Kaohsiung Journal of Medical Sciences (2013) 29, 667–672

Available online at www.sciencedirect.com

SciVerse ScienceDirect

journal homepage: http://www.kjms-online.com

ORIGINAL ARTICLE

Predictive value of vertebral artery extracranial color-coded duplex sonography for ischemic stroke-related vertigo

Li-Min Liou [a], Hsiu-Fen Lin [b,c], I-Fang Huang [a], Yang-Pei Chang [b], Ruey-Tay Lin [b,c], Chiou-Lian Lai [b,c,*]

[a] *Department of Neurology, Kaohsiung Municipal Hsiaokang Hospital, Kaohsiung Medical University, Kaohsiung, Taiwan*
[b] *Department of Neurology, Kaohsiung Medical Hospital, Kaohsiung Medical University, Kaohsiung, Taiwan*
[c] *Department of and Master's Program in Neurology, Faculty of Medicine, College of Medicine, Kaohsiung Medical University, Kaohsiung, Taiwan*

Received 13 August 2012; accepted 5 November 2012
Available online 30 August 2013

KEYWORDS
Ischemic stroke;
Posterior circulation;
Sonography;
Vertebral artery;
Vertigo

Abstract Vertigo can be a major presentation of posterior circulation stroke and can be easily misdiagnosed because of its complicated presentation. We thus prospectively assessed the predictive value of vertebral artery extracranial color-coded duplex sonography (ECCS) for the prediction of ischemic stroke-related vertigo. The inclusion criteria were: (1) a sensation of whirling (vertigo); (2) intractable vertigo for more than 1 hour despite appropriate treatment; and (3) those who could complete cranial magnetic resonance imaging (MRI) and vertebral artery (V2 segment) ECCS studies. Eventually, 76 consecutive participants with vertigo were enrolled from Kaohsiung Municipal Hsiao-Kang Hospital, Kaohsiung, Taiwan between August 2010 and August 2011. Demographic data, neurological symptoms, neurologic examinations, and V2 ECCS were assessed. We chose the parameters of peak systolic velocity (PSV), end diastolic velocity (EDV), PSV/EDV, mean velocity (MV), resistance index (RI), and pulsatility index (PI) to represent the hemodynamics. Values from both sides of V2 segments were averaged. We then calculated the average RI (aRI), average PI (aPI), average PSV (aPSV)/EDV, and average (aMV). Axial and coronal diffusion-weighted MRI findings determined the existence of acute ischemic stroke. We grouped and analyzed participants in two ways (way I and way II analyses) based on the diffusion-weighted MRI findings (to determine whether there was acute stroke) and neurological examinations. Using way I analysis, the "MRI (+)" group had

* Corresponding author. Department of Neurology, Kaohsiung Medical University Hospital, No. 100, Tzyou 1st Road, Kaohsiung City 807, Taiwan.
E-mail address: lai95069@gmail.com (C.-L. Lai).

1607-551X/$36 Copyright © 2013, Kaohsiung Medical University. Published by Elsevier Taiwan LLC. All rights reserved.
http://dx.doi.org/10.1016/j.kjms.2013.01.015

significantly higher impedance (aRI, aPI, and aPSV/EDV ratio) and lower velocity (aPSV, aEDV, and aMV(PSV + EDV/2)), compared to the "MRI (−)" group. The cutoff value/sensitivity/specificity of aPSV, aEDV, aMV, aPI, aRI, and aPSV/EDV between the MRI (+) and MRI (−) groups were 41.15/61.5/66.0 ($p = 0.0101$), 14.55/69.2/72.0 ($p = 0.0003$), 29.10/92.1/38.0 ($p = 0.0013$), 1.07/76.9/64.0 ($p = 0.0066$), 0.62/76.9/64.0 ($p = 0.0076$), and 2.69/80.8/66.0 ($p = 0.0068$), respectively. Using way II analysis, lower aEDV and aMV, and higher aRI, aPI, and aPSV/EDV ratio could determine the "MRI (+) without focal signs" group. The cutoff value/sensitivity/specificity of aEDV, aMV, aPI, aRI, and aPSV/EDV between the MRI (+) without focal signs and MRI (−) groups were 9.10/71.4/96.0 ($p = 0.0005$), 15.65/57.1/96.0 ($p = 0.0124$), 1.10/100/70.0 ($p = 0.0002$), 0.64/100/70.0 ($p = 0.0023$), and 2.80/100/70.0 ($p = 0.0017$), respectively. In conclusion, using demographic data and clinical symptoms, it was difficult to determine the patients with ischemic stroke-related vertigo. Although neurological examinations still have diagnostic value, the high impedance and low velocity pattern of V2 ECCS can be an add-on method for the screening of acute ischemic stroke-related vertigo, even for those without focal neurological signs.
Copyright © 2013, Kaohsiung Medical University. Published by Elsevier Taiwan LLC. All rights reserved.

Introduction

Vertigo is one of the most common complaints encountered in clinical practice [1], affecting approximately 20−30% of the general population [2]. About 7−11% of all cases of vertigo in the general population may be related to a major presentation of brain insult, of which ischemic posterior circulation stroke (PCS) is the leading cause [3].

Compared to carotid artery stenosis, only limited data are available on the natural course of vertebral artery (VA) stenosis and its relationship with the clinical characteristics of PCS [4]. However, with improvements in neuroimaging methods [5], the role of extracranial VA has been emphasized in PCS. Kim et al [6] reported a prevalence of ≥50% stenosis of the proximal VA in 44%, and the distal VA/basilar artery in 36.1% of patients with PCS [6]. With regard to prognosis, patients with both symptomatic and asymptomatic VA stenosis probably have an increased risk of PCS [4,7]. Furthermore, the severity of VA stenosis seems to be related to PCS more than carotid stenosis to carotid territory events, and is associated with multiple transient ischemic attacks at presentation and a high risk of early recurrence [4].

In the present study, we hypothesized that VA extracranial color-coded duplex sonography (ECCS) would be able to determine the patients with PCS by examining the differences in hemodynamics between patients with and without PCS, and so be used as a screening tool for ischemic stroke-related vertigo (isVertigo).

Materials and methods

Participants

This was a prospective study. The Institutional Review Board of Kaohsiung Municipal Hsiao-Kang Hospital, Kaohsiung, Taiwan approved all study protocols, and the study participants provided informed consent. Eighty consecutive patients with intractable vertigo were recruited between August 2010 and August 2011 using the following inclusion criteria: (1) a sensation of whirling (vertigo); (2) intractable symptoms persisting for more than 1 hour despite being given appropriate dosages of diphenhydramine, benzodiazepine (diazepam or lorazepam), vasodilator (betahistine hydrochloride), and diuretic (acetazolamide) one after another; and (3) those who were able to complete magnetic resonance imaging (MRI) and VA ECCS studies. The exclusion criteria included: (1) failure to obtain informed consent; (2) inability to undergo MRI because of either a contraindication or an inability to cooperate; (3) MRI disclosed a nonischemic stroke insult, for example, intracranial hemorrhage, brain tumor, or arterial vascular malformations, or axial and coronal diffuse-weighted (DW) MRI determined the existence of acute ischemic stroke; and (4) MRI disclosed VA hypoplasia (diameter <2 mm) [8] because it is difficult to differentiate hypoplasia from occlusion by ECCS [9].

We grouped and analyzed the participants in two ways (way I and way II analyses) based on MRI scans (whether there was hyperintensity on axial and coronal DW-MRI) and whether there were focal neurological signs. In way I analysis, we separated the patients into "MRI (+)" and "MRI (−)" groups to investigate whether V2 ECCS could determine the patients with acute ischemic stroke (Table 1). In way II analysis, we separated the patients with acute isVertigo into "MRI (+) with focal signs" and "MRI (+) without focal signs" groups to investigate whether V2 ECCS could determine the acute ischemic stroke patients without focal signs (Table 2).

Measurements

ECCS technique

After written informed consent was provided, VA ECCS was assessed using a Philips SONOS 7500 (Philips Ultrasound, WA, USA) ultrasonography system equipped with a 5-MHz linear probe. VA ECCS was performed within 24 hours after symptom onset. After the patient had been lying down (supine with the head straight and neck extended) for 15 minutes in a quiet room, ECCS was used to visualize bilateral vertebral arteries (V2 segment) three times at 20-

Table 1 Demographic and clinical characteristics, and transcranial color-coded duplex sonography indices of the "MRI (−)" and "MRI (+)" groups (way I analysis).

	MRI (−)	MRI (+)	*p*
Patient number (%)	*n* = 50 (65.79%)	*n* = 26 (34.21%)	
Male (%) [a]	47.06	50.00	0.8070
Age (y)[b]	63.22 ± 1.90	67.63 ± 2.96	0.2143
Demographic data			
Diabetes mellitus [a]	25.53	33.33	0.4927
Hypertension [a]	48.94	70.83	0.0748
Dyslipidemia [a]	21.28	37.50	0.1499
Alcoholism [a]	6.38	4.17	0.6947
Smoking [a]	8.51	8.33	0.9797
Ischemic heart disease [a]	6.38	13.04	0.3635
Atrial fibrillation [a]	2.13	4.17	0.6326
Old cerebral vascular disease [a]	18.00	7.69	0.2256
Clinical symptoms			
Recent URI [a]	36.00	26.92	0.4243
Severity [a]	60.00	76.92	0.1331
Ataxia only when vertigo [a]	68.00	53.85	0.2275
1st episode [a]	40.00	53.85	0.2499
Posture-related [a]	76.00	72.00	0.7088
Nausea [a]	54.00	50.00	0.7405
Vomiting [a]	44.00	42.31	0.8876
Palpitation/chest tightness [a]	52.00	53.85	0.8784
Tinnitus [a]	54.00	46.15	0.5161
Hearing impairment [a]	68.00	46.15	0.0657
Fullness [a]	22.00	15.38	0.4849
Otalgia [a]	12.00	3.85	0.2128
Headache [a]	42.00	46.15	0.7291
Neurological examinations			
	36% (18/ 50)	73.08% (19/ 26)	−
Horizontal nystagmus [a, c]	30.00	30.77	0.9448
Cranial nerve sign [a]	2.00	15.38	**0.0293**
Bell phenomenon [a]	92.00	88.46	0.6181
Hemiparesis [a]	6.00	23.08	**0.0338**
Babinski sign [a]	4.00	3.85	0.9739
Ataxia [a]	6.00	34.62	**0.0015**
Truncal ataxia [a]	2.00	15.38	**0.0293**
Limb ataxia [a]	4.00	19.23	**0.0345**
Sensory deficit [a]	2.00	7.69	0.2423
Asymmetric deep tendon reflex [a]	2.00	2.63	0.6420
V2 ECCS			
aPSV [b]	49.60 ± 25.34	38.03 ± 11.90	**0.0309**
aEDV [b]	18.78 ± 7.99	13.02 ± 5.39	**0.0015**
aMV [b]	29.05 ± 13.12	21.35 ± 6.88	**0.0067**
aPI [b]	1.05 ± 0.26	1.25 ± 0.34	**0.0062**
aRI [b]	0.62 ± 0.08	0.66 ± 0.09	**0.0078**
aS/D ratio [b]	2.76 ± 0.81	5.58 ± 8.72	**0.0252**

Data are presented as % or mean ± SD unless otherwise indicated.
aEDV = average EDV; aMV = average mean velocity; aPI = average PI; aPSV = average PSV; aRI = average RI; aS/D = average PSV/ EDV; MRI = magnetic resonance imaging; MRI (+) = acute ischemic stroke group by diffusion-weighted MR imaging; V2 ECCS = Segment 2 of Vertebral Artery Transcranial Color-Coded Duplex Sonography; *p* = *p*-value (figures in boldface indicate $p < 0.05$.)
[a] By the χ^2 test.
[b] By the *t* test.
[c] No participants were found to have vertical nystagmus.

minute intervals. All VA Doppler examinations were performed by Dr. Hsiu-Fen Lin, who was blinded to the patient's history and neurological examination. Gain and velocity settings of the color Doppler unit were adjusted to ensure that all examinations were technically adequate. Data on Doppler waveforms and velocities were obtained with an angle of insonation of 60° or less, and the V2 segment was then identified. The sonographer first imaged the common carotid artery in a longitudinal section on B-mode from a lateral approach. Once the probe had been positioned over the long axis of the common carotid artery, it was slid posteriorly (without any rotation). The acoustic windows from the transverse processes of the vertebrae were then seen, and one segment (or more) of the V2 section was seen between windows. Once the orientation of the relevant segment of the VA had been established, the vessel was imaged with color Doppler and the direction of flow established. For the pulsed wave, Doppler was used to display the waveform in the V2 to measure the peak systolic velocity (PSV) and end diastolic velocity (EDV). After a mean of three values, we obtained mean PSV (mPSV) and mean EDV (mEDV) for both sides. We then calculated mean velocity (MV) as (mPSV + mEDV)/2, pulsatility index (PI) as (mPSV − mEDV)/MV [10] and resistance index (RI) as (mPSV − mEDV)/mPSV [11]. Both sides of the vessels were evaluated, and values from both sides were averaged to obtain the average PSV (aPSV), average EDV (aEDV), average MV (aMV), average S/D (aS/D) ratio, average RI (aRI), and average PI (aPI) values. Angle-corrected measurements were performed in an axis vessel view more than 2 cm in length that was insonated with an angle of less than 60°. Flow grades were measured on both VAs at a depth between 7 cm and 9 cm. Sonographic data were evaluated offline by two observers blinded to the patients' clinical, computerized tomography, and MRI data.

Cerebral MRI

Cerebral MRI scans were performed within 48 hours after symptom onset using a 3.0-T scanner (Signa VH3; GE Medical Systems, Milwaukee, WI, USA). Spin−echo T1-weighted axial and sagittal images (TR = 484 ms; TE = 8−9 ms; slice thickness = 5 mm; intersection gap = 1 mm), fast spin−echo

Table 2 V2 ECCS index between MRI (−) without old infarction and MRI (+) with/ without focal signs groups (way II analysis).

	MRI (−)	MRI (+) without focal signs [a]	*p*	MRI (+) with focal signs [a]	*p*
n (%)	50 (65.79%)	7 (9.21%)		19 (25%)	
Age [b]	64.10 ± 12.92	68.00 ± 15.61	0.4687	66.95 ± 11.90	0.4068
Male (%)	48 %	57.14 %	0.6501	47.37 %	0.9626
aPSV [b]	49.60 ± 25.34	37.69 ± 18.17	0.1811	38.15 ± 9.30	0.0582
aEDV [b]	18.78 ± 7.99	10.40 ± 4.13	**0.0018**	13.98 ± 5.57	**0.0177**
aMV [b]	29.05 ± 13.12	19.50 ± 7.86	**0.0344**	22.04 ± 6.58	**0.0290**
aPI [b]	1.05 ± 0.26	1.48 ± 0.43	**0.0033**	1.166 ± 0.26	0.0796
aRI [b]	0.61 ± 0.08	0.72 ± 0.09	**0.0040**	0.64 ± 0.09	0.1176
aPSV/ EDV ratio [b]	2.76 ± 0.81	12.13 ± 15.60	**0.0037**	3.16 ± 1.24	0.0591

Data are presented as % or mean ± SD unless otherwise indicated.
aEDV = average EDV; aMV = average mean velocity; aPI = average PI; aPSV = average PSV; aPSV/ EDV = average PSV/ EDV; aRI = average RI; MRI = magnetic resonance imaging; MRI (+) = acute ischemic stroke group by diffusion-weighted MR imaging; V2 ECCS = Segment 2 of Vertebral Artery Transcranial Color-Coded Duplex Sonography; *p* = *p*-value (figures appear in boldface indicate *p*-value < 0.05.)
[a] Focal signs indicate items in the category "neurologic examinations" in Table 1.
[b] By *t* test and nonparametric analysis.

T2-weighted axial images (TR = 4000 ms; TE = 98 ms; slice thickness = 5 mm; intersection gap = 1 mm), fluid-attenuated inversion recovery (FLAIR) and diffusion-weighted axial and coronal images with a single-shot echo-planar imaging technique (TR/TE = 10,000/minimum; *b* = 0, 1000; field of view = 30; slice thickness = 5 mm; intersection gap = 1 mm) were obtained. The MRI (+) group was defined as those participants with hyperintensity on axial or coronal diffusion-weighted imaging. The MRI (−) group was defined as those participants without signal abnormalities on T1, T2, or diffusion-weighted MRI.

Statistical analysis

Statistical analysis was performed with the use of JMP software, version 8.02 (SAS Institutes Inc., Cary, NC, USA). Age, aPSV, aEDV, aMV, aS/D ratio, aRI, and aPI measurements were analyzed using *t* test and nonparametric tests. Receiver operating characteristic curves were used to determine the cutoff value, sensitivity, and specificity. Sex, diabetes mellitus, hypertension, dyslipidemia, smoking, alcohol consumption, ischemic heart disease, and atrial fibrillation were analyzed using Chi-square test. A *p* value of <0.05 was considered to be statistically significant.

Results

In total, 76 patients (mean age = 65.17 ± 12.84 years; males = 48.68%) with intractable vertigo were enrolled for analysis (four patients were excluded from the study: one patient had atresic VA, two patients had primary intracerebral hemorrhages, and one patient had intracerebral gliomas). Initially, only 19 patients were clinically diagnosed to have stroke-related ischemic stroke because of focal signs on neurological examinations. Twenty-five patients had abnormal ECCS indices (at least 1 index > the cutoff value), and 26 patients had positive MRI findings (MRI (+) group). Therefore, the proportions of patients with an initial diagnosis of stroke-related vertigo confirmed by MRI and VA ECCS were 73.08% (19/26) and 76% (19/25), respectively.

Twenty-six (34.21%) of the patients (mean age = 67.63 ± 2.96 years) were found to have acute ischemic stroke (MRI (+) group), whereas 50 patients (65.79%; mean age = 63.22 ± 1.90 years) did not have acute ischemic stroke (MRI (−) group) (Table 1). There were no significant differences in demographic data and clinical symptoms between these two groups. With regard to the neurological examinations, the MRI (+) group had a higher percentage of patients with cranial nerve signs, hemiparesis, and truncal or limb ataxia.

With regard to V2 ECCS, the MRI (+) group had higher aRI, aPI, and aPSV/EDV ratio of VA flow, and lower aPSV, aEDV, and aMV. The corresponding lesion sites of the MRI (+) group are shown in Table 2 (way I analysis).

Table 3 Stroke lesion sites associated with MRI (+) and MRI (+) with and without focal neurologic signs groups.

	Way II analysis		Way I analysis
Lesion site	MRI (+) without focal signs [a]	MRI (+) with focal signs [a]	MRI (+)
Thalamus	3 (42.86)	1 (5.26)	4 (15.38)
Cerebellum	2 (28.57)	4 (21.05)	6 (23.08)
Pons-medulla	2 (28.52)	7 (36.85)	9 (34.63)
Parietal cortex	—	3 (15.79)	3 (11.54)
Basal ganglion	—	3 (15.79)	3 (11.54)
Occipital cortex	—	1 (5.26)	1 (3.85)

Data are presented as *n* (%)
MRI = magnetic resonance imaging; MRI (+) = acute ischemic stroke group by diffusion-weighted MR imaging.
[a] Focal signs indicate items in the category "neurologic examinations" in Table 1.

Table 4 Cut-off values, sensitivity, specificity and AUC in way I and way II analyses.

	Way I analysis					Way II analysis [a]									
	MRI (+) vs. MRI (−)					MRI (+) without focal signs vs. MRI (−)					MRI (+) with focal signs vs. MRI (−)				
	Cut-off	Sens (%)	Spec (%)	AUC	*p*	Cut-off	Sens (%)	Spec (%)	AUC	*p*	Cut-off	Sens (%)	Spec (%)	AUC	*p*
aPSV	41.15	61.5	66.0	0.65	**0.0101**	—	—	—	—	—	41.25	63.2	66.0	0.65	**0.0186**
aEDV	14.55	69.2	72.0	0.74	**0.0003**	9.10	71.4	96.0	0.87	**0.0005**	15.20	63.2	72.0	0.69	**0.0082**
aMV	29.10	92.1	38.0	0.69	**0.0013**	15.65	57.1	96.0	0.75	**0.0124**	27.96	89.5	42.0	0.67	**0.0089**
aPI	1.07	76.9	64.0	0.69	**0.0066**	1.10	100	70.0	0.85	**0.0002**	—	—	—	—	—
aRI	0.62	76.9	64.0	0.68	**0.0076**	0.64	100	70.0	0.84	**0.0023**	—	—	—	—	—
aPSV/EDV	2.69	80.8	66.0	0.70	**0.0068**	2.80	100	70.0	0.84	**0.0017**	—	—	—	—	—

aEDV = average end diastolic velocity; aMV = average mean velocity; aPI = average pulsatility index; aPSV = average peak systolic velocity; aPSV/EDV = average PSV/ EDV; aRI = average resistance index; AUC = area under curve; MRI = magnetic resonance imaging; MRI (+) = acute ischemic stroke group by diffusion-weighted MR imaging; Sens = sensitivity; Spec = specificity; V2 ECCS = Segment 2 of Vertebral artery Transcranial Color-Coded Duplex Sonography.

[a] - indicates no significant difference, so data are not presented in the table.

Pontomedullar, cerebellar, and thalamic lesions accounted for 73.07% of all strokes.

In way II analysis, we separated the patients into MRI (−), MRI (+) without focal signs, and MRI (+) with focal signs groups (Table 3). Compared with the MRI (−) group, the MRI (+) without focal signs group had significantly lower aEDV and aMV and higher aRI, aPI, and aS/D ratio, and the MRI (+) with focal signs group had significantly lower aEDV and aMV. Table 2 (way II analysis) shows the corresponding lesion sites.

We further calculated the cutoff values and the corresponding sensitivities and specificities in way I and way II analyses (Table 4). In way I analysis, there were significant differences in all parameters between the MRI (+) and MRI (−) groups. In way II analysis, there were significant differences in aEDV, aMV, aRI, aPI, and aPSV/EDV between the MRI (−) and MRI (+) without focal sign groups. In addition, there were significant differences in aPSV, aEDV, and aMV between the MRI (−) and MRI (+) with focal signs groups.

Discussion

Sonography in the acute setting of stroke patients allows for the identification and the site of clots, prediction of outcomes, and study of the dynamic processes of vessel recanalization, in both the acute phase and follow-up [12]. The present study demonstrates the role of V2 ECCS and neurological examinations, but not clinical characteristics in the prediction of isVertigo, even for those without focal neurological signs.

There were several important findings in the current study. First, compared to the relatively high prevalence of VA atresia in Western populations (15%), the prevalence in our study was only 1.3%, which is similar to a previous study on a Chinese population (2−3%) [8]. Therefore, its effect on the results can be considered negligible. Second, compared to the high transtemporal window failure rate (about 16.3−20%) in transcranial color-coded duplex sonography for middle cerebral arteries [10,13], our failure rate for V2 ECCS was zero, which is similar to the findings of a previous report [14]. Therefore, although PCS contributes most to isVertigo [15], it is reasonable to use V2 ECCS in the screening of isVertigo. Third, atherosclerotic disease in the internal carotid artery and proximal VA is considered to share a common pathogenesis [16,17], and as V2 is less variable and easier to access, the use of V2 ECCS as a screening test is encouraging.

Because about 75% of the general population have an asymmetric VA [18], we averaged bilateral VA parameters to represent the hemodynamics. A normal VA Doppler waveform usually demonstrates a low-resistance flow pattern [18], and when there is distal obstruction, the flow pattern becomes high resistance [19]. Some studies have reported that duplex ultrasound has a high specificity (93−98%) but a relatively low sensitivity (70%) for the diagnosis of extracranial VA stenosis, especially for the proximal part [19]. However, V2 ECCS should have both good sensitivity and specificity, because although some part of 80−90% of all VAs can be insonated, V2 is seen clearly in nearly all patients [20]. In addition, the main role of ECCS here is to examine the distal obstruction of the VA (suggestive of vertebrobasilar insufficiency), instead of the proximal part.

Most textbooks state that isVertigo and peripheral vertigo have distinct clinical symptoms [21]. However, there is much overlap between isVertigo and peripheral vertigo [22]. Any disintegration of the posture-vestibular, the visual, or the somatosensory system will result in vertigo [23], which may explain why patients with isVertigo can have atypical presentations [24], and why basal ganglion and cortical strokes in our study could result in vertigo.

Neurological examinations can provide valuable information in determining isVertigo, but patients do not always have focal signs. In Kerber et al's [25] study, these type of patients accounted for 20% of cases in an emergency room. This is where VA ECCS may be of particular value.

Recently, contrast-enhanced magnetic resonance angiography (MRA) has been shown to have a good overall agreement with digital subtraction angiography [26]. Structural MRI also has high sensitivity for tiny stroke lesions in the posterior fossa [27]. However, MRI examinations are too expensive to be used for a screening test. In the

present study, we used cranial MRI/MRA to include cases with acute ischemic stroke, exclude VA hypoxia, and work backward to determine the difference with regard to VA ECCS index between each group.

The most important finding in our study is that V2 ECCS could determine the patients with isVertigo in those without focal signs. This may be because although both groups were associated with posterior circulation-related lesions, the MRI (+) with focal signs group was further associated with cerebral cortex and basal ganglion lesions.

There are several limitations to our study. First, the data were collected at a local hospital and thus subject to variability. Second, VA ECCS may not be as accurate in the prediction of lesions far from the posterior circulation, such as the cerebral cortex and basal ganglion lesions. However, such cases are rare in clinical practice, and VA ECCS still proved to have value in differential diagnosis. In conclusion, using only demographic data and clinical symptoms, it was difficult to determine the patients with isVertigo. Although neurological examinations still have diagnostic value, the high impedance and low velocity pattern of V2 ECCS as used in this study can be an add-on method for the screening of acute isVertigo, even for those without focal neurological signs.

References

[1] Schappert SM, Burt CW. Ambulatory care visits to physician offices, hospital outpatient departments, and emergency departments: United States, 2001—02. Vital Health Stat 2006; 13(159):1—66.

[2] Chu YT, Cheng L. Vertigo and dizziness. Acta Neurol Taiwan 2007;16:50—60.

[3] Karatas M. Central vertigo and dizziness: epidemiology, differential diagnosis, and common causes. Neurologist 2008;14: 355—64.

[4] Marquardt L, Kuker W, Chandratheva A, Geraghty O, Rothwell PM. Incidence and prognosis of $>$ or $=$ 50% symptomatic vertebral or basilar artery stenosis: prospective population-based study. Brain 2009;132:982—8.

[5] Crawley F, Clifton A, Brown MM. Treatable lesions demonstrated on vertebral angiography for posterior circulation ischaemic events. Br J Radiol 1998;71:1266—70.

[6] Kim SH, Lee JS, Kwon OK, Han MK, Kim JH. Prevalence study of proximal vertebral artery stenosis using high-resolution contrast-enhanced magnetic resonance angiography. Acta Radiol 2005;46:314—21.

[7] Compter A, van der Worp HB, Algra A, Kappelle LJ. Prevalence and prognosis of asymptomatic vertebral artery origin stenosis in patients with clinically manifest arterial disease. Stroke 2011;42:2795—800.

[8] Kao CL, Tsai KT, Chang JP. Large extracranial vertebral aneurysm with absent contralateral vertebral artery. Tex Heart Inst J 2003;30:134—6.

[9] Buckenham TM, Wright IA. Ultrasound of the extracranial vertebral artery. Br J Radiol 2004;77:15—20.

[10] Kenton AR, Martin PJ, Abbott RJ, Moody AR. Comparison of transcranial color-coded sonography and magnetic resonance angiography in acute stroke. Stroke 1997;28:1601—6.

[11] Zanette EM, Fieschi C, Bozzao L, Roberti C, Toni D, Argentino C, et al. Comparison of cerebral angiography and transcranial Doppler sonography in acute stroke. Stroke 1989;20:899—903.

[12] Malferrari G, Bertolino C, Casoni F, Zini A, Sarra VM, Sanguigni S, et al. The eligible study: ultrasound assessment in acute ischemic stroke within 3 hours. Cerebrovasc Dis 2007; 24:469—76.

[13] Seidel G, Kaps M, Gerriets T. Potential and limitations of transcranial color-coded sonography in stroke patients. Stroke 1995;26:2061—6.

[14] Trattnig S, Hubsch P, Schuster H, Polzleitner D. Color-coded Doppler imaging of normal vertebral arteries. Stroke 1990;21: 1222—5.

[15] Garg BP, Edwards-Brown MK. Vertebral artery compression due to head rotation in thalamic stroke. Pediatr Neurol 1995; 12:162—4.

[16] Castaigne P, Lhermitte F, Gautier JC, Escourolle R, Derouesne C, Der Agopian P, et al. Arterial occlusions in the vertebro-basilar system. A study of 44 patients with post-mortem data. Brain 1973;96:133—54.

[17] Roberts LH, Demetriades D. Vertebral artery injuries. Surg Clin North Am 2001;81:1345—56.

[18] Cloud GC, Markus HS. Diagnosis and management of vertebral artery stenosis. Q J Med 2003;96:27—54.

[19] Khan S, Cloud GC, Kerry S, Markus HS. Imaging of vertebral artery stenosis: a systematic review. J Neurol Neurosurg Psychiatry 2007;78:1218—25.

[20] Kuhl V, Tettenborn B, Eicke BM, Visbeck A, Meckes S. Color-coded duplex ultrasonography of the origin of the vertebral artery: normal values of flow velocities. J Neuroimaging 2000; 10:17—21.

[21] Baloh RW. Vertigo. Lancet 1998;352:1841—6.

[22] Newman-Toker DE, Cannon LM, Stofferahn ME, Rothman RE, Hsieh YH, Zee DS. Imprecision in patient reports of dizziness symptom quality: a cross-sectional study conducted in an acute care setting. Mayo Clin Proc 2007;82:1329—40.

[23] Morningstar MW, Pettibon BR, Schlappi H, Schlappi M, Ireland TV. Reflex control of the spine and posture: a review of the literature from a chiropractic perspective. Chiropr Osteopat 2005;13:16.

[24] Cnyrim CD, Newman-Toker D, Karch C, Brandt T, Strupp M. Bedside differentiation of vestibular neuritis from central "vestibular pseudoneuritis". J Neurol Neurosurg Psychiatry 2008;79:458—60.

[25] Kerber KA, Brown DL, Lisabeth LD, Smith MA, Morgenstern LB. Stroke among patients with dizziness, vertigo, and imbalance in the emergency department: a population-based study. Stroke 2006;37:2484—7.

[26] Yang CW, Carr JC, Futterer SF, Morasch MD, Yang BP, Shors SM, et al. Contrast-enhanced MR angiography of the carotid and vertebrobasilar circulations. AJNR 2005;26: 2095—101.

[27] Forster A, Ottomeyer C, Wolf ME, Kern R, Griebe M, Gass A, et al. Dynamic susceptibility contrast perfusion MRI identifies persistent vessel pathology in acute pontine stroke. Cerebrovasc Dis 2010;29:389—94.