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Original Article

Multimodality Techniques in Microsurgical Clipping as the Gold Standard Treatment in the Management of Basilar Tip Aneurysm: A Case Series

Abstract

Introduction: Basilar aneurysms represent 5%–7% of all intracranial aneurysms. The main goal of open surgery is to achieve complete obliteration of the aneurysmal sac using minimal invasive technique while emphasizing on avoidance of complication. **Materials and Methods:** We performed a retrospective cohort study of nine cases of unruptured basilar tip aneurysm referred to the Fujita Health University Banbuntane-Hotokukai Hospital, Japan. The objective of the study was to analyze the surgical outcomes of unruptured basilar tip aneurysm. **Results:** Nine patients with unruptured basilar tip aneurysm were referred to our hospital between 2015 and 2017. The median size of the aneurysm and age were 4.00 mm (interquartile range [IQR] = 3.25–6.75 mm) and 58 years (IQR = 54–70 years), respectively. Five patients (55.6%) were presented with multiple intracranial aneurysms. Surgical adjuncts such as intraoperative neuromonitoring, intraoperative indocyanine green (ICG) angiography with dual-image videoangiography (DIVA), and neuroendoscope were used. Two patients developed transient postoperative oculomotor nerve palsy which resolved spontaneously. The median duration of surgery and days of hospitalization were 292 min (IQR = 237.5–350.5 min) and 12 days (IQR = 12–25 days), respectively. There was no mortality recorded in this case series. **Conclusion:** Microsurgical clipping of basilar tip aneurysm is safe in unruptured basilar tip aneurysm with a low risk of postoperative mortality or morbidity. All complications reported in this case series were transient with no long-term sequalae. The improved safety profile of microsurgical technique is due to the availability of intraoperative neuromonitoring, neuroendoscope, ICG, and DIVA. The application of multimodality technique in neurovascular surgery has also helped to achieve complication avoidance. The obliteration of the aneurysmal sac helps to restore the laminar blood flow in the bifurcation and distal blood vessels and improves the brain perfusion.

Keywords: *Basilar tip aneurysm, dual-image videoangiography, indocyanine green, neuroendoscope, neuromonitoring*

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Introduction

Basilar aneurysms represent about 5%–7% of all intracranial aneurysms.[1-4] In the vertebrobasilar distribution, basilar tip aneurysm is the commonest.[5] In a population-based study without comorbidity with a mean age of 50 years, the prevalence of unruptured intracranial aneurysm was estimated to be about 3%.[2] Treatment of incidental finding of any intracranial aneurysm is advocated in those aged below 60 years with aneurysm size at 5 mm and above. However, in those aged above 60 years and in whom the intracranial aneurysm is located in the basilar apex, anterior communicating artery, and posterior communicating artery, treatment is warranted as the risk of rupture is high.[5,6] Microsurgical clipping rather than endovascular coiling should be the first treatment choice unless in high-risk patients.[6] A pooled analysis of prospective cohort study of unruptured intracranial aneurysm showed that the Japanese population exhibits higher risk of rupture among patients with posterior circulation aneurysm than those in North American and European countries. The risk factors were age above 70 years, underlying hypertension, and a previous history of subarachnoid hemorrhage.[7] While microsurgical clipping has been accepted as gold standard treatment, endovascular treatment has been gaining popularity as an alternative treatment to microsurgical treatment. Nevertheless, patients are still exposed to significant risks of mortality and morbidity despite the advancement in endovascular management.

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We describe nine cases of unruptured basilar tip aneurysms treated with microsurgical clipping at a single institution from the years 2015 to 2017 and their outcomes.

Materials and Methods

We performed a retrospective study of a cohort of nine cases of unruptured basilar tip aneurysm referred to the Fujita Health University Banbuntane Hotokukai Hospital, Nagoya, Aichi, Japan. Demographic data including preoperative planning, perioperative management, and outcome were studied. The objective of the study was to analyze the surgical outcome of unruptured basilar tip aneurysm. Median and interquartile range (IQR) were used due to the small number of patients. Hemoscope® version 2015, (EBM CO., LTD., Tokyo, Japan) was used to calculate the diameter of the vessels and their flow rate.

Demographic data

A total of nine patients with unruptured basilar tip aneurysm were referred to our hospital between 2015 and 2017. The median age was 58 years (IQR = 54–70 years). The patients were predominantly female with six patients (66.7%), while the remaining three patients were male. Five patients (55.6%) presented with multiple intracranial aneurysms which include intracranial-anterior choroidal aneurysm, anterior communicating artery aneurysm, anterior cerebral artery aneurysm, and middle cerebral aneurysm. Two patients (22.2%) were presented with a history of chronic smoking; four patients (44.4%) were suffered from hypertension; two patients (22.2%) with underlying hyperlipidemia and two patients (22.2%) with underlying bronchial asthma. There was one patient with a previous history of Grave's disease and another one with a history of congenital patent ductus arteriosus. The demographic data are summarized in Table 1.

Table 1: Demographic data

ID	Age (years)	Sex	Premorbid medical illness/ cranial surgery	Modifiable lifestyle risks
A	76	Female	Hyperlipidemia, BrA, Cervical spondylosis	None
B	60	Male	None	None
C	53	Female	Previous cranial surgery (clipping)	Smoker (15 sticks/day; 20 years)
D	64	Female	Hypertension	None
E	78	Female	Hypertension	None
F	56	Female	History of Grave's disease and respiratory dysfunction	None
G	58	Male	Hypertension, hyperlipidemia	Smoker
H	55	Female	None	None
I	53	Male	None	None

BrA - Bronchial asthma

Surgical planning

All patients were subjected to two-dimensional (2D) and three-dimensional (3D) computed tomography angiography (CTA), computational fluid dynamics (CFD) study, with 3D digital subtraction angiography (DSA) if indicated, and magnetic resonance imaging (MRI) as preoperative imaging [Figure 1]. The preoperative workups of all the patients and their findings are shown in Table 2. Vascular board meetings have been conducted for all cases prior to surgery. A graphical simulation was used [Figure 2] to decide on the best surgical approach. All surgeries were performed under general anesthesia. Intra operative adjunct such as endoscope and dual-image videoangiography (DIVA) were used in all the cases. Intraoperative somatosensory-evoked potential (SSEP) and motor-evoked potential (MEP) monitoring were used in the last six cases [Figure 3].

Results

Median size of the basilar tip aneurysm in this series was 4.00 mm (IQR = 3.25–6.75 mm). The average diameter of basilar trunk was 4.84 mm, while the average diameter for left and right Posterior cerebral artery (PCA) was 2.10 and 2.06 mm, respectively. The average calculated flow rate in the basilar trunk was 52.6 ml/min, while that in both left and right PCAs was 28.0 and 23.8 ml/min, respectively [Table 3]. Left anterior temporal approaches were performed in six patients (66.7%), while the remaining was on the right side [Table 4]. Only one patient has been subjected to previous cranial surgery for intracranial aneurysm clipping procedure. There were only two patients requiring posterior clinoidectomy due to low position of the neck of the basilar tip aneurysm. In 2016, one patient developed temporary oculomotor nerve palsy

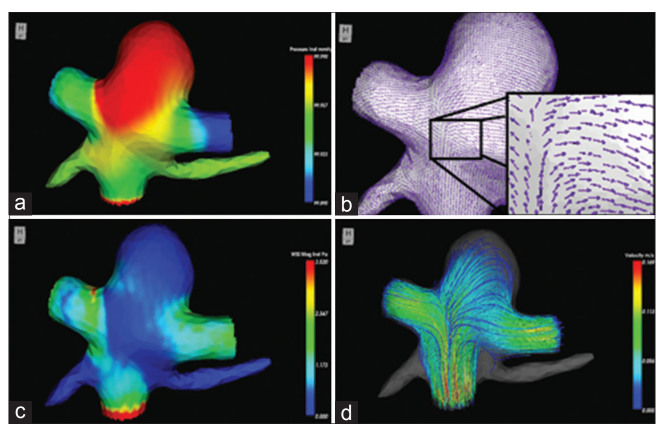

Figure 1: Computational fluid dynamics. Computational fluid dynamics using Hemoscope® 2015 software: (a) wall pressure, showing high wall pressure demonstrated in the basilar tip aneurysmal sac; (b) wall shear stress vector, showing direction of flow (inset) within the surrounding blood vessels and the aneurysm; (c) wall shear stress pressure, showing low wall shear stress pressure within the aneurysm; (d) streamline, showing stream pattern with color coding (to determine the velocity) within the surrounding vessels and aneurysm

postoperatively. In this patient, MEP and SSEP were not been used. Since then, intraoperative neuromonitoring has been routinely used. Abnormal intraoperative MEP recordings were detected in two cases. One of the patients who developed disappearance of MEP recording intraoperatively was due to the occlusion of the internal carotid artery (ICA). The MEP recordings improved to only 75% of the baseline postoperatively. However, postoperatively, he did not suffer from any hemiparesis or hemisensory loss, but developed temporary right oculomotor nerve palsy. In the other patient, intraoperative

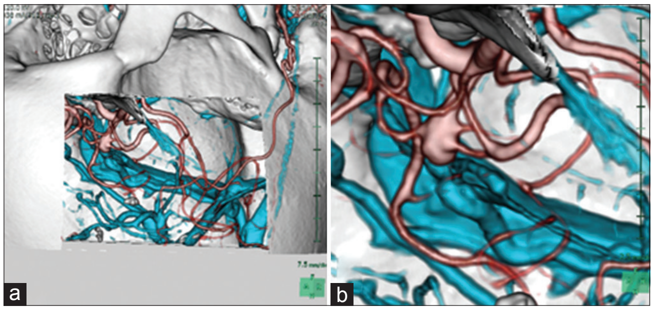

Figure 2: Three-dimensional computed tomography angiography and computed tomography venography with removal of bone simulating the best surgical approach. (a) Right pterional approach planning using three-dimensional computed tomography angiography images with computed tomography angiography and venogram; (b) close-up view of the basilar tip aneurysm

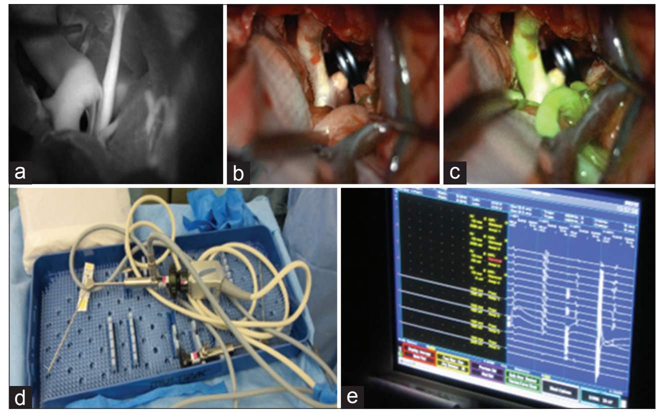

Figure 3: Multimodality adjuncts used in neurovascular surgery. (a) Appearance of arteries in the microscope FL800 after administration of indocyanine green; (b) microscopic view under white light of clipped basilar tip aneurysm; (c) microscopic view using dual-image videography after administration of indocyanine green; (d) neuroendoscope; (e) intraoperative neuromonitoring

Table 2: Pre-operative neuroimaging and findings

ID	Preoperative Neuroimaging	Size of aneurysm (mm)	Projection	Other findings (Aneurysm/fetal Pcom)
A	CTA	3.5	Superior	Small Acom
B	MRI/MRA, CTA	4	Superior-posterior	IC-Acho, Fetal Pcom
C	MRI/MRA, DSA	3	Superior-anterior	None
D	MRI/MRA, CTA, DSA	4	Superior-anterior	None
E	MRI/MRA, CTA, DSA	7	Superior-left lateral	MC, IC-Pcom, MC-IC junction, AC, IC-Acho
F	MRI/MRA, DSA	6	Superior	IC
G	MRI/MRA, CTA	6.5	Superior-anterior	MC
H	MRI/MRA, CTA	7	Superior	Fetal Pcom
I	MRI/MRA, CTA	3	Superior-posterior	None

MRI=Magnetic resonance imaging, MRA=Magnetic resonance angiography, CTA=Computed tomography angiography, DSA=Digital subtraction angiography, Acom=Anterior communicating, IC=Internal carotid, Acho=Anterior Choroidal, Pcom=Posterior communicating, MC=Middle cerebral

Table 3: Analysis of diameter of the posterior cerebral artery and basilar artery and their flow rate in reference to the size of aneurysm

ID	Diameter (mm)						Size of aneurysm (mm)	Flow rate (ml/min)					
	BA	Left PCA	Right PCA	BA/left PCA	BA/right PCA	BA/AVD		BA	Left PCA	Right PCA	BA/left PCA	BA/right PCA	BA/AVD
A	2.8	2	2.2	1.40	1.27	1.34	3.5	49	29	20	1.69	2.45	2.07
B	3	2.3	2	1.30	1.50	1.40	4	57	34	22	1.68	2.59	2.13
C	2.6	1.7	1.6	1.53	1.63	1.58	3	39	21	18	1.86	2.17	2.01
D	2.8	2.6	2.4	1.08	1.17	1.12	4	47	26	22	1.81	2.14	1.97
E	3.6	2.7	3.1	1.33	1.16	1.25	7	104	41	63	2.54	1.65	2.09
F	2.6	1.4	2.2	1.86	1.18	1.52	6	37	8	26	4.63	1.42	3.02
G	2.2	1.4	1.7	1.57	1.29	1.43	6.5	22	8	14	2.75	1.57	2.16
H	3	2.4	1.2	1.25	2.50	1.88	7	58	52	5	1.12	11.6	6.36
I	3	2.4	2.1	1.25	1.43	1.34	3	60	33	24	1.82	2.50	2.16
Mean	2.84	2.10	2.06	1.40	1.46	1.43	4.89 (mean) 4.0 (median)	52.6	28.0	23.8	2.21	3.12	2.66

AVD – Average; BA – Basilar artery; PCA – Posterior cerebral artery baseline MEP recordings were achieved within minutes from the initial changes without any neurological sequale postoperatively. The median duration of surgery was 292 min (IQR = 237.5–350.5 min).

All patients were extubated immediately postoperatively and ambulated on day 1 postoperatively. The median days of hospitalization were 12 days (IQR = 12–25 days). On follow-up, both patients who developed oculomotor nerve palsy had achieved complete neurological recovery at the 6th and 8th months postoperatively [Table 4]. Delayed complication was found in one patient who developed postoperative hydrocephalus. She was treated with a lumboperitoneal shunt placement. Another patient developed delayed chronic subdural hematoma formation ipsilateral to the side of surgical site and treated with subdural drainage with uneventful admission [Table 5]. The morbidity of the surgeries was 33.3% without any permanent neurological deficits. There was no mortality recorded in this case series.

Case illustration 1

A 55-year-old female with no known medical illness presented with incidental finding of anterosuperior pointing basilar tip aneurysm during brain screening program using magnetic resonance angiography (MRA) [Figure 4]. She was not a smoker or alcoholics. She had been screened for suitability of endovascular treatment earlier. However, due to findings of narrow distance between perforators and the aneurysm sac, she was referred for microsurgical clipping. The left P1 was noted to be dominant. She was admitted electively on August 12, 2017. A CFD performed showed high wall pressure and low wall shear stress (WSS) pressure within the aneurysmal sac [Figure 5]. She underwent left anterior temporal craniotomy clipping of the aneurysm. The duration of the surgery was 4 h and 27 min. Intraoperative indocyanine green (ICG) (DIVA) [Figure 6], neuroendoscope [Figure 7], and MEP monitoring were used. She was discharged 12 days later with no deficits. Her 3rd-month follow-up on November 28, 2017, and MRI

Table 4: Surgical approaches and their findings

ID	Laterality, approach	Duration of surgery (min)	MEP		Intraoperative difficulty	Postoperative complication
			Intraoperative	Postoperative		
A	Left pterional	332	MEP not used	MEP not used	None	None
B	Left anterior temporal	190	MEP not used	MEP not used	None	None
C	Right anterior temporal	341	MEP not used	MEP not used	Low positioned BA tip aneurysm requiring posterior clinoidectomy	Transient oculomotor nerve palsy
D	Right anterior temporal	208	Decreased amplitude	Returned to baseline	ICG-confirmed perforating branch	None
E	Left anterior temporal	271	No change	No change	None	None
F	Left anterior temporal	360	No change	No change	None	None
G	Right anterior temporal	455	MEP disappeared	75% of baseline	Mobilized ICA with anterior clinoidectomy and low positioned BA tip aneurysm (posterior clinoidectomy)	Transient oculomotor nerve palsy
H	Left anterior temporal	292	No change	No change	None	None
I	Left anterior temporal	267	No change	No change	Many penetrating branches	None

MEP – Motor-evoked potential; ICG – Indocyanine green; ICA – Internal carotid artery; BA – Basilar artery

Table 5: Follow-up records

ID	Postoperative vascular study	Findings	Glasgow Outcome Scale		Other delayed complications requiring surgical intervention
			3 months	6 months	
A	None	None	5	5	None
B	MRI/MRA	No ischemic change/no residual aneurysm	5	5	None
C	None	None	5	5	None
D	None	None	5	5	None
E	None	None	5	5	Delayed hydrocephalus that underwent LP shunt
F	MRI/MRA, CTA	No residual aneurysm, clipping of MCA aneurysm on May 3, 2018	5	5	None
G	MRI/MRA	No ischemic change/no residual aneurysm	5	5	Delayed onset of right CSDH at 5 months postoperatively, drainage; uneventful
H	MRI/MRA, CTA	No ischemic change/no residual aneurysm	5	5	None
I	MRI/MRA	No ischemic change/no residual aneurysm	5	5	None

MRI – Magnetic resonance imaging; MRA – Magnetic resonance angiography; CTA – Computed tomography angiography; MCA – Middle cerebral artery; LP – Lumboperitoneal; CSDH – Chronic subdural hematoma

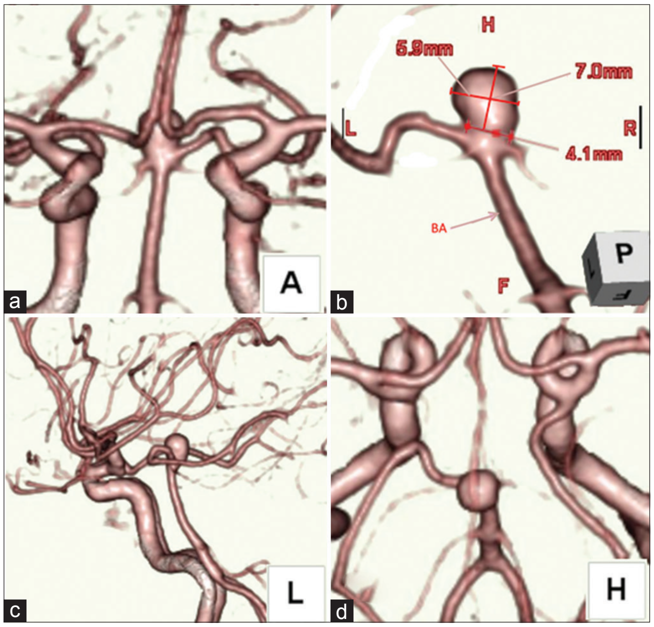

Figure 4: Preoperative three-dimensional computed tomography angiography on July 5, 2017. (a) Anteroposterior view; (b) measurement of the basilar tip aneurysm; (c) left lateral view; (d) head view

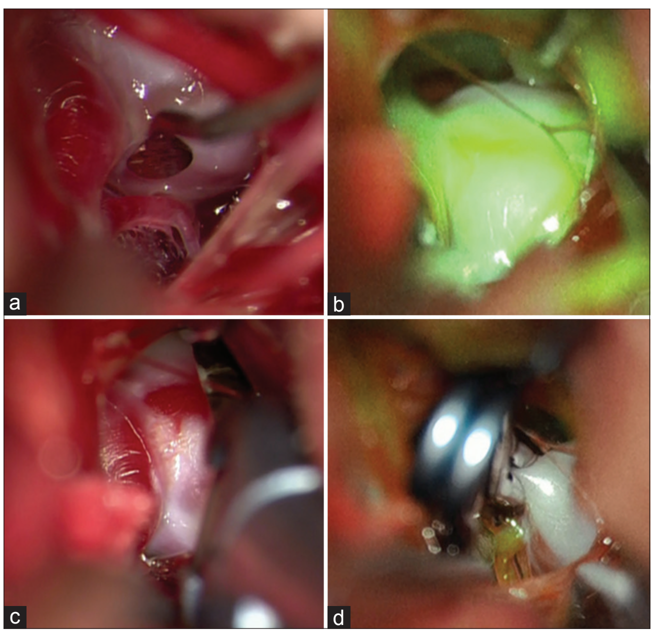

Figure 6: Intraoperative microscopic view. (a) Blunt dissection of the perforators from the wall of the aneurysm; (b) dual-image videoangiography used to inspect the sac of the aneurysm prior to clip application; (c) application of the aneurysmal clip; (d) repeat dual-image videoangiography slowing total occlusion of the sac of the aneurysm, and blood flow in all the perforators is preserved

performed on the same day revealed a small right M1 saccular aneurysm [Figure 8]. Postoperative CFD showed reduction in the wall pressure of the basilar bifurcation with remaining low WSS pressure and improved WSS vectors and streamline [Figure 9]. It also demonstrated an improvement in the diameter of right P1 due to improved

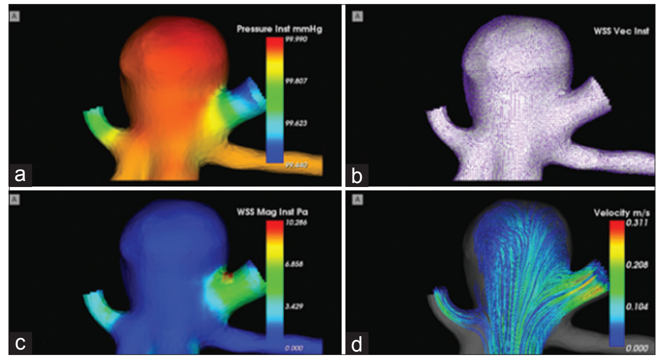

Figure 5: A computational fluid dynamic. (a) High wall pressure within the sac of the aneurysm; (b) wall shear stress vector showing change in the direction of angle of the vectors at the neck and sac of the aneurysm in comparison with the vectors in the bifurcation; (c) wall shear stress pressure showing a low wall shear stress pressure within the aneurysmal sac, suggestive of low flow within the aneurysmal sac with high risk of rupture in a narrow neck and small saccular aneurysm; (d) streamline showing low velocity within the sac of the aneurysm with comparison to the velocity with both P1

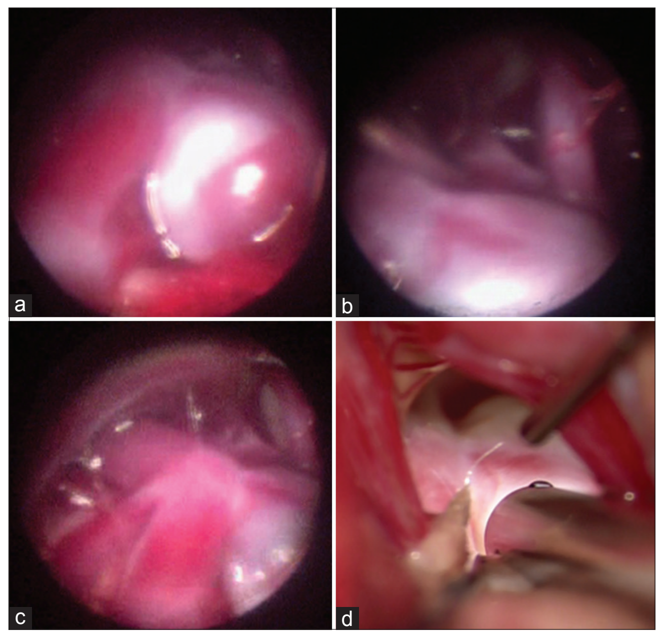

Figure 7: Intraoperative images. (a) Neuroendoscopic view on the neck of aneurysm showing a perforator on the ipsilateral wall of the sac of the aneurysm; (b) neuroendoscopic view of contralateral posterior cerebral artery (P1 segment) with a perforator crossing at the junction between right P1 and the neck of the aneurysm; (c) Neuroendoscopic view of the ipsilateral P1 and superior cerebellar artery; (d) microscopic view of the position of the neuroendoscope during inspection of aneurysmal sac and its surrounding structures with the neuroendoscope

blood flow within it. This is evident by the reduction in the ratio between velocity in basilar artery and the average velocity within both P1 [Table 6]. Otherwise, she was well with no complaints. She was planned for follow-up CTA in 1-year time. During her 6th month follow-up, she was asymptomatic. She was scheduled for repeat CTA on November 2, 2018.

Case illustration 2

A 56-year-old female with a history of Grave's disease 20 years ago presented to Banbuntane Hospital, Nagoya, on January 26, 2016, with incidental findings of multiple intracranial aneurysms. She was diagnosed to have basilar tip, internal carotid-anterior choroidal, and middle cerebral artery aneurysms since 5 years prior to the referral. She was asymptomatic of Grave's disease since she has been on regular medications and follow-up by the endocrinologist. Initial MRA done on September 25, 2012, and DSA done on November 14, 2012, revealed basilar tip saccular aneurysm measuring 4.2 mm × 6.2 mm. She was not keen for any treatment at that moment. Follow-up CTA done on January 26, 2016, revealed enlarging superior pointing aneurysm measuring 5.8 mm × 6.2 mm [Figure 10]. A CFD was performed showed high wall pressure and low WSS pressure within the aneurysmal sac [Figure 11]. She was admitted on February 12, 2017. She underwent left anterior temporal craniotomy and clipping of basilar tip and left MCA aneurysms [Figure 12]. The surgery was uneventful with duration of 6 h. MEP monitoring and ICG (DIVA) and neuroendoscope were used during the surgery [Figure 13]. However, she had prolonged hospitalization due to respiratory dysfunction caused by her underlying disease. She was discharged 34 days later. She was asymptomatic for any neurological issue during 3-month follow-up on November 5, 2017. Postoperative MRA on June 16, 2017, and CTA on January 15, 2018, did not reveal any residual basilar tip aneurysm [Figure 14]. CFD study revealed improvement in the streamline and WSS vectors at the bifurcation with no area and high wall pressure despite the WSS pressure remained low at the bifurcation [Figure 15]. There was a reduction in the ratio between velocity in basilar artery and the average velocity within both P1 [Table 6]. She was readmitted recently on May 3, 2018, for elective clipping of the MCA aneurysm. The surgery was uneventful and she was discharged well.

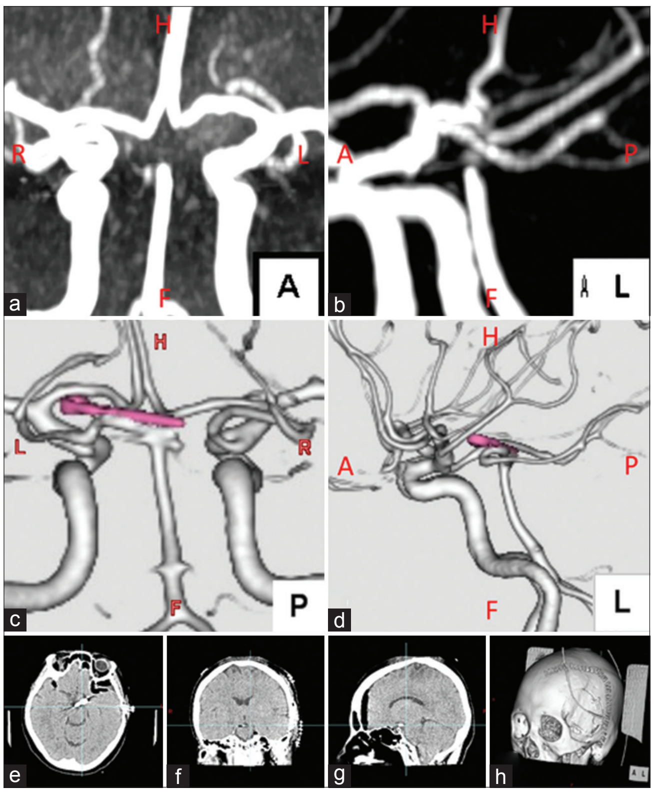

Figure 8: Postoperative imaging: (a) Anterior view of the magnetic resonance angiography showing no residual aneurysm; (b) Lateral view of the magnetic resonance angiography showing no residual aneurysm; (c) posterior view of the computed tomography angiography showing the position of the aneurysmal clip with no residual aneurysm; (d) lateral view of the computed tomography angiography showing the position of the aneurysmal clip with no residual aneurysm; (e-h) axial, coronal, sagittal, and three-dimensional skull views of the postoperative computed tomography scan of the brain

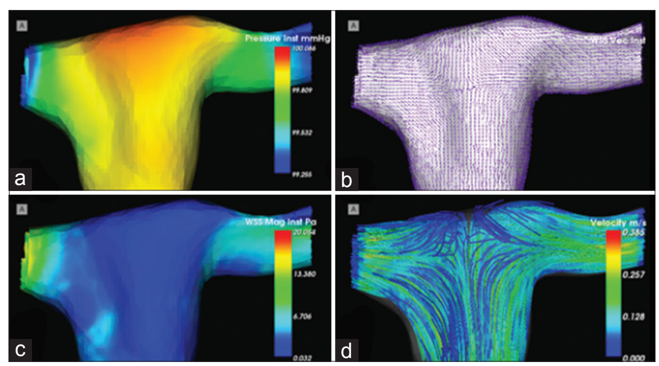

Figure 9: A computational fluid dynamic. (a) Lower wall pressure at the bifurcation of the basilar artery; (b) wall shear stress vector showing improved vectors at the bifurcation and no convergent vectors are seen; (c) wall shear stress pressure showing a low wall shear stress pressure at the bifurcation; (d) streamline showing low velocity at the midline of the bifurcation but improved streamline at the peripherals with improved velocity and lamina flow within right P1 segment

Table 6: Comparison between pre- and post-operative data shown in two illustrated cases

ID	Diameter (mm)						Size of aneurysm (mm)	Flow rate (ml/min)					
	BA	Left PCA	Right PCA	BA/left PCA	BA/right PCA	BA/AVD		BA	Left PCA	Right PCA	BA/left PCA	BA/right PCA	BA/AVD
Case 1 pre	3	2.4	1.2	1.25	2.50	1.88	7	58	52	5	1.12	11.6	6.36
Case 1 post	3.6	2.1	2.2	1.71	1.64	1.68	No residual	100	40	47	2.5	2.13	2.32
Case 2 pre	2.6	1.4	2.2	1.86	1.18	1.52	6	37	8	26	4.63	1.42	3.02
Case 2 post	2.7	2.1	3.0	1.29	0.90	1.10	No residual	42	11	30	3.82	1.4	2.61

AVD – Average; BA – Basilar artery; PCA – Posterior cerebral artery

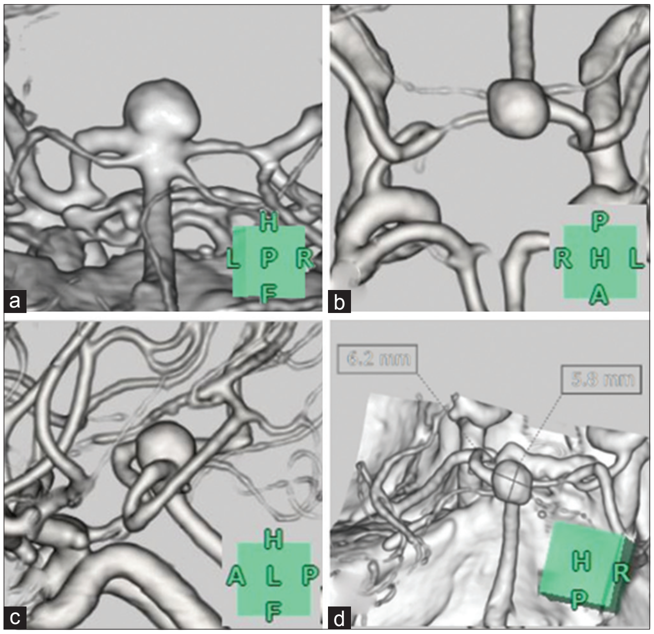

Figure 10: Computed tomography angiography showing a saccular aneurysm at the basilar tip measuring 6.2 mm × 5.8 mm. (a) Posterior view; (b) head view; (c) left view; (d) head view

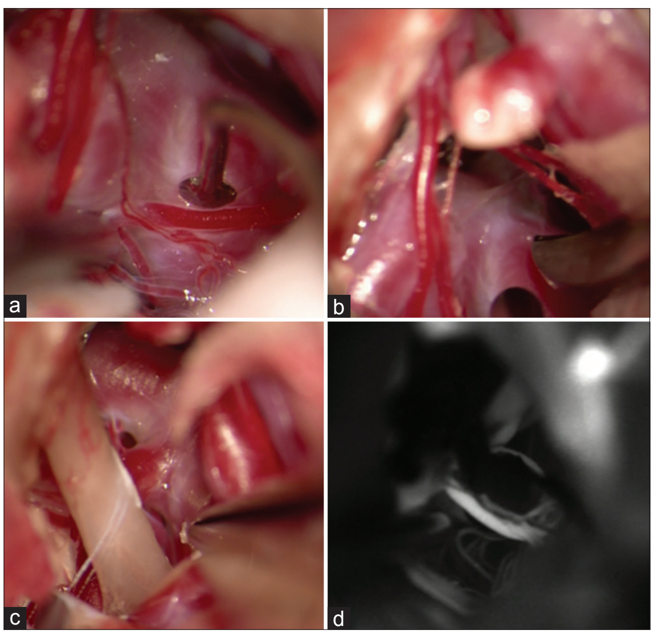

Figure 12: Intraoperative microscopic view. (a) Blunt dissection of the perforators from the ipsilateral wall of the aneurysm; (b) sharp dissection of the arachnoid surrounding the sac of the aneurysm with saccular aneurysm of middle cerebral artery seen; (c) inspection of the ipsilateral anterolateral wall of the neck of the aneurysm; (d) intraoperative angiography using indocyanine green in the microscopic view showing total occlusion of the sac of the aneurysm and preservation of blood flow in all the surrounding perforators

Discussion

A population-based, prospective angiographic study had demonstrated that about 20% of patients have more than one aneurysm.[4] In our cohort, there were five out of nine patients (55.6%) with multiple intracranial aneurysms.

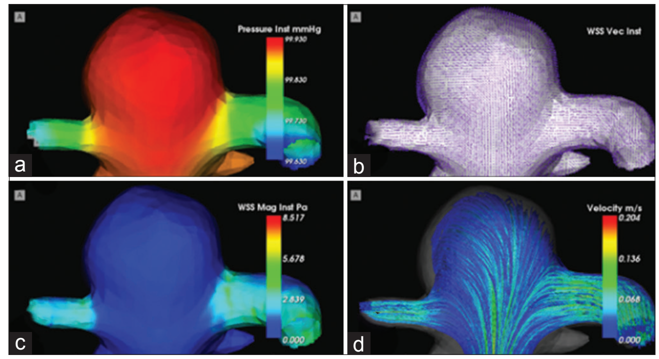

Figure 11: A computational fluid dynamic performed showing high wall pressure and low wall shear stress pressure within the aneurysmal sac before surgery. (a) High wall pressure; (b) convergent wall shear stress vectors within the aneurysmal sac; (c) low wall shear stress pressure suggestive of low flow within the sac if the aneurysm; (d) nonlamina streamline within the sac of the aneurysm

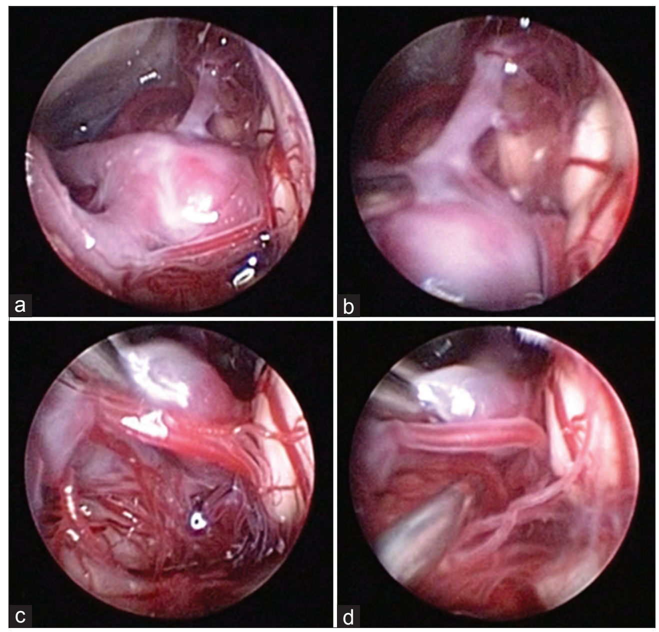

Figure 13: Intraoperative neuroendoscopic images. (a) A perforator at the proximal left posterior communicating artery (P1 segment) located just after the sac of the aneurysm; (b) contralateral posterior cerebral artery (P1 segment) with a perforator crossing at the junction between right P1 and the neck of the aneurysm; (c) postclipping with the inspection of the ipsilateral anterior aspect of all the perforators; (d) inspection of the neck of the aneurysm to ensure complete occlusion of the aneurysm

Preoperative workup is essential following initial screening. Computed tomography angiography (CTA) offers high sensitivity and specificity with accurate information in the size, volume, and characteristic of the aneurysmal wall, the surrounding perforators, and veins.[8] This allows neurosurgeons to perform surgical planning without the need of more invasive DSA. The imaging data which are stored in the Digital Imaging and Communications in Medicine can be used in the CFD study as compared to DSA. In this case series, there were only four patients (44.4%) who had undergone preoperative DSA studies.

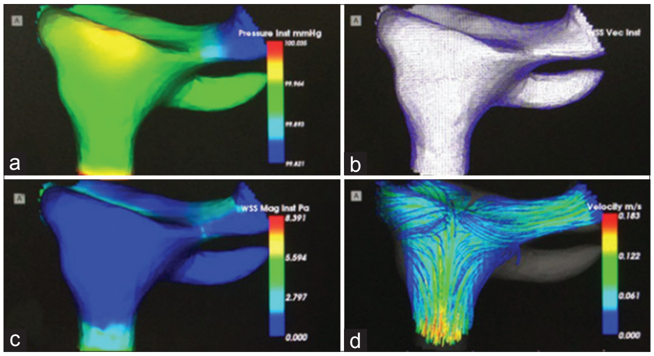

Figure 14: A computational fluid dynamic. (a) Lower wall pressure at the bifurcation of the basilar artery; (b) wall shear stress vector showing improved vectors at the bifurcation and no convergent vectors are seen; (c) wall shear stress pressure showing a low wall shear stress pressure at the bifurcation; (d) streamline showing improved streamline at the bifurcation with improved velocity toward both P1

The CFD study allows us to identify the flow within the aneurysmal sac and the proximal and distal vessels. It also allows us to determine the weak point on the surface of the aneurysmal sac which may cause intraoperative rupture during surgical procedure. The pressure exerted on the intracranial aneurysmal wall can be determined in comparison to its proximal and distal vessels. High wall pressure and low WSS pressure with convergent WSS vectors are usually suggestive of wall with a high risk of rupture. The streamline within the vessels and aneurysm sac can also be studied. In the preoperative simulation planning, consideration should be made to have a direct visualization of the weak point in the aneurysm which is essential to enable easy bleeding control if it ruptures. Postoperative CFD study allows study on the change of hemodynamics of blood stream to be conducted. In the two case illustrations, findings of increased diameter and rate of blood flow in the P1 segment of the nondominant PCA postclipping of basilar tip aneurysm were noted. Following the obliteration of aneurysmal sac, the laminar blood flow is restored. This eventually improves the perfusion to the brain.

Alternatively, high-resolution T1-weighted and steady-state free precession image can be used to determine semi-quantitative aneurysmal wall thickness. This technique can also be utilized in determining the presence of surrounding cerebrospinal fluid which may indicate arachnoid plane between the aneurysmal sac and the brain structure.[9] If a dynamic flow study is warranted in certain cases, a 3D DSA offers greater advantages to the neurosurgeons in comparison to 2D DSA. The 3D DSA allows anatomical correlation and due to its 3D visualization, it has becoming an essential imaging study for preoperative planning.[10]

In general, for a cohort of population with unruptured intracranial aneurysm, predictors of poor surgical outcome include aneurysmal size, posterior circulation especially basilar tip, a history of ischemic cardiovascular diseases, and the presence of aneurysmal symptoms other than rupture.[11] Surgical approaches must be based on some principles of guidance. For skull-base extra-axial lesion such as intracranial aneurysm, approach should be directed toward the existing surgical corridor. A proper arachnoid dissection and separation between structures such as arteries, veins, and between two lobes and nerves will allow more clearer pathway toward the target. A previous thought of having the shortest route and hence spending minimal time to reach a target as the best surgical strategy mentioned in an article[12] may not be so true if the selected path needs a remarkable degree of brain retraction. The advancement in microneurosurgical techniques and instruments allows neurosurgeons to do sufficient arachnoid dissection without compromising any neural tissues and blood vessels.

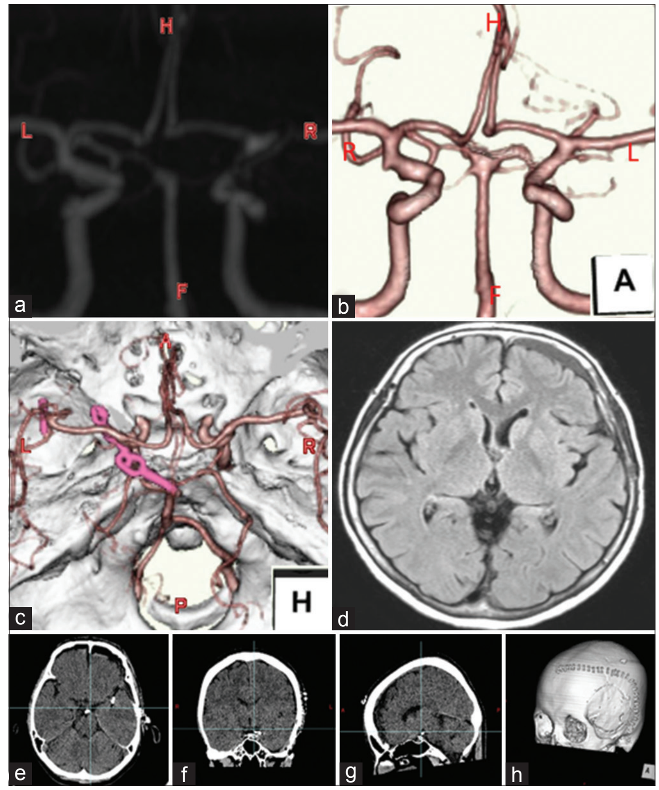

Figure 15: Postoperative imaging. (a) Anterior view of the magnetic resonance angiography showing no residual aneurysm; (b) anterior view of the three-dimensional computed tomography angiography showing no residual aneurysm; (c) head view of computed tomography angiography with bone at the skull base showing position of both aneurysmal clips at the middle cerebral artery and basilar tip; (d) postoperative magnetic resonance imaging fluid-attenuated inversion recovery sequence with no flair signal seen in the brain; (e-h) axial, coronal, sagittal, and three-dimensional skull views of the postoperative computed tomography scan of the brain

An institution in the United States of America advocates the use of dynamic brain retraction system than rigid brain retraction.[13] In our opinion, with good brain relaxation therapy, optimal positioning of the patient's head and body, good arachnoid dissection, drainage of cerebrospinal fluids, adequate bone opening, and removal with the right selection of surgical pathway or corridor to the lesion, the use of brain retraction can be negligible. Sometimes, a suction device can also act as a dynamic retraction system during surgery. In our case series, none of the patients developed brain parenchymal lesion following surgery when we reviewed all the postoperative CT scans of the brain.

Preoperative simulation has becoming an essential step in the preoperative planning. This simulation allows neurosurgeons to visualize structure which may obscure the path toward the targeted lesion or structure. While structures such as temporal or frontal lobes can be displaced quite distant from their original anatomical position with proper arachnoid dissection, this may not be so true to some other structures such as cranial nerves and ICA. Some institutions which have intraoperative CT facility and neuronavigation system can utilize the integration of intraoperative CTA with preoperative CTA or MRA and the operating neurosurgeon can visualize those images from the microscope eyepieces.[14] In our opinion, a good understanding and knowledge in neuroanatomy and a thorough study of individual preoperative 3D imaging may be sufficient in order to determine best patient's head position on the operating table and bone opening to reach the target with fewer difficulties. There are limitations in both preoperative neuroimaging and intraoperative CTA as small vessels or perforators may not be identified or be visualized in those images. In order to identify and secure all perforators during surgery, intraoperative adjuncts such as the intraoperative DIVA (which utilizes the intravenous injection of ICG) and high-magnification operating neuromicroscope and neuroendoscope allow thorough inspection of any of the vascular structures surrounding the neck and the sac of the aneurysm.

Anterior clinoidectomy and opening dura ring may be necessary in some cases when mobilization of the ICA is necessary. This is to allow the visualization of the neck of aneurysm which is blocked by the ICA. Posterior clinoidectomy is performed if the basilar tip is located at a lower position. The direct visualization of the neck of the basilar tip aneurysm is essential. Inspection and release of any surrounding perforators surrounding the aneurysm is important. Injury to even the smallest perforator may be catastrophic to the patient.

Embolization offers greater comfort to patients with such disease as no open surgery is required. Nevertheless, the procedure poses a high degree of risk and considered as an invasive and blind procedure. Medicolegal implications which are faced by the endovascular specialists due to procedural complications have been a great concern in some of the recent publications.[15]

The introduction of minimally invasive techniques allows not only the neurosurgeons to explore new surgical corridors, but also to achieve minimized blood loss and maximal postoperative complication avoidance. Endovascular coiling is a reasonable alternative to microsurgical clipping in those patients who are at higher risk for open surgery such as the elderly and medically ill and its anatomical position in an unfavorable situation such as posterior projection of basilar tip aneurysm.[6]

In basilar trunk and tip aneurysms, the major disadvantage of endovascular technique with stent-assisted coiling is the risk of compromising blood flow to the perforators. The occlusion rate of basilar tip aneurysm coiling was poor as reported in a retrospective cohort study with 92% occlusion rate in aneurysm size <10 mm but as low as 61% occlusion rate in the remaining patients with aneurysmal size 10 mm and above.[16]

A proper preoperative planning allows good decision-making if such patients are good candidates for open surgeries. It also allows the neurosurgeon to determine the best entry from the skull base to the basilar tip aneurysm. Besides the skull-base bony structure, the position of other structures such as posterior cerebral arteries, perforators from the basilar artery, posterior communicating artery, and ICA is best to be identified in the preoperative simulation technique to avoid unnecessary difficulty while in actual surgery. In some institutions, biomodel utilizing 3D print technology is used for such preoperative surgical simulation.[17]

Although the number of cases treated as shown in this article is small, it gives us the opportunity to revisit our pioneer role as a neurosurgeon by offering microsurgical treatment to those patients suffered from this disease. The transformation of microsurgical techniques and skills, along with the advancements in surgical microinstruments and surgical adjuncts such as neuroendoscope, intraoperative angiography, intraoperative neuromonitoring, and hemostatic agents, allows microsurgical treatment rendered to each individual patients to be at their advantages.

There was no mortality reported in this case series. Transient oculomotor palsy is common in the surgery of basilar tip aneurysm. This case series reported two cases (22.2%) with such morbidity but fully recovered in 6 and 8 months. This is much lower than the published series with no mortality been reported.[18]

Conclusion

Microsurgical clipping of basilar tip aneurysm is safe in unruptured basilar tip aneurysm even in the elderly patients. All complications reported in this case series were transient with no long-term sequelae. Surgical adjuncts such as intraoperative neuromonitoring, intraoperative angiography, and neuroendoscope are important for such surgery. The improved safety profile of microsurgical technique is due to the availability of neuroendoscope, ICG, and DIVA. These multimodality techniques in microsurgical clipping of basilar tip aneurysm enable neurosurgeons to perform minimally invasive surgery. The application of multimodality technique in neurovascular surgery has also helped to achieve complication avoidance. Hence, microsurgical clipping of most basilar tip aneurysms is safe with low risk of postoperative mortality or morbidity. The obliteration of the aneurysmal sac helps to restore the laminar blood flow and improves the brain perfusion.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed

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Conflicts of interest

There are no conflicts of interest.

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