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Visibility of the Lesser Sphenoid Wing Is an Important Indicator for Detecting the Middle Cerebral Artery on Transcranial Color-Coded Sonography

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Key Words
Cerebrovascular disease · Lesser sphenoid wing · Middle cerebral artery · Transcranial color-coded sonography · Stroke

Abstract
Background: Failure to detect the sphenoidal segment of the middle cerebral artery (M1) on transcranial color-coded sonography (TCCS) results from either M1 occlusion or an insufficient temporal bone window (TBW). We sought to identify a simple indicator on B mode images for M1 evaluation. ***Methods:*** Consecutive acute ischemic stroke patients with an intact M1 segment underwent prospective TCCS evaluation. Visibilities of the contralateral temporal bone (CTB), midbrain (MB) and lesser sphenoid wing (LSW) on B mode images were defined as follows: 'invisible', 'poor' if the contour was less than 50% visible, 'fair' if more than 50% visible and 'good' if totally visible. M1 detectability on color Doppler images was defined as follows: 'INVISIBLE', 'POOR' if the M1 was detected as color dots, 'FAIR' if linearly but discontinuously detectable, and 'GOOD' if linearly and continuously detectable. The relationship between each structure's visibility and M1 detectability was assessed. ***Results:*** Seventy-six patients with 152 TBWs were evaluated. The CTB was 'invisible' in 2%, 'poor' in 22%, 'fair' in 36% and 'good' in 40%. Visibility of the MB was 36, 24, 26 and 14%, respectively. Visibility of the LSW was 16, 22, 29 and 32%, respectively. The M1 was 'INVISIBLE' in 51%, 'POOR' in 7%, 'FAIR' in 7% and 'GOOD' in 35%. Spearman's rank correlation coefficient between each structure's visibility and M1 detectability was 0.68 for the CTB, 0.66 for the MB and 0.80 for the LSW, respectively ($p < 0.001$ for all). ***Conclusion:*** Visibility of the LSW on B mode appears to be a better indicator than other structures for M1 evaluation.
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Background

Transcranial color-coded duplex sonography (TCCS) is widely used to evaluate the intracranial arterial system in patients with acute stroke [1–4]. There have been insufficient data to compare the ability of ultrasonographic examination to visualize intracranial structures and vessels through the skull bone in different races [5–7]. There is some reported data on success rates for Doppler ultrasound in different races, with the highest success rates in northern Europeans, and lower in most other populations (Asians, African Americans, Hispanics) [8–10].

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There is much less reported data on relative success rates in different races for intracranial B mode imaging. Asian populations have a high frequency of poor temporal bone windows (TBWs) [8–10]; failure to detect the sphenoidal portion of the middle cerebral artery (M1) on TCCS could be secondary to M1 occlusion or to an inadequate TBW, or sometimes to poor technique or wrong gain settings. The hyperechoic lesser sphenoid wing and superior margin of the petrous pyramid were proposed to be indicators for the identification of the middle and posterior cerebral arteries [11]. This study aimed to clarify the relationship between visibilities of the contralateral temporal bone (CTB), midbrain (MB) and ipsilateral lesser sphenoid wing (LSW) on B mode images and the detectability of the ipsilateral M1 on color Doppler images by TCCS. We have attempted to develop a simple indicator to determine whether failure to detect flow in the M1 is secondary to local arterial disease or to an inadequate bone window.

Subjects and Methods

Consecutive patients with acute ischemic stroke admitted to our stroke center within 7 days after stroke onset between January 2009 and July 2009 were prospectively registered. They were evaluated by intracranial magnetic resonance imaging (MRI) for brain and intracranial magnetic resonance angiography (MRA) for intracranial arteries with a 1.5-tesla system (Magnetom Vision; Siemens, Germany), and carotid duplex ultrasonography for the common carotid artery and the extracranial internal carotid artery (ICA) using a Hitachi EUB-8500 ultrasound machine (Hitachi Medical Corp, Tokyo, Japan) with a 7.5-MHz linear probe on admission. Patients having an M1 or an ICA with luminal stenosis >50% or occlusion on baseline intracranial MRA or carotid ultrasonography, those having a pacemaker, or those who had an extracranial-intracranial arterial bypass were excluded from our study.

TCCS Examination

TCCS examination using a Hitachi EUB-8500 ultrasound machine with a 2- to 2.5-MHz sector probe was performed transtemporally in horizontal projection within 24 h after initial MRA and carotid US evaluations. Patients were lying in a supine, left lateral or right lateral decubitus position according to the side of the TBW examined and the patient's condition. With a scanning depth of 15.5 cm as a fixed depth, the CTB was visualized first for orientation, and the visibilities of the CTB, MB and LSW were assessed. On B mode images, the MB is hypoechoic and butterfly-shaped, and it is surrounded by hyperechoic subarachnoid cisterns, and the LSW has a hyperechoic outline of the bony structures at the skull base [11]. The B mode gain was initially set at 20 and adjusted to optimize structure delineation in the ultrasound image. Then color Doppler ultrasound was used to identify the intracranial arteries. The color gain was set at 38 as a default value and adjusted to obtain an optimum color display to the setting just below that in which background noise first becomes apparent. The velocity color scale was initially set at ±27.3 cm/s. To mitigate aliasing, color flow velocity settings were changed between ±2.3 and ±54.7 cm/s. The M1 at a depth of 4–6 cm was evaluated as a unidirectional flow toward the probe on color Doppler images. If color dots or discontinuous color were initially detected, whether the vessel was the M1 or not was judged based on the depth, the positional relationships with the probe and the intracranial structures, and the direction of blood flow, and further attempts to manipulate the probe superiorly and inferiorly to identify the remainder of the M1 were performed. If the MB and LSW could not be clearly identified, we carefully measured the intracranial head diameter by using the B mode and used the actual depth to guide the examination. Two experienced vascular neurologists who knew the information of the M1 on baseline MRA assessed the visibilities of the MB, LSW and CTB on B mode images and assigned patients into 4 categories as follows: 'invisible' if the hyperechoic CTB within the echo window, the peduncle of the MB or the hyperechoic LSW within the echo window was not visible at all; 'poor' if it was visible less than 50%; 'fair' if it was visible more than 50%, and 'good' if it was almost totally visible (fig. 1, 2). The detectability of the M1 was assessed on color Doppler images and assigned into similar categories as follows: 'INVISIBLE' if the M1 was undetected, 'POOR' if detected as color dots, 'FAIR' if linearly but discontinuously detectable and 'GOOD' for being linearly and continuously detectable (fig. 2, 3). When the M1 was assigned into the category 'INVISIBLE', the detectabilities of the anterior and posterior cerebral arteries from the same TBW were also evaluated to ascertain the absence of a proper TBW according to the recent consensus recommendations [4]. The posterior cerebral artery was detectable if the precommunicating segment, proximal or distal postcommunicating segment was detected. The interrater and intrarater agreements for each of the categories (invisible, poor, fair and good), by kappa statistic, were 0.45 and 0.64 for the MB, 0.62 and 0.85 for the LSW, 0.61 and 0.71 for the CTB, and 0.89 and 0.96 for the M1, respectively, according to the offline video monitoring evaluations of 20 randomly selected patients by the above-mentioned two experienced vascular neurologists.

Contrast-Enhanced TCCS Examination

Contrast-enhanced TCCS examination was performed in the initial 10 patients who had 'INVISIBLE', 'POOR' or 'FAIR' detection of the M1 on color Doppler images after they had given their informed consent. Levovist (Bayer Health Care, Leverkusen, Germany), an ultrasound contrast agent consisting of granules composed of 99.9% galactose and 0.1% palmitic acid, was used. Levovist was injected at a dose of 2.5 g diluted in 7 ml of 0.9% saline resulting in a concentration of 300 mg/ml (total volume, 8.5 ml). A 4.25-ml bolus of Levovist was injected into an antecubital vein within 10 s, followed by a 10-ml saline chaser bolus for the one side. A second injection for the other side was administered after the first contrast effect had faded out. Detectability improvement on contrast-enhanced TCCS examination was defined as improvement of M1 detectability on contrast-enhanced TCCS by one or more categories compared with that on non-contrast-enhanced examination.

Data Analysis

The percentages of each finding were calculated for all patients, by sex and by age (<70 years old or ≥70 years old). The percent-

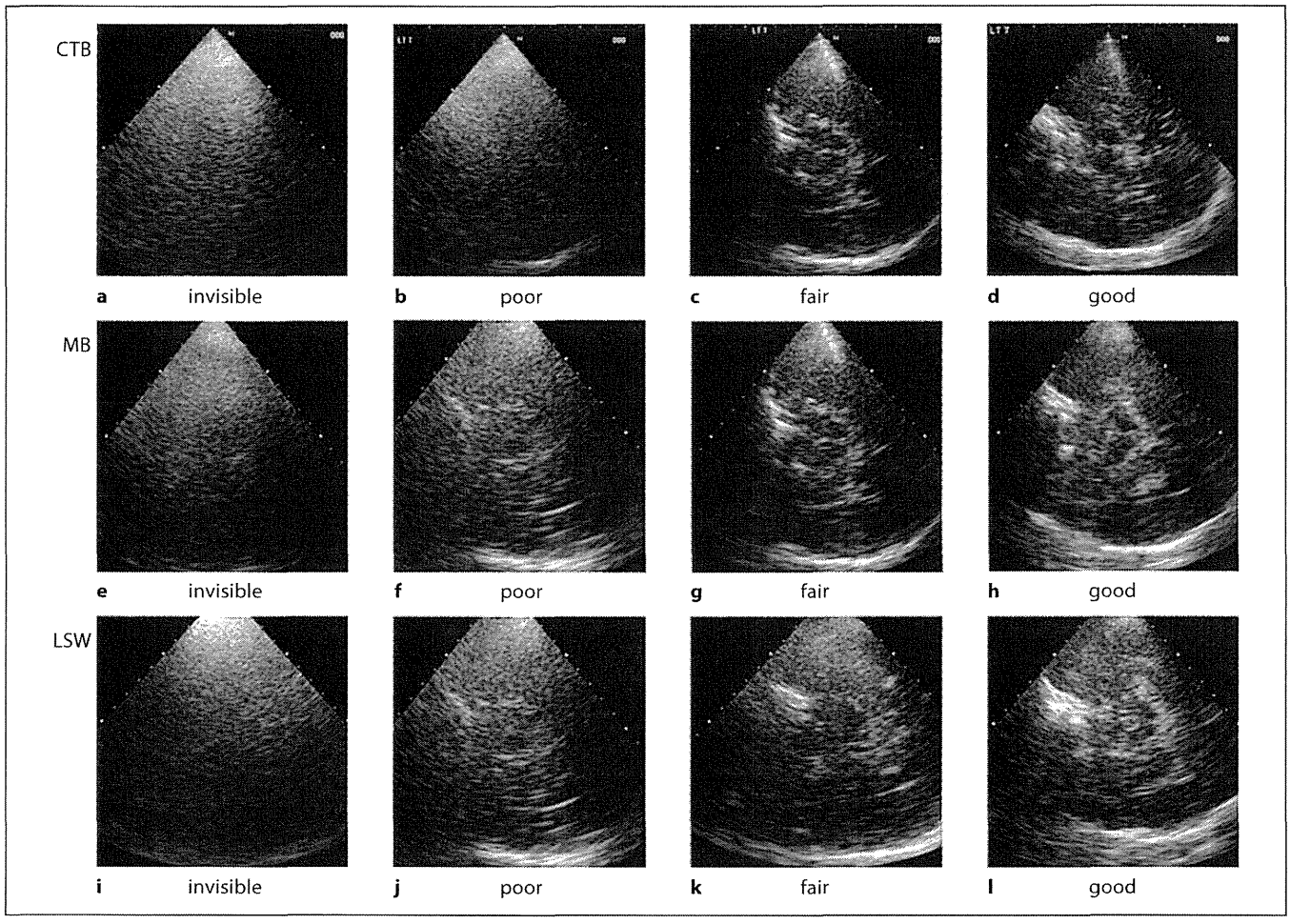

Fig. 1. Visibilities of CTB (**a–d**), MB (**e–h**) and LSW (**i–l**) on B mode images. invisible = The contour is not visible; poor = the contour is less than 50% visible; fair = the contour is more than 50% visible; good = the contour is almost totally visible.

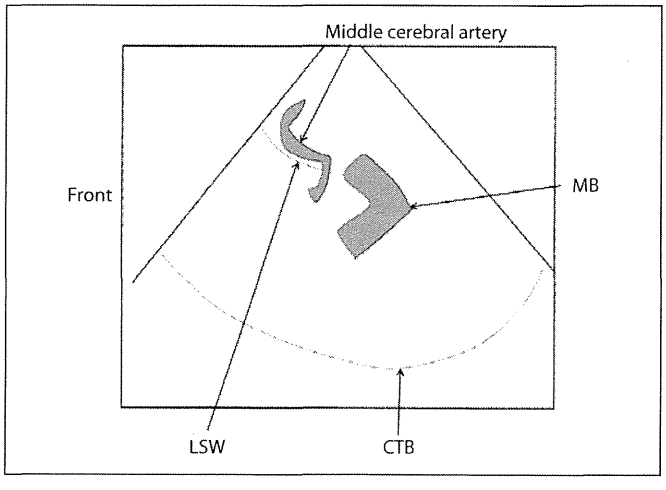

Fig. 2. A schema of CTB, MB, LSW and middle cerebral artery.

Color version available online

ages of each category were compared by sex and by age using the χ^2 test. The relationship between each structure's visibility and M1 detectability was analyzed using Spearman's rank correlation. The percentages of M1 detection improvement by categorical visibility of each structure on B mode images were calculated.

Results

One hundred and twenty-four acute ischemic stroke patients admitted to our stroke center during the study period were investigated. Forty-six patients who had vascular abnormality on MRA (13 ICA occlusion, 5 ICA stenosis ≥50%, 1 ICA pseudo-occlusion, 14 middle cerebral artery M1 occlusion, 13 middle cerebral artery M1 stenosis ≥50%), 1 patient having a pacemaker, and 1 patient

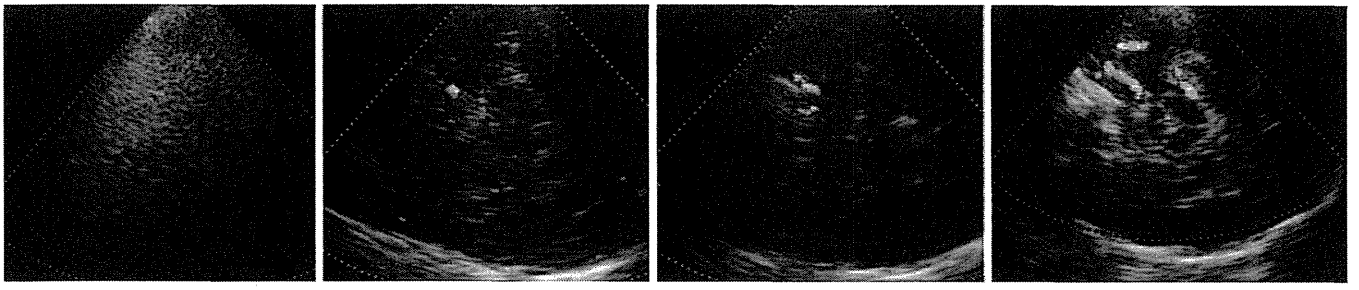

Fig. 3. M1 detectability on color Doppler images. **a** The M1 is undetectable (INVISIBLE). **b** The M1 is detected as color dots (POOR). **c** The M1 is linearly but discontinuously detectable (FAIR). **d** The M1 is linearly and continuously detectable (GOOD).

who had superficial temporal artery/middle cerebral artery anastomosis were excluded. Seventy-six patients (48 men, 71 ± 12 years old) with 152 TBWs were evaluated by TCCS. None of these had a large infarction which caused brain displacement on MRI. Table 1 summarizes the percentages of each structure's visibility on B mode images and M1 detectability on color Doppler images for all patients, by sex and by age. There were 38 TBWs of women aged ≥70 years, 42 TBWs of men aged ≥70 years, 18 TBWs of women aged <70 years and 54 TBWs of men <70 years. The CTB, MB and LSW were visible on B mode in 98, 64 and 84%, respectively; levels of visibility are shown in table 1. The M1 was detected in 49% on color Doppler images, and M1 detectability was 'POOR' in 7%, 'FAIR' in 7% and 'GOOD' in 35%. Structural visibilities on B mode and M1 detectability were better in men than in women and in younger adults (<70 years old) than in older adults (≥70 years old). Among 77 TBWs with an 'INVISIBLE' M1, the anterior cerebral artery was detectable only through 4 TBWs, and the PCA was detectable through 25 TBWs (table 2).

The correlation coefficient between each structure's visibility and M1 detectability was 0.68 for the CTB, 0.66 for the MB and 0.80 for the LSW ($p < 0.001$ for all; table 3). The M1 was detectable as 'GOOD' in 40 (82%) out of 49 TBWs with 'good' LSW visibility, although it was so in 43 (70%) out of 61 TBWs with 'good' CTB visibility and in 17 (77%) out of 22 TBWs with 'good' MB visibility. When the LSW was invisible, the M1 was not detected. When the LSW was less than 50% visible, the M1 was detected in 9%. When the LSW was more than 50% visible, the M1 was detected in 55%. When the LSW was almost totally visible, the M1 was detected in 98%. The correlation coefficients between each structure's visibility and M1 detectability in men were 0.62 for the CTB, 0.60 for the MB and 0.74 for the LSW ($p < 0.001$ for all); those in women were 0.58, 0.53 and 0.72, respectively ($p < 0.001$ for all). Those of younger adults were 0.61, 0.58 and 0.74, respectively ($p < 0.001$ for all); those of older adults were 0.71, 0.70 and 0.80, respectively ($p < 0.001$ for all).

Contrast-enhanced TCCS examination was performed in 20 TBWs of 10 patients (table 4). In 8 of 20 TBWs (40%), the M1 was identified with 1 or more category improvements compared with that on non-contrast-enhanced examination. The detection improvement of the M1 was ascertained for no TBWs with 'invisible' LSW, 50% with 'poor' LSW, 57% with 'fair' LSW and 50% with 'good' LSW.

Discussion

In this study, categorical visibilities of the CTB, MB and LSW on B mode images and categorical M1 detectability on color Doppler images by TCCS were determined in Japanese acute ischemic stroke patients without stenotic lesions of the M1 or ICA on baseline MRA or carotid ultrasonography. The major findings were as follows: first, the M1 was detectable by TCCS in 49% in this study of patients with a known patent M1. Second, visibilities of the CTB, MB and LSW on B mode images had positive correlations with M1 detectability on color Doppler images. Third, LSW visibility was a better indicator than CTB and MB visibilities for evaluation of the M1. Fourth, contrast-enhanced TCCS examination provided better M1 detection than nonenhanced examination in half of the TBWs through which each structure was vis-

Table 1. Structural visualization and M1 detectability by TCCS

Structural visualization on B mode image		invisible	visible			p
			poor	fair	good	
Structural visualization on B mode image						
CTB	Total (152 TBWs)	3 (2)	34 (22)	54 (36)	61 (40)	
	Women (56 TBWs)	3 (5)	25 (45)	16 (29)	12 (21)	<0.0001[a]
	Men (96 TBWs)	0	9 (9)	38 (40)	39 (51)	
	Aged ≥70 years (80 TBWs)	3 (4)	23 (29)	30 (38)	24 (30)	0.0163[b]
	Aged <70 years (72 TBWs)	0	11 (15)	24 (33)	37 (51)	
	Women aged ≥70 years (38 TBWs)	3 (8)	20 (53)	10 (26)	5 (13)	0.0689[c]
	Women aged <70 years (18 TBWs)	0	5 (28)	6 (33)	7 (39)	
	Men aged ≥70 years (42 TBWs)	0	3 (7)	20 (48)	19 (45)	0.3486[d]
	Men aged <70 years (54 TBWs)	0	6 (11)	18 (33)	30 (56)	
MB	Total (152 TBWs)	55 (36)	36 (24)	39 (26)	22 (14)	
	Women (56 TBWs)	37 (66)	10 (18)	7 (13)	2 (4)	<0.0001[a]
	Men (96 TBWs)	18 (19)	26 (27)	32 (33)	20 (21)	
	Aged ≥70 years (80 TBWs)	39 (49)	22 (28)	17 (21)	2 (3)	<0.0001[b]
	Aged <70 years (72 TBWs)	16 (22)	14 (19)	22 (31)	20 (28)	
	Women aged ≥70 years (38 TBWs)	30 (79)	6 (16)	2 (5)	0	0.0061[c]
	Women aged <70 years (18 TBWs)	7 (39)	4 (22)	5 (28)	2 (11)	
	Men aged ≥70 years (42 TBWs)	9 (21)	16 (38)	15 (36)	2 (5)	0.0046[d]
	Men aged <70 years (54 TBWs)	9 (17)	10 (19)	17 (31)	18 (33)	
LSW	Total (152 TBWs)	25 (16)	34 (22)	44 (29)	49 (32)	
	Women (56 TBWs)	15 (27)	23 (41)	10 (18)	8 (14)	<0.0001[a]
	Men (96 TBWs)	10 (10)	11 (11)	34 (35)	41 (43)	
	Aged ≥70 years (80 TBWs)	16 (20)	22 (28)	23 (29)	19 (24)	0.0700[b]
	Aged <70 years (72 TBWs)	9 (13)	12 (17)	21 (29)	30 (42)	
	Women aged ≥70 years (38 TBWs)	13 (34)	16 (42)	5 (13)	4 (11)	0.1649[c]
	Women aged <70 years (18 TBWs)	2 (11)	7 (39)	5 (28)	4 (22)	
	Men aged ≥70 years (42 TBWs)	3 (7)	6 (14)	18 (43)	15 (36)	0.3460[d]
	Men aged <70 years (54 TBWs)	7 (13)	5 (9)	16 (30)	26 (48)	
M1 detectability on color Doppler images		INVISIBLE	POOR	FAIR	GOOD	p
M1	Total (152 TBWs)	77 (51)	11 (7)	11 (7)	53 (35)	
	Women (56 TBWs)	42 (75)	3 (5)	2 (4)	9 (16)	<0.0001[a]
	Men (96 TBWs)	35 (36)	8 (8)	9 (9)	44 (46)	
	Aged ≥70 years (80 TBWs)	46 (58)	8 (10)	7 (9)	19 (24)	0.0198[b]
	Aged <70 years (72 TBWs)	31 (43)	3 (4)	4 (6)	34 (47)	
	Women aged ≥70 years (38 TBWs)	29 (76)	3 (8)	1 (3)	5 (13)	0.5002[c]
	Women aged <70 years (18 TBWs)	13 (72)	0	1 (6)	4 (22)	
	Men aged ≥70 years (42 TBWs)	17 (40)	5 (12)	6 (14)	14 (33)	0.1146[d]
	Men aged <70 years (54 TBWs)	18 (33)	3 (6)	3 (6)	30 (56)	

Values are represented by numbers of TBWs, with percentages in parentheses.
[a] Women versus men by χ^2 test. [b] Aged ≥70 years versus aged <70 years by χ^2 test. [c] Women aged ≥70 years versus women aged <70 years by χ^2 test. [d] Men aged ≥70 years versus men aged <70 years by χ^2 test.

ible ('poor', 'fair' or 'good'), whereas TBWs with 'invisible' MB or LSW could not gain any contrast improvement for M1 detection.

TCCS is widely used to evaluate the intracranial arterial system in patients with acute stroke. The main limitation of TCCS arises from poor acoustic insonation conditions via the TBW, particularly in Asians, women and older patients. The failure rate because of an insufficient acoustic bone window is approximately 10–20% of patients in Western countries [8–10] and 20–30% of

Table 2. Anterior (ACA) and posterior cerebral artery (segment 1 and 2) detectabilities of 77 TBWs with 'INVISIBLE' M1

	INVISIBLE	POOR	FAIR	GOOD
ACA	73	3	1	0
P1	71	5	1	0
Proximal P2	59	10	6	2
Distal P2	57	4	11	5

Values are represented by numbers of TBWs.

Table 3. Relationship between structural visualization and M1 detectability

		M1 detectability				Spearman's ρ	p
		INVISIBLE	POOR	FAIR	GOOD		
CTB	invisible (3 TBWs)	3	0	0	0	0.68	<0.0001
	poor (34 TBWs)	33	0	1	0		
	fair (54 TBWs)	32	8	4	10		
	good (61 TBWs)	9	3	6	43		
MB	invisible (55 TBWs)	48	5	1	1	0.66	<0.0001
	poor (36 TBWs)	19	3	4	10		
	fair (39 TBWs)	7	2	5	25		
	good (22 TBWs)	3	1	1	17		
LSW	invisible (25 TBWs)	25	0	0	0	0.80	<0.0001
	poor (34 TBWs)	31	2	1	0		
	fair (44 TBWs)	20	6	5	13		
	good (49 TBWs)	1	3	5	40		

Values are represented by numbers of TBWs.

patients in Asian countries [4, 5]. In our study, this rate was 51%. Low M1 detectability in women and older patients was consistent with previous reports [9, 10]. Therefore, simple indicators to judge acoustic insonation conditions via the TBW are important to evaluate the M1 segment.

Insonations of B mode and color Doppler seem to be similarly affected by the temporal bone, because structural visibilities on B-mode images had significantly positive correlations with M1 detectability on color Doppler images for all patients, by sex and by age. The closer spatial relationship of the M1 with the LSW than with the CTB or MB seems to explain the present results that LSW visibility had the best correlation with M1 detectability. When the M1 was 'INVISIBLE' on color Doppler images, the precommunicating segment, proximal and distal postcommunicating segments were detected in 32% but the anterior cerebral artery was rarely detectable via the same TBW. Based on our results, the following criteria for

Table 4. M1 detectability improvement by contrast enhancement

		Improvement of M1 detectability
CTB	invisible (0 TBWs)	–
	poor (4 TBWs)	0
	fair (5 TBWs)	1 (20)
	good (11 TBWs)	7 (64)
MB	invisible (6 TBWs)	0
	poor (7 TBWs)	4 (57)
	fair (4 TBWs)	3 (75)
	good (3 TBWs)	1 (33)
LSW	invisible (5 TBWs)	0
	poor (6 TBWs)	3 (50)
	fair (7 TBWs)	4 (57)
	good (2 TBWs)	1 (50)

Values are represented by numbers of TBWs, with percentages in parentheses.

M1 evaluation on TCCS were developed. If the LSW is almost totally visible, M1 occlusion may be considered in patients with M1 invisibility. If the LSW is invisible or less than 50% visible, M1 invisibility on TCCS does not directly indicate M1 occlusion, and an additional imaging modality, such as MRA or CT angiography, is required. If the LSW is more than 50% visible and the M1 is not detectable, more than 50% or totally, visibility of the CTB and MB indicates probable M1 occlusion.

The addition of an ultrasound contrast agent allows adequate diagnosis in about 80–90% of patients with insufficient bone windows [12–20]. In our Japanese stroke patients, 40% of TBWs had an improved detection of the M1 on contrast-enhanced examination. In patients with invisible structures on B mode images, the administration of a contrast agent did not result in vessel identification. Therefore, TBWs with poor, fair and good visibility and insufficient M1 detection seem to be appropriate candidates for contrast-enhanced TCCS examination.

There were some limitations in this study. First, M1 occlusion on TCCS cannot be discussed from our findings because of the study exclusion of patients with luminal stenosis >50% or occlusion of the M1 or ICA on MRA and those with large infarction which may cause brain displacement. Second, severe atherosclerosis often causes arterial tortuosity and calcification. Arterial tortuosity might shift the M1 further from the LSW, and calcification might prevent ultrasound insonation. Third, machine specificity might affect structural visibility and M1 detectability. Fourth, the small sample size might affect the statistical correlation between the M1 detectability and the visibility of each anatomical structure, and a larger study might be needed to confirm our results. Finally, because our vascular neurologists knew that all the patients had a patent M1, the results might be overestimated.

Conclusion

The visibility of the LSW on B mode images was well correlated with M1 detection in Japanese aged patients with acute ischemic stroke having a patent M1. Our findings warrant future studies to determine detailed criteria of M1 occlusion using TCCS in patients with acute ischemic stroke.

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Disclosure Statement

None.

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Identification of Internal Carotid Artery Dissection by Transoral Carotid Ultrasonography

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Key Words
Transoral carotid ultrasonography · Cerebrovascular disease · Internal carotid artery dissection · Stroke

Abstract
Background and Purpose: Conventional transsurface carotid ultrasonography (TSCU) via the cervical surface often fails to detect dissection of the extracranial internal carotid artery (ICA). The role of transoral carotid ultrasonography (TOCU) in the detection of ICA dissection was examined. ***Method:*** Patients with unilateral extracranial ICA dissection identified by digital subtraction angiography (DSA) from our database of patients with ischemic stroke or transient ischemic attack (TIA) were reviewed. Findings of dissection were compared between TSCU and TOCU. ***Results:*** Eight patients (7 men, 37–69 years old), including 7 with ischemic stroke and 1 with TIA, had ICA dissection. By DSA, dissection was identified between the first and third vertebrae in 4 patients and from the third cervical vertebra to the intracranial level in the remaining 4. TOCU images revealed an intimal flap as definite evidence of dissection in all patients. In 7 patients, color flow signals were not seen in false lumens, indicating thrombosed lumens. Four patients showed morphological changes of dissection on follow-up TOCU, including a patient with recovery of color flow signals in false lumens. The diameter of the dissected ICA was 7.3 ± 0.7 mm and that of the contralateral ICA was 4.9 ± 0.6 mm ($p = 0.008$). In contrast, TSCU did not enable any conclusive findings of ICA dissection to be made in any patient. Six patients had intramural hematoma on T_1-weighted MRI, and 2 had an intimal flap with a double lumen on magnetic resonance angiography. ***Conclusion:*** TOCU has advantages over TSCU in achieving an accurate diagnosis and follow-up evaluation of ICA dissection.

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Introduction

Internal carotid arterial (ICA) dissection accounts for approximately 2–3% of all ischemic strokes [1, 2] and is one of the important causes of stroke in young and middle-aged patients [3–6]. The pathogenesis of ICA dissection is often unknown. Most ICA dissections occur spontaneously or follow a sudden head movement, a chiropractic manipulation, and many types of sports activities [7, 8]. Because ICA dissection sometimes causes brain ischemia and subarachnoid hemorrhage [6], immediate vascular evaluation and treatment are necessary. Among the diagnostic tools for identifying dissections, including

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digital subtraction angiography (DSA) [9, 10], magnetic resonance imaging (MRI) [11], magnetic resonance angiography (MRA) [12, 13], computed tomography angiography (CTA) [14–16] and conventional transsurface carotid ultrasonography (TSCU) [17–20], TSCU is handy and safe. However, ICA dissection typically occurs at least 2 cm distal to the bifurcation, at the level of the second and third cervical vertebrae, and extends over a variable distance [3]. The distal extracranial ICA cannot be examined by TSCU as it lies behind bones and cannot be imaged in B-mode. Doppler on TSCU can provide information about the distal ICA only if there is a flow-limiting stenosis or occlusion that results in abnormal waveforms. Thus, the lesion may be underdiagnosed by routine TSCU examination.

Transoral carotid ultrasonography (TOCU), a new ultrasound technique that was developed in our institute [21], can identify the distal extracranial ICA that is invisible on TSCU [21]. We and others have reported the utility of TOCU in evaluating various ICA pathologies, including distal extracranial ICA stenosis, occlusion, pseudo-occlusion, moya moya disease and dissection [22–28]. In particular, TOCU seems to be superior to TSCU in detecting ICA dissection during acute stroke because of its ability to visualize the high portion of the extracranial ICA. We previously reported some cases with ICA dissection proven by TOCU [26–28]. However, the utility of TOCU should be assessed not only in isolated cases. In this study, the utility of TOCU in evaluating consecutive patients with ICA dissection as the final diagnosis was examined based on comparison with other imaging modalities, such as DSA, MRI and TSCU.

Subjects and Methods

Patients with stroke or transient ischemic attack (TIA) caused by extracranial ICA dissection confirmed by DSA from our database of 6,026 patients with ischemic stroke or TIA who were admitted to our hospital between 1999 and 2010 were reviewed.

Basically, all patients in our database underwent intracranial MRI/MRA and TSCU unless MRI was contraindicated. When ICA stenosis or occlusion was detected on these regular examinations or when dissection was suspected as a cause of ICA lesions based on typical histories and symptoms, including sports activities and cephalocervical pain, or absence of other obvious causes for the lesions, DSA was performed after obtaining the patient's informed consent. Three-dimensional (3D) rotational angiography with a standard Integris BV5000 biplane system (Philips Medical System, Best, The Netherlands) was also performed if needed. The system provides contrast angiographic vascular luminal rotational X-ray image acquisition in multiple planes with reconstruction on a 3D work station [10]. The diagnosis of ICA dissection was made by DSA based on the review by Provenzale [11] and the criteria of the Spontaneous Cervicocephalic Arterial Dissections Study [29]. Briefly, the presence of an intimal flap with a double lumen was a direct finding for identifying ICA dissection. The pearl-and-string sign, string sign, pearl sign, retention of contrast, total occlusion with proximal distension, and tapered occlusion on DSA needed further evidence, such as morphological change on DSA or intramural hematoma on T_1 MRI. The level of the dissection was established based on DSA findings. The findings of TSCU, TOCU and MRI/MRA were compared using DSA as the gold standard. Patients' clinical backgrounds, stroke types, stroke risk factors, and prognoses were reviewed as well.

TSCU and TOCU Examinations

TSCU and TOCU examinations were performed using an ATL Ultramark 9 HDI (Advanced Technology Laboratories, Bothell, Wash., USA) with a 5- to 10-MHz linear probe and a 5- to 9-MHz micro convex probe, respectively, or an Aplio™ XU (Toshiba Co. Ltd, Tokyo, Japan) with a 7.5-MHz linear probe and a 6-MHz micro convex probe, respectively. For TSCU examination, the standard approach using B mode, color flow imaging, and pulsed Doppler was performed in the decubitus position. The probes for TOCU examination were originally designed for transrectal use. We performed TOCU in patients with ICA territory stroke who were suspected to have pathological lesions at the extracranial distal ICA based on TSCU or intracranial MRI/MRA findings; evaluation of the extracranial distal ICA was mandatory. We used a protocol for identifying patients who needed to undergo further evaluations for ICA dissection, notably patients with ICA territory ischemia or retinal ischemia of unknown etiology based on standard evaluations including head computed tomography, head MRI and MRA, TSCU, electrocardiogram monitoring and blood test. Those with concomitant symptoms or signs, such as headache, neck pain, face pain, ipsilateral Horner's syndrome, pulsatile tinnitus or lower cranial nerve palsy, were especially suspected of having ICA dissection. For such patients, DSA or cervical MRI/MRA was preferentially performed and TOCU was added if needed prior to mid-2008. After mid-2008, TOCU was preferentially performed. TOCU was repeated to evaluate morphological changes every 1–3 days during hospitalization when ICA dissection was detected on initial examination. The details of the TOCU examination procedure have been reported previously [21]. Briefly, the probe was covered with a disposable probe cover made of sterile thin gum after covering the tip of the probe with echo jelly. Then, the probe was inserted transorally and touched the pharyngeal posterolateral wall. Basically, we did not use local anesthesia because the pharyngeal reflex rarely occurs. For patients with severe pharyngeal reflex, one or two pushes of 8% xylocaine spray to the pharyngeal posterolateral wall were used. The display was in the vertical plane to longitudinally detect and assess extracranial ICA, and in the axial plane for horizontal assessment. The ICA was identified by delineation of a vessel running linearly from the lower to the upper pharynx and by confirming that flow was proceeding upward to the skull base and that branching was absent using B-mode and color flow imaging. The ICA was usually identified at the level of the second and third cervical vertebrae, based on our unpublished data, which show the spatial relationship between the TOCU probe and the cervical vertebrae on the X-ray. B-mode was used

Table 1. Clinical characteristics

	Case 1 [26]	Case 2 [28]	Case 3	Case 4 [27]	Case 5	Case 6	Case 7	Case 8
Sex	male	male	female	male	male	male	male	male
Age, years	37	52	62	69	51	57	42	48
Type of stroke	IS	TIA	IS	IS	IS	IS	IS	IS
Prior history of stroke	absent	absent	absent	absent	absent	absent	absent	absent
Risk factors	dyslipidemia, smoking, drinking	hypertension	none	none	none	none	hypertension	none
Affected side	right	right	right	left	right	left	right	left
Cephalocervical pain	headache	absent	absent	orbital pain	absent	absent	headache	headache
Neurological findings	hoarseness, hemiparesis	hemiparesis	dysarthria, hemiparesis	hyperesthesia, visual field blurring	USN, dysarthria, hemiparesis, hypoesthesia	aphasia	USN, dysarthria, hemiparesis, hypoesthesia	aphasia, hemiparesis

IS = Ischemic stroke; USN = unilateral spatial neglect.

to measure the distal ICA diameter from the near to the far adventitial edge. Pulsed Doppler was used to measure the flow velocity of the distal ICA with an angle correction within 60° between the blood flow direction and the Doppler interrogation. Color Doppler was used to identify flow signals in true and false lumens. The lumen which tapered from the ICA was defined as a true lumen and the other was defined as a false lumen [17]. When flow signals were absent in false lumens, the lumens were considered to be thrombosed. An intimal flap with a double lumen was a definite finding for identifying ICA dissection by both TSCU and TOCU. Furthermore, the maximum diameter of the dilated extracranial ICA was measured from the near to the far adventitial edges and compared with the diameter of the contralateral ICA at almost the same distance from the carotid bifurcation. The probe was carefully horizontally swept in the vertical plane to detect the maximum diameter of the vessel's center to avoid overmeasurement in case the vessel is tortuous or turning.

MR Examinations

MRI of the cervical ICA was performed on a 1.5-tesla scanner (Magnetom Vision or MAGNETOM Sonata, Siemens Medical Systems, Erlangen, Germany) with standard neck array coils. The MRI protocol was composed of T_1-weighted images and 3D-time of flight MRA. MRA was performed on both intracranial and extracranial vessels. Intracranial MRA was performed on admission and extracranial MRA was performed during hospitalization. Gadolinium-enhanced MRA was not performed routinely. Intramural hematoma and luminal diameter on both sides were assessed by T_1 MRI while intimal flap with double lumen, stenosis and dilatation, and pseudoaneurysm were evaluated by MRA by an experienced radiologist. Patients who did not tolerate MRI because of claustrophobia or because they had pacemakers were diagnosed based on brain CT and DSA.

Data Evaluation

Continuous variables were compared with the Wilcoxon signed rank test. A value of $p < 0.05$ was considered statistically significant.

Results

Eight patients (7 men, age 37–69 years) with extracranial ICA dissection were identified from the database. Seven patients developed ischemic stroke and 1 developed TIA ipsilaterally to the affected ICA. The initial TOCU examination was performed after confirmation of dissection by DSA in 5 patients and prior to DSA in the other 3 (cases 5, 6, 8), whose clinical history strongly suggested ICA dissection. The detailed clinical presentations of 3 of these 8 patients have been previously reported [26–28]. Table 1 summarizes the patients' clinical characteristics, and table 2 shows the results of the DSA, TSCU, TOCU and MRI/MRA examinations. The basis of the diagnosis by DSA was the double-lumen sign with an intimal flap in 2, dilatation and stenosis in 3, and tapered occlusion in 4. On DSA, the dissection site was restricted to the level between the first and third cervical vertebrae in 4 patients, and the dissection extended from the third cervical vertebra to the intracranial ICA in the remaining 4 patients. Four patients showed morphological changes of dissection on follow-up DSA. In case 2, who initially had an intimal flap with a double lumen on day 1, a saccular type pseudoaneurysm was detected on day 16. In case 4, who initially had severe stenosis on day 1, an intimal flap with a double lumen with a fusiform-type pseudoaneurysm appeared on day 7. In case 5, who initially had proximal dilatation and stenosis, and a distal saccular-type aneurysm on day 3, the stenotic lesion became wider and an additional aneurysm was detected on day 19. In case 8, who initially had an ICA tapering occlusion on day 1, the ICA was recanalized on day 17. Figures 1 and

Table 2. Imaging findings

Modality	Findings	Case 1 [26]	Case 2 [28]	Case 3	Case 4 [27]	Case 5	Case 6	Case 7	Case 8
CT/MRI	location of ischemia	ant-choroid, PCA	corona radiata	MCA cortex	MCA central gyrus	MCA cortex and deep area	MCA cortex	MCA cortex	MCA cortex
DSA	location of dissection	C3-siphon	C1–C2	C1–C2	C1–C2	C1–C3	C3-distal IC	C3-distal IC	C3-distal IC
	location of carotid artery bifurcation	between C3 and C4	C3	between C3 and C4	C3	between C3 and C4	C4	C4	between C3 and C4
	intimal flap with double lumen[1]	–	–	present	present	–	–	–	–
	dilatation and stenosis	–	present	–	present	present	–	–	–
	tapering occlusion	present	–	–	–	–	present	present	present
	pseudoaneurysm	–	saccular	fusiform	fusiform	saccular	–	–	–
	morphological change	–	present	–	present	present	–	–	present
TOCU	intimal flap/double lumen[1]	present	present	present	present	present	present	present	present
	false lumen	thrombosed	thrombosed	not thrombosed	thrombosed[2]	thrombosed	thrombosed	thrombosed	thrombosed[2]
	stenosis	–	present	–	present	present	–	–	–
	occlusion	–	–	–	–	–	–	–	–
	dissected arterial diameter, mm	7.1	7.3	6.3	7.0	7.9	6.5	7.7	6.5
	contralateral arterial diameter, mm	5.0	4.0	5.6	5.6	4.4	4.9	4.2	4.9
	pseudoaneurysm	–	undetectable	fusiform	fusiform	saccular	–	–	–
	morphological change	–	present	–	present	present	–	–	present
	initial Doppler flow abnormality	present[3]	present[4]	–	present[3]	–	present[3]	present[3]	present[3]
	sequential flow pattern change	–	present[2]	–	present[4]	present[4]	–	–	present[5]
TSCU	intimal flap/double lumen[1]	–	–	–	–	–	–	–	–
	arterial narrowing	present	–	–	–	present	–	–	present
	dissected arterial diameter, mm	8.8	9.9	4.3	6.7	5.8	4.5	4.8	8.5
	contralateral arterial diameter, mm	7.3	5.9	4.0	5.3	6.0	4.8	4.3	5.4
	arterial dilatation	–	present	–	–	–	–	–	–
	morphological change	–	–	–	–	present	–	–	present
	initial Doppler flow abnormality	present[3]	–	–	present[3]	–	present[3]	present[3]	present[3]
	sequential flow pattern change	–	–	–	present[5]	present[4]	–	–	present[5]
Cervical MRI and MRA	intimal flap with double lumen	–	–	present	present	–	–	–	–
	intramural hematoma	present	present	–	–	present	present	present	present
	ICA stenosis	–	present	–	–	present	–	–	present
	occlusion	present	–	–	–	–	present	present	present
	pseudoaneurysm	–	present	–	–	present	–	–	–

ant-choroid = Anterior choroidal artery; C1 = first cervical vertebra level; C2 = second cervical vertebra level; C3 = third cervical vertebra level; CT = computed tomography; MCA = middle cerebral artery; PCA = posterior cerebral artery; siphon, carotid siphon; USN = unilateral spatial neglect; C1–3 = cervical vertebra levels; siphon, carotid siphon.

[1] Direct findings of arterial dissection.

[2] Normalized peak flow velocity.

[3] Absence of end diastolic velocity indicating distal occlusion.

[4] High peak flow velocity (>200 cm/s) indicating stenosis.

[5] Normalized end-diastolic flow velocity.

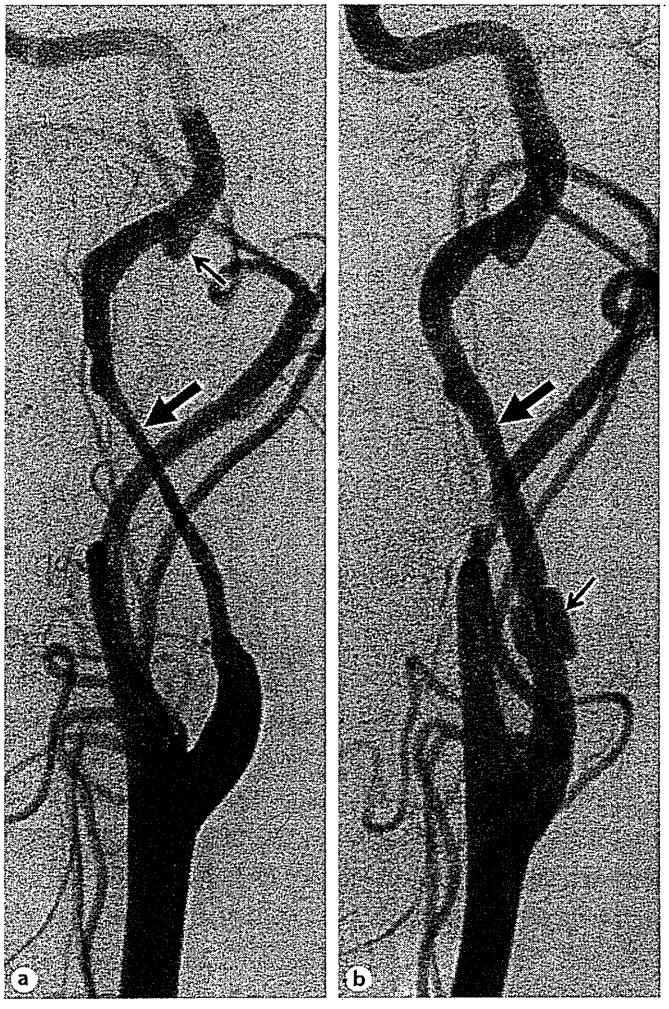

Fig. 1. Dissection of the extracranial ICA on a common carotid DSA image in case 5. **a** Right anterior oblique view on day 3. Dilatation and stenosis in the proximal ICA (thick arrow) and an aneurysm in the distal extracranial ICA (thin arrow) are shown. **b** Right anterior oblique view on day 19. The stenotic lesion becomes wider (thick arrow). A new aneurysm appears in the proximal ICA (thin arrow).

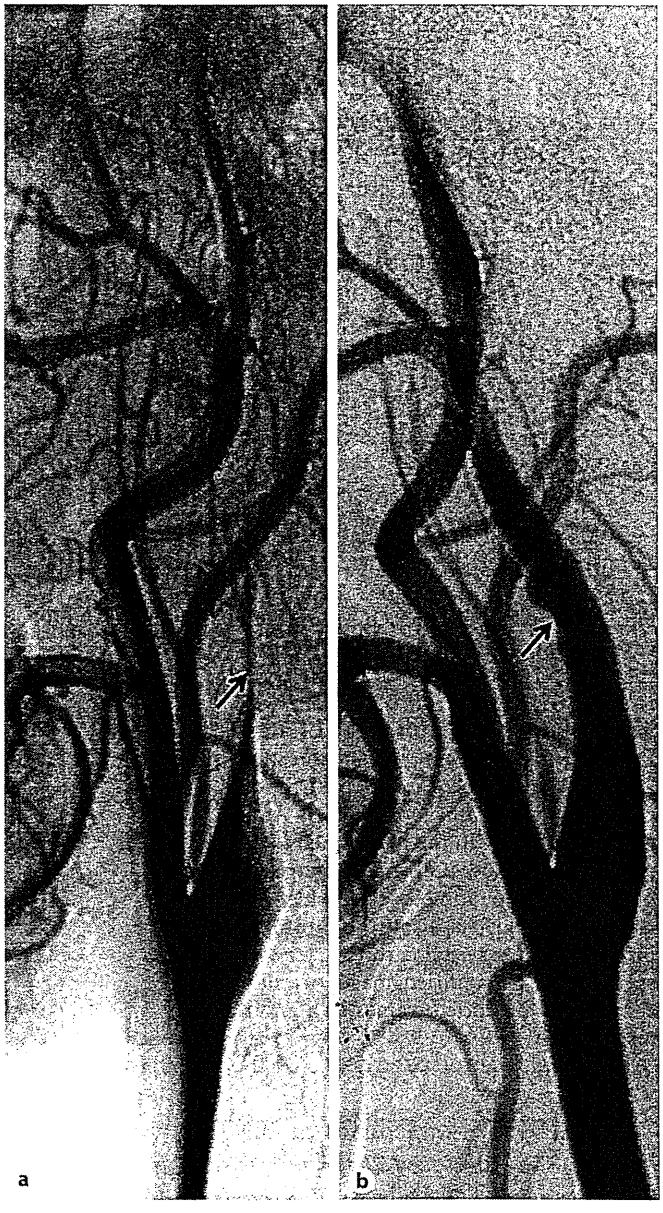

Fig. 2. Dissected ICA on a common carotid DSA image in case 8. **a** Lateral view on day 1, showing tapering ICA occlusion (arrow). **b** Recanalized dissected ICA (arrow) on day 17.

2 show sequential DSA images in cases 5 and 8, respectively.

By TOCU, a double lumen with an intimal flap was identified in all 8 patients. Color signals were absent in false lumens of 7 patients on the initial TOCU, indicating a thrombosed lumen; on the 2nd follow-up TOCU, little forward blood flow was present in the false lumen and in the course of time the flow volume increased gradually, indicating disappearance of the intraluminal thrombi in 1 patient (case 4) [27]. The luminal diameter at the height of the second cervical vertebra was 7.3 ± 0.7 mm in the dissected ICA and 4.9 ± 0.6 mm in the contralateral ICA in all patients ($p = 0.008$). No patient had a tortuous or turning vessel at the measurement point. On the initial Doppler examination, 5 patients displayed absence of end-diastolic velocity, indicating distal ICA occlusion, and 1 patient had ICA stenosis. As all the occluded arte-

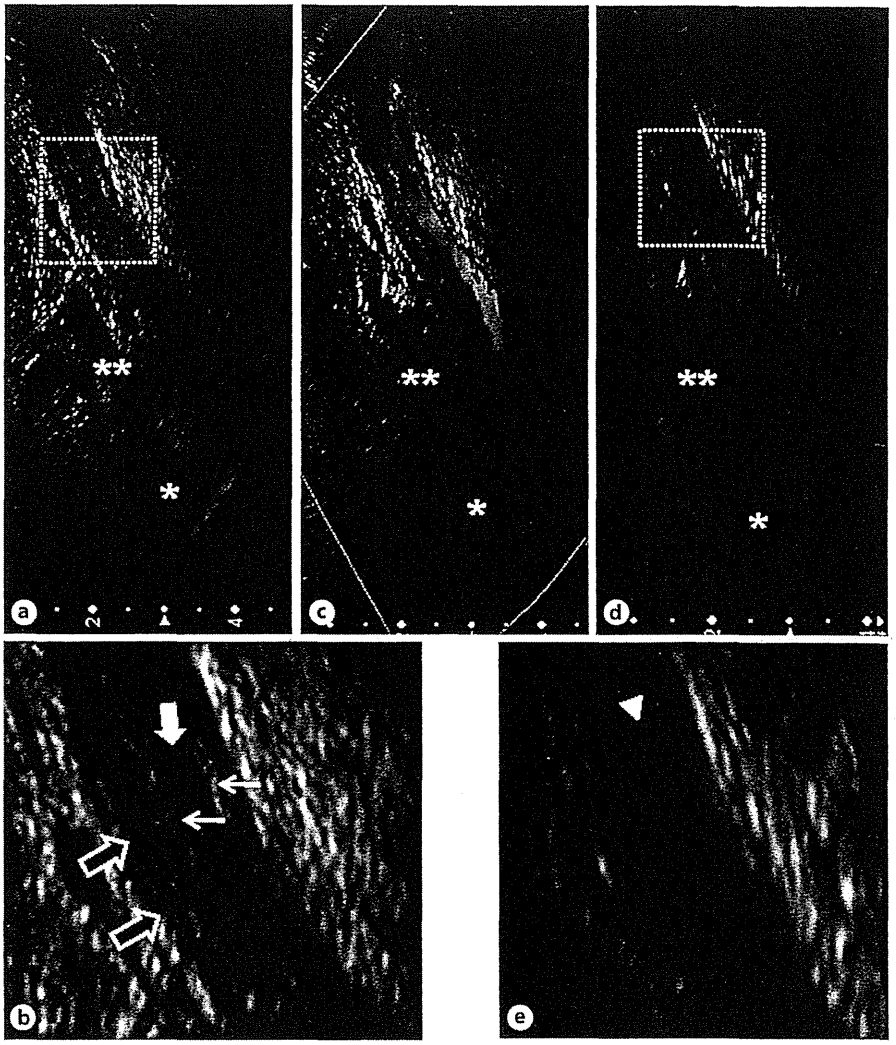

Fig. 3. Dissected ICA on TOCU images in case 5. **a**, **b** Longitudinal B-mode image of the right ICA on day 3. Narrowing of the true lumen (thick arrow), thrombosed false lumens (open arrows), and intimal flaps (thin arrows) are shown more than 2 cm distal to the carotid bifurcation. **c** Color Doppler image on day 3. Antegrade blood flow in the true lumen is observed. **d**, **e** Follow-up B-mode images on day 26. The true lumen turns wider (arrowhead). * and ** indicate the carotid bifurcation and external carotid artery, respectively. **b**, **e** Magnified images of lesions surrounded by dotted frames in **a** and **d**, respectively.

rial sites were at the level of the intracranial ICA, direct findings of ICA occlusion were not made by TOCU. On follow-up TOCU, dynamic changes of the dissected artery were detected in 4 patients (cases 2, 4, 5, 8). Narrowing of the true lumen and increased flow velocity, indicating a stenotic change in the ICA, improved on sequential follow-up TOCU (cases 2, 4, 5). In case 8, reperfusion with antegrade blood flow of the true lumen was detected. A pseudoaneurysm was detected in 3 patients (cases 3–5), and a pseudoaneurysm was missed in case 2, probably due to its high position. Figures 3 and 4 show sequential TOCU images in cases 5 and 8, respectively.

In contrast, definite findings specific to dissections, including a double lumen with an intimal flap, could not be made by TSCU in any patients. Six patients (cases 1, 4–8) showed nonspecific findings indicative of arterial stenosis or occlusion; 3 had mild arterial narrowing (<50%) with presumably a thin, echogenic intravascular structure which probably represents an intimal flap was found at a short distance above the bifurcation on B-mode images [17], 5 (cases 1, 4, 6, 7, 8) had absent end-diastolic flow of the ICA, suggesting distal ICA occlusion, and 1 (case 5) had increased peak systolic flow velocity exceeding 200 cm/s (203 cm/s), suggesting ICA stenosis.

Arterial dilatation of the proximal carotid ICA was visualized in only 2 patients by TSCU whereas TOCU identified arterial dilatation of the dissected extracranial ICA using in all patients.

Cervical MRI/MRA was performed in all patients from 6 days to 1 month after stroke onset. Gadolinium-

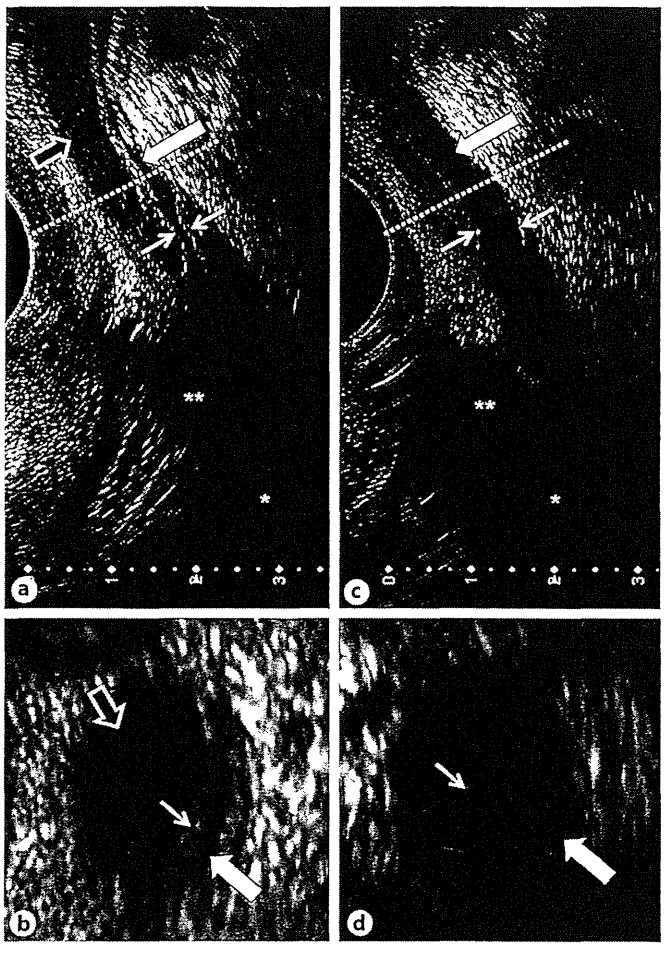

Fig. 4. Dissected ICA on TOCU images in case 8. **a**, **b** Longitudinal (**a**) and axial (**b**) B-mode TOCU images on day 8, showing narrowing of the true lumen (filled arrows), thrombosed false lumens (open arrows), and intimal flaps (thin arrows). **c**, **d** Follow-up B-mode images on day 32. The wider true lumen (filled arrows) and intimal flaps (thin arrows) are shown. * and ** indicate the carotid bifurcation and external carotid artery, respectively. Dotted lines in **a** and **c** indicate the levels of axial B-mode in **b** and **d**, respectively.

enhanced MRA was performed in 3 patients (cases 2, 5, 6). Cervical MRA images revealed an intimal flap with a double lumen in 2 patients, ICA stenosis and a pseudoaneurysm in another 2 patients, and ICA tapering occlusion and a thrombosed false lumen in 4 patients. On the axial view of T_1-weighted MRI, 6 patients had intramural hematomas, with high signals between the first and third cervical vertebrae in 2 and from the third vertebra to the intracranial ICA in 4. The luminal diameter on T_1-weighted images was 7.7 ± 0.9 mm in the dissected ICA and 5.6 ± 0.8 mm in the contralateral ICA ($p = 0.008$).

Discussion

The utility of TOCU in the diagnosis of ICA dissection has only been reported in isolated case reports, all from our institute [26–28]. This is the first report on the identification of ICA dissection using TOCU in consecutive stroke patients with ICA dissection as the final diagnosis. The first major finding of this study is that TOCU provided results comparable with those made by DSA and MRA for the diagnosis of dissection based on the presence of an intimal flap with a double lumen in all patients. Although Benninger et al. [30] reported that TSCU plus transcranial ultrasound was highly accurate in the diagnosis of ICA dissection, their definition of the diagnosis was mainly based on indirect findings, such as changes in the ICA blood flow pattern. It seems to be difficult to identify direct findings such as intimal flap and double lumens by TSCU. In addition, several unique signs, such as arterial stenosis, patency and thrombotic changes in true and false lumens, were also easily detectable using TOCU. The second major finding is that sequential changes in morphology and color flow signals, which are other important findings indicative of dissection, were identified in half of the present patients on follow-up TOCU. Third, a larger luminal diameter of the dissected ICA as compared with the contralateral ICA was measurable by TOCU. These results show the advantages of TOCU over TSCU in the diagnosis of dissection. Since the carotid artery bifurcation is generally higher in Asian patients (at the lower part of the third cervical vertebra) than in Western patients (approximately the fourth cervical vertebra) [31, 32], TOCU seems to be especially useful in Asian patients.

The utility of TOCU in the diagnosis of ICA dissections has changed over the last 12 years. In 5 of 8 patients in whom ICA dissections had already been proven by DSA, TOCU was simply used to confirm the diagnosis and to follow up changes over time. In 3 recent patients, we used TOCU before DSA in those with suspected ICA dissection whereas we preferred cervical MRI/MRA evaluations for suspected lesions of the extracranial distal ICA.

Since TOCU was not done in all of the patients of our database, the specificity of the diagnosis of ICA dissection using TOCU cannot be assessed. Thus, we cannot conclude that TOCU represents a gold standard for diagnosing dissections. At least, one can say that TOCU is useful for identifying false lumens and obtaining information as to their blood flow. For example, changes in the color flow signals in the false lumen indicate growth or

decrease of intramural clots. In contrast, DSA often delineates false lumens as nonspecific arterial stenosis or occlusion and requires a 3D rotational technique for detailed identification. T_1-weighted MRI of an intramural hematoma is better or more convincing, especially in cases of ICA occlusion identified by DSA. TOCU is superior to MRI and MRA for the documentation of real-time blood flow visualization and flow velocity measurement; such information reflects changes in arterial diameter and arterial reopening. In patients with only flap and/or aneurysmal dilatation TOCU might provide complementary information to that provided by DSA and MRI/MRA. In addition, TOCU is noninvasive, does not augment the dissection, and is easily repeatable at the bedside. Thus, TOCU is available both as a screening and as a frequent follow-up method of uncommon strokes. For example, a patient with developing arterial dilatation or aneurysmal change on follow-up within a short interval is a candidate for emergent surgery or intra-arterial catheter treatment.

The tip of the probe is about 2 cm across in diameter. The pharyngeal reflex rarely occurs because the probe just touches the posterolateral wall and the examination usually takes only a few minutes. Based on our unpublished data, ICA was visible without local anesthesia in more than 95% of the patients and no patients had aspiration pneumonia related to TOCU.

This study has some limitations. The first limitation is the small patient number, which partly results from the ethnic peculiarity; a nationwide survey in Japan indicates that only 2.4% of all patients with cervicocephalic dissection had extracranial ICA dissection whereas 63% had intracranial vertebral artery dissection [29]. Second, some patients having ICA dissection might have been misdiagnosed and might have missed the opportunity to undergo TOCU. DSA is not routine for all stroke inpatients and the lack of universally established criteria for dissection might prevent accurate diagnosis even by DSA. Third, TOCU was performed after DSA in the initial 5 patients; this caused sample selection bias. Finally, the imaging quality of TOCU has greatly improved during the 10-year study period; e.g. a newer Aplio™ XU with a 6-MHz micro convex probe provides a wider view of the ICA (up to 6–7 cm from the bifurcation) than the ATL Ultramark 9 HDI with a 5- to 9-MHz micro convex probe (approximately up to 3 cm) [21].

In conclusion, TOCU enabled definite diagnoses of extracranial ICA dissection and was superior to conventional TSCU. TOCU is a promising diagnostic tool in patients with extracranial ICA dissection.

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Disclosure Statement

None.

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Clopidogrel Two Doses Comparative 1-Year Assessment of Safety and Efficacy (COMPASS) Study in Japanese Patients with Ischemic Stroke

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Key Words
Clopidogrel · Ischemic stroke · Secondary prevention

Abstract
Background: Clopidogrel 75 mg once daily is licensed in Japan for the prevention of recurrent ischemic cerebrovascular events in adults as the usual dosage. However, a lower dose (50 mg) is an option in patients at an increased risk of bleeding depending on age, body weight and symptoms. This study compared the safety of both 75- and 50-mg doses of clopidogrel in patients with noncardioembolic ischemic stroke. ***Methods:*** This was a double-blind, double-dummy postmarketing clinical trial carried out across 118 Japanese institutions. Patients with an episode of noncardioembolic ischemic stroke at least 8 days prior to randomization, who were aged <75 years or had a body weight >50 kg were randomized to 50 or 75 mg clopidogrel once daily for 52 weeks. The primary endpoint was the incidence of bleeding adverse events. The secondary safety endpoints included the incidence of serious adverse events, serious bleeding adverse events and other prespecified adverse events. The secondary efficacy endpoint was the incidence of vascular events, including ischemic stroke, myocardial infarction, and peripheral artery disease. ***Results:*** A total of 1,110 patients were randomized to clopidogrel 50 mg (n = 558) or 75 mg (n = 552). No significant difference between the groups was detected in the incidence of bleeding adverse events, which was 14.0 and 16.5% in the clopidogrel 50- and 75-mg groups, respectively (hazard ratio = 0.831, 95% CI = 0.615–1.124, p = 0.2274). Additionally, there was no statistical difference with respect to any of the secondary safety endpoints. No significant difference between the groups was detected in the incidence of serious adverse events, which was 8.6 and 9.5% in the clopidogrel 50- and 75-mg groups, respectively (hazard ratio = 0.877, 95% CI = 0.597–1.289, p = 0.5035), and there was no significant difference between the groups in the incidence of serious bleeding events, which was 1.7 and 1.5% in the clopidogrel 50- and 75-mg groups, respectively (hazard ratio = 1.240, 95% CI = 0.489–3.142, p = 0.6496). The percentages of intracranial hemorrhage in the 50- and 75-mg groups were 0.18% (1/558) and 0.18% (1/552), respectively. The cumulative incidence of vascular events was somewhat lower in the 75-mg group, but was not statistically different (2.6 vs. 3.8%; p = 0.4118). ***Conclusions:*** Clopidogrel 75 mg provides a clinically acceptable safety profile and suggests better clinical benefit as compared to clopidogrel 50 mg for the secondary prevention of ischemic stroke in Japanese patients who are <75 years old with a body weight >50 kg, considering the balance of safety and efficacy on this trial.

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Introduction

Ischemic stroke is well recognized as a leading cause of death and disability worldwide. In Japan, the incidence of ischemic stroke is 260–357 per 100,000 person-years, corresponding to a mortality rate of 45–68 per 100,000 person-years [1]. Moreover, in patients who survive a first ischemic stroke, the risk of recurrence is high; 4.83% for Japanese patients enrolled in the REACH registry [2] and 24.5% in Japanese patients with mild strokes [3] within 2 years. Therefore, administration of antiplatelet agents is essential for the secondary prevention of ischemic stroke [4].

The antiplatelet agent clopidogrel is a thienopyridine agent that inhibits platelet aggregation by selectively and irreversibly inhibiting the binding of adenosine diphosphate to its platelet receptor P2Y12 [5]. In a large, predominantly Caucasian population at risk of ischemic events due to atherosclerotic vascular disease (manifested as ischemic stroke, myocardial infarction, or symptomatic peripheral arterial disease), clopidogrel 75 mg once daily was shown to be more effective than aspirin 325 mg once daily for the prevention of ischemic events [6]. On the basis of these and other results, clopidogrel 75 mg once daily has been licensed for more than 10 years in Western countries for the prevention of atherothrombotic events in patients with ischemic cerebrovascular, coronary, or peripheral arterial disease [7, 8].

Studies conducted in Japan among patients with a history of ischemic stroke have demonstrated that clopidogrel 75 mg once daily is better tolerated than ticlopidine 200 mg once daily, and shows noninferior efficacy with regard to the secondary prevention of vascular events [9, 10]. However, any bleeding adverse events requiring attention were observed with a higher incidence among patients receiving clopidogrel who were aged ≥75 years (vs. <75 years) or weighed <50 kg (vs. ≥50 kg) [9]. Consequently, in Japan, clopidogrel is licensed for oral use at a dose of 75 mg once daily, but, depending on the patient's age and body weight, a dose of 50 mg once daily is recommended.

Thus, the present postmarketing study compared the safety and efficacy of clopidogrel 50 and 75 mg for the secondary stroke prevention in Japanese patients, who were aged <75 years and weighed >50 kg.

Materials and Methods

Study Design

This study was a multicenter, single-country, randomized, double-blind, double-dummy phase IV trial (NCT00386191) designed to compare the safety of 50 and 75 mg of clopidogrel for the secondary stroke prevention in Japanese patients. The primary safety endpoint was the incidence of bleeding adverse events. The secondary safety endpoints included the incidence of serious adverse events (SAEs), serious bleeding adverse events, and prespecified adverse events of interest comprised of leukopenia, neutropenia, thrombocytopenia, and hepatic dysfunction. The incidence of vascular events was used to compare the efficacy of the two clopidogrel doses.

Patients were recruited to the study from 118 Japanese medical institutions. Patients aged 20–74 years with a body weight >50 kg were eligible for the study if they had experienced an episode of noncardioembolic ischemic stroke at least 8 days prior to randomization and their clinical course preceding randomization was well documented, or if they had experienced an ischemic stroke confirmed at the study institution using diagnostic brain imaging (assessed by CT or MRI) performed <12 weeks before treatment initiation.

The main exclusion criteria for the study were: patients with cardiogenic stroke or disease that could precipitate cardiogenic cerebral thromboembolism, such as atrial fibrillation or valvular heart disease (including valve replacement); patients with a transient ischemic attack occurring after the last episode of ischemic stroke; patients with a serious impairment that would hinder the detection of a new ischemic event (e.g. bedridden, needing total assistance, or dementia); patients with bleeding diathesis, coagulopathy, or hemorrhagic disease; patients with a history of intracranial hemorrhage; patients with diabetic retinopathy; patients with hypertension and insufficient control of blood pressure despite antihypertensive therapy, and patients with malignancy (except complete remission from malignancy <5 years prior to randomization), cardiac disease, serious renal disease or abnormal creatinine levels, leukopenia, neutropenia, thrombocytopenia, severe hepatic dysfunction, or a history of drug allergy.

Within 2 weeks of obtaining informed consent, patients were randomly allocated to receive either clopidogrel 50 or 75 mg. Based on an application from the investigator, a centralized patient registration center confirmed the patient eligibility, and notified his/her registration and an allocation number to identify the study drug among the distributed drugs to the investigator and the sponsor by telephone or facsimile. If a patient was ineligible due to noncompliance with the inclusion and exclusion criteria, the centralized patient registration center notified the fact to the investigator.

Double-blinding was maintained in both treatment groups throughout the course of the study as follows: a controller confirmed the indistinguishability of the study drugs and of their package appearances at the time of randomized allocation and between finalization of all case report forms and the key code breaking. The controller established the key codes and emergency key codes to cope with emergencies. The controller also retained the key codes and emergency key codes in sealed and signed envelopes until the time of key code breaking.

Patients assigned to the 50-mg group received two 25-mg clopidogrel tablets and one 75-mg placebo tablet that was indistinguishable from the 75-mg clopidogrel tablet (3 tablets in total). Those patients assigned to the 75-mg group received two 25-mg placebo tablets that were indistinguishable from the 25-mg clopidogrel tablets and one 75-mg clopidogrel tablet (3 tablets in total). The doses for the 50- and 75-mg groups were administered orally once daily after a meal.