



# WEB-only treatment of ruptured and unruptured intracranial aneurysms: a retrospective analysis of 47 aneurysms

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## Abstract

**Background** WEB (Woven EndoBridge) device is an intrasaccular flow diverter designed for endovascular treatment of intracranial aneurysms. Recent clinical trials showed good feasibility, safety, and efficacy profiles. In most of the published studies however, aneurysms treated with adjunctive devices other than WEB such as coils or stents were included which might make it difficult to reflect the real potential of this device. The purpose of this single-center study was to present the results of ruptured and unruptured aneurysms treated only with WEB device.

**Method** Between April 2013 and July 2018, 47 (ruptured, 12; 25.5%) intracranial aneurysms treated only with WEB and a follow-up of at least 3 months were included in the study. Angiographic outcome at follow-up, peri-procedural complication rate, and rate of retreatment were recorded.

**Results** Of the 47 aneurysms, 12 (25.5%) were ruptured. The mean size of the aneurysms was 6.3 mm (ruptured, 5.4 mm; unruptured, 6.6 mm). Median follow-up period was 9 months. Complete occlusion was observed in 26/47 aneurysms (55.3%; ruptured, 66.6%; unruptured, 51.4%). Thirteen aneurysms (27.6%; ruptured, 16.6%; unruptured, 31.4%) showed a neck remnant. In 4/47 aneurysms (8.5%; ruptured, 8%; unruptured, 8.5%), persistent contrast enhancement inside the WEB was recorded. In 4/47 patients (8.5%; ruptured, 8%; unruptured, 8.5%), an aneurysm remnant was noted. Adequate occlusion (complete occlusion and neck remnant) was observed in 43/47 aneurysms (91.4%; ruptured, 91.6%; unruptured, 91.4%). Retreatment rate was 6.3% (ruptured, 8%; unruptured, 5.7%). Six (12.7%; ruptured, 25%; unruptured, 8.5%) thromboembolic events were recorded. Hemorrhagic complications occurred in two patients (4.2%; ruptured, 16.6%; unruptured, 0%).

**Conclusions** WEB enables adequate occlusion of ruptured and unruptured intracranial aneurysms mostly without requirement of long-term antiplatelet therapy. The benefit is seen especially by the wide-necked aneurysms, but indications should be extended to include narrow-necked, smaller, and side-wall aneurysms.

**Keywords** Woven EndoBridge · Intracranial aneurysm · Endovascular treatment · Subarachnoid hemorrhage

## Introduction

WEB (Sequent Medical, Aliso Viejo, CA, USA) is a complex device designed for endovascular treatment of intracranial aneurysms via diverting the intrasaccular flow, thus promoting intra-aneurysmal thrombus formation.

Recent clinical trials showed good feasibility, safety, and efficacy profiles, especially for the embolization of wide-necked and ruptured aneurysms because of not needing any adjunctive device or in most cases not requiring any post-procedural antiplatelet therapy [1–8]. Over time, utilization possibilities of the device have expanded to include endovascular embolization of side-wall aneurysms, recurrent aneurysms after coiling or usage as an adjunctive device to coiling, or even occlusion of cerebral arteries [9–14]. However, in most of the published studies, aneurysms treated with adjunctive devices such as coils or stents were also included which might make it difficult to reflect the real potential of this device. The purpose of this single-center study was to present the follow-up results of ruptured and unruptured aneurysms treated only with the WEB device.

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## Methods and materials

We conducted a retrospective search in our database for all patients who underwent endovascular therapy for treatment of cerebral aneurysms using only WEB device in our institution between April 2013 and July 2018. Aneurysms occluded with additional devices (coils and stents) were excluded from the study. All 3 types of WEB device, dual layer (DL), single layer (SL), and single layer sphere (SLS), were used for treatment of the aneurysms.

### Data collection

Data were collected retrospectively. For each patient and aneurysm, the following data were gathered: age, sex, rupture status, aneurysm location and size (dome size and height), neck size, aspect ratio, peri- and post-operative antiplatelet therapy, treatment-related complications, retreatment rate, and occlusion status at follow-up.

### Indications of WEB device

In our institution, WEB is mostly indicated for wide-necked bifurcation aneurysms regardless of size and rupture status. However, our practice has evolved over the years according to our positive experiences into considering WEB as the first choice whenever possible. Still, aneurysms in certain locations such as paraophthalmic or cavernous internal carotid artery (ICA) are being treated using either flow diverters or stent-assisted coiling.

### Procedural data

Embolization was performed on a biplane angiographic system (Siemens, Erlangen, Germany) by 4 interventional neurointerventionalists with varying experience (Y.O., M.B., M.S., and B.S.). All procedures were done under general anesthesia using standard femoral approach. Patients received an intravenous bolus of 5000 IU heparin after femoral puncture. Apart from heparin in the pressure bags for flushing (1000 IU/L), heparin therapy was not continued during or after the procedure.

After navigating the guiding catheter into the relevant supraaortic artery, we catheterized aneurysms by using a combination of an appropriate microcatheter and microwire chosen according to the WEB size. The required WEB size was determined from the 3D angiographic dataset with calibrated distance measurements. According to the recommendations of the manufacturer, WEB was oversized to secure the maximum stable position inside the aneurysm with little bulging into the parent vessel lumen. WEB device was then deployed in the aneurysmal sac. A control angiogram, mostly a 3D angiography, followed to check the position of the device inside the

aneurysm sac and flow stagnation inside the aneurysm. In case of inadequate positioning, the device was resheathed and repositioned. In case of inappropriate sizing, the device was resheathed and removed and another device was deployed in the aneurysm. Once the right-sized device was correctly positioned and detached, a final digital subtraction angiography (DSA) run was performed. A non-contrast computed tomography (CT) scan routinely followed to exclude an immediate procedure-related complication. Pre- and post-operative antiplatelet regimens were the following: In our institution, each unruptured case receives 100 mg acetylsalicylic acid (ASA) and 75 mg clopidogrel 5 days prior to the treatment if possible. Otherwise, they are loaded with 500 mg ASA and 375 mg clopidogrel the day before treatment. If only WEB is employed, depending on the extent of WEB protrusion into the parent vessel or neck size of the aneurysm, either double antiplatelet regimen for further 4–6 weeks or single antiplatelet regimen (100 mg ASA daily) for up to 6 months continues. In ruptured aneurysms, once the rupture point is secured, if the aneurysm neck is wide or some prolapse of WEB into the parent artery is seen, single antiplatelet, usually acetylsalicylic acid 100 mg daily, is given for 4–6 weeks. In case of periprocedural thromboembolic complications in ruptured aneurysms, short-term double antiplatelet therapy usually for 6 months is continued.

### Follow-up

Follow-up included an initial DSA or CT angiography (CTA) no later than 6 months after the treatment. Depending on the results, further angiographic controls either with DSA, CTA, or magnetic resonance angiography (MRA) were scheduled. Only patients with angiographic follow-up later than 3 months were included.

### Reevaluation

Follow-up imaging data were reevaluated by three neuroradiologists (Y.O., M.B., and B.S.). Aneurysm occlusion was evaluated by two methods: a four-grade scale (1: complete obliteration, 2: residual neck, 3a: aneurysm enhancement inside the WEB with full coverage of the aneurysm orifice and good wall apposition, and 3b: aneurysm remnant) and a simplified binomial system grading as either adequate occlusion (complete occlusion or neck remnant) or aneurysm remnant.

## Results

### Population and aneurysm characteristics

Between April 2013 and July 2018, 55 patients with 58 intracranial aneurysms were treated in our institution using the

WEB device only. Six patients were treated during the last 3 months of the study period. Four patients were lost to follow-up, and one 84-year-old patient with severe subarachnoid hemorrhage (SAH) due to a ruptured posterior inferior cerebellar artery (PICA) aneurysm died in the hospital because of pulmonary complications. The remaining 47 aneurysms in 45 patients (women, 33; 73.3%) with a mean age of 60 years (range, 36–80) treated with WEB device only and having at least a 3-month follow-up imaging were included in the study. Of the 47 aneurysms, 12 (25.5%) were ruptured. In 20/47 aneurysms (42.5%; ruptured, 33.3%; unruptured 45.7%), the neck size was  $\geq 4$  mm. Thirty-one (65.9%; ruptured, 66.6%; unruptured, 65.7%) aneurysms had an aspect ratio of  $\leq 1.5$  and considered wide-necked aneurysms. Table 1 outlines further characteristics of the aneurysms including locations.

Three (6.3%) patients had multiple unruptured WEB-only treated aneurysms (6 aneurysms total; one patient with a middle cerebral artery (MCA) and an intradural ICA aneurysm, one with an anterior communicating artery (Acom) and a basilar tip aneurysm, and one with a MCA and a basilar tip aneurysm).

Forty-three aneurysms (91.5%) were treated with WEB SL, one aneurysm (2.1%) was treated with WEB DL, and 3 (6.4%) aneurysms were treated with WEB SLS.

### Anatomical results at follow-up

Median follow-up period was 9 months. Twenty-nine out of 45 (64.4%) patients had at least one DSA during follow-up. The rest (35.6%) had CTA as first-line imaging modality. Grade 1 occlusion was observed in 26/47 aneurysms (55.3%). Thirteen aneurysms (27.6%) showed a grade 2

occlusion. Four out of 47 aneurysms (8.5%) were grade 3a, and 4/47 patients were grade 3b. Adequate occlusion was observed in 43/47 aneurysms (91.4%; ruptured, 91.6%; unruptured, 91.4%) (Table 2).

### Retreatment

Three aneurysms (6.3%; ruptured, 8%; unruptured, 5.7%) were retreated. An unruptured Acom aneurysm was retreated via surgical clipping 1 year after WEB treatment due to asymptomatic reperfusion. A ruptured Acom aneurysm treated with WEB was retreated after 15 months via surgical clipping due to neck reperfusion and symptomatic acute thrombotic occlusion of the anterior cerebral artery. An unruptured cavernous segment aneurysm was retreated via flow diverter-assisted coiling due to asymptomatic reperfusion 6 months after WEB implantation.

### Complications

Six (12.7%; ruptured, 25%; unruptured, 8.5%) thromboembolic events were seen. In two patients, immediate occlusion of the parent artery occurred after deployment of the WEB device. In one case, the WEB could be resheathed and in the other one, WEB was already detached. In order to restore perfusion, a Solitaire AB stent (eV3, Irvine, CA, USA) was deployed. In both cases, intravenous tirofiban was started during the intervention and later changed to double oral antiplatelet therapy. Both patients were discharged without any sequela. In three patients, thromboembolic complications were seen during the first week after the treatment. One patient with

**Table 1** Aneurysm measurements and locations

	Total (47 aneurysms)	Ruptured (12 aneurysms)	Unruptured (35 aneurysms)
<b>Aneurysm measurements</b>			
Mean size (range)	6.3 mm (4–12.3 mm)	5.4 mm (4–6.9 mm)	6.6 mm (4.1–12.3 mm)
Mean aneurysm width (range)	5.9 mm (3.5–12.3 mm)	4.7 mm (3.5–6.9 mm)	6.3 mm (4.1–12.3 mm)
Mean neck size (range)	4 mm (2.4–7.9 mm)	3.7 mm (2.5–4.8 mm)	4.1 mm (2.4–7.9 mm)
Mean aspect ratio (range)	1.4 (0.7–2.5)	1.4 (0.9–1.8)	1.5 (0.7–2.5)
<b>Aneurysm locations</b>			
Acom	15 (32%)	6 (50%)	9 (25.7%)
MCA	11 (23.4%)	4 (34%)	7 (20%)
Basilar	8 (17%)	–	8 (22.8%)
PICA	4 (8.5%)	1 (8%)	3 (8.7%)
Intradural ICA	3 (6.3%)	–	3 (8.7%)
Pcom	2 (4.2%)	1 (8%)	1 (2.8%)
Pericallosal	2 (4.2%)	–	2 (5.7%)
SCA	1 (2.1%)	–	1 (2.8%)
Cavernous ICA	1 (2.1%)	–	1 (2.8%)

Acom anterior communicating artery, MCA middle cerebral artery, PICA posterior inferior cerebellar artery, ICA internal carotid artery, Pcom posterior communicating artery, SCA superior cerebellar artery

**Table 2** Follow-up anatomic results and retreatment rate

Anatomic results at follow-up	Total (%)	Ruptured (%)	Unruptured (%)
Complete occlusion (grade 1)	26/47 (55.3)	8/12 (66.6)	18/35 (51.4)
Neck remnant (grade 2)	13/47 (27.6)	2/12 (16.6)	11/35 (31.4)
Persistent contrast enhancement inside WEB (grade 3a)	4/47 (8.5)	1/12 (8)	3/35 (8.5)
Aneurysm remnant (grade 3b)	4/47 (8.5)	1/12 (8)	3/35 (8.5)
Adequate occlusion	43/47 (91.4)	11/12 (91.6)	32/35 (91.4)
Retreatment	3/47 (6.3)	1/12 (8)	2/35 (5.7)

an Acom aneurysm showed an artery of Heubner infarction. In one patient, four unruptured aneurysms were treated endovascularly in the same session (a MCA and intradural ICA aneurysm with WEBs and a pericallosal and posterior communicating artery (Pcom) aneurysm with coils). The patient had an embolic MCA territory infarction on the same side of the aneurysm treated with WEB, which could also be related to the Pcom aneurysm on the same side showing a partial coil dislocation. One patient with an unruptured Acom aneurysm developed the day after the treatment transient aphasia without proven vessel occlusion or thrombosis. All three patients left the hospital without neurological deficits. In one patient with a ruptured Acom aneurysm, delayed neck reperfusion and acute occlusion of the parent artery occurred after 15 months. The patient had a left anterior cerebral artery infarction. The reperfusion was treated by clipping. At discharge, he had a mild leg paresis. Hemorrhagic complications occurred in two patients (4.2%; ruptured, 16.6%; unruptured, 0%). Both were reruptures of ruptured aneurysms during navigation of a VIA 21 microcatheter (Sequent Medical, Aliso Viejo, CA) into the aneurysm and deployment of the WEB, respectively. In both cases, bleeding could be managed rapidly so that the patients recovered without any sequela. No delayed hemorrhage was noted (Table 3).

## Discussion

### Aneurysm occlusion rates

The purpose of this retrospective study was to evaluate the results of WEB-only treatment of ruptured and unruptured aneurysms in a single center. At a median follow-up of 9 months, we observed a higher adequate occlusion rate

(91.4%) than it was reported in the meta-analyses and latest prospective trials (79–85%) [1–8]. However, looking only at the recent large case series, adequate occlusion rates rise above 90% [10, 12, 15–19]. This could be related to the increased operator experience and technical improvements done on the device and delivery systems. But it also could present a bias because of gradually increasing numbers of neurovascular centers in which, if possible, WEB is considered first choice in aneurysm treatment irrespective of location, size, and rupture status. WEB was originally designed to overcome the problems in treatment of wide-necked bifurcation aneurysms which have an inherent tendency to recur. Therefore, older published data is mostly based on treatment of wide-necked aneurysms excluding narrow-necked or smaller aneurysms with less tendency to recur [20–23]. Recent introduction of low-profile systems further expanded the abilities of WEB to include even smaller aneurysms [15, 18]. Studies with extended indications of WEB demonstrated adequate occlusion rates consistently above 90% [10, 12, 17, 19]. In our series, 57.5% of aneurysms had a neck size smaller than 4 mm.

Retreatment rate in our study was consistent with the literature (5.6–8%) [1–8]. Only three aneurysms (6.3%) were retreated. Two Acom aneurysms, one ruptured and one unruptured, were retreated via surgical clipping after 15 and 12 months after WEB treatment, respectively. According to the neurosurgeon, WEB did not present extra difficulties regarding the clip placement. An unruptured cavernous segment aneurysm was retreated via flow diverter-assisted coiling due to reperfusion 6 months after WEB implantation.

### Complications

In our series, the rate of thromboembolic events (12.7%) was consistent with the prior published data (8–14.4%) [1–8].

**Table 3** Procedure-related complications

Event type	Total (%)	Ruptured (%)	Unruptured (%)
Thromboembolic	6 (12.7)	3 (25)	3 (8.5)
- Immediate	2 (4.2)	1 (8.3)	1 (2.8)
- During the first week	3 (6.3)	1 (8.3)	2 (5.7)
- Delayed (15 months later)	1 (2.1)	1 (8.3)	–
Hemorrhagic	2 (4.2)	2 (16.6)	–

Most of them occurred either during the intraprocedural or early post-procedural period before hospital discharge. All except one patient left the clinic without any sequela. This was a case with a ruptured Acom aneurysm, initially treated using a WEB device and showed complete occlusion at the 3-month angiographic follow-up. Fifteen months following the treatment, the patient presented with a sudden leg paresis. DSA showed distal migration of the WEB inside the aneurysm, reperfusion of the proximal aneurysm sac, and thrombotic occlusion of the A2 segment of the left anterior cerebral artery. The reperfusion was treated by clipping. At discharge, he had a mild leg paresis and a modified Rankin scale score of 1 (Fig. 1). This was the only case in our series with delayed symptomatic recurrence. We believe that due to the same reasons discussed above and decrease of usage of adjunctive devices along with better management of antiplatelet therapy, newer case series tend to report lower rates of thromboembolic complications. In their meta-analysis, Lv et al. found higher thromboembolic complication rates in cases before 2013 (10%) than in cases after 2013 (6%) [5].

Hemorrhagic complications occurred in two patients (4.2%) which was in line with the meta-analyses (1.2–6%) [1–8]. Both were reruptures of ruptured Acom aneurysms. In one case, rerupture occurred due to displacement of the VIA 21 microcatheter inside the aneurysm while pushing the WEB up inside the microcatheter, and in the other case, the

microcatheter was located too distal in the aneurysm, and the WEB perforated the sac with its tip during deployment. In both cases, oversizing of WEB was not the cause of rerupture. In the latter case, WEB was chosen even small for that aneurysm, so a stable neck remnant remained on follow-up. However, in both cases, bleeding could be managed rapidly so that the patients recovered without any sequela.

### Use of assisting devices

In our series, only in one patient with a wide-necked unruptured MCA bifurcation aneurysm a stent was used because of acute thrombotic occlusion of a MCA branch due to WEB prolapse. WEB was already detached and in order to restore perfusion a Solitaire AB stent was deployed and intravenous tirofiban started during the intervention and later changed to double oral antiplatelet therapy. The patient discharged without sequela. In the literature, use of adjunctive devices is highly operator-dependent and was reported at up to 15.3% [21]. Nevertheless, recent studies with less strict inclusion criteria regarding the neck and dome size and location of aneurysms showed very few to none the use of adjunctive devices [2, 4, 17, 19]. Mostly, stents were employed to prevent a WEB prolapse into the parent artery or in case of prolapse and thrombus formation to restore perfusion. Balloon remodeling–assisted WEB treatment is a new technique



**Fig. 1** Ruptured Acom aneurysm treated with WEB device. DSA before embolization (a). Immediately after (b). Arrows point the markers of WEB. Three-month DSA showed no sign of recurrence (c). Fifteen months after the treatment, acute infarction in the anterior cerebral artery

territory (d) due to occlusion of the left A2-segment (e: MRA). MRA showed no aneurysm recurrence. But DSA (f) performed on the same day demonstrated aneurysm recurrence and occlusion of the left A2-segment. Recurrence was treated surgically

described by Mihalea et al. used in wide-necked bifurcation aneurysms with specific complex anatomy to assist the WEB deployment [24]. WEB-assisted coiling is also described in the literature by Leyon et al. in treatment of large aneurysms using the WEB to protect the neck and the rest of the aneurysm coiled through a jailed microcatheter [11].

WEB prolapse is a problem mostly encountered in the treatment of wide-necked bifurcation aneurysms. It may occur before or after detachment of the device. In our study group, 31 (65.9%) aneurysms had an aspect ratio of  $\leq 1.5$  and considered wide-necked aneurysms. Other than the one aneurysm mentioned above, in none of the wide-necked aneurysm any adjunctive device was necessary. In most of the cases, we could manage the non-thrombotic WEB prolapse with short-term double antiplatelet therapy and observed that this was not an issue anymore at the follow-up because of WEB compression.

In our experience, the real advantage of WEB shows itself in ruptured bifurcation aneurysms with low aspect ratio which would otherwise be treated with stent-assisted coiling. Over the years, our practice has changed into considering WEB as the first choice in the setting of aneurysmal subarachnoid hemorrhage. Recent introduction of smaller sized devices and 0.017-in. microcatheters expanded the indications and made stable catheterization of more distal and smaller aneurysms possible even in cases with severe vasospasm.

### Antiplatelet therapy

Use of antiplatelet drugs is not mandatory, making the WEB reasonable in the setting of subarachnoid hemorrhage especially due to wide-necked aneurysms, which present difficulties with standard coil treatment. Reported use of post-procedural antiplatelet medications varies in the literature. In their series of 100 ruptured aneurysms treated with WEB, van Rooij et al. [19] reported no use of post-procedural antiaggregation, whereas Arthur et al. and Pierot et al. reported 50% and 78% use of either single or double antiplatelet medication in the post-procedural period [2, 7]. Such a difference could be related to the smaller number of ruptured cases and larger number of wide-necked cases in the latter studies. In our institution, each unruptured case receives double antiplatelets prior to the endovascular treatment irrespective of the planned strategy. In WEB cases, depending on the extent of device protrusion into the parent vessel or neck size of the aneurysm, either double or single antiplatelet regimen continues for a shorter period of time than required for stent-assisted coiling. In ruptured cases, once the rupture point is secured, if the aneurysm neck is wide or some prolapse of WEB into the parent artery is seen, single antiplatelet, usually acetylsalicylic acid 100 mg daily, is given for 4–6 weeks. In our series, only one ruptured case with low-grade SAH required post-procedural short-term double antiplatelet therapy. The patient

had an acute occlusion of the parent artery because of an oversized WEB device which was not yet detached. WEB could be resheathed and glycoprotein IIb/IIIa inhibitor was started to be later changed to double antiplatelets.

### Limitations and strengths

Limitations of this study include its retrospective nature, self-reporting of angiographic results, and the small number of patients. The strong point of the study is including a homogeneous group of aneurysms with WEB-only treatment. We believe that only such a study population could reflect the true capabilities of the device.

### Conclusion

WEB-only treatment enables adequate occlusion of ruptured and unruptured intracranial aneurysms with high technical success and stable results at short- and mid-term follow-up without requiring long-term dual antiplatelet therapy. The complication rates are within acceptable range. The benefit is seen especially by the wide-necked aneurysms which otherwise would be treated mostly with stent-assisted coiling. Both surgical clipping and endovascular methods could successfully be performed in the aneurysm recurrence after WEB.

### Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical approval** All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Informed consent** The study protocol was approved by the local ethics committee. For this type of study, formal consent is not required.

**Abbreviations** *WEB*, Woven EndoBridge; *DL*, Dual layer; *SL*, Single layer; *SLS*, Single layer sphere; *DSA*, Digital subtraction angiography; *CT*, Computed tomography; *ASA*, Acetylsalicylic acid; *SAH*, Subarachnoid hemorrhage; *PICA*, Posterior inferior cerebellar artery; *Acom*, Anterior communicating artery; *MCA*, Middle cerebral artery; *ICA*, Internal carotid artery; *Pcom*, Posterior communicating artery

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