98 (55) |
| <strong>Race — no./total no. (%)†</strong> | | |
| White | 83/92 (90) | 79/90 (88) |
| Black | 8/92 (9) | 10/90 (11) |
| Asian or other | 1/92 (1) | 1/90 (1) |
| <strong>Hispanic ethnic group — no. (%)†</strong> | 7/92 (8) | 8/90 (9) |
| <strong>NIHSS score‡</strong> | | |
| Median | 17 | 17 |
| Interquartile range | 13–19 | 13–20 |
| <strong>Prestroke score of 0 or 1 on modified Rankin scale — no./total no. (%)§</strong> | 93/94 (99) | 96/98 (98) |
| <strong>Medical history — no./total no. (%)</strong> | | |
| Hypertension | 56/97 (58) | 66/98 (67) |
| Diabetes mellitus | 15/97 (15) | 12/98 (12) |
| Current or past tobacco use | 39/93 (42) | 41/96 (43) |
| Atrial fibrillation | 38/97 (39) | 35/98 (36) |
| Myocardial infarction | 11/97 (11) | 8/98 (8) |
| Serum glucose — mg/dl¶ | 131±47 | 131±46 |
| <strong>Administration of intravenous t-PA at outside hospital — no./total no. (%)</strong> | 35/94 (37) | 31/98 (32) |
| <strong>Interval from symptom onset to start of intravenous t-PA — min</strong> | | |
| Median | 117 | 110.5 |
| Interquartile range | 80–155 | 85–156 |
| <strong>Parenchymal imaging variable</strong> | | |
| <strong>ASPECTS value∥</strong> | 9 | 9 |
| <strong>Interquartile range</strong> | 8–10 | 7–10 |
| <strong>Penumbra imaging performed — no./total no. (%)</strong> | 75/97 (77) | 83/98 (85) |
| <strong>Target-mismatch profile — no./total no. (%)</strong>\textsuperscript{**} | 64/75 (85) | 69/83 (83) |</p>
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Intravenous t-PA Alone (N=98)</th>
<th>Stent Retriever plus Intravenous t-PA (N=98)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site of intracranial-artery occlusion — no./total no. (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal carotid artery</td>
<td>15/94 (16)</td>
<td>17/93 (18)</td>
</tr>
<tr>
<td>Middle cerebral artery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>First segment††</td>
<td>72/94 (77)</td>
<td>62/93 (67)</td>
</tr>
<tr>
<td>Second segment††</td>
<td>6/94 (6)</td>
<td>13/93 (14)</td>
</tr>
<tr>
<td>Process time — min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stroke onset to randomization</td>
<td>188</td>
<td>190.5</td>
</tr>
<tr>
<td>Interquartile range</td>
<td>130–268</td>
<td>141–249</td>
</tr>
<tr>
<td>Stroke onset to groin puncture</td>
<td>NA</td>
<td>224</td>
</tr>
<tr>
<td>Interquartile range</td>
<td>NA</td>
<td>165–275</td>
</tr>
<tr>
<td>Stroke onset to first deployment of stent retriever</td>
<td>NA</td>
<td>252</td>
</tr>
<tr>
<td>Interquartile range</td>
<td>NA</td>
<td>190–300</td>
</tr>
<tr>
<td>Arrival in emergency department to groin puncture</td>
<td>NA</td>
<td>90</td>
</tr>
<tr>
<td>Interquartile range</td>
<td>NA</td>
<td>69–120</td>
</tr>
<tr>
<td>Qualifying image to groin puncture</td>
<td>NA</td>
<td>57</td>
</tr>
<tr>
<td>Interquartile range</td>
<td>NA</td>
<td>40–80</td>
</tr>
</tbody>
</table>

* Plus–minus values are means ±SD. There were no significant differences between the two groups. One patient in the group that received intravenous tissue plasminogen activator (t-PA) alone requested the deletion of all data. Three additional patients in the group that received intravenous t-PA alone (1 patient who died and 2 who withdrew) are missing some baseline data owing to early study exit, including data on the prestroke modified Rankin Scale score, the hospital site of intravenous t-PA administration, and site of intracranial-artery occlusion for all 3 patients, and data on sex, race, and ethnic group for 1. Data on race and ethnic group were missing for all 13 patients in France owing to national regulations. Data regarding the location of the arterial occlusion were missing for 7 patients because the core laboratory considered that imaging could not be assessed with complete reliability. Two patients were deemed by the core laboratory to not have occlusions in the internal carotid artery or the first or second segment of the middle cerebral artery. A total of 37 patients did not have baseline penumbral imaging performed, after a protocol amendment making penumbral imaging optional. Data regarding additional baseline characteristics are shown in Table S4 in the Supplementary Appendix. NA denotes not applicable.

† Race and ethnic group were self-reported.
‡ Scores on the National Institutes of Health Stroke Scale (NIHSS) range from 0 to 42, with higher scores indicating more severe neurologic deficit.
§ Scores on the modified Rankin scale for the assessment of global disability range from 0 (no symptoms) to 6 (death).
¶ To convert the values for glucose to millimoles per liter, multiply by 0.05551.
∥ The Alberta Stroke Program Early CT Score (ASPECTS) ranges from 0 to 10, with higher scores indicating a smaller infarct core.
** The target-mismatch profile was defined as meeting the following criteria as assessed on CT perfusion or diffusion imaging and perfusion MRI: the core infarct lesion measured 50 ml or less, the volume of tissue with a time to maximum delay of more than 10 seconds was 100 ml or less, and the mismatch volume was at least 15 ml and the mismatch ratio was more than 1.8:1.0.
†† These occlusions were classified as first-segment occlusions by the treating site at the time of study entry but as second-segment occlusions by the core imaging laboratory.
STATISTICAL ANALYSIS

For the primary outcome, we analyzed the score on the modified Rankin scale at 90 days using simultaneous success criteria of the overall distribution of the score (shift in disability levels) and the proportion of patients who were functionally independent. Both criteria needed to be met in order for the study to be declared positive. The statistical hypothesis on the scale shift was that the distribution over the entire range of scores (except for scores of 5 or 6, which were collapsed into a single group) among patients in the intervention group would be more favorable than the distribution in the control group, as analyzed by means of the Cochran–Mantel–Haenszel test.

A simultaneous requirement for success was that the difference in the proportion of patients with a score of 0 to 2 nominally meet a prespecified minimum, which varied according to the final sample size at trial discontinuation or completion, with a larger benefit required with a smaller sample size (Table S2 in the Supplementary Appendix). Missing final scores on the modified Rankin scale were handled with the use of the last-observation-carried-forward approach when a score was available from the 30-day visit or the visit at 7 to 10 days. Power and sample size were determined with the use of the sequential-analysis plan with five interim analyses for efficacy, futility, and safety. (Details are provided in Table S2 in the Supplementary Appendix and in the full statistical analysis plan in the protocol.)

After the preliminary results of the Multicenter Randomized Clinical Trial of Endovascular Treatment for Acute Ischemic Stroke in the Netherlands (MR CLEAN) and the Endovascular Treatment for Small Core and Anterior Circulation Proximal Occlusion with Emphasis on Minimizing CT to Recanalization Times (ESCAPE) trial were reported,16,18 our data and safety monitoring board recommended holding enrollment, and the first interim efficacy analysis was performed slightly early (including 196 rather than 200 patients). In February 2015, the study was halted when the interim efficacy analysis showed that the prespecified stopping-criteria boundary for efficacy had been crossed. A test to determine whether the data across clinical sites could be pooled showed no evidence of heterogeneity of treatment effect (P=0.73 by the Breslow–Day test), so pooled study results are presented. All P values are two-sided.

RESULTS

CHARACTERISTICS OF THE PATIENTS

From December 2012 through November 2014, 196 patients underwent randomization (98 in each group) at 39 centers in the United States and Europe. Reasons for exclusion are listed in Table S3 in the Supplementary Appendix.

The demographic and clinical characteristics of the two treatment groups at baseline were well balanced (Table 1, and Table S4 in the Supplementary Appendix). Figure S2 in the Supplementary Appendix shows the enrollment and follow-up of patients in the trial.

INTERVENTION

In the intervention group, the time from symptom onset to groin puncture was 224 minutes (interquartile range, 165 to 275), the time from the start of intravenous t-PA to groin puncture was 77 minutes (interquartile range, 50 to 142), and the time from study-qualifying brain imaging to groin puncture was 57 minutes (interquartile range, 40 to 80). In the intervention group, the stent retriever was deployed in 87 patients (89%); the reasons for nondeployment are listed in Table S5 in the Supplementary Appendix. Among these 87 patients, the median time from groin puncture to first deployment of the stent retriever was 24 minutes (interquartile range, 18 to 33). General anesthesia was used in 36 patients (37%) in the intervention group.

PRIMARY OUTCOME

Treatment with thrombectomy with the use of the stent retriever met both of the simultaneous success criteria. Thrombectomy treatment was associated with a favorable shift in the distribution of global disability scores on the modified Rankin scale at 90 days (P<0.001 by the Cochran–Mantel–Haenszel test, which was lower than the P value of 0.01 that was specified for early stopping; number needed to treat for one additional patient to have a less-disabled outcome, 2.6). The shift toward better outcomes was consistent in direction across all the score levels of the modified Rankin scale (Fig. 1). The proportion of patients who were functionally independent (modified Rankin scale score, ≤2) at 90 days was
higher in the intervention group than in the control group, with an absolute difference of 25 percentage points, which exceeded the 12-percentage-point boundary that was prespecified for early stopping. Results remained significant in sensitivity analyses that used multiple imputation and worst-case and best-case scenarios to account for missing data (Table S6 in the Supplementary Appendix) and in analyses that were adjusted for imbalances in baseline prognostic features (Table S7 and Fig. S3 in the Supplementary Appendix).

**SECONDARY OUTCOMES**

Prespecified secondary clinical efficacy outcomes and technical efficacy outcomes regarding revascularization are shown in Table 2; additional prespecified and post hoc outcomes are shown in Tables S10 and S13 in the Supplementary Appendix. The proportion of outcomes indicating functional independence at 90 days was significantly higher in the intervention group than in the control group, with an absolute difference of 25 percentage points (95% confidence interval [CI], 11 to 38) and a risk ratio of 1.70 (95% CI, 1.23 to 2.33; P<0.001; number needed to treat for one additional patient to be functionally independent, 4.0). Mortality at 90 days did not differ significantly between the intervention group and the control group (9% and 12%, respectively; P=0.50).

In the intervention group, substantial reperfusion (50 to 99%) or complete reperfusion (100%) at the end of the procedure occurred in 73 of the 83 patients (88%) who underwent placement of the stent retriever (Table S9 in the Supplementary Appendix). A total of 4 additional patients who

### Table 2. Primary and Secondary Outcomes.*

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Intravenous t-PA Alone (N=98)</th>
<th>Stent Retriever plus Intravenous t-PA (N=98)</th>
<th>Risk Ratio (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary outcome: score on modified Rankin scale at 90 days†</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>No. of patients with data</td>
<td>93</td>
<td>98</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median score</td>
<td>3</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interquartile range</td>
<td>2–5</td>
<td>1–4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary outcomes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clinical efficacy outcome</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Functional independence at 90 days — no./total no. (%)‡</td>
<td>33/93 (35)</td>
<td>59/98 (60)</td>
<td>1.70 (1.23–2.33)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Change in NIHSS score at 27 hr</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of patients with data</td>
<td>92</td>
<td>97</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean change</td>
<td>-3.9±6.2</td>
<td>-8.5±7.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Death at 90 days — no./total no. (%)§</td>
<td>12/97 (12)</td>
<td>9/98 (9)</td>
<td>0.74 (0.33–1.68)</td>
<td>0.50</td>
</tr>
<tr>
<td>Revascularization outcome¶</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Substantial reperfusion immediately after thrombectomy — no./total no. (%)</td>
<td>NA</td>
<td>73/83 (88)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Successful reperfusion at 27 hr — no./total no. (%)</td>
<td>21/52 (40)</td>
<td>53/64 (83)</td>
<td>2.05 (1.45–2.91)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

* Plus–minus values are means ±SD. CI denotes confidence interval, and NA not applicable.
† Shown are the results of the prespecified Cochran–Mantel–Haenszel test for the shift in disability score. Similar results were found in the analysis of the common odds ratio (odds ratio, 2.63; 95% CI, 1.57 to 4.40; P<0.001).
‡ Functional independence was defined as a score of 0, 1, or 2 on the modified Rankin scale.
§ One patient in the group that received intravenous t-PA alone requested the deletion of all data, including vital status.
¶ Substantial reperfusion was defined as reperfusion of at least 50% and a modified Thrombolysis in Cerebral Infarction score of 2b (50 to 99% reperfusion) or 3 (complete reperfusion). Successful reperfusion was defined as reperfusion of at least 90%, as assessed with the use of perfusion CT or MRI. Data on successful reperfusion were not obtained for all the patients after the adoption of the protocol amendment making penumbral imaging optional.
underwent the intervention did not have a final angiogram that could be assessed. Successful reperfusion (≥90%) at 27 hours, assessed by means of perfusion CT or MRI, was more frequent in the intervention group than in the control group (53 of 64 patients [83%] vs. 21 of 52 [40%), P<0.001).

SAFETY
The rates of serious adverse events (36% in the intervention group and 31% in the control group, P=0.54) and symptomatic intracranial hemorrhage (0% and 3%, respectively; P=0.12) did not differ significantly between the treatment groups (Table 3, and Table S11 in the Supplementary Appendix). There was no significant between-group difference in the rate of all intracranial hemorrhage subtypes that were assessed radiologically, but there were numerically more subarachnoid hemorrhages in the intervention group than in the control group (four patients and one patient, respectively; P=0.37). No serious adverse events and seven nonserious adverse events were adjudicated to be device-related (Table S12 in the Supplementary Appendix).

SUBGROUP ANALYSES
Within the constraints of the study sample size, no evidence of heterogeneity of treatment effect was detected in any of the eight prespecified subgroups (Fig. 2, and Fig. S4 in the Supplementary Appendix). The benefit of thrombectomy with the stent retriever plus intravenous t-PA over intravenous t-PA alone was also observed in the prespecified subgroup of patients who received intravenous t-PA within 3 hours after symptom onset (P<0.001) (Table S8 in the Supplementary Appendix).

DISCUSSION
Our study showed that in patients with acute ischemic stroke with confirmed large-vessel occlusions of the anterior circulation who were treated with intravenous t-PA, treatment with the stent retriever within 6 hours after symptom onset improved functional outcomes at 90 days. For every 2.6 patients who were treated, 1 additional patient had an improved disability outcome; for every 4.0 patients who were treated, 1 additional patient was functionally independent at 90-day follow-up.

These findings confirm and extend those of recent trials.16–18 Our trial emphasized speedy endovascular therapy in patients selected by means of imaging, similar to the protocol used in the ESCAPE trial,18 and achieved onset-to-reperfusion

<table>
<thead>
<tr>
<th>Table 3. Safety Outcomes.*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outcome</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Primary safety outcomes</td>
</tr>
<tr>
<td>Any serious adverse event at 90 days†</td>
</tr>
<tr>
<td>Symptomatic intracranial hemorrhage at 27 hr</td>
</tr>
<tr>
<td>Additional safety outcomes at 27 hr</td>
</tr>
<tr>
<td>Parenchymal hematoma</td>
</tr>
<tr>
<td>Type 1</td>
</tr>
<tr>
<td>Type 2</td>
</tr>
<tr>
<td>Subarachnoid hemorrhage</td>
</tr>
</tbody>
</table>

* NA denotes not applicable.
† A serious adverse event was an adverse event that led to death, a life-threatening illness or injury, permanent impairment of a body structure or a body function, inpatient or prolonged hospitalization, medical or surgical intervention to prevent permanent life-threatening illness or injury or permanent impairment to a body structure or a body function, or fetal distress, fetal death or a congenital anomaly or birth defect. Serious adverse events that are classified according to organ system are shown in Table S11 in the Supplementary Appendix. None of the serious adverse events were adjudicated by the clinical-events committee to be device-related. Nonserious adverse events that were deemed to be device-related are shown in Table S12 in the Supplementary Appendix.
times that were faster than those in MR CLEAN and in studies of early-generation interventions. The median time from arrival in the emergency department to groin puncture of 90 minutes was faster than the 120-minute target that is recommended in current multisociety guidelines. In our trial, study sites were provided with a prespecified efficiency target of performing groin puncture within 70 minutes after qualifying imaging, and continuous central review encouraged rapid workflow. For patients with intravenous t-PA that was initiated at study centers, groin puncture and stent-retriever deployment could take place while t-PA was infusing.

Several aspects of the treatment and treatment response were distinctive in our study. The rate of substantial or complete reperfusion (88%) among patients undergoing intracranial intervention was higher in this trial than in previous trials. The high reperfusion rate is probably due in part to the more homogeneous patient population (more occlusions in the first segment of the middle cerebral artery and fewer intracranial or cervical occlusions of the internal carotid artery) and the more homogeneous intervention (an ef-
fective stent retriever and no other device classes and no intraarterial fibrinolytic agent) in this trial than in earlier trials. The frequency of functional independence in the intervention group was high in our trial (60%) and was greater than that observed in MR CLEAN (33%) and similar to that observed in the ESCAPE trial (53%) and the Extending the Time for Thrombolysis in Emergency Neurological Deficits — Intra-Arterial (EXTEND IA) trial (71%).17 The high frequency of this outcome probably reflects the earlier start of the intervention,23-26 the exclusion of patients with large core infarcts on the basis of imaging,27,28 and the greater reperfusion rate in our trial, as compared with the other trials.

No significant differences in treatment effect were detected across all the prespecified subgroups, including such factors as age, sex, degree of neurologic deficit, site of occlusion, and size of infarct core on qualifying imaging, although the moderate sample size limited the power of this analysis. We also performed a prespecified analysis comparing patients who received intravenous t-PA at an outside hospital and were transferred to a study center for thrombectomy with those who received both the intravenous t-PA and the endovascular intervention at the study center. One third of the patients were treated with intravenous t-PA at an outside hospital. These patients had less favorable outcomes overall; however, their relative benefit from endovascular therapy did not differ significantly from that observed in patients who received intravenous t-PA at the study site (Fig. 2, and Fig. S4 in the Supplementary Appendix).

The rates of serious adverse events did not differ significantly between the study groups overall or within major organ categories, and no device-specific serious adverse events were observed. The most common nonserious device-specific adverse event was transient, intraprocedural vasospasm without clinical sequelae. Rates of symp-

tomatic hemorrhage were low and did not differ significantly between the two treatment groups. Subarachnoid hemorrhage and intracerebral hematomas as assessed radiologically were also uncommon.

Our study has several limitations. First, we studied a homogeneous cohort of patients treated with intravenous t-PA; additional trials are needed to delineate the effects of stent-retriever therapy in other populations of patients with acute ischemic stroke, including those who are ineligible for intravenous t-PA, those who present more than 6 hours after symptom onset (including those who awaken after having had a stroke), and those with occlusions in the second segment of the middle cerebral artery or the posterior circulation. Second, study conduct included a continuous quality-improvement program to improve endovascular workflow efficiency at the participating sites. Implementation of similar quality-improvement programs in routine care settings,29 as has been done on a broad scale for intravenous t-PA,30 would be required to ensure similar stent-retriever outcomes in regular practice. Finally, all the enrolling sites were tertiary care centers with established stroke-intervention programs staffed by experienced neurointerventionists. These results may not be generalizable to clinical sites without requisite neurointerventional expertise.

In conclusion, we found that in patients with acute ischemic stroke due to large-vessel occlusion who had small or moderate ischemic cores, emergency neurovascular thrombectomy with the stent retriever was safe and effective in achieving reperfusion and substantially reduced the degree of disability and increased the proportion of patients with functional independence 3 months after stroke.

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Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

APPENDIX

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