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Original Article

Postcontrast CT to Estimate Arteriosclerotic Stenosis at the Site of Occlusion before Emergency Endovascular Treatment for Vertebral–Basilar Artery Occlusion

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Objective: Thrombectomy may be an effective therapy for vertebrobasilar artery (VBA) occlusion in addition to carotid or middle cerebral artery occlusion. Underlying arterial stenosis can be a cause of failure in thrombectomy; however, it is difficult to identify candidates with VBA occlusion before thrombectomy. The purpose of our study was to investigate whether postcontrast computed tomography (pcCT) is useful for identifying candidates with VBA occlusion for thrombectomy.
Methods: In this retrospective study, we included patients who 1) were admitted to our institution between January 1, 2013, and July 1, 2019; 2) underwent pcCT; and 3) underwent emergency endovascular therapy for VBA occlusion. We defined no opacification of the top of the basilar artery (BA) in reconstructed coronal images of pcCT scans as distal BA occlusion and opacification of the top of the BA as distal BA open. We assessed the presence of underlying arterial stenosis at the site of occlusion according to angiographic findings during endovascular procedures. We also evaluated the relationship between the distal BA findings and the presence of underlying arterial stenosis.
Results: Thirty-two patients met our inclusion criteria and were analyzed. Among 19 patients with distal BA occlusion, none (0%) had ischemic stroke with underlying arterial stenosis. Among 13 patients with distal BA open, 4 (31%) were diagnosed with ischemic stroke without underlying arterial stenosis and 9 (69%) with underlying arterial stenosis ($p < 0.001$).
Conclusion: Distal basilar-artery findings in reconstructed coronal postcontrast CT images were useful for identifying candidates with VBA occlusion for thrombectomy.

Keywords ▶ vertebrobasilar artery occlusion, endovascular thrombectomy

Introduction

Acute basilar artery (BA) occlusion accounts for approximately 1% of all patients with cerebral infarction and approximately 8% of those with symptomatic cerebral infarction involving the vertebral–BA region.[1–3] The mortality rate related to a serious condition is approximately 40%.[4] The efficacy of mechanical thrombectomy for anterior circulation major artery occlusion was previously demonstrated,[5,6] and this procedure has become the standard treatment. Its efficacy for posterior circulation acute ischemic stroke has also been suggested,[7] but several studies reported that the addition of percutaneous transluminal angioplasty (PTA) was necessary when arteriosclerotic stenosis was detected at the site of occlusion during mechanical thrombectomy.[8–10] The presence of arteriosclerotic stenosis at the site of occlusion prevents early recanalization. This study investigated the usefulness of preoperative postcontrast computed tomography (pcCT) for the diagnosis of vertebral/BA occlusion and estimation of the presence of arteriosclerotic stenosis at the site of occlusion.

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Materials and Methods

In this retrospective cross-sectional study, we included acute ischemic stroke patients who 1) were brought to our center between January 1, 2013, and July 1, 2019; 2) underwent emergency pcCT, leading to a diagnosis of vertebral/BA occlusion; and (3) underwent emergency endovascular

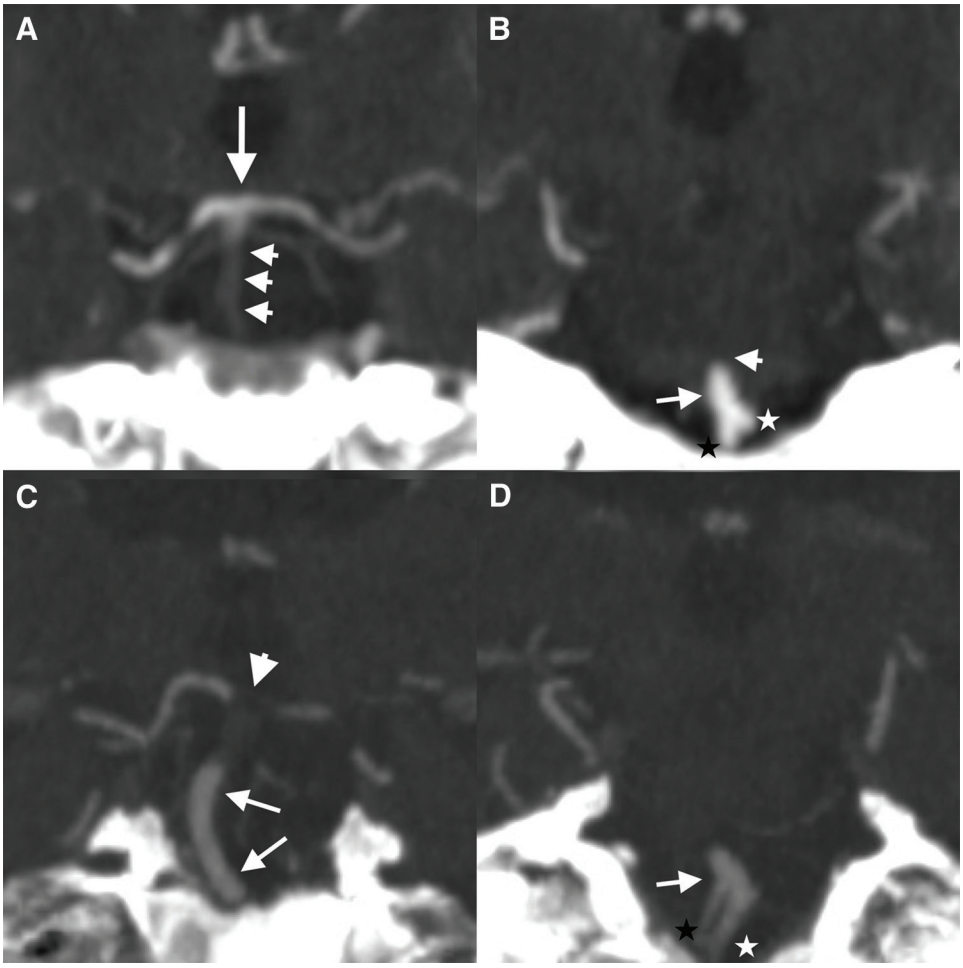

Fig. 1 Coronal sections on postcontrast CT in a patient in whom the BA end was patent (Case 1). (**A**) The BA end was sufficiently visualized (arrow). The center of the BA was insufficiently visualized (arrow heads). (**B**) The BA was occluded at its distal end (arrow head), but the proximal segment (arrow) and bilateral vertebral arteries (black asterisk: right vertebral artery, white asterisk: left vertebral artery) were sufficiently visualized. Coronal sections on postcontrast CT in a patient in whom the BA end was occluded (Case 2). (**C**) The BA end was not visualized (arrow head). The central and proximal (arrows) areas of the BA were sufficiently visualized. (**D**) The BA–vertebral artery confluence (arrow) and bilateral vertebral arteries (black asterisk: right vertebral artery, white asterisk: left vertebral artery) were sufficiently visualized. BA: basilar artery

treatment (mechanical thrombectomy, angioplasty, or thrombolysis). We excluded patients in whom recanalization was not achieved and in whom it was difficult to evaluate the presence of arteriosclerotic stenosis. We examined the relationships of the basic patient information, neurological severity on arrival, previous risk factors for arteriosclerosis, medical history/presence of atrial fibrillation on electrocardiography at the time of arrival, preoperative pcCT findings, angiographic findings, and successful reperfusion with arteriosclerotic stenosis at the site of occlusion.

Postcontrast computed tomography

In the Emergency Outpatient Unit, 4D intracranial imaging was performed following precontrast CT.[11] Subsequently, pcCT from the aortic arch to the head was conducted; intravenous infusion of contrast medium (iopamidol) at 40 mL was started at 3.8 mL/second, followed by the infusion of physiological saline at 30 mL in order to use the total volume of contrast medium. CT of the aortic arch to the parietal region was initiated 13 seconds after the start of contrast-medium infusion (Aquilion PRIME; Canon Medical Systems, Tochigi, Japan).

PcCT classification

Based on preoperative pcCT findings of the aortic arch to head, the subjects were divided into 2 groups: terminal patency (the BA end was enhanced) and terminal occlusion (the BA end was not enhanced). In addition, the latter was

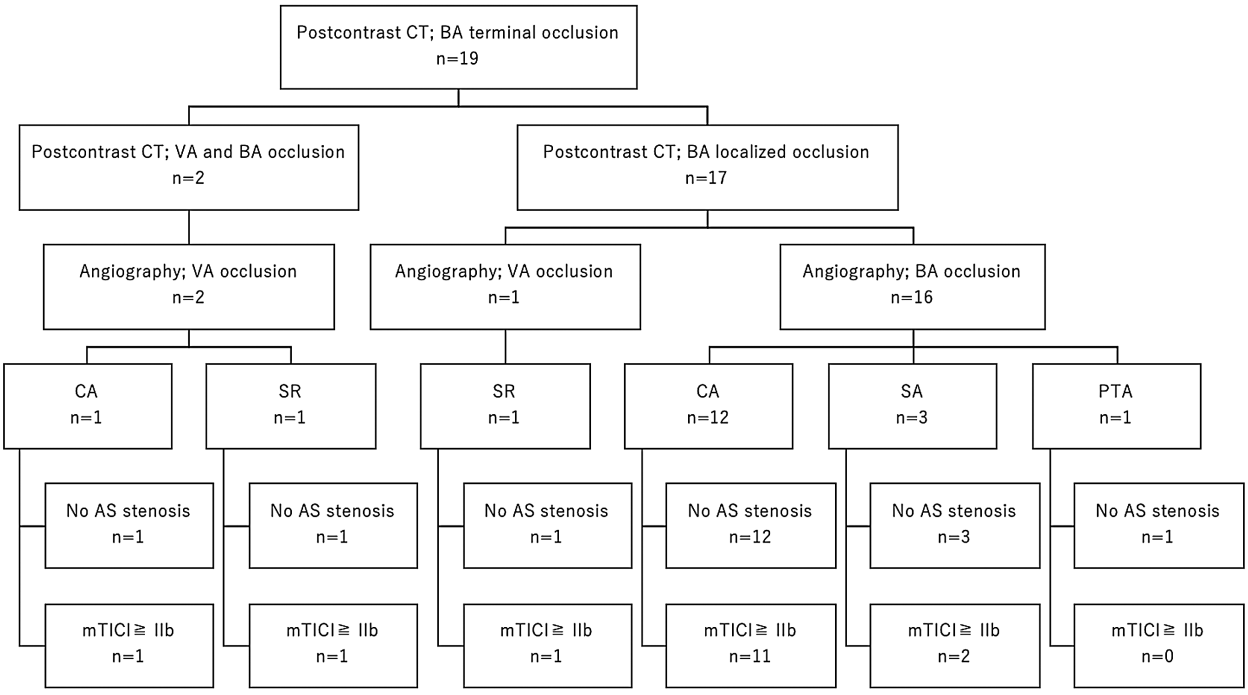

Fig. 2 Relationships among postcontrast CT findings of the vertebral/basilar arteries, angiographic findings, endovascular treatment, AS stenosis, and successful reperfusion in the terminal occlusion group on postcontrast CT. AS: atherosclerotic

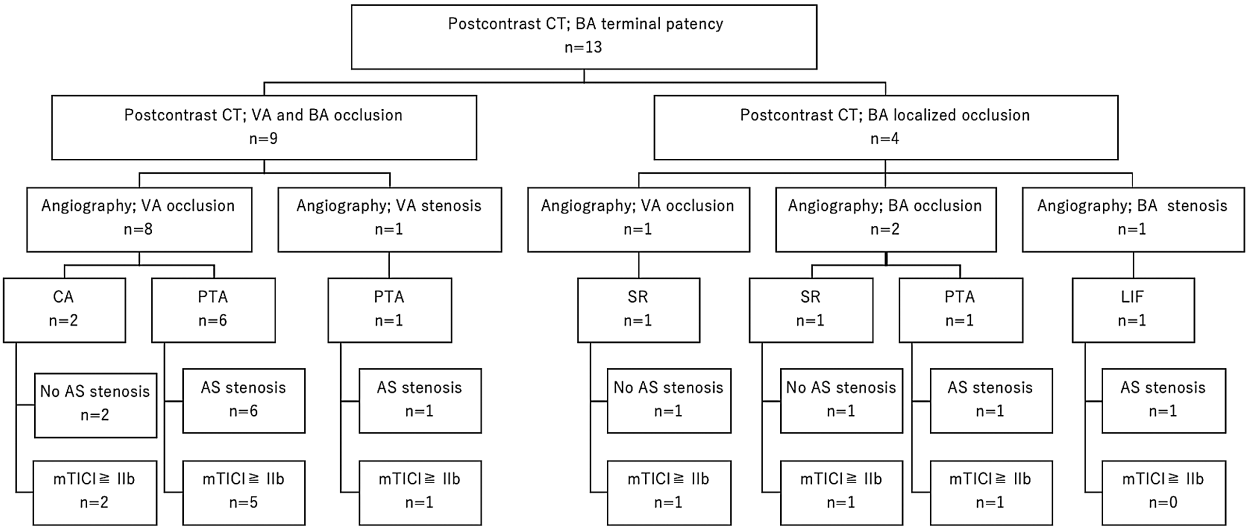

Fig. 3 Relationships among postcontrast CT findings of the vertebral/basilar arteries, angiography findings, endovascular treatment, AS stenosis, and successful reperfusion in the terminal patency group on postcontrast CT. AS: atherosclerotic

divided into 2 subgroups: vertebral/BA occlusion (occlusion involved the vertebral artery) and BA-localized occlusion (occlusion was localized to the BA) (**Figs. 1–3**).

Angiographic findings

Based on diagnostic vertebral arteriography findings, the subjects were divided into 4 groups: angiography-vertebral artery occlusion (the BA distal to the confluence was not visualized due to the stagnation of contrast medium in the vertebral artery), angiography-vertebral artery stenosis (a markedly stenotic lesion of the vertebral artery was present), angiography-BA stenosis (the BA was also visualized by contrast medium), and angiography-BA occlusion (**Figs. 2** and **3**).

Endovascular treatment procedures

The site of occlusion on pcCT was evaluated using diagnostic vertebral arteriography. When angiography demonstrated

Table 1 Criteria for evaluating the presence of arteriosclerotic stenosis at the site of occlusion on postcontrast CT

Final recanalization treatment procedure	Arteriosclerotic stenosis was absent	Arteriosclerotic stenosis was present
Mechanical thrombectomy	Stenosis was absent on angiography before and immediately after surgery	Marked stenosis was present on pre-/intraoperative angiography
Angioplasty	Stenosis was absent on pre-/intraoperative angiography	Marked stenosis was present on pre-/intraoperative angiography
Local thrombolysis	Stenosis was absent on angiography before and immediately after surgery	Marked stenosis was present on pre-/intraoperative angiography

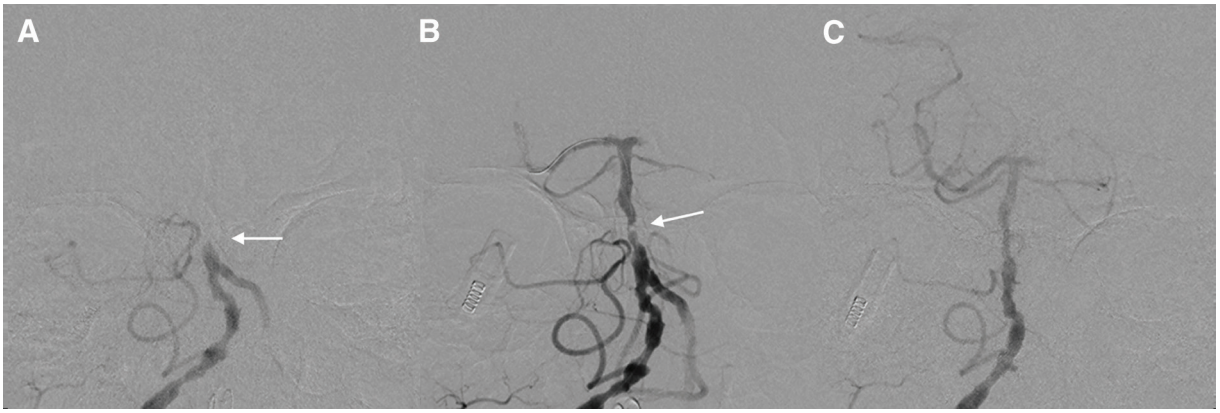

Fig. 4 Angiography (frontal views) for a patient in whom the BA end was patent on postcontrast CT in the same case as Case 1 in **Fig. 1**. (**A**) Diagnostic angiography before treatment. The proximal BA was completely occluded (arrow). (**B**) Immediately after mechanical thrombectomy. Recanalization of the BA was achieved, but marked stenosis remained at the site of occlusion (arrow) and the patient was regarded as having atherosclerotic stenosis. (**C**) PTA was added, leading to sufficient recanalization of the BA. BA: basilar artery; PTA: percutaneous transluminal angioplasty

≥70% stenosis (warfarin-aspirin symptomatic intracranial disease [WASID] method),[12,13] PTA or local intra-arterial fibrinolysis (LIF) was performed. When it demonstrated occlusion, mechanical thrombectomy or PTA was conducted. When sufficient recanalization was not achieved using a single procedure, another procedure for recanalization was added. When combining several procedures, the endovascular treatment procedure performed last was regarded as the final recanalization treatment procedure. It was classified into mechanical thrombectomy (thrombectomy with an aspiration catheter alone: CA, thrombectomy with a stent retriever: SR), PTA, and LIF.

Evaluation of arteriosclerotic stenosis at the site of occlusion (Table 1)

Patients in whom angiography before/during endovascular treatment demonstrated ≥70% stenosis (WASID method) requiring the consideration of PTA at the site of occlusion detected on pcCT were regarded as having arteriosclerotic stenosis at the site of occlusion (**Fig. 4**). Those in whom angiography before/during/immediately after endovascular treatment revealed no stenotic lesion at the site of occlusion detected on pcCT were regarded as having no arteriosclerotic stenosis at the site of occlusion (**Fig. 5**).

Successful reperfusion

Reperfusion was evaluated using the modified Thrombolysis in Cerebral Infarction (mTICI) scale. mTICI IIb to III recanalization was regarded as effective.[14] Patients with mTICI 0 recanalization were excluded from the analysis.

Evaluation

We investigated the relationships of the basic patient information, neurological severity, risk factors for arteriosclerosis, presence of atrial fibrillation, pcCT findings, and angiographic findings with the presence of arteriosclerotic stenosis at the site of occlusion.

Statistical analysis

Differences between unpaired variables were compared using Fisher's exact test for categorical variables. Non-normally distributed continuous variables were expressed as medians and interquartile ranges, and the Mann-Whitney U-test was used to compare unpaired groups. A p-value <0.05 was regarded as significant. For all analyses, we

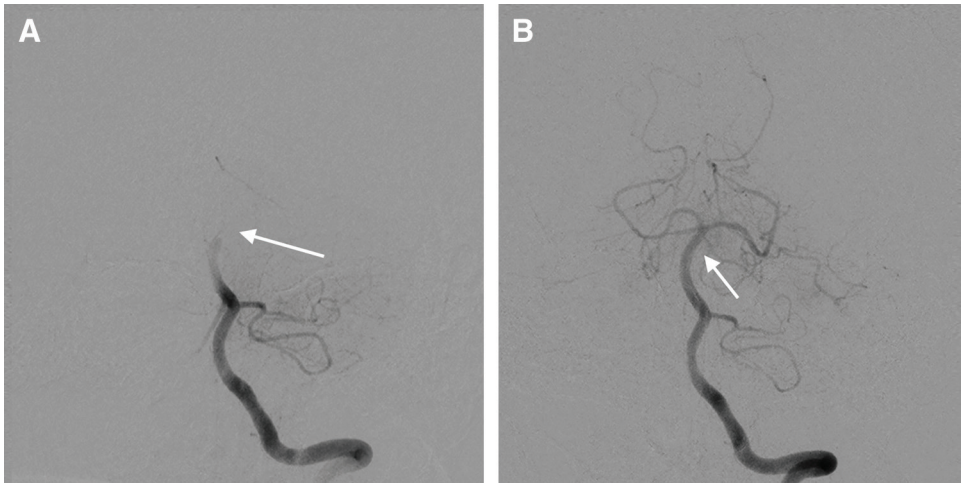

Fig. 5 Angiography (frontal views) for a patient in whom the BA end was occluded on postcontrast CT in the same case as Case 2 in **Fig. 1**. (**A**) Diagnostic angiography before treatment. The center of the BA was completely occluded (arrow), and its periphery was not enhanced. (**B**) Immediately after mechanical thrombectomy. Successful reperfusion of the distal BA was achieved (arrow). There was no residual stenosis. The patient was regarded as having no atherosclerotic stenosis. BA: basilar artery

used the JMP version 14.3.0 software (SAS Institute, Cary, NC, USA).

Ethical approval

All procedures performed in the study were in accordance with the ethical standards of the institution (Shonan Kamakura General Hospital) and with the 1964 Helsinki Declaration. The Tokushukai Group Ethical Committee approved our retrospective analysis (TGE 01285-024). Written informed consent was not required because the data involved routine medical care, the retrospective access to medical records in elderly patients treated previously, and the anonymization of patient identifiers.

Results

During the study period, emergency endovascular treatment for acute ischemic stroke related to vertebral–BA occlusion was performed on 41 patients, among whom, preoperative pcCT was conducted for 34. We analyzed 32 patients (**Table 2**), excluding 2 in whom recanalization at the site of occlusion was not achieved and it was difficult to evaluate the pathogenesis. The median age was 78 years, and there were 22 males (69%). Atrial fibrillation was noted in 12 patients (38%). The underlying diseases consisted of hypertension in 23 patients (72%), dyslipidemia in 14 (44%), and diabetes mellitus in 9 (28%).

PcCT findings

The terminal occlusion group consisted of 19 patients. In 17, the BA end was not visualized. In 2, the vertebral to basilar arteries were not visualized (**Fig. 2**). The terminal patency group consisted of 13 patients. In 9, the vertebral to basilar arteries were not visualized. In 4, a localized site of the BA was not visualized (**Fig. 3**).

Angiographic findings

Of the 19 patients in the terminal occlusion group classified on pcCT, diagnostic angiography demonstrated vertebral artery occlusion in 3 and BA occlusion in 16 (**Fig. 2**). Of the 13 patients in the terminal patency group, diagnostic angiography demonstrated vertebral artery stenosis in 1, vertebral artery occlusion in 8, BA stenosis in 1, and BA occlusion in 2 (**Fig. 3**). Of 12 patients in whom angiography demonstrated vertebral artery occlusion and intracranial information was unable to be obtained, the BA distal to the site of occlusion, involving the BA end, was not visualized on pcCT in 3, whereas the BA end distal to the site of occlusion was visualized in 9 (**Figs. 2** and **3**).

Endovascular treatment procedures and arteriosclerotic stenosis at the site of occlusion (Tables 2 and 3)

In 18 of 19 patients with terminal occlusion on pcCT, mechanical thrombectomy alone was completed and arteriosclerotic stenosis was absent. In 1 patient, mechanical thrombectomy did not lead to recanalization and PTA was

Table 2 Relationship between analytical variable and arteriosclerotic stenosis

Variables	Arteriosclerotic stenosis: present (n = 9)	Arteriosclerotic stenosis: absent (n = 23)	p
Age (median, interquartile range) (years)	75.5 (72.75–85.25)	78.0 (73.00–84.75)	ns
Sex			
Male	7	15	ns
Female	2	8	
NIHSS score (median, interquartile range)	29.5 (21.25–35.00)	31 (9.75–35.5)	ns
Atrial fibrillation			
Present	1	11	ns
Absent	8	12	
Hypertension			
Present	7	16	ns
Absent	2	7	
Dyslipidemia			
Present	2	12	ns
Absent	7	11	
Diabetes mellitus			
Present	1	8	ns
Absent	8	15	
Effective recanalization			
Present (mTICI IIb–III)	7	20	ns
Absent (mTICI I–IIa)	2	3	
Contrast-enhanced CT findings: BA end			
Patent	9	4	<0.001
Occluded	0	19	

BA: basilar artery; mTICI: modified Thrombolysis in Cerebral Infarction; NIHSS, National Institutes of Health Stroke Scale; ns: not significant

additionally performed, but successful reperfusion was not achieved and the procedure was completed. At the site of occlusion, arteriosclerotic stenosis was absent (**Fig. 2**). In 4 of 13 patients with terminal patency on pcCT, mechanical thrombectomy alone was completed and arteriosclerotic stenosis was absent. Of the other 9 patients, PTA was performed on 8 and LIF on 1. However, arteriosclerotic stenosis was present in all 9 patients (**Fig. 3**). In 23 (72%) of the 32 patients, arteriosclerotic stenosis was absent at the site of occlusion on pcCT (**Table 2**).

There was no significant correlation between successful reperfusion and the presence of arteriosclerotic stenosis at the site of occlusion. However, successful reperfusion was achieved in 7 (78%) of 9 patients with arteriosclerotic stenosis and in 20 (87%) of 23 patients without arteriosclerotic stenosis; the successful reperfusion rate was slightly higher in the arteriosclerotic-stenosis-free patients (**Figs. 2** and **3**). Regarding the relationship between successful reperfusion and pcCT findings, successful reperfusion was achieved in 16 (84%) of the 19 patients in the terminal occlusion group and in 11 (85%) of the 13 patients in the terminal patency group; there was no significant difference.

There were no significant associations between the presence of arteriosclerotic stenosis at the site of occlusion and age/sex/presence of risk factors for arteriosclerosis/National Institutes of Health Stroke Scale score/presence of atrial fibrillation (**Table 1**). However, arteriosclerotic stenosis at the site of occlusion was absent in 11 (92%) of 12 patients with atrial fibrillation and in 12 (60%) of 20 patients without atrial fibrillation; the percentage was slightly higher in the former. In the 19 patients with occlusion of the BA end on pcCT, arteriosclerotic stenosis at the site of occlusion was absent (0%). Of the 13 patients with patency of the BA end, arteriosclerotic stenosis was present in 9 (69%). The pcCT findings at the BA end were correlated with the presence of arteriosclerotic stenosis at the site of occlusion ($p < 0.001$) (**Table 2**).

Discussion

This study suggested that arteriosclerotic stenosis is absent at the site of occlusion when the BA end is occluded on preoperative pcCT, whereas it is present when the BA end is patent. In 72% of patients with cerebral infarction in whom pcCT led to a diagnosis of vertebral–BA occlusion, arteriosclerotic stenosis was absent at the site of occlusion. In 28% of patients, it was present at the site of occlusion. The presence of atrial fibrillation was not correlated with

Table 3 Relationship between the final recanalization treatment procedure and arteriosclerotic stenosis

Final recanalization treatment procedure	Arteriosclerotic stenosis: absent	Arteriosclerotic stenosis: present
Mechanical thrombectomy	22	0
Aspiration catheter	15	0
Stent retriever	7	0
Angioplasty	1	8
Local thrombolysis	0	1

the presence of arteriosclerotic stenosis at the site of occlusion, but the incidence of atrial fibrillation (48%) was higher in the arteriosclerotic-stenosis-free group; the relationship between the 2 factors may become significant if the number of patients increases.

A previous study reported that unsuccessful reperfusion led to serious sequelae or death in approximately 80% of patients with marked BA occlusion at the time of onset.[1] Recently, several retrospective studies demonstrated the efficacy of mechanical thrombectomy for posterior circulation major artery occlusion.[7,15,16] Important factors for the favorable prognosis of patients with posterior circulation cerebral infarction included a favorable collateral pathway, narrow extent of occlusion, early reperfusion, and successful state of reperfusion.[7,17–20] In patients with posterior circulation cerebral infarction, atherosclerosis was more frequent than in those with anterior circulation cerebral infarction.[21] In particular, this tendency was more marked in Asians.[2,22] According to several studies using imaging procedures for the diagnosis of BA occlusion, atherosclerotic occlusion was noted in 26% to 36%, embolic occlusion in 30% to 35%, occlusion related to other factors (including vertebral artery dissection) in 6% to 8%, and idiopathic occlusion in 22% to 35%.[1,23] In this study, arteriosclerotic stenosis was present at the site of occlusion in 28% of the subjects; therefore, atherothrombotic infarction may have accounted for approximately 28%.

Before the development of devices for mechanical thrombectomy, the arterial injection of thrombolytic agents or balloon angioplasty had been primarily selected for endovascular treatment regardless of the pathogenesis of cerebral infarction. In 1999, emergency intracranial coronary artery stenting for BA occlusion was reported, but the presence of arteriosclerotic stenosis at the site of occlusion was not reviewed.[24] Recent studies suggested the efficacy of mechanical thrombectomy for anterior circulation major artery occlusion,[5,6] aiding in the establishment of treatment for anterior circulation major artery occlusion. However, several studies reported that the presence of intracranial artery stenosis was involved in unsuccessful mechanical thrombectomy,[25,26] and others suggested the necessity of adding PTA (balloon angioplasty, stenting) for arteriosclerotic stenosis.[8,9] In this study, arteriosclerotic stenosis was absent at the site of occlusion when pcCT demonstrated occlusion of the BA end, whereas it was present at the site of occlusion in 69% of patients when the BA end was patent on pcCT. Thus, if pcCT demonstrates occlusion of the BA end, mechanical thrombectomy for an embolus should be promptly performed. If mechanical thrombectomy does not lead to successful reperfusion after confirming the patency of the BA end on pcCT, the procedure can be promptly switched to PTA through antiplatelet-drug administration without repeating mechanical thrombectomy, considering the presence of arteriosclerotic stenosis.

A previous study reported that the intracranial vertebral artery frequently involved arteriosclerotic stenosis.[27] In this study, arteriosclerotic stenosis at the site of occlusion was present in 7 (64%) of 11 patients with vertebral artery occlusion on pcCT. It was present in 6 (50%) of 12 patients with vertebral artery occlusion on diagnostic angiography; when pcCT or diagnostic angiography demonstrated vertebral artery occlusion, the possibility of arteriosclerotic stenosis at the site of occlusion was high in comparison with the overall rate (28%). In 12 patients in whom diagnostic angiography demonstrated vertebral artery occlusion (**Figs. 2** and **3**), diagnostic angiography provided no information on the development of intracranial collateral pathways distal to the site of occlusion, but pcCT confirmed the patency of the BA end and the occlusion site before endovascular treatment in 9 of the 12 patients. This information was useful for performing a recanalization procedure for the region of occlusion site. To evaluate cerebrovascular occlusion, MRA may be selected, but the signal intensity of slow blood flow is reduced due to the spin saturation phenomenon on 3D time-of-flight imaging, resulting in poor visualization.[28] Therefore, pcCT may be more useful than MRA for accurately evaluating the patency or occlusion of the BA end. In this study, arteriosclerotic stenosis at

the site of occlusion was absent in some patients even in the group in which the BA end was patent on pcCT. If arteriosclerotic stenosis is absent at the site of occlusion, embolus-related occlusion should be initially considered. However, large, hard emboli may have been caught in the blood vessel during migration, leading to occlusion, although emboli reached the BA end in many patients. Furthermore, there was no patient with arteriosclerotic stenosis at the site of occlusion in the terminal occlusion group on pcCT. However, if hypoplasia of the bilateral posterior communicating arteries or insufficient collateral-pathway development is present, the BA end may not be enhanced on pcCT at the time of occlusion due to an arteriosclerotic stenotic lesion on the proximal side of the BA.

In 3 of the 32 patients, the unilateral vertebral artery origin was occluded. In 2 of the 3 patients, the BA end was occluded; vertebral artery stump syndrome might have been present.[29] We performed endovascular treatment through the non-occluded vertebral artery and did not conduct recanalization of occlusion at the origin.

Limitations of This Study

This was a retrospective cross-sectional study involving a small number of Asian patients at a single institution. No other races were examined. A prospective multicenter cooperative study involving an increased number of patients should be performed to confirm our results.

Conclusion

Postcontrast CT before emergency endovascular treatment was useful for diagnosing vertebral-BA occlusion and estimating the presence of arteriosclerotic stenosis at the site of occlusion. If postcontrast CT demonstrates occlusion of the BA end, arteriosclerotic stenosis may be absent at the site of occlusion. If the BA end is patent, arteriosclerotic stenosis may be present at the site of occlusion.

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Disclosure Statement

The authors declare no conflict of interest.

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