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Tubridge flow diverter for the treatment of recurrent cerebral aneurysms

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Abstract

Background & Objective: The Tubridge flow diverter is a commonly used device in China for reconstructing the parental artery and occluding complex intracranial aneurysms. However, there is limited experience with the device in treating recurrent intracranial aneurysms. The purpose of this study is to assess the safety and effectiveness of the Tubridge flow diverter in treating recurrent single-coiling aneurysms. *Methods:* The clinical records of patients with recurrent intracranial aneurysms who were treated with a Tubridge flow diverter were reviewed to show the therapeutic process, occlusion rate, and clinical outcomes associated with this treatment method. *Results*: Five patients with recurrent aneurysms of the internal carotid artery after singe coiling were included in the study. The recurrent aneurysmal sac had a mean length and width of 8.34/4.30 mm. All five Tubridge flow diverters were implanted without any unfold failure. The last angiographic follow-up showed a complete occlusion rate of 100%. Five branch arteries were covered, and only one branch artery disappeared during follow-up. No cases of cerebral infarction or intracranial hemorrhage were found among the patients. *Conclusions*: Our initial findings indicate that the Tubridge flow diverter could be a reliable and successful method for treating recurring single-coil aneurysms. We observed that the branch arteries were well-preserved, and no patients experienced cerebral infarction or hemorrhage. However, further research is necessary to establish clear indications and potential complications through a multicenter randomized controlled trial with long-term follow-up.

Keywords: Tubridge, flow diverter, internal carotid artery, recurrent aneurysm

INTRODUCTION

After treatment of intracranial aneurysms, there is a recurring rate that is particularly high following endovascular treatment. Several factors contribute to this recurrence, including the size of the aneurysm, the treatment method used, and the Raymond grade immediately following surgery.[1,2]

In the field of aneurysm treatment, the primary management methods are microsurgical clipping, endovascular reconstructive therapy, and close monitoring.[3] Recently, the use of blood flow diverter technology, specifically the Pipeline, has shown promising results in the treatment of recurrent aneurysms.[4-6] However, there is limited research on the efficacy of Tubridge in treating recurrent aneurysms.

Tubridge is a native flow diverter device commonly used in China designed to treat complex aneurysms that were previously difficult to manage through clipping or endovascular treatment, including large or giant aneurysms.[7] It provides an effective option for treatment, and many experts have attested to its safety and efficacy in treating aneurysms. However, there are currently few studies evaluating the use of Tubridge flow-diverter in endovascular reconstructive treatment of recurrent intracranial aneurysms. Hence, we gather the clinical records, assess the occlusion rate and outcomes after Tubridge deployment, analyze the existing

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literature, and deliberate on its potential future applications.

METHODS

Patients selection

This paper describes a retrospective analysis of clinical data from previously treated cases. Specifically, we gathered information on instances of recurrent aneurysms along the internal carotid artery despite singe coiling that were treated with the Tubridge flow diverter between 2019 and 2022 treated in our centre in Hangzhou, China. These aneurysms may have been ruptured or unruptured, irregularly shaped, or large enough to cause mass effect.

Anticoagulation and antiplatelet management

After the micro-catheter was placed, each patient received systemic heparin. Throughout the procedure, the activated clotting time was maintained at 2-3 times the baseline. To prepare for the procedure, each patient was given dual antiplatelet drugs (100 mg/day aspirin plus 75 mg/day clopidogrel) for at least 3-5 days. Following the deployment of the Tubridge flow-diverter, patients received an intravenous loading dose of tirofiban at 5μg/kg for 3-5 minutes, followed by a maintenance dose of 0.1μg/(kg/min) for 24 hours. The postoperative antiplatelet regimen that was administered is as follows: £3 months, 100 mg/day of aspirin and 75 mg/day of clopidogrel were given; >3 months, 100 mg/day of aspirin was given for one year.

Tubridge flow diverter and implantation procedure

The Tubridge flow diverter is a self-expanding stent that is woven with nickel-titanium and platinum-iridium microfilaments. With a pore size of 0.040-0.050 mm^2, it provides high metal coverage of approximately 30.0%-35.0% at the aneurysm neck after full opening. The stent has two flared ends and is mounted to a delivery wire that is constrained within a removable sheath. To prevent vascular injury, the tip of the delivery wire is J-shaped. The Tubridge flow diverters currently come in a range of diameters (2.5-6.5 mm) and lengths (12-45 mm). To introduce the Tubridge flow diverter, a micro-catheter with a diameter of 0.029 inches ((0.7366mm)) is used to access the target zone. The device is then deployed by pushing the delivery wire while simultaneously withdrawing the micro-catheter. The device can be retracted until it reaches the marker in the middle of the Tubridge. It is possible to perform coiling embolization before the stent is fully released. If the first flow diverter is not sufficient, a second one may be used. Typically, the rate of shortening after full deployment is less than 50%, but this may vary based on the size of the device and any differences in diameter between the proximal and distal vessels.

Angiographic evaluation and clinical outcome

The angiography was conducted using digital subtraction angiography protocols. The results of the angiography were determined based on the retention or decreased filling of the contrast agent in the aneurysmal sac immediately after the procedure. The treating interventionalist assessed the occlusion of the aneurysm on follow-up angiography imaging. The occlusion rate was categorized as complete occlusion (100%), near-complete occlusion (90%–100%), and partial occlusion (less than 90%).

RESULTS

Patients characteristics

Five male patients with a total of five aneurysms were identified between 2019 and 2022. The patients had a mean age of 50 years, with ages ranging from 35 to 63 years. Three out of five patients had a high BMI (≥24). The pretreatment mRS score was 0 for all patients, except for one patient who was 1, representing 20% of the procedures (Table 1).

Aneurysm characteristics

Five aneurysms were found in the anterior circulation, with mean original dimensions of 14.52 mm in length and 12.08 mm in width. The recurrent aneurysmal sacs had a mean length and width of 8.34 and 4.0 mm, respectively (Table 1). The parent artery had a mean proximal/distal diameter of 3.56/3.04 mm. All five aneurysms were treated with single coiling, including one that had ruptured.

Implantation outcome

Five Tubridge devices were implanted, with a mean diameter/length of 3.3/29 mm. There were no instances of opening failure during the procedure, and no coiling embolization treatments were performed for any inflow jet. Branch coverage, including the ophthalmic artery and posterior communicating artery, occurred in all arteries,

Table 1: Baseline characteristics of enrolled patients

Parameters	Recurrent aneurysms
No. of cases	5
Age(±SD years old)	50.40±11.40
Gender(M/F)	5(100%)/0(0%)
BMI≥24	3(60%)
Pretreatment mRS	
0	4(80%)
1	1(20%)
2-5	0(0%)
No. of Aneurysms	5
Side of Aneurysms	
Right	0(0%)
Left	5(100%)
Aneurysm locations	
ICA ophthalmic segment	3(60%)
ICA communicating segment	2(40%)
Aneurysm measurements(±SD mm)	
Mean width(original/recurrent)	12.08±8.03/4.30±1.53
Mean length(original/recurrent)	14.52±7.85/8.34±5.82
Parent artery diameter(±SD mm)	
Distal diameter	3.04±0.59
Proximal diameter	3.65±0.58

though one branch artery disappeared during follow-up. There were no cases of intracranial hemorrhage or infarct. However, all patients experienced decreased filling or retention of contrast agent in the aneurysmal lumen (Table 2).

Follow-up outcome

The mean time of the last angiographic follow-up was 8 months. There were no stent stenosis or ischemia events observed (Figure 1). During the last angiographic follow-up, complete occlusion was achieved in 100% of cases (Table 3). Additionally, the mRS of the last follow-up improved in all patients (1/1), and there were no reports of morbidity or mortality (Table 3).

DISCUSSION

In this article, we share a significant experience regarding the placement of Tubridge flow diverters for the treatment of recurrent aneurysms resulting

Table 2: Treatment by Tubridge flow diverter

Parameters	Recurrent aneurysms
No. of stents	5
Stent size(±SD mm)	
Diameter	3.3(±0.45)
Length	29(±2.24)
Unfold failure	0(0%)
Coiling	0(0%)
Branch coverage	5(100%)
OA	3(60%)
PCA	2(40%)
Stagnation/Decreased contrast filling	5(100%)
Adverse event(infarction/hemorrhage)	0 (0%)

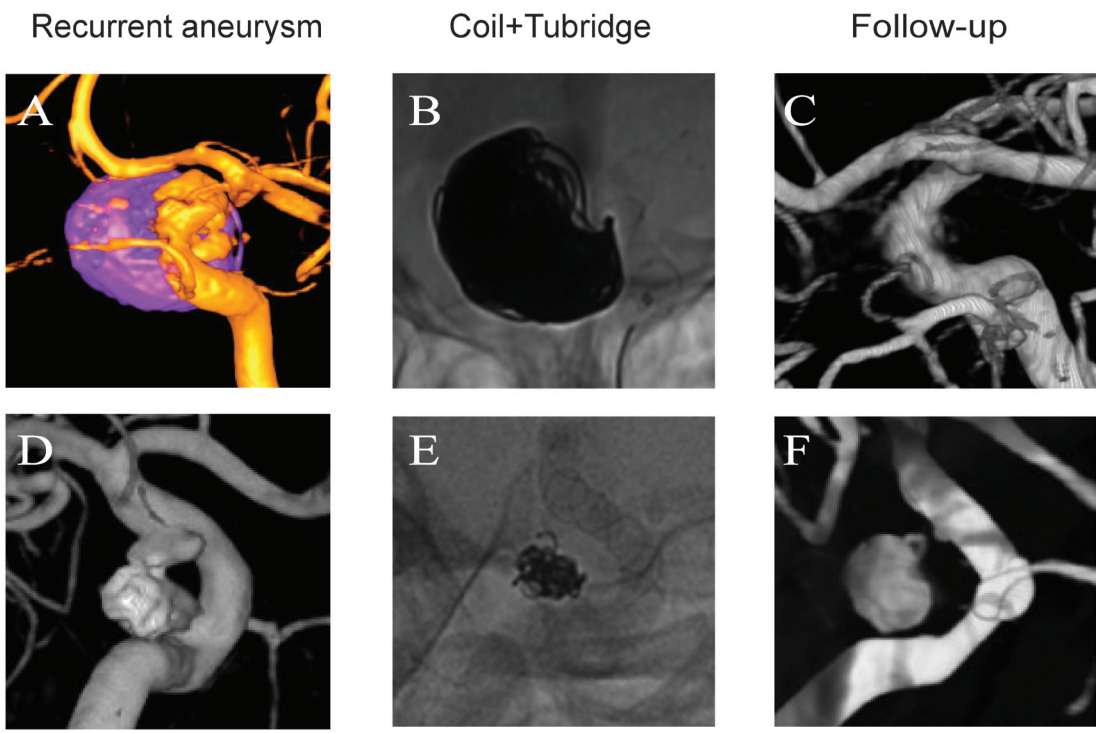

Figure 1 Tubridge flow diverter deployment of recurrent aneurysms along internal carotid artery.
A: Large recurrent aneurysm in the left internal carotid artery (ophthalmic segment), 25mm´21mm (original sac), 11.7mm´6.5mm (recurrent sac); parent artery diameter, 3.43 mm-3.02mm; B: stent size 3.5 mm-30 mm.
D: Medium recurrent aneurysm in the left internal carotid artery (communicating segment), 7.7mm´5.6mm (original sac), 4.5mm´2.8mm (recurrent sac); parent artery diameter, 4.01 mm -3.30mm; B: stent size 3.0 mm-25 mm.
B and E show well opening of Tubridge flow diverters.
C and F show well occluding with Tubridge flow diverters.

from single coiling along the internal carotid artery. The decision to attempt flow diverter treatment was influenced by factors such as the size of the aneurysmal sac and parent vessel. Our findings indicate a high rate of complete occlusion in cases of recurrent aneurysms, and we observed improvements in preoperative symptoms among patients. These findings indicate a high occurrence of occlusion in recurrent cerebral aneurysms located along the internal carotid artery.

Table 3: Outcome measures of follow-up

Parameters	Recurrent aneurysms
Last angiography(months)	8
Stent stenosis	0(0%)
Occlusion rate	
Complete	5(100%)
Near-complete	0(0%)
Partial	0(0%)
Branch patent	4(80%)
mRS	
Improved	1/1(100%)
No change	0
Worsened	0

Flow diverter treatment of recurrent cerebral aneurysms

Although the annual recurrence rate of aneurysms is unknown, studies have shown that there is a cumulative risk of 9.6% to 22% for recurrence or de novo formation 20 years after clipping.[8] Screening for recurrent aneurysms at 10, 15, and 20 years can detect 36.6%, 65.3%, and 95.1% of lesions, respectively.[8] Previous studies have found that certain factors, such as younger age, ruptured aneurysm, posterior communicating artery aneurysm, and aneurysm size over 10mm, are significantly associated with aneurysm recurrence.[1] The recurrence of cerebral aneurysms can be effectively treated through either endovascular embolization or microsurgical clipping.[3] However, the selection of the preferred method must be based on individual factors such as the specific aneurysm, parent artery, patient's condition, as well as the surgeon and surgical materials employed.

In recent times, flow diverter devices have emerged as an effective treatment option for recurrent aneurysms, offering a high embolization rate and low risk of complications. In a study conducted by Adeeb *et al*., seven patients with recurrent aneurysms who had previously undergone microsurgical clipping were treated with the Pipeline Embolization Device.[5] The results were promising, with no instances of morbidity or mortality associated with the device placement. Furthermore, all patients achieved complete occlusion, as confirmed by imaging follow-up. In a recent retrospective study, Daou *et al*. reported that the Pipeline Embolization Device was successful in treating thirty-two cases of recurrent aneurysms after coiling.[4] The treatment resulted in complete occlusion of the aneurysm in 76.7% of patients and near-complete occlusion (≥90%) in 10%, resulting in a total rate of complete or near-complete occlusion of 86.7%. Additionally, all patients, including those with incomplete occlusion, experienced a significant reduction in aneurysm size. According to the study, a good clinical outcome was observed in 97% of patients, with only one patient (3%) experiencing complications in the form of an intracerebral hemorrhage. Fortunately, there were no fatalities. Kühn *et al*. conducted a review of recurrent or residual aneurysms that had been treated with coiling or clipping.[6] They concluded that the Pipeline Embolization Device can be safely and effectively used after previous coiling or clipping procedures.

The use of flow diverters to treat recurrent aneurysms after stent-assisted coil embolization has been a topic of controversy due to concerns about lower embolization rates and safety. However, a study conducted by Heiferman *et al*. found that 76% of the aneurysms showed improved Raymond class occlusion at the 12-month follow-up, with 38% being completely occluded.[9] Additionally, all aneurysms demonstrated decreased filling. To ensure proper wall apposition and prevent endoleak, it is crucial to consider appropriate stent sizing, as well as proximal and distal construct coverage. Additionally, it is important to prevent flow diverter deployment between previously deployed stent struts. According to Daou *et al*., the use of Pipeline Embolization Device treatment resulted in complete aneurysm occlusion in 55.6% of patients who underwent stent-assisted embolization (21 patients), compared to 80.4% of patients who did not receive stent-assisted embolization (63 patients) (P=0.036).[10] The retreatment rate for the Pipeline Embolization Device group was 11.1%, while the rate for group 2 was 7.1% (P=0.62). At the latest follow-up, the Pipeline Embolization Device group had a good clinical outcome rate of 81%, while the nostent-assisted embolization group had a rate of 93.2% (P=0.1). Complications were observed in 14.3% of patients in the Pipeline Embolization Device group and 9.5% of patients in the nostent-assisted embolization group (P=0.684). The Pipeline Embolization Device is less effective in managing aneurysms that have been previously stented compared to nonstented aneurysms. Stent placement prior to using this device can worsen its safety and efficacy profile.

Safety and efficacy of Tubridge flow diverter

The flow diverter concept involves redirecting blood flow away from the aneurysmal sac and promoting reconstruction of the parent artery, rather than simply shrinking the sac through embolization. The safety of this approach is assessed by monitoring the occurrence of ischemia, bleeding, mass effects, morbidity, and mortality. Meanwhile, its effectiveness is measured by evaluating changes in flow patterns, contrast stagnation, or reduced filling during angiography, as well as the rate of complete occlusion observed in follow-up angiography. The Tubridge flow diverter is a stent-like device with a high metal coverage rate and low porosity. Its purpose is to divert blood flow away from the aneurysm sac while maintaining normal perfusion

of the branch artery. It comes in a variety of lengths and diameters, is radiopaque, has a flared end, is retrievable, and has a low shortening rate. Unlike other flow diverters, it does not increase complications, delivery difficulty, or opening difficulty. Coils can be introduced into the aneurysmal sac at the same time as flow diverter placement. This helps the micro-catheter cross the neck and promotes aneurysmal thrombosis. In cases of wide neck aneurysms, coils can also provide excellent support for flow diverters.[7,11]

Numerous studies have shown that Tubridge is an effective treatment option for a range of complex aneurysms. Large or giant aneurysms pose a challenge for treatment as clipping and coil embolization may not be effective. However, Tubridge placement has been found to have a higher success rate of complete embolization compared to stent-assisted coils, while also maintaining patent branch vessels and avoiding any instances of morbidity or mortality.[7] According to some experts, large aneurysms, middle cerebral artery aneurysms, and vertebral artery aneurysms have shown promising results with high embolization rates, preservation of branch vessels, and a positive prognosis.[11-13]

Currently, there is limited literature on the use of our method for Tubridge flow diverter placement. Zhang *et al*. found that out of the 7 aneurysms treated with stent-assisted coiling and the 1 aneurysm treated with single coiling using Tubridge, five aneurysms were completely occluded. However, two aneurysms had a residual neck and one had severe asymptomatic stenosis in the parent artery.[14] Some studies have reported that flow diverters, such as pipeline, are not as effective in treating recurrent aneurysms when the initial treatment involved stent implantation compared to single embolization.[9-10]

In addition to other factors, it is important to take into account ischemic events and stent stenosis. Ischemic stroke occurs in approximately 4.7% to 7.3% of cases.[15] Almost half of these events are attributed to perforating artery infarction during flow diverter treatment.[16] Additionally, in-stent stenosis is detected in 38% to 39% of patients treated with Silk and Pipeline flow diverter, which is believed to be caused by an endotheliocyte reaction of the artery wall to the device. Early angiographic follow-up is important for detecting in-stent stenosis, which typically occurs within the first two months after flow diverter deployment. While most stenosis cases are mild to moderate, they can be treated conservatively with enhanced medical therapy.[17]

The Tubridge flow diverter, a native endovascular reconstruction device, has demonstrated excellent efficacy and safety in treating complex aneurysms, with effective occlusion rate and clinical outcome, acceptable adverse events, comparable to other flow diverters.[18,19]

We conducted a review of clinical data from five single coiling aneurysms that underwent the procedure. Our results indicate that the devices were successfully implanted without any unfolding failures or adverse events. Additionally, all aneurysms achieved complete occlusion on the last angiographic follow-up. There were no instances of symptomatic thromboembolic complications or intracranial hemorrhage observed in any of the aneurysms.

We acknowledge that our study is limited to being a retrospective study from a single center, with a specific number of patients and a limited follow-up time. Despite these limitations, we included parameters about patient characteristics, aneurysms, management, follow-up, imaging studies, and evaluation of aneurysm occlusion. Our report on recurrent aneurysms treated by Tubridge will still make a significant contribution to the existing literature.

In conclusion, our initial findings suggest that the Tubridge flow diverter could be a secure and efficient stent for treating recurrent cerebral aneurysms that have undergone single coiling along the internal carotid artery. Nevertheless, we need to confirm indications and potential complications, which warrant a multicenter randomized controlled trial with long-term follow-up.

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DISCLOSURE

Ethics: The institutional review board of the hospital approved this study and waived the requirement for patient informed consent due to its retrospective design. Informed consents were obtained from all individual in the study including all surgical procedures.

Data availability: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Conflicts of interest: None

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