Journal of Neuroradiology 46 (2019) 141–147

Available online at ScienceDirect www.sciencedirect.com

Elsevier Masson France EM|consulte www.em-consulte.com

Original article

Bail-out intracranial stenting with Solitaire AB device after unsuccessful thrombectomy in acute ischemic stroke of anterior circulation

Sergio Nappini[a,*], Nicola Limbucci[a], Giuseppe Leone[b], Andrea Rosi[a], Leonardo Renieri[a], Arturo Consoli[a], Antonio Laiso[a], Iacopo Valente[c], Francesco Rosella[c], Riccardo Rosati[d], Salvatore Mangiafico[a]

[a] *Neurovascular Interventional Unit, Careggi University Hospital, Florence. Largo P. Palagi, 1-50134 Florence, Italy*
[b] *Department of Advanced Biomedical Sciences, Federico II University of Naples, Naples, Italy*
[c] *Department of Bioimaging and Radiological Sciences, Institute of Radiology, "A. Gemelli" Hospital-Catholic University, Rome, Italy*
[d] *Vascular and Interventional Radiology Unit, Department of Radiological, Oncological and Anatomo-pathological Sciences, Sapienza University of Rome, Rome, Italy*

ARTICLE INFO

Article history:
Available online 18 June 2018

Keywords:
Stroke
Thrombectomy
Stents
Reperfusion
Arteries

ABSTRACT

Background. – Recent trials established the efficacy of mechanical stent-retriever thrombectomy for treatment of stroke patients with large vessel occlusion (LVO) in the anterior circulation. However, stent-retriever thrombectomy may not accomplish successful recanalization in all patients. The aim of this study is to report the role of bail-out permanent stenting after failure of mechanical thrombectomy.
Methods. – Among 430 patients included in a prospectively maintained database, we analysed 325 cases of anterior circulation LVO. Mechanical thrombectomy (mTICI 2b-3) was effective in 213/325 (65%) and failed in 112/325 (35%). Bail-out intracranial stenting was performed in 17/325 (5.2%) patients. In all cases a fully retrievable detachable stent was used (Solitaire AB, Medtronic).
Results. – No intraprocedural technical complications occurred. Successful reperfusion (mTICI 2b/3) was achieved in 12/17 patients (70.6%). Three (17.6%) patients died: one extensive infarction in the internal carotid artery territory, one large intracerebral haemorrhage, and one massive pulmonary embolism. Haemorrhagic conversion, both symptomatic and asymptomatic, occurred in 2/17 (11.7%). Good clinical outcome (mRS 0–2) at 3-months was achieved in 41.2% of patients.
Conclusion. – Bail-out intracranial stenting after unsuccessful thrombectomy is technically feasible and the associated haemorrhagic risk seems acceptable in selected patients. We suggest that bail-out intracranial stenting, is safe and effective in selected patients with LVO stroke who failed to respond to thrombectomy.

Introduction

There is growing evidence of the efficacy of mechanical thrombectomy (MT) with stent-retrievers for the treatment of acute ischemic stroke (AIS) due to large vessel occlusion (LVO) in the anterior circulation, as demonstrated by recent large clinical trials [1–5]. However, adequate recanalization (mTICI 2b/3) was not achieved in 29% of trial cases [6]. Stent-retriever failure may occur due to anatomical challenges (e.g., a tortuous arterial tree from the aortic arch to the target occlusion site), large clot burden, tandem occlusion, clot characteristics (fresh versus organized clot) [7,8], as well as different etiology (embolic versus non-embolic occlusion) [9].

Some treatment strategies such as intra-arterial chemical thrombolysis [10] or primary intracranial stenting have been proposed [11–21]. Particularly, permanent self-expanding stent placement has been evaluated as a primary approach [13,14] or as a rescue tool for recanalization of acute intracranial LVO [22–24].

* Corresponding author.
E-mail addresses: nappini@gmail.com (S. Nappini), nicolalimb@gmail.com (N. Limbucci), g.leonemd@gmail.com (G. Leone), andrea.rosi87@gmail.com (A. Rosi), leonardo.renieri@hotmail.it (L. Renieri), onemed21@gmail.com (A. Consoli), antoniolaiso07@gmail.com (A. Laiso), iacopovalentemd@gmail.com (I. Valente), francesco.rosella.md@gmail.com (F. Rosella), dopliker@yahoo.it (R. Rosati), mangiax@libero.it (S. Mangiafico).

https://doi.org/10.1016/j.neurad.2018.05.004
0150-9861/

Although intracranial stenting is not widely used for the treatment of AIS due to LVO, this technique may achieve a good recanalization rate. In a recent multicenter study, rescue intracranial stenting (RS) led to recanalization in 64.6% of cases and to a good clinical outcome in 39.6% of patients [24]. This procedure can achieve rapid flow restoration by means of an endovascular bypass of the clot, however the main drawback of this technique is the necessity of dual antiplatelet therapy, which can be harmful in patients with AIS [25].

The aim of this study is to report our experience with intracranial stenting as a bail-out procedure after failure of MT.

Materials and methods

Study design

We retrospectively reviewed all patients with AIS treated with endovascular thrombectomy at our Institution between July 2010 and February 2016. Among 430 cases included in a prospectively maintained database, we selected 325 patients with anterior circulation LVO. Tandem occlusions were included. Patients with intracranial arterial dissections and intracranial stenosis were excluded. MT was successful (mTICI 2b-3) in 213/325 (65%) patients and failed in 112/325 (35%). Bail-out intracranial stenting was performed in 17/112 (15.2%) patients who underwent unsuccessful MT. This population was selected and analysed.

The population was stratified according to age, sex, occlusion site, National Institutes of Health Stroke Scale (NIHSS), Glasgow Coma Scale (GCS), Modified Rankin Scale (mRS) and Alberta Stroke Program Early CT score (ASPECTS) at baseline. Vascular risk factors such as arterial hypertension, diabetes mellitus, hypercholesterolemia, smoking (current or stopped within five years), coronary artery disease (history of angina pectoris, myocardial infarction, previous coronary artery recanalization or by-pass surgery), cardiac arrhythmia such as atrial fibrillation, were also assessed. Time to groin, angiographic collateral circulation scale according to the Careggi Collateral Scale (CCS) [26,27], eventual systemic thrombolytic therapy and endovascular technique were also reported. Collateral circulation was classified as good if the CCS was class 3 or higher.

The degree of recanalization was measured by the modified treatment in cerebral ischemia (mTICI) scale at final angiographic runs, which were reviewed by an experienced neuroradiologist; successful recanalization was defined as mTICI 2b/3. Intraprocedural complications, intracerebral haemorrhage score according to ECASS I trial [28] and ASPECTS at discharge CT were evaluated. NIHSS after the procedure, at 24 hours and at discharge were recorded.

Clinical outcome was assessed by a neurologist who was not involved in the endovascular procedures using the mRS at 3 months. Good clinical outcome was defined as mRS 0–2 at 3-month follow-up.

Population

We enrolled 17 consecutive patients (10 M, 7 F), mean age 62 years (37–80). Patients characteristics are summarized in Table 1. Comorbidities included: hypertension in 8/17 (47%), diabetes mellitus in 3/17 (17.6%), hypercholesterolemia in 4/17 (23.5%), coronary artery disease in 2/17 (11.7%), atrial fibrillation in 4/17 (23.5%), smoking in 6/17 (35.3%). Mean NIHSS was 20 (range 9–35); mRS at the admission was 0 in 16 patients and mRS 1 in 1 patient (5%). Mean GCS was 12 (range 7–15). Mean ASPECTS at admission was 9 (range 7 to 10).

Table 1
Demographic and clinical characteristics.

Sex	10 M (59%) 7 F (41%)
Age (years) + ranges	62 (37–80)
Hypertension	8/17 (47%)
Diabetes mellitus	3/17 (17.6%)
Hypercholesterolemia	4/17 (23.5%)
Smoking	6/17 (35.3%)
Coronary syndrome	2/17 (11.7%)
Atrial fibrillation	4/17 (23.5%)
NIHSS at admission (average, range)	20 (9–35)
mRS at admission (average, range)	0 (0–1)
GCS at admission (average, range)	12 (7–15)
ASPECTS (average, range)	9 (7–10)
Occlusion site	
ICA + MCA	8/17 (47.1%)
ICA T siphon	2/17 (11.8%)
MCA (M1)	7/17 (41.1%)
Side	
Right	4/17 (23.5%)
Left	13/17 (76.5%)
Systemic thrombolysis	
Yes	8/17 (47%)
No	9/17 (53%)

NIHSS: National Institutes of Health Stroke Scale; mRS: modified Rankin Scale; GCS: Glasgow Coma Scale; ASPECTS: Alberta Stroke Program Early CT score.

Overall, 8 patients (47%) underwent systemic thrombolytic therapy with rt-PA; the other patients had contraindications to systemic thrombolysis. Mean onset-to-groin puncture time was 263′ (ranging between 165′ and 403′) in the patients with a known onset time. Two patients had a wake-up stroke, with average mean last time seen normal time 600′.

The location of the arterial occlusion involved both the internal carotid artery (ICA) origin and the middle cerebral artery (MCA) in 8/17 patients (47.1%) (tandem occlusions), the carotid siphon in 2/17 (11.8%) and the MCA in 7/17 (41.1%) patients. Four occlusions (23.5%) were located on the right side and 13 (76.5%) on the left one. The cervical internal carotid occlusions were sustained by dissections in 6 cases and atherosclerotic lesions in 2 cases. In 70.6% of cases the collateral circulation was good since the CCS was classified as class 3 or higher (Table 2).

Endovascular treatment and medication

Inclusion criteria to MT were AIS with NIHSS $\geq$ 6 and onset time < 6 hours. All patients underwent base CT and CT-angiography (CTA) before endovascular treatment. Neuroradiological inclusion criteria were ASPECTS $\geq$ 6 and anterior circulation LVO at CTA. Digital subtraction angiography and endovascular thrombectomy

Table 2
Endovascular procedures.

Onset to puncture time (average, range)	
16/18 (89%)	236 minutes (165–403)
2/18 (11%) Wake-up stroke	600 minutes (480–720)
CCS scale	
CCS1	1/17 (5.9%)
CCS2	4/17 (23.5%)
CCS3	8/17 (47.1%)
CCS4	3/17 (17.6%)
CCS5	1/17 (5.9%)
Number of thrombectomy attempts before stenting (median)	4
Concomitant CAS	8/17 (47.1%)
Intraprocedural technical complications	0%
Antiplatelet therapy at 24 hours	
Dual antiplatelet	13/17 (76.4%)

CCS: Careggi Collateral Stroke Scale; CAS: carotid artery stenting.

were performed in all patients. Persistent arterial occlusion after thrombectomy was related to inability to remove the clot, whereas intracranial stenosis was not considered an inclusion criteria. Angiographic collateral circulation was estimated according to CCS [27].

Under conscious sedation an 8-Fr balloon-guiding catheter (Merci, Concentric, Stryker) was positioned in the ICA. In all patients with ICA origin occlusion, a carotid stent (Wallstent, Boston Scientific, Natick, MA) was placed before intracranial thrombectomy. Then the guiding catheter was advanced beyond the stent into the distal cervical ICA. The intracranial occlusion was crossed with a microcatheter (Rebar 18 or 27, Medtronic) and stent-retriever thrombectomy was performed with a Solitaire (Medtronic) in 15 cases (88%) or Trevo in 2 cases (12%) (Stryker Neurovascular). Retrieval was attempted for a maximum of 4 times with the same device, but in three patients 2 further attempts were performed with a different device.

After stent-retriever thrombectomy failure, we evaluated the opportunity to deploy a permanent stent in the occluded segment (Solitaire AB, Medtronic). A 4×20 or 4×30 stent was used in the MCA and 6×30 in the carotid syphon. The main indication for permanent stenting was effectiveness of flow restoration when the device was in place, with reocclusion or residual severe stenosis after retrieval. Successful recanalization was defined when mTICI 2b-3 recanalization was persistent on a delayed angiogram acquired at least a 15-minute after stent deployment. After stent detachment, an i.v. bolus of Tirofiban (Aggrastat) was administered according to the weight (25 mcg/kg) in 3 minutes, followed by a 12-hours i.v. infusion (0.1 mcg/kg). After 12 hours CT was performed to rule-out asymptomatic or symptomatic intracerebral haemorrhage (SICH) and, if no bleeding was reported, aspirin 300 mg and loading dose of clopidogrel (300 mg) were administered. Dual antiplatelet treatment with aspirin 100 mg and clopidogrel 75 mg was continued for 3 months followed by a lifelong single antiplatelet treatment with aspirin.

Clinical and neuroradiological follow-up

CT was repeated after 24 hours and at discharge. In case of a neurological deterioration (an increase in NIHSS score ≥ 4) emergency CT was repeated to rule out ICH.

Clinical and functional outcome was assessed by a neurologist who was not involved in the endovascular procedures using the mRS at 3 months. Good clinical outcome was defined as mRS 0–2 at 3-month follow-up.

Treated vessel and stent patency was assessed by 3 CTA or Magnetic Resonance Angiography (MRA) after 3 months.

Results

Recanalization rate

No periprocedural technical complication occurred. Bail-out stenting achieved successful reperfusion (mTICI 2b/3) in 12/17 patients (70.6%): mTICI 3 in 6 (35.3%) and a mTICI 2b in 6 (35.3%) (Fig. 1). Recanalization was unsuccessful in 5/17 patients (29.4%) (Table 3). In 3 of these patients the stent achieved partial unsatisfactory flow restoration (mTICI 2a); in 2 patients, the stent initially achieved flow restoration but lately occluded at serial angiographic runs after the detachment.

Clinical results

Ten patients (58.8%) clinically improved after 24 hours with average NIHSS of 15 (ranging from 3 to 29). Haemorrhage occurred

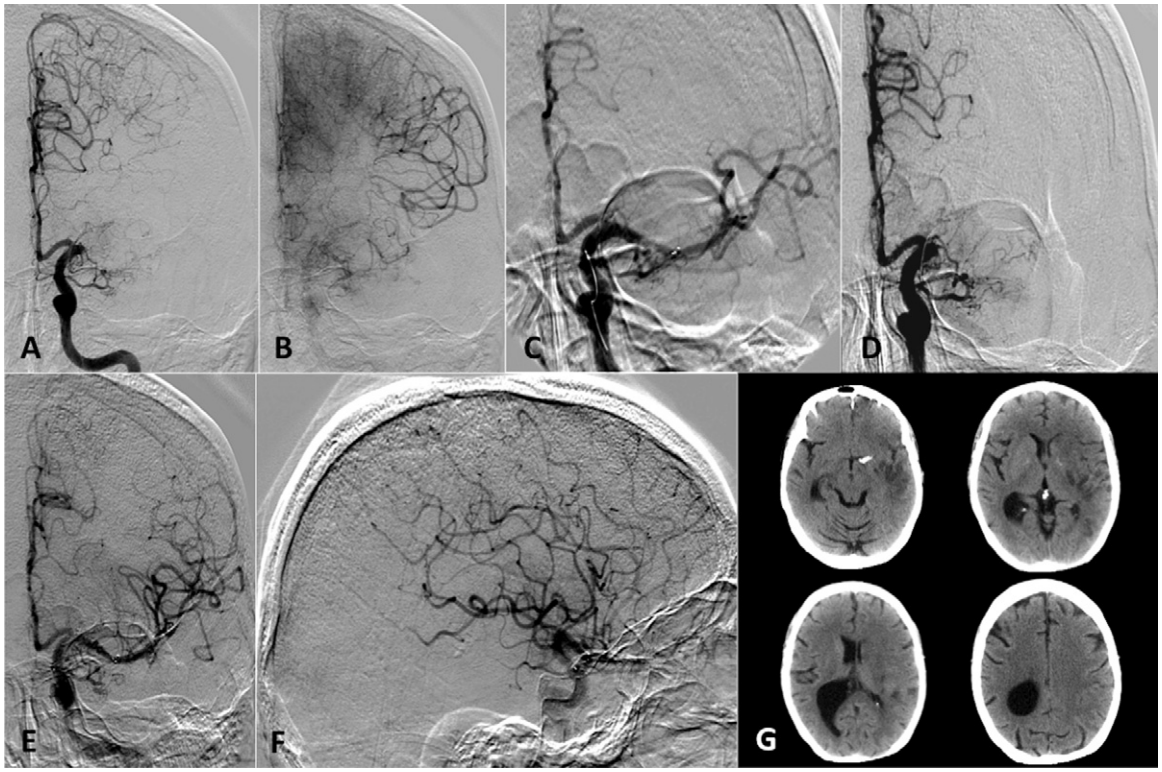

Fig. 1. (A) Patient presenting with occlusion of M1 proximal segment of the MCA. (B). Good Leptomeningeal collateral circulation through the anterior cerebral artery. (C). Deployment of the Solitaire AB (4×30 mm): bypass phenomenon through the stent is evident. (D). Recanalization failure after 4 thrombectomy attempts. (E, F). Restored flow after Solitaire AB deployment and subsequent detachment. (H). CT scan at 1 month shows infarction of the left basal ganglia and of the ipsilateral anterior temporal lobe.

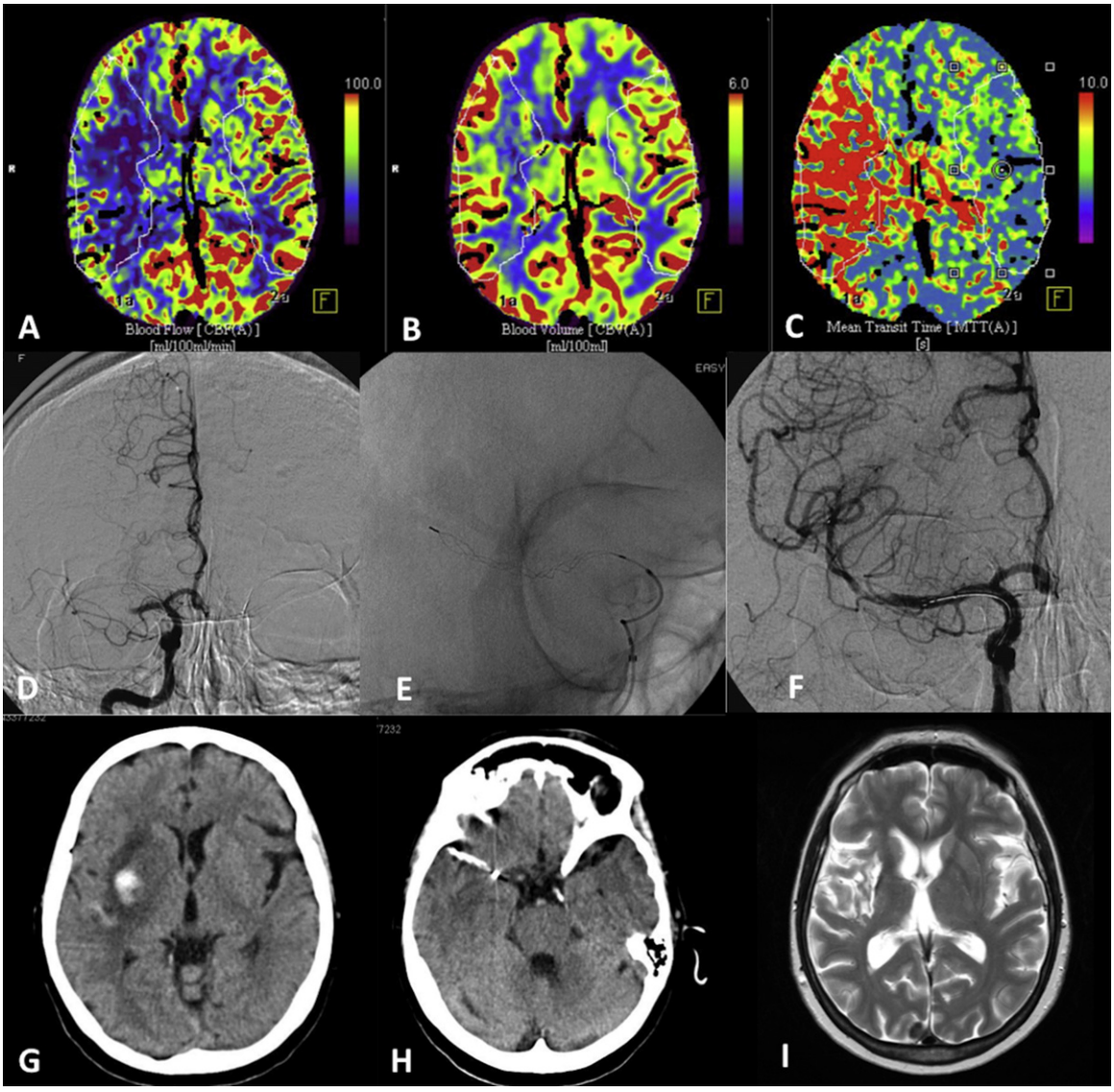

Fig. 2. (A, B, C). Patient presenting with occlusion of the right MCA; pre-treatment CT perfusion shows wide perfusional mismatch in the MCA territory. (D). Angiographic study shows occlusion of the proximal M1 segment of the right MCA. (E). Recanalization failure after 4 thrombectomy attempts with Trevo stent-retriever. (F). Restored flow after Solitaire detachment. (G, H). CT scan at 72 h shows haemorragic conversion (PH1) of the right basal ganglia. (I). MR (TSE T2-w) at 3 months shows late chronic stage hemorrhagic lesion of the right lenticular nucleus.

in 2 patients (11.7%), one classified as PH1 (Fig. 2) and one as PH2. At discharge, the mean NIHSS was 10 (ranging from 0 to 23).

At discharge, the functional evaluation was good (mRS 0–2) in 3 patients (17.7%), and unfavourable (mRS 3–5) in 11 patients (64.6%). Three patients (17.7%) died in hospital; none of them had undergone thrombolytic treatment. An octogenarian with previous history of hypertension and diabetes mellitus, poor collateral circulation (CCS2) at angiography, T-siphon occlusion and unsuccessful recanalization (mTICI 0) died after large brain infarction. Another octogenarian died for hemispheric haemorrhagic transformation after successful recanalization of a M1 occlusion. The third death occurred in a sexagenarian because of massive pulmonary embolism and subsequent acute respiratory distress syndrome 48 hours after successful MCA recanalization.

At 3-months clinical follow-up 7/17 patients (41.2%) had a favourable outcome (mRS 0–2) with substantial improvement or stability of mRS in all of them (Table 3). Target vessel and stent patency was confirmed at follow-up neuroimaging evaluation in all alive patients. Correlation of the occlusion site with mTICI and with mRS at 3 months is showed on Tables 4 and 5.

Discussion

Since the publication of large clinical trials, stent-retriever thrombectomy has been recognized as the new standard of care in association with intravenous thrombolysis for AIS due to LVO [1–5]. Nevertheless, adequate recanalization is not always achieved, as the failure rate of thrombectomy is about 30% [5,6]. Acute intracranial stenting after failure of intra-arterial fibrinolysis or other endovascular techniques has been reported by some retrospective studies before the advent of MT [11–21]. The rationale of permanent stenting is to obtain an endovascular by-pass of the clot, in order to achieve fast flow restoration. Despite some encouraging results, primary stenting has not gained wide acceptance and it is regarded an off-label procedure. Intracranial stenting requires dual antiplatelet therapy or glycoprotein-IIb/IIIa (GpIIb/IIIa) inhibitor administration, which may increase the risk hemorrhagic after cerebral infarction [25,29].

RS after failure of MT has been evaluated in two series [22,23] and in a recent large multicenter study [24].

Table 3
Clinical outcome and follow-up.

Reperfusion rate mTICI	mTICI 0		1/17 (5.9%)	
	mTICI 1		1/17 (5.9%)	
	mTICI 2a		3/17 (17.6%)	
	mTICI 2b		6/17 (35.3%)	
	mTICI 3		6/17 (35.3%)	
Parenchimal hemorrhage	PH1	1/17 (5.9%)		
	PH2	1/17 (5.9%)		
Death	3/17 (17.6%)			
NIHSS at 24 hours (average, range)	15 (3–29)			
ASPECTS at 24 hours	7 (0–10)			
ASPECTS at discharge (range) (median 7 days)	6 (0–10)			
NIHSS at discharge (range) (median 7 days)	10 (0–23)			
mRS at discharge	0–2	3/17 (17.7%)	0	1/17 (5.9%)
			1	–
			2	2/17 (11.8%)
	3–5	11/17 (64.6%)	3	3/17 (17.6%)
			4	3/17 (17.6%)
			5	5/17 (29.4%)
	6	3/17 (17.7%)		
mRS at 3 months	0–2	7/17 (41.2%)	0	2/17 (11.8%)
			1	1/17 (5.9%)
			2	4/17 (23.5%)
	3–5	7/17 (41.2%)	3	3/17 (17.6%)
			4	2/17 (11.8%)
			5	2/17 (11.8%)
	6	3/17 (17.6%)		

mTICI: modified treatment in cerebral ischemia; PH1: parenchimal hematoma 1; PH2: parenchimal hematoma 2.

The first series of RS was published by Beak et al. [22]. They retrospectively analyzed 17 consecutive patients who underwent permanent stenting after failure of thrombectomy, comparing this population with 28 patients who failed thrombectomy but did not undergo any rescue treatment. Stenting group had 83.3% of adequate recanalization rate and a more favorable outcome (mRS 0–2 35.3 vs. 7.1%). SICH (stenting 11.8 vs. untreated 14.3%) and mortality rate (stenting 23.5 vs. untreated 39.3%) did not significantly differ between the two groups. The single center series of Baracchini et al. [23], analyzed a group of 23 patients, treated by RS. Successful recanalization (mTICI 2b/3) was obtained in 73.9% cases. RS patients had significantly better outcome (mRS 0–2 56.5%) compared to patients who did not underwent RS after failed thrombectomy (mRS 0–2 17.4%), with lower mortality (4.3 vs. 39.1%). Interestingly SICH rate did not differ between the two groups (4.3 vs. 4.3%).

The largest experience with RS was published by Chang et al. [24]. In this multicenter series, RS was evaluated analyzing a retrospective cohort of 16 centers. RS patients had significantly higher good outcome rate compared to patients who did not underwent RS (mRs 0–2 39.6 vs. 22%). No significant difference in SICH rate (16.7 vs. 20%) and mortality rate (12.5 vs. 19%) were reported. Among RS patients, those with successful recanalization achieved good outcome (54.8%), which was comparable to the one obtained after recanalization with MT (55.4%). Comparing our series to the one by Chang et al. [24], we obtained similar outcome (mRs 0–2 41.2 vs. 39.6%), mortality rate (17.6 vs. 12.5%) and SICH (11.7 vs. 16.7%).

Data of these 3 series [22–24] and our study are summarized in Table 6. Overall patients treated with RS were 105. Intravenous thrombolysis was administered in 39/105 patients (25.6%). The implanted stents were mainly the Solitaire AB. Generally, the rate of good recanalization (mTICI 2b/3) was 73/105 (69.5%). A favorable clinical outcome was reported in 42/105 patients (40%), SICH occurred in 13/105 patients (12.3%) and the total mortality rate was 13.3% (14/105).

In the series of Baek et al. [22] and Baracchini et al. [23] antiplatelet regimen was i.v. administration of GpIIb/GpIIIa inhibitors, as well as in our series, while in the Chang et al. one [24] the antiplatelet therapy was decided according to the protocol of every center.

In our study, we administered Tirofiban, a GpIIb/GpIIIa inhibitor, instead of dual antiplatelet therapy. The rationale of this choice is that Tirofiban decreases the risk of acute stent thrombosis since it has a more rapid effect, shorter half-life (about 1.5 hours) and the recovery time of platelet function is 4 hours after withdrawal.

In fact, both the Clopidogrel-aspirin association and Abciximab, one of the most used GpIIb/IIIa inhibitor, have longer recovery time of platelet function after withdrawal (12 hours and 7 days respectively). Therefore, in case of SICH, patients under Tirofiban have a shorter recovery time of platelet function and dual antiplatelet therapy can more safely administered after the 12-hour CT control. Although Tirofiban administration in patients with AIS is associated with fatal SICH and poor clinical outcome [29], Beak et al. [22] and Baracchini et al. [23] found a substantial equal hemorrhagic rate in patients with anterior circulation AIS treated with or without intracranial stent and Tirofiban administration. Comparably to other studies [22–24], we did not observe a significant increase of fatal SICH using Tirofiban. Particularly, as observed in the multicenter study by Chang et al. [24], stent patency was guaranteed by GpIIb/GpIIIa inhibitors, and SICH was not related to any form of antiaggregation. In this study, intracranial stenting was the only independent factor associated with favorable outcome and lower mortality rates. However, the number of enrolled patients was low and they did not report any information about collateral circulation in the two groups.

In our experience, intracranial stenting was contemplated as a rescue strategy in all severe strokes in which MT failed. Since a poor pial collateral circulation should be considered an absolute contraindication to permanent stenting, collateral flow at CTA and/or DSA was evaluated. Poor collateral circulation is associated

Table 4
Correlation of occlusion site with mTICI.

	mTICI 0	mTICI 1	mTICI 2A	mTICI 2B	mTICI 3
ICA + MCA	–	1/17 (5.9%)	–	2/17 (11.8%)	5/17 (29.4%)
MCA (M1)	–	–	2/17 (11.8%)	4/17 (23.5%)	1/17 (5.9%)
ICA T siphon	1/17 (5.9%)	–	1/17 (5.9%)	–	–

Table 5
Correlation of occlusion site with mRS at 3 months.

	mRS 0	mRS 1	mRS 2	mRS 3	mRS 4	mRS 5	mRS 6
ICA + MCA	1/17 (5.9%)	1/17 (5.9%)	3/17 (17.6%)	2/17 (11.8%)	1/17 (5.9%)	–	–
MCA (M1)	1/17 (5.9%)	–	1/17 (5.9%)	1/17 (5.9%)	1/17 (5.9%)	1/17 (5.9%)	2/17 (11.8%)
ICA T siphon	–	–	–	–	–	1/17 (5.9%)	1/17 (5.9%)

Table 6
Review of the literature of bail-out intracranial stenting in acute ischemic stroke of anterior circulation.

Author	N° patients[a]	IV rtPA	Type of device	mTICI 2b/3 (%)	Symptomatic intracranial haemorrhage (%)	Death (%)	mRS 0–2 (%)[b]
Baek et al., 2016 [22]	17	5 (29.4%)	Solitaire AB Wingspan	14/17 (83.3)	2/17 (11.8)	4/17 (23.5)	3/17 (5.3)
Baracchini et al., 2017 [23]	23	4 (17.4%)	Solitaire AB	17/23 (73.9)	1/17 (4.3)	1/17 (4.3)	13/23 (56.5)
Chang et al. [24]	48	22 (45.8%)	Solitaire AB (77%) Wingspan (16.7%) Enterprise (4.7%) Coronary (2.1%)	31/48 (64.6)	8/48 (16.7)	6/48 (12.5)	19/48 (39.6)
Present study	17	8 (47%)	Solitaire AB	11/17 (70.6)	2/17 (11.7)	3/17 (17.6)	7/17 (41.2)
Total	105	39/105 (25.6%)	–	73/105 (69.5)	13/105 (12.3)	14/105 (13.3)	42/105 (40)

NS: not specified.
[a] Selected patients with ischemic stroke of anterior circulation.
[b] Including T-siphon occlusion.

with larger infarction development and higher rate of hemorrhagic transformation [26]. Obviously, hemorrhagic transformation can be catastrophic in a patient under dual antiplatelet therapy or platelet inhibition. Nevertheless, since those evidences were not clear since few years ago, we also included few patients with poor collateral circulation at the beginning of our experience.

Permanent bail-out stenting should be considered only if the flow is adequately restored when the device is deployed in the target vessel. The use of a retrievable and detachable stent, such as the Solitaire AB, is essential to enhance the safety and feasibility of RS. Indeed, before stent detachment, the operator can evaluate the proper positioning across the clot, the efficacy of the by-pass effect and eventual reocclusion before the administration of antiplatelet agents. Nevertheless, in our series 2 stents underwent acute reocclusion in the angio suite after detachment (mTICI 0–1). This adverse event was probably facilitated by either clot penetration through the struts of the stent or new clot formation.

Our study includes a major proportion of tandem intracranial-extracranial occlusion (47.1% of our population) treated with bail-out strategy. The natural history of tandem occlusions is poor because they badly respond to intravenous thrombolysis [30] and MT can be negatively affected by the extracranial occlusion [31,32]. In this subgroup, we obtained successful recanalization in 7/8 patients (87.5%) and a good clinical outcome in 5/8 patients (62.5%).

This study has some limitations: it is retrospective (although data were prospectively recorded in our database), it is conducted in a single center and the number of enrolled patients is low.

Conclusion

We assume that bail-out intracranial stenting after unsuccessful thrombectomy is technically feasible and the associate haemorrhagic risk may be considered acceptable. However, primary intracranial stenting should be considered in very selected cases, when other revascularization techniques fail. The possible advantages should be balanced against the risk of the dual antiplatelet therapy. The high recanalization rate of thrombectomy has made uncommon the necessity of permanent bail-out stenting, however this approach can dramatically improve clinical outcome in a subgroup of patients who presumably would have a very poor outcome due to persistent major vessel occlusion. Further series with larger patient population and, hopefully, a prospective randomized trial, would be useful to define the role of bail-out intracranial stenting after failure of thrombectomy.

Ethical standards and patient consent

We declare that all human and animal studies have been approved by the ethics committee of our institution and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. We declare that all patients gave informed consent prior to inclusion in this study.

Disclosure of interest

The authors declare that they have no competing interest.

References

[1] Berkhemer OA, Fransen PS, Beumer D, van den Berg LA, Lingsma HF, Yoo AJ, et al. A randomized trial of intraarterial treatment for acute ischemic stroke. N Engl J Med 2015;372:11–20 [Erratum, N Engl J Med 2015; 372:394].
[2] Demchuk AM, Goyal M, Menon BK, Eesa M, Ryckborst KJ, Kamal N, et al. ESCAPE trial investigators endovascular treatment for small core and anterior circulation proximal occlusion with emphasis on minimizing CT to recanalization times (ESCAPE) trial: methodology. Int J Stroke 2014:25.
[3] Jovin TG, Chamorro A, Cobo E, de Miquel MA, Molina CA, Rovira A, et al. Thrombectomy within 8 hours after symptom onset in ischemic stroke. N Engl J Med 2015;372:2296–306, http://dx.doi.org/10.1056/NEJMoa1503780.
[4] Saver JL, Goyal M, Bonafe A, Diener HC, Levy EI, Pereira VM, et al. Stent-retriever thrombectomy after intravenous t-PA vs. t-PA alone in stroke. N Engl J Med 2015;372(24):2285–95, http://dx.doi.org/10.1056/NEJMoa1415061.
[5] Campbell BC, Hill MD, Rubiera M, Menon BK, Demchuk A, Donnan GA, et al. Safety and efficacy of Solitaire stent thrombectomy: individual patient data meta-analysis of randomized trials. Stroke 2016;47:798–806, http://dx.doi.org/10.1161/STROKEAHA.115.012360 [PubMed PMID: 26888532].
[6] Goyal M, Menon BK, van Zwam WH, Dippel DW, Mitchell PJ, Demchuk AM, et al., HERMES collaborators. Endovascular thrombectomy after large-vessel ischaemic stroke: a meta-analysis of individual patient data from five randomised trials. Lancet 2016;387:1723–31.
[7] Marder VJ, Chute DJ, Starkman S, Abolian AM, Kidwell C, Liebeskind D, et al. Analysis of thrombi retrieved from cerebral arteries of patients with acute ischemic stroke. Stroke 2006;37(8):2086–93.
[8] Singh P, Kaur R, Kaur A. Clot composition and treatment approach to acute ischemic stroke: the road so far. Ann Indian Acad Neurol 2013;16(4):494–7.
[9] Kim BM. Causes and solutions of endovascular treatment failure. J Stroke 2017;19:131–42.
[10] Mullen MT, Pisapia JM, Tilwa S, Messé SR, Stein SC. Systematic review of outcome after ischemic stroke due to anterior circulation occlusion treated with intravenous, intra-arterial, or combined intravenous + intra-arterial thrombolysis. Stroke 2012;43:2350–5.
[11] Levy EI, Mehta R, Gupta R, Hanel RA, Chamczuk AJ, Fiorella D, et al. Self-expanding stents for recanalization of acute cerebrovascular occlusions. AJNR Am J Neuroradiol 2007;28:816–22.
[12] Brekenfeld C, Schroth G, Mattle HP, Do DD, Remonda L, Mordasini P, et al. Stent placement in acute cerebral artery occlusion: use of a self-expandable intracranial stent for acute stroke treatment. Stroke 2009;40:847–52.
[13] Levy EI, Siddiqui AH, Crumlish A, Snyder KV, Hauck EF, Fiorella DJ, et al. First Food and Drug Administration-approved prospective trial of primary intracranial stenting for acute stroke: SARIS (stent-assisted recanalization in acute ischemic stroke). Stroke 2009;40:3552–6, http://dx.doi.org/10.1161/STROKEAHA.109.561274.
[14] Levy EI, Rahman M, Khalessi AA, Beyer PT, Natarajan SK, Hartney ML, et al. Midterm clinical and angiographic follow-up for the first food and drug administration-approved prospective. Single-arm trial of primary stenting for stroke: SARIS (Stent-Assisted Recanalization for Acute

Ischemic Stroke). Neurosurgery 2011;69:915–20, http://dx.doi.org/10.1227/NEU.0b013e3182222011afd1 [discussion 920].
[15] Levy EI, Ecker RD, Horowitz MB, Gupta R, Hanel RA, Sauvageau E, et al. Stent-assisted intracranial recanalization for acute stroke: early results. Neurosurgery 2006;58:458–63.
[16] Mocco J, Hanel RA, Sharma J, Hauck EF, Snyder KV, Natarajan SK, et al. Use of a vascular reconstruction device to salvage acute ischemic occlusions refractory to traditional endovascular recanalization methods. J Neurosurg 2010;112:557–62.
[17] Sauvageau E, Samuelson RM, Levy EI, Jeziorski AM, Mehta RA, Hopkins LN, et al. Middle cerebral artery stenting for acute ischemic stroke after unsuccessful Merci retrieval. Neurosurgery 2007;60:701–6.
[18] Dumont TM, Natarajan SK, Eller JL, Mocco J, Kelly Jr WH, Snyder KV, et al. Primary stenting for acute ischemic stroke using the enterprise vascular reconstruction device: early results. J Neurointerv Surg 2014;6:363–72, http://dx.doi.org/10.1136/neurintsurg-2013-010794.
[19] Natarajan SK, Sonig A, Mocco J, Dumont TM, Thind H, Hartney ML, et al. Primary stenting for acute ischemic stroke using the enterprise intracranial stent: 2-year results of a Phase-I Trial. J Vasc Interv Neurol 2015;8:62–7.
[20] Gonzalez LF, Jabbour P, Tjoumakaris S, Teufack S, Dumont A, Rosenwasser R, et al. Primary stenting for stroke. Neurosurgery 2011;69(E1338) [author reply, E1338-9].
[21] Linfante I, Samaniego EA, Geisbüsch P, Dabus G. Self-expandable stents in the treatment of acute ischemic stroke refractory to current thrombectomy devices. Stroke 2011;42:2636–8.
[22] Baek JH, Kim BM, Kim DJ, Heo JH, Nam HS, Yoo J. Stenting as a rescue treatment after failure of mechanical thrombectomy for anterior circulation large artery occlusion. Stroke 2016;47:2360–3.
[23] Baracchini C, Farina F, Soso M, Viaro F, Favaretto S, Palmieri A, et al. Stentriever thrombectomy failure: a challenge in stroke management. World Neurosurg 2017, http://dx.doi.org/10.1016/j.wneu.2017.03.070.
[24] Chang Y, Kim BM, Bang OY, Baek JH, Heo JH, Nam HS, et al. Rescue stenting for failed mechanical thrombectomy in acute ischemic stroke: a multicenter experience. Stroke 2018;49(4):958–64, http://dx.doi.org/10.1161/STROKEAHA.117.020072.
[25] Heck DV, Brown MD. Carotid stenting and intracranial thrombectomy for treatment of acute stroke due to tandem occlusions with aggressive antiplatelet therapy may be associated with a high incidence of intracranial hemorrhage. J Neurointerv Surg 2015;7:170–5, http://dx.doi.org/10.1136/neurintsurg-2014-011224.
[26] Consoli A, Andersson T, Holmberg A, Verganti L, Saletti A, Vallone S, et al. CT perfusion and angiographic assessment of pial collateral reperfusion in acute ischemic stroke: the CAPRI study. J Neurointerv Surg 2016, http://dx.doi.org/10.1136/neurintsurg-2015-012155 [pii: neurintsurg-2015-012155].
[27] Mangiafico S, Consoli A, Renieri L, Rosi A, De Renzis A, Vignoli C, et al. Semi-quantitative and qualitative evaluation of pial leptomeningeal collateral circulation in acute ischemic stroke of the anterior circulation: the Careggi Collateral Score. Ital J Anat Embryol 2013;118:277–87.
[28] Fiorelli M, Bastianello S, von Kummer R, del Zoppo GJ, Larrue V, Lesaffre E, et al. Hemorrhagic transformation within 36 hours of a cerebral infarct: relationships with early clinical deterioration and 3-month outcome in the European Cooperative Acute Stroke Study I (ECASS I) cohort. Stroke 1999;30(11):2280–4.
[29] Kellert L, Hametner C, Rohde S, Bendszus M, Hacke W, Ringleb P, et al. Endovascular stroke therapy: tirofiban is associated with risk of fatal intracerebral hemorrhage and poor outcome. Stroke 2013;44:1453–5.
[30] Linfante I, Llinas RH, Selim M, Chaves C, Kumar S, Parker RA, et al. Clinical and vascular outcome in internal carotid artery versus middle cerebral artery occlusions after intravenous tissue plasminogen activator. Stroke 2002;33:2066–71.
[31] Saqqur M, Uchino K, Demchuk AM, Molina CA, Garami Z, Calleja S, et al. Site of arterial occlusion identified by transcranial doppler predicts the response to intravenous thrombolysis for stroke. Stroke 2017;38:948–54.
[32] Soize S, Kadziolka K, Estrade L, Serre I, Barbe C, Pierot L. Outcome after mechanical thrombectomy using a stent retriever under conscious sedation: comparison between tandem and single occlusion of the anterior circulation. J Neuroradiol 2014;41(2):136–42.