ECHOCOLOR DOPPLER LESSONS

ECHOCOLOR DOPPLER ROLE IN ACUTE CEREBROVASCULAR DISEASE.
B) ECHOCOLOR DOPPLER OF THE INTRACRANIAL VESSELS

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Echocolor Doppler role in acute cerebrovascular disease.

Echocolor Doppler of the intracranial vessels

INTRODUCTION

In the acute phase of cerebral ischemia, patients may show similar clinical presentation but the occlusive patterns of the intracranial arteries and the severity of perfusion deficit may be dramatically different.

The transcranial color Doppler (TCCD) is one of the tools to explore the intracranial vessels, to identify if there is a blockage and to localize any stenosis/occlusion.

In particular TCCD in stroke patients is noninvasive, relatively inexpensive, easily repeatable diagnostic test ideal in the diagnosis and monitoring of the effectiveness of therapy.

While the neuroimaging, in acute stroke, is principal in the space domain, TCCD has introduced the time domain into the management of stroke patients by providing serial imaging and monitoring reperfusion of intracranial arteries after stroke.

In this lesson the role of the echocolor Doppler of the intracranial vessels in acute cerebrovascular disease is presented.
1. COLOR DOPPLER US OF THE EXTRA CRANIAL ARTERIES (CDU)

2. TRANSCRANIAL COLOR DOPPLER (TCCD)
TRANSCRANIAL COLOR DOPPLER IN PATIENTS WITH ACUTE CEREBROVASCULAR DISEASE

- in the acute phase of cerebral ischemia, patients may show similar clinical presentation but the occlusive patterns of the intracranial arteries and the severity of perfusion deficit may be dramatically different

- TCCD is one of the tools to explore the intracranial vessels, to identify if there is a blockage and to localize any stenosis/occlusion
TCCD, in acute stroke patients, is useful for:

a) diagnostic
b) prognostic
c) therapeutie value
TCCD IN ISCHEMIC STROKE

a) diagnostic value
b) prognostic value
c) therapeutic value
a) TCCD diagnostic value

TCCD is able, in real time:

I. to detect if there is a stenosis/occlusion of an intracranial artery
II. to detect the site of any occlusion
III. to record the flow of the intracranial artery with steno/occlusion (the US flow-grade classification)
IV. to detect cerebral microembolic signals (MES)
a) TCCD diagnostic value

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US in d.d ischemic stroke diagnostic value

A) TCCD IS USEFUL FOR DIAGNOSTIC VALUE

- MCA stenosis
- T occlusion
- MCA occlusion
- MCA2 occlusion

A. DIFFERENT OCCLUSION

B. DIFFERENT PROGNOSIS

C. DIFFERENT THERAPY!
A) TCCD IS USEFUL FOR DIAGNOSTIC VALUE

extracranial  Lt. VA occlusion and intracranial VA rt. stenosis
TCCD IN ACUTE STROKE PATIENTS

diagnostic value

1) intracranial artery stenosis
   a. focal disease
   b. diffuse disease

2) intracranial artery occlusion
TCCD IN ACUTE STROKE PATIENTS
diagnostic value

1) intracranial artery stenosis
   a. focal disease
   b. diffuse disease

2) intracranial artery occlusion
US in d.d ischemic stroke diagnostic value

US IN INTRACRANIAL STENOSIS

1. focal intracranial disease ($\geq 50\%$ diameter reduction)
2. diffuse disease
**VASCULAR STENOSIS**

**US DIAGNOSIS**

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**focal IS diagnosis**

i. local flow acceleration

ii. disturbed flow with spectral broadening in the region of the stenosis due to the increase in low frequency and retrograde flow components

iii. reduced maximum and mean flow velocities distal to the stenosis

_Lindegaard K.F.: J Neurol Neurosurg Psychiat 1986_
US in d.d ischemic stroke diagnostic value

CRITERIA GENERALLY USED FOR US DIAGNOSIS OF INTRACRANIAL ARTERIAL STENOSIS:

A. criteria WASID/SONIA (TCD-MFV)
B. criteria BAUMGARTNER et al. (TCCD-PSV)
CRITERIA GENERALLY USED FOR US DIAGNOSIS OF INTRACRANIAL ARTERIAL STENOSIS:

A. criteria WASID/SONIA (TCD-MFV)
- MCA: \( \geq 100 \text{ cm/sec} (>50\%) \)
- TICA/ACA: \( \geq 90 \text{ cm/sec} (>50\%) \)
- VA/BA/PCA: \( \geq 80 \text{ cm/sec} (>50\%) \)
- stenotic to prestenotic MFV ratio > 2

or

B. criteria BAUMGARTNER et al. (TCCD-PSV)
intracranial stenosis <50% / \( \geq 50\% \)
- MCA: \( \geq 155 / 220 \text{ cm/s} \)
- ACA: \( \geq 120 / 155 \text{ cm/s} \)
- PCA: \( \geq 100 / 145 \text{ cm/s} \)
- BA: \( \geq 100 / 140 \text{ cm/s} \)
- VA: \( \geq 90 / 120 \text{ cm/s} \)
US in d.d ischemic stroke diagnostic value

MCA and PCA stenosis
US diagnosis

US detection of IS with Angiography as Standard of Reference

Peak systolic velocities
- MCA: $\geq 155 / 220$ cm/s
- ACA: $\geq 120 / 155$ cm/s
- PCA: $\geq 100 / 145$ cm/s
- BA: $\geq 100 / 140$ cm/s
- VA: $\geq 90 / 120$ cm/s

Baumgartner R.W. Stroke 1999

PCA: PSV = 2.63 m/s.

MCA: PSV = 2.26 m/s.
VA 4 STENOSIS *(cut off stenosis > 50%: PSV > 120 cm./sec.)*

a. VA4 rt.: aliasing and significantly elevated velocity (= 218 cm/s.) indicative of a significant stenosis

b. VA4 lt.: significantly elevated velocity (=223 cm/s.) indicative of a significant stenoses

*Baumgartner R.W. Stroke 1999*
intracranial stenosis
US diagnosis

1. focal intracranial disease (≥ 50% diameter reduction)

2. diffuse disease:
   i. multiple segments of one artery
   ii. long (>1 cm) stenosis in one major artery
intracranial stenosis
US diagnosis

US IN INTRACRANIAL STENOSIS
in case of:

i. a very severe stenosis
ii. or a long (>1 cm) intracranial segment stenosis
iii. or multiple stenoses in a single artery

a combination of low mean flow velocity and high pulsatility index is possible

diffuse MCA stenosis

- low velocity (PSV = 0.48 m/s.) in MCA diffuse severe stenosis

*in diffuse severe intracranial stenosis systolic velocity can be low*
TCCD IN ACUTE STROKE PATIENTS

diagnostic value

1) intracranial artery stenosis
   a. focal disease
   b. diffuse disease

2) intracranial artery occlusion
In presence of intracranial artery occlusion
the TCCD features are:

1. the absence of color or power flow signal in the artery occluded with
2. no or minimal flow at the corresponding Doppler spectrum
3. and presence of normal appearance of ipsilateral other intracranial arteries
intracranial artery occlusion
middle cerebral artery (a,b,c)
1. absence of color or power flow signal in the artery occluded
2. normal appearance of ipsilateral other intracranial arteries
a) TCCD diagnostic value

TCCD is able, in real time:

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II. to detect the site of any occlusion

III. to record the flow of the intracranial artery with steno/occlusion (the US flow-grade classification)

IV. to detect cerebral microembolic signals (MES)
US are able to record the flow of the intracranial artery with steno/occlusion (US flow-grade classification)

**US FLOW-GRADE CLASSIFICATION:**

- grade 0 = absent flow signal
- grade 1 = minimal flow signal
- grade 2 = blunted flow-signal
- grade 3 = dampened flow-signal
- grade 4 = stenotic flow-signal
- grade 5 = normal flow-signal

*Demchuk AM et al. (2001) Thrombolysis in Brain Ischemia (TIBI) TCD flow grades predict clinical severity, early recovery and mortality in intravenous TPA treated patients. Stroke*
US FLOW-GRADE CLASSIFICATION:

**Grade 0 Absent flow signal:**
No detectable Doppler shift distal to the occlusion site

**Grade 1 Minimal flow signal:**
Absent end-diastolic flow and a short systolic spike

**Grade 2 Blunted flow-signal:**
Delayed systolic flow acceleration and a MFV < 30 cm./sec.

**Grade 3 Dampened flow-signal:**
Pulsatile signal with normal acceleration, MFV decrease of >30% compared to normal side, and positive end diastolic flow

**Grade 4 Stenotic flow-signal:**
Low resistance flow with a significant focal velocity increase; may also be seen in hyperemia

**Grade 5 Normal Flow-signal**
Low resistance flow with no significant difference in velocities compared to the normal site

Andrew M. Demchuk, Stroke 2001
a) TCCD diagnostic value

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IV. to detect cerebral microembolic signals (MES)
TCCD and MES

- TCCD is the only test for detection of cerebral microembolic signals (MES), harbingers of stroke, that may be present in various cardiovascular and cerebrovascular disorders and procedures.

- MES are particles of thrombus or atheromatous plaque or particles of air in cerebral circulation: they can derive from ulcerated plaques, from atrial thrombus, from prosthetic heart valves, as well as during TEA or arterial stenting.
The US monitoring allows the assessing the source of embolism and provides important pathophysiological information and the evaluation of the risk for embolic stroke.

Molloy J, Markus HS (1999). Stroke 30

So TCCD can give important information in stroke patients because can show:

a), b), c) reduced blood flow velocity (intracranial stenosis/occlusion)
d) microembolic signals may be the harbingers of a stroke
US: D.D. IN ISCHEMIC STROKE

a) diagnostic value

b) prognostic value

c) therapeutic value
b) TCCD prognostic value

TCCD is able, in real time to detect if there is a stenosis/occlusion and to record the flow of the intracranial artery with steno/occlusion (TCCD is useful to differentiate the subtypes of stroke)

different ischemic stroke --> different prognosis
US in d.d ischemic stroke: prognostic value

B) TCCD IS USEFUL FOR PROGNOSTIC VALUE

A. DIFFERENT OCCLUSION
B. DIFFERENT PROGNOSIS
C. DIFFERENT THERAPY!
US in d.d ischemic stroke prognosis value

different ischemic stroke--> different prognosis

Figure 2. Observed *percentage surviving* (Kaplan-Meier estimates) after incident ischemic stroke among 442 residents of Rochester, Minnesota, 1985 to 1989, with common ischemic stroke subtypes.

*Petty GW et al, Stroke 2000*
US in acute ischemic stroke

- Cerebral CT and duplex scanning of the cervical arteries have shown scarce prognostic value, while transcranial Doppler findings were able to predict clinical evolution.

- Only emergency transcranial Doppler remained a strong independent predictor of poor outcome by revealing an MCA occlusion or its failure to recanalize.

Baracchini C. Stroke 2000
US in acute ischemic stroke: prognostic value.

Absence of MCA occlusion

- the absence of an MCA occlusion or blood flow velocity reduction was a strong predictor of early clinical improvement

*Goertler M. Stroke 1998*
The absence of a MCA occlusion or blood flow velocity reduction was a strong predictor of early clinical improvement.

*Goertler M. Stroke 1998*

**two ischemic stroke patients:**
The ICA stenosis is similar but the intracranial circulation is different (pat. a with ACM open, pat. b with ACM occluded) → pts with different prognosis.
US in acute ischemic stroke: prognostic value.

distal vs proximal MCA occlusion

- patients with distal MCA occlusion are twice as likely to have a good long-term outcome as patients with proximal MCA occlusion and patients with terminal ICA occlusions are least likely to show early or long term response

*Saqqur M et al for CLOTBUST Investigators (2007) Site of Arterial Occlusion Identified by Transcranial Doppler Predicts the Response to Intravenous Thrombolysis for Stroke. Stroke*
US in d.d ischemic stroke prognostic value

- 50 of the 57 (88%) pts. with main-stem occlusion, examined by Doppler US, were dead or dependent 3 months after stroke
- an occlusion of the main stem of the MCA within 6 h after stroke was an independent predictor for poor outcome
- 50% of pts with US diagnosis of branch occlusions and 63% with normal MCA had a good outcome
- combination of CT scan without early signs of infarction and a normal MCA resulted in a predictive value of 71% for a good functional outcome

US in d.d ischemic stroke prognostic value

89 consecutive patients divided into:

- ICA occlusion
- ICA stenosis
- combined occlusion of the ICA, MCA and ACA
- T occlusion (siphon, MCA and ACA)
- MCA occlusion, MCA stenosis

Results

- extracranial pathology: 18%
- intracranial lesions: 41.6%
- combined occlusions (ICA, MCA and ACA): 11.2%

Each subgroup differed significantly for neurological assessment:

1. at the admission (NIHSS)
2. and in outcomes measures:
   - 3-months mortality,
   - and scales of disability as Barthel Index at day 5 and 3-months modified Rankin Scale

Malferri G. Eligible study; Cerebrovasc Dis 2007
US in acute ischemic stroke: prognostic value

- the 5 degrees of the US flow-grade classification correlate with initial stroke severity, clinical recovery, and mortality in intravenous thrombolysis treated stroke patients

US FLOW-GRADE CLASSIFICATION: PROGNOSTIC VALUE

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Emergent TCD TIBI (thrombolysis in brain ischemia) classification:

a. correlates with initial stroke severity, clinical recovery, and mortality in IV-tPA–treated stroke patients

b. a flow-grade improvement correlated with clinical improvement

*Andrew M. Demchuk, Stroke 2001*
STROKE PATIENTS:
TCCD may be used to evaluate the intracranial effects of extracranial stenosis, including:

a. assessment of collateral flow pathways
b. and evaluation of vasomotor reserve

TCCD prognostic value
Case reports:

two patients (a and b) with ischemic stroke with similar hemodynamic stenosis of the right ICA and inveterate occlusion of the left ICA

but

i. with different collateral blood flow
ii. and different vasomotor reserve (VMR) with the transcranial Doppler

a) and b): patients with different prognosis!
US in d.d ischemic stroke prognostic value

case report patient a: collateral supply via posterior and anterior communicating arteries with MCA good flow-signal
good the vasomotor reserve
US in d.d. ischemic stroke prognostic value

**Case report patient b:**
- absence of the right anterior communicating artery
- collateral supply via posterior communicating arteries (BA with PSV = 1.70 m/s) with MCA blunted flow-signal

*the vasomotor reserve is exhausted*
US: D.D. IN ISCHEMIC STROKE

a) diagnostic value
b) prognostic value
c) therapeutic value
US in d.d ischemic stroke therapeutic value

C) TCCD IS USEFUL FOR THERAPEUTIC VALUE

MCA stenosis

T occlusion

MCA occlusion

MCA2 occlusion

A. DIFFERENT OCCLUSION

B. DIFFERENT PROGNOSIS

C. DIFFERENT THERAPY!
c) TCCD therapeutic value

As clinical response to thrombolysis is influenced by the site of occlusion, TCCD may be crucial to determining the type of acute therapy to institute.
c) therapeutic value

a. intravenous thrombolysis is more efficacious for distal thrombus

b. TCCD is useful in the monitoring of the reperfusion and the effectiveness of therapy

c. intra-arterial thrombolysis or mechanical thrombectomy may be more efficacious for treatment of a proximal large-vessel occlusion
US in d.d ischemic stroke therapeutic value

SITE OF ARTERIAL OCCLUSION AND RESPONSE TO INTRAVENOUS THROMBOLYSIS

- patients with distal MCA occlusion were twice as likely to have a good long-term outcome as patients with proximal MCA
- clinical response to thrombolysis is influenced by the site of occlusion. Patients with no detectable residual flow signals as well as those with terminal ICA occlusions are least likely to respond early or long term

US in d.d ischemic stroke therapeutic value

c) therapeutic value

a. intravenous thrombolysis is more efficacious for distal thrombus whereas

b. TCCD is useful in the monitoring of the reperfusion and the effectiveness of therapy

c. intra-arterial thrombolysis or mechanical thrombectomy may be more efficacious for treatment of a proximal large-vessel occlusion
transcranial color Doppler
in patients with acute cerebrovascular disease

- TCCD, in the acute phase of stroke, is very useful to monitor recanalization during therapy

Duration of arterial recanalization

I) sudden recanalization (abrupt appearance of normal or stenotic low-resistance signal)

II) stepwise recanalization (flow improvement over 1 to 29 minutes)

III) slow recanalization (30 to 60 minutes)

*Speed of Intracranial Clot Lysis With Intravenous Tissue Plasminogen Activator Therapy Sonographic Classification and Short-Term Improvement.*

the speed of clot lysis is predictor of good outcome

In acute phase, the intracranial stenosis/occlusions have a dynamic course and the speed of clot lysis is the strongest predictor of good outcome: unlike sudden and stepwise TCCD patterns, slow recanalization is associated with poorer short and long-term outcomes

Mikulik R et al for the CLOTBUST Investigators (2007) Accuracy of Serial National Institutes of Health Stroke Scale Scores to Identify Artery Status in Acute Ischemic Stroke. Circulation
correlation between recanalization and outcome

- formal meta-analysis confirms a strong correlation between recanalization and outcome in acute ischemic stroke
- recanalization is strongly associated with improved functional outcomes and reduced mortality

speed of tPA-induced clot lysis, DWI lesion evolution and clinical outcome

- the speed of tPA-induced clot lysis predicts DWI lesion evolution and clinical outcome
- unlike sudden and stepwise patterns, slow recanalization is associated with greater DWI lesion growth and poorer short-and long-term outcomes

*Delgado-Mederos R. Stroke 2007*
c) therapeutic value

a. intravenous thrombolysis is more efficacious for distal thrombus whereas
b. TCCD is useful in the monitoring of the reperfusion and the effectiveness of therapy

- c. intra-arterial thrombolysis or mechanical thrombectomy may be more efficacious for treatment of a proximal large-vessel occlusion
In absence of early recanalization during intravenous thrombolysis, there is clinical benefit to proceed to intrararterial therapy


In this case early TCCD patterns may help in making the choice of the modality of thrombolysis
US in d.d ischemic stroke therapeutic value

- despite comparable age and NIHSS scores before IV tPA, MCA occlusions have lower day 1 and 3 NIHSS scores and higher proportion of recanalization compared with
- ICA occlusions.

*Italo Linfante MD. Stroke 2002*

- a combined IV/intra-arterial or mechanical thrombolysis may be needed to achieve early recanalization in ICA occlusions.
- in the absence of early recanalization during IV thrombolysis, there was clinical benefit to proceed to IA therapy for a significative proportion of patients (56%).

*Italo Linfante MD. Stroke 2002*
US in d.d ischemic stroke therapeutic value

MCA 2 occlusion: ev thrombolysis
US in d.d ischemic stroke therapeutic value

T OCCLUSION: combined iv/ia or mechanical thrombolysis?
TCCD MAIN LIMITS
CDU main limits

TCCD LIMITS

- a 10–15% rate of inadequate temporal windows, particularly in older women, due to the thickness of the skull
- the difficulty in studying distal segments and non-hemodynamic stenosis

These limitations can be corrected through training and the use of contrast agents
CDU main limits

- the use of echo contrast agents reduces the rate of ultrasound-refractory patients to 5-10%


a) without contrast agents

b) with contrast agents
CDU main limits

TCCD LIMITS

Of course, when it is clinically appropriate, other neuroimaging modalities are necessary for the final confirmation of the US diagnosis.
TCCD CONCLUSION

TCCD, in stroke patients, is noninvasive, relatively inexpensive, easily repeatable diagnostic test ideal in the diagnosis and monitoring of the effectiveness of therapy

While the neuroimaging, in acute stroke, is principal in the space domain, TCCD has introduced the time domain into the management of stroke patients by providing serial imaging and monitoring reperfusion of intracranial arteries after stroke

short videos and playlists on echocolor Doppler of the intracranial vessels in acute cerebrovascular disease are available on my youtube channel: 
http://www.youtube.com/channel/UCij561sX0bQoEjXlWKuPnKg