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AJNR Am J Neuroradiol 2014, 35 (3) 524-528
doi: https://doi.org/10.3174/ajnr.A3707
http://www.ajnr.org/content/35/3/524

Complications of Endovascular Treatment for Acute Stroke in the SWIFT Trial with Solitaire and Merci Devices

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ABSTRACT

BACKGROUND AND PURPOSE: Treatment of patients with ischemic stroke after endovascular treatment requires in-depth knowledge of complications. The goal of this study was to make endovascular treatment for acute ischemic stroke safer through an in-depth review of the major periprocedural complications observed in the Solitaire FR With Intention for Thrombectomy (SWIFT) trial.

MATERIALS AND METHODS: The SWIFT data base was searched for major peri-procedural complications defined as symptomatic intracranial hemorrhage within 36 hours, SAH, air emboli, vessel dissection, major groin complications, and emboli to new vascular territories.

RESULTS: Major peri-procedural complications occurred in 18 of 144 patients (12.5%) as follows: symptomatic intracranial hemorrhage, 4.9%; air emboli, 1.4%; vessel dissection, 4.2%; major groin complications, 2.8%; and emboli to new vascular territories, 0.7%. Rates of symptomatic intracranial bleeding by subtype were PH1, 0.7%; PH2, 0.7% (PH1 indicates hematoma within ischemic field with some mild space-occupying effect but involving ≤30% of the infarcted area; PH2, hematoma within ischemic field with space-occupying effect involving >30% of the infarcted area); intracranial hemorrhage remote from ischemic zone, 0%; intraventricular hemorrhage, 0.7%; and SAH, 3.5%. We did not observe any statistically significant associations of peri-procedural complications with age; type of treatment center; duration of stroke symptoms; NIHSS score, IV thrombolytics, atrial fibrillation, site of vessel occlusion; rescue therapy administered after endovascular treatment; or device. Comparing the Merci with the Solitaire FR retrieval device, we observed symptomatic cerebral hemorrhage (10.9% versus 1.1%; $P = .013$); symptomatic SAH (7.3% versus 1.1%; $P = .07$), air emboli (1.8% versus 1.1%; $P = 1.0$), emboli to new vascular territories (1.8% versus 0%; $P = .38$), vessel dissection (1.8% versus 4.5%; $P = .65$), and major groin complications (3.6% versus 7.9%; $P = .48$). Angiographic vasospasm was common but without clinical sequelae.

CONCLUSIONS: Understanding of procedural complications is important for treatment of patients with stroke after endovascular treatment. We observed fewer endovascular complications with the Solitaire FR device treatment compared with Merci device treatment, particularly symptomatic cerebral hemorrhage.

ABBREVIATION: SICH = symptomatic intracranial hemorrhage; TIMI = Thrombolysis in Myocardial Infarction; CEC = Clinical Events Committee

Intravenous tissue plasminogen activator has been proven to be efficacious in recanalization of occluded intracranial vessels and improvement of clinical outcome for acute ischemic stroke.[1] A meta-analysis of 53 studies including 2066 patients with acute stroke demonstrated a 46.2% overall recanalization rate with IV fibrinolysis.[1,2] However, IV tPA has limited ability to open occlusions of medium and large arteries such as the internal carotid artery, proximal middle cerebral artery, or basilar artery, with recanalization rates reported as low as 10%.[2,3] Because of these limitations, catheter-based approaches for acute ischemic stroke have been developed to directly infuse thrombolytics at the site of the thrombus or mechanically extract and disrupt the clot.[3-13] As with systemic thrombolytics, endovascular treatments for acute ischemic stroke carry the risk of intracranial bleeding. These treatments also carry additional risks related to vascular access, catheter placement, direct vessel injury, and the type of device deployed.

The Solitaire FR With Intention for Thrombectomy (SWIFT) trial provides additional information about endovascular ap-

Received March 26, 2013; accepted after revision May 16.

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Evidence-Based Medicine Level 2.

http://dx.doi.org/10.3174/ajnr.A3707

proaches for acute stroke and directly compares the Solitaire FR device (Covidien, Irvine, California) with the Merci retrieval device (Stryker Neurovascular, Fremont, California) in a prospective, randomized trial. Results of the primary end point for this study have been reported separately.[13] Acute stroke trials have consistently highlighted the importance of achieving early reperfusion while keeping procedural complication risks as low as possible. The therapeutic time windows are tight, and gains achieved by flow restoration are easily erased by symptomatic intracranial bleeding caused by procedural complications. The SWIFT trial reports a significant technical advance for mechanical thrombectomy by use of the Solitaire device compared with current technology (Merci retriever); the focus of this report is an in-depth analysis of the major procedural complications of this trial.

MATERIALS AND METHODS

The SWIFT trial was a multicenter, prospective, randomized, parallel-group, noninferiority study enrolling patients diagnosed with acute ischemic stroke for which endovascular intervention was indicated.[13] After a roll-in phase in which the investigational Solitaire FR device was used for 2 patients at each participating center, subsequent patients were randomly assigned on a 1:1 basis for thrombectomy with either the investigational Solitaire FR device or the US Food and Drug Administration–cleared Merci retriever. The Solitaire device consists of a self-expanding stent integrated onto a delivery wire. The stent is deployed across the thrombus, allowing its tines to intercalate with the thrombus, and is then retracted into a guide catheter by traction on the wire. The Merci retriever system has received Food and Drug Administration clearance for removal of thrombus and consists of a helical terminus that is deployed distally to the thrombus and then pulled back into the guide catheter. The aim of the SWIFT study was to demonstrate substantial equivalence by obtaining prospective clinical data on the safety and efficacy of the Solitaire FR device compared with the Merci device for patients diagnosed with acute ischemic stroke. On the basis of the SWIFT study results, the Solitaire FR received Food and Drug Administration clearance in March 2012.

The primary efficacy end point of the study was arterial recanalization of the occluded target vessel measured by Thrombolysis in Myocardial Infarction (TIMI) score[14] of 2 or 3 after the use of the study device. All patients received clinical evaluations at 24 hours, 30 days, and 90 days after the procedure.

Clinical and technical complications were prospectively collected for patients enrolled into the SWIFT trial. These events were independently reviewed and adjudicated by a central Clinical Events Committee (CEC). The type, timing, severity, outcome, relationship to study device or procedure, and other attributes of each complication were assessed. The CEC followed conventions and definitions established by the Common Terminology Criteria for Adverse Events of the National Cancer Institute.[15] Neuroimaging was independently reviewed by a core lab. Because of early termination of the study, data were available on 31 roll-in patients treated with Solitaire FR device and 113 patients randomly assigned to either the Merci device or the Solitaire FR device.

Definitions

A clinical or technical event was judged to be procedure- or treatment-related when there was a strong temporal relationship to the procedure or device implantation, such as bleeding from femoral puncture site or adverse reaction to contrast administration.

The major intracranial procedural complications in this substudy are defined as symptomatic intracranial hemorrhage (SICH), SAH, air emboli, vessel dissection, serious groin complication, and emboli to new vascular territory. Cerebral hemorrhages were classified according to the European Cooperative Acute Stroke Study (ECASS) criteria[16] as follows:

SICH is defined as any PH1, PH2, RIH, SAH, or intraventricular hemorrhage associated with a decline in NIHSS score $\geq$4 within 24 hours (PH1 indicates hematoma within ischemic field with some mild space-occupying effect but involving $\leq$30% of the infarcted area; PH2, hematoma within ischemic field with space-occupying effect involving >30% of the infarcted area; RIH, any intraparenchymal hemorrhage remote from the ischemic field).

Asymptomatic intracranial hemorrhage is defined as any intracranial hemorrhage within 24 hours not meeting the above criteria for symptomatic intracranial hemorrhage.

The major extracranial procedural complications in this substudy are defined as extracranial vessel dissection and serious groin complication.

Device-Related: Study Devices and Ancillary Devices

A study device–related adverse event is defined as an event with a strong temporal relationship to the use of the device and no plausible alternative etiology. An example is an arterial wall dissection caused by the study device. In some patients, the CEC was unable to distinguish whether the study device or ancillary devices (such as guidewires) contributed to the complication. In these circumstances, the CEC took a conservative view, and these events were adjudicated to the study device.

An ancillary device–related adverse event is directly related to the delivery catheter (system), and another cause is unlikely. An example is a vessel perforated by a guidewire.

Adverse events classified as major access site adverse events are defined as access site pseudoaneurysm, femoral hematoma, retroperitoneal hematoma, access site bleeding, access site bruising/ecchymosis, and access site occlusion.

Statistical analysis was completed by use of SAS version 9.2 (SAS Institute, Cary, North Carolina). Descriptive statistics were tabulated, and probability values were computed by use of the Fisher exact test, comparing patients as assigned with their respective roll-in or randomly assigned treatment groups.

RESULTS

The SWIFT trial enrolled 144 patients. The study population consisted of 31 patients treated during the roll-in phase with the Solitaire FR device and 113 randomly assigned patients (58 Solitaire FR; 55 Merci). A prespecified efficacy stopping rule triggered early trial termination. The CEC adjudicated 644 adverse events, and the core imaging lab reviewed neuroimaging. The overall rate for major peri-procedural events was 12.5% (Table 1). Mortality rates without and with major peri-procedural events were 23.8%

Table 1: Major procedural complications

	Present	Absent	Percentage
Symptomatic cerebral hemorrhage	7	137	4.9%
Air emboli	2	142	1.4%
Emboli to new vascular territory	1	143	0.7%
Serious groin complication	4	140	2.8%
Vessel dissection	5	139	3.5%
Total number of patients	18	126	12.5%

Table 2: Intracranial bleeding complications

Type of Intracranial Bleeding	Asymptomatic (%)	Symptomatic (%)	Total (%)
PH1	6 (4.2)	1 (0.7)	7 (4.9)
PH2	5 (3.5)	1 (0.7)	6 (4.2)
RIH	1 (0.7)	0 (0)	1 (0.7)
IVH	5 (3.5)	1 (0.7)	6 (4.2)
SAH	6 (4.2)	5 (3.5)	11 (7.6)

Note:—Total number of subjects with symptomatic cerebral hemorrhage is less than the sum of individual subtype rows because some subjects had more than 1 radiologic subtype of intracranial hemorrhage. RIH indicates any intraparenchymal hemorrhage remote from the ischemic field; IVH, intraventricular hemorrhage.

and 33.3%, respectively ($P = .39$). The major peri-procedural events can be categorized as intracranial or extracranial.

The major intracranial complications were classified as symptomatic cerebral hemorrhage, air emboli, and emboli to new vascular territory (Table 1). The pattern of SICH ($n = 7/144$, 4.9%) was categorized by the core imaging lab as follows (Table 2): isolated intracerebral hemorrhage ($n = 2$), isolated SAH ($n = 4$), isolated intraventricular hemorrhage ($n = 1$), and combined intracerebral and subarachnoid hemorrhage ($n = 0$). Asymptomatic intracerebral hemorrhage was present in 44 of 144 (30.5%) and included hemorrhagic infarctions. On radiographic review of CT brain imaging after the endovascular treatment, air emboli (Fig 1*D*) were present in 2 of 144 patients (1.4%), and 1 was determined to be a serious adverse event. Six patients with major intracranial complications underwent hemicraniectomy (Solitaire FR roll-in, 0/31, 0%; Solitaire FR randomized, 1/58, 1.7%; Merci randomized, 5/55, 9.1%, $P = .11$ for randomly assigned groups).

The major extracranial, peri-procedural complications were classified as vessel dissection and serious groin complication (Table 1). Complications were present in 7% of patients, but no long-term disability or death was attributed to these events. One patient underwent fasciotomy related to leg ischemia attributed to femoral artery access. Angiographic vasospasm was commonly observed (29/144, 20%), but no clinical sequelae were observed. Vessel dissection occurred in 5 patients (3.5%; Table 5) and was adjudicated as a serious adverse event in 1. The sites of vessel dissection were in the cervical carotid artery except for 1 patient with dissections involving both the cervical and petrous portions of the ICA. Three dissections were managed conservatively, 1 dissection was treated with balloon angioplasty, and 1 dissection was treated with stent placement.

We compared rates of peri-procedural complications against clinical (Table 3) and technical factors (Table 4). Although statistically significant differences were not observed for any clinical or technical factors, we wish to highlight the numerically higher rates observed for duration of symptoms ≥6 hours, NIHSS score ≥20, tPA failure, and presence of atrial fibrillation.

Table 3: Association of major procedural complications and clinical factors

Major Procedural Complications	Yes, *n* (%)	No, *n* (%)	*P*
Age, 22–64 y	8 (13.8%)	50 (86.2%)	.80
Age, 65+ y	10 (11.6%)	76 (88.4%)	
Duration of symptoms <4 hours	3 (11.5%)	23 (88.5%)	.68
Duration of symptoms 4–6 hours	7 (10.9%)	57 (89.1%)	
Duration of symptoms 6+ hours	5 (14.7%)	29 (85.3%)	
NIHSS score 0–10	1 (12.5%)	7 (87.5%)	.81
NIHSS score 11–20	12 (12.0%)	88 (88.0%)	
NIHSS score >20	5 (13.9%)	31 (86.1%)	
IV tPA contraindicated	8 (10.5%)	68 (89.5%)	.46
IV tPA failed	10 (15.2%)	56 (84.8%)	
Atrial fibrillation	11 (14.7%)	64 (85.3%)	.46
No atrial fibrillation	7 (10.1%)	62 (89.9%)	

Table 4: Analysis of major procedural complications and technical factors

Major Procedural Complications	Present *n* (%)	*P*
Academic centers	14 (13.9%)	.59
Community centers	4 (9.3%)	
Roll-in patients	3 (9.7%)	.76
Randomly assigned patients	15 (13.3%)	
Solitaire FR	10 (11.2%)	.61
Merci	8 (14.5%)	
No rescue therapy administered	12 (11.9%)	.79
Rescue therapy administered	6 (14.0%)	
Carotid T occlusion	5 (19.2%)	.53
ICA occlusion	0 (0.0%)	
MCA occlusion	12 (11.5%)	
M1 occlusion	8 (9.5%)	
M2 occlusion	4 (20.0%)	
VB occlusion	0 (0.0%)	
Successful revascularization (TIMI 2–3)	7 (43.8%)	.6
Unsuccessful revascularization	63 (53.4%)	

Note:—VB indicates vertebrobasilar.

The head-to-head comparison of peri-procedural complications observed with the Merci and Solitaire FR devices is shown in Table 5. Higher rates of SICH were observed after treatment with the Merci device compared with the Solitaire FR device (Solitaire FR 1/89, 1.1%; Merci 6/55, 10.9%; $P = .013$). Restoration of TIMI grade 2–3 flow was higher after treatment with the Solitaire FR device compared with the Merci device (TIMI grade 2–3 flow: Solitaire roll-in, 17/27, 63%; Solitaire randomized, 37/54, 68.5%; Merci randomized, 16/53, 30.2%; $P = .0001$). SICH followed successful revascularization (TIMI grade 2 or 3 flow) in 3 of 70 patients (Solitaire FR roll-in, 0/17, 0%; Solitaire FR randomized, 1/37, 2.7%; Merci, 2/16, 12.5%; $P = .21$). Rates of SAH trended lower with the Solitaire FR device compared with the Merci device (Table 5).

DISCUSSION

We observed important differences between complications of systemic (IV) thrombolysis and endovascular (intra-arterial) treatment (Table 6). The major risk of systemic thrombolysis is symptomatic intracranial bleeding and is generally intraparenchymal. This complication carries a 50% mortality rate.[1] In comparison, the pattern of intracranial bleeding after endovascular therapy is more variable and carries a greater risk of SAH. Rates of symptomatic intracranial bleeding in the SWIFT trial in the Solitaire FR treatment arm[13] (1.1%) were significantly lower compared with

Table 5: Association of major procedural complications and embolectomy device

Type of Complication	MERCI % (*n*/*N*) [events]	Solitaire % (*n*/*N*) [events]	*P*
SAH symptomatic	7.3% (4/55) [4]	1.1% (1/89) [1]	.070
SAH asymptomatic	5.5% (3/55) [3]	3.4% (3/89) [3]	.67
ICH PH1 symptomatic	1.8% (1/55) [1]	0.0% (0/89) [0]	.38
ICH PH2 symptomatic	1.8% (1/55) [1]	0.0% (0/89) [0]	.38
IVH symptomatic	1.8% (1/55) [1]	0.0% (0/89) [0]	.38
ICH asymptomatic	27.3% (15/55) [15]	27.0% (24/89) [25]	1.00
Ischemic stroke symptomatic	12.7% (7/55) [7]	3.4% (3/89) [3]	.044
All symptomatic ICH	10.9% (6/55) [6]	1.1% (1/89) [1]	.013
Air emboli	1.8% (1/55) [1]	1.1% (1/89) [1]	1.00
Emboli to same vascular territory	5.5% (3/55) [3]	4.5% (4/89) [4]	1.00
Emboli to new vascular territory	1.8% (1/55) [1]	0.0% (0/89) [0]	.38
Device detachment	0.0% (0/55) [0]	0.0% (0/89) [0]	1.00
Vessel dissection	1.8% (1/55) [1]	4.5% (4/89) [4]	.65
Vessel vasospasm on angiography	16.4% (9/55) [10]	22.5% (20/89) [20]	.40
Vessel vasospasm symptomatic	0.0% (0/55) [0]	0.0% (0/89) [0]	1.00
Major access site issues	3.6% (2/55) [2]	7.9% (7/89) [8]	.48
Study device–related AE	16.4% (9/55) [13]	10.1% (9/89) [14]	.31
Ancillary device–related AE	3.6% (2/55) [2]	7.9% (7/89) [8]	.48
Technical difficulty with device	7.3% (4/55) [4]	10.1% (9/89) [12]	.77

Note:—IVH indicates intraventricular hemorrhage; ICH, intracerebral hemorrhage; AE, adverse event.

Table 6: Complications of systemic (IV) thrombolysis and endovascular (intra-arterial) treatment

Trial	Symptomatic ICH	SAH
NINDS	6.4%	0%
PROACT I	15.4%	na
PROACT II	10.2%	na
IMS I	6.3%	0%
IMS II	9.9%	na
Merci	7.8%	3.5%
Multi-Merci	9.8%	9.9%
Penumbra	10%	5%
SWIFT-all	4.9%	7.6%
SWIFT-Merci arm	10.9%	12.7%
SWIFT-Solitaire arm	1.1%	4.5%

the NINDS trial[1](6.4%) and the SWIFT Merci treatment arm (10.9%) and were lower than published trials that used intra-arterial thrombolysis[4,5,6,8] or the Penumbra device (Penumbra, Alameda, California).[9] The SICH rate observed with the Merci device in the SWIFT trial (10.9%) was similar to that in prior studies[7,10] (Table 6).

SAH was not reported in the NINDS IV tPA trial[1] but has been reported in other device trials (Table 6) and case series.[17] The rate of SAH was higher in this trial compared with earlier interventional stroke trials but similar to rates in a recent study by UCLA[17] and the Multi-MERCI trial (Table 6). A key difference between earlier interventional stroke trials such as the PROACT trials and more recent trials is the use of thrombectomy devices in addition to intracranial placement of microcatheters and infusion of intra-arterial thrombolytics. In the MERCI trial,[7] 5 patients were adjudicated with symptomatic SAH (5/141; 3.5%), and the authors attributed the symptomatic SAH to vessel perforations. Asymptomatic SAH was not reported separately in this trial; therefore the total SAH encountered probably exceeds this rate. In the Multi-MERCI trial, 3 (2.7%) patients had symptomatic SAH and 8 (7.2%) had asymptomatic SAH, for a total SAH rate of 9.9% (11/111).

Our hypothesis that thrombectomy devices pose a greater risk of SAH compared with microcatheter delivery of intra-arterial thrombolytics is supported by a recent analysis by the UCLA Endovascular Stroke Therapy Investigators.[17] They reported that SAH was detected after primary intra-arterial thrombolysis (6.5%) but was numerically more likely after Merci retriever thrombectomy (14.1%). They had an overall 15.6% rate of SAH after endovascular treatment of acute ischemic stroke (20/128 procedures), and independent predictors of SAH in their study were procedure-related vessel perforation, rescue angioplasty after thrombectomy, distal MCA occlusion, and hypertension. The IMS I and II Investigators[18] also suggested that microcatheter contrast injections may contribute to intracranial bleeding caused by pressure-related effects or toxicity of contrast agents. Four instances of vessel perforation were observed in SWIFT: 1 patient treated with Solitaire (1/58; 1.7%) and 3 treated with Merci (3/55, 5.5%; $P = .35$[13]). The trend toward lower rates of symptomatic SAH with the Solitaire FR device (1.1%) compared with the Merci device is encouraging (7.3%, Table 6).

Reperfusion is a double-edged sword. Early reperfusion will limit ischemic damage to both the brain and the cerebrovasculature. Late reperfusion can cause cerebral hemorrhage by restoration of cerebral blood flow to infarcted brain and associated vasculature and may contribute to brain edema.[19] Theoretically, reperfusion by use of mechanical thrombectomy should have a lower rate of hemorrhagic transformation when direct vessel injury is minimized and flow restoration occurs quickly. The results of the Solitaire FR treatment arm of the SWIFT trial are consistent with this concept. One advantage of the Solitaire device over the Merci device is the rapid flow restoration with stent deployment that occurs before clot removal. Whether this expediency in flow restoration contributed to the lower SICH rates observed with Solitaire FR versus Merci will require additional analysis.

The lower rates of SICH observed with Solitaire FR compared with Merci devices may be related to other technical factors besides the higher and more rapid rate of reperfusion. After advancement of the embolectomy devices into the intracranial thrombus, the withdrawal of the devices into the guide catheter exerts traction on the arterial tree. These mechanical forces may contribute to SICH by direct endoluminal trauma or through shear forces on the perforating vessels as the parent vessel undergoes traction. In a preclinical model, less endovascular injury was observed with Solitaire as compared with Merci use.[20]

The IMS III trial results[21] highlight the importance of rapid restoration of flow. A favorable functional outcome at 3 months (a modified Rankin Scale score of 0–2) occurred in 12.7% of patients with TICI score of 0, 27.6% with TICI score of 1, 34.3–47.9% with TICI score of 2a or 2b, and 71.4% with TICI score of 3. In this trial, treating physicians used different devices and intra-arterial tPA doses at their discretion. Only 4 patients enrolled in this trial were treated with the Solitaire FR device.

This study has strengths and weaknesses. The strengths include the multicenter, randomized, prospective study design, independent adjudication of adverse events by a CEC, and review of neuroimaging by a core lab. This is the first endovascular stroke trial to directly compare 2 thrombectomy devices. The weakness of this study is the limited sample size ($n = 144$) and the variability in operator experience and skill with mechanical thromboembolectomy that is inherent to multicenter studies.

CONCLUSIONS

"Experience is what you get when you don't get what you want."[22] Detailed knowledge of peri-procedural complications is important for the treatment of patients with stroke after endovascular treatment. The results of the IMS III trial highlight the importance of maximizing the time to restore flow while keeping procedural complication risks low for acute ischemic stroke. Fewer endovascular complications were observed with Solitaire FR device treatment compared with Merci device treatment, particularly symptomatic cerebral hemorrhage. Device registries will be helpful to gain deeper understanding of rare events. This trial illustrates a significant technical advance for mechanical thrombectomy by use of the Solitaire device compared with current technology (Merci retriever); this report has focused on the major procedural complications.

ACKNOWLEDGMENTS

Funding for the SWIFT trial was provided by ev3/Covidien. No funding was provided to the authors for data analysis and manuscript preparation and submission.

Drs Akins, Pakbaz, and Amar served on the Clinical Events Committee and received modest time-based compensation as consultants. Dr Fields served as a clinical site co-investigator in the SWIFT trial, and his institution received modest enrollment-based compensation to offset study costs.

Disclosures: Paul T. Akins—*RELATED: Consulting Fee or Honorarium:* ev3*; *Fees for Participation in Review Activities, Such as Data Monitoring Boards, Statistical Analysis, Endpoint Committees, and the Like:* ev3,* Comments: I served on the Clinical Events Committee for the SWIFT trial. I did not receive compensation directly and fees were paid to The Permanente Medical Group. Arun P. Amar—*RELATED: Fees for Participation in Review Activities, Such as Data Monitoring Boards, Statistical Analysis, Endpoint Committees, and the Like:* Covidien, Comments: Received market value time-based compensation to serve as chairman of Clinical Events Committee for the SWIFT trial; *UNRELATED: Consultancy:* Reverse Medical, Comments: Received market value time-based compensation to serve as chairman of Clinical Events Committee for the ReSTORE trial; *OTHER RELATIONSHIPS:* Scheduled to be chairman of Clinical Events Committee for PUFS trial (Covidien), to be paid market value time-based compensation. Ramin Pakbaz—*RELATED: Grant:* Covidien,* Comments: Fellowship grant; *Fees for Participation in Review Activities, Such as Data Monitoring Boards, Statistical Analysis, Endpoint Committees, and the Like:* Covidien, Comments: Complication adjudication committee member. Jeremy Fields—*RELATED: Consulting Fee or Honorarium:* Covidien, Stryker, Comments: I have lectured on interventional treatment of stroke for Covidien (manufacturer of Solitaire). I have acted as a trainer for various devices marketed by Stryker (manufacturer of the Merci retriever) (**money paid to institution*).

REFERENCES

1. National Institute of Neurological Disorders and Stroke rt-PA Stroke Study Group. **Tissue plasminogen activator for acute ischemic stroke.** *N Engl J Med* 1995;333:1581–87
2. Rha J, Saver JL. **The impact of recanalization on ischemic stroke outcome: a meta-analysis.** *Stroke* 2007;38:967–73
3. Tenser MS, Amar AP, Mack WJ. **Mechanical thrombectomy for acute ischemic stroke using the Merci retriever and Penumbra aspiration systems.** *World Neurosurg* 2011;76(6 Suppl):S16–23
4. Del Zoppo GJ, Higashida RT, Furlan AJ, et al, and the PROACT Investigators. **PROACT: a phase II randomized trial of recombinant pro-urokinase by direct arterial delivery in acute middle cerebral artery stroke.** *Stroke* 1998;29:4–11
5. Furlan A, Higashida R, Wechsler L, et al, for the PROACT Investigators. **Intra-arterial prourokinase for acute ischemic stroke: the PROACT II Study: a randomized controlled trial** *JAMA* 1999;282:2003–11
6. IMS Study Investigators. **Combined intravenous and intra-arterial recanalization for acute ischemic stroke: the Interventional Management of Stroke Study.** *Stroke* 2004;35:904–11
7. Smith WS, Sung G, Starkman S, et al, for the MERCI Trial Investigators. **Safety and efficacy of mechanical embolectomy in acute ischemic stroke: results of the MERCI Trial.** *Stroke* 2005;36:1432–40
8. IMS II Trial Investigators. **The Interventional Management of Stroke (IMS) II Study.** *Stroke* 2007;38:2127–35
9. Bose A, Henkes H, Alfke K, et al, for the Penumbra Phase 1 Stroke Trial Investigators. **The Penumbra system: a mechanical device for the treatment of acute stroke due to thromboembolism.** *AJNR Am J Neuroradiol* 2008;29:1409–13
10. Smith WS, Sung G, Saver J, et al, Multi MERCI Investigators. **Mechanical thrombectomy for acute ischemic stroke: final results of the Multi MERCI trial.** *Stroke* 2008;39:1205–12
11. Miteff F, Faulder KC, Goh AC, et al. **Mechanical thrombectomy with a self-expanding retrievable intracranial stent (Solitaire AB): experience in 26 patients with acute cerebral occlusion.** *AJNR Am J Neuroradiol* 2011;32:1078–81
12. Machi P, Costalat V, Lobotesis K, et al. **Solitaire FR thrombectomy system: immediate results in 56 consecutive acute ischemic stroke patients.** *J Neurointerv Surg* 2012;4:62–66
13. Saver JL, Jahan R, Levy EI, et al, for the SWIFT trialists**. Solitaire flow restoration device versus the Merci retriever in patients with acute ischaemic stroke (SWIFT): a randomized, parallel-group, non-inferiority trial.** *Lancet* 2012;380:1241–49
14. TIMI Study Group. **The Thrombolysis in Myocardial Infarction (TIMI) trial: phase I findings.** *N Engl J Med* 1984;33:523–30
15. Cancer Therapy Evaluation Program, Common Terminology Criteria for Adverse Events, Version 3.0, DCTD, NCI, NIH, DHHS March 31, 2003 (http://ctep.cancer.gov), Publish Date: August 9, 2006
16. Hacke W, Kaste M, Fieschi C, et al, for the ECASS Study Group. **Intravenous thrombolysis with recombinant tissue plasminogen activator for acute hemispheric stroke: the European Cooperative Acute Stroke Study (ECASS).** *JAMA* 1995;274:1017–25
17. Shi Z-S, Liebeskind DS, Loh Y, et al, and UCLA Endovascular Stroke Therapy Investigators. **Predictors of subarachnoid hemorrhage in acute ischemic stroke with endovascular therapy.** *Stroke* 2010;41:2775–81
18. Khatri P, Broderick JP, Khoury JC, et al, IMS I and II Investigators. **Microcatheter contrast injections during intra-arterial thrombolysis may increase intracranial hemorrhage risk.** *Stroke* 2008;39:3283–87
19. Teal PA, Pessin MS. **Hemorrhagic transformation: the spectrum of ischemia-related brain hemorrhage.** *Neurosurg Clin North Am* 1992;3:601–10
20. Mehra M, Hendricks GH, O'Callaghan JM, et al. **Preclinical in-vivo safety evaluation of thrombectomy devices in the canine cerebrovasculature (abstract).** *Stroke* 2012;43:A139
21. Broderick JP, Palesch YY, Demchuk AM, et al, for the IMS III Investigators. **Endovascular therapy after intravenous t-PA versus t-PA alone for stroke.** *N Engl J Med* 2013;368:893–903
22. Pausch R. *The Last Lecture.* New York: Hyperion Books; 2008