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ABSTRACT

BACKGROUND AND PURPOSE: In clinical practice, stent diameter is one of the variable properties important for endovascular treatment. A consensus guideline for stent retriever size selection has yet to be established. The aim of this study was to investigate the effects of different diameters of Solitaire retrievers on outcomes.

MATERIALS AND METHODS: Of 628 patients enrolled from the Endovascular Treatment for Acute Anterior Circulation Ischemic Stroke Registry, 256 were treated with the Solitaire 4-mm device and 372, with the 6-mm device. We matched patients treated with the 2 stent sizes using propensity score analysis. The successful outcome was reperfusion as measured by the modified Thrombolysis in Cerebral Infarction score immediately postprocedure and the dichotomized modified Rankin Scale score at 90 days. Symptomatic intracerebral hemorrhage and in-hospital mortality were also recorded.

RESULTS: After propensity score analysis, group outcomes did not differ. In addition, in patients with atherosclerosis-related occlusion, a higher reperfusion rate ($P = .021$) was observed in the Solitaire 4 group, as well as a shorter time interval ($P = .002$) and fewer passes ($P = .025$). Independent predictors of successful reperfusion in patients with atherosclerotic disease on logistic analysis were the small stent (OR, 3.217; 95% CI, 1.129–9.162; $P = .029$) and the propensity score acting as a covariate (OR, 52.84; 95% CI, 3.468–805.018; $P = .004$).

CONCLUSIONS: We found no evidence of a differential effect of intra-arterial therapy based on the size of Solitaire retrievers. In patients with atherosclerotic disease, favorable reperfusion was associated with deployment of a small stent.

ABBREVIATIONS: ACTUAL = Endovascular Treatment for Acute Anterior Circulation Ischemic Stroke Registry; IQR = interquartile range; mTICI = modified TICI; ST 4 = 4-mm Solitaire stent retriever; ST 6 = 6-mm Solitaire stent retriever

Large-vessel occlusion accounts for 28%–46% of all ischemic strokes and leads to poor prognosis and high mortality.[1] Since 2015, the results of several clinical randomized trials have suggested that intra-arterial treatment is safe and effective for anterior circulation large-vessel occlusion.[2-7] The success also demonstrated the benefit of newer stent devices in endovascular recanalization therapies because most patients were treated with retrievable stents in these trials.

In these trials, most devices used for mechanical thrombectomy were retrievable stents such as the Solitaire FR (Covidien, Irvine, California)[8] or the Trevo retriever (Stryker, Kalamazoo, Michigan).[9] The Solitaire is a self-expanding and retrievable stentlike device that restores blood flow immediately by thrombus entrapment between the stent struts and the vessel wall,[10] achieving substantially better safety and efficacy outcomes than former

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devices.[11] This device was at first designed for aneurysms, with a variety of diameters made available to meet the needs of different sizes of intracranial vessels.[12] For mechanical thrombectomy, stents with 4- and 6-mm diameters delivered through 0.021- and 0.027-inch microcatheters, respectively, optimize performance in intracranial large vessels in present day interventional therapy. The Trevo retriever is structurally similar to the Solitaire FR, with a stent cell geometry designed to integrate the clot into the stent for retrieval.[13,14]

It has been reported that a difference in stent size potentially influences stent properties, including radial force, flexibility, and deliverability.[15-17] The radial force represents the supporting action of the stent on the vessel wall to prevent elastic retraction, while flexibility and deliverability exemplify the ability to pass through the occluded site. Several studies have found that a stent with a large radial force is suitable for proximal vessels and atherosclerotic modified vessels with hardened or calcified plaque, while a more flexible stent should be used in a tortuous or distant vessel.[16,18]

In addition, extensive evidence shows that the stent diameter is associated with in-stent restenosis[19] and change in blood flow after intracranial stent implantation,[20] as well as adverse events after percutaneous coronary intervention.[21,22] These results demonstrated the impact of stent size on vascular interventional therapy and also showed the importance and necessity of research on device size in mechanical thrombectomy. However, as yet there is no established guideline for stent selection, with the choice being been left entirely to the interventionist. Hence, uncertainties remain about the benefit and risk of endovascular intervention in relation to different sizes of stents. This study addresses the uncertainties regarding stent size for thrombectomy.

MATERIALS AND METHODS

Study Design and Participants

This is a retrospective observational study on the efficacy and safety of endovascular treatment of acute ischemic stroke in real-world practice. We aimed to evaluate the impact of the sizes of stentlike thrombectomy devices on the outcome of treated patients with ischemic stroke due to large-vessel occlusion of the anterior circulation. Patients were those registered in the Endovascular Treatment for Acute Anterior Circulation Ischemic Stroke Registry (ACTUAL) from January 2014, to June 2016. ACTUAL was a multicenter registry program involving 21 comprehensive stroke centers across 10 provinces in China. All patients with acute ischemic stroke who underwent intra-arterial treatment were registered in ACTUAL. The local ethics committees approved the use of retrospective patient data. The procedure protocol was standardized in each center.

Generally, patients would receive endovascular treatment under the following conditions: 1) They were diagnosed with acute ischemic stroke; 2) had large-artery occlusion in the anterior circulation, including the internal carotid artery, middle cerebral artery (MCA M1 or M2), or anterior cerebral artery A1 or A2; 3) had evidence obtained by CTA, MR angiography, or digital subtraction angiography; 4) were 18 years of age or older; 5) had a premorbid modified Rankin Scale score of <2; 6) had a pretreatment National Institutes of Health Stroke Scale score of >5; and 7) could be treated within 6 hours of stroke onset. For selected patients who did not meet these criteria, endovascular treatment was still performed on the basis of a favorable benefit-risk ratio estimate.

To retain the homogeneity of the enrolled patients, we excluded patients treated with intra-arterial thrombolysis alone, or diagnosed with concomitant aneurysm or arteriovenous malformations. For the present study, we selected patients treated with retrievable stents.

Patients

Of 698 patients from ACTUAL, 44 accepted angioplasty therapy and/or stent placement alone, 5 were treated with a thrombus aspiration device alone, 17 were treated with a microguidewire to disrupt clots alone, and 4 were fitted with the Trevo retriever rather than the Solitaire retriever. To maintain consistency of device type, we excluded patients treated with the Trevo retriever. Ultimately, a study cohort of 628 patients treated with the Solitaire stent retriever was enrolled.

Procedures

If they met the criteria for intravenous thrombolytic therapy, patients received intravenous therapy with alteplase within 4.5 hours after the onset of stroke before mechanical treatment. Patients beyond a time window of 4.5 hours or with a contraindication to intravenous thrombolysis were treated directly with mechanical treatment.

Regarding mechanical therapy, patients were treated via femoral access. Under roadmap guidance, a microcatheter was advanced over a guidewire placed through the thrombus, after which the guidewire was removed and DSA was performed to confirm the occlusion. Next, the Solitaire retriever was advanced through the microcatheter across the occluded segment. The stent was unsheathed simultaneous to the microcatheter being pulled back. After 3–5 minutes to allow full expansion, the stent was withdrawn along with the microcatheter. If occlusion persisted, the sequence was repeated (Fig 1).

Choices of anesthesia and rescue therapy were left to the discretion of the interventionist. Stent selection depended on vascular tortuous morphology and sites of occluded vessels in general. A large stent was preferred in a proximal or straight artery, while a small stent was usually chosen for tortuous or distant arteries. The preference of the operator was also important for stent selection.

Outcomes

Successful outcome was defined as achieving a modified TICI (mTICI) score of 2b–3 immediately postprocedure and a functional outcome at 90 days evaluated with the dichotomized modified Rankin Scale score (0–2 versus 3–6). Rates of in-hospital mortality and symptomatic intracerebral hemorrhage within 72 hours after endovascular treatment were recorded. Symptomatic intracerebral hemorrhage was diagnosed according to the Heidelberg Bleeding Classification.[23] Technical complications with the device were also recorded, including vessel perforation, vessel dissection, subarachnoid hemorrhage, stent fracture, and failure to deploy. Outpatient or telephone follow-up was performed to assess the functional outcome by mRS score at each institution.

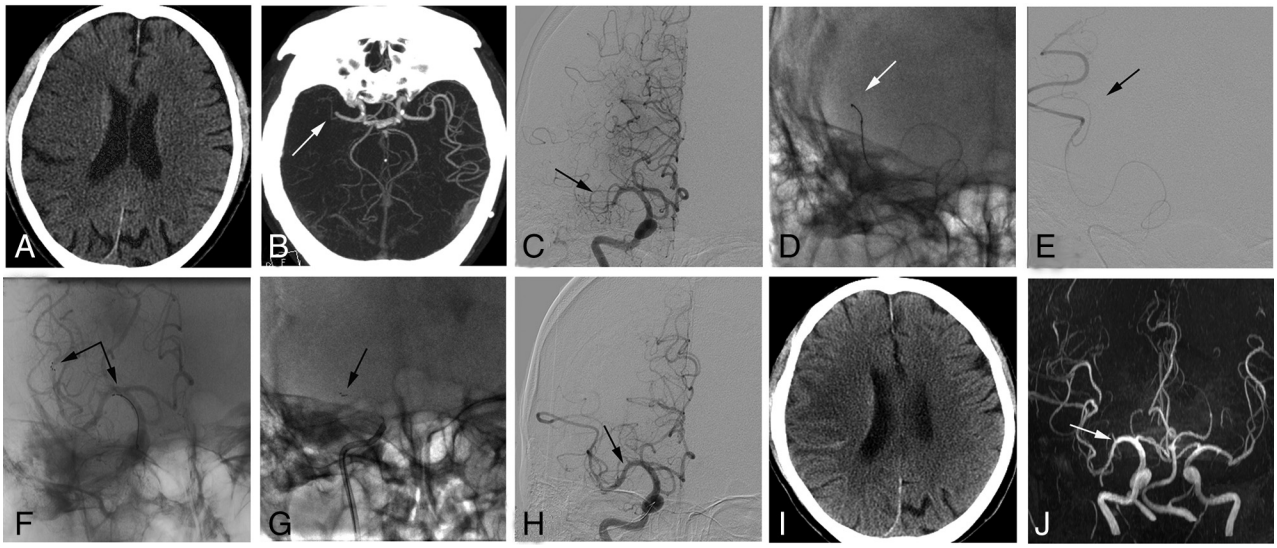

FIG 1. A 72-year-old male patient who presented with weakness of the left limb for 4 hours. *A*, CT on admission does not show a large-territory infarct. *B*, CTA shows right MCA segment occlusion (*arrow*). *C*, DSA confirms occlusion of the right MCA segment (*arrow*). *D*, A microguidewire crosses the occluded artery. *E*, A microcatheter crosses the thrombus to the distal segment through the microguidewire. *F*, Angiogram after deployment of the Solitaire 6 × 30 mm stent retriever shows restoration immediately in the MCA. *Arrows* show proximal and distal markers of the Solitaire device. *G*, The stent retriever is unsheathed with the microcatheter being pulled back simultaneously (*arrow*). *H*, After 3 passes of thrombectomy, the final angiography shows a mTICI flow of grade 2B in the right MCA with favorable perfusion (*arrow*). *I*, CT postprocedure at 24 hours shows no obvious intracerebral hemorrhage. *J*, MRA postprocedure at 7 days shows good recanalization (*arrow*).

Statistical Analysis

Univariate analysis of baseline characteristics was compared between 2 groups according to stent diameter (4-mm Solitaire stent retriever [ST 4] versus 6 mm [ST 6]) with the Student *t* test (normal distribution) or the Mann-Whitney test (non–normal distribution) for continuous variables and a χ^2 test for categoric variables. In primary analysis, baseline variables differed statistically between the 2 groups. To control bias and minimize imbalance of baseline characteristics, we performed a 1:1 matched model based on the propensity score with the nearest neighbor matching algorithm without replacement. We compared patients treated with ST 4 and ST 6 using the Wilcoxon signed rank test and the McNemar test after matching. In addition, matched models of stroke subtype and vessel occlusion site were performed to conduct subgroup analysis. Furthermore, a logistic regression model with the propensity score as a covariate was computed to evaluate the effect of device choice.

The data were analyzed by SPSS Statistics, Version 22.0 (IBM, Armonk, New York), R statistical and computing software (Version 2.153; http://www.r-project.org/), SPSS Statistics–Essentials for R 22 (https://sourceforge.net/projects/ibmspssstat/), and PSMATCHING 3.03 (SPSS Statistics extension bundle document; https://sourceforge.net/projects/psmspss/). Two-sided P values $<$ .05 were statistically significant.

RESULTS

Study Population

Of the 628 enrolled patients, 59.2% (372/628) were treated with 4-mm, and 40.6% (256/628), with 6-mm Solitaire retrievers. There were 58.3% (366/628) men, and the average age was 66 years (range, 56–74 years). The median baseline NIHSS score was 17 (range, 12–21). Delay from symptom onset to door of the emergency department was 125 minutes (60–222 minutes). Delay from stroke onset to groin puncture was 270 minutes (205–350 minutes). When successful recanalization was defined as an mTICI score of 2b or 3, 84.4% (530/628) of the enrolled patients obtained successful recanalization of the targeting artery after endovascular treatment. In these patients who were recanalized (84.4%), the median time from puncture to reperfusion was 102 minutes (75–144 minutes). The proportion of patients with an mRS score of 0–2 at 90 days was 41.7% (262/628). Symptomatic intracerebral hemorrhage occurred in 16.1% (101/628) of patients within 24 hours after endovascular treatment, and death occurred in 24.2% (152/628) of patients. Device-related complications included vessel perforation, 1.3% (8/628); vessel dissection, 1.4% (9/628); subarachnoid hemorrhage, 2.1% (13/628); stent fracture, 0.2% (1/628); and failure to deploy, 0.2% (1/628).

Baseline Characteristics

Univariate analysis of baseline data suggested that no difference existed between the 2 groups except for the following: age (ST 6, 68 years; interquartile range [IQR], 58–75 years; ST 4, 64 years; IQR, 53–73 years; $P = .003$); atrial fibrillation (ST 6, 51.2%; ST 4, 37.2%; $P < .001$); ASPECTS (ST 6, 9; IQR, 7–10; ST 4, 9; IQR, 8–10; $P < .001$); NIHSS (ST 6, 17; IQR, 13–21; ST 4, 16; IQR, 12–20; $P = .029$); atherosclerotic occlusions (ST 6, 37.1%; ST 4, 46%; $P = .027$); cardiac embolism occlusions (ST 6, 57%; ST 4, 47.5%; $P = .02$); ICA occlusions (ST 6, 60.5%; ST 4, 23.1%; $P < .001$); MCA occlusions (ST 6, 39.1%; ST 4, 76.3%; $P < .001$); and favorable collateral flow (American Society of Interventional and Therapeutic Neuroradiology, Society of Interventional Radiology grade), 2–3 (ST 6, 38.8%; ST 4, 57.8%; $P < .001$). Baseline characteristics are summarized in Table 1.

Table 1: Baseline characteristics before and after matching[a]

	Before Matching			After Matching		
	ST 6 (*n* = 256)	ST 4 (*n* = 372)	*P*	ST 6 (*n* = 169)	ST 4 (*n* = 169)	*P*
Age (median) (IQR) (yr)	68 (58–75)	64 (53–73)	.003	67 (56–75)	64 (53–73)	.103
Women (No.) (%)	112 (43.8%)	150 (40.3%)	.392	71 (42%)	64 (37.9%)	.505
AF (No.) (%)	131 (51.2%)	138 (37.2%)	.001	80 (47.3%)	67 (39.6%)	.160
Hypertension (No.) (%)	158 (61.7%)	231 (62.1%)	.924	112 (66.3%)	105 (62.1%)	.500
Diabetes mellitus (No.) (%)	45 (17.6%)	66 (17.7%)	.958	35 (20.7%)	29 (17.2%)	.488
Current smoker (No.) (%)	69 (27%)	92 (24.7%)	.531	49 (29%)	41 (24.3%)	.389
SBP (median) (IQR) (mm Hg)	145 (130–161)	144 (130–160)	.537	148 (129–163)	148 (130–160)	.393
GLU (median) (IQR) (mmol/L)	6.9 (5.83–8.9)	6.7 (5.77–8.38)	.173	6.83 (5.6–9.25)	6.9 (5.81–8.69)	1.000
ASPECTS (median) (IQR)	9 (7–10)	9 (8–10)	.001	9 (7–10)	9 (8–10)	.784
NIHSS (median) (IQR)	17 (13–21)	16 (12–20)	.029	17 (13–21)	17 (13–21)	1.000
IV (No.) (%)	81 (31.6%)	119 (32%)	.927	56 (33.1%)	61 (36.1%)	.657
Time from onset to visit (median) (IQR) (min)	130 (75–230)	120 (60–214)	.058	138 (64–224)	120 (58–214)	.316
Time from onset to puncture (median) (IQR) (min)	280 (210–350)	270 (205–347)	.692	279 (202–345)	270 (195–346)	.589
Stroke subtype						
Atherosclerotic (No.) (%)	95 (37.1%)	171 (46%)	.027	68 (40.2%)	73 (43.2%)	.644
Cardiac embolism (No.) (%)	146 (57%)	177 (47.5%)	.02	90 (53.3%)	85 (50.3%)	.657
Undetermined etiology (No.) (%)	15 (5.9%)	24 (6.5%)	.763	11 (6.5%)	11 (6.5%)	1.000
Artery occlusion site						
ICA (No.) (%)	155 (60.5%)	86 (23.1%)	<.001	78 (46.2%)	76 (45%)	.791
MCA (No.) (%)	100 (39.1%)	284 (76.3%)	<.001	90 (53.3%)	93 (55%)	.607
ACA (No.) (%)	1 (0.4%)	2 (0.5%)	1.000	1 (0.6%)	0	1.000
Collateral flow grade (ASITN/SIR)			<.001			.261
0–1 (No.) (%)	156 (61.2%)	156 (42.2%)		93 (55%)	83 (49.1%)	
2–3 (No.) (%)	99 (38.8%)	214 (57.8%)		76 (45%)	86 (50.9%)	

Note:—ASITN/SIR indicates American Society of Interventional and Therapeutic Neuroradiology, Society of Interventional Radiology; AF, atrial fibrillation; GLU, glucose; ACA, anterior cerebral artery; SBP, systolic blood pressure.

[a] The logistic regression model used for the determination of the propensity score included the following factors: age, sex, atrial fibrillation, hypertension, diabetes, time from onset to groin puncture, NIHSS score, ASPECTS, stroke subtype, site of vessel occlusion, and collateral blood flow.

Table 2: Clinical outcomes before and after matching

	Before Matching			After Matching		
	ST 6 (*n* = 256)	ST 4 (*n* = 372)	*P*	ST 6 (*n* = 169)	ST 4 (*n* = 169)	*P*
mTICI			.013			.532
0–2a (No.) (%)	51 (19.9%)	47 (12.6%)		31 (18.3%)	26 (15.4%)	
2b–3 (No.) (%)	205 (80.1%)	325 (87.4%)		138 (81.7%)	143 (84.6%)	
Workflow time						
Time from puncture to reperfusion (median) (IQR) (min)	111.5 (80–153)	97 (72–140)	.007	108 (75–147)	100 (75–156)	1.000
Time from stent deployment to reperfusion (median) (IQR) (min)	61 (30–94)	44 (20–75)	<.001	58 (30–87)	45 (21–82)	.021
Passes (median) (IQR)	2 (1–3)	2 (1–3)	.001	2 (1–3)	2 (1–3)	.375
≤3 (No.) (%)	210 (82%)	323 (86.8%)	.099	106 (62.7%)	119 (70.4%)	.154
Rescue therapy (No.) (%)	134 (52.3%)	184 (49.5%)	.478	85 (50.3%)	84 (49.7%)	1.000
Complications						
Vessel dissection (No.) (%)	3 (1.2%)	6 (1.6%)	.744	2 (1.2%)	5 (3.0%)	.453
Arterial perforation (No.) (%)	2 (0.8%)	6 (1.6%)	.482	2 (1.2%)	2 (1.2%)	1.000
Stent failure to deploy (No.) (%)	1 (0.4%)	0	.408	1 (0.6%)	0	1.000
Isolated SAH (No.) (%)	4 (1.6%)	9 (2.4%)	.459	3 (1.8%)	1 (0.6%)	.625
Symptomatic ICH (No.) (%)	41 (16%)	60 (16.1%)	.970	22 (13%)	27 (16%)	.511
Asymptomatic ICH (No.) (%)	92 (35.9%)	118 (31.7%)	.271	56 (33.1%)	67 (39.6%)	.248
mRS 90 days			.003			.087
0–2 (No.) (%)	89 (34.8%)	173 (46.5%)		64 (37.9%)	79 (46.7%)	
3–6 (No.) (%)	167 (65.2%)	199 (53.5%)		105 (62.1%)	90 (53.3%)	
In-hospital mortality (No.) (%)	74 (28.9%)	78 (21%)	.022	38 (22.5%)	39 (23.1%)	1.000

Note:—ICH indicates intracerebral hemorrhage.

Outcomes before and after Matching

Table 2 shows the outcomes before and after matching. Primary results of outcomes before matching suggested that the ST 4 group had a higher rate of reperfusion postprocedure ($P = .013$) and a favorable independent outcome at 90 days ($P = .003$), as well as lower in-hospital mortality ($P = .022$). Efficacy with regard to time was also observed in the ST 4 group, including reduced time of the procedure ($P = .007$) and time from stent deployment to reperfusion ($P < .001$), as well as fewer passes of thrombectomy ($P = .001$).

However, primary univariate analysis of baseline characteristics showed an imbalance between the 2 groups (Table 1). To minimize the impact of unbalanced factors, we matched a 1:1 model based on the propensity score in which unbalanced base-

Table 3: Baseline characteristics of atherosclerotic-related occlusion before and after matching[a]

	Before Matching			After Matching		
	ST 6 (*n* = 95)	ST 4 (*n* = 171)	*P*	ST 6 (*n* = 66)	ST 4 (*n* = 66)	*P*
Age (mean) (SD) (yr)	65 (11)	63 (13)	.086	64 (11.4)	62 (11.7)	.249
Women (No.) (%)	28 (29.5%)	47 (27.5%)	.730	16 (24.2%)	16 (24.2%)	1.000
Hypertension (No.) (%)	65 (68.4%)	115 (67.3%)	.845	48 (72.7%)	42 (63.6%)	.307
Diabetes mellitus (No.) (%)	21 (22.1%)	30 (17.5%)	.365	16 (24.2%)	7 (10.6%)	.078
Current smoker (No.) (%)	34 (35.8%)	56 (32.7%)	.615	25 (37.9%)	25 (37.9%)	1.000
SBP (median) (IQR) (mm Hg)	148 (135–163)	147 (130–160)	.351	148 (135–162)	140 (129–160)	.268
GLU (median) (IQR) (mmol/L)	6.54 (5.46–9.00)	6.70 (5.68–8.32)	.812	6.41 (5.2–8.95)	6.62 (5.7–8.34)	.538
ASPECTS (median) (IQR)	9 (7–10)	9 (8–10)	.012	9 (8–10)	10 (8–10)	.233
NIHSS (median) (IQR)	16 (12–20)	16 (11–19)	.154	16 (12–19)	16 (11–19)	.873
IV (No.) (%)	30 (31.6%)	61 (35.7%)	.500	25 (37.9%)	24 (36.4%)	1.000
Time from onset to visit (median) (IQR) (min)	153 (90–232)	120 (60–216)	.032	152 (90–220)	122 (49–242)	.450
Time from onset to treatment (median) (IQR) (min)	293 (225–364)	280 (210–356)	.352	289 (224–351)	275 (206–355)	.532
Artery occlusion site						
ICA (No.) (%)	55 (57.9%)	33 (19.3%)	<.001	32 (48.5%)	29 (43.9%)	.375
MCA (No.) (%)	39 (41.1%)	136 (79.5%)	<.001	33 (50%)	36 (54.5%)	.375
ACA (No.) (%)	1 (1.1%)	2 (1.2%)	.931	1 (1.5%)	1 (1.5%)	1.000
Collateral flow grade (ASITN/SIR)			.023			1.000
0–1 (No.) (%)	50 (52.6%)	65 (38.2%)		32 (48.5%)	31 (47%)	
2–3 (No.) (%)	45 (47.4%)	105 (61.8%)		99 (51.5%)	214 (53%)	

Note:—ASITN/SIR indicates American Society of Interventional and Therapeutic Neuroradiology, Society of Interventional Radiology; GLU, glucose; ACA, anterior cerebral artery; SBP, systolic blood pressure.

[a] The logistic regression model used for the determination of the propensity score included the following factors: age, time from onset symptom to visit, time from onset to groin puncture, NIHSS score, ASPECTS, site of vessel occlusion, and collateral blood flow.

Table 4: Clinical outcomes of atherosclerotic-related occlusion before and after matching

	Before Matching			After Matching		
	ST 6 (*n* = 95)	ST 4 (*n* = 171)	*P*	ST 6 (*n* = 66)	ST 4 (*n* = 66)	*P*
mTICI			.012			.021
0–2a (No.) (%)	20 (21.1%)	17 (9.9%)		16 (24.2%)	6 (9.1%)	
2b–3 (No.) (%)	75 (78.9%)	154 (90.1%)		50 (75.8%)	60 (90.9%)	
Workflow time						
Time from puncture to reperfusion (median) (IQR) (min)	125 (90–180)	103 (75–145)	.001	120 (89–170)	95 (65–136)	.013
Time from stent deployment to reperfusion (median) (IQR) (min)	69 (32–117)	45 (23.5–79)	.001	67 (33–114)	46 (19–68)	.002
Passes (median) (IQR)	2 (1–3)	2 (1–2)	.042	2 (1–3)	1 (1–2)	.025
≤3 (No.) (%)	75 (78.9%)	151 (88.3%)	.041	51 (77.3%)	60 (90.9%)	.064
Rescue therapy (No.) (%)	68 (71.6%)	99 (57.9%)	.027	47 (71.2%)	38 (57.6%)	.164
Complications						
Arterial perforation (No.) (%)	0	4 (2.3%)	.300	0	2 (3.0%)	.500
Vessel dissection (No.) (%)	1 (1.1%)	2 (1.2%)	1.000	0	2 (3.0%)	.500
Stent failure to deploy (No.) (%)	1 (1.1%)	0	.357	1 (1.5%)	0	1.000
Isolated SAH (No.) (%)	0	6 (3.5%)	.092	0	1 (1.5%)	1.000
Symptomatic ICH (No.) (%)	13 (13.7%)	18 (10.5%)	.442	6 (9.1%)	4 (6.1%)	.754
Asymptomatic ICH (No.) (%)	29 (30.5%)	52 (30.4%)	.984	19 (28.8%)	24 (36.4%)	.405
mRS 90 days			.032			.486
0–2 (No.) (%)	37 (38.9%)	90 (52.6%)		28 (42.4%)	33 (50%)	
3–6 (No.) (%)	58 (61.1%)	81 (47.4%)		38 (57.6%)	33 (50%)	
In-hospital mortality (No.) (%)	19 (20%)	29 (17%)	.537	13 (19.7%)	15 (22.7%)	.832

Note:—ICH indicates intracerebral hemorrhage.

line characteristics and other variables influencing outcomes were taken into account (Table 1).

After propensity score matching, baseline variables were equally distributed in the 2 groups (Table 1). Outcomes of efficacy and safety did not differ between the groups, except for a shorter time from stent deployment to reperfusion in the ST 4 group ($P = .021$).

Subgroup Analysis

Primary analysis of baseline data also revealed that selection bias was present in the stroke type and occluded vessels. ST 4 was used more than ST 6 for patients with atherosclerotic disease (46% versus 37.1%, $P = .027$) and MCA occlusion (76.3% versus 39.1%, $P < .001$), while ST 6 was more frequently used than ST 4 in patients with cardiogenic stroke (57% versus 47.5%, $P = .02$) and ICA occlusion (60.5% versus 23.1%, $P < .001$). To explore the effect of device choice on stroke type and vessel occlusion site, we performed subgroup analyses of models of atherosclerotic disease, cardiac embolism, ICA, and MCA (Tables 3 and 4 and Online Tables 1–3).

Results suggested better outcomes for the ST 4 group in stroke classification models. In the atherosclerotic disease model, the ST 4 group demonstrated favorable reperfusion ($P = .012$, Table 4)

and better independent outcomes at 90 days ($P = .032$). In addition, increased time efficacy ($P = .001$), fewer attempts ($P = .042$), and lower frequency of rescue therapy ($P = .027$) were also observed in the ST 4 group. In the cardiac embolism model, lower mortality was reported in the ST 4 group ($P = .035$, On-line Table 1). When patients were stratified into those with ICA and MCA occlusions, the effects of the stent diameter size on functional outcomes did not show differences in the 2 patient groups (On-line Tables 2 and 3).

Propensity score analysis was also performed in these 4 models, the results of which showed a difference after matching in only the atherosclerotic disease model. Matched analysis of the atherosclerotic disease model showed favorable recanalization ($P = .021$) and time efficacy ($P = .013$) and fewer attempts ($P = .025$) in the ST 4 group (Table 4).

Finally, a logistic regression model was conducted to assess potential predictors of mTICI postprocedure, in which the propensity score acted as a covariate. As a result, ST 4 (OR, 3.217; 95% CI, 1.129–9.162; $P = .029$) and the propensity score (OR, 52.84; 95% CI, 3.468–805.018; $P = .004$) were identified as independent predictors of favorable reperfusion for patients with atherosclerotic disease (On-line Tables 4 and 5).

DISCUSSION

To the best of our knowledge, this is the first study to investigate the effect of different diameter sizes of stent retrievers on endovascular treatment. Whereas in the primary analysis, we found that patients in the small-stent group obtained better outcomes of efficacy and safety, after we adjusted the imbalance of baseline data, no difference was apparent. In patients with atherosclerotic disease, propensity score matching analysis suggested that a small stent was an independent predictor of successful reperfusion.

Our study aimed to describe the relationship between stent size and outcomes. Although the outcomes did not differ, the time interval between stent deployment and reperfusion was shorter when a small stent was used. Because this interval represents the validity time of stent action, the result suggests greater deliverability with a smaller stent. Consequently, a small stent may be a better choice, especially for tortuous vessels. Also, as is well-known, any delay in the time before reperfusion can lead to worse outcomes, and the prognosis improves the sooner endovascular reperfusion is achieved.[24-26] Hence, choosing a small stent with excellent deliverability could achieve quicker lesion location and thus avoid wasting time.

Selection bias of stent choice exists in the real world. In this study, a small stent was mainly used for patients with MCA occlusion, while the large stent was used mainly for large-vessel occlusion attributable to ICA occlusion and cardiac embolism. This approach appears reasonable, and results of our primary analysis suggested a difference in outcomes for the cardiac embolism model. However, after adjusting for imbalance and bias, propensity score analysis revealed no difference in the outcomes of both the ST 4 and ST 6 groups in the cardiac embolism and MCA and ICA models. It seems that in these cases, outcomes do not rely on stent size, and both choices may thus be equally feasible.

The most interesting finding was that the small stent was associated with better reperfusion in patients with atherosclerotic disease (On-line Table 4). Large vessels occluded with atherosclerotic lesions, accompanied by in situ stenosis to some extent, result in tortuous and complicated vascular morphology. When one uses thrombectomy via a stent retriever, the vessels tend to be reoccluded after initial reperfusion because of subsequent platelet aggregation.[27] A small stent advanced through a thinner microcatheter is more flexible[15] and can pass through lesions in complex pathways comfortably and rapidly, with better deliverability. The small size is also associated with a low stent-release force,[15] making the release of the stent smoother and safer with greater accuracy. On the other hand, the radial force decreases incrementally with increasing stent diameter,[16,17] so a small stent with a large radial force could maintain vessel wall stability during the procedure. These stent characteristics help to increase time efficiency and recanalization. Another interesting finding was that attempted passes observed with the small stent were fewer. The endovascular procedure unavoidably injures the arterial wall and induces local inflammation and proliferation of smooth-muscle cells, resulting in intimal hyperplasia and restenosis.[19] Loh et al[28] and Angermaier et al[29] reported that >3 attempts would not only be futile with a low additional successful revascularization but also increase the risk of vascular injury and other complications. Hence, a smaller stent with fewer passes could reduce the risk of restenosis and mechanical injury, providing practical clinical value.

It was reported that long stents were an independent predictor of major adverse cardiac events after acute myocardial infarction.[21] Postprocedural new DWI lesions occurred after carotid artery stent placement more often in patients with longer stents.[30] In this study, stent retrievers of 4 mm in diameter included lengths of 15 and 20 mm; stent retrievers of 6 mm in diameter included lengths of 20 and 30 mm. The retrievers with larger diameters are longer. Therefore, it is highly possible that the stent length influences the effects of interventional therapy.

Our study illustrates that both sizes of the Solitaire stent retriever for thrombectomy appear clinically applicable, providing efficacy and safety. The small stent is associated with better recanalization in large-vessel occlusion caused by intracranial atherosclerotic disease. In Asia, atherosclerotic disease is the main cause of acute ischemic stroke, unlike in Western countries.[31] In China, the incidence of atherosclerotic disease accounts for 33%–50% of strokes, higher than in the West (8%–10%).[32,33] Therefore, a small stent may be a better choice for this type of patient. However, these results cannot be generalized until a multicenter randomized controlled trial is designed to test and verify the assumption.

This is the first study to explore the influence of choosing different-sized stents on the effect of endovascular therapy for large-vessel occlusion in China. Our data came from a multicenter study, the samples of which were representative, reflecting real-world clinical practice. We also used a statistical method, namely propensity score matching analysis, which could control bias effectively and minimize the imbalance among groups in observational studies.[34]

Our research also has several limitations. The study was a retrospective, multicenter program, and the data were self-reported by the site investigator, which included selection bias. The registry

did not include CTA or MRA scans at 24 hours after the operation, so the value of mTICI only represented the immediate reperfusion postprocedure. Thrombus burden was not evaluated before treatment based on CTA because not all patients underwent preprocedural CTA examination. Vessel stenoses at 3 months were not assessed in this study due to lack of vascular image results. Some values were also missing from the original reporting data.

CONCLUSIONS

In this analysis of patients with acute large-vessel ischemic stroke, no differences in efficacy and safety were observed in patients treated with Solitaire retrievable stents of differing diameters. Using smaller retrievers was associated with improved recanalization for occlusion of atherosclerotic etiology. With a 4-mm stent, procedure times were shortened and pass attempts were reduced.

APPENDIX

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