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Original Article

Comparison of self-expandable stents and balloon-mounted stents in the treatment of symptomatic intracranial vertebral artery atherosclerotic stenosis

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Abstract: Objective: To compare the safety and efficacy of self-expandable stents (SES) and balloon-mounted stents (BMS) in the treatment of severe symptomatic intracranial vertebral artery atherosclerotic stenosis (SIVAAS). Methods: The clinical and imaging data of 76 consecutive cases who were stented for SIVAAS in our centers in ten years were reviewed retrospectively. The cases were divided into SES group and BMS group as per the type of stents. Conventional risk factors of atherosclerosis, the relationship between stenosis and the origin of posterior inferior cerebellar artery (PICA), whether the stenosis was located at the dural-entry zone of the vertebral artery (VA), the interventional access, periprocedural complications, and clinical and imaging follow-up results were analyzed statistically. Results: 77 stenotic lesions in 76 cases were included. Totally 51 SES and 26 BMS were implanted successfully. There was no significant difference in periprocedural complications (1 vs. 2, P = 0.544), incidence of restenosis (13.2% vs. 14.3%, P = 0.628) and long-term death or stroke (4 vs. 7, P = 0.33) between the two groups. The degree of residual stenosis in SES group was higher than in BMS group (10 (0%-40%) vs. 0 (0%-15%); P = 0). More BMS were selected in lesions located at the dural-entry zone of VA (45.1% vs. 73.1%, P = 0.02). There were more BMS implanted when lesions located proximal to origin of PICA (SES vs. BMS = 23.5% vs. 57.7%, P = 0.003) or when lesions with straighter access (SES vs. BMS = 29.4% vs. 69.2%, P = 0.001). More SES implanted when lesions located distal to PICA (SES vs. BMS = 43.1% vs. 15.4%, P = 0.015) or when lesions with moderate tortuous access (SES vs. BMS = 60.8% vs. 23.1%, P = 0.002). For stenotic lesions with moderate tortuous interventional access, SES group cases had longer survival time without stroke or death (P = 0.008). Conclusion: Both SES and BMS showed high safety and efficacy for the treatment of SIVAAS. SES was more recommended for the stenotic lesions with tortuous interventional access. BMS was more recommended for the lesions located at the dural-entry zone of VA or proximal to PICA origin.

Keywords: Self-expandable stent, balloon-mounted stent, vertebral artery stenosis, intracranial atherosclerotic stenosis, intracranial vertebral artery

Introduction

Intracranial atherosclerosis (ICAS) is an important cause of cerebral ischemia and, when symptomatic, associated with a high risk of recurrent stroke. It is accounts for as high as 42%-54% of ischemic stroke in Asian population [1, 2]. The Chinese intracranial atherosclerosis (CICAS) trial evaluated 2864 consecutive patients with cerebral ischemia and found a prevalence of ICAS of 46.6% [3]. The recurrence rate is about 3%-4% following the first onset of ischemic stroke or transient ischemic attack (TIA) [4]. In the Stenting and Aggressive Medical Management for Preventing Recurrent Stroke in Intracranial Stenosis (SAMMPRIS) trial, nearly 1 in 8 symptomatic patients had recurrent stroke within 12 months of observation despite aggressive medical management [5]. Angioplasty alone might be a safer endo-

vascular technique for the treatment of ICAD, but it still unknow the real rate of restenosis and the frequency of bailout stenting or rescue therapy.

At the beginning of endovascular treatment for ICAD, most knowledge about stent placement for intracranial stenosis is from case series in which the use of coronary stents was attempted in intracranial vasculatures [6-9]. Stent placement seems superior to balloon angioplasty alone in improving posttreatment results and reducing dissection and recoil frequencies [8-11]. It has achieved relatively good short-term results in those cases with hypoperfusion damage in territory supplied by the stenosis artery [12-14]. However, 2 randomized trials, the SAMMPRIS and the Vitesse Intracranial Stent Study for Ischemic Therapy (VISSIT) trial showed medical therapy was superior to stenting [5, 15]. On the other side, there are also some studies found fewer events of stroke, transient ischemic attack (TIA), and death in patients with endovascular therapy for ICAS, which were lower than those reported in the SAMMPRIS and VISSIT trials [16, 17]. A study pool also revealed that fewer adverse events occurred in patients with ICAS treated with endovascular therapy with a long follow-up [17]. Many operators believed that modifications in patient selection and procedural aspects can substantially reduce the 1-month stroke and/or death rate following intracranial stent placement, and stenting for patients who had severe symptomatic ICAS combined with poor collaterals had a good prognosis [18]. But restenosis rates and long-term stroke and death event rates of intracranial stents still need to be evaluated.

There are two kind of stents using in the clinical for ICAS nowadays, self-expandable stents (SES) and balloon-mounted stents (BMS). The Wingspan SES (Stryker, Kalamazoo, MI) was the first device approved by the Food and Drug Administration for the treatment of ICAD in coordination with use of the Gateway angioplasty balloon. With experienced interventionalists, and proper patient selection, it was demonstrated a lower periprocedual complication rate and excellent safety profile [18, 19]. While for intracranial BMS, it has higher radial force and its deployment is simpler. But it was less flexible and difficult to navigate along tortuous vessels, also it's not appropriate to be used in longer, curved lesions and lesions with mismatch of vessel size [20]. Some reports showed higher restenosis rate for SES than BMS [16, 21, 22] cases.

The intracranial vertebral artery (ICVA) is relatively straight, also with fewer branches to make this segment a favorable location for stenting. However there is no literature specifically addressing the difference between SES and BMS to treat ICVA stenosis. Here we retrospectively analyzed the data of symptomatic intracranial vertebral artery atherosclerotic stenosis (SIVAAS) treated with SES and BMS in our centers and compared their safety and effectiveness.

Materials and methods

Subjects and methods

Data collection: The protocol for this study was approved by our institutional ethics committee and written informed consent for each patient was obtained. The data of patients who underwent stenting for SIVAAS from May 2009 to April 2019 were retrospectively analyzed. The data we collected include patients' baseline characteristics, conventional stroke risk factors (hypertension, diabetes mellitus, coronary artery disease, hyperlipemia, history of previous stroke or transient ischemia attack, current smoking), location of stenosis, degree of preprocedual stenosis, degree of residual stenosis post procedure, types of stent (SES or BMS), rate of periprocedural complication, clinical outcome and angiographic follow-up. In addition, attempts of pre-dilation times were recorded in the SES group.

Inclusion criteria: All Patients had recent minor stroke (modified Ranking scale (MRS) score ≤2) or transient ischemic attack (TIA) attributed to the stenosis of ICVA. They failed to respond to standard medical therapy (at least single antiplatelet therapy and statin) and had at least one atherosclerosis risk factor. The degree of stenosis was severe (≥70%) as defined by the Warfarin-Aspirin Symptomatic Intracranial Disease Trial (WASID) criteria[13].

Exclusion criteria: Patients were excluded if the stenostic lesions was not atheroslerotic or two stents were deployed for tandem lesions.

Patients with intracranial hemorrhage in the territory of the stenotic VA were also be excluded.

Subgroups: Lesions were divided into different subgroups according different standards. According to the relationship between stenosis and the origin of PICA, there were four types. Type 1 is the stenosis proximal to origin of PICA. Type 2 is the stenosis involving the origin of PICA. Type 3 is the stenosis distal to origin of PICA. Type 4 is the situation without PICA originating from ICVA.

The lesions may also be divided into two groups by being at the dura-entry zone of VA (where VA piercing the dura and entering cranium) or not.

According to the vessel access for the stenting procedure, there are three types. In Type 1, access is straight and smooth. Type 2 access is with moderate tortuosity and slight atherosclerosis. Type 3 access is with severe tortuosity and atherosclerosis.

The distribution of stenotic lesions, the degree of residual stenosis, perioperative complications, restenosis rate, the rate of long-term stroke or death in different subgroups were analyzed. The degree of stenosis and restenosis was blindly measured by two experienced neuroradiologists using the WASID criteria.

Periprocedural management: The procedures were performed at least 2 weeks after the index infarction. All patients were loaded with 300 mg aspirin and 75 mg clopidogrel daily for at least 3 days before the procedure. They received general heparization after arterial sheath was introduced and ACT was kept in 200-300 ms throughout the procedure.

After stenting procedure, patients were closely monitored for potential neuro deficits in the first 24 hours. Blood pressure was controlled with medicine, targeting 100-130 mmHg for systolic pressure. 300 mg aspirin and 75 mg clopidogrel daily were maintained for 3 months. Then 100 mg of aspirin daily was suggested for lifetime.

Operation procedure: All procedures were performed under general anesthesia. A 6-french guiding catheter (Envoy, Codman, USA) was navigated to the vertebral artery at the level of inferior to dentata. The stenosis and the collateral circulation were evaluated. The following strategy was used in the SES group. An exchangeable microwire (Transend Floopy 300, Boston Scientific, USA) was navigated across the stenosis assisted by microcatheter to the straight segment of the posterior cerebral artery (PCA). Then microcatheter was retrieved. A undersized balloon (Gateway; Boston Scientific, USA) was then advanced to covered the stenosis lesion along exchangeable microwire. Balloon angioplasty was performed slowly under fluroscopy. If angiography after the dilation was not satisfying, the dilation was repeated with a higher pressure. Once angioplasty achieved satisfaction, the balloon was retrieved with microwire left in place. The SES stent (Wingspan, Boston Scientific, USA) was then advanced over the exchangeable microwire to the stenosis. Angiography was performed again to confirm stent position and the stent was deployed. Had another injection to confirm sound stent expansion and blood flow restoration distal to the stenosis territory. Technical success was defined as complete lesion coverage with residual stenosis less than 50%. If the residual stenosis was higher than 50%, post dilation was performed. In BMS group, stent diameter was determined by referring to the smaller side of the normal vessel adjoining to stenosis. The stent was tracked over a microwire directly or using a exchanging technique and was supposed to cover the lesion completely. After position confirmation, the balloon was inflated gently and BMS was deployed. Result was then assessed by angiography. BMS used in this study included Apollo or Firebird, (MicroPort Medical, China) and Excel (JW Medical Systems, Weihai, China).

Follow-up: All patients had clinical follow-up at 3, 6, and 12 months after the procedure. Subsequently asymptomatic patients had annual follow-up. All patients had angiography at 6 months or 1 year after procedure. They had subsequent yearly CTA follow-up if there was no symptomatic restenosis. Short-term evaluation included significant residual stenosis and periprocedural stroke and death. Long-term adverse events included in-stent restenosis, stroke related to stented vessel or all-cause mortality during the follow-up period beyond 30 days after procedure. Restenosis, excluding postoperative residual stenosis, was defined

as ≥50% stenosis (within the stent or not exceeding 5 mm beyond proximal and distal end of the stent), which was evaluated by angiography. Degree of restenosis was defined as the difference between stenosis immediately after stent deployment and at follow-up in percentage.

Statistical analysis

Chi-square test was used to compare demographic variables, risk factors, and clinical features between the BMS and SES groups. Continuous variables (e.g., age and degree of stenosis) were compared using Student's t test. The interventional access between groups were compared using Mann-Whitney test. The normality test of data was performed by shapiro-wilk test. The follow-up duration was non-normal distributed and whether it was balanced was tested by Mann-Whitney test. The Kaplan-Meier method and log-rank test were used to detect the differences of survival time without stroke or death and degree of restenosis along with follow-up time between groups. All statistical analyses were performed with SPSS version 21.0 (IBM Corp. Armonk, NY, USA).

Results

Demographic information

A total of 76 cases with 77 stenosis were included in this study. One case in BMS group suffered bilateral intracranial vertebral artery stenosis. The total technical success rate was 100% (77 positions of stenosis/77 stents, 51 treated with SES and 26 with BMS). The comparison of demographics, conventional risk factors for cerebrovascular disease, characteristics of lesions and complications between the two groups were showed in **Table 1**. The proportion of patients with hyperlipemia in SES group was higher than in BMS group (29.4% vs. 7.7%; P = 0.03). Although the degree of stenosis before stenting had no difference (SES vs. BMS; 77% (54.3%-99%) vs. 74.58% (54.50%-85.71%), P = 0.69), there was significant difference in residual stenosis post procedure in two groups (SES vs. BMS: 10 (0%-40%) vs. 0 (0%-15%); P = 0).

Periprocedural outcomes

The total periprocedural complication rate (stroke and death within 30 days) was 3.9% (3/77). In BMS group, one patient developed intracerebral hemorrhage in right temporal lobe 48 hours post procedure, he completely recovered in one year. Another patient developed SAH and hydrocephalus 3 hours post procedure and died at seventh day post procedure. In SES group, one patient developed weakness in left limbs a week post procedure. As angiography confirmed in-stent thrombosis, the second SES (Enterprise, Codman, USA) was deployed as a rescue device. The patient still had blurred speech and minor left paralysis with MRS 2 in the 3-year follow-up (**Table 1**).

Follow-up outcomes

Clinical follow-up rate was 97.4% (75/77). One patient died in periprocedural stage and one was lost in follow-up. The median follow-up duration was 40 (range, 2-141) months. The long-term stroke or death rates was 14.7% (11/75). There was no significant difference between SES and BMS group (log-rank, P = 0.330) concerning the long-term stroke or death rate (**Table 2**).

Angiographic follow up rate was 76.6% (59/77). The median follow-up duration was 12 (range, 2-127) months. Total restenosis rate was 13.6% (8/59). Restenosis rate in SES group was 13.2% (5/38). One of them had ischemic stroke event. Restenosis rate in BMS group was 14.3% (3/21). All of them were asymptomatic. There was no significant difference between SES and BMS group (log-rank, P = 0.628) concerning the restenosis rate (**Table 3**; **Figure 2**). So was the degree of restenosis (SES 0 (0%-65%) vs. BMS 0 (0%-90%), P = 0.663) (**Table 3**).

Subgroups analysis

In BMS group, more stenosis located at the dural-entry zone (45.1% vs. 73.1%, P = 0.02) (**Table 1**). In the subgroup of lesions in dural-entry zone, more residual stenosis rate in SES group (SES vs. BMS = 15 (0-40) vs. 0 (0-10), **Table 4**). Comparing with lesions at other segment, dural-entry zone lesions tended to have balloon angioplasty twice or more times (8/23 vs. 2/28, P = 0.034) before SES implanted. There were more lesions treated with BMS when they located proximal to the origin of PICA (SES vs. BMS = 23.5% vs. 57.7%, P = 0.003, **Table 1**) or when lesions with Type 1 access (SES vs. BMS = 29.4% vs. 69.2%, P = 0.001,

Table 1. Patient characteristics and periprocedural complications, degree of restenosis comparison between SES and BMS groups

Variable	N = 77 (stenosis)		*P* value
	SES (N = 51)	BMS (N = 26)	
Age	65 (40-79)	63 (38-75)	0.444
Male (n = 68)	46 (90.2%)	22 (84.6%)	0.729
Hypertension	41 (80.4%)	23 (88.5%)	0.567
DM	14 (27.5%)	7 (26.9%)	0.961
CAD	4 (7.8%)	2 (7.7%)	1
Smoking	22 (43.1%)	10 (38.5%)	0.694
Hyperlipemia	15 (29.4%)	2 (7.7%)	0.03*
Clinical diagnosis			0.694
CI	20 (39.2%)	9 (34.6%)	
TIA	31 (60.8%)	17 (65.4%)	
Complications	1 (2.0%)	2 (7.7%)	0.544
CI	1		
CH or SAH		2	
Location			0.566
Left VA	34 (66.7%)	19 (73%)	
Right VA	17 (33.3%)	7 (27%)	
Degree of preprocedural stenosis	77% (54.3%-99%)	74.58% (54.5%-85.71%)	0.111
Degree of residual stenosis	10% (0%-40%)	0% (0%-15%)	0*
Stenosis at the VA segment where VA piercing the dura			0.02*
Yes	23 (45.1%)	19 (73.1%)	
No	28 (54.9%)	7 (26.9%)	
Relationship between stenosis and origin of PICA†			0.005*
Type 1	12 (23.5%)	15 (57.7%)	0.003*
Type 2	9 (17.6%)	1 (3.8%)	0.179
Type 3	22 (43.1%)	4 (15.4%)	0.015*
Type 4	8 (15.7%)	6 (23.1%)	0.629
Interventional Access‡			0.003*
Type 1	15 (29.4%)	18 (69.2%)	0.001*
Type 2	31 (60.8%)	6 (23.1%)	0.002*
Type 3	5 (9.8%)	2 (7.7%)	1

*: P<0.05. †: Stenosis lesions were divided into four types according to the relationship between stenosis and origin of PICA: type 1, Stenosis located proximal to origin of PICA; type 2, Origin of PICA was involved in stenosis; type 3, stenosis located distal to origin of PICA; type 4, without PICA originating from intracranial VA. ‡: The interventional access of stenosis were divided into 3 types: type 1, Access was straight and smooth; type 2, access was moderate tortuous and slightly atherosclerotic; type 3, access was with severe tortuous and atherosclerotic. DM diabetes mellitus, CAD coronary artery disease, CI cerebral infarction, TIA transient ischemic attack, CH cerebral hemorrhage, SAH subarachnoid hemorrhage, VA vertebral artery.

Table 1). More SES implanted when lesions located distal to PICA (SES vs. BMS = 43.1% vs. 15.4%, P = 0.015) or when lesions with moderate tortuous access (SES vs. BMS = 60.8% vs. 23.1%, P = 0.002).

Kaplan-Meier survival analysis revealed that cases in the SES group with Type 2 access had longer stroke-free survival and overall survival (P = 0.008, **Figure 1A**). There was no significant difference in survival analysis of restenosis between two groups' cases with Type 2 access (P = 0.683, **Figure 1B**).

Discussion

We presented clinical and angiographic outcomes of 76 patients with 77 SIVAAS who were treated with BMS or SES. The technical success rate was 100%. Perioperative complica-

Table 2. Comparison of SES and BMS groups in patients received clinical follow-up

Variable	N = 75 (stents)		*P* value
	SES (N = 50)	BMS (N = 25)	
Stenosis at the VA segment where VA piercing the dura			
Yes	23 (46%)	18 (72%)	0.033*
No	27 (54%)	7 (28%)	
Relationship between stenosis and origin of PICA†			0.01*
Type 1	12 (24%)	14 (56%)	0.006*
Type 2	8 (16%)	1 (4%)	0.258
Type 3	22 (44%)	4 (16%)	0.016*
Type 4	8 (16%)	6 (24%)	0.6
Interventional access‡			0.005*
Type 1	15 (30%)	17(68%)	0.002*
Type 2	30 (60%)	6 (24%)	0.003*
Type 3	5 (10%)	2 (8%)	1
Clinical follow-up			
Long-term stroke/death	4 (8%)	7 (28%)	0.330 (Log-Rank)
Follow-up duration	36 (2-98)§	62 (2-141)	0.122 (Mann-Whitney)

*: P<0.05. §: the data was non-normal distributed (shapiro-wilk test, P>0.05). Other demonstrations were same as footnotes in **Table 1**.

Table 3. Comparison of SES and BMS groups in patients received imaging follow-up

Variable	N = 59 (stents)		*P* value
	SES (N = 38)	BMS stents (N = 21)	
Stenosis at the VA segment where VA piercing the dura			
Yes	17 (44.7%)	16 (76.2%)	0.02*
No	21 (55.3%)	5 (23.8%)	
Relationship between stenosis and origin of PICA†			0.011*
Type 1	8 (21.1%)	12 (57.1%)	0.005*
Type 2	6 (15.8%)	1 (4.8%)	0.404
Type 3	18 (47.4%)	3 (14.3%)	0.011
Type 4	6 (15.8%)	5 (23.8%)	0.683
Interventional access‡			0.016*
Type 1	11 (29.0%)	14 (66.7%)	0.005*
Type 2	23 (60.5%)	5 (23.8%)	0.007
Type 3	4 (10.5%)	2 (9.5%)	1
Imaging follow-up			
Restenosis rate	5 (13.2%)	3 (14.3%)	0.628 (Log-Rank)
Follow-up duration	8.5 (2-88)§	17 (4-127)§	0.163 (Mann-Whitney)
Degree of restenosis	0 (0%-65%)	0 (0%-90%)	0.663

*: P<0.05. §: the data was non-normal distributed (shapiro-wilk test, P>0.05). Other demonstrations were same as footnotes in **Table 1**.

tions were 3.9%. The total long-term stoke rate and mortality was 14.7% (11/75). Miao [16] reported outcome of treating intracranial stenosis with SES and BMS. The total technical success rate and periprocedural complications in their study was 97.3% (292/300) and 4.3% (13/300), respectively. Yet intracranial VA stenosis just account for 24.3% of the subjects in their study. Compter [23] reported VA stenosis treatment with SES and BMS. The total rate of

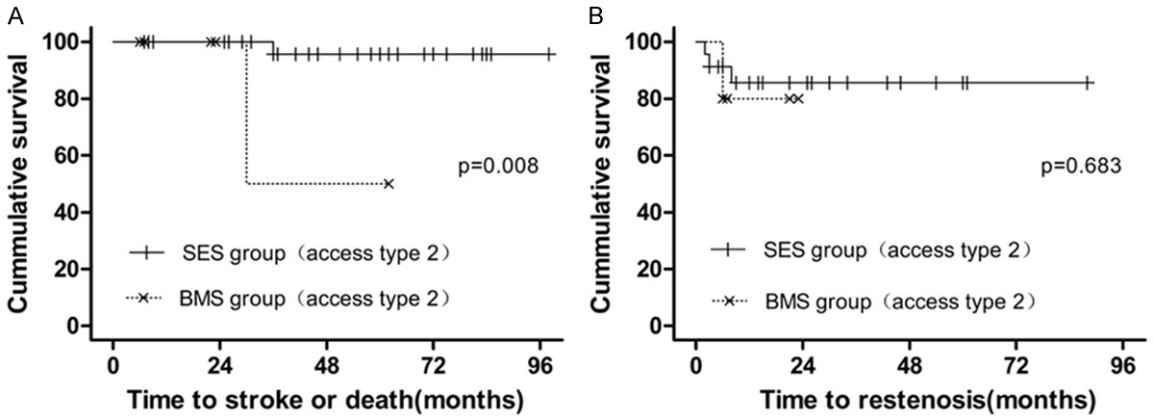

Figure 1. Clinical and angiographic outcomes of patients with interventional access type 2. A. Based on follow-up of clinical and angiographic outcomes, survival analysis revealed that SES group cases with access of type 2 had longer survival time without stroke or death. B. There was no significant difference in survival analysis of restenosis between two groups for lesions with interventional access type 2. The ordinates were the percentages of cumulative survival.

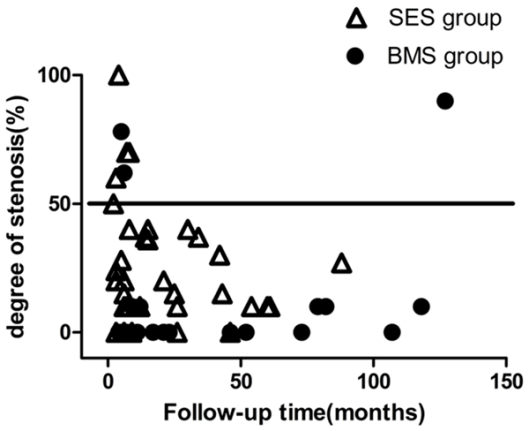

Figure 2. Scatter plot of stenosis degree along with the follow-up time in the SES and BMS groups. Every point in the figure represent an imaging follow-up stent. The abscissa was follow-up duration. And the ordinate was the degree of stenosis in imaging follow-up. The plots with ordinate greater than 50% represented cases developed restenosis.

periprocedural complications was 5%, but there were 22% (2/9) cases in the subgroup of intracranial stenosis developed stroke or death within 30 days after procedure. In their study, the total rate of long-term stoke and death was 19%, but the proportion of intracranial VA stenosis was still very small. Our results were consistent with theirs in general. The rate of restenosis in our study was 13.6%, which was a little lower than 24.5% and 14.4% in the literatures [21, 22]. According to our results, treating SIVAAS with SES and BMS, compared with treating MCA stenosis, has better safety and effectiveness.

According to our results, there was no significant difference between SES group and BMS group in periprocedural complication rate. It was consistent with the intracranial stent study reported by other researchers [16-18, 20]. While the rate of periprocedural complications in the SAMMPRIS study [5] and VISSIT study [15] were higher than in our study (3.9%), which were 14.7% and 24.1%, respectively. The difference may be explained by the fact that stenting procedure in SAMMPRIS and VISSIT study was performed within 30 days after onset of TIA or stroke. Another reason might be lack of experience of the operators. In SAMMPRIS study, evaluation was based on continuous 20 stenting procedures of a certain operator, and just 3 cases were treated with SES. In VISSIT study, an operator with a volume of more than 10 case of intracranial stenting in the past year was eligible. On the contrary, in CASSISS study [17], the operators were required to have a volume of at least 30 intracranial stenting procedures every year in recent 3 years to be eligible. The technical success rate in CASSISS study was 100% and the rate of periprocedual complications was only 2%. The third reason to explain the lower rate of periprocedural complications in our study is the anatomy traits of ICVA. ICVA is straighter than other intracranial vessels and has fewer perforators, there are two vertebral arteries in nor-

Table 4. Comparison of periprocedural complications, residual stenosis, long-term adverse events and restenosis between 3 subgroups analysis

	Periprocedural complications	Residual stenosis	Long-term adverse events (Log-Rank)	Restenosis (Log-Rank)
Stenosis at the VA segment where VA piercing the dura				
Yes	0/23:2/19	15 (0-40):0 (0-10)*	2/23:5/18	3/17:1/16
No	1/28:0/7	10 (0-40):0 (0-15)*	2/27:2/7	2/21:2/5
Relationship between stenosis and origin of PICA†				
Type 1	0/12:1/15	12.5 (0-40):0 (0-10)*	2/12:3/14	1/8:1/12
Type 2	0/9:0/1§	13.3±11.5:0 (constant)	0/8:1/1‖	2/6:0/1‖
Type 3	1/22:1/4	10 (0-40):0 (constant)*	2/22:1/4	2/18:0/3
Type 4	0/8:0/6§	20 (0-40):0 (0-15)*	0/8:2/6	0/6:2/5
Interventional access‡				
Type 1	0/15:2/18	10 (0-40):0 (0-15)*	0/15:6/17	1/11:2/14
Type 2	1/31:0/6	15 (0-40):0 (constant)*	1/30:1/6*	3/23:1/5
Type 3	0/5:0/2§	22±13.10:0 (Constant)*	3/5:0/2	1/4:0/2

*: P<0.05. The data was compared as SES group: BMS group; §: no periprocedural complications occurred in this subgroup; ‖: Log-Rank analysis could not be performed because only 1 stenosis was treated with BMS in this subgroup. Other demonstrations were same as footnotes in **Table 1**.

mal development cases, another VA provided good collateral blood flow during operation. These traits add on the safety of stenting procedure.

In our study, we found that the degree of residual stenosis in SES group was higher than in BMS group. This was consistent with some previously studies of intracranial vascular stenting [20, 22]. To prevent complications, we tried to avoid in-stent balloon angioplasty after stent was deployed, unless the residual stenosis was more than 50%. We believed the radial forces of SES could alleviate the residual stenosis as reported [24]. More stenotic lesions located at the dural-entry zone of VA were treated with BMS in our study, because the dura was leathery and sometimes even with calcification. This situation limited the effect of angioplasty with submaximal balloon predilation in SES procedure. This phenomenon was also proven from the fact that stenotic lesions at dural-entry zone tended to have twice or more times of balloon angioplasty before SES deployment. Our results didn't demonstrate the relation between complication incidences and times of balloon dilation. But we believed that unnecessary repetition of balloon dilation should be avoided as much as possible. We recommend BMS for the lesions at the dural-entry zone.

In our study, more lesions were treated with BMS when they were located proximal to PICA or when the lesions with access of type 1. The reason was that the BMS was more rigid than SES. It also needed higher deploying pressure and had higher redial force compared with SES [8]. Additionally, BMS's wall apposition is a problem if the lesion with a significant mismatch in the diameter between the proximal and distal segments. These traits might lead to higher probability of migration in vessel and its perforator. Our results are in favor of selecting SES if the stent has to cover the PICA origin or to be positioned more distally during SIVAAS stenting. The lesion could be expanded with submaximal and high compliant balloon first before SES implanted. The SES system was more flexible and safer to tortuous lesion and branch vessels.

This study revealed no significant difference in the incidence of in-stent restenosis between SES and BMS group, which is inconsistent with some previous studies [22]. The reason might still be the anatomic traits of ICVA. The course of ICVA is relatively straight and there is less perforator, which makes stenting safer. Residual stenosis is also less significant and the blood flow is more regular. Regular blood flow brought higher shear stress to the vessel wall and would inhibit the intimate's hyperplasia [25, 26].

Our study found no differences in long-term adverse events (stroke of the territory of the stented vessel all-cause mortality) between two groups. This was consistent with previous studies [20, 22] in MCA stenosis. The overall symptomatic in-stent restenosis rate in our

study was 1.7% (SES group). SAMMPRIS [5] (21%) and VISSIT [15] (36.2%) study observed higher rate. This implies that restenosis after ICVA stenting may not represent the same level of concern as in MCA. We suggest explaining this from anatomy point of view. Our subgroups analysis showed that SES group lesions with type 2 access had longer stroke-free survive or overall survive than BMS group. That meant for stenosis with interventional access with moderate tortuosity and mild atherosclerosis, SES looks to have better clinical outcomes. SES is more flexible and could be delivered to distal vessels easier and safer. Some other studies also recommended to choose SES in more tortuous access, while reserving BMS for relatively straighter access [20, 22].

This study had some potential limitations. It is a single center, retrospective study with relatively small sample size. Treatment allocation between SES and BMS was not randomized and might have been based on morphologic traits of lesion and tortuosity degree of the access arteries. Three different BMS products were included in this study, which may interfere the comparison. A randomized, multicenter, parallel trial might be required to compare the clinical efficacy of the two types of stent for SIVAAS.

Conclusions

Both SES and BMS had relatively low periprocedural complication rate and low long-term stroke or death in stenting treatment for SIVAAS. Stenting should be a safe and effective alternative treatment for SIVAAS refractory to medicine. For the SIVAAS with tortuous interventional access, SES is recommended. For stenotic lesions located at the dural-entry zone of the VA or proximal of PICA origin, the BMS is recommended.

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Disclosure of conflict of interest

None.

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