

# Comparison of Internal Shunts during Carotid Endarterectomy under Routine Shunting Policy

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## Abstract

We compared patients who underwent carotid endarterectomy (CEA) using two-way and three-way internal shunts and discussed which shunt was more appropriate and effective for surgeons. Eighty-two patients (mean 69.5 ± 6.1 years old, mean degrees of stenosis 79.6 ± 10.4%) who had undergone CEA by our routine shunting policy were examined concerning the difference of Sundt and Pruitt-Inahara (P-I) shunts in clinical use. Carotid clamping time for the P-I shunt was over 2 minutes longer than that by Sundt in either split or conventional continuous arteriotomy ( $p < 0.001$ ). The proportions of cases with multiple trials of either arteriotomy or insertion of a shunt tube, cases detected more than one high-intensity spot on diffusion-weighted images of magnetic resonance imaging after CEA, and cases detected postoperative intimal flaps detected by multi-detector CT angiography showed no significant differences between the two shunt groups. The two-way Sundt shunt was quicker than the three-way P-I shunt in placement with no remarkable problems. Split arteriotomy was not useful in shortening the placement time for either Sundt or P-I shunt tubes, compared with continuous arteriotomy. A simple two-way shunt with easy handling like the Sundt shunt would be also appropriate to choose in selective shunting under the unfamiliarity of treating shunts.

Key words: carotid endarterectomy, internal shunt, two-way shunt, three-way shunt, routine shunting

## Introduction

In carotid endarterectomy (CEA) for carotid stenosis, shunt placement minimizes interrupted blood flow and ensures sufficient cerebral perfusion during carotid cross clamping, preventing ischemic events without requiring strict intraoperative neurologic monitoring. Some surgeons therefore advocate routine shunting protocol during CEA, though potential disadvantages such as plaque or air emboli, intimal damage, and arterial dissection during the procedure have been identified as concerns. The issue of whether routine or selective shunting is superior in CEA is still not conclusive, with insufficient evidence from randomized controlled trials.<sup>1)</sup>

Shunt tubes are generally divided into two categories: two-way and three-way types. The former includes Sundt,<sup>2)</sup> Javid,<sup>3)</sup> and Argyle<sup>4)</sup> shunts, and the latter Pruitt-Inahara,<sup>5)</sup> Brener,<sup>6)</sup> and Furui<sup>7)</sup> shunts. Most surgeons tend to have a favorite shunt and prefer not to use a different type, especially with selective

shunting protocol providing fewer opportunities of handling shunts than routine shunting.

We have been using a routine shunting policy for years and had the occasion to change from a two-way shunt to a three-way shunt because of supply disruption to our country in 2008. Since we felt some differences in clinical use between these two shunts and there are few reports comparing two-way and three-way shunts, we set out to compare their performance and discuss which shunt is more appropriate and effective for surgeons.

## Materials and Methods

### I. Patient population

We examined a total of 88 consecutive CEAs with primary closure with internal shunt for carotid stenoses performed from June 2002 to December 2012. Among them, 82 patients (mean 69.5 ± 6.1 years old [y/o], mean degree of stenosis 79.6 ± 10.4%) in whom the entire procedures of insertion of an internal shunt was captured by operative video recordings were finally chosen. The patients' data

**Table 1 Clinical characteristics of cases on whom the different shunts were used**

	Total	Sundt	Pruitt-Inahara	p value*
Number of treatments	82	48	34	-
Age (years old)	69.5 ± 6.1	69.6 ± 6.9	69.4 ± 4.8	0.88
Male sex (%)	67 (81.7)	37 (77.1)	30 (88.2)	0.32
Symptomatic case (%)	63 (76.8)	37 (77.1)	26 (76.5)	0.84
Degree of carotid stenosis %	79.6 ± 10.4	80.6 ± 10.2	78.2 ± 10.7	0.31
Diameter of IC mm <sup>†</sup>	4.1 ± 0.5	4.0 ± 0.5	4.2 ± 0.5	0.08
Diameter of CC mm <sup>†</sup>	6.1 ± 0.6	6.0 ± 0.7	6.2 ± 0.4	0.11

\*Student's *t*-test was performed except for "male sex" and "symptomatic case" with chi-square test. <sup>†</sup>measured on multi-detector CT angiography. CC: common carotid, IC: internal carotid.

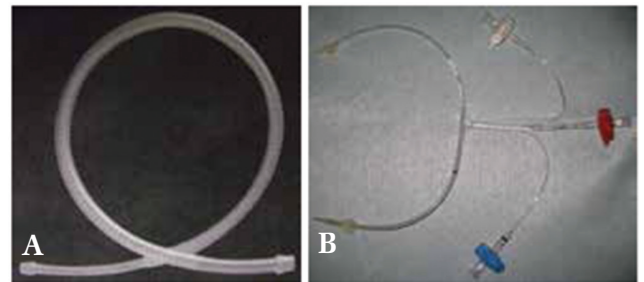
are summarized in Table 1.

The ethical guidelines for clinical studies issued by the Japanese Health Labor and Welfare Ministry (2008) were strictly observed, however, informed patient consent was not required for this retrospective study.

## II. Operation, internal carotid shunts, and examinations

Surgical indications for the treatment of carotid stenosis adhered to the criteria of the North American Symptomatic Carotid Endarterectomy Trial (NASCET)<sup>8)</sup> and the Asymptomatic Carotid Atherosclerosis Study (ACAS).<sup>9)</sup>

CEA was performed in a standard fashion with primary closure using an internal shunt by the same procedures by both participating surgeons, Yamada K. and Katano H.<sup>10)</sup> Sundt shunts (NL850-5070, Integra Neurosciences, Plainsboro, New Jersey, USA) were used until March 2008, when supplies were disrupted, after which Pruitt-Inahara (P-I, 9 Fr, LeMaitre Vascular Inc., Burlington, Massachusetts, USA) shunts were used instead. The Sundt shunt is a simple two-way shunt constructed with silicone elastomer and stainless steel spring reinforcement to minimize kinking and occlusion of the cannula lumen (Fig. 1A). The shunts used were 30 cm in length to allow formation of an external loop. The ends of the shunts have cone-shaped bulbs to facilitate fixation of the shunt in the vessel. The precise maneuver of shunting has been described previously.<sup>11)</sup> Briefly, the inside of the shunt is filled with saline and is thereby confirmed to be free of air. After closing the internal carotid (IC) and common carotid (CC) arteries with vascular clamps, the IC end of the Sundt shunt was inserted and fixed by tightening a vascular loop around the bulb at the end of the shunt tube. Then the CC tube end was inserted, maintaining backbleeding from the IC, followed by fixing with a tourniquet. Continuous flow



**Fig. 1 A: Sundt shunt.** This shunt is a simple two-way shunt constructed of silicone elastomer with stainless steel spring reinforcement to minimize kinking and occlusion of the cannula lumen. It is 30 cm long to allow the formation of an external loop. The ends of the shunts have cone-shaped bulbs to facilitate fixation of the shunt in the vessel. This photo is cited and modified from Sundt Carotid Sellsheet.pdf (<http://www.integralife.com/>). **B: Pruitt-Inahara shunt.** This 31-cm-long shunt is a three-way (T-shaped) shunt with a balloon at both the internal and common carotid tube ends. The T-port can be used for infusion and flushing and removal of air and embolic particles, and for checking and monitoring ongoing blood flow or pressure.

through the shunt was confirmed with a Doppler flow meter.

The P-I shunt is 31 cm long, and is a three-way (T-shaped) shunt with a balloon at both the IC and CC tube ends (Fig. 1B).<sup>5)</sup> A T-port can be used for infusion and flushing and removal of air and embolic particles, and for checking and monitoring ongoing blood flow or pressure. After filling the shunt tube with saline, the IC end of the shunt was inserted and the balloon inflated with saline followed by gentle fixation with a vascular loop. Reverse flow from the IC was confirmed and the air was removed through the T-port by syringe and then the IC side of the tube was transiently clamped. The CC end was

inserted, the balloon was inflated, and the tourniquet was gently tightened. Anterograde flow from CC was checked and any air was again removed through the T-port; then the clamp on the IC end was released. Continuous flow from the CC to IC was confirmed by Doppler flow meter. The carotid clamping time was defined as the time between clamping CC and confirmation of blood flow from the CC to the IC through a shunt.

In 13 cases with high degrees of carotid stenosis (mean  $82.4 \pm 10.8\%$ ), we performed split arteriotomies in expectation of prompt insertion of shunts. Short arteriotomies are made separately on IC and CC, in which the tubes can then be placed, skipping the site of the most severe stenosis where one may stray from the true lumen of the IC. Following insertion and fixation of the shunt tube, the two arteriotomies are connected for subsequent plaque resection.

Regional cerebral oxygen saturation (rSO<sub>2</sub>) was measured with near-infrared spectroscopy (NIRS, NIRO 300, Hamamatsu Photonics, Hamamatsu)<sup>12)</sup> during CEA. The transcranial sensors were set over the forehead bilaterally according to the manufacturer's instructions, and rSO<sub>2</sub> was recorded every 30 seconds.

MR imaging including diffusion-weighted (DW) images was performed the day after CEA to detect newly developed ischemia as a high-intensity spot (HIS) with a 1.5-T imaging system (Gyrosan Intera, Philips, Amsterdam, the Netherlands) using a single-shot diffusion echo planar imaging (EPI) sequence with the following parameters: TR 2917 ms, TE 83 ms, flip angle 90°, 5.0-mm section thickness, field-of-view 23.0 cm, number of excitations 1, b value = 0 and 1,000 s/mm<sup>2</sup>.<sup>13)</sup>

Multi-detector CT angiography (MDCTA) was performed with a 16-row system (IDT-16, Philips)<sup>14)</sup> to check diameters of IC/CC and postoperative intimal flaps on maximum intensity projection (MIP) and original axial images.

### III. Statistical analysis

All statistical evaluations were performed with Statview version 5.0 (SAS Inc., Cary, North Carolina, USA) and StatMate III (ATMS, Tokyo), and all results are presented as means  $\pm$  SDs. The chi-square test with Yates' correction and the Student's *t*-test were used for comparisons. Probability (*p*-) values < 0.05 were considered significant.

## Results

The characteristics for all cases are shown in Table 1. There were no significant differences between the cases using Sundt and P-I internal shunts in terms

of patient age, gender, degrees of stenosis, and the percentage of symptomatic cases (Table 1).

The carotid clamping time for the P-I shunt demonstrated significantly longer time (more than 2 minutes longer) than that for the Sundt shunt (*p* < 0.001, Table 2). No significant difference in clamping time was found between cases with split and conventional continuous arteriotomies using either type of shunt (Table 2). Rather, in the P-I shunt cases, the cases with split arteriotomy took about 20 sec longer than the cases with continuous arteriotomy. Either way, the cases with P-I shunt took longer clamping time than those with Sundt shunt, regardless of which arteriotomy was applied (*p* < 0.001).

The proportions of cases in which multiple trials of either arteriotomy or insertion of the shunt tube were needed were 18.8% in the Sundt and 20.6% in the P-I shunt, revealing no significant difference in difficulty of insertion (Table 3). The cases in which more than one HIS was detected on diffusion-weighted magnetic resonance (DW MR) images after CEA were counted and their ratio to the cases with available postoperative DW images was compared. In this calculation, there was no significant difference between the two shunt groups (25.0% vs. 29.4%, Table 3). Postoperative small intimal flaps were detected by MDCTA in one case with a Sundt shunt and two with P-I shunts (2.1 vs. 5.9 %, not significant, Table 3). Ten cases out of 51 rSO<sub>2</sub> measurements (19.6%) during clamping at either shunt insertion or removal showed an rSO<sub>2</sub> decrease more than 10% compared to the pre-clamping values, but the difference between shunt groups was not significant (Table 3).

## Discussion

In the present study, we could not find any difference between the cases using Sundt and P-I shunts in

**Table 2 Comparison of clamping times using each arteriotomy**

Arteriotomy	Sundt	Pruitt-Inahara	<i>p</i> value*
Total	4:00 $\pm$ 1:33	6:19 $\pm$ 1:46	< 0.001
Continuous	3:59 $\pm$ 1:40	6:16 $\pm$ 1:35	< 0.001
Split	4:03 $\pm$ 0:45	6:39 $\pm$ 2:07	< 0.001
<i>p</i> value <sup>†</sup>	0.86	0.69	-

Values indicated in min:sec. \*Student's *t*-test for comparison between the time with two shunts, <sup>†</sup>Student's *t*-test for comparison between the time with the two arteriotomies.

**Table 3 Comparison of the results between the two internal shunts**

	Total	Sundt	Pruitt-Inahara	p value*
Multiple trials of arterectomy or insertion (%)	19.5 (16/82)	18.8 (9/48)	20.6 (7/34)	0.94
Postoperative HIS on MRI DWI (%)	27.8 (15/54)	25.0 (5/20)	29.4 (10/34)	0.97
Postoperative intimal flap on IC (%)	3.7 (3/82)	2.1 (1/48)	5.9 (2/34)	0.76
rSO <sub>2</sub> decrease in NIRS (%)	19.6 (10/51)	23.8 (5/21)	16.7 (5/30)	0.78

\*chi-square test. DWI: diffuse weighted image, HIS: high-intensity spot, IC: internal carotid, MRI: magnetic resonance imaging, NIRS: near-infrared spectroscopy, rSO<sub>2</sub>: regional oxygen saturation.

trial times for arteriotomy or insertion, frequency of postoperative HIS on MR imaging, and postoperative intimal flaps on MDCTA, although clamping time for insertion of the shunt was apparently quicker in cases with Sundt than with P-I shunts. Comparisons of the two shunts are summarized in Table 4.

Since the Sundt shunt has cone-shaped bulb at both ends of the tube, a tube with relatively larger diameter should be inserted.<sup>15)</sup> On the other hand, the P-I tube has a smaller diameter but is relatively stiff and has to be inserted further, up to the end of the balloon.<sup>5)</sup> Ultimately, the difficulty in insertion was almost same in cases with either shunt, as shown by the frequency of multi-trials of insertion of the tube or arteriotomy, despite there being no significant differences with regard to IC and CC diameters in the two shunt groups ( $p = 0.08$  and  $0.106$ , respectively, Table 1). If fixation with vascular loop for the cases with P-I shunt could be omitted as was described in the manufacturer's instructions, perhaps the clamping time would be reduced. The shunt tube must, however, be turned upside and downside in plaque resection, which might move over to the balloon to drop out the tube with only weak inflation pressure. Therefore, we make it a rule to reinforce the fixation by tightening the vascular loop gently, as performed at other institutes as well.<sup>16)</sup> Though we used quick manipulation of the vascular loop and the tourniquet through the experience with Sundt shunts, the ring-shaped clip that has been applied by some surgeons<sup>17)</sup> may present an opportunity to shorten the fixation time.

The strongest point of three-way shunt, like P-I, is the presence of the T-port for irrigation and removal of air and particles from inside the tube, which has been shown to reduce the incidence of thrombotic events.<sup>17)</sup> Though Wilkinson et al.<sup>18)</sup> showed that a Javid shunt had a higher incidence of emboli, we did not experience a difference between Sundt and P-I shunts in postoperative thrombotic complications, as indicated by HIS on DW MR images, in our series. Some investigators use the T-port to measure stump

pressure<sup>2)</sup> but this is not required, and not many surgeons use the port for this purpose. Despite that, surgeons often feel that a T-port as well as the two tubes for inflation of balloons sometimes gets in the way of smooth resection of the carotid plaque, especially in moving the tube up and down. From the results of present study, under routine shunting protocol and no need for measurement of stump pressure or blood pressure monitoring, the two-way Sundt shunt may have an advantage compared to the three-way P-I shunt in terms of smoother and quicker insertion of the tube with no significant difference in incidence of thrombotic complications and intimal damage.

Wisman et al.<sup>19)</sup> investigated 156 patients who experienced CEA with a selective shunting protocol (Javid shunt) and found that longer time intervals between the determination that a shunt was needed and the actual function of the shunt (the need for shunt-to-shunt time; NST) increased the 30-day stroke/death rate. In patients with an NST over 6 minutes, more than 1 of 4 patients sustained a stroke or died. They recommended that shunt placement should be as quick as possible. Some advocating no or selective shunting said the cases which really need shunting are limited to about 20% of the entire cases.<sup>1)</sup> However, as was also experienced in our study, there are not a few cases in which it is difficult to insert a shunt tube and doing so requires a long time: these include cases with high carotid bifurcation, elongated IC, and a heavily calcified carotid.<sup>19)</sup> In particular, the cases which need shunts in the selective shunting protocol may have poor tolerance for ischemia, meaning that prompt restoration of blood flow by smooth insertion of a shunt will be essential. If a surgeon encounters such tough cases under the unfamiliarity of treating shunts, it is obvious that quick shunt insertion for minimized ischemia is hardly expected. In that sense, a simple two-way shunt with easy handling like the Sundt shunt would be appropriate to choose even in selective shunting.



**Table 4 Summary of comparison of the internal shunts**

Shunt	Sundt	Pruitt-Inahara
Structure, fixation	Two-way, vascular loop	Three-way (T-port), balloons
Outer diameter of the tube (IC/CC) (mm)	Large (3.8/5.5)*	Small (3.0/4.0)
Minimum distance from the tip necessary to be inserted (IC/CC) (mm)	Short (4.0/6.0)**	Long (19.0/33.0)***
Materials and flexibility of the tube	Silicone, flexible	Polyurethane, relatively stiff
Difficulty in insertion <sup>†</sup>		Almost same
Clamping time for insertion <sup>††</sup>	Short	Long
Plaque resection	Relatively smooth for simple structure	Sometimes hindered by the T-port and the two tubes for balloons
Postoperative thrombotic complication <sup>†</sup>		Almost same
Postoperative intimal damage on IC <sup>†</sup>		Almost same

\*Outer diameter of the cone-shaped bulb, \*\*Distance from the tip to the end of the cone-shaped bulb, \*\*\*Distance from the tip to the end of the balloon, <sup>†</sup>See Table 3, <sup>††</sup>See Table 2. CC: common carotid, IC: internal carotid.

There are a few limitations to our study. First, there is a limitation in a study design because the operations using both shunts were performed in different periods. Generally speaking, however, an operation performed more recently with a more skilled technique with or without improved devices should be superior to an old one. Since we found little advantage with the recent operations compared to the former ones in the present study, it is conceivable to say that the operations performed in the older periods might have some superiority and be even safer. The second limitation of our study is the relatively small sample size. Further studies with larger numbers of patients are warranted to clarify the issue. Third, we regarded Sundt and P-I shunts as representative two-way and three-way shunts, respectively. There are, however, many other modified types of internal shunts of various diameters, lengths, materials, and structures,<sup>7,20,21)</sup> which may improve the drawbacks pointed out in the present study.

### Conclusion

It is reasonable to say a two-way shunt like Sundt is satisfactory to use in CEA, because placement of the shunt is quicker and smoother than a three-way shunt like P-I, and the simple structure is less impeditive for operative procedures without increasing the incidence of postoperative embolization and intimal damage. Compared to conventional continuous arteriotomy, split arteriotomy did not affect the clamping time for either Sundt or P-I shunt tubes.

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### Conflicts of Interest Disclosure

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices in the article. All authors who are members of The Japan Neurosurgical Society (JNS) have registered online Self-reported COI Disclosure Statement Forms through the website for JNS members.

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