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Mechanical thrombectomy with Solitaire AB stents for the treatment of intracranial venous sinus thrombosis

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Abstract

Background: Cerebral venous sinus thrombosis (CVST) is a rare clinicopathological entity with substantial diagnostic and therapeutic dilemmas. The appropriate management of CVST remains to be defined.

Purpose: To evaluate the efficiency and safety of mechanical thrombectomy with Solitaire AB stents for the treatment of intracranial venous sinus thrombosis.

Material and Methods: Twenty-three consecutive patients with CVST who were treated with mechanical thrombectomy using Solitaire AB stents between January 2013 and October 2014 were retrospectively analyzed. The headache intensity was evaluated according to the visual analogue scale (VAS), and neurological function was assessed using the National Institute of Health Stroke Scale (NIHSS). Follow-up data were available for all patients for 6–14 months. Magnetic resonance imaging (MRI) and magnetic resonance venography (MRV) were performed at 3 and 6 months after neurointervention, and telephone interviews were performed monthly thereafter. The Wilcoxon signed-rank test was used to compare the evaluation data (VAS and NIHSS) at admission and discharge.

Results: Twenty-six Solitaire AB stents were used. No neurointervention-related complications were noted. The symptoms were significantly improved after neurointervention in all patients. The comparisons between the VAS and NIHSS evaluations at admission and discharge were significantly different ($P < 0.05$). No recurrence was observed during the follow-up period.

Conclusion: Mechanical thrombectomy with Solitaire AB stents is safe and effective for the treatment of CVST and can significantly improve clinical symptoms. The occurrence of complications is low, and the prognosis is favorable.

Keywords

Brain, veins, thrombosis, stents, thrombectomy

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Introduction

Cerebral venous sinus thrombosis (CVST) is a rare clinicopathological entity, with substantial diagnostic and therapeutic dilemmas (1–3). This condition was first described by Ribes in 1825 (4). CVST accounts for approximately 0.5% of all stroke cases (5), and is associated with an unfavorable prognosis and high mortality rate in the range of 5–30% (6,7). CVST predominately affects adult individuals in the age range of 20–40 years (8,9). A female predominance has been reported, and female sex represents a predisposing factor for the development of CVST (2,3,5,9–11).

The treatment options for CVST include anticoagulation, thrombolysis, and endovascular interventional modalities, such as balloon dilatation and stent angioplasty (3,12–14). Systemic anticoagulation, which is the most traditional and widely used modality, provides considerable improvement compared with conservative methods; nevertheless, this strategy is not efficacious in all patients (6). Recent studies have suggested that

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endovascular interventions have substantially lower mortality rates (8–14%) and significantly better outcomes (12,14–17). The administration of thrombolytics in CVST has been associated with increased rates of intracranial hemorrhage or visceral bleeding (3,5,6). There is a significant lack of evidence regarding the proper dosage, route of administration, and safety of this procedure. Given the recent advances in interventional neurointervention, endovascular mechanical thrombectomy has been reported to be an effective alternative in the management of individuals with severe CVST who respond poorly to systemic anticoagulation (13,16,17). To date, the clinical evidence is primarily based on case reports and small clinical series, in which less than 10 cases were enrolled. Furthermore, the option of endovascular treatment in CVST is not included in the existing treatment guidelines (6). A consensus regarding the appropriate management of CVST remains to be defined.

This study aimed to investigate a strategy, which included mechanical thrombectomy with Solitaire AB stents only, in a CVST cohort to determine the clinical profiles and surgical outcomes over time.

Material and Methods

This study was approved by the Research and Drug Clinical Study Ethics Committee of the First Affiliated Hospital of Zhengzhou University. Twenty-three consecutive patients diagnosed with CVST, who were referred to our department between January 2013 and October 2014, were retrospectively analyzed. CVSTs were diagnosed based on digital subtraction angiography (DSA) evidence. The inclusion criteria included thrombosis in the superior sagittal sinus, straight sinus, transverse sinus, or sigmoid sinus. The exclusion criteria included: (i) solitary cortical vein thrombosis; or (ii) CVST patients with mild intracranial hypertension who significantly improved after anticoagulation alone.

The time of onset, onset symptoms, and medical histories of the patients were determined. The radiological images were comprehensively analyzed. The headache intensity was evaluated according to the visual analogue scale (VAS), and neurological function was assessed using the National Institute of Health Stroke Scale (NIHSS). These evaluations were performed before neurointervention, immediately after neurointervention, and during the follow-up period every month.

Mechanical thrombectomy procedure

All procedures were performed under general anesthesia. Using a transfemoral approach, a 6-F Envoy guide catheter (Cordis, Inc., Miami, FL, USA) was placed in the jugular foramen or sigmoid sinus. A heparinized saline solution was continuously perfused through the catheter during the procedure. A Rebar 18 microcatheter (ev3 Neurovascular, Irvine, CA, USA) and a 4×20 mm Solitaire AB stent (ev3 Neurovascular) were used for superior sagittal sinus thrombosis, and a Rebar 27 microcatheter and a 6×30 mm Solitaire AB stent (ev3 Neurovascular) were used for transverse sinus thrombosis and sigmoid sinus thrombosis. Solitaire FR device was not available during our study, so Solitaire AB stents were used instead. After turning off the heparin perfusion in the Y valve, aspiration of guiding catheter was performed simultaneously by an assistant until the stent was retrieved successfully, in order to prevent pulmonary embolism. For complicated multifocal thrombosis in different sinuses, a multi-step procedure with stents of different diameters was performed. If the recanalization attempt was unsuccessful, the procedure was repeated three to five times. The number of Solitaire AB device passes was recorded. There were no adjunctive therapy or fibrinolytics used in combination with Solitaire mechanical thrombectomy. Possible neurointervention-related complications were examined by dynamic CT scanning directly after the procedure as well as at a second CT scanning performed after 7 days.

Post-interventional anticoagulation

Following diagnosis, low-molecular-weight heparin-calcium (5000 units) (Zhaokepham, Hefei, PR China) was administered via subcutaneous injection (every 12 h). This strategy was continued after neurointervention until discharge. A warfarin formula was recommended as a substitute (which was initiated 3 days before discharge; initial dosage of 2.5 mg/day); the dosage was adjusted according to the international normalized ratio (INR) within a range of 2–3 mg/day. The warfarin regimen was continued for at least 6 months.

Follow-up

Follow-up data for all patients were obtained during individual office visits or telephone interviews. Magnetic resonance imaging (MRI) and magnetic resonance venography (MRV) were performed at 3 and 6 months after neurointervention, and telephone interviews were performed monthly thereafter.

Statistical analysis

SPSS 20.0 software (SPSS Inc., Chicago, IL, USA) was used for statistical analyses. The Wilcoxon signed-rank test was used for the comparisons of evaluation data

(VAS and NIHSS) at admission and discharge. P values ≤ 0.05 were considered significant.

Results

Computed tomography (CT) and MRI were available for all patients before neurointervention (Fig. 1a). Twenty-three patients were diagnosed with CVST, which included nine cases with solitary thrombosis in the superior sagittal sinus, five cases with thrombosis in the superior sagittal sinus and cortical vein thrombosis, three cases with solitary thrombosis in the transverse sinus, three cases with thrombosis in the transverse sinus and thrombosis in the sigmoid sinus, and three cases with thrombosis in the superior sagittal sinus and thrombosis in the transverse sinus. Additionally, five patients presented with petechial hemorrhages, and one patient presented with diffused cerebral infarction with hemorrhage.

None improved on anticoagulation alone, without significant change of VAS score for headache in our cohort, and all patients underwent neurointervention. None developed symptomatic pulmonary emboli using this technique in our study. Recanalization was achieved in all 23 patients. Twenty-six Solitaire AB stents were used, including 17 stents (4×20 mm) and nine stents (6×30 mm). Thrombectomy was repeated three to five times per patient for a total of 91 times. Thrombotic material removed by the Solitaire AB stents was sent to histopathological examinations for examining the components of thrombosis (Fig. 2). Thirteen patients were awake at admission; the

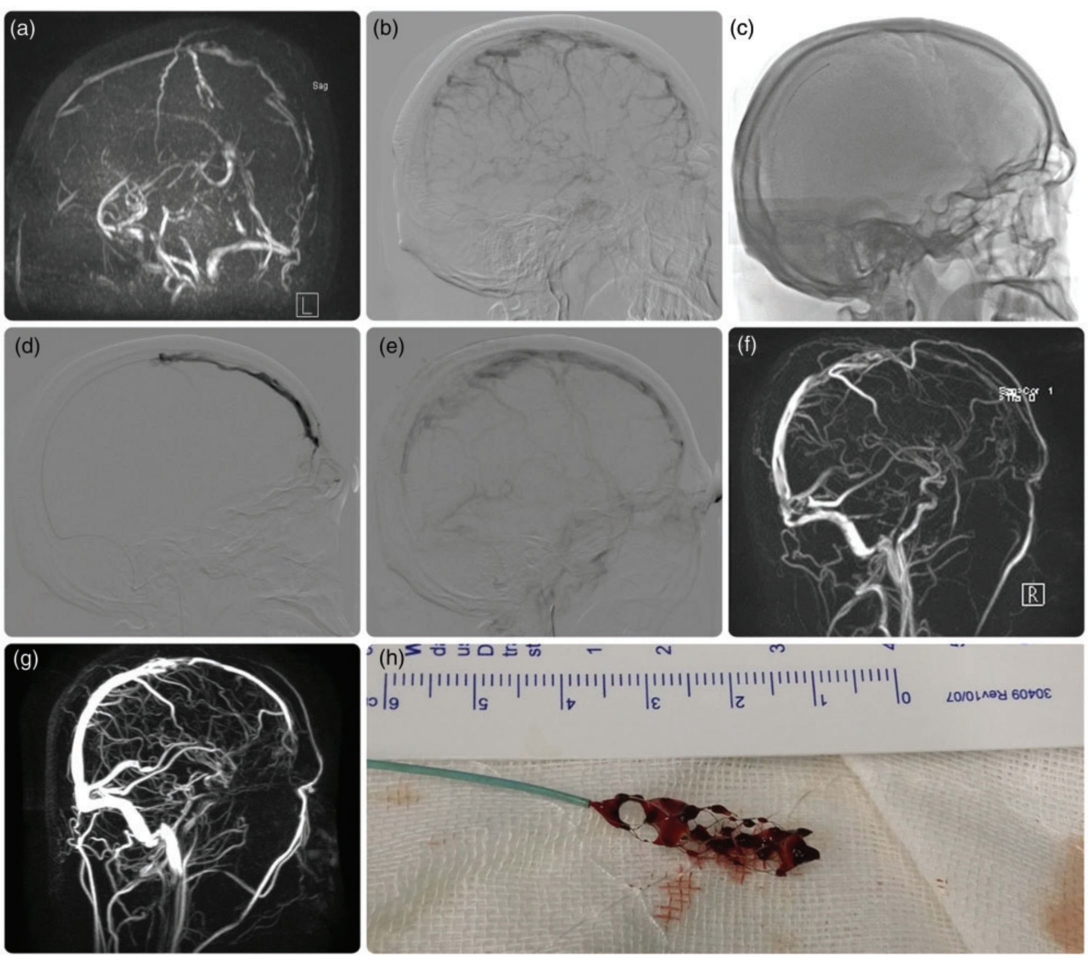

Fig. 1. The preoperative magnetic resonance venography reveal thrombosis in the superior sagittal sinus and the transverse sinus (a). The intraoperative internal carotid angiography reveals a venous filling defect (b). The angiography shows the deployment of Solitaire AB stent (c). After the thrombectomy, the intra-sinus angiography by micro-catheter confirm a recanalization of venous sinus (d). After the thrombectomy, the angiography via internal carotid artery confirm a recanalization of venous sinus (e). The magnetic resonance venography at discharge show the recanalization of venous sinus (f). The follow-up magnetic resonance venography 6 months after thrombectomy confirm a better recanalization (g). The thrombosis was removed by Solitaire AB stents (h).

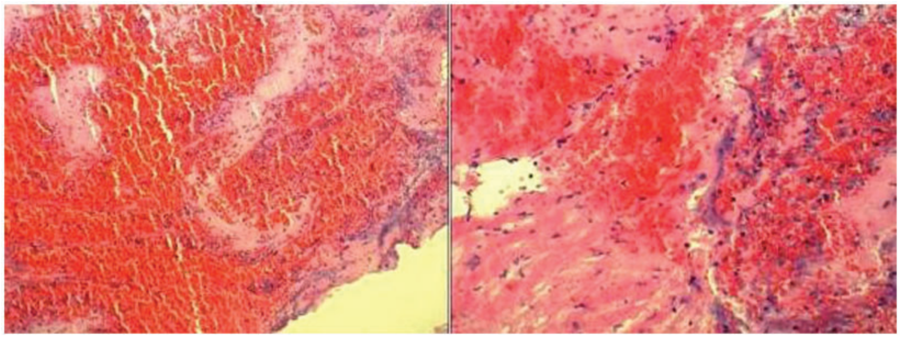

Fig. 2. Histopathological examinations confirm the components of thrombosis (hematoxylin and eosin stain, original magnification ×200).

headache significantly improved immediately following treatment. Nine patients achieved a remarkable improvement in headache 1–3 days after neurointervention (Fig. 1b–e). An additional patient developed cerebral herniation before neurointervention. The consciousness gradually improved following the neurointervention and the patient woke up 5 days later with right hemiplegia with incomplete motor aphasia at discharge. No neurointerventional-related complications, including cerebral hemorrhage, cerebral infarction, or intracranial infection, were found among the 23 cases. The clinical evaluation of headache intensity and neurological function of the CVST patients are summarized in Table 1. The comparison between the VAS and NIHSS evaluations at admission and discharge were significantly different ($P < 0.05$; Table 2).

Follow-up data were available for all patients for 6–14 months. No recurrence was observed (Fig. 1f, g). The patient with herniation who fell into a coma before neurointervention and remained right hemiplegia with incomplete motor aphasia at discharge, experienced a favorable recovery and regained self-care abilities and complete language function during the follow-up period.

Discussion

CVST is a rare cause of stroke that most commonly afflicts individuals of middle age (3,5,10). The incidence of CVST in children and neonates is approximately seven cases per million individuals per year, whereas the incidence in adults is three to four cases per million individuals (18). Recent clinical series and review studies have confirmed a female predominance, with a male:female ratio of 1:3 (3,6,10,18). Female gender represents a predisposing factor for the development of CVST due to: (i) estrogen imbalance, which may be induced by oral contraceptives, pregnancy, or puerperium (10,19); (ii) a congenital hypercoagulable state, including protein C or protein S deficiency, and antithrombin III or V factor resistance; and (iii) a hypercoagulable state caused by other diseases, including malignant tumors, infections, nephrotic syndrome, polycythemia, leukocytosis, severe anemia, and dehydration (19–23). In contrast to arterial thrombosis, individuals with CVST typically present with more complicated clinical manifestations. Headache represents the most commonly reported symptom of CVST. More than 80% of individuals have severe headaches with a much longer duration than the other cause of headaches (24,25). Other symptoms and signs include papilledema (50% of all CVST individuals), focal neurological deficits (30–80%), epileptic seizure (40%), cranial nerve palsy, and cognitive impairment (infrequent) (19,25,26).

Following advances in imaging technology, an early diagnosis of CVST is feasible. The CT manifestations of CVST are non-specific, highly variable, and may mimic several other clinical conditions. Identification that depends on non-contrast CT is challenging because of the subtle nature of CVST signs, and a definitive diagnosis requires MRI, MRV, or digital subtraction angiography (DSA). Evidence suggests that MRI combined with MRV is the preferred option for diagnosis and follow-up observation of CVST; this combined approach is accurate, non-invasive, inexpensive, and repeatable (5,27). In the current study, follow-up MRV data were available for all patients and confirmed a favorable surgical outcome. The diagnostic value of DSA in CVST should be recognized, including the determination of the occlusion location and the identification of the direction of venous blood flow.

The treatment options for CVST include anticoagulation, thrombolysis, and endovascular interventional modalities, such as balloon dilatation and mechanical thrombectomy (6,18). It has been widely accepted that systemic anticoagulation provides considerable improvement compared with conservative methods. Nevertheless, it is not efficacious in all patients. Lyons et al. described the first successful use of systemic

Table 1. The clinical evaluation of headache intensity and neurological function of CVST patients.

Patient no.	Age (years)	Sex	Duration since onset (days)	Thrombosis location	Preoperative VAS	Postoperative VAS	Preoperative NIHSS	Postoperative NIHSS
1	28	M	38	SSS	9	2	17	8
2	30	F	21	SSS + CV	7	3	19	9
3	20	F	45	TS + SS	9	1	12	10
4	17	M	17	SSS	8	1	15	7
5	43	M	11	TS + SS	7	2	16	9
6	23	M	17	SSS + CV	9	3	14	8
7	45	F	15	SSS + TS	7	2	17	10
8	54	M	23	SSS	9	2	18	8
9	38	F	27	TS	7	1	19	9
10	51	F	33	SSS	9	2	12	10
11	47	F	36	TS + SS	8	3	15	7
12	26	M	22	SSS + CV	9	1	16	9
13	65	M	23	SSS	7	1	14	8
14	37	F	5	SSS	9	2	17	10
15	43	F	3	TS	8	2	19	8
16	29	F	21	TS	9	3	12	9
17	54	M	12	SSS	7	1	19	10
18	36	F	37	SSS + TS	9	1	19	8
19	32	M	11	SSS	8	2	12	9
20	49	F	19	SSS + CV	7	3	15	10
21	40	F	15	SSS + TS	7	2	16	7
22	29	M	34	SSS	8	2	14	9
23	33	F	2	SSS + CV	6	1	17	8

CV, cortical vein; SSS, superior sagittal sinus; TS, transverse sinus.

Table 2. The statistical comparison of evaluation data.

Assessment system	On admission	At discharge	Z value	*P* value
VAS	8.00 + 0.85	2.08 + 0.90	−3.081	<0.05
NIHSS	13.75 + 3.49	4.92 + 0.29	−4.205	<0.05

heparin in 1941 (28). The subsequent randomized, prospective, placebo-controlled studies confirmed a significantly lower mortality and morbidity in the heparin-therapy group, and some authors have suggested that heparin should be the treatment of choice for individuals who experience clinical deterioration, including hemorrhagic infarcts (29,30). However, the high risk of hemorrhagic complications creates a substantial dilemma regarding the use of heparin in the treatment of patients with CVST. Furthermore, the indwelling catheter for thrombolytic injection can increase the risk of infection. Consequently, several additional modalities have been used to facilitate recanalization and symptomatic improvement in refractory patients.

Following recent advances in interventional procedures, endovascular mechanical thrombectomy comprises a new treatment strategy that has recently been used in the treatment of patients with severe CVST (12–17). The venous sinus wall is composed of dense fibrous connective tissue, which is tough and inelastic, and the venous sinus has no vascular valve. These features make thrombectomy with stents feasible, which thus avoids transposition of the sinus, vascular tear, or bleeding (16,17). Mechanical thrombectomy was first performed for treatment of CVST in the 1990s (31); thus, the safety and efficacy have been widely confirmed (16,17). This therapeutic approach provides a mechanism for clot removal; it effectively decreases the risk of hemorrhagic complications and mortality rates, and it significantly improves the prognosis. Mechanical thrombectomy can be performed via several methods, including balloon angioplasty, stenting, clot maceration, and rheolytic thrombectomy (3,5,6,18).

Mechanical thrombectomy breaks and cuts the thrombosis via physical mechanisms, which makes the clots loosen in the venous sinus. Clinicians can subsequently perform a contact thrombolysis until the venous sinus lumen recanalization is achieved. The mechanical strategy helps to increase the contact area of the thrombosis with fibrinolytics, which improves the efficiency of the thrombolysis and increases the recanalization rate of the venous sinus. Mechanical thrombectomy is particularly well suited for refractory CVST patients in the following conditions: (i) the thrombosis has a long duration; (ii) thrombolysis alone is not efficacious or is complicated by intracranial hemorrhage; and (iii) situations in which the dosage of fibrinolytics should be strictly limited. It is noteworthy that the application of stents in mechanical thrombectomy can avoid or effectively reduce the dosage of thrombolytics. The intracranial Solitaire stent has high plasticity and good maneuverability, and it allows repeated deployments and retrievals during neurointervention. Solitaire AB stents have both closed and open meshes, and the deliberate design enables immediate blood flow restoration and clot retrieval (32). In recent years, this device has been widely used in the embolization of intracranial aneurysms and the recanalization of arterial occlusion in individuals with acute cerebral infarction (33,34). Furthermore, Solitaire AB stents exhibit significant merits in the treatment of patients who miss the thrombolytic therapeutic time window, who fail to thrombolysis, or who have thrombolytic contraindications.

Recently, other thrombectomy devices have been introduced into clinical use, such as a Penumbra (Penumbra Inc., Alameda, CA, USA), Merci thrombectomy device (Concentric Medical Inc., Mountain View, CA, USA), and balloon catheters. Evidence regarding the efficacy of these approaches in the treatment of CVST has not yet been reported. Furthermore, several authors have proposed that these devices are not suitable for CVST treatment considering the irregular sinus wall and tough nature of thrombosis in CVST (35).

Thrombolytics may be not necessary in mechanical thrombectomy with solitaire AB stents. Notably, mechanical thrombectomy in individuals with CVST is distinct from individuals with intracranial atherothrombosis because of the irregular structures of the venous sinus wall, and immediate imaging evaluation in CVST is typically difficult. The surgical goal of mechanical thrombectomy in CVST patients involves venous sinus recanalization and the re-establishment of blood stream access. Although a partial recanalization may be achieved, the blood supply compensation can save patients from severe conditions such as hematencephalon and coma (16,17). Furthermore, oral antithrombotic therapy should be administered in patients with CVST after mechanical thrombectomy. Nevertheless, the appropriate duration of antithrombotic therapy has not been established via randomized controlled studies. In the current cohort, a 6-month warfarin regimen was administered, and the prognosis has been shown to be favorable.

Despite these promising findings, there are several limitations that must be considered in the interpretation of the results. There is a limitation of our study that a control or comparison group is lacking. Different methods for treating this disease have been performed and comparison studies will be reported in the future. In this retrospective study, the inclusion of patients was done retrospectively, which brings up possibilities for bias and are a limitation of our study. Some cases were followed up for a short period only, so long-term follow-up is needed to further confirm our conclusions. No neurointervention-related complications were found among our 23 patients.

Only anticoagulation therapy was continued directly after intervention, without use of thrombolytics such as urokinase, complication of cerebral hemorrhage could be decreased. Besides, indwelling catheter was no longer needed for thrombolysis after interventional procedure, the possibility of intracranial infection could be low. These improvements could account for our encouraging result, however, neurointervention-related complications can be noted if large number of patients are investigated, which needs to be studied in the future by enrolling more patients.

In conclusion, CVST is a rare entity, which remains a therapeutic challenge. Mechanical thrombectomy with Solitaire AB stents is safe and effective for CVST treatment. The occurrence of complications is low, and the prognosis is favorable. Thus, the clinical application of this strategy is promising.

Declaration of conflicting interests

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