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Transcranial Color-Code Doppler: Like the Laennec "Stethoscope" for Stroke Neurologist in Acute Stroke Care

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Abstract

Background: Transcranial Color-Code-Doppler (TCCD) may become a real "stethoscope" for stroke neurologists at the acute phase by exploring intracranial arteries, as Rene Laennec invented the stethoscope for cardiac auscultation.

Methods: At the Garibaldi Hospital of Catania, a stroke neurologist performed TCCD to explore middle cerebral artery (MCA) in acute stroke patients following by CT-angiography (CTA). It was used the Thrombolysis in Brain Ischemia (TIBI) grading system for residual flow for MCA exploration with TCCD.

Results: 30 patients (mean age was 60.7 years ± 12.7 SD; 19 females and 11 males) were included.

The mean total time for TCCD exploration was seven minutes. MCA was normal (TIBI: 5) in 19 patients; 5 had MCA stenosis (TIBI: 2-3) and 2 MCA occlusion (TIBI: 0). CTA confirmed these findings.

Conclusions: TCCD is fast, non-invasive and reliable to detect MCA stenosis and occlusion. We encourage stroke neurologists to use it like a cerebral "stethoscope" at the acute stroke care.

Keywords: Transcranial Color-Code Doppler; Acute Ischemic Stroke; Middle Cerebral Artery

Introduction

Imaging of intracranial arteries is essential to establish as soon as possible the mechanism of cerebral ischemia and monitoring reperfusion therapies in ischemic stroke [1-2]. Advances in technology have led to ultrasound devices that allow for easy incorporation into daily practice.

With appropriate training, ultrasound examinations allow to better diagnose pathology and guide treatment strategies [3-4].

Transcranial Color-Code Doppler (TCCD) ultrasonography, as Laennec stethoscope in 1816**5**, involves acoustic functions [6-7]. By a low-frequency transducer, placed on the scalp, it allows to exploring the basal cerebral arteries (through relatively thin bone windows) and to measure the cerebral blood flow velocity and its alteration [8-9-10]. Like Laennec stethoscope the Doppler probe is non-invasive, reliable and non-ionising to enable bedside monitoring [11-12]. TCCD can identify any stenosis or occlusion [13-14] with the possibility of monitoring reperfusion after thrombolytic and/or trombectomy therapies [15-16] in stroke patients.

The aim of our study is to show the advantages to practise a TCCD in the emergency assessment of stroke patients considered as a "stethoscope" of the vascular neurologist.

First, it can avoid the necessity to realise a CT-angiography (CTA) that is more invasive, it takes more time and it needs to avoid contrast agent allergy and others contraindications (as renal failure, diabetes) [17]. Second, it's less expensive and it can be faster realised at the emergency department. Moreover, it could be help in decision of combined thrombolytic treatment with intra-arterial trombectomy in case of proximal occlusion of carotid artery at the acute phase and it can be also faster combined with an extra cranial Doppler imaging, if others information are necessaries (for example extra cranial carotid stenosis/occlusion).

Occlusion of the MCA or its branches is the most common type of anterior circulation infarct, accounting for approximately 90% of infarcts and two thirds of all first strokes. MCA is the largest of the intracerebral vessels and supplies through its pial branches almost the entire convex surface of the brain, including the lateral frontal, parietal, and temporal lobes, insula, claustrum, and extreme capsule. The lenticulostriate branches of the MCA supply the basal ganglia, including the caput nuclei caudate, the putamen, the lateral parts of the internal and external capsules, and sometimes the extreme capsule [18].

Occlusion of the MCA commonly occurs either in the main stem (M1) or in one of the terminal superior and inferior divisions (M2). Of MCA territory infarcts, 33% involve the deep MCA territory, 10% involve superficial and deep MCA territories, and over 50% involve the superficial MCA territory [19].

The aim of our study is to provide a basic understanding about the use of TCCD at the acute phase, in particular for analysing abnormalities in the middle cerebral artery (MCA).

Methods

We included consecutives patients between September and December 2015 admitted to the Stroke Unit of Garibaldi Hospital in Catania for acute onset of anterior clinical symptoms caused by a cerebral ischemia or a transient ischemic attack (TIA) and a NIHSS score > 5 and < 25. We excluded hemorrhagic ictus.

TCCD was performed at the stroke unit within a time window of 12 hours from acute event.

We utilised Philips iE33 Ultrasound Machine utilizing 2.5 Hz probe (Figure 1a; 1b).

Figure: 1a **Figure:** 1b

Figure: 1a: TCCD, Stroke unit, Garibaldi Hospital, Catania;

Figure: 1b: 2.5 Hz probe

TCCD is conducted using transcranial color-coded duplex sonography, in which it is displayed a two-dimensional color-coded image [17, 20].

Baseline data included: age, sex, NIHSS score, aetiology of the embolic cerebral vessel occlusion. The first step was to localise a cranial window where the ultrasound beam can penetrate without being excessively dampened. The various blood vessels were identified from the window used, the depth of insonation, the direction of blood flow with respect to the probe, and characteristics of the TCCD waveform.

The middle cerebral artery (MCA) was identified through the transtemporal window, with the flow direction normally towards the probe, about 30-60 mm from the skull surface. The transtemporal window found between the angle of the eye ant the pinna above the zygomatic ridge and is the major route for insonating the middle cerebral artery. At about 60 mm, the internal carotid artery (ICA) divides into the MCA and anterior cerebral artery (ACA), which flows away from the probe and this bifurcation is one of the most important reference points for TCCD. Anomalies of the circle of Willis are common and a thorough knowledge of the anatomy of the blood vessels is an essential requisite for accurate interpretation.

We used the Thrombolysis in Brain Ischemia (TIBI) grading system for residual flow by TCCD (Table 1). The TIBI residual flow classification consists of 6 grades. The individual flow grades are described in Figure [313, 21]. TCCD diagnoses was based on the detection of altered blood flow velocity, absence of blood flow, changes in the spectral waveform, or changes in pulsatility in a specific vessel.

Table 1: Thrombolysis in Brain Ischemia (TIBI) grading system for residual flow.

Grade 0 absent flow signal	Lack of regular pulsatile flow
Grade 1 minimal flow signal	Systolic spikes of variable velocity and duration; Absent of diastolic flow
Grade 2 blunted flow signal	Systolic flow acceleration of variable duration; Positive end diastolic velocity and pulsatility index (IP) <1.2
Grade 3 dampened flow signal	Normal systolic flow acceleration; Positive end diastolic velocity; Decreased mean flow velocities (MFV) by >30% compared to control side
Grade 4 stenotic flow signal	MFV >80 cm/s AND velocity differences >30 % compared to control side; MFV >30 % compared to control side AND signs of turbulence (if both side affected)
Grade 5 normal flow signal	< 30 % mean velocity difference compared to control; Similar waveform shapes compared to control

Results

30 patients with acute cerebrovascular disease (TIA or acute ischemic stroke) were investigated with TCCD followed by CTA.

TCCD examination were realised by a vascular neurologist at the acute phase of stroke.

The mean total time for the TCCD realisation was 7 minutes for each patient.

We included 26 patients and we excluded 4 patients since it wasn't possible to find the trans temporal window.

Mean age was 60.7 years ± 12.7 SD: 19 females and 11 males. In 19 patients (63.3 %) MCA examination was normal (TIBI: 5). Seven patients (23.3%) showed pathological findings on MCA evaluation: 5 patients (16.7 %) had a stenosis of MCA (TIBI: 2-3) and 2 patients (6.7%) an occlusion (TIBI: 0); see Table 2a. Six patients had proximal MCA stenosis (M1), one patient distal MCA stenosis (M2).

We treated four of these patients with intravenous rt-PA. Patients had no adverse events. In case of focal hemodynamic intracranial stenosis the TCCD features were: in the region of the stenosis, a local flow acceleration, a disturbed flow with spectral broadening and retrograde flow components due to the increase in low frequency. In case of intracranial artery occlusion, the TCCD features were: the absence of color or power flow signal in the artery occluded, with no or minimal flow at the corresponding Doppler spectrum; see Table 2b.

CTA confirmed these all the pathological findings; see Table 2c and Figure 2a; 2b.

Table 2: TCD and CTA pathological MCA findings.
a) M1: proximal, M2: distal;
b) TIBI grading system for residual flow with TCD;
c) CTA grading of stenosis.

Patient	MCA side (M1, M2) a)	TCD finds b)	CTA finds c)
1	M1 stenosis	Local flow acceleration (TIBI:3)	Mild-to-moderate tortuosity
2	M1 stenosis	Spectral broadening (TIBI:3)	Irregular arterial wall
3	M2 occlusion	Absence of power flow signal (TIBI: 0)	Absence of flow
4	M1 stenosis	Turbulence in blood flow (TIBI:2)	Excessively severe tortuosity
5	M1 stenosis	Local flow acceleration (TIBI:3)	Mild-to-moderate tortuosity
6	M1 occlusion	Absence of colour (TIBI: 0)	Absence of flow
7	M1 stenosis	Persistent retrograde blood flow (TIBI:2)	Moderate-to-severe tortuosity

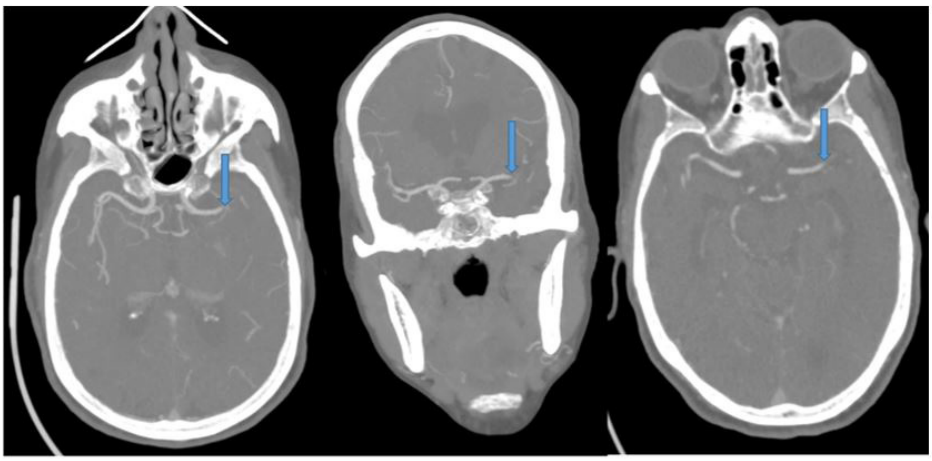

Figure 2a

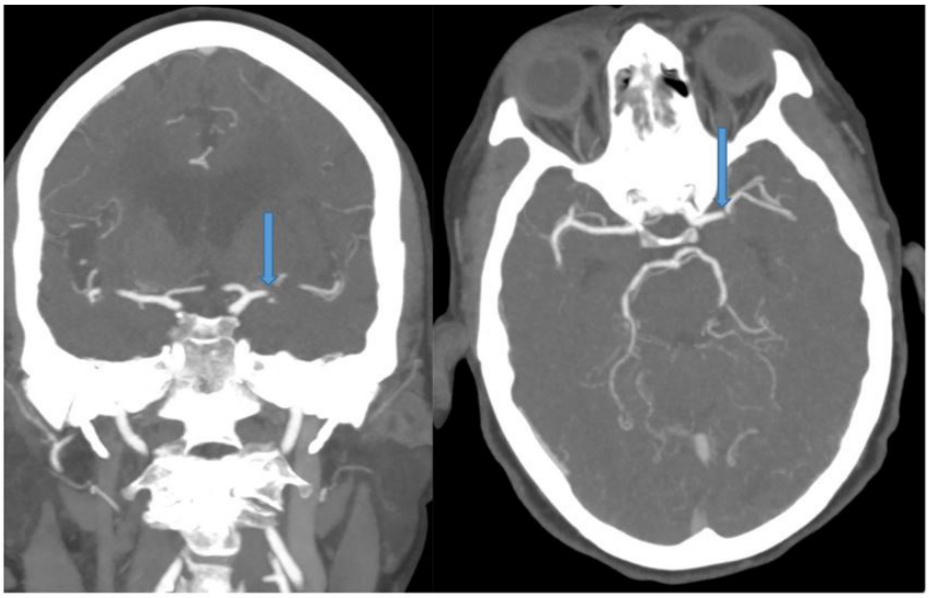

Figure 2b

Figure 2a: Coronal and axial MIP reformat and axial CTA planes demonstrating distal left M1 occlusion (long arrows).

Figure 2b: Coronal and axial MIP reformat CTA demonstrating middle M1 left occlusion (long arrows).

Discussion

Our study confirms that TCCD is reliable to detect MCA stenosis and occlusion and the transcranial probe can be compared to the "stethoscope" [22], so we encourage stroke neurologists to realize it at the acute stroke phase [23-24].

In a recent Cochrane, TCCD provide reasonably accurate diagnostic information about occlusion or stenosis of intracranial arteries with summary sensitivity and specificity of 95% [25-26]. On the contrary, in a metanalysis comparing extra-cranial Color-Doppler and CTA, the weighted kappa was 0.85 (95% CI 0.76-0.94), and the accuracy was 0.78. When the arteries were classified into medical and potentially surgical groups, the kappa was 0.76 (95% CI 0.70-0.83), and the accuracy was 0.89 [27].

At the acute phase of stroke, TCCD is able to evaluate quickly the intracranial arteries and monitor the possible recanalization of occluded vessel ensuring the follow-up of dynamic lesions, such as the intracranial stenosis and occlusions [28]. Furthermore, it is able to detect, in real time, the site and to record the flow of the intracranial stenosis/occlusion and may be crucial to establish the type of acute therapy. As clinical response to thrombolysis is influenced by the type and/or site of occlusion, TCCD may be crucial to determine the type of acute therapy [29].

In our study, we utilized the TIBI classification of residual flow to evaluate the degree of stenosis or occlusion with TCCD [21].

Some authors [30] have shown that TIBI classification on TCCD is an independent factor, like initial NIHSS, predicting early recanalization and clinical outcome. Sensitivity and specificity were higher when combining NIHSS and TIBI (sensitivity 0.92, specificity 0.82).

The major limitations of TCCD are the high operator dependency and a 13% rate of inadequate temporal windows, particularly in older patients, due to the thickness of the skull.

Other limitation is related to the difficulty in studying distal segments and non-hemodynamic stenosis.

Conclusions

TCCD is inexpensive, easily repeatable, fast, non-invasive, reliable tools for evaluating the extra- and intracranial arteries and may be considered as the stethoscope of stroke neurologist who manages patients with acute cerebrovascular disease.

TTCD in acute stroke patients, is useful for diagnostic, prognostic and therapeutic value. In this study, we confirmed that TCCD is important to detect, in real time, the site of the intracranial stenosis/occlusion and may be crucial to determine the type of acute therapy and also to monitor its effectiveness.

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Conflict of Interest

The authors declare no conflict of interest.

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