

Original Article

The short- and long-term efficacies of endovascular interventions for the treatment of acute ischemic stroke patients

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Abstract: Objective: We aimed to investigate the short- and long-term efficacies of endovascular interventional therapy in acute ischemic stroke (AIS) patients. Methods: In this retrospective study, 94 patients with AIS were recruited and divided into a control group (n=51) that was administered intra-arterial thrombolysis and an observation group (n=43) that was administered Solitaire stent thrombectomies. The postoperative recanalization and overall response rates were recorded in both groups. The hemodynamic parameters (high shear viscosity, low shear viscosity, plasma viscosity, and hematocrit), and the C-reactive protein, interleukin 6, and fibrinogen levels were compared between the two groups before and after the treatment. In addition, the National Institutes of Health Stroke Scale and the modified Rankin Scale scores were analyzed before the treatment and at 1 and 3 months after the treatment in both groups. After a 3-year follow-up, a survival analysis was also performed using the Kaplan-Meier survival method. Results: The overall response and recanalization rates were higher in the observation group than they were in the control group ($P<0.05$). Before the treatment, there were no significant differences in the hemodynamic parameter, C-reactive protein, interleukin, 6 and fibrinogen levels in the two groups ($P>0.05$). After the treatment, the above levels in both groups decreased compared to their levels before the treatment, and the observation group had significantly lower levels than the control group ($P<0.05$). Moreover, no significant differences were seen in National Institutes of Health Stroke Scale and modified Rankin Scale scores between the two groups before the treatment ($P>0.05$). After the treatment, the above scores were decreased in both groups at 1 and 3 months compared to their pre-treatment levels, and the scores were significantly lower in the observation group than they were in the control group at 1 month after the treatment ($P<0.05$). After a 3-year follow-up, the Kaplan-Meier survival curves demonstrated that the survival times were significantly longer in the observation group than they were in the control group ($P<0.05$). Conclusion: Solitaire stent thrombectomy markedly ameliorates neurological deficits in AIS patients, improves their recanalization rate, regulates the inflammatory response and hemodynamics in the lesion areas, thus exerting favorable short- and long-term clinical effects.

Keywords: Endovascular intervention, acute ischemic stroke, short- and long-term

Introduction

Acute ischemic stroke (AIS) refers to a series of acute clinical symptoms resulting from brain infarction caused by cerebral artery occlusion. Epidemiological studies have shown that AIS accounts for >80% of all stroke cases worldwide and has a tendency to affect younger patients [1-4]. In clinical practice, the main means of treating AIS are to promptly open occluded vessels and improve cerebral blood perfusion, including intravenous thrombolysis and endovascular interventional therapy [4, 5].

Studies have shown that the time window for intravenous thrombolytic therapy is narrow, and the therapeutic effect is insignificant for some proximal intracranial large vessel occlusions [6, 7]. Intra-arterial thrombolysis (IAT) and mechanical thrombectomy are two vascular interventional treatments. On the one hand, IAT can significantly dissolve the thrombus and facilitate the recovery of neurological function; on the other hand, it tends to result in an ischemia-reperfusion injury and an insufficient improvement of the blood hypercoagulable state due to the extended thrombolysis time [8-10].

As mechanical endovascular treatment technology develops, stent-retriever thrombectomy has also been gradually recognized by many medical workers and patients in recent years, but choosing arterial thrombolysis and mechanical thrombectomy still perplexes medical staff [11, 12]. Based on the studies, we investigated the short- and long-term outcomes of two endovascular interventions, namely, arterial thrombolysis and stent thrombectomy in treating AIS, so as to provide a relevant basis for better selection clinically.

Materials and methods

General data

This is a retrospective study on 94 patients with AIS admitted to our hospital from January 2016 to January 2017. The study cohort was divided into the control group (n=51), which was treated using IAT and the observation group (n=43) which was treated with Solitaire stent thrombectomy. There were 26 males and 17 females in the control group (average age: 58.7 ± 3.4 years) and 32 males and 19 females in the observation group (average age: 59.2 ± 2.9 years). Ethics approval for the study was given by the Ethics Committee of our hospital, and written informed consent form was obtained from all patients.

Inclusion and exclusion criteria

The patients were eligible for enrollment in the study if they were diagnosed with AIS according to the diagnostic criteria issued by the Cerebrovascular Disease Study Group, Chinese Society of Neurology, Chinese Medical Association, published in 2014 (and this was their first onset) [13], if they had an onset time ≤ 24 h, if they were between 18-80 years old, and if they had no contraindications to thrombolytic or vascular interventional therapy.

The patients were ineligible for enrollment in the study if they were also suffering from other organ diseases, severe cerebrovascular diseases, coagulation dysfunction, heart failure, or autoimmune diseases, if they had a history of surgery in the past 3 months if they had poor compliance, and if they participated in other studies at the same time.

Treatment methods

All the patients underwent routine treatment, including the correction of their water-electrolyte imbalance and the regulation of their acid-base balance (sodium chloride injection, Hunan Kelun Pharmaceutical Co., Ltd., China; potassium chloride injection, Grand Pharma (China) Co., Ltd., China; calcium bicarbonate injection, Sinopharm Group Rongsheng Pharmaceutical Co., Ltd.).

The control group was given arterial thrombolytic therapy: After disinfection, the right femoral artery was punctured using the Seldinger technique, followed by the placement of a 6F sheath (Terumo, Japan). After the cerebral artery occlusion was confirmed using whole cerebral angiography (Siemens, Germany), a 6F support tube was inserted in the ipsilateral vertebral artery, and the microcatheter was placed in the occluded artery under the guidance of a microwire. Also, 200,000 U urokinase (Wuhan Humanwell Pharmaceutical Co., Ltd., China) dissolved in 20 mL normal saline was pumped at a flow rate of 20,000 U/min, and angiography was performed to evaluate the status of the occluded vessel. If there was no recanalization, the liquid could be pumped again. Ultimately, the catheter was withdrawn and the insertion sites were dressed with a sterile gauze after the disinfection.

The observation group was administered a Solitaire AB stent thrombectomy: The catheter insertion methods were the same as above. A microcatheter was navigated distal to the point of occlusion, and the 4 mm \times 20 mm Solitaire AB stent (Terumo, Japan) was advanced and was temporarily deployed to allow full expansion. After 2 minutes, the stent and microcatheter were pulled back as a single unit, and cerebral angiography was performed to assess the status of the occluded vessel. If there was no recanalization, multiple thrombectomy could be conducted.

Outcome measures

Fasting venous blood samples were drawn from each subject into two 3 mL tubes at enrollment before the treatment and on the morning of the tenth day after the treatment. A tube of blood was centrifuged at 3000 r/min for 5 min to sep-

arate the serum, followed by the measuring the interleukin-6 (IL-6), C-reactive protein (CRP), and fibrinogen (FIB) levels using enzyme-linked immunosorbent assays (ELISA) (multifunctional microplate reader, Hamilton Company, Switzerland). The other sample tube was used to determine the hemodynamic parameters (high shear viscosity, low shear viscosity, plasma viscosity, hematocrit) using an automatic hemorheology analyzer (Mindray Medical, China) according to the instructions of the kits purchased from Beyotime Biotechnology Co., Ltd. (Shanghai, China).

Both groups were compared according to their National Institutes of Health Stroke Scale (NIHSS) levels and their modified Rankin Scale (mRS) scores upon enrollment and before treatment and at 1 and 3 months after the treatment. The NIHSS scores ranged from 0 to 28 points, with higher scores indicating worse neurological function. As for the mRS, higher scores indicated a better prognosis [14, 15].

Clinical efficacy evaluation: The clinical efficacy was graded as markedly effective (NIHSS score reduced by $\geq 45\%$), effective (NIHSS score reduced by 18-44%), or ineffective (NIHSS score reduced by $\leq 17\%$) [16].

Overall response rate = (markedly effective cases+ effective cases)/total number of cases *100%.

Vascular recanalization rate: The Modified Thrombolysis in Cerebral Infarction Classification (mTICI) grade was determined immediately after the operation to assess the vascular recanalization, which was presented as 0 points, no perfusion; Grade 1, minimal blood flow passing through the occluded segment; Grade 2a, partial filling $< 50\%$ downstream territory; Grade 2b, partial filling $\geq 50\%$ downstream territory; Grade 3, complete perfusion. Grade $\geq 2b$ indicated successful recanalization [17].

The recanalization rate = (cases of Grade 2b +3)/total number of cases *100%.

After a 3-year follow-up, the survival times of the patients in both groups were recorded. The survival time began on the date of the initial surgery in our hospital and ended with the date of the patient's death or recurrence, or with the last follow-up in January 2020 (in all cases except the death and recurrence cases).

Statistical analysis

All the data analyses were performed using SPSS 22.0 software. Chi-square tests (χ^2 test) were used for the comparisons of the enumeration data expressed as the cases/percentage (n/%). The measurement data were expressed as the mean \pm standard deviation ($\bar{x} \pm sd$), and independent sample t-tests were used for the comparisons between the two groups. Paired sample t-tests were used for the comparisons within a group before and after the treatment. Moreover, Mann-Whitney U tests were used for the ranked data, and univariate survival analyses were performed using the Kaplan-Meier method. $P < 0.05$ was considered statistically significant.

Results

Comparison of the general data

There were no significant differences in terms of age, gender, etc. between the two groups ($P > 0.05$), suggesting the two groups were comparable. See **Table 1**.

Comparison of the clinical efficacy

In the observation group, a marked improvement in the treatment efficacy was observed in 23 patients and an improvement was observed in 19 patients. While in the control group, a marked improvement was observed in 18 patients and an improvement in 24 patients. The overall response rate was better in the observation group than it was in the control group (97.67% vs. 79.24%, $P < 0.05$). See **Table 2**.

Comparison of recanalization

The successful recanalization (mTICI grade $\geq 2b$) rate in the observation group was significantly higher than it was in the control group (95.35% vs. 80.39%, both $n = 41$; $P < 0.01$). See **Table 3**.

Comparison of serum IL-6, CRP, and FIB levels before and after the treatment

Before the treatment, no significant differences were identified in the CRP, IL-6, or FIB levels between the two groups ($P > 0.05$). After the treatment, the CRP, IL-6, and FIB levels in both groups decreased compared to their pre-treat-

Table 1. The general patient data

Item	Observation group (n=43)	Control group (n=51)	t/ χ^2	P
Age (years)	58.7±3.4	59.2±2.9	0.770	0.444
Gender			0.051	0.821
Male	26	32		
Female	17	19		
Onset-treatment-time (h)	3.4±1.1	3.2±1.3	0.797	0.428
History of Hypertension (n)			0.042	0.838
Yes	11	14		
No	32	37		
History of diabetes (n)			0.015	0.902
Yes	8	10		
No	35	41		
History of CHD(n)			0.085	0.772
Yes	2	3		
No	41	48		
BMI (kg/m ²)	25.23±3.37	25.42±2.94	0.292	0.771

Note: BMI: body mass index; CHD: coronary heart disease.

ment levels, but the observation group indicated much lower levels than the control group ($P<0.05$). See **Table 4**.

Comparison of the hemodynamic parameters before and after the treatment

Before the treatment, no significant differences were seen regarding the high shear viscosity, low shear viscosity, plasma viscosity, and hematocrit between the two groups ($P>0.05$). After the treatment, the hemodynamic parameter levels of both groups were reduced compared with their pre-treatment levels, but the observation group showed lower levels than the control group ($P<0.05$). See **Table 5**.

Comparison of the NIHSS and mRS scores before the treatment and at 1 and 3 months after the treatment

Before the treatment, no significant differences were found in terms of the NIHSS and mRS scores in the two groups ($P>0.05$). At 1 and 3 months after the treatment, the NIHSS and mRS scores were decreased in both groups. At 1 month after the treatment, the NIHSS and mRS scores were significantly lower in the observation group than they were in the control group ($P<0.05$). See **Table 6**.

Comparison of the survival times

After a 3-year follow-up, there were 34 survival cases, and 9 deaths or recurrent cases, for a

survival rate of 79.07% and a survival time of 32.8 ± 0.9 months in the observation group. There were 35 survival cases, and 16 deaths or recurrent cases, for a survival rate of 68.63% and a survival time of 29.1 ± 1.2 months in the observation group. This indicated that there was significant difference between the two groups ($P=0.038$), as shown in **Figure 1**.

Discussion

Our study showed that the patients' recanalization rate was 80.39% after the IAT. After the treatment, the inflammatory response, the hemodynamic parameters, and the neurological function were all improved. The results suggest that IAT has a good clinical effect, but there is still room for improvement in the recanalization rate. Previous studies have shown that IAT can significantly increase the vascular recanalization rate of the internal carotid artery and vertebrobasilar systems in AIS patients and can promote better NIHSS and mRS scores and the recovery of patients' living abilities [18, 19]. Additionally, early IAT can also reduce the serum inflammatory factor levels such as CRP and IL-6 in AIS patients, thereby alleviating the body's inflammatory state of the body and any neuronal damage. However, some studies have reported that IAT may also lead to adverse events such as unstable blood pressure, re-occlusion, and intracranial hemorrhage. Moreover, about 20%-40% patients with massive intracranial hemorrhages still experienced recanalization failure and acute occlusion [20].

Endovascular mechanical thrombectomy refers to the removal of a blood clot using local vacuum aspiration of the proximal catheter or the contact of clots with distal catheter tips in combination with aspiration [12]. Our study revealed that the Solitaire AB stent showed much better results in the recanalization rate, inflammatory symptoms, hemodynamic parameters, and neurological function than IAT. As one of the main mechanical thrombectomy devices, the Solitaire AB stent is mainly made of a thin-walled nickel-titanium tube with a laser cutting

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Table 2. Comparison of the clinical efficacy (n, %)

Group	Markedly effective (n, %)	Effective (n, %)	Ineffective (n, %)	Overall response rate (%)
Observation group (n=43)	23 (53.49)	19 (44.19)	1 (2.33)	97.67
Control group (n=51)	18 (35.29)	24 (47.06)	9 (17.65)	79.24
U	823.500			
P	0.022			

Table 3. Comparison of the recanalization

Group	mTICI Grading (n, %)				Recanalization rate (%)
	Grade 1	Grade 2a	Grade 2b	Grade 3	
Observation group (n=43)	1 (2.33)	1 (2.33)	17 (39.53)	24 (55.81)	95.35
Control group (n=51)	6 (11.76)	4 (7.84)	28 (54.90)	13 (25.49)	80.39
U	706.000				
P	0.001				

Note: mTICI: Modified Thrombolysis in Cerebral Infarction Classification.

Table 4. Comparison of the serum IL-6, CRP, and FIB levels before and after the treatment

Group	FIB (g/L)		CRP (mg/L)		IL-6 (ng/L)	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
Observation group (n=43)	8.22±1.17	3.02±0.98*	17.63±2.27	8.78±1.09*	31.78±4.45	22.49±3.79*
Control group (n=51)	8.31±1.24	4.15±1.01*	17.52±2.44	11.42±1.22*	31.56±4.34	27.96±2.47*
t	0.360	5.479	0.225	10.969	0.242	8.121
P	0.720	<0.001	0.823	<0.001	0.809	<0.001

Note: Compared within the same group before the treatment, *P<0.05. IL-6: interleukin-6; CRP: C-reactive protein; FIB: fibrinogen.

Table 5. Comparison of the hemodynamic parameters before and after the treatment

	Observation group (n=43)	Control group (n=51)	T	P
High shear viscosity (mPas)				
Before treatment	7.07±1.05	7.13±1.12	0.266	0.791
After treatment	4.22±0.93*	5.01±0.94*	4.079	<0.001
Low shear viscosity (mPas)				
Before treatment	11.04±3.06	11.13±3.12	0.141	0.889
After treatment	7.02±2.25*	8.43±2.13*	3.116	0.002
Plasma viscosity (mPas)				
Before treatment	1.97±0.31	1.99±0.29	0.323	0.748
After treatment	1.52±0.24*	1.79±0.22*	5.686	<0.001
Hematocrit (mol/L)				
Before treatment	50.87±5.56	51.12±5.34	0.222	0.825
After treatment	41.25±4.43*	46.71±4.05*	6.238	<0.001

Note: Compared within the same group before the treatment, *P<0.05.

and closed-loop design. According to its working principle, a microcatheter is navigated just distal to the clot. The Solitaire stent is advanced

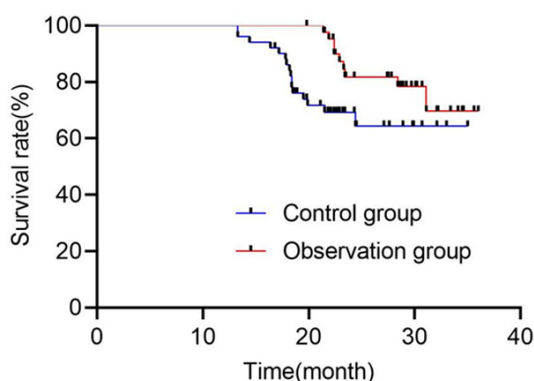
and is temporarily deployed within the clot by withdrawing the microcatheter over the stent for several minutes to allow the recanalization. On retrieval, the clot can be seen entangled within the meshwork of the stent. As previous studies show, the efficacy and safety of the Solitaire AB stent thrombectomy is a topic of controversy [20]. However, in recent years, a large number of studies have found that the use of Solitaire AB for thrombectomy has a better recanalization effect on occluded vessels, and it also exerts a better dredg-

ing effect on some stenotic vessels [21, 22]. The Solitaire AB stent was reported to have a higher recanalization rate than IAT, and it has a

Table 6. Comparison of the NIHSS and mRS scores before the treatment and at 1 and 3 months after the treatment

Group	Observation group (n=43)	Control group (n=51)	t	P
NIHSS				
Before the treatment	10.44±2.21	10.78±2.05	0.773	0.442
1 month after the treatment	6.21±1.56*	7.48±1.35*	4.232	<0.001
3 months after the treatment	3.23±0.79*#	3.41±0.84*#	1.063	0.290
mRS				
Before the treatment	3.94±0.46	3.91±0.48	0.308	0.759
1 month after the treatment	1.72±0.56*	2.44±0.61*	5.917	<0.001
3 months after the treatment	1.21±0.22*#	1.25±0.24*#	0.836	0.405

Note: Compared within the same group before the treatment, *P<0.05; compared within the same group at 1 month after the treatment, #P<0.05. NIHSS: National Institutes of Health Stroke Scale; mRS: modified Rankin Scale.

**Figure 1.** The Kaplan-Meier survival curves.

simple and repeatable method of operation [21]. All of the above findings suggest that Solitaire AB stent thrombectomy can achieve better clinical results.

Previous studies have focused more on short-term outcomes such as the recanalization rates and the changes in the hemodynamic parameters in AIS, but there are still few studies on its long-term prognosis [20, 21]. In this study, we further analyzed the effect of the two methods on the long-term prognoses of AIS patients after a 3-year follow-up. The results demonstrated that after the 3-year follow-up, the Solitaire AB stent thrombectomy was significantly superior to IAT in terms of the survival rates and survival times, indicating that Solitaire AB stent thrombectomies have much better long-term prognoses.

However, this study also has some shortcomings. The pathological component of the thrombus was not analyzed to provide a relevant

basis for the better choice. The Solitaire AB stent has a poor therapeutic effect on thrombi with diameters of less than 2 mm, so this needs to be further explored. Also, this was a single-center study with a small sample size, hence, more multi-center studies with larger sample sizes are needed to confirm the conclusion in the future.

In summary, endovascular interventional therapy for AIS patients is significantly effective, and Solitaire stent thrombectomy can markedly alleviate the symptoms of neurological deficits in AIS patients, improve the recanalization rate, regulate the inflammatory response and hemodynamics to some extent, and thus exert good short- and long-term clinical efficacy.

Disclosure of conflict of interest

None.

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