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Outcome of Standard and High-Risk Patients With Acute Anterior Circulation Stroke After Stent Retriever Thrombectomy

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Background and Purpose—Stent retrievers have become an important tool for the treatment of acute ischemic stroke. The aim of this study was to analyze outcome and complications in a large cohort of patients with stroke treated with the Solitaire stent retriever. The study also included patients who did not meet standard inclusion criteria for endovascular treatment: low or high baseline National Institutes of Health Stroke Scale score, ≥80 years of age, extensive ischemic signs in middle cerebral artery territory, and time from symptom onset to endovascular intervention >8 hours.

Methods—Consecutive patients with acute anterior circulation stroke treated with the Solitaire FR were analyzed. Data on characteristics of endovascular interventions, complications, and clinical outcome were collected prospectively. Patients who met standard inclusion criteria were compared with those who did not.

Results—A total of 227 patients were included. Mean age was 68.2±14.7 years, and median National Institutes of Health Stroke Scale score on admission was 16 (range, 2–36). Reperfusion was successful (thrombolysis in cerebral infarction, 2b–3) in 70.9%. Outcome was favorable (modified Rankin Scale, 0–2) in 57.7% of patients who met standard inclusion criteria and 30.3% of those who did not. The rates for symptomatic intracranial hemorrhage were 3.7% and 13.1%, for death 11.4% and 33.8%, and for symptomatic intraprocedural complications 2.5% and 4.8%, respectively.

Conclusions—Patients <80 years of age, without extensive pretreatment ischemic signs, and baseline National Institutes of Health Stroke Scale score ≤30 had high rates of favorable outcome and low periprocedural complication rates after Solitaire thrombectomy. Successful reperfusion was also common in patients not fulfilling standard inclusion criteria, but worse clinical outcomes warrant further research with a special focus on optimal patient selection.   (***Stroke***. 2014;45:152-158.)

Key Words: stroke ■ thrombectomy

Stent retrievers have become valuable as thrombectomy devices for the treatment of acute ischemic stroke. The reasons for this are 3-fold. First, stent retrievers restore perfusion in the occluded vascular territory immediately after insertion. Second, they can readily be retrieved and achieve a high rate of vessel recanalization, and third, unlike traditional stents, they are not permanently deployed and do not have device-related adverse events in the long term. The Solitaire FR (ev3-Covidien, Irvine, CA) was the first dedicated stent retriever, commercially introduced in Europe in November 2009. The percentage of patients with successful reperfusion with the Solitaire retriever was higher (64%–100%)[1–14] than after pharmacological intra-arterial thrombolysis (63.2%) or intravenous thrombolysis (46.2%).[15] After stent retriever thrombectomy, favorable clinical outcomes were achieved in ≤77% of patients

with anterior circulation strokes.[16] However, most studies using the Solitaire excluded patients with expected high risk for adverse outcome and patients with only mild stroke symptoms (ie, patients whose treatment was not advised according to contemporary guidelines).[3–5,9,11,14,16–20] Thus, safety and outcome of stent retriever thrombectomy in patients who do not meet standard inclusion criteria for endovascular stroke treatment are not known. The aim of this study was to analyze safety and outcome of Solitaire treatment in a large cohort of patients with anterior circulation stroke and to compare patients with and without risk factors that presumably predict adverse outcomes.

Patients and Methods

Patients with acute stroke admitted to our stroke center are continuously recorded in the Bernese Stroke Registry. In this analysis, we

assessed clinical outcome, procedural characteristics, and periprocedural complications in all patients with anterior circulation stroke who were treated with the Solitaire FR stent retriever. Part of the data of 49 patients has been included into retrospective and prospective international studies on thrombectomy.[12,14,21] The study was approved by our institutional review board.

Preinterventional Patient Assessment

Neurological deficits were scored by a neurologist using the National Institutes of Health Stroke Scale (NIHSS). Baseline demographic and clinical data were recorded prospectively.

Computed tomography (CT) or MRI of the head was performed before therapy, including CT angiography or contrast-enhanced MR angiography depicting the aortic arch and the neck and intracranial vessels. Images were assessed for extensive early ischemic signs in the middle cerebral artery (MCA) territory, defined as an Alberta Stroke Program Early CT Score (ASPECT) of ≤6 on CT, or <5 on diffusion-weighted imaging on MRI.[14,22] When both pretreatment CT and MRI were available, the MRI ASPECT score was used for classification of infarct size.

Therapy

Criteria for endovascular therapy were an acute neurological deficit of <24 hours duration and an NIHSS score ≥4 or isolated aphasia. In addition, the causative vessel occlusion had to be accessible by an endovascular route, intracranial hemorrhage had to be excluded on admission CT or MRI, and clinical and laboratory findings advising against endovascular therapy had to be absent. Endovascular strategy was based on clinical data and multimodal CT or MRI.

Endovascular therapy was performed under general anesthesia or conscious sedation with monitored anesthesia care. High-resolution, biplane flat panel diagnostic 4-vessel cerebral angiography was performed before endovascular treatment (Axiom Artis zee; Siemens, Erlangen, Germany). The site of vessel occlusion was categorized as internal carotid artery (ICA), tandem (ICA in combination with MCA and/or anterior cerebral artery), carotid-T, M1 segment of MCA, M2 segment of MCA, and multiple (MCA in combination with anterior cerebral artery). Characteristics from endovascular therapy were

assessed by review of digital subtraction angiography series and written reports.

Leptomeningeal collaterals supplying the occluded vessel territory were graded as poor if no angiographically relevant collaterals were visualized, as moderate if minimal leptomeningeal anastomoses were visualized, and as good if leptomeningeal anastomoses were filling the occluded vessel territory by more than half.

Retrieval of the stent was performed in flow arrest using a balloon-mounted guiding catheter placed with its tip as close as possible to the skull base, to prevent the ICA from collapsing during aspiration. Triple-access catheter technique was used if the artery to access the thrombus was extremely tortuous or large arterial branches originated between the balloon catheter and the thrombus (Figure). Using this technique, a high volume 5 or 6F distal access and aspiration catheter was advanced over the wire of the stent retriever in front of the occlusion site. The extraction of the clot and stent was performed under simultaneous aspiration at the distal access and inflation of the balloon catheter. In addition to thrombectomy with the Solitaire, thromboaspiration with a distal access catheter and simultaneous aspiration with a balloon catheter if applicable, intra-arterial thrombolysis, percutaneous transluminal angioplasty, or intracranial or extracranial stent placement were used in individual patients as deemed necessary.

In patients with tandem occlusions, we preferentially performed stenting after distal thrombectomy as the last step, using a distal protection system. In this way, distal thrombectomy of the MCA or distal ICA can be performed in flow arrest caused by the more proximal ICA occlusion. To avoid stent-associated complications, we usually performed percutaneous transluminal angioplasty alone and continued with stenting only, if rapid reocclusion occurred. Patency of the carotid bifurcation, with or without stenting, was closely bedside monitored in the stroke unit using Doppler ultrasound.

Intraprocedural complications included vessel wall dissection, vessel perforation, severe vasospasm, in-stent thrombosis, device failure, embolization, and immediate reperfusion hemorrhage. Severe vasospasm was defined as vasospasm necessitating intra-arterial spasmolysis using nimodipine or papaverine. Symptomatic intraprocedural complications were defined as adverse events associated with an increase in NIHSS score of ≥4 points or death at 24 hours.
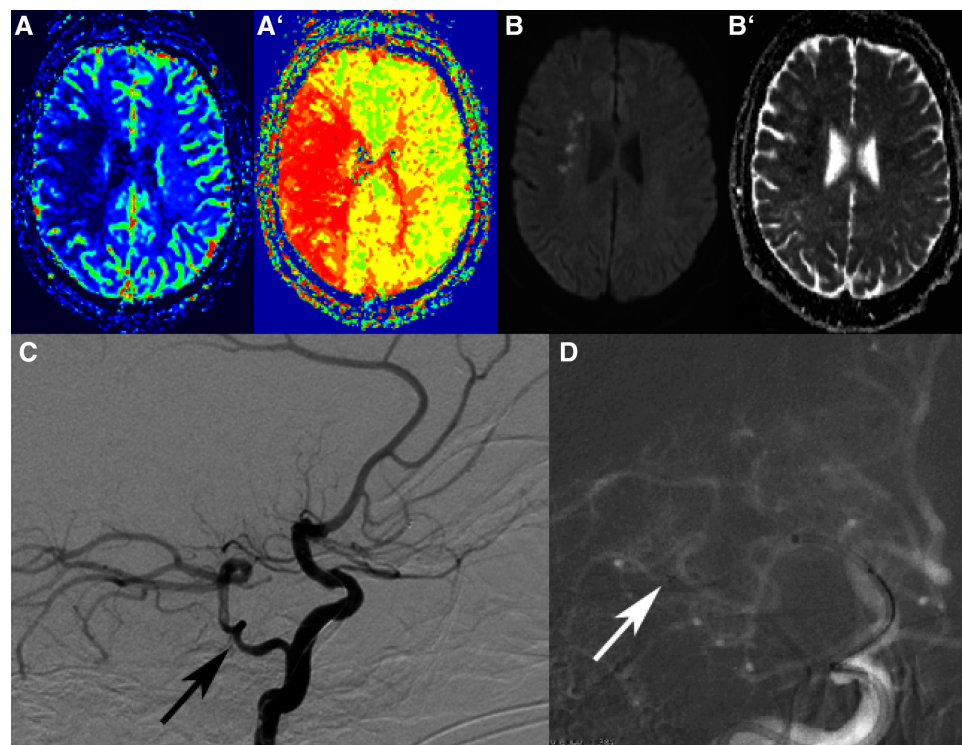
Figure. A 53-year-old woman with proximal right middle cerebral artery (MCA) occlusion with dysarthria and left-sided hemiparesis (National Institutes of Health Stroke Scale [NIHSS] score, 15). Preinterventional MR perfusion shows decreased cerebral blood flow and increased time to peak of almost the entire MCA territory (**A** and **A'**) in contrast to small, scattered lesions on diffusion-weighted imaging (**B**) and apparent diffusion coefficient maps (**B'**). Digital subtraction angiography (lateral projection; **C**) confirms proximal M1 occlusion and persistent trigeminal artery (black arrow). Roadmap with deployed Solitaire stent (white arrow at distal end) and 5F aspiration catheter in the proximal M1 segment (anteroposterior projection; **D**), protecting the trigeminal artery from any displacement of thrombotic material during stent retrieval. NIHSS score after 1 day was 4 and outcome at 3 months was favorable (modified Rankin Scale, 1).

Cerebral reperfusion was assessed at the end of the endovascular procedure, using biplane or 3-dimensional rotational angiography, according to the thrombolysis in cerebral infarction grading system.[23]

Postinterventional Patient Assessment

A CT or MRI was obtained 24 to 72 hours after treatment, or earlier in case of clinical deterioration. The occurrence of symptomatic intracranial hemorrhages (sICH) or asymptomatic intracranial hemorrhages within 72 hours from stroke onset was recorded according to the Prolyse in Acute Cerebral Thromboembolism (PROACT) II criteria.[24] Clinical outcome was assessed 3 months after stroke using the modified Rankin Scale (mRS).

Statistical Analysis

Categorical variables were compared with the 2-tailed Fisher exact test. To determine the predictors of clinical outcome, death, and reperfusion success, a forward stepwise logistic regression including all variables with a $P<0.2$ in univariate analysis was performed. These variables were age, sex, baseline NIHSS score, occlusion site, degree of collaterals, ASPECT score, time from symptom onset to arterial puncture, anesthesia type, reperfusion success, symptomatic intraprocedural complication, peri-interventional intramural arterial dissection, atrial fibrillation, diabetes mellitus, arterial hypertension, hypercholesterolemia, coronary artery disease, previous stroke, current or previous smoking, and family history of stroke. Successful reperfusion was defined as thrombolysis in cerebral infarction grades 2b and 3. Clinical outcome was dichotomized into favorable functional outcome (mRS, 0–2) and poor outcome (mRS, 3–6). Patients with baseline NIHSS score <8 or >30, patients aged ≥80 years, patients with extensive ischemic signs in the MCA territory, or patients with time from symptom onset to endovascular intervention >8 hours were assigned to the group who did not meet standard inclusion criteria. Patients with missing data on one of these criteria were excluded from stratification. A P value of <0.05 was considered significant. Statistics were performed with SPSS version 21 (IBM Corp, Armonk, NY).

Results

From January 2010 to November 2012, 510 patients received endovascular treatment for acute ischemic stroke. A total of 227 patients were treated with the Solitaire stent retriever and were included in this study. Pretreatment imaging was performed by MRI in 125 (55.1%), CT in 74 (32.6%), and both MRI and CT in 27 patients (11.9%). One patient had a stroke during percutaneous aortic valve replacement and pretreatment CT or MRI was not performed. In 79 patients (34.8%), endovascular treatment was performed after intravenous thrombolysis with recombinant tissue-type plasminogen activator (median recombinant tissue-type plasminogen activator dose, 47 mg; range, 30–77). Baseline characteristics are shown in Table 1. Eighty-one patients (35.7%) met standard inclusion criteria for endovascular stroke treatment. Hundred forty-five patients (63.9%) did not fulfill all criteria, and 35 of them violated >1 criterion. Vascular risk factors were similar in patients meeting standard inclusion criteria and those who did not.

Baseline ASPECT scores and extent of leptomeningeal collaterals are given in Table I in the online-only Data Supplement. Collateral status could not be determined in 1 patient with carotid-T occlusion because angiograms of the contralateral side were missing. Patients presenting with a baseline NIHSS score <8 had significantly better collateral supply than patients with an NIHSS score ≥8 ($P=0.028$), and patients with extensive ischemic signs in the MCA territory had significantly worse collaterals compared with those with less extensive ischemic changes ($P<0.001$).

Procedural Characteristics

Of the 227 patients included in the study, 105 (46.3%) were treated with the Solitaire alone. In 122 patients (53.7%), additional techniques were used. In patients treated with the Solitaire alone, the median procedure time was 44 minutes (range, 15–171) versus 114 minutes (range, 31–282) in patients receiving multimodal endovascular therapy. In 225 patients (99.1%), the Solitaire could be deployed over the thrombus. In 2 patients, the Solitaire could not be completely passed over the thrombus because of elongated vessels. The median number of passes by the stent retriever was 1 (range, 1–6). An immediate bypass effect, restoring at least a trickle of flow through the occluded vessel after temporary deployment of the stent retriever, was seen in 184 patients (81.4%).

Table 1. Baseline Characteristics of 227 Patients Treated With the Solitaire

	Overall (n=227)	Patients Meeting Standard Criteria (n=81)	NIHSS <8 (n=27)	NIHSS >30 (n=11)	Age ≥80 y (n=50)	Extensive Ischemic Signs in MCA Territory (n=69)	Time From Symptom Onset to Arterial Puncture >8 h (n=22)
Age, y, mean (SD)	68.2 (14.7)	66.5 (12.5)	65.5 (14.5)	59.4 (13.8)	83.6 (2.6)	65.1 (16.0)	67.1 (14.5)
Women, n (%)	111 (48.9)	35 (43.2)	15 (55.6)	7 (63.6)	30 (60.0)	32 (46.4)	10 (45.5)
Baseline NIHSS score, median (range)	16 (2–36)	15 (8–26)	6 (2–7)	36 (36–36)	17.5 (4–36)	20 (6–36)	16.5 (8–22)
Extensive ischemic signs in MCA territory, n (%)	69/226 (30.5)	0 (0.0)	2 (7.4)	6 (54.5)	13 (26.0)	69 (100)	5 (22.7)
Occlusion site, n (%)							
Internal carotid artery	2 (0.9)	1 (1.2)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.4)	0 (0.0)
Carotid-T	42 (18.5)	11 (13.6)	1 (3.7)	3 (27.3)	11 (22.0)	22 (31.9)	3 (13.6)
Tandem occlusion	25 (11.0)	11 (13.6)	3 (11.1)	0 (0.0)	3 (6.0)	6 (8.7)	6 (27.3)
MCA M1	135 (59.5)	55 (67.9)	18 (66.7)	6 (54.5)	29 (58.0)	34 (49.3)	11 (50.0)
MCA M2	12 (5.3)	1 (1.2)	5 (18.5)	1 (9.1)	4 (8.0)	1 (1.4)	1 (4.5)
Multiple occlusions	11 (4.8)	2 (2.5)	0 (0.0)	1 (9.1)	3 (6.0)	5 (7.2)	1 (4.5)

MCA indicates middle cerebral artery; and NIHSS, National Institutes of Health Stroke Scale.

In 85.5% of all interventions, the Solitaire FR 4×20 mm was used, in 10.1% the Solitaire FR 6×30 mm, and in 4.4% both were used. In 161 patients (70.9%), successful reperfusion (thrombolysis in cerebral infarction, 2b–3) was achieved (Table 2; Table II in the online-only Data Supplement).

In multiregression analysis, more extensive leptomeningeal collaterals (P=0.011; odds ratio [OR], 1.716; 95% confidence interval [CI], 1.131–2.604) predicted successful reperfusion independently.

In the majority of patients, endovascular interventions were performed under general anesthesia (n=196 [86.3%]). Good outcome (mRS, 0–2) was more often in patients undergoing treatment with conscious sedation compared with patients receiving general anesthesia (n=19/31 [61.3%] versus n=53/190 [36.3%]; P=0.010).

Intraprocedural Complications

In 74 patients (32.6%), 84 intraprocedural complications occurred (Table III in the online-only Data Supplement). Nine patients (4.0%) had clinically symptomatic complications. Most of the symptomatic complications were related to problems in the cervical ICA such as iatrogenic dissection (n=3) or in-stent thrombosis (n=3).

Vessel perforation was observed in 2 patients (1 M1 and 1 M2 perforation). Bleeding stopped spontaneously in the patient with the M1 perforation after retraction of the stent retriever, and we were able to stop the bleeding in the patient with the M2 perforation by superselective occlusion of the MCA branch with a drop of glue (Histoacryl; B. Braun Melsungen AG, Melsungen, Germany). In both patients, follow-up CT on the next day showed no extension of the subarachnoid hemorrhage. Material failure occurred in 1 patient in whom the stent was lost from the push wire during retraction in the M1 segment. Treatment with aspirin and Plavix was initiated. The vessel remained open, and the patient experienced no new symptoms. After recanalization and stent placement in ICA occlusions, immediate in-stent thrombosis was seen in 8 of 36 patients (22.2%; Precise; Cordis, a Johnson & Johnson company, Miami Lakes, FL, and Cristallo Ideale; Invatec S.p.A., Roncadelle, Italy). In-stent thrombosis was successfully treated in all patients with intra-arterial Abciximab (ReoPro; Centocor B.V., Leiden, The Netherlands) or heparin. No in-stent thrombosis occurred after permanent Solitaire deployment. Distal clot embolization was observed in 15 patients (6.6%). Six embolizations occurred in a previously uninvolved vascular territory.

Clinical Outcome and Bleeding Complications

Follow-up imaging with CT or MRI within 72 hours was performed in 225 patients (99.1%). sICH occurred in 22 patients (9.7%) and asymptomatic intracranial hemorrhage in 34 (15.0%; Table 3). Of 18 anticoagulated patients with an international normalized ratio ≥1.7, sICH occurred in 4 (22.2%), whereas only 18 of 207 patients (8.7%) with an international normalized ratio <1.7 had an sICH. At 3 months, 221 patients (97.4%) underwent assessment of the mRS. Outcome was favorable (mRS, 0–2) in 88 patients (39.8%) and poor (mRS, 3–6) in 133 patients (60.2%).

Multiregression analysis demonstrated successful reperfusion (P=0.012; OR, 2.790; 95% CI, 1.254–6.209), higher ASPECT score (P=0.037; OR, 1.190; 95% CI, 1.011–1.402), younger age (P<0.001; OR, 0.935; 95% CI, 0.908–0.963), lower NIHSS score on admission (P<0.001; OR, 0.834; 95% CI, 0.781–0.890), and absence of diabetes mellitus (P=0.018; OR, 0.284; 95% CI, 0.100–0.806) to be independent predictors of favorable clinical outcome.

Mortality at 3 months was 25.7% (n=57/222). Failed reperfusion (P=0.005; OR, 0.354; 95% CI, 0.172–0.729), advancing age (P=0.001; OR, 1.056; 95% CI, 1.023–1.091), higher NIHSS score on admission (P<0.001; OR, 1.120; 95% CI, 1.062–1.181), and diabetes mellitus (P=0.001; OR, 4.375; 95% CI, 1.855–10.320) were independent predictors of death. Carotid-T occlusions showed the highest mortality rate (39.0%).

Comparison of Patients Who Met Standard Inclusion Criteria With Those Who Did Not

Successful reperfusion was achieved in 71% of patients not fulfilling standard inclusion criteria, which is similar to the 70.4% in the group who met the criteria (P=1.000). Outcome was favorable (mRS, 0–2) in 57.7% of patients who met standard inclusion criteria and in 30.3% of those who did not (P<0.001). The rates for sICH were 3.7% and 13.2% (P=0.021), for death 11.4% and 33.8% (P<0.001), and for

Table 2. Treatment Details

	Overall (n=227)	Patients Meeting Standard Criteria (n=81)	NIHSS <8 (n=27)	NIHSS >30 (n=11)	Age ≥80 y (n=50)	Extensive Ischemic Signs in MCA Territory (n=69)	Time From Symptom Onset to Arterial Puncture >8 h (n=22)
Time from symptom onset to arterial puncture, min, median (range)	235 (64–1426)	222 (110–472)	253 (115–437)	218 (155–370)	233.5 (120–594)	229 (120–778)	621 (494–1426)
Time from arterial puncture to final reperfusion, min, median (range)	79 (15–282)	81 (16–213)	54 (23–173)	86 (26–282)	61 (21–261)	84 (23–241)	76 (15–196)
Successful reperfusion (TICI, 2b–3), n (%)	161 (70.9)	57 (70.4)	23 (85.2)	7 (63.6)	37 (74.0)	43 (62.3)	15 (68.2)
Multimodal endovascular therapy, n (%)	122 (53.7)	44 (54.3)	13 (48.1)	6 (54.5)	24 (48.0)	39 (56.5)	13 (59.1)

MCA indicates middle cerebral artery; NIHSS indicates National Institutes of Health Stroke Scale; and TICI, thrombolysis in cerebral infarction.

Table 3.   Bleeding Complications and Clinical Outcome

	Overall (n=227)	Patients Meeting Standard Criteria (n=81)	NIHSS <8 (n=27)	NIHSS >30 (n=11)	Age ≥80 y (n=50)	Extensive Ischemic Signs in MCA Territory (n=69)	Time From Symptom Onset to Arterial Puncture >8 h (n=22)
sICH, n (%)	22/226 (9.7)	3 (3.7)	1 (3.7)	1 (9.1)	7/49 (14.3)	13/68 (19.1)	2 (9.1)
aICH, n (%)	34/226 (15.0)	15 (18.5)	2 (7.4)	2 (18.2)	5/49 (10.2)	11/68 (16.2)	2 (9.1)
Favorable outcome (mRS, 0–2) at 3 mo, n (%)	88/221 (39.8)	45/78 (57.7)	20/26 (76.9)	1/10 (10.0)	5/49 (10.2)	14/68 (20.6)	8 (36.4)
Dead at 3 mo, n (%)	57/222 (25.7)	9/79 (11.4)	1/26 (3.8)	5/10 (50.0)	22/49 (44.9)	29/68 (42.6)	4 (18.2)

aICH indicates asymptomatic intracranial hemorrhage; MCA, middle cerebral artery; mRS, modified Rankin Scale; NIHSS, National Institutes of Health Stroke Scale; and sICH, symptomatic intracranial hemorrhage.

symptomatic intraprocedural complications 2.5% and 4.8% (P=0.709), respectively.

Patients of old age (≥80 years) reached a favorable outcome in a low percentage (n=5/49 [10.2%]; P<0.001). Low rates of good outcome were also observed in patients with extensive ischemic signs in the MCA territory on admission (n=14/68 [20.6%]; P<0.001) and patients with baseline NIHSS score >30 (n=1/10 [10.0%]; P=0.054). The highest mortality rates occurred in patients of old age (n=22/49 [44.9%]; P=0.001), those, who had extensive ischemic lesions on initial imaging (n=29/68 [42.6%]; P<0.001), and patients with high baseline NIHSS score (n=5/10 [50.0%]; P=0.129). Figures I and II in the online-only Data Supplement give an overview of the distribution of mRS scores in patients of old age compared with those who were younger and of patients with extensive ischemic signs in the MCA territory compared with those without, respectively. The percentage of patients with moderately severe to severe disability (mRS, 4–5) in the elderly population was not significantly different from that in younger patients (n=10/49 [20.4%] versus 25/173 [14.5%]; P=0.375). Similar rates of moderately severe to severe disability were observed in patients with extensive ischemic signs compared with those without (n=11/68 [16.2%] versus 24/152 [15.8%]; P=1.000).

Patients who received endovascular treatment >8 hours after stroke onset had comparable rates of good outcome (P=0.821) and mortality (P=0.607) as those whose treatment began ≤8 hours after ictus.

Discussion

Thrombectomy with the Solitaire proved to be highly effective in our 81 patients with acute ischemic stroke of the anterior circulation and a median baseline NIHSS score of 15 who met standard inclusion criteria for endovascular stroke treatment. Reperfusion was successful in 70.4%, outcome was favorable in 57.7%, survival at 3 months was 88.6%, and symptomatic intraprocedural complications occurred in only 2.5%.

Successful reperfusion in patients fulfilling standard inclusion criteria was similar to previous studies (64%–100%).[1–14] Previously reported favorable clinical outcomes ranged from 29% to 77%, depending mainly on whether patients with posterior circulation strokes were included. The median NIHSS scores in these studies were generally high (median NIHSS scores, 15–38).[2,4,7,9,11,12,14,16,17,21]

Several previous studies with the Solitaire stent retriever excluded patients with an expected low chance of a favorable outcome (ie, patients with baseline NIHSS score >30, patients ≥80 years, patients with extensive ischemic signs in the MCA territory and patients treated >8 hours after symptom onset).[3–5,9,11,14,16–19] Notably, more than half of the patients in our series (64.1%) did not meet standard criteria. As this patient population generally constitutes a large part of patients treated at high-volume stroke centers, findings on outcome in this group are of particular importance.

Successful reperfusion rate in elderly patients was similar to that in younger patients. This indicates that age-related atherosclerotic changes do not influence technical success with the Solitaire, but favorable outcome (10.2%) and survival (55.1%) in patients ≥80 years of age were lower than in the younger cohort. Similar results were found in a retrospective comparison of patients ≥80 years of age and younger patients undergoing endovascular treatment for acute ischemic stroke.[25] It remains unknown what effect successful reperfusion in the elderly has on clinical outcome. IST-3 revealed similar treatment effects of intravenous thrombolysis in patients >80 years of age compared to younger patients, despite a generally worse outcome in the elderly.[26] It also has to be noted that in our series more than a third of patients of old age achieved a mRS score ≤3. Although mortality was markedly higher in the elderly, the percentage of patients with moderately severe to severe disability (mRS, 4–5) was not significantly different compared to that in younger patients (20.4% versus 14.5%; Figure I in the online-only Data Supplement). Apart from a significantly higher prevalence of atrial fibrillation in the elderly (n=32/44; 72.7%; P=0.002), we did not find any significant difference in imaging or clinical baseline characteristics, which could have acted as possible confounders on outcome.

Fewer patients with extensive ischemic signs in the MCA territory showed favorable outcomes (20.6%) and survival at 3 months (57.4%) compared with those who met standard inclusion criteria, and their sICH rates were markedly increased (19.1% versus 3.8%). Percentages of patients with moderately severe to severe disability (mRS, 4–5) were still similar in patients with extensive ischemic signs and those without (16.2% versus 15.8%; Figure II in the online-only Data Supplement). In our study, none of the patients with an MRI ASPECTS ≤3 or a CT ASPECTS ≤4 on pretreatment imaging reached a favorable outcome. This is in line with a previous report.[27] No unequivocally accepted definition of extensive ischemic signs in the MCA territory exists in literature. For reasons of comparability, we used the ASPECTS-based definition from the STAR trial.[14]

Outcome and survival in patients treated >8 hours after symptom onset did not differ from those treated ≤8 hours. This is most likely the result of patient selection and emphasizes the importance of imaging for treatment decision. We treated patients beyond 8 hours only when a considerable perfusion-diffusion mismatch and none or only minor signs of early ischemic changes were present. Despite the small size of this patient subgroup, which precludes from drawing firm conclusions, our results are in line with findings from previously published retrospective studies that showed that endovascular therapy might be used with acceptable safety >6 and 8 hours, respectively, after stroke onset.[28,29]

Symptomatic intraprocedural complications occurred in only 9 of 227 patients (4.0%). As in other studies with stent retrievers, vasospasm necessitating pharmacological spasmolysis was the most common complication, but it was not associated with an elevated risk for sICH or asymptomatic intracranial hemorrhage. Distal clot embolization was rarely observed (n=15/227 [6.6%]). In 4 of 11 patients (36.6%) with emboli directly associated with stent retriever thrombectomy, a distal access catheter (Outreach DAC; Concentric Medical, Mountain View, CA and VASCO+35 ASPI; Balt, Montmorency, France) was used. In 1 of these 4 patients, flow arrest was not achieved during stent retrieval because the balloon guiding catheter could not be inflated because of previous ICA stenting. First, distal access catheters were used with the intention to minimize the risk of embolic events by shortening the distance, the thrombus had to be retracted through the vessel and by providing additional aspiration during stent retrieval. Second, they were used to facilitate access in patients with tortuous or ectatic vascular anatomy.

In our study, the majority of endovascular interventions (86.3%) were performed under general anesthesia. Controversy exists about whether general anesthesia or conscious sedation should be preferred in endovascular stroke treatment.[30–32] In our series, patients undergoing treatment with conscious sedation had a significantly higher rate of good outcome compared with patients receiving general anesthesia. This finding could have been biased by the fact that almost all patients with severe stroke (NIHSS score >30 or extensive ischemic signs in the MCA territory) received general anesthesia. After exclusion of these patients, the difference in favorable outcome between the conscious sedation and general anesthesia group was no longer significant.

It has to be noted, that in more than half of the patients, other endovascular techniques apart from the Solitaire were used to achieve final revascularization. This emphasizes that traditional techniques such as intra-arterial thrombolysis or thromboaspiration still remain important complementary components of endovascular stroke treatment.

Limitations of our study are that data from imaging were partly analyzed retrospectively, although clinical data were collected prospectively. Moreover, our nonrandomized single-center study has the inherent limitation of a potential selection bias. Furthermore, this is not a randomized study, and only indirect comparisons with results of other studies are possible.

Nevertheless, despite limited comparability attributable to different revascularization techniques, favorable outcomes in patients who met standard inclusion criteria were more frequent

than in the active arm of PROACT II as well as the endovascular and intravenous thrombolysis arms of Interventional Management of Stroke-3.[24,33] This finding further supports the preferential use of stent retrievers compared with older thrombectomy devices or isolated intra-arterial thrombolysis.

Conclusions

Patients <80 years of age, without extensive pretreatment ischemic signs on brain imaging, and with a baseline NIHSS score ≤30 had high rates of favorable outcome and low periprocedural complication rates with Solitaire thrombectomy for ischemic stroke. Technical success was also high in patients not fulfilling standard inclusion criteria, but worse clinical outcomes in most of the nonstandard subgroups warrant further research to determine more precisely which individuals may benefit from stent retriever treatment.

Acknowledgments

Disclosures

References

1. Soize S, Barbe C, Kadziolka K, Estrade L, Serre I, Pierot L. Predictive factors of outcome and hemorrhage after acute ischemic stroke treated by mechanical thrombectomy with a stent-retriever. *Neuroradiology*. 2013;55:977–987.

2. Mourand I, Machi P, Milhaud D, Picot MC, Lobotesis K, Arquizan C, et al. Mechanical thrombectomy with the Solitaire device in acute basilar artery occlusion. *J Neurointerv Surg*. May 4, 2013. http://jnis.bmj.com/content/early/2013/05/03/neurintsurg-2012–010629.long. Accessed September 27, 2013.

3. Roth C, Reith W, Walter S, Behnke S, Kettner M, Viera J, et al. Mechanical recanalization with flow restoration in acute ischemic stroke: the ReFlow (mechanical recanalization with flow restoration in acute ischemic stroke) study. *JACC Cardiovasc Interv*. 2013;6:386–391.

4. Castaño C, Dorado L, Guerrero C, Millán M, Gomis M, Perez de la Ossa N, et al. Mechanical thrombectomy with the Solitaire AB device in large artery occlusions of the anterior circulation: a pilot study. *Stroke*. 2010;41:1836–1840.

5. Bae GS, Kwon HJ, Kang CW, Choi SW, Kim SH, Koh HS. Mechanical thrombectomy using a solitaire stent in acute ischemic stroke; initial experience in 40 patients. *J Cerebrovasc Endovasc Neurosurg*. 2012;14:164–169.

6. Andersson T, Kuntze Söderqvist Å, Söderman M, Holmin S, Wahlgren N, Kaijser M. Mechanical thrombectomy as the primary treatment for acute basilar artery occlusion: experience from 5 years of practice. *J Neurointerv Surg*. 2013;5:221–225.

7. Mordasini P, Brekenfeld C, Byrne JV, Fischer U, Arnold M, Heldner MR, et al. Technical feasibility and application of mechanical thrombectomy with the Solitaire FR Revascularization Device in acute basilar artery occlusion. *AJNR Am J Neuroradiol*. 2013;34:159–163.

8. Stampfl S, Hartmann M, Ringleb PA, Haehnel S, Bendszus M, Rohde S. Stent placement for flow restoration in acute ischemic stroke: a single-center experience with the Solitaire stent system. *AJNR Am J Neuroradiol*. 2011;32:1245–1248.

9. Machi P, Costalat V, Lobotesis K, Maldonado IL, Vendrell JF, Riquelme C, et al. Solitaire FR thrombectomy system: immediate results in 56 consecutive acute ischemic stroke patients. *J Neurointerv Surg*. 2012;4:62–66.

10. Dorn F, Stehle S, Lockau H, Zimmer C, Liebig T. Endovascular treatment of acute intracerebral artery occlusions with the solitaire

stent: single-centre experience with 108 recanalization procedures. *Cerebrovasc Dis*. 2012;34:70–77.

11. Costalat V, Machi P, Lobotesis K, Maldonado I, Vendrell JF, Riquelme C, et al. Rescue, combined, and stand-alone thrombectomy in the management of large vessel occlusion stroke using the solitaire device: a prospective 50-patient single-center study: timing, safety, and efficacy. *Stroke*. 2011;42:1929–1935.

12. Dávalos A, Pereira VM, Chapot R, Bonafé A, Andersson T, Gralla J; Solitaire Group. Retrospective multicenter study of Solitaire FR for revascularization in the treatment of acute ischemic stroke. *Stroke*. 2012;43:2699–2705.

13. Espinosa de Rueda M, Parrilla G, Zamarro J, García-Villalba B, Hernández F, Moreno A. Treatment of acute vertebrobasilar occlusion using thrombectomy with stent retrievers: initial experience with 18 patients. *AJNR Am J Neuroradiol*. 2013;34:1044–8.

14. Pereira VM, Gralla J, Davalos A, Bonafé A, Castaño C, Chapot R, et al. Prospective, multicenter, single-arm study of mechanical thrombectomy using solitaire flow restoration in acute ischemic stroke. *Stroke*. 2013;44:2802–2807.

15. Rha JH, Saver JL. The impact of recanalization on ischemic stroke outcome: a meta-analysis. *Stroke*. 2007;38:967–973.

16. Cohen JE, Rabinstein AA, Ramirez-de-Noriega F, Gomori JM, Itshayek E, Eichel R, et al. Excellent rates of recanalization and good functional outcome after stent-based thrombectomy for acute middle cerebral artery occlusion. Is it time for a paradigm shift? *J Clin Neurosci*. 2013;20:1219–1223.

17. Saver JL, Jahan R, Levy EI, Jovin TG, Baxter B, Nogueira RG, et al; SWIFT Trialists. Solitaire flow restoration device versus the Merci Retriever in patients with acute ischaemic stroke (SWIFT): a randomised, parallel-group, non-inferiority trial. *Lancet*. 2012;380:1241–1249.

18. Mpotsaris A, Bussmeyer M, Buchner H, Weber W. Clinical outcome of neurointerventional emergency treatment of extra- or intracranial tandem occlusions in acute major stroke: antegrade approach with wall stent and solitaire stent retriever. *Clin Neuroradiol*. 2013;23:207–215.

19. Miteff F, Faulder KC, Goh AC, Steinfort BS, Sue C, Harrington TJ. Mechanical thrombectomy with a self-expanding retrievable intracranial stent (Solitaire AB): experience in 26 patients with acute cerebral artery occlusion. *AJNR Am J Neuroradiol*. 2011;32:1078–1081.

20. Sacks D, Black CM, Cognard C, Connors JJ III, Frei D, Gupta R, et al. Multisociety consensus quality improvement guidelines for intraarterial catheter-directed treatment of acute ischemic stroke, from the American Society of Neuroradiology, Canadian Interventional Radiology Association, Cardiovascular and Interventional Radiological Society of Europe, Society for Cardiovascular Angiography and Interventions, Society of Interventional Radiology, Society of Neurointerventional Surgery, European Society of Minimally Invasive Neurological Therapy, and Society of Vascular and Interventional Neurology. *J Vasc Interv Radiol*. 2013;24:151–63.

21. Brekenfeld C, Schroth G, Mordasini P, Fischer U, Mono ML, Weck A, et al. Impact of retrievable stents on acute ischemic stroke treatment. *AJNR Am J Neuroradiol*. 2011;32:1269–1273.

22. Pexman JH, Barber PA, Hill MD, Sevick RJ, Demchuk AM, Hudon ME, et al. Use of the Alberta Stroke Program Early CT Score (ASPECTS) for assessing CT scans in patients with acute stroke. *AJNR Am J Neuroradiol*. 2001;22:1534–1542.

23. Higashida RT, Furlan AJ, Roberts H, Tomsick T, Connors B, Barr J, et al; Technology Assessment Committee of the American Society of Interventional and Therapeutic Neuroradiology; Technology Assessment Committee of the Society of Interventional Radiology. Trial design and reporting standards for intra-arterial cerebral thrombolysis for acute ischemic stroke. *Stroke*. 2003;34:e109–e137.

24. Furlan A, Higashida R, Wechsler L, Gent M, Rowley H, Kase C, et al. Intra-arterial prourokinase for acute ischemic stroke. The PROACT II study: a randomized controlled trial. Prolyse in Acute Cerebral Thromboembolism. *JAMA*. 1999;282:2003–2011.

25. Mono ML, Romagna L, Jung S, Arnold M, Galimanis A, Fischer U, et al. Intra-arterial thrombolysis for acute ischemic stroke in octogenarians. *Cerebrovasc Dis*. 2012;33:116–122.

26. Sandercock P, Wardlaw JM, Lindley RI, Dennis M, Cohen G, Murray G, et al; IST-3 Collaborative Group. The benefits and harms of intravenous thrombolysis with recombinant tissue plasminogen activator within 6 h of acute ischaemic stroke (the third international stroke trial [IST-3]): a randomised controlled trial. *Lancet*. 2012;379:2352–2363.

27. Goyal M, Menon BK, Coutts SB, Hill MD, Demchuk AM; Penumbra Pivotal Stroke Trial Investigators, Calgary Stroke Program, and the Seaman MR Research Center. Effect of baseline CT scan appearance and time to recanalization on clinical outcomes in endovascular thrombectomy of acute ischemic strokes. *Stroke*. 2011;42:93–97.

28. Jung S, Gralla J, Fischer U, Mono ML, Weck A, Lüdi R, et al. Safety of endovascular treatment beyond the 6-h time window in 205 patients. *Eur J Neurol*. 2013;20:865–871.

29. Jovin TG, Liebeskind DS, Gupta R, Rymer M, Rai A, Zaidat OO, et al. Imaging-based endovascular therapy for acute ischemic stroke due to proximal intracranial anterior circulation occlusion treated beyond 8 hours from time last seen well: retrospective multicenter analysis of 237 consecutive patients. *Stroke*. 2011;42:2206–2211.

30. Jumaa MA, Zhang F, Ruiz-Ares G, Gelzinis T, Malik AM, Aleu A, et al. Comparison of safety and clinical and radiographic outcomes in endovascular acute stroke therapy for proximal middle cerebral artery occlusion with intubation and general anesthesia versus the nonintubated state. *Stroke*. 2010;41:1180–1184.

31. Abou-Chebl A, Lin R, Hussain MS, Jovin TG, Levy EI, Liebeskind DS, et al. Conscious sedation versus general anesthesia during endovascular therapy for acute anterior circulation stroke: preliminary results from a retrospective, multicenter study. *Stroke*. 2010;41:1175–1179.

32. Brekenfeld C, Mattle HP, Schroth G. General is better than local anesthesia during endovascular procedures. *Stroke*. 2010;41:2716–2717.

33. Broderick JP, Palesch YY, Demchuk AM, Yeatts SD, Khatri P, Hill MD, et al; Interventional Management of Stroke (IMS) III Investigators. Endovascular therapy after intravenous t-PA versus t-PA alone for stroke. *N Engl J Med*. 2013;368:893–903.

Outcome of standard and high risk patients with acute anterior circulation stroke after stent retriever thrombectomy

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SUPPLEMENTAL TABLES

Supplementary Table I. **Additional Baseline Imaging Characteristics of 227 Patients Treated With the Solitaire**

	Overall (n=227)	Patients meeting standard criteria (n=81)	NIHSS <8 (n=27)	NIHSS >30 (n=11)	Age ≥80 years (n=50)	Extensive ischemic signs in MCA territory (n=69)	Time from symptom onset to arterial puncture >8 hours (n=22)
MRI ASPECTS, median (range)	6 (0—10)	7 (5—10)	7 (4—10)	5 (4—6)	7 (3—10)	3.5 (0—4)	6.5 (3—10)
CT ASPECTS, median (range)	8 (2—10)	9 (7—10)	10 (9—10)	6 (4—8)	8 (4—10)	5 (0—6)	8.5 (5—10)
Leptomeningeal collaterals	n=226					n=68	
Good	74 (32.7)	30 (37.0)	14 (51.9)	2 (18.2)	18 (36.0)	9 (13.2)	10 (45.5)
Moderate	110 (48.7)	41 (50.6)	12 (44.4)	5 (45.5)	19 (38.0)	38 (55.9)	7 (31.8)
Poor	42 (18.6)	10 (12.3)	1 (3.7)	4 (36.4)	13 (26.0)	21 (30.9)	5 (22.7)

NIHSS indicates National Institutes of Health Stroke Scale; MCA, middle cerebral artery; ASPECTS, Alberta Stroke Program Early CT Score.

Supplementary Table II.   Additional Endovascular Treatment Details

|	Overall (n=227)	Patients meeting standard criteria (n=81)	NIHSS <8 (n=27)	NIHSS >30 (n=11)	Age ≥80 years (n=50)	Extensive ischemic signs in MCA territory (n=69)	Time from symptom onset to arterial puncture >8 hours (n=22)
Reperfusion grade							
TICI 3, n (%)	84 (37.0)	32 (39.5)	11 (40.7)	3 (27.3)	16 (32.0)	24 (34.8)	7 (31.8)
TICI 2b, n (%)	77 (33.9)	25 (30.9)	12 (44.4)	4 (36.4)	21 (42.0)	19 (27.5)	8 (36.4)
TICI 2a, n (%)	32 (14.1)	12 (14.8)	3 (11.1)	2 (18.2)	7 (14.0)	13 (18.8)	3 (13.6)
TICI 1, n (%)	13 (5.7)	7 (8.6)	1 (3.7)	1 (9.1)	0 (0.0)	3 (4.3)	2 (9.1)
TICI 0, n (%)	21 (9.3)	5 (6.2)	0 (0.0)	1 (9.1)	6 (12.0)	10 (14.5)	2 (9.1)
Use of distal access catheter	91 (40.1)	28 (34.6)	9 (33.3)	5 (45.5)	17 (34.0)	34 (49.3)	13 (59.1)
Multimodal endovascular therapy							
Thromboaspiration, n (%)	63 (27.8)	19 (23.5)	7 (25.9)	2 (18.2)	11 (22.0)	23 (33.3)	10 (45.5)
Intraarterial thrombolysis with urokinase, n (%)	52 (22.9)	20 (24.7)	8 (29.6)	2 (18.2)	10 (20.0)	17 (24.6)	2 (9.1)
Stent intracranial (Solitaire), n (%)	8 (3.5)	3 (3.7)	0 (0.0)	1 (9.1)	2 (4.0)	2 (2.9)	3 (13.6)
Stent intracranial (other), n (%)	4 (1.8)	2 (2.5)	0 (0.0)	1 (9.1)	1 (2.0)	1 (1.4)	0 (0.0)
Stent extracranial, n (%)	33 (14.5)	13 (16.0)	6 (22.2)	1 (9.1)	0 (0.0)	9 (13.0)	5 (22.7)
Anesthesia							
General anesthesia, n (%)	196 (86.3)	70 (84.4)	16 (59.3)	11 (100)	44 (88.0)	67 (97.1)	19 (86.4)
Conscious sedation, n (%)	31 (13.7)	11 (13.6)	11 (40.7)	0 (0.0)	6 (12.0)	2 (2.9)	3 (13.6)

NIHSS indicates National Institutes of Health Stroke Scale; MCA, middle cerebral artery; TICI, Thrombolysis in Cerebral Infarction.

**Supplementary Table III.   Overview of Intra-Procedural Complications**

	Overall (n=227)	Patients meeting standard criteria (n=81)	NIHSS <8 (n=27)	NIHSS >30 (n=11)	Age ≥80 years (n=50)	Extensive ischemic signs in MCA territory (n=69)	Time from symptom onset to arterial puncture >8 hours (n=22)
Patients with symptomatic intra-procedural complications, n (%)	9 (4.0)	2 (2.5)	2 (7.4)	0 (0.0)	1 (2.0)	4 (5.8)	0 (0.0)
Total of patients with intra-procedural complications, n (%)	74 (32.6)	25 (30.9)	8 (29.6)	5 (45.5)	13 (26.0)	23 (33.3)	9 (40.9)
Occurrence rate of different complications							
Dissection, n (%)	11 (4.8)	3 (3.7)	1 (3.7)	0 (0.0)	2 (4.0)	4 (5.8)	1 (4.5)
Vessel perforation, n (%)	2 (0.9)	1 (1.2)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.4)	0 (0.0)
Severe vasospasm, n (%)	43 (18.9)	16 (19.8)	6 (22.2)	2 (18.2)	4 (8.0)	11 (15.9)	7 (31.8)
In-stent thrombosis, n (%)	8 (3.5)	1 (1.2)	3 (11.1)	1 (9.1)	2 (4.0)	3 (4.3)	0 (0.0)
Device failure (Solitaire), n (%)	1 (0.4)	1 (1.2)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Device failure (other), n (%)	2 (0.9)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (2.9)	0 (0.0)
Embolization, n (%)	15 (6.6)	5 (6.2)	0 (0.0)	2 (18.2)	5 (10.0)	6 (8.7)	1 (4.5)
Immediate reperfusion hemorrhage, n (%)	1 (0.4)	1 (1.2)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Other, n (%)	1 (0.4)	0 (0.0)	0 (0.0)	0 (0.0)	1 (2.0)	1 (1.4)	0 (0.0)

NIHSS indicates National Institutes of Health Stroke Scale; MCA, middle cerebral artery.

SUPPLEMENTAL FIGURES
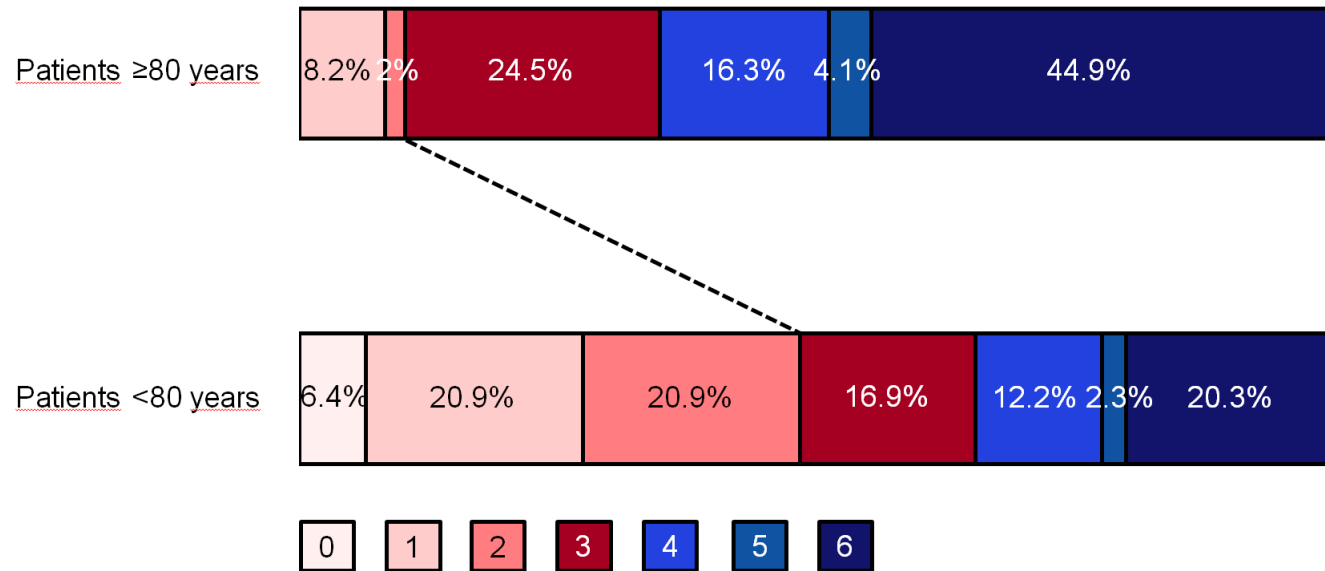
Supplementary Figure I. Comparison of 3-month modified Rankin Scale scores of disability between patients ≥80 (n=49) and those <80 years of age (n=173).
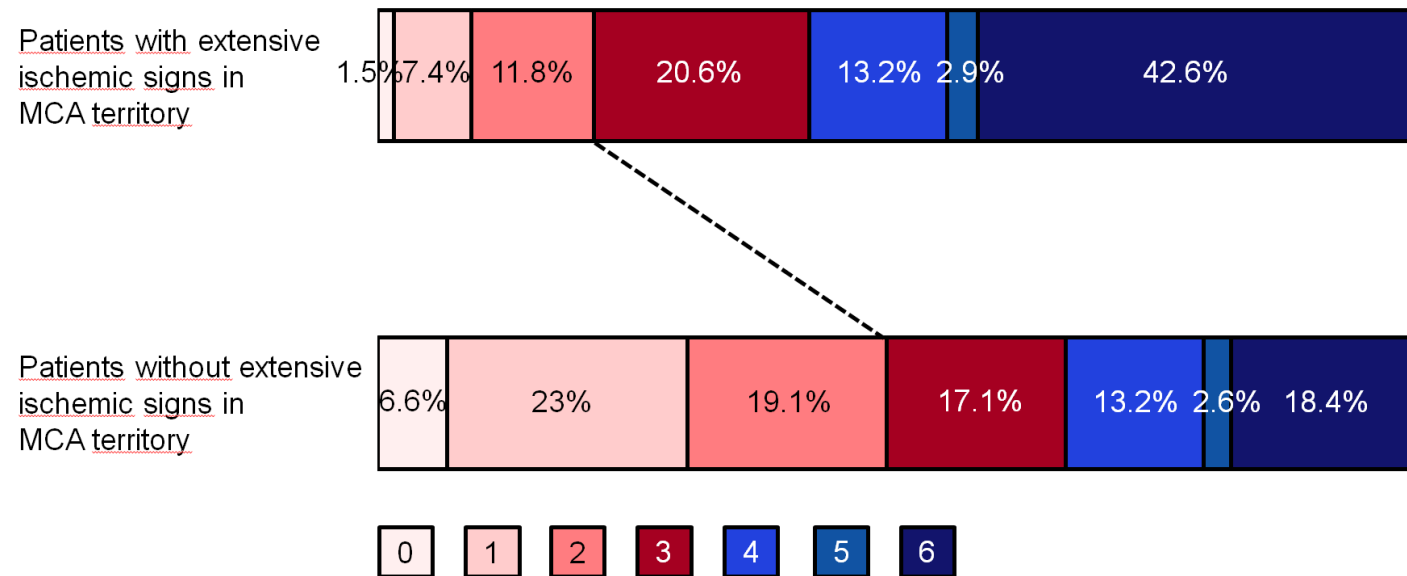
Supplementary Figure II. Comparison of 3-month modified Rankin Scale scores of disability between patients with early extensive ischemic signs in the MCA territory (n=68) and those without (n=157).