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Original Article

Safety and effectiveness of the LVIS and LVIS Jr devices for the treatment of intracranial aneurysms: Final results of the LEPI multicenter cohort study

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ABSTRACT

Background: The Low profile visualized intraluminal support (LVIS)/LVIS Jr is a self-expanding braiding stent for the treatment of intracranial aneurysm. This study is to determine the safety and effectiveness of the LVIS/LVIS Jr for the treatment of intracranial aneurysms in a real-world setting.
Methods: This prospective, observational, multicenter study enrolled patients with unruptured, ruptured and recanalized intracranial aneurysms treated with the LVIS stents, between February 2018 to December 2019. Primary endpoint was the cumulative morbidity and mortality rate (CMMR) assessed at 12 months follow-up (FU).
Results: A total of 130 patients were included (62.3 % women, mean age 55.9 ± 11.4) on an intention-to-treat basis. Four patients (3.1 %) had 2 target aneurysms; 134 total aneurysms were treated. The aneurysms were mainly located on the middle cerebral artery (41/134; 30.6 %) and the anterior communicating artery (31/

Abbreviations: AEs, Adverse Events; CTA, Computed Tomography Angiography; CMMR, Cumulative morbidity and mortality rate; LEPI, etude post-inscription; LVIS, Low profile visualized intraluminal support; mRS, modified Rankin Scale; MRI, Magnetic Resonance Imaging; WFNS, World Federation of Neurosurgical Societies

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134; 23.1 %). The CMMR at 1 year linked to the procedure and/or device was 4.6 % (6/130). The overall mortality was 1.5 % (2/130), none of these deaths adjudged as being linked to the procedure and/or device. All aneurysms (134/134, 100 %) were successfully treated with LVIS stent and/or other devices. At a mean FU of 16.8 months post-procedure, complete/nearly complete occlusion was achieved in 112 aneurysms (92.6 %), and only 3 patients (2.5 %) required aneurysm retreatment.
Conclusion: This study provides evidence that the LVIS/LVIS Jr devices are safe and effective in the treatment of complex intracranial aneurysms, with very high rates of adequate occlusion at FU. These angiographic results are stable over time with an acceptable complication rate.
Trial Registration: ClinicalTrial.gov under NCT 03553771.

Introduction

Endovascular treatment of intracranial aneurysms has become an established first-line treatment as safe and effective as a surgical approach.[1–3] However, endovascular coiling of wide neck aneurysms remains challenging with an increased risk of morbidity and mortality,[4,5] requiring the use of balloon remodeling or stent-assisted coiling.[6,7] The latter technique offers better long-term angiographic results compared to the use of balloon remodeling technique or unassisted coiling, especially in wide-necked aneurysms.[8] On the other hand, stent deployment generates flow alteration inside the aneurysm[9] and integrates into the arterial wall of the vessel, promoting aneurysm healing.[10,11]

The Low-Profile Visualized Intraluminal Support (LVIS and LVIS Junior, Microvention/Terumo, Tustin, CA) devices are self-expandable stents developed for stent-assisted coiling of complex intracranial aneurysms. The safety and efficacy of the LVIS/LVIS Jr devices have been studied either alone or in combination with other stents in clinical and in-vitro studies or meta-analyses.[12–20] These clinical studies have demonstrated high rates of implantation success and complete short- and long-term aneurysm occlusion, supporting their positive appraisal in France for registration by the National Health system. However, it remains uncertain what the safety and effectiveness would be in real-word use. The purpose of this study was to summarize the safety and effectiveness of the LVIS devices for the treatment of ruptured or unruptured intracranial aneurysms in a real-world setting as requested by the French National Authority for Health.

Methods

Study design

The LVIS Etude post-inscription (LEPI) study was a prospective, observational, and multicenter study that included 17 French centers, conducted between February 2018 and December 2019. The aim of the study was to evaluate the morbidity, mortality, and efficacy of LVIS stents in an intention-to-treat population. All centers treated enrolled patients with LVIS and LVIS Jr consecutively and exhaustively.

The study received the required national regulatory authorization from a French national Ethics Committee (Comité de Protection des Personnes OUEST III). The LEPI study was registered in ClinicalTrial.gov under NCT 03553771. All enrolled patients agreed to the use of their anonymized data collection in the study frame. The appropriate Ethics Committee reviewed and approved the Informed Consent Form for this study. As this study evaluated the use of LVIS/LVIS Jr stents in a real-world setting, no additional eligibility criteria were required.

The study results were analyzed by the intention-to-treat approach. Any patient for whom an LVIS device was introduced into the microcatheter during the procedure was considered to be enrolled in the LEPI register with the intention of treating (whether or not the stent was successfully delivered). A subpopulation for which at least one LVIS/LVIS Jr device was deployed during the procedure was also analyzed. Patients included but not treated, as well as procedure failures, were kept in the analysis population.

Device characteristics and procedures

The LVIS/LVIS Jr devices (MicroVention, Inc, AlisoViejo, California, USA) are self-expanding stents comprised of a single braided nickel-titanium wire with a closed-cell design and can be deployed and retrieved through a standard microcatheter with an internal diameter of 0.017″ (LVIS Jr) or 0.021″ (LVIS).[13,15] The LVIS/LVIS Jr devices are available in diameters ranging from 2.5 to 5.5 mm (unconstrained).

All enrolled patients underwent a standard neuroendovascular procedure with the intent of delivering and implanting an LVIS device across the aneurysm neck under antiplatelet therapy. Pre, intra and post-operative antithrombotic medication was left to the discretion of each center according to local protocols, ruptured status, and operator's decision. There was no requirement for preoperative platelet function testing as part of the protocol nor for the use of specific access, sheaths, or guiding catheters. The LVIS/LVIS Jr device could be used to treat ruptured and unruptured aneurysms.

Study endpoints

The primary safety endpoint was the cumulative morbidity and mortality rate (CMMR) assessed at 12 months follow-up, defined by the incidence of adverse events (AEs) with sequelae related to the treatment and/or device observed during the procedure, up to 1 year after treatment (safety endpoint). An independent adjudication evaluating all AEs was conducted by an expert neurointerventionalist.

The secondary endpoints included:

1. To determine the clinical outcome. It was assessed with the modified Rankin Scale (mRS) score at the intermediate (between 3 and 6 months depending on the center) and long-term (between 12 and 18 months depending on the center) follow-up with favorable and unfavorable outcomes defined by mRS scores of 0–2 and >2, respectively.
2. The rate of aneurysmal occlusion at intermediate and final follow-up evaluated angiographically by the local investigators. It was classified as complete occlusion, residual neck, or residual aneurysm according to the Raymond-Roy occlusion scale[21] by the local investigators using magnetic resonance imaging (MRI), computed tomography angiography (CTA) or conventional angiography according to the protocols of the centers. Parent artery, stent patency, and in-stent stenosis relative to a threshold of 50 % were also evaluated.
3. To report the aneurysm retreatment rate at 1-year post procedure.

Statistical analysis

Considering the CMMR was expected at 10 %[22,23] to achieve an estimated accuracy of ± 5 % the target population size was estimated at 130 patients (with a loss to follow-up rate of 10 %, the estimated accuracy was ± 5.5 %). Descriptive statistics were used to present the results as absolute number (percentage) for discrete variables and mean (SD) or median (25th−75th percentiles) for continuous variables as appropriate. Subgroup analyses were also performed. A sensitivity analysis using an imputation method for missing data was planned if more than 10 % of the data was missing for one of the safety endpoints (LOCF "Last Observation Carry Forward" method). However, at long-term follow-up, less than 10 % of the data was missing. Therefore, in accordance with the protocol, they were not replaced but were noted as missing in the results table. Statistical analyses were performed with SAS software (SAS Institute, North Carolina, USA, version 9.4).

This article was prepared according to the Strengthening the Reporting of Observational Studies in Epidemiology statement.

Results

Baseline characteristics

One hundred and thirty patients were included in 17 Neuroradiology centers during an inclusion period of 22 months, and no patients were excluded from the analysis. Flow of patient enrollment is presented in supplementary Figure I. Eight (6.2 %) patients left the study prematurely: 2 patients (1.5 %) died, 4 patients (3.1 %) were lost to follow-up and 2 patients (1.5 %) left from the study for another reason. Among the 4 patients lost to follow-up, 3 had a favorable neurological evaluation with an mRS of 0 at the intermediate follow-up and 1 patient had an mRS of 2 at the intermediate follow-up (one and a half months post-procedure). Of the 130 patients analyzed, 4 (3.1 %) had 2 target aneurysms, therefore 134 aneurysms were treated in the study. One hundred and twenty-two aneurysms (122/134, 91.0 %) were unruptured and middle cerebral artery was the main location (41/134, 30.6 %). Patient demographics and baseline characteristics are reported in Table 1.

Table 1
Baseline characteristics of included patients.

	Total N = 130 patients / 134 aneurysms
Age, years, mean±SD (median)	55.9 ± 11.4 (56.0)
Male sex, n (%)	49 (37.7%)
Medical history, n (%)	
Smoking	75 (57.7%)
Diabetes	8 (6.2%)
Hypertension	47 (36.2%)
Intracranial ischemic stroke	6 (4.6%)
Intracranial hemorrhagic stroke	25 (19.2%)
Transient ischemic attack	3 (2.3%)
Family history of aneurysm	12 (9.2%)
Polycystic kidney disease	2 (1.5%)
Baseline mRS, n (%)	
0	113 (86.9%)
1	9 (6.9%)
2	2 (1.5%)
>2	6 (4.6%)
Ruptured aneurysms, n (%)	12 (9.0%)
Aneurysm location, n (%)	
Anterior cerebral artery	8 (6.0%)
Anterior communicating artery	31 (23.1%)
Middle cerebral artery	41 (30.6%)
Internal carotid artery	33 (23.6%)
Basilar artery	16 (12.0%)
Others posterior location*	5 (3.7%)
Aneurysm size, n (%)	
Height, mm, mean±SD (median)	5.9 ± 3.9 (4.9)
Width, mm, mean±SD (median)	5.5 ± 3.1 (4.6)
Neck, mm, mean±SD (median)	4.1 ± 1.6 (3.8)
Dome-to-neck ratio, n (%)	
<2	113 (85.6%)
≥ 2	19 (9.0%)
Missing data	2
Small aneurysms (<10 mm), n (%)	121 (91.0%)
Large aneurysms (≥10 mm), n (%)	12 (9.0%)
Missing data	1
Parent artery	
Distal diameter, mm, mean±SD,	2.4 ± 0.7
Proximal diameter, mm, mean±SD	2.8 ± 0.8
Retreatment of previously treated aneurysm, n (%)	32 (23.9%)
Clip	1 (0.7%)
Coiling	27 (20.1%)
WEB	4 (3.0%)

* Supraclinoid internal carotid artery (17; 12.7 %), cavernous internal carotid artery (2; 1.5 %), petrous internal carotid artery (1; 0.7 %), carotid bifurcation (10; 7.5 %), ophthalmic artery (3; 2.2 %)
**Posterior inferior cerebellar artery (2; 1.5 %), posterior cerebral artery (2; 1.5 %), and vertebral artery (1; 0.7 %).

Procedural characteristics and device data

All aneurysms (134/134, 100 %) were successfully treated with at least one LVIS device.

Four of the 152 stents (2.6 %) used were not implanted: 2 (1.3 %) stents due to technical reasons (detachment and opening problem), 1 was not appropriately sized and 1 had been desterilized due to a technical mistake. One hundred and forty-eight stents were implanted to treat the 134 aneurysms, including 121 LVIS Jr (81.8 %) and 27 LVIS (18.2 %). One hundred and nine aneurysms (109/134, 81.3 %) were treated in combination with coils, mainly using the jailing technique (51/109, 46.8 %). Procedural data are presented in Table 2.

Seventy-four patients (74/130, 56.9 %) received double antiplatelet therapy (DAP) preoperatively and 30 (23.1 %) received single antiplatelet therapy (SAT) preoperatively. Data relating to antiplatelet treatments after endovascular treatment are presented in the supplementary results (supplementary Table I).

Primary safety endpoint

Procedure - or device - related AEs with sequelae and permanent morbidity occurred in 6 patients (6/130, 4.6 %) with a mean follow-up of 16.8 ± 5.4 months. These AEs occurred either during or after the procedure (3.8 % and 0.8 % respectively). The six patients meeting the primary safety endpoint all presented with ischemic stroke. Of them, 2 were procedure-related, 3 were device-related (one of them was also linked to an ancillary flow-diverter stent), and 1 was device- and procedure-related.

Overall, 2 patients (1.5 %, 95 % CI: [0.18; 5.45]) died during the study. Neither was adjudged by the expert as procedure- and/or device-related. One death was related to the patient's subarachnoid hemorrhage on admission to the hospital (mRS = 5 and World Federation of Neurosurgical Societies scale (WFNS) = 4). The reason for the second death remains unknown, but at the last angiographic control (10 months after the procedure) of this patient, the aneurysm was completely occluded, the parent artery was patent and the patient's mRS score was 0.

Secondary endpoint

Clinical outcome

Clinical outcomes, evaluated with the mRS score on the entire population are shown in supplementary Table II. Most of the patients evaluated after the endovascular procedure (107/130, 82.3 %), at the intermediate follow-up (103/127, 81.1 %) and at the long-term

Table 2
Endovascular procedure-related data.

	Total N = 130 patients
Number of aneurysms treated per patient, n (%)	
1	126 (96.9%)
2	4 (3.1%)
Number of stents placed per aneurysm, n (%)	
0	0 (0.0%)
1	121 (90.3%)
2	12 (9.0%)
3	1 (1.7%)
Treatment technique for multiple stents, n (%)	
Y-stenting	6 (46.2%)
Telescopic stenting	6 (46.2%)
Other	1 (7.7%)
Use of additional device, n (%)	
Coils	109 (81.3%)
Other intra-saccular device	19 (14.2%)
Flow-diverter	3 (2.2%)
Other type of stent	2 (1.5%)
Treatment technique for coils + stents, n (%)	
Coiling with the jailing technique	51/109 (46.8%)
Coiling passing through the stent LVIS (trans-stent)	14/109 (12.8%)
« Stent-jack » technique	2/109 (1.8%)
Coiling and subsequent deployment of the LVIS stent (post-coiling)	15/109 (13.8%)
Balloon-assisted coiling before LVIS deployment	25/109 (22.9%)
Other (trans-stent and jailing)	2/109 (1.8%)
Antiplatelet regiments before endovascular treatment, n (%)	
No antiplatelet therapy	26/130 (20.0%)
Single antiplatelet therapy	30/130 (23.1%)
Aspirin	2/130 (1.5%)
Clopidogrel	9/130 (6.9%)
Ticagrelor	18/130 (13.8%)
Other	1/130 (0.8%)
Dual antiplatelet therapy	74/130 (56.9%)
Aspirin + Clopidogrel	2/130 (1.5%)
Aspirin + Ticagrelor	28/130 (21.5%)
Aspirin + Prasugrel	26/130 (20.0%)
Antiplatelet regimen during endovascular procedure, n (%)	
Aspirin	49 (37.7%)
Heparin	110 (84.6%)
Eptifibatide	4 (3.1%)
Abciximab	4 (3.1%)
Tirofibran	7 (5.4%)
Other	6 (4.6%)

follow-up (104/123, 84.6 %) had no symptoms (mRS = 0). The mRS score was relatively stable during follow-up as presented in Fig. 1.

Six patients (6/130, 4.6 %) had a baseline mRS >2. Two were in the ruptured group (mRS = 5), two had a history of hemorrhagic stroke (mRS = 3 and mRS = 4), and the 2 other patients had no rupture or history of rupture, (and were mRS = 3 at baseline). At the intermediate follow-up (4.9 ± 2.0 months), 4.7 % (6/127, 95 % CI: [1.75 −10]) of patients had an mRS score higher than 2. Among these six patients, one had subarachnoid hemorrhage due to a ruptured anterior communicating artery aneurysm (baseline mRS = 5 and WFNS = 4 before treatment) and died of diffuse cerebral edema (unrelated to the procedure or the device). Another patient had a mRS score of 4 before treatment, and a slight deterioration was noted during the intermediate follow-up (mRS = 5). Two patients did not show any neurological deterioration, with mRS = 3 before the procedure and no change during the follow-up. Two patients presented with neurological deterioration following an ischemic stroke: one of them had right hemiparesis and left mydriasis, and the other one had right hemiplegia.

At a long-term follow-up (16.8 ± 5.4 months), seven patients (5.7 %; 7/123, 95 % CI: [2.31 −11.38]) had an mRS score higher than 2. These were the same six patients as those with mRS >2 at the intermediate follow-up, with in addition a patient who died (mRS = 6) of unknown cause.

Aneurysm occlusion rates and retreatment

During intermediate follow-up (4.9 ± 2.0 months) and long-term follow-up (16.8 ± 5.4 months), less than 10 % of imaging data was missing (9 aneurysms at intermediate follow-up and 14 aneurysms at long-term follow-up). The result of aneurysm occlusion was assessed using the Raymond-Roy scale,[21] all based on investigating centers assessments of angiography (43.8 % at long term follow-up), MRI (57.6 % at long term follow-up), and CTA (8.3 % at long term follow-up).

Most aneurysms (70.1 %, 94/134) were completely occluded immediately post-procedure, with 75.0 % (93/124) of aneurysms showing stable or progressive occlusion at intermediate and 75.2 % (91/121) at long-term follow-ups. The efficacy results are reported in Table 3.

The grade of occlusion improved for 22/125 (17.6 %) aneurysms between the immediate post-procedure and the intermediate follow-up, and was stable for 88/125 (70.4 %) aneurysms. It was also considered as improved for 12/121 (9.9 %) aneurysms between the intermediate and long-term follow-ups, and stable for 97/121 (80.2 %) aneurysms. Only 3 aneurysms (3/121, 2.5 %) were retreated between the intermediate and long-term follow-ups.

Two cases of minor parent artery stenosis (inferior to 50 % of the normal arterial lumen) were identified (1.6 %, 2/125) at the intermediate follow-up and 1 case (0.8 %, 1/125) at the long-term follow-up. The patency of the parent artery after the procedure did not differ from the intermediate follow-up to the long-term follow-up. There was no in-stent stenosis (≥ 50%) or occlusion at the various angiographic follow-ups.

Subgroup analysis

Subgroup analyzes were conducted showing no statistical difference in AEs between patients with ruptured or unruptured aneurysms (p = 1.00), posterior or anterior circulation (p = 0.249), or proximal or distal circulation (p = 0.665). It should be noted that CMMR was only related to patients in the unruptured group. Similar subgroup analyzes were performed showing no difference in the rate of patients with an mRS score > 2 between patients with a ruptured or unruptured aneurysm (p = 0.522), anterior circulation or posterior circulation (0.318), or proximal or distal circulation (p = 1.00). See supplementary Table III. Subgroup analyses also showed no difference in complete aneurysm occlusion rate or retreatment rate between ruptured or unruptured aneurysms (p = 0.198), anterior or posterior circulation (p = 0.984), or proximal or distal circulation (p = 0.728). See supplementary Table IV.

Discussion

The LEPI study reported 4.6 % of CMMR at 1 year linked to the procedure and/or device, 1.5 % of mortality rate, and 100 % deployment success rate with 92.6 % of adequate occlusion rate at a mean follow-up of 16.8 months post-procedure in a real-world setting. The excellent technical success and durable angiographic outcome further confirmed the excellent outcome demonstrated from previous multicenter studies evaluating the LVIS devices.[14,15] The study also reported 2.5 % of retreatment rate between the intermediate and long-term follow-ups.

Endovascular treatment of intracranial aneurysms using stent assisted coiling allows secure positioning of the coils by preventing their protrusion into the artery and increasing packing density, which promote long-term stability of the occlusion.[24,25] Wide neck aneurysms remain among the most difficult aneurysms to treat surgically or endovascularly[26] and despite the presence of new devices such as flow-diverters[27,28] and flow-disrupters,[29,30] stent-assisted coiling

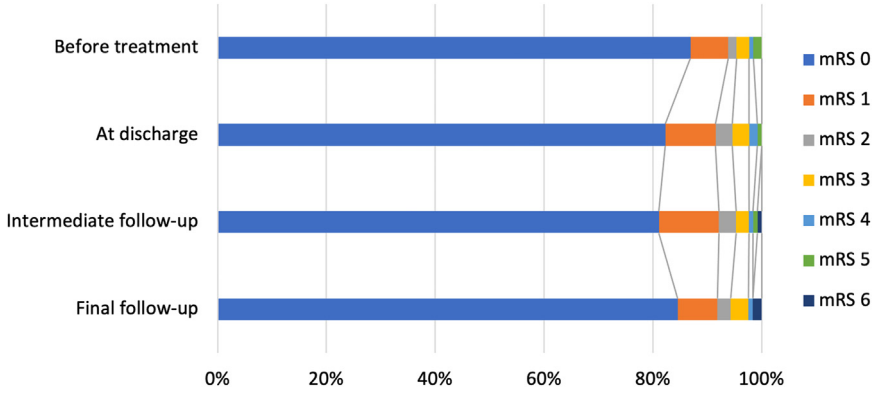

Fig. 1. Evolution of the mRS score during follow-up.
mRS: Modified Rankin Scale.

Table 3
Aneurysm occlusion rate.

	Immediate post-procedure N = 134 aneurysms	Intermediate FU* N = 124 aneurysms	Final FU** N = 121 aneurysms
Total occlusion, n (%) (95% CI)	94 (70.1%)	93 (75.0%) [66.4 – 82.3]	91 (75.2%) [66.5 – 82.6]
Residual neck, n (%)	22 (16.4%)	22 (17.7%)	21 (17.4%)
Residual aneurysm, n (%)	18 (13.4%)	9 (7.3%)	6 (5.0%)
Retreatment, n (%) (95% CI)			3 (2.5%) [0,5 – 7,1]
Missing data		*10*	*13*

* 4.9 ± 2.0 months.
** 16.8 ± 5.4 months.
FU: Follow-up.

remains an essential treatment for the management of intracranial aneurysms with a satisfactory rate of aneurysmal occlusion.[31]

In this LEPI study, endovascular treatment with LVIS/LVIS Jr stent appeared safe and effective for the treatment of intracranial aneurysm. The use of the LVIS/LVIS Jr stent in the real-world setting was associated with high deployment success rate, low cumulative morbidity and mortality rate and good mid-term and long-term angiographic results. Two of the 152 stents (1.3 %) were used but not implanted due to deployment or detachment failure, a slightly lower rate to the ones observed in the TRAIL and the pivotal US LVIS studies using LVIS devices (4.8 % and 2.7 % respectively), or other studies using the Neuroform Atlas (7.0 %, Stryker Neurovascular, Fremont, California, USA)[32] and the Leo (15.8 %, BALT Extrusion, Montmorency, France)[33] stents. Only 2.5 % of the intention-to-treat population (3 patients) required target aneurysm retreatment during the study, a similar rate to what has been reported for the Atlas (3.8 %) and Leo (1.9 %) stents. Regarding efficacy, angiographic data support complete occlusion and satisfactory (complete and adequate) occlusion rates after more than 1 year of follow-up in 75.2 % and 92.6 %, respectively. Although some of this imaging data is based on both MRI and CTA, these findings are consistent with the results of previous studies using the LVIS,[14,15] and show further improvement compared with recent data concerning nearly complete occlusion of the Leo (89.0 %) stent.[33] Moreover no significant in-stent stenosis was documented with the LVIS devices in this study compared to the Atlas (1.3 %)[32] advocating for its safety as it may significantly compromise the parent vessel.[34]

The LEPI study evaluated procedure- and/or device-associated AEs and allowed for an exhaustive collection of real-life data describing patients treated with the LVIS devices. The cumulative morbidity and mortality rates as defined in the protocol by the number of patients presenting an AEs with clinical sequelae(s) related to the procedure and/or the device was 4.6 %. These rates are comparable to those obtained in similar studies on the device. Moreover, among the six patients meeting the primary safety endpoint, one of them was related to the lack of premedication with antiplatelets. Twenty percent of the patients did not receive any antiplatelet treatment before the endovascular treatment, and 15.4 % did not receive heparin during endovascular procedure. Given the relevance of antiplatelet therapy to prevent thrombosis during the placement of neurovascular stent, this lack of premedication has probably affected patient outcome, but reflects the current practice in a real-world setting and the need for antiplatelets and antithrombotic guidelines in neurointerventional procedures.[35,36] The TRAIL and the pivotal US LVIS study showed morbidity rate of 5.6 % and morbidity-mortality rate of 5.2 %, respectively.[14,15] The mortality rate was 1.5 % and no death was procedure- and/or the device-related. The present data are in line with other studies focusing on the Neuroform Atlas (0.5 %)[32] or the Leo stent (0.6 %).[33] The safety of LVIS devices is also supported by the consistency of the mRS score during the study with 95.3 % of patients having a mRS score 0–2 before the treatment, and 94.3 % at the long-term follow-up. Additionally, half of the devices were implanted at the level of anterior communicating artery or middle cerebral artery bifurcation emphasizing the accuracy of theses stents and their ability to navigate distally. These distal locations also demonstrate the advantages of using braided stents over flow-diverting stents in terms of safety when a branch of the sylvian bifurcation or an anterior cerebral artery is covered by the stent, or perforating arteries as in the posterior circulation.[37] These stents are also particularly useful for complex treatments and Y-stenting. Interestingly, the six patients cured with the Y-stenting technique were treated with two LVIS devices and had no symptoms at last follow-up (mRS=0) attesting to their safety with this type of technique. Among other techniques, balloon-assisted coiling before LVIS deployment remains an innovative and very interesting technique, particularly with the use of LVIS JR compatible with the use of Scepter C or Scepter XC (Microvention/Terumo, Tustin, CA). Indeed, the stent can be deployed immediately after coiling without any new catheterization maneuver, thus

reducing the navigation risk. Also, in case of no need for stent or perforation during coiling this technic allows to prevent stent deployment. The LVIS stent provides higher mesh density compared to laser-cut stents as the Enterprise stent (Cordis Neurovascular, Miami, FL, USA), which improves the coils stabilization and allows a higher coil packing density.[17] In addition, the braided stents provides higher pore density compared to laser-cut stents, improving the flow-diverting hemodynamic effect of these devices.[38,39]

We acknowledge several limitations as our study was single-arm, observational and open-label study in the real-world setting without imaging core laboratory. All patients in France for whom the LVIS Jr stent was used during the study periods could not be included, but selection biases were minimized by conducting a study with few selection criteria. Indeed, all patients who did not object to data collection and for whom an LVIS or an LVIS Jr was used for the treatment of an intracranial aneurysm could potentially be included in the study. This study was nearly comprehensive nationwide, as only 18 LVIS devices were used at 3 non-participating centers during the study period. The assessment bias for the primary safety endpoint was minimized since all the clinical events that occurred in the study were reviewed and analyzed independently by an expert neurointerventionalist who judged the type of event, the clinical impact, the severity, and the relationship of the event to the device and/or procedure. Moreover, attrition bias was low because data quality control was performed. The data from the centers were checked by an independent clinical research associate, and all the centers were subject to at least one monitoring visit. Concerning patients lost to follow-up, the number of patients discharged prematurely is very low given the observational nature of this study: only six patients out of the 130 included (4.6 %) left the study prematurely apart from two deaths. Finally, to account for confounding bias, subgroup analyzes were performed to determine the influence of aneurysm location and ruptured/unruptured aneurysm status. And no statistically significant difference was shown between the different groups on the evaluation criteria.

Herein the LEPI study remains concordant with other published studies of the LVIS devices. But further studies are needed to investigate the long-term effectiveness of the LVIS and LVIS Jr devices over the time, and national registers could help providing comparative analysis with other stent-assisted coiling devices.

Conclusion

The LEPI study investigated the safety and efficacy of LVIS/LVIS Jr stent for endovascular treatment of intracranial aneurysms. This study demonstrates that in real-world settings, the LVIS and LVIS Jr stents are safe and effective devices with long-term satisfying efficacy for the treatment of complex intracranial aneurysms.

Declaration of Competing Interest

MP reports support for attending meetings and/or travel from Balt, and stock or stock options (Basecamp Vascular, Synchron, Radical Catheter, Vastrax, Intradys). LP reports consulting fees from Balt, Microvention, Phenox. FC reports consulting fees from Balt, Medtronic, Microvention, Stryker, stock or stock options (Collavidance, Intradys), and leadership or fiduciary role in other board, society, committee or advocacy group, paid or unpaid (Artedrone). PM reports consulting fees from Medtronic, Stryker, Artiria, payment to his institution (Codman), and served as chairman of the adverse events monitoring committee for this study, sponsored by Microvention. GM reports consulting fees from Microvention, Balt, Stryker, honoraria for lectures (Medtronic, Johnson & Jonhson). AR reports consulting fees from Balt. The other authors report no conflicts.

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Contributors

CM and MP: study concept and design.
GF: wrote the manuscript.
All named authors contributed substantially to the work described by actively participating in data collection and analysis, edited the manuscript, and approved the final version.

Ethics approval

The study received required national regulatory authorization from a French national Ethics Committee (Comité de Protection des Personnes OUEST III, France (17.10.54): positive opinion of November 21, 2017). The LEPI study was registered in ClinicalTrial.gov under NCT 03553771.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.neurad.2023.10.007.

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