Low-Profile Visualized Intraluminal Support Stent for the Endovascular Treatment of Traumatic Internal Carotid Artery Pseudoaneurysms

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Research Article

Keywords: pseudoaneurysms, low-profile visualized intraluminal support stent, internal carotid artery, trauma

Posted Date: September 24th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-925492/v1>

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Abstract

Objectives Optimal treatment strategies for traumatic internal carotid artery (ICA) pseudoaneurysms are controversial. The low-profile visualized intraluminal support (LVIS) device is a braided stent with a metal coverage rate between traditional laser cut stents and flow diversion devices. We report here our therapy strategy using the LVIS stent-assisted coiling for treatment of traumatic ICA pseudoaneurysms.

Methods Patients with traumatic ICA pseudoaneurysms treated by the LVIS stent-assisted coiling in our center between January 2015 to June 2021 were reviewed. The complications, radiographic, and clinical outcomes of these patients were analyzed.

Results A total of 12 pseudoaneurysms in 12 patients were included. Immediate postoperative angiogram showed that six (50%) aneurysms were Raymond grade 1, four (33.3%) were grade 2, and two (16.7%) were grade 3. Two patients with severe primary cranial injury discontinued treatment after the procedure. During the follow-up of the other ten patients, two patients (20%) received additional coiling because of recanalization of the pseudoaneurysm. At the last angiographic follow-up examination, all aneurysms were Raymond grade 1. Postoperative multiple cerebral infarction occurred in two patients. Of the ten patients with a mean clinical follow-up of 32.2 ± 27.9 (median, 18) months, eight patients recovered well, one patient had right hemiplegia, and one patient died of airway damage, which was unrelated to the pseudoaneurysm.

Conclusions LVIS stent-assisted coiling was a feasible approach for the treatment of traumatic ICA pseudoaneurysms.

Introduction

Traumatic pseudoaneurysm is a rare disease, which results from disruption of the arterial wall with formation of a contained extravascular hematoma connected to the ruptured vessel. Traumatic internal carotid artery (ICA) pseudoaneurysm is even more rare. Traffic accident, fall injury, and iatrogenic injury are the most common etiologies. As the wall of the pseudoaneurysm is vulnerable, risk of rupture is far higher with pseudoaneurysm than with real aneurysms. Therefore, timely diagnosis and therapy are very important. Traditional microsurgical therapies include direct clipping, wrapping-clipping, suturing, ligation of the ICA, and trapping with or without bypass [20]. However, these surgical methods are usually difficult and complex, especially in patients with acute bleeding or significant brain swelling.

With the development of endovascular techniques and materials, different endovascular approaches have been applied for the treatment of intracranial pseudoaneurysms [16, 20]. Several studies have reported stent-assisted coiling treatment for intracranial pseudoaneurysms with different outcomes [6, 8, 10, 12, 13]. Flow diversion devices implantation with or without coils and covered stent implantation were reported to be effective as therapy of pseudoaneurysms [5, 15, 18, 19]. However, the use of flow diversion devices accompanied with dual antiplatelet therapy before the procedure may be limited in patients with acute bleeding. Meanwhile, covered stents may occlude important branches adjacent to the aneurysms.

The low-profile visualized intraluminal support (LVIS) device is a braided self-expanding stent with a metal coverage rate between laser cut stents and flow diversion devices (on average 23%). Only several case reports have described the use of LVIS stents for treatment of intracranial pseudoaneurysms in English literature, but these were not in the ICA [11, 12]. Therefore, its safety and efficacy in treatment of ICA pseudoaneurysms are unclear. Here, we share our treatment experience of traumatic ICA pseudoaneurysms using LVIS stent-assisted coiling in a case series. In addition, we review different treatment methods for ICA pseudoaneurysms.

Methods

Between January 2015 to June 2021, 33 consecutive patients with traumatic pseudoaneurysm were referred to our center. Of these, 12 patients (one female and 11 males) with 12 traumatic ICA pseudoaneurysms were treated with LVIS stent-assisted coiling and enrolled in this study. This study was approved by the institutional review board of First Affiliated Hospital of Nanchang University, Jiangxi province, China. Because the study was retrospective, informed consent of patients was not required.

Endovascular technique

All procedures were performed under general anesthesia. A 6F guiding catheter or intermediate catheter was introduced into the target ICA through a right femoral approach. Angiograms were performed to visualize the location and morphology of the pseudoaneurysm, and to measure the diameter of the pseudoaneurysm and parent artery. Semi-jailing technique was adopted in all procedures. First, a Headway 21 microcatheter (MicroVention, Tustin, CA, USA) was navigated to the distal part of the parent artery and an Echelon 10 microcatheter (EV3, Plymouth, MN, USA) was navigated to the aneurysmal neck via a Synchro 14 microwire (Stryker, Kalamazoo, MI, USA). Then, the LVIS stent was delivered to the Headway 21 microcatheter tip. The stent was released to cover the aneurysmal neck after some coils were introduced in the aneurysmal cavity. More coils were introduced until complete occlusion was achieved or no additional coils could be deployed safely.

Anticoagulation and antiplatelet management

During the procedure, all patients received heparin systemically to maintain an activated clotting time between 250–300 seconds. If patients had an acute ruptured pseudoaneurysm, no antiplatelet therapy was administered before the procedure. Instead, 5 µg/kg tirofiban was administered by intravenous injection before the stent was released. After the procedure, these patients received a loading dose of aspirin and clopidogrel (300 mg each), and a 0.1 µg/kg/min maintenance infusion of tirofiban for 8 hours. However, in patients with unruptured pseudoaneurysm, dual antiplatelet therapy (clopidogrel 75 mg/day, aspirin 100 mg/day) was administered at least 3 days before the procedure. After the procedure, all patients received a daily dose of clopidogrel (75 mg) and aspirin (100 mg) for 1 month, followed by aspirin only for at least 5 months.

Clinical and angiographic follow-up

A brain computed tomography (CT) scan was routinely performed the day after the procedure. In principle, follow-up digital subtraction angiography (DSA) was performed to evaluate the aneurysm occlusion status at 1 and 6 months after the procedure, and magnetic resonance angiography was performed annually thereafter. Angiographic results were assessed using the 3-point Raymond scale where: 1, complete occlusion; 2, neck remnant; and 3, sac remnant [14]. Clinical outcomes were evaluated according to the Glasgow outcome scale (GOS) at discharge and follow-up.

Results

The detailed information of all patients is shown in Table 1. The mean age of these patients was 32.1 ± 16.5 years. The most common etiology was traffic accident (66.7%), followed by fall-down injury (16.7%), and iatrogenic injury in surgery (16.7%). The distribution of the ICA pseudoaneurysms according to the classification of Bouthellier et al. [3] was as follows: C5 in one patient, C4 in four patients, and C7 in seven patients. The mean maximum aneurysm diameter and neck were 6.2 ± 3.1 mm and 2.5 ± 0.9 mm, respectively. Preoperative Hunt-Hess grade was 0 in three patients (25%), III in five patients (41.7%), and IV in four patients (33.3%).

Table 1
Characteristics of patients and aneurysms, treatment, and clinical and angiographic outcomes

Case NO.	Sex/Age (years)	Etiology	Initial Symptom	SAH	H-H grade	Aneurysmal Location	Maximum Diameter/Neck (mm)	Stent Version (mm)	Surgical Outcome		Maximum Angiographic Follow-up	
									Raymond Grade	GOS	Months	Ray Gra
1	F/23	Traffic accident	Headache	Yes	III	R/C5	3.4×3.4/2.7	3.5×20 3.5×15	2	4	73	1
2	M/30	Traffic accident	Epistaxis, unconsciousness	Yes	IV	R/C7	4.1×2.5/2.5	3.5×20	1	3	71	1
3	M/28	Fall	Headache, epistaxis	Yes	III	L/C7	6.2×5.0/2.2	3.5×15	3	5	54	1
4	M/49	Iatrogenic	Headache, epistaxis	No	0	L/C4	4.5×1.5/1.4	3.5×20	2	5	35	1
5	M/54	Traffic accident	Headache	Yes	III	L/C7	4.1×3.1/1.4	3.5×20	2	2	-	-
6	M/19	Traffic accident	Unconsciousness	Yes	IV	R/C4	4.6×5.3/3.5	3.5×20	3	2	6	1
7	M/13	Fall	Unconsciousness	Yes	IV	R/C7	9.7×8.0/1.1	3.5×20	1	2	-	-
8	M/15	Traffic accident	Unconsciousness	Yes	IV	L/C7	3.3×3.0/1.9	3.5×20	1	2	18	1
9	M/17	Traffic accident	Confusion	Yes	III	R/C7	12.1×9.3/3.3	4.5×20	1	3	18	1
10	M/27	Iatrogenic	Vision loss	No	0	L/C4	11.5×6.8/3.6	4.5×20	1	5	12	1
11	M/54	Traffic accident	Confusion	Yes	III	L/C7	4.8×3.7/2.8	3.5×20	2	5	6	1
12	M/56	Traffic accident	Headache, epistaxis	No	0	L/C4	5.6×4.4/3.7	3.5×20	1	5	6	1
SAH: subarachnoid hemorrhage, H-H: Hunt-Hess, GOS: Glasgow outcome scale, R: right, L: left, -: not applicable												

Eleven patients were treated by single LVIS stent-assisted coiling, and one patient was treated by two overlapping LVIS stents-assisted coiling. The angiogram at the end of procedure showed that six aneurysms (50%) were Raymond grade 1, four aneurysms (33.3%) were grade 2, and two aneurysms (16.7%) were grade 3. Two patients (cases 5 and 7) with severe primary cranial injury discontinued treatment after the procedure. In the other ten patients with angiographic follow-up, the mean follow-up was 29.9 ± 26.8 (median, 18) months. Two patients, cases 1 and 8, received additional coiling because of recanalization of the pseudoaneurysm 17 days and 2 months after their initial operation, respectively. At their last angiographic follow-up, all aneurysms were Raymond grade 1.

Postoperative multiple cerebral infarction occurred in two patients (cases 2 and 8). Case 2 recovered well, except for mild memory loss, but case 8 had a right hemiplegia. For the ten patients with clinical follow-up, the mean follow-up period was 32.2 ± 27.9 (median, 18) months. Clinic outcomes of those patients assessed by GOS are shown in Table 1. During follow-up, one patient died of airway damage, which was unrelated to the pseudoaneurysm (case 6). For the remaining nine patients who survived, eight patients (88.9%) had GOS 5 and one patient (11.1%) had GOS 1.

Illustrative case 1 (Patient No.2)

One day prior to presentation in our center, the patient presented with epistaxis and unconsciousness after a traffic accident and had been admitted to another hospital. CT scan showed subarachnoid hemorrhage, ventricular hemorrhage, skull base fracture and pulmonary contusion. A pseudoaneurysm at the C7

segment of the right ICA was detected by DSA after the patient had been transferred to our hospital (Fig. 1a). An emergent single LVIS stent-assisted coiling was performed successfully. Angiogram at the end of operation showed the aneurysm was completely occluded (Fig. 1b), and the coils were adjacent to the parent artery (Fig. 1c). Multiple cerebral infarction was detected by CT the next day (Fig. 1d). At follow-up 1 month later, DSA revealed that the pseudoaneurysm had disappeared (Fig. 1e), but the coils had separated from the parent artery (Fig. 1f). During a clinical follow-up at 71 months, it appeared that the patient had recovered well, except for mild memory loss.

Illustrative case 2 (Patient No.10)

This young patient underwent a transsphenoidal microsurgery because of invasive pituitary prolactinoma 9 years ago. The surgery had been terminated due to a massive bleeding. The patient had been discharged with no complications, and received long-term pharmacotherapy. The prolactinoma shrank soon after the pharmacotherapy, but it was shown to grow again two months ago. Because of this drug resistance, another surgery was planned. However, the preoperative CT angiography showed a left cavernous ICA pseudoaneurysm (Fig. 2a). LVIS stent-assisted coiling was successfully performed for the treatment of the pseudoaneurysm. Angiogram at the end of procedure demonstrated the aneurysm was completely occluded (Fig. 2b). At follow-up 6 month later, no recurrence of aneurysm was observed by DSA (Fig. 2c). During the follow-up period, the patient recovered well without complications.

Discussion

Optimal treatment strategies for traumatic ICA pseudoaneurysms are controversial. In this study, we reviewed 12 patients with 12 traumatic ICA pseudoaneurysms treated with LVIS stent-assisted coiling. With the exception of two patients who discontinued treatment and one patient who died of airway damage, which was unrelated to the pseudoaneurysm, most patients (8/9, 88.9%) recovered well during follow-up.

In the past, various surgical methods have been performed to treat pseudoaneurysms, and were proven to have different shortcomings. Direct clipping is not always feasible and durable because pseudoaneurysms lack a true neck. Wrapping-clipping, microsurgical suturing of the vessel defect, and trapping with or without bypass are complex and challenging, especially in the petrous, cavernous, and paraclinoid segments. Ligation of the ICA may result in severe ischemic complications, and collateral retrograde blood flow may result in treatment failure. Nowadays, surgical treatment is only applied for pseudoaneurysms accompanied by a large hematoma exerting a significant mass effect, and minimal invasive endovascular techniques are more preferred in clinical practice.

Endovascular techniques, including coiling, stent-assisted coiling, flow diversion device implantation with or without coils, covered stent implantation, and occlusion of the ICA, have been used for the treatment of traumatic ICA pseudoaneurysms. Packing of the aneurysmal cavity with coils has been reported in several case reports [1, 2, 4, 9]. Because of absence of a true aneurysm neck, aneurysm recurrence is a major complication [2, 9]. Occlusion of the ICA is not recommended as first-line therapy because patients may develop ischemic complications [7].

Cohen et al. [6] have reported on the treatment of three ICA pseudoaneurysms by balloon-expandable bare stent-assisted coiling. In this report, two aneurysms were completely occluded and one aneurysm reoccurred. Ogilvy et al. [13] reported on a successful treatment of a supraclinoid ICA pseudoaneurysm using single Enterprise stent-assisted coiling. Lim et al. [10] described a supraclinoid ICA pseudoaneurysm that was successfully cured by two overlapping Enterprise stents-assisted coiling.

Pipeline device implantation was also reported for the treatment of ICA pseudoaneurysms [5]. The Pipeline device has a high metal coverage rate of 30–35%, and therefore has a better flow diversion effect than bare stents. Nevertheless, it is stiffer than traditional stents, which leads to more difficult navigation in the tortuous ICA, and thereby may worsen the vascular damage during its deployment.

Two case series have reported the successful treatment of traumatic ICA pseudoaneurysms with the Willis covered stent [18, 19]. Covered stent implantation can immediately exclude the aneurysm from the parent artery and restore the normal blood flow. The major limitation is that the covered stents may occlude important branch vessels adjacent to the aneurysms. There is a high requirement for antiplatelet therapy with both flow diversion devices and covered stent implantation, which is accompanied with additional bleeding risk for patients with acute cerebral hemorrhage or multiple injury.

There are two reasons why the LVIS stent was chosen here. Firstly, compared with traditional stents, it has a higher metal coverage rate and a smaller cell size. The LVIS stent has a mean metal coverage rate (23%) between conventional laser cut stents (6–11%) and flow diversion devices (30–35%). A higher metal coverage rate results in improved blood flow diverting effects, such as reduced blood flow velocity and wall shear stress at the aneurysmal wall. Theoretically, the LVIS stent promotes aneurysm thrombosis better than conventional stents. Wang et al. [17] demonstrated that a single LVIS stent resulted in more blood flow decrease than 2 overlapping Enterprise stents. The cell size (1.0 mm × 0.3 mm) of LVIS stents is smaller than that of non-braided stents, which provides protection for small coil prolapse. Secondly, the damaged parent artery wall is incomplete and vulnerable. The use of stents with strong radial force may cause further damage to the parent artery. Also, the push-pull technique used in the release of flow diversion devices may result in further damage. In contrast, the release of the LVIS stent is simple, especially the 3.5 mm diameter version. It is important to note that attempts to increase the metal coverage rate at the pseudoaneurysmal neck by compressing the LVIS stent is dangerous, as this can lead to further damage to the artery wall.

Because of the vulnerability of the pseudoaneurysmal wall, a tight coil embolization of the pseudoaneurysmal cavity is more dangerous than in the real saccular aneurysmal cavity. In case 2 in our study, the coils had separated clearly from the parent artery during follow-up (Fig. 1f). This demonstrates that the pseudoaneurysmal wall was consisted of a vulnerable hematoma. With the absorption of the extravascular hematoma and repairment of the damaged artery, the coils may separate from the parent artery.

We have gained some experience on coil insertion that is shared here. First, the microcatheter should only be navigated to the aneurysmal neck, which in fact is the defect of the parent artery. Second, two-dimensional coil or soft coil should be selected instead of three-dimensional coil. The diameter of the coil should

be 1–2 mm smaller than that of the pseudoaneurysm. Finally, if tight embolization of the aneurysmal cavity cannot be completed, the maximum number of coils should be inserted at the aneurysmal neck. Coils that protrude into the parent artery can be applied when necessary to form a “cap effect” between the stent and the parent artery.

Of the ten patients with angiographic follow-up, two (20%) patients received additional coiling because of pseudoaneurysm recurrence. Considering the high recurrent rate of pseudoaneurysm, close angiographic follow-up is recommended. The first follow-up visit should be scheduled within 1 month.

There are some limitations in this study. First, our study was retrospective with a small sample size. Second, most patients’ follow-up time was short. Finally, considering the heterogeneity of pseudoaneurysms with regard to etiologies, locations, sizes, and comorbidities of patients between our study and previous studies, no direct comparison of efficacy and safety of different treatment methods could be made.

Conclusion

This study demonstrated that LVIS stent-assisted coiling is a feasible approach in treating patients with traumatic ICA pseudoaneurysms. Given the high recurrent rate of pseudoaneurysms, close follow-up of patients is recommended.

Abbreviations

ICA internal carotid artery

LVIS low-profile visualized intraluminal support

CT computed tomography

DSA digital subtraction angiography

GOS Glasgow outcome scale

Declarations

Acknowledgments: None.

Author contribution Conception and design: Song Tan, Xiaobing Zhou, Yang Wang.

Data collection and analysis: Yuzhao Lu, Lingfeng Lai, Xiaofei Huang, Bin Li. Drafting the article: Song Tan. Critically revising the article: Xiaobing Zhou, Yang Wang. Reviewed submitted version of manuscript: all authors.

Funding This work was supported by the National Natural Science Foundation of China (grant number: 81960330).

Conflict of Interest The authors report no conflict of interest.

Availability of data and material All data of this study are available from the corresponding author on reasonable request.

Code availability Not applicable.

Ethics approval This study was approved by the ethics committee of First Affiliated Hospital of Nanchang University, Jiangxi province, China (approval number: 2020-047).

Consent to participate Informed consent was not required because of the retrospective design of our study.

Consent for publication Not applicable.

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Figures

Figure 1

A 30-year-old man with a ruptured right ICA pseudoaneurysm treated with LVIS stent-assisted coiling. (a) DSA shows a pseudoaneurysm at the communicating ICA. (b, c) Immediate postprocedural angiogram reveals that the pseudoaneurysm was totally occluded, and the coils were adjacent to right ICA. (d) Computed tomography scan the next day after the procedure shows multiple cerebral infarction. (e, f) Follow-up DSA at 1 month shows the pseudoaneurysm has disappeared, but the coils are separated from the right ICA. ICA, internal carotid artery; DSA, digital subtraction angiography

Figure 2

A 27-year-old man with a left ICA pseudoaneurysm treated with LVIS stent-assisted coiling. (a) DSA shows a pseudoaneurysm at the cavernous ICA. (b) Angiogram at the end of procedure shows total occlusion of the pseudoaneurysm. (c) Follow-up DSA at 6 months shows no recurrence of the pseudoaneurysm, and patency of the parent artery without stenosis. ICA, internal carotid artery; DSA, digital subtraction angiography