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AJNR Am J Neuroradiol published online 5 September 2019
http://www.ajnr.org/content/early/2019/09/05/ajnr.A6183

Published September 5, 2019 as 10.3174/ajnr.A6183

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ABSTRACT

BACKGROUND AND PURPOSE: The Woven EndoBridge 17 has recently been introduced to the market for facilitated endovascular treatment of small bifurcation aneurysms (≤7 mm) with low-profile microcatheters. We compared the Woven EndoBridge 17 with its predecessor versions in terms of procedural safety and feasibility.

MATERIALS AND METHODS: This was a multicenter review of aneurysms ranging from 3 to 7 mm treated with the Woven EndoBridge between 2011 and 2019. Aneurysm characteristics, procedural parameters, and complications were retrospectively compared between treatment with the Woven EndoBridge 17 and a control group that was treated with its predecessor versions, using inverse probability of treatment weighting.

RESULTS: Thirty-eight aneurysms treated with a Woven EndoBridge 17 (mean size, 4.9 ± 1.5 mm) and 70 treated with a predecessor version of the Woven EndoBridge 17 (mean size, 5.6 ± 1.4 mm) were included. The predecessor version of the Woven EndoBridge 17 had a higher failure rate (10.3%) than the Woven EndoBridge 17 (0%, $P = .05$). Additional stent placement was performed more often with the predecessor version of the Woven EndoBridge 17 (10.0%) than with the Woven EndoBridge 17 (2.6%, adjusted $P = .005$). The predecessor version of the Woven EndoBridge 17 was associated with a higher thromboembolic event rate (14.3%) than the Woven EndoBridge 17 (5.3%, adjusted $P = .002$). Neurologic complications (Woven EndoBridge 17: 2.6%; predecessor version of the Woven EndoBridge 17: 2.9%, adjusted $P = 1.0$) and immediate complete aneurysm occlusion rates (Woven EndoBridge 17: 57.9%; predecessor version of the Woven EndoBridge 17: 54.3%, adjusted $P = .21$) did not differ significantly between groups.

CONCLUSIONS: In the current study, the Woven EndoBridge 17 was associated with a potentially lower thromboembolic event rate than the predecessor version of the Woven EndoBridge 17, without compromising the immediate aneurysm occlusion rate. Long-term clinical and angiographic outcome analysis will be necessary to draw a definite conclusion.

ABBREVIATIONS: AcomA = anterior communicating artery; IPTW = inverse probability of treatment weighting; pWEB = predecessor version of the Woven EndoBridge 17; SL = Single-Layer; WEB = Woven EndoBridge

Intrasaccular flow disruption is a cutting-edge treatment option for intracranial aneurysms, in particular for wide-neck and bifurcation aneurysms, which are typically difficult to treat by standard endovascular techniques.[1-3] The Woven EndoBridge (WEB; Sequent Medical, Aliso Viejo, California) is a self-expanding flow disruptor that is placed in the aneurysm sac and seals the aneurysm neck without the compelling need for supporting devices.[4-6] Its safety and efficacy have been demonstrated in several large, multicenter studies.[7-13] For instance, in the Woven EndoBridge Intrasaccular Therapy (WEB-IT) study, the adverse event rate was 0.7% among 148 patients, achieving adequate aneurysm occlusion in 84.6% at 1-year follow-up.[14]

Since the introduction of the Dual-Layer WEB in 2010, the WEB has been progressively refined and new systems such as the Single-Layer (SL) and Single-Layer Sphere WEBs have been introduced to the market, mainly to facilitate device deployment while maintaining good neck coverage and reducing procedural complications.[1,15-18] Whereas the early-generation WEBs could be delivered through only 0.027- to 0.033-inch microcatheters,

Received May 21, 2019; accepted after revision July 14.

From the Department of Neuroradiology (L.G., L.P., M.S., J.B., C.K.), University Hospital of Cologne, Cologne, Germany; Center for Neurosurgery (L.G., B.K.), University of Cologne, Faculty of Medicine and University Hospital, Cologne, Germany; Department of Neuroradiology (T.L., M.H., F.D.), University Hospital Munich, Munich, Germany; and Department of Neuroradiology (E.S.), University Hospital of Berlin (Charité), Berlin, Germany.

L. Goertz and T. Liebig contributed equally to this work.

Please address correspondence to Lukas Goertz, MD, Department of Neuroradiology, University Hospital of Cologne, Kerpener Str 62, 50937 Cologne, Germany; e-mail: lukas.goertz@uk-koeln.de

http://dx.doi.org/10.3174/ajnr.A6183

newer versions of the Single-Layer and Single-Layer Sphere types up to 7 mm in diameter were redesigned for delivery through a 0.021-inch microcatheter (WEB 21).

The WEB 17 is the latest generation. It is composed of fewer and thinner nitinol wires than the WEB 21 (72–108 versus 144–216 wires) and comes with a new delivery wire, which has been reduced from 0.020 to 0.015 inches.[19] Due to these modifications, the WEB 17 is compatible with a 0.017-inch inner-diameter microcatheter. The aim of this modification was to widen the range of applicability of the WEB, in particular for small and distally located aneurysms. To date, the WEB 17 system is available as the WEB Single-Layer (size range, 3 × 2 to 7 × 4 mm), which is oblong, and as the WEB Single-Layer Sphere (size range, 4–7 mm), which is more spherical.

Because the introduction of the WEB 17 system is relatively recent, clinical data on its safety and feasibility profile are still limited. The objective of the current study was to present our multicenter experience in treating small aneurysms with the WEB 17 and to compare the complication rates and procedural aspects with predecessor WEB systems. To address a potential selection bias, we performed an inverse probability of treatment weighting approach using propensity scores.

MATERIALS AND METHODS

The authors retrospectively reviewed consecutive patients who underwent WEB embolization at 3 German high-volume neurovascular centers (University Hospital Cologne, University Hospital Munich and University Hospital Berlin, Charité) between January 2011 and February 2019. In accordance with the institutional guidelines, ethics committee approval was not required for this retrospective study.

Inclusion and Exclusion Criteria

All patients treated with the WEB at the 3 institutions were retrospectively reviewed. Exclusion criteria were defined as follows: 1) WEB size >7 mm, 2) aneurysm size >7 mm, 3) previously treated aneurysms, and 4) treatment of multiple aneurysms with the WEB device during a single procedure. We report on patients with failed WEB implantations; however, these aneurysms were excluded from comparative analysis of complications and procedural aspects. The enrolled patients were divided into WEB 17 and predecessor version of the WEB 17 (pWEB) groups, on the basis of whether they were treated with the WEB 17 or with predecessor WEB versions.

Procedure

After diagnosis of a ruptured or unruptured intracranial aneurysm, the case was discussed within a multidisciplinary team among vascular neurosurgeons and interventional neuroradiologists and treatment decisions were made in consensus. The use of the WEB was left to the discretion of the neurointerventionalist. In general, the WEB was used for wide-neck and bifurcation aneurysms with unfavorable configuration for endovascular coiling as a treatment alternative for stent-assisted procedures or microsurgical clipping. At all 3 centers, the neurointerventionalists were initially trained and later proctored by the same neurointerventionalist (T.L.); this procedure ensured a homogeneous treatment technique across centers.

All procedures were performed via a transfemoral approach with the patient under general anesthesia in a biplane angiosuite (Philips AlluraClarity FD 20/15, Philips Healthcare, Best, the Netherlands and Siemens Axiom Artis, Siemens, Erlangen, Germany). The WEB 17 was delivered through the dedicated VIA 17 microcatheter (Sequent Medical), and the pWEB, through dedicated larger VIA microcatheters.

The appropriate WEB size was selected according to the aneurysm width and height as measured on 2D DSA images. Implant sizes were chosen to be slightly larger than the maximum aneurysm diameter as recommended in the instructions for use. We aimed to treat all aneurysms of <7 mm with the WEB only, without the use of additional intraluminal devices such as stents or flow diverters to avoid long-term antiplatelet medication. However, if the WEB tended to protrude into the parent vessel, an intracranial stent was additionally implanted at the operator's discretion. Adjunctive coiling was used in selected cases to provide optimal aneurysm occlusion.

Anti-Aggregation Therapy

For treatment of unruptured aneurysms, a bolus of heparin (5000 IU) was administered after groin puncture, followed by aliquots of 1000 IU/h. Heparin was discontinued at the end of the procedure. In all patients with unruptured aneurysms, acetylsalicylic acid, 100 mg/day, was administered 5–7 days before the procedure and continued for a minimum of 4–6 weeks. If additional stent implantation was necessary, dual antiplatelet therapy with acetylsalicylic acid, 100 mg, and clopidogrel, 75 mg, was administered for at least 4 months after the procedure. Thereafter, acetylsalicylic acid monotherapy was continued life-long. In patients with ruptured aneurysms treated with the WEB only, no antiplatelets were administered.

In scheduled cases, platelet inhibition was tested with acetylsalicylic acid and accessory P2Y12 assays when required (VerifyNow; Accumetrics, San Diego, California). A platelet inhibition level between 350 and 550 acetylsalicylic acid response units and 30%–90% for clopidogrel was requested. An insufficient response to either drug was counteracted by dose escalation (eg, clopidogrel, 150 mg/day) or substitution with prasugrel (60-mg bolus, 10 mg/day).

Data Collection

The following variables were collected retrospectively from the medical charts: patient age, sex, rupture status, World Federation of Neurosurgical Societies grading scale score, Fisher score, treatment duration, fluoroscopy time, radiation exposure, and amount of applied contrast. Procedural complications were recorded by 2 researchers (L.G., M.H.) who were not involved in aneurysm treatment. We report both symptomatic and asymptomatic events. All thromboembolic and hemorrhagic events are reported. The severity of ischemic stroke was assessed by the National Institutes of Health Stroke Scale, and any change of ≥1 point was considered a complication. Adverse events associated

Table 1: Baseline patient and aneurysm characteristics[a]

	WEB 17 (n = 38)	pWEB (n = 70)	P Value	Adjusted P Value
Patient age (yr)	55.7 ± 12.7	57.3 ± 12.2	.54	.72
Female sex	25 (65.8%)	52 (74.3%)	.35	.61
Ruptured aneurysms	10 (26.3%)	24 (34.3%)	.39	.59
WFNS I	2 (5.3%)	10 (14.3%)	.82	.06
WFNS II	2 (5.3%)	3 (4.3%)		
WFNS III	2 (5.3%)	4 (5.7%)		
WFNS IV	1 (2.6%)	2 (2.9%)		
WFNS V	3 (7.9%)	5 (7.1%)		
Fisher 1	1 (2.6%)	2 (2.9%)	.77	.30
Fisher 2	0 (0%)	2 (2.9%)		
Fisher 3	3 (7.9%)	5 (7.1%)		
Fisher 4	6 (15.8%)	13 (18.6%)		
Aneurysm location				
AcomA	14 (36.8%)	15 (21.4%)	.08	.92
Pericallosal	0 (0%)	1 (1.4%)	1.0	.24
MCA	4 (10.5%)	15 (21.4%)	.19	.60
ICA				
Paraophthalmic	1 (2.6%)	7 (10.0%)	.26	.06
PcomA	4 (10.5%)	5 (7.1%)	.72	.55
Terminus	3 (7.9%)	0 (0%)	.04	.25
BA	9 (23.7%)	24 (34.3%)	.25	.82
SUCA	1 (2.6%)	0 (0%)	.35	.01
PICA	2 (5.3%)	3 (4.3%)	1.0	.53
Anterior circulation	26 (68.4%)	43 (61.4%)	.47	.63
Posterior circulation	12 (31.6%)	27 (38.6%)		
Bifurcation location	27 (71.1%)	54 (77.1%)	.49	.72
Aneurysm size (mm)	4.9 ± 1.5	5.6 ± 1.4	.007	.55
Neck width (mm)	3.6 ± 1.1	4.2 ± 1.3	.04	.95
D/N ratio	1.4 ± 0.5	1.4 ± 0.4	.56	.90
Wide neck	35 (92.1%)	65 (92.9%)	1.0	.66

Note:—WFNS indicates World Federation of Neurosurgical Societies grading scale; D/N ratio, dome-to-neck ratio; PcomA, posterior communicating artery; BA, basilar apex; SUCA, superior cerebellar artery.

[a] Data are number and percentage of means.

with persisting neurologic deficits at discharge were defined as neurologic complications.

Angiography

Baseline conventional 4-vessel DSA scans were reviewed to determine aneurysm size, aneurysm neck width, and dome-to-neck ratio. Wide-neck aneurysms were defined as having a neck width of ≥4 mm and/or a dome-to-neck ratio of ≤2.

The Raymond-Roy occlusion classification was used to evaluate immediate aneurysm occlusion after WEB implantation: 1) complete occlusion, 2) neck remnant, and 3) aneurysm remnant. Complete occlusion and neck remnants were defined as adequate occlusion. Immediate aneurysm occlusion was assessed independently on the basis of 2D-DSA by 3 consultant neuroradiologists (C.K., E.S., F.D.). Discrepancies were resolved in consensus.

Statistical Analysis

Quantitative data were presented as numbers and percentages and analyzed with the χ^2 and Fisher exact tests. Quantitative data were presented as means with SDs and tested for normality using the Shapiro-Wilk test. Groups were compared using the unpaired t test (normally distributed data) or the Mann-Whitney U test (non-normally distributed data). Bivariate correlation analysis was performed using the Pearson and Spearman correlation coefficients. To account for a potential selection bias, we performed an inverse probability of treatment weighting (IPTW) approach based on the propensity score model. IPTW was used as a statistical technique to create 2 synthetic study groups with comparable propensity scores, in which treatment assignment was independent of measured baseline characteristics. This method aimed to minimize a potential selection bias and to obtain comparative estimates of treatment effects. Propensity scores were calculated using a multivariate logistic regression model with the WEB 17 treatment as the response and the following covariates: patient age, sex, ruptured/unruptured status, aneurysm location, aneurysm size, and neck width. Statistical analysis was performed using SPSS Statistics for Windows, Version 25.0 (IBM, Armonk, New York). A P value $< .05$ was considered as statistically significant.

RESULTS

Patient and Aneurysm Characteristics

Among 165 aneurysms treated during the study period, 108 aneurysms in 108 patients met our inclusion criteria and were enrolled. Fifty-seven aneurysms were excluded for the following reasons: WEB size of >7 mm (n = 30), aneurysm size of >7 mm (n = 11), failed WEB implantation (n = 8), treatment of recurrent aneurysms (n = 6), and treatment of multiple aneurysms with the WEB during 1 procedure (n = 2). The mean patient age was 56.7 ± 12.3 years (range, 21–87 years), and 77 patients (71.3%) were women. Thirty-four patients (31.5%) were treated for ruptured aneurysms, and 74 (68.5%), for unruptured aneurysms. The aneurysms were most frequently located at the basilar artery tip (33, 30.6%), followed by the anterior communicating artery (AcomA) (29, 26.9%), and the middle cerebral artery (19, 17.6%). The mean aneurysm size was 5.3 ± 1.5 mm (range, 3–7 mm), and the mean neck width was 4.0 ± 1.2 mm (range, 1.5–7.2 mm). A total of 100 aneurysms (92.6%) were classified as wide-neck.

Of 108 aneurysms, 38 were treated with the WEB 17 (35.2%) and 70 with pWEBs (64.8%). In the pWEB group, 64 patients were treated with a 0.021-inch microcatheter, and 6, with a 0.027-inch microcatheter. Baseline patient and aneurysm characteristics were comparable between the 2 groups, except for a larger aneurysm size (WEB 17: 4.9 ± 1.5 mm; pWEB: 5.6 ± 1.4 mm, P = .007) and a wider neck (WEB 17: 3.6 ± 1.1 mm; pWEB: 4.2 ± 1.3 mm, P = .042) in the pWEB group, as outlined in Table 1. To address this selection bias, we performed an IPTW adjustment approach based on the

Table 2: Procedural specifics[a]

	WEB 17 (*n* = 38)	pWEB (*n* = 70)	*P* Value	Adjusted *P* Value
WEB type				
DL	0 (0%)	6 (8.6%)	.09	.003
SL	31 (81.6%)	46 (65.7%)	.08	.001
SLS	7 (18.4%)	18 (25.7%)	.39	.02
WEB only	36 (94.7%)	62 (88.6%)	.49	.02
Additional coiling	1 (2.6%)	1 (1.4%)	1.0	1.0
Additional stents	1 (2.6%)	7 (10.0%)	.26	.005
Treatment duration (min)	122 ± 67	133 ± 67	.48	.007
Fluoroscopy time (min)	25.4 ± 20.1	27.6 ± 23.3	.77	.02
Radiation dose (cGy × cm^2)	10,319 ± 7108	11,899 ± 9142	.55	.03
Contrast (mL)	151 ± 68	145 ± 72	.59	.70

Note:—DL indicates Dual-Layer; SLS, Single-Layer Sphere.
[a] Data are number and percentage of means.

Table 3: Immediate angiographic results

	WEB 17 (*n* = 38)	pWEB (*n* = 70)	*P* Value	Adjusted *P* Value
Complete occlusion (RROC 1)	22 (57.9%)	38 (54.3%)	.55	.21
Neck remnant (RROC 2)	8 (21.1%)	11 (15.7%)		
Aneurysm remnant (RROC 3)	8 (21.1%)	21 (30.0%)		

Note:—RROC indicates Raymond-Roy occlusion classification.

Table 4: Procedure-related complications

	WEB 17 (*n* = 38)	pWEB (*n* = 70)	*P* Value	Adjusted *P* Value
Thromboembolic events	2 (5.3%)	10 (14.3%)	.21	.002
Ischemic stroke	1 (2.6%)	5 (7.1%)	.42	.06
Hemorrhagic complications	2 (5.3%)	1 (1.4%)	.28	.37
Neurologic complications	1 (2.6%)	2 (2.9%)	1.0	1.0

propensity score model, achieving comparable groups regarding all baseline characteristics (Table 1).

Aneurysm Treatment

Procedural specifics are detailed in Table 2. Implantation of the WEB 17 was technically successful in all aneurysms (38/38, 100%), compared with 8 treatment failures in the pWEB group (8/78, 10.3%, $P = .052$). Failed WEB implantation was recorded at the anterior communicating artery ($n = 3$), paraophthalmic regions of the internal carotid artery ($n = 3$), middle cerebral artery bifurcation ($n = 1$), and basilar apex ($n = 1$). The mean aneurysm size ranged from 3.3 to 6.9 mm. Reasons for failed implantation were WEB protrusion with impeded blood flow ($n = 3$), WEB malposition ($n = 3$), and delivery failure due to a sharp aneurysm angle in sidewall aneurysms ($n = 2$). Aneurysms with failed WEB implantation were excluded from further analysis as stated above. Of 108 included aneurysms, 98 (90.7%) were treated by the WEB only, 36 (94.7%) were in the WEB 17 group, and 62 (88.6%) were in the pWEB group ($P = .489$). In both groups, adjunctive coils were used in 1 patient to achieve immediate complete aneurysm occlusion, respectively. Additional stent placement was performed more often after implantation of predecessor WEBs (7/70, 10.0%) than after embolization with the WEB 17 (1/38, 2.6%). This difference was not significant in the unweighted analysis ($P = .256$) but became significant after IPTW adjustment ($P = .005$).

The smallest WEB 17 version, the WEB SL 3 × 2 mm, was used for treatment of 3 small wide-neck aneurysms with a maximum diameter ranging from 3 to 3.3 mm. The aneurysms were located at the AcomA, the basilar apex, and the M1 segment of the MCA, respectively. Navigation and delivery of the WEB were smooth in all cases, resulting in immediate complete occlusion in 2 cases and 1 neck remnant, without any incidence of adverse events. In a fourth case, a 7-mm large, bilobed AcomA aneurysm was treated, and the WEB SL 3 × 2 was used to occlude 1 aneurysm lobe, while the second lobe was embolized with 3 coils.

The average treatment duration was 128 ± 67 minutes, 122 ± 67 minutes for the WEB 17 and 133 ± 67 minutes for WEB controls ($P = .475$). The mean fluoroscopy time was 26.8 ± 22.2 minutes, 25.4 ± 20.1 minute for the WEB 17 and 27.6 ± 23.3 minutes for the pWEB ($P = .765$). The mean radiation dose was 11331 ± 8466 cGy × cm^2, 10319 ± 7108 cGy × cm^2 for the WEB 17 and 11899 ± 9142 cGy × cm^2 for the pWEB ($P = .552$). On average, 146 ± 70 mL of contrast was used, 151 ± 68 mL for the WEB 17 and 145 ± 72 mL for the pWEB ($P = .585$). After IPTW adjustment, treatment with the WEB 17 was associated with significantly shorter treatment duration ($P = .007$), shorter fluoroscopy time ($P = .016$), and reduced radiation exposure ($P = .031$) compared with predecessor WEBs.

Bivariate correlation analysis showed no significant correlation between treatment date and treatment duration ($r = -0.08$, adjusted $P = .36$) and radiation exposure ($r = -0.05$, adjusted $P = .5$).

Angiographic Outcome

Immediate complete occlusion after WEB implantation was obtained in 60 aneurysms (55.6%); neck remnants, in 19 (17.6%); and aneurysm remnants, in 29 (26.9%). Immediate occlusion rates were not significantly different between both treatment groups, either in the unweighted ($P = .55$) or the weighted analysis ($P = .21$) (Table 3).

Complications

Procedural complications are detailed in Table 4. In the WEB 17 group, there were 2 thromboembolic events (5.3%). In the first

case, a patient was treated for a ruptured PICA aneurysm. After the procedure, the patient had transient hemianopsia. The CT scan showed a partial posterior infarction of the posterior cerebral artery, which occurred most likely due to thromboembolism during WEB placement. In the second patient, implantation of a WEB into an unruptured AcomA aneurysm resulted in stenosis of the left A2 segment, which could be reopened by additional stent implantation. The patient did not have any symptoms after the procedure.

Furthermore, there were 2 hemorrhagic events (5.3%) related to the WEB 17 implantation. The first patient was treated for an unruptured aneurysm and had a subarachnoid hemorrhage from a proximal perforating artery, which probably ruptured due to manipulation of the microwire. The patient was discharged to a rehabilitation center with persisting mild hemiparesis. In the second case, perforation of an unruptured AcomA aneurysm occurred during device delivery; however, the bleeding was stopped immediately by WEB implantation and the patient did not have any symptoms.

The overall neurologic complication rate after WEB 17 implantation was 2.6%, and there was no procedure-related mortality.

The WEB 17 was associated with a lower thromboembolic event rate (5.3%) compared with the pWEB (14.3%, $P = .208$). After adjustment for the propensity score, this difference was statistically significant ($P = .002$). Moreover, there was a borderline significant trend toward a higher ischemic stroke rate after pWEB placement in the weighted analysis ($P = .055$). In the subgroup analysis of the pWEB group, thromboembolic events occurred tendentially more often in ruptured aneurysms (25%, 6/24) than in unruptured aneurysms (8.9%, 4/46, $P = .08$). The neurologic complication rate was similar between both groups (WEB 17: 2.6%; pWEB: 2.9%; $P = 1.0$, adjusted $P = 1.0$).

DISCUSSION

In the current study, we evaluated the treatment of small aneurysms (≤7 mm) with the new low-profile WEB 17 and compared the results with predecessor WEB systems. To produce reliable results and to address a potential selection bias, we performed a separate IPTW analysis using propensity scores.

Small aneurysms located at a bifurcation represent a technical challenge for endovascular therapy, even when using the WEB device.[20] Moreover, the WEB is difficult to deliver to distally located aneurysms because it requires deployment by a relatively large microcatheter.

The WEB 17 consists of a reduced number of nitinol wires and can be delivered through a VIA 17 microcatheter, which is less rigid than the predecessor VIA 21. The flexible design of the WEB 17 system facilitates navigation through tortuous vessels and sharp-angled branching points. Besides navigation to more distally located aneurysms, reducing the delivery diameter of the WEB system may also facilitate the treatment of sidewall aneurysms, which can be difficult to treat with the more rigid 0.021-inch system. In a previous study on ICA sidewall aneurysms, we reported deployment failure due to malrotation of the device after delivery of the pWEB in 2 aneurysms with sharp aneurysm angles.[21] Because WEB positioning could not be improved, the WEBs were finally removed and the aneurysms were treated with standard coiling. We speculate that treatment of these aneurysms would have been possible with the low-profile WEB 17.

In our study, WEB 17 implantation was technically successful in all cases. In contrast, there were 8 treatment failures in the WEB 21 group (10.3%). Although this difference might be partially related to increased operator experience during WEB 17 implantation, it indicates the high feasibility of WEB 17 treatment.

To date, there are 2 available studies on the WEB 17. Van Rooij et al[19] analyzed 46 aneurysms and reported a technical success rate of 100%. Similar technical success was reported by Mihalea et al[22] in a study of 28 aneurysms. Both authors reported that handling the WEB 17 was smoother compared with predecessor versions and required less push and pull forces. However, the authors also acknowledged that the WEB 17 is more susceptible to deformation during delivery because it has fewer and thinner nitinol wires, resulting in a weaker structure and shape retention. These properties can result in malposition and neck remnants after delivery, which may require WEB repositioning and repeat deployment. Thus, Mihalea et al recommended validating the WEB position with VasoCT (Philips Healthcare) immediately after deployment.[22]

Our data corroborate the subjective ease of navigation and deployment of the WEB 17. Generally, positioning the WEB 17 was feasible, as reflected by a 100% technical success rate and a reduced use of intracranial stents, which were typically implanted if a WEB protruded into the parent vessel lumen. In our experience, repositioning the WEB 17 was not generally necessary, and immediate angiographic results were comparable with those with the predecessor WEB systems. Our results indicated that treatment with the WEB 17 was associated with reduced treatment duration, fluoroscopy time, and radiation exposure, which became significant after IPTW adjustment. Although we could not show a significant correlation between treatment date and treatment duration or radiation exposure, the differences in additional stent implantation and shorter treatment duration may be, in part, attributed to increasing operator experience during the study period, thus potentially favoring the WEB 17 group. However, in our experience, the WEB 17 system is more flexible and has a better conformability than the predecessor versions. Due to a comparably rigid design of the nitinol wires, the predecessor WEBs might have been more likely to protrude into the parent artery, in particular in cases in which the aneurysm axis deviates greatly from the vessel axis. In contrast, we observed that the WEB 17 generally adapts to the aneurysm wall very smoothly, showing a lower tendency to alter aneurysm geometry and to cause parent artery stenosis. Although a direct statistical comparison is difficult, our data support the impression that navigation and deployment of the WEB 17 may be smoother than in the predecessor WEB versions.

In the present study, we treated 3 very small aneurysms on the order of 3 mm with the new WEB SL 3 × 2 mm. Two were located at a bifurcation; and 1, at the M1 segment. In all cases, the device could be deployed smoothly, and adverse events did not occur. Immediate angiographic control showed complete occlusion in 2 cases and a neck remnant in the third case.

Thromboembolism is considered the most prevalent event related to WEB implantation.[18] Muskens et al[23] performed a meta-analysis on 718 aneurysms treated with the WEB before the introduction of the WEB 17 system and reported a thromboembolic event rate of 10.3%. Because most thromboembolic events remain asymptomatic, the WEB constitutes a safe treatment option with major morbidity and mortality as low as 3% and 2%, respectively.[24] In the current study, the safety results of the WEB control group are within the range cited previously, with thromboembolic events occurring in 14.3% and neurologic complications in 2.9%.[15,18,23]

In the comparative analysis, the thromboembolic event rate in the WEB 17 group was 5.3% and thus was much lower than in the WEB control group. This might be, in part, related to a smaller portion of aneurysms treated in combination with intracranial stents. Beyond that, a lower profile of all materials used, ease of use, and shorter procedure times associated with the WEB 17 system favor reducing the potential for thromboembolic events. Among intracranial stents and flow diverters, several in vivo and ex vivo studies have already suggested that miniaturization of the stent design and the delivery system may reduce the thrombogenicity of the device.[25-28] Hence, miniaturization of the WEB system might also contribute to reduced thrombogenicity of the system. Moreover, we observed that the WEB 17 showed a reduced tendency to protrude into the parent vessel, though we did not quantify this aspect. Finally, a slightly higher portion of ruptured cases in the pWEB group may also contribute to a higher thromboembolic event rate.[29]

In previous studies, similar results were obtained. The thromboembolic event rate was 4% in the study by Mihalea et al[22] and 5% in the study by van Rooij et al.[19]

These findings collectively suggest a high procedural safety profile of the WEB 17 system. Because treatment of small bifurcation aneurysms proved to be highly efficacious and could be achieved more smoothly than with predecessor WEB versions, we believe the WEB 17 system is a highly valuable adjunct to the neurointerventional armamentarium, and we have been using the WEB 17 exclusively for small aneurysms of <7 mm. Additional studies will be required to further expand the indications of the WEB 17.

Limitations

Our study has several limitations. Although we performed a multicenter study, the sample size was only moderate and data were collected retrospectively, making a generalization of the data difficult. To mitigate this limitation in part and to minimize a potential selection bias, we performed an IPTW approach based on propensity scores. Patients were not consecutive but were selected on the basis of the mentioned inclusion criteria and the anticipated suitability for WEB treatment. Because the introduction of the WEB 17 is relatively recent, angiographic follow-up is incomplete and was not reported in the current study. A further limitation is that aneurysm occlusion was not determined by a core laboratory, which might bias the interpretation of the angiographic results.[30] To reduce this potential bias at least in part, all angiographic images were assessed blinded and independently by 3 experienced consultant neurointerventionalists (C.K., F.D., E.S.). Discrepancies were resolved by consensus. Finally, increased operator experience may have favored the WEB 17 group in terms of complication rates and treatment duration.

CONCLUSIONS

Deployment of the new low-profile WEB 17 in small aneurysms was generally smooth and required less stent assistance than the predecessor WEB versions. The VIA 17 facilitates microcatheter navigation toward the target vessel, especially in situations with a complex vascular anatomy. If procedural time and the amount of radiation exposure can be used as surrogate parameters to measure ease of use, then the WEB 17 is a definite improvement over the pWEB. Finally, the thromboembolic event rate of the WEB 17 was lower compared with predecessor WEBs, seemingly without compromising treatment efficacy. These features make the WEB 17 a valuable adjunct to the existing WEB range and expand indications to very small aneurysms.

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