Effectiveness and Technical Considerations of Solitaire Platinum 4×40 mm Stent Retriever in Mechanical Thrombectomy with Solumbra Technique

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Objective: The Solitaire Platinum 4×40 mm stent retriever contains radiopaque markers with a long length. We evaluated the effect of Solitaire Platinum 4×40 mm stent retriever in Solumbra technique thrombectomy, and compared it with shorter Solitaire stent retrievers.

Methods: A total of 70 patients who underwent Solumbra technique thrombectomy with equal diameter (4 mm) and different length (40 vs. 20 mm) Solitaire stent retrievers were divided into two groups: the Solitaire Platinum 4×40 mm stent (4×40) group and the Solitaire FR 4×20 mm stent or Solitaire Platinum 4×20 mm stent (4×20) group. The clinical outcomes, Thrombolysis in Cerebral Infarction score, the first pass reperfusion status, and complications were evaluated and compared between the two groups. Multivariate analysis was performed to evaluate the predictive factors for reperfusion and complete reperfusion from the first pass.

Results: Higher first-pass reperfusion and complete reperfusion were achieved in the 4×40 group (68.0% and 48.0%) than in the 4×20 group (46.7% and 33.3%; p=0.004 and 0.007, respectively). In multivariate analysis, radiopaque device and longer stent retriever were correlated with first-pass reperfusion (p=0.014 and 0.008, respectively) and first-pass complete reperfusion (p=0.022 and 0.012, respectively).

Conclusion: Our study demonstrated the usefulness of the Solitaire Platinum 4×40 mm stent retriever, which led to higher first-pass reperfusion and complete reperfusion rates than the Solitaire FR 4×20 mm stent or the Solitaire Platinum 4×20 mm stent, especially in Solumbra technique thrombectomy.

Key Words: Angiography • Reperfusion • Stents • Stroke • Thrombectomy.

INTRODUCTION

Mechanical thrombectomy (MT) is the primary modality for the treatment of acute ischemic stroke (AIS) caused by large artery occlusion (LAO). In addition, the MT technique continues to evolve in terms of its effectiveness and diversity. Initially, the effectiveness of stent retriever techniques was demonstrated via several randomized controlled trials and

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meta-analyses, and the usefulness of contact aspiration technique was shown in several studies. In addition, a number of studies demonstrated that the chance of first-pass reperfusion was increased in Solumbra technique thrombectomy (stent retriever with simultaneous aspiration). Along with the evolution of MT techniques, devices for thrombectomy have also developed. The Solitaire AB stent (ev3; Covidien, Irvine, CA, USA) was the first stent-retriever device used in MT, and was developed further into the Solitaire flow restoration (FR) device and subsequently to the Solitaire 2 revascularization device. Solitaire is a nitinol stent retriever with laser-cut, attached to a push-wire with a closed-cell scaffolding design. However, the Solitaire FR stent retriever had a major disadvantage of poor visualization. The next generation Solitaire stent retriever, the Solitaire Platinum (Medtronic, Dublin, Ireland) has radiopaque platinum markers, which are spaced 10 mm apart. The use of a radiopaque device is known to be associated with first-pass reperfusion. In addition to the characteristics of the stent retriever, the size of the stent may affect the outcomes of MT. The appropriate stent diameter is disputed, and several reports suggested conflictingly, that a stent with a larger or smaller diameter was better. However, in terms of stent length rather than diameter, Haussen et al. reported that longer stent retrievers enhance thrombectomy performance, probably due to the larger device-thrombus interaction area and smaller chances of missing the target site.

For these reasons, the authors used Solitaire Platinum 4×40 mm stent retriever with a Solumbra technique. Therefore, the purpose of our study was to assess the potential benefits of Solitaire Platinum 4×40 mm stent retriever with its radiopacity and long length, and compared it with other Solitaire stent retrievers, especially in patients who underwent MT with Solumbra technique. In addition, the technical considerations involved in Solumbra technique thrombectomy with Solitaire Platinum 4×40 mm stent retriever are also discussed.

**MATERIALS AND METHODS**

**Study population**

This retrospective study with prospectively collected data was approved by the Local Institutional Review Board (IRB No. VCI7RESI0048) of each participating center. The data of patients with LAO who underwent Solumbra technique thrombectomies with a Solitaire stent retriever of equal diameter (4 mm) between January 2018 and July 2019 were obtained from each institution’s stroke database and evaluated. All of the procedures were performed by two experienced neuro-interventionalists at two centers. A total of 70 patients were identified for enrollment. These patients were dichotomized into: 1) a 4×40 group using 4×40 mm Solitaire stent retrievers (Solitaire Platinum 4×40 mm stent retriever) and 2) a 4×20 group using 4×20 mm Solitaire stent retrievers (Solitaire FR 4×20 mm or Solitaire Platinum 4×20 mm stent retrievers). Prior to thrombectomy, intravenous tissue plasminogen activator (IV t-PA, alteplase) was administered to patients within 4.5 hours after stroke onset at a maximum dose of 0.9 mg/kg in accordance with the European Cooperative Acute Stroke Study (ECASS) III trial. The inclusion criteria were as follows: 1) occlusion of the distal intracranial carotid artery (ICA), middle cerebral artery (MCA, M1, or M2), or posterior circulation (vertebral artery, or basilar artery) established by computed tomography angiography (CTA); 2) neurologic deficits; and 3) Solumbra technique thrombectomy with 4 mm Solitaire stent retriever. The exclusion criteria were: 1) the detection of hemorrhage on the initial CT scan; 2) presence of a large ischemic core with an Alberta Stroke Program Early CT Score (ASPECTS) ≤6; 3) MT with a simple stent retriever or the contact aspiration technique, and 4) Solumbra technique thrombectomy with a stent retriever other than a 4 mm Solitaire stent retriever, such as a Solitaire FR 6×30 mm, a Solitaire Platinum 6x40 mm, a Trevo XP Provue (Stryker Neurovascular, Fremont, CA, USA), Eric (MicroVention Terumo, Tustin, CA, USA), or Revive (Codman Neurovascular, San Jose, CA, USA) devices. All patients underwent CT immediately after the intervention to evaluate hemorrhage. In addition, vessel status and hemorrhage were evaluated by CTA 24 hours after MT. Hemorrhagic transformation of the infarct and vessel status was confirmed by magnetic resonance angiography (MRA) with susceptibility-weighted imaging on day 7 after MT.

**Device selection and Solumbra technique**

Solumbra technique thrombectomy with a 4 mm Solitaire stent retriever was performed in patients with AIS caused by LAO. All of the MT procedures were performed using the Solumbra technique, entailing thrombus retraction with a stent
retriever, such as the Solitaire FR 4×20 mm (ev3; Covidien) or the Solitaire Platinum 4×20 mm or 4×40 mm (Medtronic) and simultaneous aspiration with a 5 Fr SOFIA (Sofia 5; MicroVention-Terumo, Tustin, CA, USA) or a 6 Fr AXS Catalyst 6 (CAT6; Stryker Neurovascular, Mountain View, CA, USA). In almost cases, an 8 Fr balloon-guiding catheter (BGC) (FlowGate2 [FG2]; Stryker Neurovascular, Fremont) was applied. An illustration of MT with the Solumbra technique is shown in (Fig. 1). Under consciousness sedation, an 8 Fr FG2 BGC was placed in the proximal ICA. A microcatheter (Excel-sior XT-18; Stryker Neurovascular, Fremont) with a microwire was advanced as distally as possible from the occlusion site, and the aspiration catheter was approached close to the occlusion site, followed by deployment of the stent retriever in the

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**Fig. 1.** Solumbra technique thrombectomy with a Solitaire platinum 4×40 mm stent retriever. A: Initial angiography revealed left M1 occlusion. B: A non-subtracted image showed a deployed Solitaire platinum 4×40 mm stent retriever (black arrow: the proximal end of the working device; black dotted arrow: the distal end of the working device) and a 6 French Catalyst (CAT6) aspiration catheter (white arrow: distal tip of the aspiration catheter). C: Using a weak pull of the Solitaire platinum 4×40 mm stent retriever, the distal tip of the CAT6 aspiration catheter is moved to the proximal end of the working length of the stent retriever. To contact the thrombus, the distal tip of the CAT6 should be placed just proximal to the thrombus (black arrow: the proximal end of the working length of the stent; white arrow: distal tip of the aspiration catheter). D: After retrieval of the Solitaire platinum 4×40 mm and CAT6 with simultaneous aspiration, angiography revealed the complete reperfusion status of the left M1.
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distal portion of the occlusion site. After the 3 to 5 minutes of waiting after stent deployment to promote stent clot integra-

32) tion, the aspiration catheter with suction and the stent re-

triever were slowly removed as a single unit. At this time, a
dual aspiration technique was used at the BGC with manual aspiration15.

Multivariable factors and outcome and complications

Multivariable factors including patient sex, age, risk factors,
prior stroke or transient ischemic attack (TIA), history of pre-
vious anti-platelet or anti-coagulant use, ASPECTS score, ap-
plication of IV t-PA, stroke etiology by Trial of ORG 10172 in
Acute Stroke Treatment (TOAST) classification1, site of the ar-
terial occlusion, and procedure time (time from groin puncture
to reperfusion) were reviewed. All patients underwent clinical
assessment using the National Institutes of Health Stroke Scale
(NIHSS) (range, 0–42; with higher scores indicating more se-
vere neurologic deficit) and modified Rankin Scale (mRS)
scores at 3 months (a favorable clinical outcome was defined as
mRS ≤2). The radiologic results were evaluated according to
the thrombolysis in cerebral infarction (TICI) grading system,
successful recanalization (TICI grade of 2b or 3), first-pass re-
perfusion (modified TICI, mTICI 2b or 3 with the first pass),
and first-pass complete reperfusion (mTICI 3 with the first
pass). Various complications, such as post-thrombectomy hem-
orrhage at 24 hours, symptom-related hemorrhage at 24 hours,
vessel perforation, arterial dissection, distal emboli, hemor-
rhagic transformation of the infarct on MRA 7 days after MT,
and 3-month mortality were reviewed. Post-thrombectomy
hemorrhage at 24 hours was defined as the occurrence of intra-
cerebral hemorrhage or subarachnoid hemorrhage on a CTA
scan obtained 24 hours after the procedure. All multimodal
factors and clinical data were analyzed by all authors.

Statistical analyses

All data were analyzed using Stata Statistical Software, re-
lease 15 (Stata, College Station, TX, USA). Between-group
comparisons were calculated using Student’s t-test/Mann-
Whitney U test or chi-squared test/Fisher’s exact test. Multi-
variate logistic regression analyses were performed for vari-
ables with <0.2 level of significance in univariate analysis.
Two-tailed p-value of ≤0.05 were considered to indicate sig-
nificant difference.

Table 1. Baseline characteristics of patients in Solumbra technique thrombectomy, according to the length of Solitaire stent retriever

<table>
<thead>
<tr>
<th>Variable</th>
<th>4×40 (25 patients)</th>
<th>4×20 (45 patients)</th>
<th>p-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dermographic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex, male</td>
<td>14 (56.0)</td>
<td>27 (60.0)</td>
<td>0.601</td>
</tr>
<tr>
<td>Age (years)</td>
<td>72.0±12.7</td>
<td>69.0±13.1</td>
<td>0.449</td>
</tr>
<tr>
<td>HTN</td>
<td>15 (60.0)</td>
<td>25 (55.6)</td>
<td>0.552</td>
</tr>
<tr>
<td>DM</td>
<td>5 (20.0)</td>
<td>10 (22.2)</td>
<td>0.680</td>
</tr>
<tr>
<td>Af</td>
<td>8 (32.0)</td>
<td>12 (26.7)</td>
<td>0.346</td>
</tr>
<tr>
<td>CAD</td>
<td>5 (20.0)</td>
<td>9 (20.0)</td>
<td>0.889</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>7 (28.0)</td>
<td>16 (35.6)</td>
<td>0.465</td>
</tr>
<tr>
<td>Smoking</td>
<td>5 (20.0)</td>
<td>13 (28.9)</td>
<td>0.263</td>
</tr>
<tr>
<td>Prior stroke or TIA</td>
<td>4 (16.0)</td>
<td>7 (15.6)</td>
<td>0.793</td>
</tr>
<tr>
<td>Previous anti-platelet use</td>
<td>6 (24.0)</td>
<td>9 (20.0)</td>
<td>0.571</td>
</tr>
<tr>
<td>Previous anti-coagulant use</td>
<td>3 (12.0)</td>
<td>4 (8.9)</td>
<td>0.466</td>
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<tr>
<td>Occlusions in the left hemisphere</td>
<td>14 (56.0)</td>
<td>24 (53.3)</td>
<td>0.702</td>
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<td>IV t-PA</td>
<td>8 (32.0)</td>
<td>18 (40.0)</td>
<td>0.109</td>
</tr>
<tr>
<td>Initial NIHSS</td>
<td>10 (2–18)</td>
<td>8 (2–18)</td>
<td>0.127</td>
</tr>
<tr>
<td>ASPECTS score</td>
<td>9 (6–10)</td>
<td>9 (6–10)</td>
<td>0.924</td>
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<td>Etiology of stroke</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardio-embolic</td>
<td>10 (40.0)</td>
<td>22 (48.9)</td>
<td>0.297</td>
</tr>
<tr>
<td>Atherosclerosis</td>
<td>7 (28.0)</td>
<td>10 (22.2)</td>
<td>0.382</td>
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<td>Dissection</td>
<td>1 (4.0)</td>
<td>1 (2.2)</td>
<td>0.307</td>
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<tr>
<td>Other or undetermined</td>
<td>7 (28.0)</td>
<td>12 (26.7)</td>
<td>0.693</td>
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<tr>
<td>Site of arterial occlusion</td>
<td></td>
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<tr>
<td>MCA</td>
<td>13 (52.0)</td>
<td>27 (60.0)</td>
<td>0.419</td>
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<tr>
<td>Distal ICA</td>
<td>10 (40.0)</td>
<td>13 (28.9)</td>
<td>0.310</td>
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<tr>
<td>Posterior circulation</td>
<td>2 (8.0)</td>
<td>5 (11.1)</td>
<td>0.507</td>
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<tr>
<td>Procedure detail</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Procedure time (minutes)</td>
<td>34 (14–82)</td>
<td>46 (15–91)</td>
<td>0.247</td>
</tr>
<tr>
<td>Use of BGC</td>
<td>24 (96.0)</td>
<td>42 (93.3)</td>
<td>0.776</td>
</tr>
<tr>
<td>Aspiration catheter, CAT6: Sofia5</td>
<td>21 : 4</td>
<td>33 : 12</td>
<td>0.186</td>
</tr>
<tr>
<td>Radiopaque stent retriever</td>
<td>25 (100.0)</td>
<td>20 (44.4)</td>
<td>0.001†</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation, median (interquartile range), or number (%). *p-values are calculated by chi-square test or Fisher’s exact test and Mann-Whitney U test or Student’s t-test.

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RESULTS

Baseline characteristics and procedure detail

Twenty-five patients (14 males, 56.0%) were treated via Solumbra technique thrombectomy with 4×40 mm Solitaire Platinum stent retriever (4×40 group), and 45 (27 males, 60.0%) underwent Solumbra technique thrombectomies with 4×20 mm Solitaire stent retrievers (4×20 group). The mean age of the patients in the 4×40 group was 72 years (standard deviation [SD], 12.7) and that of the 4×20 group was 69 years (SD, 13.1). There were no significant differences in multiple risk factors such as hypertension, diabetes mellitus, atrial fibrillation, coronary artery disease, dyslipidemia, smoking, history of prior stroke or TIA, history of anti-platelet use, previous anti-coagulation use, the proportion of left hemisphere strokes, and the rate of IV t-PA application, between 4×40 and 4×20 groups. The median initial NIHSS value, and ASPECTS scores were 10 and 9, respectively, in the 4×40 group and 8 and 9, respectively, in the 4×20 group, without significant difference. There was no significant difference in stroke etiology between the two groups. The site of arterial occlusion in each group was as follows (4×40 group : 4×20 group) : MCA, 13 : 27; distal ICA, 10 : 13; and posterior circulation, 2 : 5. In terms of procedure, there were no statistically significant differences in procedure time and the rate of BGC application between the two groups (p=0.247 and 0.776, respectively). The distribution ratio of the two-aspiration catheters (CAT6 : Sofia5) was 21 : 4 in the 4×40 group, and 33 : 12 in the 4×20 group (p=0.186). Radiopaque devices were significantly more common in the 4×40 group (p=0.001), suggesting that 25 non-radiopaque Solitaire FR 4×20 mm stents were included in the 4×20 group (Table 1).

Outcomes and complications

No statistically significant difference was found in the rate of successful recanalization, between the two groups (4×40 group : 4×20 group, 96.0% : 95.6%; p=0.842). However, the

<table>
<thead>
<tr>
<th>Table 2. Outcomes and complications of patients in Solumbra technique thrombectomy, according to the length of Solitaire stent retriever</th>
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<tbody>
<tr>
<td><strong>Outcome</strong></td>
</tr>
<tr>
<td>Successful recanalization</td>
</tr>
<tr>
<td>First-pass reperfusion</td>
</tr>
<tr>
<td>First-pass complete reperfusion</td>
</tr>
<tr>
<td>Favorable 3 months mRS</td>
</tr>
</tbody>
</table>

| Complication | **4×40 (25 patients)** | **4×20 (45 patients)** | **p-value** |
|---|
| Post thrombectomy hemorrhage | 2 (8.0) | 4 (8.9) | 0.627 |
| Symptomatic hemorrhage | 1 (4.0) | 2 (4.4) | 0.793 |
| Vessel perforation | 0 (0.0) | 0 (0.0) | 1.000 |
| Arterial dissection | 0 (0.0) | 0 (0.0) | 1.000 |
| Distal emboli | 2 (8.0) | 4 (8.9) | 0.679 |
| Hemorrhagic transformation of infarct | 4 (16.0) | 9 (20.0) | 0.391 |
| 3 months mortality | 2 (8.0) | 4 (8.9) | 0.497 |

Values are presented as number (%). *p-values are calculated by chi-square test or Fisher’s exact test and Mann-Whitney U test or Student’s t-test. †Statistically significant. 4×40 : Solitaire Platinum 4×40 mm stent retriever, 4×20 : Solitaire 2 FR 4×20 mm stent retriever + Solitaire Platinum 4×20 mm stent retriever, Successful recanalization : thrombolysis in cerebral infarction 2b or 3, mRS : modified Rankin Scale, Favorable mRS : 90 days mRS ≤2, First-pass reperfusion : modified thrombolysis in cerebral infarction 2b or 3 with the first pass, First-pass complete reperfusion : modified thrombolysis in cerebral infarction 3 with the first pass

<table>
<thead>
<tr>
<th>Table 3. Multivariable regression for first-pass reperfusion and first-pass TICI3 reperfusion</th>
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<tbody>
<tr>
<td><strong>Outcome</strong></td>
</tr>
<tr>
<td>First-pass reperfusion</td>
</tr>
<tr>
<td>Initial NIHSS</td>
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<tr>
<td>Radiopaque stent retriever</td>
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<tr>
<td>Long stent retriever (Platinum 4×40 mm)</td>
</tr>
<tr>
<td>First-pass complete reperfusion</td>
</tr>
<tr>
<td>Initial NIHSS</td>
</tr>
<tr>
<td>IV t-PA</td>
</tr>
<tr>
<td>CAT6 Aspiration catheter</td>
</tr>
<tr>
<td>Radiopaque stent retriever</td>
</tr>
<tr>
<td>Long stent retriever (Platinum 4×40 mm)</td>
</tr>
</tbody>
</table>

*p-values are calculated by multivariate logistic regression analysis. †Statistically significant. TICI : thrombolysis in cerebral infarction, OR : odds ratio, CI : confidence interval, First-pass reperfusion : modified TICI 2b or 3 with the first pass, NIHSS : National Institutes of Health Stroke Scale, IV t-PA : intravenous tissue-plasminogen activator, CAT6 : 6 French Catalyst, First-pass complete reperfusion : modified TICI 3 with the first pass
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The proportion of first-pass reperusions and first-pass complete reperusions was significantly higher in the 4×40 group, compared to the 4×20 group (68.0% vs. 46.7% and 48.0% vs. 33.3%, p=0.004 and 0.007, respectively). There were no significant differences in complications, between the two groups (Table 2).

**Predictors of reperfusion and full reperfusion with first pass**

In multivariate logistic regression analysis, the use of radiopaque Solitaire stent retriever (odds ratio [OR], 2.08; 95% confidence interval [CI], 1.22–3.84; p=0.014), and longer Solitaire Platinum 4×40 mm stent retrievers (OR, 2.81; 95% CI, 1.34–4.10; p=0.008) were correlated with first-pass reperfusion. In addition, multivariate logistic regression analysis for first-pass complete reperfusion indicated that the use of radiopaque devices (OR, 1.88; 95% CI, 1.20–3.12; p=0.022) and longer Solitaire Platinum 4×40 mm stents (OR, 2.12; 95% CI, 1.48–3.76; p=0.012) were independent predictors (Table 3).

**DISCUSSION**

Currently, the development of various thrombectomy techniques has enhanced the clinical and radiologic outcomes of patients with LAO^6,7,19^). Recent advances in MT pursue the first-pass effect (first-pass reperfusion or first-pass complete reperfusion), beyond simple successful recanalization^20^). The importance of the first-pass effect has been reported in various studies, where it was associated with a significantly higher chance of favorable clinical outcomes with the retrieval of the entire thrombus as a single mass on the first attempt^23,24,34^). Fewer stent passages reduced the risk of procedure-related complications, such as parenchymal hematoma and other vessel damage^3^). Therefore, the utility of the Solumbra technique contributes to reperfusion or complete reperfusion from the first pass^14,21,25^). Based on these studies, the authors used Solumbra technique for MT in most cases. In addition to thrombectomy techniques, the device may be considered a factor affecting the outcomes of MT. There are several controversies related to the selective advantages of stent retrievers with an appropriate diameter. However, recent studies have suggested that stent retrievers with longer lengths and radiopaque characteristics yield better outcomes^12,13,18,31^). In our study, longer and radiopaque stent retrievers were found to increase the first-pass effect. The reperfusion and complete reperfusion rates with first pass were significantly higher in the group with 4×40 mm long stent retrievers than in those with 4×20 mm.

![Fig. 2. Representative case of solumbra technique thrombectomy with a Solitaire platinum 4×40 mm stent retriever. A: Roadmap image shows the location of the devices, before their retrieval (black arrow: the proximal end of the working length of the stent; black dotted arrow: mid-portion marker of the stent; white arrow: distal tip of the aspiration catheter). B: By a weak pull of the Solitaire platinum 4×40 mm stent retriever, the distal tip of aspiration catheter (white arrow) should be placed just proximal to the thrombus and between the two markers (black and black dotted arrows) of the Solitaire platinum 4×40 mm stent. C: After retrieval of the Solumbra technique devices, the thrombus was captured by the aspiration catheter and stent retriever. D: Image of the solumbra technique system after retrieval, in which the tip of the aspiration catheter was located distally beyond the mid-portion marker of the stent retriever.](image-url)
short stent retrievers. Furthermore, the multivariate analysis in our study showed that stent retrievers with longer length and radiopacity improved the first-pass effect in MT with Solu-
bra technique. These findings revealed the effectiveness of Solitaire Platinum 4×40 mm stent retrievers compared to oth-
er 4 mm Solitaire stent retrievers, especially in MT with the Solu-
bra technique.

Longer stent retrievers have theoretical advantages because of the larger interaction area between the device and the thrombus, with lower chances of missing the target site than their shorter counterparts. In addition, the radiopaque characteristics of the device allow the interventionalists to view the entire stent, and confirm its optimal location and adequate vessel-wall apposition of the stent. Based on these characteristics, the usefulness of the Solitaire Platinum 4×40 mm stent retriever and its technical considerations during the Solumbra technique thrombectomy was shown in (Fig. 2). Under road-
map guidance, the microcatheter was navigated distal to the occlusion site, and the Solitaire Platinum 4×40 mm stent re-
treiver was deployed to cover the distal and proximal ends of the occlusion. The aspiration catheter was navigated close to the clot, and the microcatheter was removed to increase the aspiration flow (Fig. 2A)\(^\text{26}\). Next, the stent retriever was gently pulled with weak force and the distal tip of the aspiration catheter was moved to the distal lesion as close to the occlusion site as possible to contact the thrombus. At this time, the distal tip of the aspiration catheter should be placed just prox-
imal to the site of the thrombus, between the two markers (mid-portion of the marker and the proximal end of the work-
ing length marker) of the Solitaire platinum 4×40 mm stent retriever (Fig. 2B). After waiting several minutes to enable stent-clot integration, retrieval of the whole Solumbra system was performed for clot retrieval, with simultaneous continu-
ous suction at the aspiration catheter and dual aspiration through the BGC. When the distal tip of the aspiration catheter was adequately positioned between the mid-portion marker and the proximal end of the working length marker, the thrombus could be re-
trieved as a single mass (Fig. 2C). However, frequent failures associated with thrombus retrieval occurred when the distal tip of the aspiration catheter was located more distally, beyond the mid-portion of the stent, and re-captured more than half of the stent retriever (Fig. 2D).

In the thrombectomy procedures using the Solumbra tech-
nique, the aspiration catheter should re-capture less than half or one-third of the stent retriever to ensure an adequate stent retriever capture area to fully integrate with the clot. In addition, during the Solumbra system retrieval, the aspiration catheter is moved further distally depending on its tension, and the stent retriever is captured further by the aspiration catheter. In addition to the advantage of a long stent, the radi-
opacity of the Solitaire Platinum 4×40 mm stent retriever with its markers 10 mm apart facilitate the correct positioning of the aspiration catheter and adjust the adequate capture range of the stent retrievers, especially during Solumbra technique thrombectomy. Therefore, a long and radiopaque stent re-
treiver such as the Solitaire Platinum 4×40 mm stent retriever, is preferred for MT by Solumbra technique.

The major limitations of this study were its relatively small sample size, and the retrospective non-blinded format. Since thrombectomy in the 4×20 mm Solitaire stent retriever group was performed earlier than in the 4×40 mm Solitaire Plati-
num stent retriever group, it may be assumed that the learning curve affected the outcome. However, all thrombectomy pro-
cedures in this study were performed by neuro-intervention-
alists with several years of experience. Therefore, the learning curve would not have a significant influence on the outcome. Furthermore, the baseline characteristics in the two groups were well balanced and there were no statistically significant differences. The disadvantages of longer stent retrievers in-
clude vessel damage or larger interface area with the vessel and consequently more friction. However, in our study, there were no significant differences in hemorrhage and dissection be-
tween the two groups. In addition, our study did not include the data associated with Solitaire FR 4×40 mm retriever, which is a non-radiopaque and long Solitaire stent retriever. Other potential unmeasured confounding variables were not controlled for, although every effort was made to adjust for the possibility of spurious results.

**CONCLUSION**

In this study, the use of the Solitaire Platinum 4×40 mm stent retriever for Solumbra technique thrombectomy in pa-
ients with LAO was highly effective, without increased peri-
procedural complications, compared with prior versions of the Solitaire FR 4×20 mm stent and the Solitaire Platinum 4×
20 mm stent. The radiopacity and long length of the Solitaire Platinum 4×40 mm stent retriever may contribute to more achievement of first-pass reperfusion and first-pass complete reperfusion, especially with Solumbra technique thrombectomy. Future prospective multicenter and in vitro studies are needed to corroborate our findings.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

INFORMED CONSENT

This type of study does not require informed consent.

AUTHOR CONTRIBUTIONS

Conceptualization: HJ Y, JHS
Data curation: HJY
Formal analysis: HJY
Methodology: HJY
Project administration: HJY, JHS
Visualization: HJY
Writing - original draft: HJY
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