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Efficacy and Safety of Single versus Dual Antiplatelet Therapy for Coiling of Unruptured Aneurysms

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Background: Although the efficacy of antiplatelet therapy for coiling of unruptured cerebral aneurysms has been reported, regimens for this therapy are not yet well established. The aim of this retrospective study was to analyze correlations among the modes of antiplatelet use, aneurysmal configuration, coiling methods, and complications to elucidate the optimal antiplatelet therapy for coiling. *Methods:* The study population comprised 154 patients with unruptured aneurysms who underwent coiling with antiplatelet therapy at our institution between 2001 and 2009. The patients were categorized by mode of antiplatelet therapy (single [n = 64] or dual [n = 90]), neck size (wide [n = 80] or narrow [n = 74]), and technique used (simple [n = 42] or adjunctive [n = 112]). The incidences of hemorrhagic/ischemic complications and abnormalities on postprocedural diffusion-weighted magnetic resonance imaging (DWI) in each group were statistically assessed. *Results:* Hemorrhagic complications occurred in 1 case (1.5%) with single antiplatelet therapy and in 2 cases (2.2%) with dual antiplatelet therapy. Symptomatic ischemic complications occurred in 5 cases (7.8%) with single therapy and in 4 cases (4.4%) with dual therapy. Abnormalities were detected by DWI in 27 cases (42%) with single therapy and in 31 cases (34%) with dual therapy. No significant difference was found between modes of antiplatelet therapy even when the technique used was taken into account. In cases of wide neck, however, there were significant differences in the rate of symptomatic ischemic complications (single, 21.7%; dual, 3.5%; P = .014) and DWI abnormalities (single, 37.8%; dual, 20.9%; P = .048). *Conclusion:* Our data suggest that dual antiplatelet therapy may better prevent ischemic complications from coiling for wide-necked aneurysms compared with single antiplatelet therapy. **Key Words:** Coil embolization—antiplatelet therapy—neck width—thromboembolic complication.

Coil embolization for intracranial aneurysms has become a common technique with the development of devices and adjunctive techniques, such as balloon-assisted and double-catheter techniques. Thromboembolic events are the most feared complication of coil embolization, with a frequency of 5.52%-9%.[1-3] The use of antiplatelet drugs during the periprocedural period has been proposed to decrease the risk of this unfavorable complication, and previous studies have reported its efficacy.[4-13] None of those studies specified the optimal dose and mode (single or dual) for antiplatelet therapy, however, particularly in relation to the use of adjunctive

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techniques and aneurysmal configuration (ie, neck size) in a large series.

In the present study, patients who underwent coil embolization for unruptured cerebral aneurysm at our institution were examined retrospectively to elucidate the optimal antiplatelet therapy, which decreases the risk of ischemic complications while minimizing hemorrhagic adverse events.

Methods

Patient Population

This study was a retrospective analysis of 154 consecutive adult patients undergoing elective coil embolization of 157 intracranial saccular aneurysms between June 2001 and June 2009 at our institution. Exclusion criteria were partially thrombosed aneurysm, fusiform aneurysm treated by parent artery occlusion, no antiplatelet therapy, combination of oral anticoagulant therapies, retreatment, and stent-assisted cases.

All cases were classified by the technique used (simple or adjunctive) and the mode of antiplatelet therapy (single or dual), resulting in 4 subgroups: S1, simple technique with single antiplatelet therapy; S2, simple technique with dual antiplatelet therapy; A1, adjunctive technique with single antiplatelet therapy; and A2, adjunctive technique with dual antiplatelet therapy. Subjects were also classified by neck width (wide, ≥4 mm; narrow, <4 mm), in accordance with the report by Murayama et al,[14] and by the mode of antiplatelet therapy into another 4 subgroups: N1, narrow neck with single antiplatelet therapy; N2, narrow neck with dual antiplatelet therapy; W1, wide neck with single antiplatelet therapy; and W2, wide neck with dual antiplatelet therapy. In cases with multiple aneurysms, the aneurysm with wider neck size was counted for categorization between narrow and wide subgroups.

Antiplatelet Therapy

Administration of antiplatelet drugs was started at least 4 days before the procedure. Single agent therapy was provided with aspirin 81-200 mg/day. For dual therapy, cilostazol 100-200 mg/day, ticlopizine 100-200 mg/day, or clopidogrel 75 mg/day was added to aspirin. In the dual therapy regimens, aspirin was the first-line drug, with cilostazol or thienopyridine (ticlopidine/clopidogrel) used as an adjuvant. Aspirin/cilostazol therapy was more common than aspirin/thienopyridine therapy (68% vs 31%). In terms of the duration of antiplatelet use, administration was completed within 1-6 months after the procedure in the single therapy group. In the dual therapy group, antiplatelet drugs were reduced to one drug (aspirin in most cases) at 1 week to 3 months after the procedure, and administration was completed within the subsequent 3-6 months.

Procedure

The procedures were performed using transfemoral arterial access in a dedicated biplane neuroangiography suite (BV-3000; Philips, Best, The Netherlands), under general anesthesia after obtaining informed consent from the patient and family members. All procedures in this series were performed by 2 neuroendovascular therapists (K.M. and T.S.).

The endovascular procedures were performed after endotracheally induced general anesthesia. Anticoagulation was provided by heparin (initial dose of 4000 IU) after arterial access was obtained through the femoral artery. Coil insertion was started after confirmation of activated clotting time >250 seconds, with continuous administration of heparin to maintain activated clotting time at ~250-300 seconds. The neck remodeling technique was performed if necessary, and HyperForm or HyperGlide (ev3; Plymouth, MN) balloon catheters were used. Only bare platinum coils were placed in the sac, with the exception of 2 cases in which Matrix 2 coils (Boston Scientific, Fremont, CA) were used. After completion of coil placement, systemic heparinization was stopped but not reversed, and hemostasis at the vascular access was secured by Angioseal (St Jude Medical, Austin, TX) in most cases. Patients were transferred to a neurosurgical intensive care unit and received intravenous argatroban (120 mg/day) for 2 days.

Evaluation of Diffusion-Weighted MRI

Diffusion-weighted MRI (DWI) was performed 2-5 days after the procedure using a 1.5-T system (Magnetom Vision; Siemens, Erlangen, Germany) with a multisection, single-shot, spin-echo planar imaging sequence. Diffusion gradients were applied in each of the x, y, and z directions with 2 b values (0 and 1000 s/mm^2). Imaging parameters were as follows: echo time, 100 ms; field of view, 23 cm; matrix, 96 × 128; section thickness, 4 mm; and intersection gap, 2 mm. Conventional spin-echo magnetic resonance imaging (MRI) was also performed at each examination under T1- and T2-weighted conditions and with a fluid-attenuated inversion recovery sequence. All MRI images were reviewed by neuroradiologists who were blinded to the clinical information. When abnormalities were detected on DWI, the locations were recorded.

Statistical Analysis

Analyses were performed using JMP version 8.0 (SAS Institute, Cary, NC). Statistical significance for intergroup differences was assessed using the z test for categorical variables and the Mann-Whitney U test for continuous variables. The incidence of symptomatic ischemic complication, DWI abnormalities, and hemorrhagic complications were calculated, and statistical analyses were performed among subgroups sorted by neck size and

Table 1. *Comparison of narrow-necked and wide-necked cases (n = 154)*

	Narrow neck (n = 74; 48.1%)	Wide neck (n = 80; 51.9%)	*P* value
Adjunctive technique, n (%)	48 (64.9)	64 (80.0)	.035
Symptomatic ischemic complications, n (%)	2 (2.7)	7 (8.8)	NS
DWI abnormality, n (%)	21 (28.4)	37 (46.3)	.022

Abbreviation: NS, not significant.
A population test was performed. The adjunctive technique was significantly used when the aneurysmal neck was wide. There was an increase in postprocedural DWI abnormalities in wide-necked cases despite the statistically significant difference.

mode of antiplatelet therapy (W1, W2, N1, and N2) or technique used and mode of antiplatelet therapy (S1, S2, A1, and A2). Furthermore, symptomatic ischemic complications and DWI abnormalities were tested using age, sex, mode of antiplatelet therapy, adjunctive technique, neck size, and aneurysmal location with multivariate analysis by logistic regression. *P* values <.05 were considered to indicate a significant difference.

Results

The mean age of the study patients was 58.8 years (range, 27-80 years), and 76% (117 of 154) of patients were female. The mean maximum aneurysm diameter was 7.38 ± 2.91 mm, with a median size of 6.70 mm (range, 3.2-19.6 mm). The mean neck width was 4.20 ± 1.46 mm, with a median size of 4.0 mm (range, 1.82-10.2 mm). Of the aneurysms treated, 92 involved the internal cerebral artery (including posterior communicating artery aneurysms), 27 were at the basilar bifurcation, 15 involved the anterior cerebral artery (including the anterior communicating artery), 11 involved the basilar artery/superior cerebellar artery, 1 involved the middle cerebral artery, and 11 involved other posterior fossa sites. Multiple aneurysms were present in 3 cases. A total of 42 cases were treated using the simple technique (only one microcatheter used for coiling), and the remaining 112 cases were treated using an adjunctive technique (balloon-assist, double-catheter, or both).

Symptomatic ischemic complications were seen in 9 cases (5.8%), including 3 with transient ischemic attack (TIA). Onset of all TIAs occurred within 24 hours after the procedure. The remaining 6 symptomatic ischemic complications were nondisabling stroke (modified Rankin scale score, 0-2). DWI abnormalities were observed in 58 cases (37.7%), with 50 (32.5%) not associated with any symptoms, representing so-called "silent ischemia." One case with TIA exhibited no DWI abnormalities. Hemorrhagic complications occurred in 3 cases (1.9%), including 1 patient with intracranial hemorrhage and 2 patients with extracranial bleeding (one with groin hematoma and the other with bleeding from a gastric ulcer). No intraprocedural bleeding occurred. Dual antiplatelet therapy had been administered to 2 of the 3 patients who sustained hemorrhage.

Categorization by Technique and Mode of Antiplatelet Therapy

There were 20 cases (13%) in the S1 subgroup, 22 (14%) in the S2 subgroup, 44 (29%) in the A1 subgroup, and 68 (44%) in the A2 subgroup. The distribution of cases with symptomatic ischemia was 3 (15%) in S1, 1 (4.5%) in S2, 2 (4.5%) in A1, and 3 (4.4%) in A2. No significant differences were found between S1 and S2 (*P* = .22) or between A1 and A2 (*P* = .66).

DWI abnormalities were observed in 10 cases (50%) in S1, 5 (22.7%) in S2, 17 (38.6%) in A1, and 26 (38.2%) in A2. No significant differences were seen between S1 and S2 (*P* = .06) or between A1 and A2 (*P* = .91) in this cohort.

Categorization by Neck Width and Mode of Antiplatelet Therapy

A narrow neck was present in 74 cases; a wide neck, in 80 cases. A significant correlation was noted between neck size and DWI abnormalities (*P* = .02) (Table 1). According to categorization by neck width and mode of

Table 2. *Comparison of single and dual antiplatelet therapy in narrow-necked cases (n = 74)*

	N1 (n = 41; 55.4%)	N2 (n = 33; 44.6%)	*P* value
Adjunctive technique, n (%)	27 (65.8)	21 (63.6)	NS
Symptomatic ischemic complications, n (%)	1 (2.4)	1 (3.0)	NS
DWI abnormality, n (%)	13 (31.7)	8 (24.2)	NS

Abbreviations: NS, not significant; N1, narrow neck with single antiplatelet therapy; N2, narrow neck with dual antiplatelet therapy.
Comparisons were made between N1 and N2, and a population test was performed.

Table 3. *Comparison of single and dual antiplatelet therapy in wide-necked cases (n = 80)*

	W1 (n = 23; 28.8%)	W2 (n = 57; 71.3%)	*P* value
Adjunctive technique, n (%)	17 (73.9)	47 (82.5)	NS
Symptomatic ischemic complications, n (%)	5 (21.7)	2 (3.5)	.014
DWI abnormality, n (%)	14 (60.9)	23 (40.4)	.047

Abbreviations: NS, not significant; W1, wide neck with single antiplatelet therapy; W2, wide neck with dual antiplatelet therapy.
Comparisons were made between W1 and W2, and a population test was performed. Significant differences in the occurrence of symptomatic ischemic events and DWI abnormalities were seen between W1 and W2.

antiplatelet therapy, the subgroup distribution was 41 (27%) for N1, 33 (21%) for N2, 23 (15%) for W1, and 57 (37%) for W2. The ratio of adjunctive technique was not significant in any group (N1 and N2, *P* = .340; W1 and W2, *P* = .289). The distribution of patients with symptomatic ischemia was 1 (2.4%) in N1, 1 (3.0%) in N2, 5 (21.7%) in W1, and 2 (3.5%) in W2. A significant difference in the occurrence of symptomatic ischemic events was apparent between W1 and W2 (odds ratio [OR], 0.131; 95% confidence interval [CI], 0.023-0.734; *P* = .014), whereas the comparison of N1 and N2 revealed no significant difference (*P* = .714) (Tables 2 and 3; Fig 1).

The subgroup distribution of cases with DWI abnormalities was 13 (31.7%) in N1, 8 (24.2%) in N2, 14 (60.9%) in W1, and 23 (40.4%) in W2. There as a significant difference between W1 and W2 (*P* = .047). The ratio of new lesions detected by DWI was significantly decreased in wide neck cases using dual antiplatelet therapy (Tables 2 and 3).

The associations of DWI-detected lesions with age, sex, antiplatelet therapy, adjunctive technique, neck size, and relationship with the parent artery were tested with multivariate analysis using logistic regression (Table 4). Analysis identified neck width as a factor independently correlated with the presence of DWI abnormalities (*P* = .015), and showed that dual antiplatelet therapy was likely to reduce the rate of DWI abnormalities (*P* = .056).

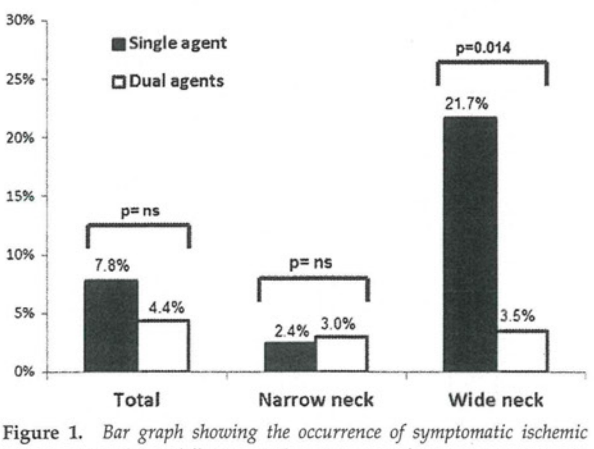

Figure 1. *Bar graph showing the occurrence of symptomatic ischemic events. A significant difference in the occurrence of symptomatic ischemic events was apparent between W1 and W2 (OR, 0.131; 95% CI, 0.023-0.734; P = .014), whereas the comparison between N1 and N2 demonstrated no significant difference.*

Discussion

Thromboembolism is the most common complication associated with coil embolization. The rate of this fearful complication ranged from 5.52% to 9% of cases in several previous clinical series.[1-3] Several recent reports have described the efficacy of periprocedural administration of antiplatelet drugs in preventing thromboembolism associated with coil embolization. Yamada et al[4] reported a reduction in the thromboembolic event rate among patients who received antiplatelet therapy either after or both before and after endovascular treatment. Layton et al[6] demonstrated the efficacy of periprocedural antiplatelet therapy and differentiated antiplatelet regimens into 3 groups: aspirin, clopidogrel, and a combination of the two. Although Layton et al concluded that the use of clopidogrel (either alone or in combination with aspirin) was the only preprocedural antiplatelet factor that showed any significant effect on local thrombus formation or symptomatic thromboembolic complications, the number of cases treated with antiplatelet drugs was small, and correlations between antiplatelet drugs and use of the balloon-assist technique were not assessed in terms of thromboembolism. No previous studies have investigated established antiplatelet regimens, particularly regarding the mode of antiplatelet drugs (single or dual) and the duration of antiplatelet therapy.

This retrospective study collected data for coil embolization of unruptured cerebral aneurysms in which periprocedural antiplatelet therapy was administered. According to the literature, factors likely associated with thromboembolism include aneurysm neck width and the use of an adjunctive technique.[5,7,15] We focused on these factors and on the antiplatelet regimen to evaluate correlations among them and with the incidence of periprocedural complications to elucidate the optimal antiplatelet therapy, with the aim of preventing thromboemobolic events without increasing hemorrhagic complications.

We added abnormalities on DWI, the imaging modality providing the most sensitive detection of early and small ischemic lesions, as one of the study endpoints because of the anticipated low rate of symptomatic ischemic

Table 4. *Results of logistic regression analysis for abnormalities identified on DWI (n = 154)*

	Profile	OR (95% CI)	*P* value
Demographics			
Male, n (%)	37 (24.0)	0.790	NS
Age, years	58.8 ± 10.0	2.263 (0.37-17.4)	NS
Aneurysmal factors			
Neck, mm	4.19 ± 1.46	20.66 (2.11-250.5)	.015
Terminal type/side wall type, n	68/86	2.006	NS
Procedure-related factors			
Single/dual agents, n	64/90	2.008	.056
Simple/adjunctive technique, n	42/112	1.072	NS

Abbreviation: NS, not significant.

complications during coiling in patients receiving antiplatelet therapy. As to the combination of antiplatelet agents for dual therapy, aspirin was the first choice in all cases. The concomitant use of cilostazol and ticlopidine/clopidogrel was absent in this study, due mainly to medicofinancial factors.

There were no definite regimen whether single or dual antiplatelet therapy was applied in each case in this retrospective study; however, dual antiplatelet agents were used preferentially in cases involving the balloon-assist technique. This preference was based on data from our previous study showing an increased incidence of silent ischemia when balloon catheters were used.[5,11]

Therefore, we first investigated the efficacy of dual antiplatelet therapy over single antiplatelet therapy when an adjunctive technique was used, and found no statistically significant difference. This finding supports the results of Brooks et al[9] and Albayram et al,[16] indicating that the balloon-assist technique itself is not a risk factor for thromboembolism.

On the other hand, significant differences in both the occurrence of symptomatic ischemic complications and the detection of new lesions on DWI when the mode of antiplatelet therapy (single or dual) was sorted by neck width (Table 3 and Fig 1). In cases with a wide-necked aneurysm, dual antiplatelet therapy decreased both symptomatic and asymptomatic ischemia. A possible mechanism underlying the increased ischemic complications in wide-necked cases is the increased coil–parent artery interface, as supported by Klötzsch et al.[17] This idea has been advanced in previous studies[4-13]; however, the present study is the first to demonstrate the efficacy of dual antiplatelet therapy over single antiplatelet therapy for aneurysmal coil embolization in wide-necked cases.

Cilostazol, an inhibitor of phosphodiesterase 3,[18] was shown to have superior efficacy and safety over aspirin in the Cilostazol Stroke Prevention Study 2.[19] The preferential use of cilostazol as an adjuvant to aspirin in the present was based on results from the Trial of Cilostazol in Symptomatic Intracranial Arterial Stenosis, which proved that the rate of hemorrhagic complications did not increase with the addition of cilostazol to aspirin,[20] and the fact that clopidogrel was unavailable in Japan until 2006.

The incidence of hemorrhagic complications was low in our series. Possible factors contributing to this finding may be the preferential use of cilostazol and the relatively short duration of antiplatelet use, which has been associated with a low risk of hemorrhagic events in several studies.[4,21,22]

The concept of using neck width, a parameter that can be easily measured before the procedure, to determine the mode of antiplatelet therapy is simple and comprehensible. A prospective, large-volume study is needed to verify whether the single antiplatelet therapy is sufficient for cases with a narrow neck, which seems preferable in terms of drug compliance and medicofinancial perspectives.

This study has some limitations. First, this was a retrospective study, and the dose and the mode of antiplatelet therapies (single or dual) might have been biased. Second, the number of study participants was insufficient to provide further information especially regarding the optimal period of antiplatelet therapy, which is another keystone for establishing optimal regimens. Further prospective evaluation is warranted to determine the optimal dose, duration, and tapering schedule for antiplatelet drugs. A prospective randomized trial will identify the optimal antiplatelet therapy for coiling of unruptured aneurysms.

Conclusion

Periprocedural dual antiplatelet therapy for coiling of unruptured cerebral aneurysms may prevent the incidence of both symptomatic ischemic complication and DWI abnormalities for wide-necked aneurysms compared with single antiplatelet therapy. Conversely, the mere use of adjunctive techniques might not be a sufficient indication for the use of dual antiplatelet therapy.

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Hybrid Operating Room for the Treatment of Complex Neurovascular and Brachiocephalic Lesions

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Background: We examine the impact of the installation of integrated hybrid operating rooms (ORs) that allow both surgical and endovascular procedures and are designed for less invasive and 1-stage treatment of complex neurovascular lesions. *Methods:* We retrospectively analyzed our experience in the treatment of complex neurovascular lesions in a hybrid OR. *Results:* Three patients with distal middle cerebral artery (MCA) aneurysms underwent a proximal clip occlusion or endovascular trapping with a superficial temporal artery–MCA bypass after correct localization of the recipient branch distal to the aneurysm using superselective intra-arterial infusion of indocyanine green under an operating microscope. Two patients with innominate artery stenosis were treated with retrograde stenting from the common carotid artery (CCA) with distal protection of the internal carotid artery (ICA) alone, and with antegrade stenting with dual protection of the ipsilateral ICA and the vertebral artery. Two patients with tandem stenosis of the proximal CCA and carotid bifurcation underwent 1-stage retrograde stenting combined with a carotid endarterectomy. A patient with the innominate artery and the proximal CCA stenosis underwent staged percutaneous antegrade angioplasty of the innominate artery followed by retrograde stenting of both lesions. A patient with tandem stenosis of the subclavian and innominate arteries underwent 1-stage retrograde stenting. In 2 patients with carotid stenosis that was difficult to access via the endovascular route, carotid stenting was performed by direct puncture of the proximal CCA. No patients suffered from new postoperative neurologic deficits. *Conclusions:* The integration of a high-end hybrid OR enables combined endovascular and surgical procedures for complex neurovascular and brachiocephalic lesions in a 1-stage treatment. **Key Words:** Angiosuite—brachiocephalic stenosis—carotid stenosis—hybrid operating room—image-guided surgery—indocyanine green—videoangiography.

With the advent of endovascular techniques, brachiocephalic and cerebrovascular lesions previously treated with direct surgical repair are increasingly treated endovascularly with or without surgical treatment.[1] The feasibility and safety of endovascular treatment of brachiocephalic lesions depends on the conditions of the access route and the systemic burden of atherosclerosis. Therefore, the risks and benefits of less invasive endovascular procedures should be weighed against the inherent risks of negotiation of difficult access routes caused by advanced atherosclerosis. Similarly, complex cerebrovascular lesions, such as giant/fusiform aneurysms and arteriovenous

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malformations, are now relatively common targets of multimodality treatment, especially if they are located in the deep eloquent area. However, serious concerns regarding multimodality treatment include the perioperative use of antiplatelet agents, inconvenience to patients undergoing 2 separate procedures, and the possibility of additive cardiac risk.

Recent developments in neurovascular surgery and interventional neuroradiology have led to the installation of integrated operating rooms (ORs) that allow both surgical and endovascular procedures. These units offer surgical and angiographic equipment and personnel and therefore require surgical planning and design. Hybrid coronary revascularization, percutaneous valvular repair, and aortic stent–graft replacements are current developments in the cardiovascular field, but the application of these innovative technologies in neurovascular areas (and their usefulness) have not been established. We report our initial experience using recently introduced hybrid ORs that are specifically designed for the less invasive and 1-stage treatment of complex cardiovascular and neurovascular lesions.

Methods

We used the Allura Xper FD20 imaging system (Phillips, Best, The Netherlands). Single-plane neuroangiographic digital subtraction angiography (DSA) units with a C-arm, with a 12- × 16-inch flat detector (2048 × 2048 matrix) were installed in the angiographic suite (Fig 1A). The C-arm of a ceiling mounted unit can be parked in a corner of the OR, which enables sufficient working space around the head and cervical operating fields. The operating table (MAQUET MAGNUS, Phillips), rotated to 3 positions (Fig 1B) for the introduction of anesthesia, angiography, and endovascular interventions (Fig 1C) and craniotomy and microsurgery (Fig 1D). Six ceiling mounted flat screens (Flex Vision XL; Philips) are located on 2 sides of the OR. Three-dimensional (3D) DSA is performed and the reconstructed images are obtained immediately. We used a Zeiss Pentero (Carl Zeiss, Jena, Germany) operating microscope.

Patients with brachiocephalic occlusive lesions underwent plaque imaging using 3D inversion recovery–based T_1-weighted imaging (magnetization-prepared rapid acquisition with the gradient echo [MPRAGE]).[2] A plaque with intensity on MPRAGE of >200% that of adjacent muscle was categorized as high signal intensity.

Postoperative neurologic deficits were assessed, and diffusion-weighted magnetic resonance imaging (DWI) was performed 3 days after of the operation, as reported previously.[3]

Results

The study population was comprised of 11 patients who had undergone hybrid procedures in the dedicated hybrid OR since January 2011 (Table 1). All procedures were performed under general anesthesia. Perioperative antiplatelet administration was aspirin in 2 cases (patients 2 and 3), aspirin and clopidogrel in 6 cases (patients 4-6, 8, and 10 and 11), and aspirin and cilostazol in 2 cases (patients 7 and 9). Three patients with distal middle cerebral artery (MCA) aneurysms underwent a proximal clip occlusion (patient 1) or endovascular trapping (patients 2 and 3), respectively, combined with a superficial temporal artery (STA)–MCA bypass after correct localization of the M4 recipient branch distal to the aneurysm using superselective intra-arterial infusion of indocyanine green (ICG) under an operating microscope. Two patients with innominate artery stenosis were treated with retrograde stenting from the surgically exposed common carotid artery (CCA) with distal protection of the internal carotid artery (ICA) alone (patient 4) or combined with temporary occlusion of the ipsilateral vertebral artery with a PercuSurge GuardWire plus (Medtronic, Inc, Minneapolis, MN; patient 5). Two cases (patients 6 and 7) with tandem stenosis of the ostial/proximal CCA and carotid bifurcation underwent 1-stage retrograde stenting, combined with a carotid endarterectomy (CEA). A patient with the innominate artery and the proximal CCA stenosis underwent staged percutaneous antegrade angioplasty of the innominate artery followed by retrograde stenting of both lesions (patient 8). A patient with tandem stenosis of the innominate and subclavian arteries underwent 1-stage retrograde stenting (patient 9). In 2 patients with carotid stenosis that was difficult to access via the endovascular route, carotid stenting was performed by direct puncture of the proximal CCA (patients 10 and 11).

Patient 1

A 46-year-old woman with a distal M3 unruptured aneurysm (Fig 2A) was put under general anesthesia in the hybrid OR. A 6-Fr sheath (Envoy; Codman, Raynham, MA) was placed in the right femoral artery and continuously irrigated with heparizined saline. A left frontotemporal craniotomy was performed on the operating table rotated to the surgical position (Fig 2B), and the STA was dissected under a microscope. Next, the patient bed was rotated into the angiographic position, and a 6-Fr guiding catheter (Envoy) was placed in the left ICA in a coaxial system with a 4-Fr catheter (OK-1S, Kaneka Medix, Tokyo, Japan) along a 0.035-inch Radifocus guidewire (Terumo, Tokyo, Japan) under heparization. An Excelsior SL-10 microcatheter (Stryker, Kalamazoo, MI) was advanced just proximal to the aneurysm under fluoroscopic road-mapping control, and ICG was infused at a concentration previously reported.[4,5] Three M4 branches were fluoresced during the first arterial phase of ICG circulation, and the STA–MCA bypass was performed in the angular artery after transient reversal of heparization after withdrawal of the guiding catheter

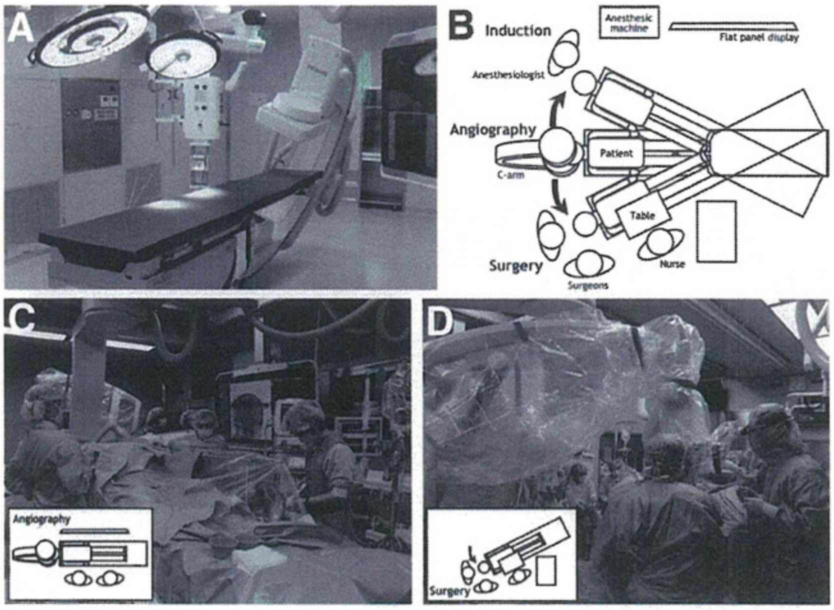

Figure 1. *Hybrid operating room (OR) at the National Cerebral and Cardiovascular Center, Osaka, Japan. Single-plane neuroangiographic digital subtraction angiography units with a C-arm and a 12- × 16-inch flat detector (2048 × 2048 matrix; Allura Xper FD20; Phillips, Best, The Netherlands) were installed in the angiographic suite. The C-arm of a ceiling mounted unit can be parked in a corner of the OR which enables sufficient working space around the head and cervical operating fields (A). The operating table (MAQUET MAGNUS, Phillips), rotated to the 3 positions for introduction of anesthesia (B), angiography (C), and endovascular interventions and craniotomy and microsurgery (D).*

from the cervical ICA (Fig 2C). Good patency of the bypass was confirmed by intravenous infusion of ICG (Fig 2D). A microcatheter (Excelsior SL-10; Stryker) was then navigated over a 0.014-inch Traxcess microguidewire (Terumo) distal to the aneurysm after the guiding catheter was replaced under reheparization, and endovascular trapping was performed using Trufill DCS Orbit coils (Cordis Endovascular, Temecula, CA). Three M4 branches distal to the aneurysm were well filled from the STA–MCA bypass on intravenous videoangiography and selective external carotid DSA (Fig 2D). The postoperative course was uneventful. Postoperative DWI revealed no new lesions.

Patient 5

A 73-year-old man with progressive asymptomatic severe stenosis at the origin of the innominate artery was referred to this hospital with a pressure difference of 60 mm Hg between bilateral brachial arteries (Fig 3A). MPRAGE images revealed a high signal intensity (compared with the sternocleidomastotid muscle) plaque at the innominate artery stenosis (Fig 3B).[2] Under general anesthesia, the right ICA was exposed for temporary clamping for distal protection. Under barbiturate protection with somatosensory-evoked potential (SEP) monitoring, the right ICA and VA were intermittently occluded using a bulldog clamp, and a PercuSurge Guardwire (Medtronic) was navigated through a 4-Fr Tempo catheter (Terumo; Fig 3C) from the right brachial artery, respectively (dual embolic protection) to prevent distal thromboembolism whenever the guidewire, balloon catheter, shuttle sheath, and stent crossed the unstable stenotic portion of the innominate artery. A 0.035-inch Radifocus guidewire (Terumo) was advanced retrogradely from the sheath in the right brachial artery through the innominate stenosis, captured in the common iliac artery by an Amplatz gooseneck snare (ev3; Microvena, Saint Paul, MN) introduced from the femoral sheath, and was pulled out from the femoral sheath. Then, the 4-Fr short femoral sheath was exchanged along the guidewire with an 8-Fr 90-cm shuttle sheath (Cook Biotech, West Lafayette, IN). The lesion was predilated with a PowerFlex P3 6-mm × 4 cm percutaneous transluminal angioplasty (PTA) balloon catheter (Cordis Endovascular). The 8-Fr shuttle sheath was advanced along with a Palmaz medium-sized stent (P2908E 25.1 × 8 mm) remounted on a Powerflex 12-mm × 4-cm well into the aorta, crossing the lesion first before positioning the stent at the deployment site. The sheath was retracted to uncover the stent. The stent was deployed using fluoroscopic and angiographic guidance (Fig 3D). The postoperative course was uneventful, with a single new spot on the postoperative DWI.

Patient 6

A 72-year-old man developed visual disturbance. A neuroradiologic examination revealed tandem stenosis at the origin of the left CCA and cervical carotid bifurcation. Plaque characterization by MPRAGE showed a low signal intensity of these lesions, but computed tomography angiography revealed a deep ulcerative plaque at the carotid bifurcation. Under general anesthesia, a 7-Fr superlong sheath (70 cm; Medikit, Miyazaki, Japan) was retrogradely introduced well below the arteriotomy site, and predilatation using a Powerflex 6-mm × 4-cm PTA balloon catheter was performed, followed by retrograde stenting (Palmaz 8 mm × 3 cm) for the lesion at the

Table 1. *Patient demographics*

Patient no.	Age	Sex	Medical history	Presentation	Diagnosis (size or % stenosis)	Associated vascular lesions/ medical conditions	MPRAGE
1	26	F	None	Asx	Infectious distal MCA aneurysm (12 mm)	Infectious endocarditis and infectious superior mesenteric artery aneurysm	NA
2	46	F	None	Asx	Distal MCA aneurysm (6 mm)	None	NA
3	69	F	HTN	Headache and progressing growth	MCA (M2) partially thrombosed large aneurysm (23 mm)	None	NA
4	74	M	HTN, DM, HPL, ASO, CKD, and CI	CI	Innominate stenosis (90%)	Tandem moderate stenosis of the ICA (65%)	High
5	73	M	HTN, DM, HPL, ICH, and MCAO	Asx and progressive stenosis	Innominate stenosis (90%)	Contralateral MCAO and left hypoplastic VA	High
6	72	M	HTN, DM, HPL, and AMI	Amaurosis fugax and progresive stenosis	Tandem stenosis of CCA orifice (60%) and ICA (70%)	Left subclavian occlusion	Low
7	83	M	HTN, DM, and HPL	CI	Tandem stenosis of CCA (23%) and ICA (0%)	TAA and AAA	High (both lesions)
8	61	M	HPL, CRF, and hemodialysis	Asx	Tandem stenosis of innominate artery (82%) and CCA orifice (80%)	Left CCAO and dense calcification of the aorta and innominate artery	Low (both lesions)
9	65	M	HTN, HPL, CRF, hemodialysis, CI, and PAF	Necessity of access route for CAG	Tandem stenosis of innominate artery (50%) and subclavian artery (75%)	AS, subclavian stenosis, right VA stenosis, and ASO	Low (both lesions)
10	74	M	HTN and SMI	Sx	Carotid stenosis (70%)	High position, type III aortic arch, and failed attempt of CAS via the transfemoral approach	High
11	67	M	HTM, HPL, AMI, and CKD	Asx (remote CI) and progressive stenosis	Carotid stenosis (77%)	High position, calcified plaque, contralateral ICS (50%), and shaggy aorta	Low

Abbreviations: AAA, abdominal aortic aneurysm; AMI, acute myocardial infarction; AS, aortic stenosis; ASO, arteriosclerosis obliterans; Asx, asymptomatic; CAG, ***; CAS, carotid stenting; CCA, common carotid artery; CI, cerebral infarction; CKD, chronic kidney disease; CRF, chronic renal failure; DM, diabetes mellitus; DSA, digital subtraction angiography; F, female; HPL, hyperlipidemia; HTN, hypertension; ICA, internal carotid artery; ICH, intracerebral hemorrhage; M, male; MCA, middle cerebral artery; MCAO, middle cerebral occlusion; MPRAGE, magnetization-prepared rapid acquisition with the gradient echo; NA, not available; PAF, paroxysmal atrial fibrillation; SMI, silent myocardial infarction; Sx, symptomatic; TAA, thoracic aortic aneurysm; VA, vertebral artery.

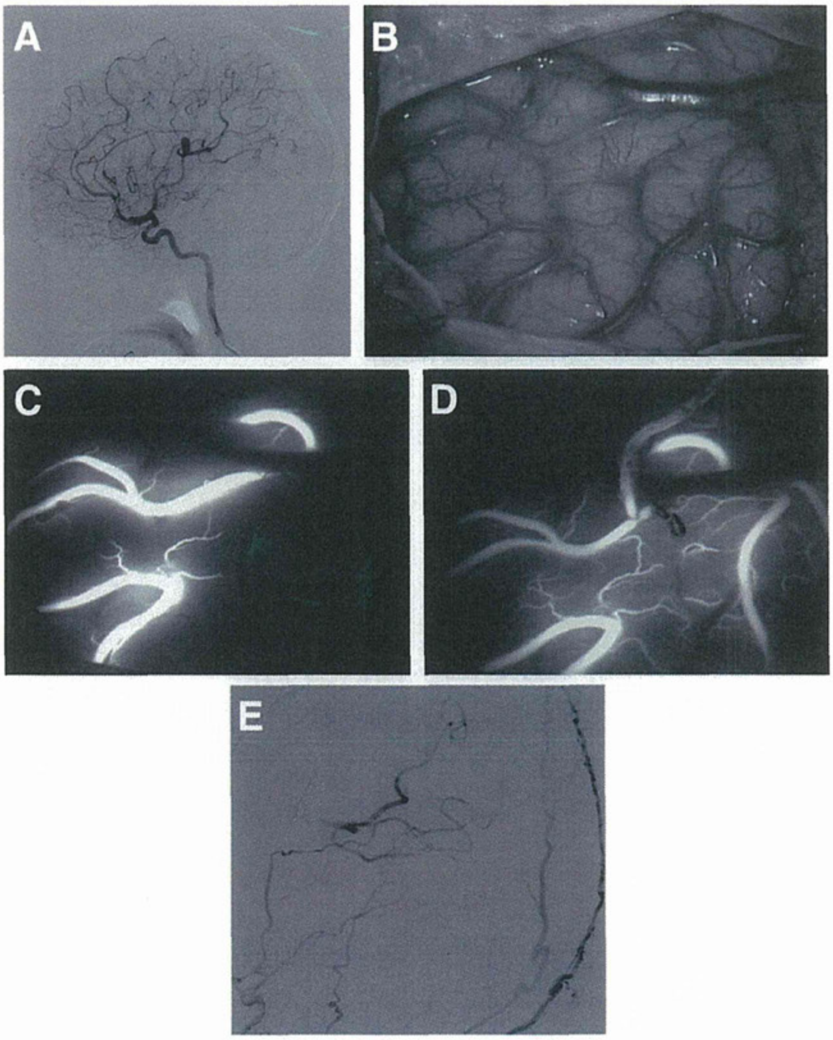

Figure 2. *A 46-year-old woman (patient 1) with distal M3 aneurysm (A) underwent 1-stage endovascular trapping combined with a superficial temporal artery–middle cerebral artery bypass. After dural opening (B), the cortical recipient artery (angular artery;* arrow*) was precisely localized by superselective intra-arterial infusion of indocyanine green under an operating microscope (C). After the patency of the bypass was confirmed by intravenous infusion of indocyanine green (D), endovascular trapping of the aneurysm was performed. Selective external carotid angiography showing all of the branches distal to the aneurysm were perfused (E). Packed coils in the aneurysm are indicated by the arrow (E).*

CCA orifice. CEA was performed next for the lesion at the carotid bifurcation. The postoperative DWI revealed an symptomatic single spot in the left parietal lobe.

Patient 8

A 61-year-old man with dialysis-dependent chronic renal failure had progressive severe stenosis of the innominate artery and the origin of the right CCA (Fig 4A). An initial attempt using a transfemoral approach failed to navigate the guidewire into the right CCA because of the acute angle between the proximal CCA and the innominate artery. As a result, PTA of the innominate artery was performed using a 6-mm × 2-cm Powerflex PTA balloon catheter (Cordis Endovascular). Four days later, the hybrid approach was performed under general anesthesia. After exposure of the right CCA and retrograde placement of a 4-Fr short sheath, 4.5 mm × 2 cm Aviator PTA balloon catheter (Cordis Endovascular) along a 0.014-inch 180-cm Dejavu guidewire (Cordis Endovascular) was navigated through the CCA stenosis with temporary occlusion of the distal internal carotid and vertebral arteries (dual protection), as described above. After predilatation, a 0.035-in × 300-cm Radifocus guidewire (Terumo) was advanced from the CCA sheath and pulled out from the femoral sheath. A Palmaz stent (P2008E) was advanced through the innominate stenosis along with an 8-Fr superlong sheath. The sheath was retracted to uncover the stent (Fig 4B). Next, a Smart Control stent 9-mm × 4-cm (Cordis Endovascular) was antegradely advanced and deployed at the proximal CCA and the distal innominate artery (Fig 4C).

Perioperative Morbidity and Mortality

No patients suffered from new neurologic deficits postoperatively, and there were no deaths. Postoperative DWI revealed a single and multiple new spots in 3 and 2 patients, respectively (Table 2). Neither restenosis nor cerebrovascular events were noted in the 3-month follow-up

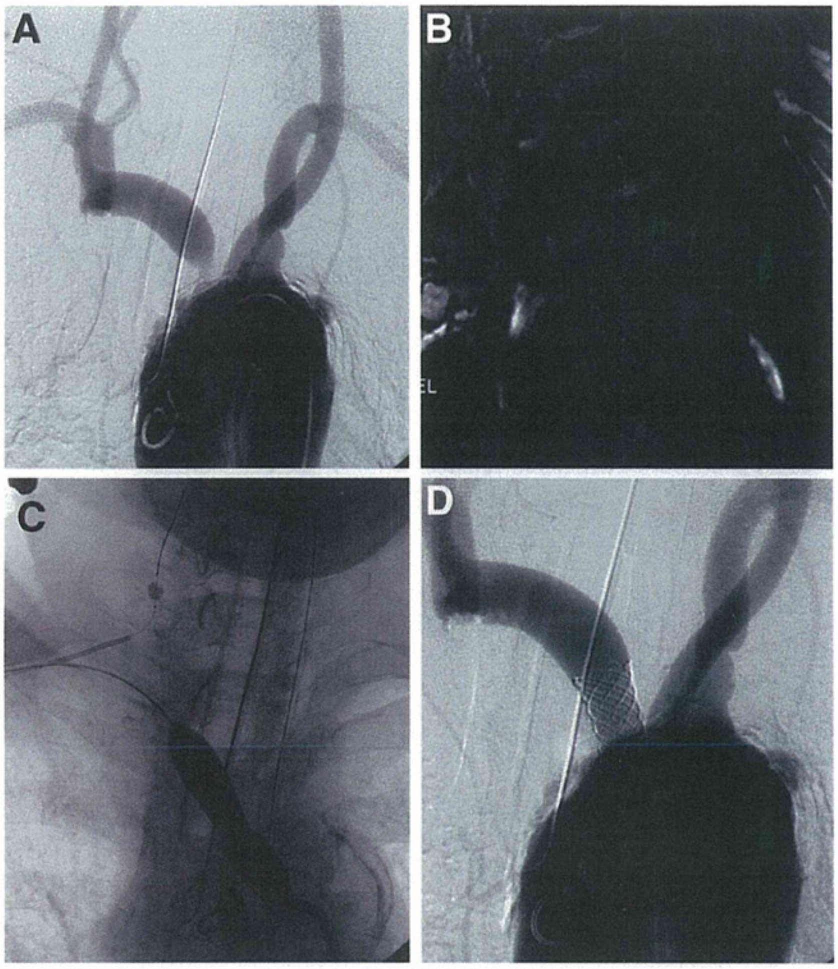

Figure 3. *A 73-year-old man (patient 5) with progressive asymptomatic severe stenosis at the origin of the innominate artery (A) showing hyperintensity on magnetization-prepared rapid acquisition with gradient echo imaging (B; arrow) underwent antegrade stenting under dual distal embolic protection of the internal carotid artery with a bulldog clamp and the vertebral artery with a PercuSurge GuardWire plus (C; arrow [Medtronic, Inc, Minneapolis, MN]). An 8-Fr shuttle sheath was advanced along with a Palmaz medium-sized stent (P2908E 25.1 × 8 mm) remounted on a Powerflex 12-mm × 4-cm, crossing the lesion first before positioning the stent at the deployment site. The sheath was retracted to uncover the stent (D).*

(Table 2). There were no perioperative hemorrhagic complications in this series.

Discussion

The value of an endovascular suite in the OR (hybrid OR), defined as an OR with appropriate digital fluoroscopic imaging equipment, has been reported in the field of cardiovascular surgery and include such as immediate correction of suboptimal results or complications of the endovascular procedure by surgery, optional conversion of an unsuccessful percutaneous approach to an open surgical procedure, and the ability to treat unexpected lesions with endovascular procedures when the radiologists are not readily available.[6,7] In the field of neurosurgery, however, the significance and indication of hybrid OR systems remains unestablished.[8] A recent metaanalysis has shown that a routine, intraoperative angiography remains the most cost-effective way to confirm satisfactory surgical aneurysm clipping.[9,10] Although results usually performed with a portable DSA are acceptable, the imaging quality is insufficient for neurovascular interventions and sophisticated imaging techniques, such as rotational angiography and 3D acquisition, are not usually available.

Procedures that should be Performed in a Hybrid Operating Room

One-stage Multimodality Treatment of Complex Cerebrovascular Lesions

Bypass with or without proximal occlusion or trapping is a critical option in the treatment of complex cerebral aneurysms that is unsuitable for clipping and coil embolization.[11,12] Peripheral intracranial aneurysms can be managed effectively by direct clip reconstruction or surgical or endovascular parent artery occlusion under bypass protection.[13] Correct localization of the cortical recipient artery distal to the aneurysm is a key step for successful revascularization, and this can be accomplished by surgical dissection, neuronavigation, and stereotactic techniques, as well as intraoperative DSA.[14-16] Recently, target bypass with precise localization of the recipient artery using superselective intra-arterial infusion of ICG was reported.[4,5] In the present series, selective

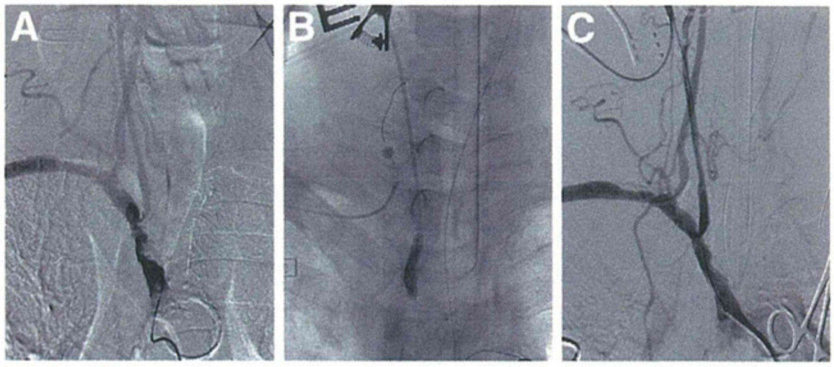

Figure 4. *A 61-year-old man (patient 8) with progressive severe stenosis of the innominate artery and the origin of the right common carotid artery (CCA; A) underwent antegrade stenting for tandem lesions of the innominate and proximal CCA. After exposure of the right CCA and retrograde placement of a 4-Fr sheath, a 4.5-mm × 2-cm Aviator percutaneous transluminal angioplasty balloon catheter (Cordis Endovascular, Temecula, CA) was navigated through the CCA stenosis with dual internal carotid artery and vertebral artery protection (B). After predilatation, a 0.035-in × 300-cm Radifocus guidewire (Terumo, Tokyo, Japan) was advanced from the sheath at the CCA and pulled out from the femoral sheath. A Palmaz stent (P2008E) was advanced through the innominate stenosis along with an 8-Fr superlong sheath. The sheath was retracted to uncover the stent (B). Next, a Smart Control stent (9 mm × 4 cm; Cordis Endovascular) was antegradely advanced and deployed at the proximal CCA and distal innominate artery (C).*

intra-arterial infusion of ICG proved to be useful in identifying the recipient cortical artery distal to deeply located fragile aneurysms without dissecting the surrounding eloquent brain. The imaging system used (Allura Xper FD20; Phillips) provided a 3D reconstruction image of the aneurysm quickly, with excellent image quality for endovascular trapping of peripheral aneurysms. Given that ICG investigation is inconclusive because of insufficient illumination of the deep surgical field, intraoperative DSA and ICG videoangiography play a complementary role in hybrid endovascular and surgical procedures. Complex arteriovenous malformation and dural fistula are also indications for such hybrid approaches.[17]

Aortic Arch Vessel Stenosis and Tandem Lesion

Recently, complex atherosclerosis of the aortic arch as a possible cause of cerebral infarction has received much attention, especially if the atheromas are located proximal to the ostium of the left subclavian artery, are >4 mm thick, and possess a mobile component.[18] The risk of stroke from atherosclerotic occlusive disease in the primary vessels of the supra-aortic trunk, however, remains less well defined, and there remains no consensus on the treatment of choice. A particularly difficult therapeutic dilemma occurs when patients present with significant ipsilateral internal carotid artery and supra-aortic trunk disease—a so-called "tandem lesion."[19] Isolated brachiocephalic or proximal common carotid disease is rarely detected, with a reported incidence of 1.8%, and is reported even less frequently (0.6%) in patients with significant ICA stenosis treated with CEA.[20] The authors routinely examined the presence and characteristics of atherosclerosis in the aorta and supra-aortic trunks by magnetic resonance imaging (MPRAGE) when cervical carotid revascularization is considered.[2] Evaluation of the plaque characteristics of the tandem lesion and the degree of stenosis may help establish the indication of the revascularization of the tandem lesions and estimate the risk of periprocedural complications.[21]

A number of centers reported excellent results with open exposure of the carotid bifurcation followed by retrograde angioplasty with/without stenting of the innominate and proximal CCAs.[22-24] If innominate stenosis contains a significant amount of plaques harboring a lipid-rich intraplaque hemorrhage revealed by MPRAGE,[2,25] the authors routinely perform temporary occlusion of the right vertebral artery and ICA (dual protection) under barbiturate neuroprotection (patients 5 and 8; Table 2). On postoperative DWI, only a single spot was observed in patient 5, suggesting the usefulness of such dual protection to prevent thromboembolic complications for high-risk cases selected based on magnetic resonance imaging of the plaque. No periprocedural morbidity was noted in the present series.

Advantages and Remaining Problems of the Neurosurgical Hybrid Operating Room

The integration of high-end angiographic imaging equipment in the OR enables image-guided surgery with high-quality images, on-table quality assessment of surgical procedures, and "one-stop shopping" procedures. Because most angiography tables do not provide for tilt and yaw the way that conventional surgical tables do, an operating table is mandatory for the treatment of complex cerebral lesions.[10] Regarding the size of the hybrid OR, it is obvious that a hybrid OR should be larger than a standard OR.[26] In an environment that is already filled with complexity, monoplane angiography may be

Table 2. *Summary of interventions and outcome*

Patient no.	Procedures	Stent/coil*	Embolic protection (location)/ neuroprotection*	Complications	New lesions on postoperative DWI	mRS score at 30 days	Follow-up (modality/interval)
1	STA–MCA bypass with superselective ICG videoangiography and proximal clipping	Sugita II (#89 and #96)	NA	None	None	0	Complete obliteration (DSA/4 mo)
2	STA–MCA bypass with superselective ICG videoangiography and endovascular trapping	Orbit Galaxy and Trufill DCS Orbit	NA	None	None	0	Complete obliteration (DSA/3 mo)
3	STA–MCA bypass with superselective ICG videoangiography and endovascular trapping	Microplex Complex-18, Hydrocoil 10 and Target Helical Ultra	NA	None	Multiple spots	1	NA
4	Retrograde stenting	Large Palmaz (P3008E)	Tourniquet (CCA) and bulldog clamp (ICA)	None	Multiple spots	0	No restenosis (duplex/6 mo)
5	Antegrade stenting	Medium Palmaz (P2908E)	Bulldog clamp (ICA) and Percusurge GuardWire (VA)	Pseudoaneurysm at the femoral puncture site	Single spot	0	No restenosis (CTA/6 mo)
6	Retrograde CAS and CEA	Medium Palmaz (P2908E)	Bulldog clamp	None	Single spot	0	No restenosis (CTA/6 mo)
7	CEA and echo-guided retrograde stenting	Precise (9-40 mm)	Tourniquet (CCA)	None	None	0	NA
8	Antegrade PTA (innominate) and antegrade stenting (innominate; CCA)	Medium Palmaz (P2008E; innominate) and Smart Control (8-40 mm; CCA)	Bulldog clamp (ICA) and Percusurge GuardWire (VA)	None	None	0	No restenosis (CTA/3 mo)
9	Retrograde innominate stenting from right CCA and retrograde subclavian stenting from right BA	Large Palmaz (P3008E; innominate), Smart Control (10-40 mm), and medium Palmaz (P2908E; subclavian)	Bulldog clamp (ICA)	None	None	1†	NA
10	CAS with direct puncture of CCA	Precise (10-40 mm)	CCA occlusion with tourniquet and FilterWire EZ (ICA)	None	Single spot	1	No restenosis (duplex/6 mo)
11	CAS with direct puncture of CCA	Precise (9-40 mm)	FilterWire EZ (ICA)	None	None	2†	No restenosis (duplex/3 mo)

Abbreviations: BA, basilar artery; CAS, carotid stenting; CEA, carotid endarterectomy; CCA, common carotid artery; CTA, computed tomographic angiography; DSA, digital subtraction angiography; DWI, diffusion-weighted magnetic resonance imaging; ICA, internal carotid artery; ICG, indocyanine green; MCA, middle cerebral artery; mRS, modified Rankin Scale; NA, not available; PTA, percutaneous transluminal angioplasty; STA–MCA, superficial temporal artery–middle cerebral artery; VA, vertebral artery.

*Trade names are property of their respective trademark holders (see text for details).

†No deterioration from preoperative status.

sufficient. Because most neuroendovascular procedures are performed with biplane angiography, the introduction of biplane angiography in sufficient space may broaden the indication of the hybrid OR in the neurosurgical field.

The intraoperative use of heparinization with/without antiplatelet use, especially clopidogrel, is another concern, especially if intracranial lesions are treated with craniotomy for multimodality treatment. Placement of a guiding catheter in a coaxial system and embolization with coils requires heparinization. Continuous irrigation of the guiding catheter and introducing a sheath with heparinized saline, and careful monitoring of the activated clotting time, transient reversal of heparinization in the microsurgery stage of the treatment, and use of cilostazol instead of clopidogrel as a second antiplatelet may minimize the risks of intra- and perioperative bleeding and embolic complications. In the present series, dual antiplatelets were used perioperatively in 72.7% of the cases, but it is important to note there were no bleeding complications in this series.

In conclusion, the integration of a high-end hybrid OR enables combined endovascular and surgical procedures for complex neurovascular and brachiocephalic lesions in a 1-stage treatment.

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Superselective Shunt Occlusion for the Treatment of Cavernous Sinus Dural Arteriovenous Fistulas

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Abstract

Background: In treating cavernous sinus dural arteriovenous fistulas (CSdAVFs), transvenous embolization of the whole affected sinus is usually performed, which may result in the disturbance of normal venous drainage, or permanent cranial nerve palsy.

Objective: To describe superselective shunt occlusion (SSSO) of CSdAVFs.

Methods: Between July 2005 and August 2011, we experienced 20 consecutive CSdAVFs. In 14 cases (70%), we could detect the restricted locus of arteriovenous shunts by way of three-dimension rotational angiography (3-D RA) and/or superselective arteriography. After navigating the microcatheter to the shunt segment, consecutive superselective arterio-venography was performed to confirm the location of the microcatheter at the proper position.

Results: In 12 of 14 cases (85.7 %) in which the shunt was restricted, coiling only in the small venous pouch or compartment, which was just downstream of the shunt point, led to complete disappearance of the shunt without obliterating the entire sinus. No recurrence or permanent cranial nerve palsy was observed during the follow-up period with a mean of 46 (3 to 69) months in 12 cases treated by SSSO.

Conclusion: This technique, which enables complete extirpation of shunts by small amounts of coils, is a feasible way to treat CSdAVFs with excellent mid- to long-term results. Understanding of the angioarchitecture by 3-D RA and consecutive superselective arterio-venography was useful. This method should be considered before sinus packing or mere obliteration of dangerous venous outlets.

Key words: cavernous sinus, dural arteriovenous fistula, transvenous, embolization

Running title: Superselective Shunt Occlusion for CSdAVFs

ABBREVIATIONS: CS = cavernous sinus, CSdAVF = cavernous sinus dural arteriovenous fistula, SSSO = superselective shunt occlusion, ECA = external carotid artery, VA = vertebral artery, CCA = common carotid artery, 3-D RA= three-dimension rotational angiography, TVE = transvenous embolization, AVF = arteriovenous fistula, FPD = flat panel detector

Introduction

Cavernous sinus dural arteriovenous fistulas (CSdAVFs) have been treated by a catheter-based approach, either transarterially, transvenously, or in combination. Among them, the transvenous approach was considered to be the most effective way to treat this disease.[1] In many cases, coil placement in the entire affected sinus has been performed.[2] This "entire sinus packing", however, carries the risk of disturbing the normal venous drainage through the cavernous sinus and the risk of permanent cranial nerve palsy caused by the mass effect of the placed coils.[3-5]

On the other hand, selective occlusion of the shunt segment (shunt point and small venous pouch or compartment in its downstream) by detecting the shunt point can prevent the problems listed above, and a few case reports have noted this concept.[6-8] None of these reports, however, had documented the technical details of this treatment and they ultimately placed many coils in the affected sinus.

Here we describe our experience in treating CSdAVFs by superselective shunt occlusion (SSSO), with a focus on its concept as well as technical tips.

Methods

Patients and methods

Our study is based on 20 consecutive patients with CSdAVFs treated at our institute between July 2005 and August 2011.

The diagnosis was made on transfemoral 6-vessel angiography including bilateral ICAs, ECAs, and VAs. Injections from bilateral CCAs were also performed so as not to miss the involvement of ascending pharyngeal arteries.[9] 3-D RAs were routinely performed in later cases to assess the whole angioarchitecture and not to ignore any involved vasculature.

Technical aspects of SSSO

At the time of intervention, which was done under general anesthesia to eliminate motion