ECHOCOLOR DOPPLER LESSONS

SUBCLAVIAN AND VERTEBRAL ARTERY ATHEROSCLEROTIC DISEASE: US PARAMETERS

SUBCLAVIAN AND VERTEBRAL ARTERY STENOSIS

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SCA and VA atherosclerotic disease: ultrasound parameters.

**SCA and VA stenosis.**

**INTRODUCTION**

In the hemodynamic stenosis of the subclavian artery (SCA) a significantly elevated velocity is present, with change of the waveform from the normal triphasic to monophasic appearance.

The hemodynamic stenosis of the SCA proximal to the vertebral artery (VA) origin may cause characteristic changes in the ipsilateral VA waveform: a mild to moderate SCA stenosis may cause, in the ipsilateral VA, characteristics waveforms with antegrade or bidirectional flow, while, in case of severe proximal SCA disease, a complete reversal of ipsilateral VA flow appears. In case of occlusion, or high grade pre-vertebral SCA stenosis, a completely retrograde waveform in the VA is present.

The VA stenosis may be distinguished by the detection of focal velocities > 100 cm/s. accompanied by disturbed flow in the more distal segment of the VA.

The absence of color/flow in the VA is suggestive of occlusion: in this case the distal VA recanalization is possible for the activation of collateral circulation. A tardus parvus distal VA waveform is suggestive of significant proximal VA stenosis or occlusion.

In this lesson the ultrasound parameters of the SCA and VA stenosis are presented.
1. SUBCLAVIAN AND EXTRACRANIAL VERTEBRAL ARTERIES
NORMAL DOPPLER PARAMETERS

2. SUBCLAVIAN AND EXTRACRANIAL VERTEBRAL ARTERIES
ATHEROSCLEROSIS

   a) subclavian artery
      - non haemodynamic stenosis
      - haemodynamic stenosis

   b) extracranial vertebral artery
      - stenosis
      - occlusion
1. SUBCLAVIAN AND EXTRACRANIAL VERTEBRAL ARTERIES
NORMAL DOPPLER PARAMETERS

2. SUBCLAVIAN AND EXTRACRANIAL VERTEBRAL ARTERIES
ATHEROSCLEROSIS

a) subclavian artery
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SUBCLAVIAN NORMAL DOPPLER PARAMETERS

- normal waveform has triphasic appearance with high resistance
  - longitudinal scan (a) and transverse scan (b): a short systolic time and no diastolic velocity
VERTEBRAL ARTERY NORMAL DOPPLER PARAMETERS

a. normal PSV for the VA2 segment is approximately 20–60 cm/s., with low resistance
b. at the origin of the VA the mean velocities are slightly higher
VERTEBRAL ARTERY NORMAL DOPPLER PARAMETERS

- a normal VA diameter is approximately 3-4 mm, with a tendency for the left VA to be larger than the right
- the VA with a larger caliber has a higher diastolic component, and vice versa
- hypoplastic VA presents:
  I. a scarce or absent diastolic flow (therefore with high resistance) or
  II. bidirectional flow
VERTEBRAL ARTERY NORMAL DOPPLER PARAMETERS

- A normal VA diameter is approximately 3-4 mm, with a tendency for the left VA to be larger than the right.
- Due to the frequent asymmetry in VA diameter, there can be considerable difference in PSV and RI.

VA rt.: diam. = 3.9 mm; PSV = 52 cm/sec.; RI = 0.65
VA lt.: hypoplasia. Diam. = 2.1 mm; PSV = 27 cm/sec.; RI = 0.88
RT VERTEBRAL ARTERY HYPOPLASIA WITH BIDIRECTIONAL FLOW
a) rt. VA hypoplasia (diam. = 1.4 mm.) with VA2 (b) and VA3 (c) biphasic flow
d) subclavian regular regular flow

it may be difficult to differentiate VA hypoplasia from VA occlusion or VA dissection
1. SUBCLAVIAN AND EXTRACRANIAL VERTEBRAL ARTERIES NORMAL DOPPLER PARAMETERS

2. SUBCLAVIAN AND EXTRACRANIAL VERTEBRAL ARTERIES ATHEROSCLEROSIS

a) subclavian artery
   - non haemodynamic stenosis
   - haemodynamic stenosis

b) extracranial vertebral artery
   - stenosis
   - occlusion
subclavian artery stenosis

SUBCLAVIAN ARTERY STENOSIS ORIGIN:
NON SIGNIFICANT STENOSIS
- no change compared to the SCA normal triphasic waveform
1. **SUBCLAVIAN AND EXTRACRANIAL VERTEBRAL ARTERIES NORMAL DOPPLER PARAMETERS**

2. **SUBCLAVIAN AND EXTRACRANIAL VERTEBRAL ARTERIES ATHEROSCLEROSIS**

   a) subclavian artery
      - non haemodynamic stenosis
      - haemodynamic stenosis

   b) extracranial vertebral artery
      - stenosis
      - occlusion
a) haemodinamic plaque at the SCA origin
b) aliasing and significantly elevated velocity in the proximal subclavian artery (=213 cm/s): change in its waveform from the normal triphasic appearance to monophasic waveform
subclavian artery stenosis

SIGNIFICANT SUBCLAVIAN ARTERY STENOSIS STENOSIS

a) aliasing in SCA haemodinamic plaque proximal to the VA origin
b) elevated velocity (=167 cm/s) and turbulent flow in the proximal SCA
HEMODYNAMIC SUBCLAVIAN ARTERY STENOSIS AND VERTEBRAL ARTERY FLOW

1. hemodynamic significant stenosis of the SCA proximal to the VA origin may cause characteristic changes in the ipsilateral VA waveform

2. mild to moderate SCA stenosis may cause, in the VA ipsilateral, characteristics waveforms with antegrade or bidirectional flow

3. in case of severe proximal SCA disease appears a complete reversal of VA ipsilateral flow
HEMODYNAMIC SCA STENOSIS AND VA FLOW

1. IN MILD TO MODERATE SCA STENOSIS:
   VA “bunny” waveform
   - preservation of antegrade VA flow and the presence of a sharp mid-systolic deceleration, with a sharp first systolic peak and a more rounded second systolic peak

2. IN SIGNIFICANT SCA STENOSIS (> 80%):
   VA to-and-fro/bidirectional waveform
   - VA waveform with initial antegrade flow and subsequent retrograde flow each cardiac cycle

3. IN OCCLUSION OR HIGH GRADE PRE-VERTEBRAL SCA STENOSIS:
   VA completely retrograde waveform
HEMODYNAMIC SCA STENOSIS AND VA FLOW

1. IN MILD TO MODERATE SCA STENOSIS:
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3. IN OCCLUSION OR HIGH GRADE PRE-VERTEBRAL SCA STENOSIS:
   completely retrograde VA waveform
1. MODERATE SCA STENOSIS

a. turbulent flow in subclavian artery origin stenosis with monophasic waveform
b. a “bunny” waveform in ipsilateral VA2 segment: antegrade flow with a deep cleft between the two systolic peaks
1. IN MILD TO MODERATE SCA STENOSIS:
   reactive hyperemia in “bunny” waveform
   - the reactive hyperemia in the ipsilateral arm after arm exercise may temporarily convert to a more abnormal waveform (VA with reversed late-systolic flow)
1. MILD-MODERATE SCA STENOSIS
change of VA PW Doppler after reactive hyperemia
a. rt. VA PW Doppler spectral image: midsystolic deceleration with antegrade late-systolic velocities
b. rt VA PW Doppler spectral image obtained after exercises of the right arm (by opening and closing the rt. hand): midsystolic deceleration with retrograde late-systolic velocities
HEMODYNAMIC SCA STENOSIS AND VA FLOW

1. IN MILD TO MODERATE SCA STENOSIS:
   "bunny" waveform
   - preservation of antegrade VA flow and the presence of a sharp mid-systolic deceleration, with a sharp first systolic peak and a more rounded second systolic peak

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3. IN OCCLUSION OR HIGH GRADE PRE-VERTEBRAL SCA STENOSIS:
   completely retrograde VA waveform
2. SIGNIFICANT SCA STENOSIS

a. SCA: aliasing and significantly elevated velocity in the proximal subclavian artery (= 472 cm/s): change in its waveform from the normal triphasic appearance to monophasic waveform

b. VA2-VA3: to-and-fro/bidirectional waveform. VA waveform with initial antegrade flow and subsequent retrograde flow each cardiac cycle
2. SIGNIFICANT SCA STENOSIS

a. SCA: aliasing and significantly elevated velocity in the proximal subclavian artery (> 400 cm/s);

b. VA2-VA3: to-and-fro/bidirectional waveform. VA waveform with initial antegrade flow and subsequent retrograde flow each cardiac cycle
2. SIGNIFICANT SCA STENOSIS

a. CTA: significant SCA stenosis. VA alternating flow signals cannot be seen

b. US: Lt. SCA monophasic waveform and high flow velocity (= 308 cm/s.) and Lt. VA2-VA4 with to-and-fro/bidirectional waveform. The rt. V2-V4 and AB flow are regular. The advantage of US over CTA is the information that can be obtained about flow direction
2. IN SIGNIFICANT SCA STENOSIS (> 80%):

reactive hyperemia in to-and-fro/bidirectional waveform

- the reactive hyperemia in the ipsilateral arm after arm exercise may temporarily convert to a more abnormal waveform (with VA completely retrograde waveform)
2. SIGNIFICANT SCA STENOSIS
change of VA PW Doppler after reactive hyperemia

a. turbulent flow in the proximal subclavian artery and (b) preservation of anterograde VA2 flow with a sharp first systolic peak and a more rounded second systolic peak

b. completely retrograde VA2 waveform after arm exercise (reactive hyperemia)
HEMODYNAMIC SCA STENOSIS AND VA FLOW

1. IN MILD TO MODERATE SCA STENOSIS:
   “bunny” waveform
   - preservation of antegrade VA flow and the presence of a sharp mid-systolic deceleration, with a sharp first systolic peak and a more rounded second systolic peak

2. IN SIGNIFICANT SCA STENOSIS (> 80%):
   to-and-fro/bidirectional waveform
   - VA waveform with initial antegrade flow and subsequent retrograde flow each cardiac cycle

3. IN OCCLUSION OR HIGH GRADE PRE-VERTEBRAL SCA STENOSIS:
   completely retrograde VA waveform
3. PRE-VERTEBRAL SCA OCCLUSION

a) post occlusive SCA flow downstream of the occlusion
b) reverse flow in the VA2 ipsilateral to a proximal subclavian artery occlusion
1. SUBCLAVIAN AND EXTRACRANIAL VERTEBRAL ARTERIES
NORMAL DOPPLER PARAMETERS

2. SUBCLAVIAN AND EXTRACRANIAL VERTEBRAL ARTERIES
ATHEROSCLEROSIS

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b) extracranial vertebral artery
   • stenosis
   • occlusion
VERTEBRAL ARTERY ATHEROSCLEROTIC STENOSIS

- the origin of the VA is the most common distribution, although stenosis may occur throughout its length
- the relationship between the severity of a VA stenosis and the peak systolic velocity has not been fully assessed
- VA stenoses may be detected by:
  - detection of focal velocities > 100 cm/s. accompanied by disturbed flow
  - a tardus waveform in the more distal VA is possible
- distal VA haemodinamic stenoses may manifest themselves as a high resistance waveform
VERTEBRAL ARTERY NON SIGNIFICANT STENOSIS

a) B mode: VA segment 0 non haemodinamic plaque
b) SCA and VA1: no color/spectral analysis change compared to normal SCA and VA
VERTEBRAL ARTERY NON SIGNIFICANT STENOSIS
a) VA segment 2 non haemodinamic plaque
b) no change compared to the VA normal waveform
VERTEBRAL ARTERY ORIGIN ATHEROSCLEROTIC HEMODINAMIC STENOSIS

a. insonation of the VA0: aliasing and turbulent flow (ostial stenoses)
b. more distal VA (AV2): a tardus waveform is indicative of a significant stenosis upstream
**VERTEBRAL ARTERY, SEGMENT 0, SIGNIFICANT STENOsis**

Case a: aliasing, a focal velocity greater than 100 cm/s, accompanied by disturbed flow downstream is indicative of a significant stenosis.

Case b: aliasing accompanied by PSV = 106 cm/sec. is suggestive of a stenosis.
VERTEBRAL ARTERY, SEGMENT 2, SIGNIFICANT STENOSIS

a. aliasing and high velocity flow (PSV = 219 cm/s.) on the VA 2 stenosis
b. low velocity downstream the stenosis (VA2 PSV = 53 cm/s.; VA3 PSV = 21 cm/s.)
**AV0 HAEMODINAMIC STENOSIS**

a. right VA0: area of color disturbance
b. spectral Doppler waveform indicates a PSV = 196 cm/s, confirming a stenosis

**AV2 HAEMODINAMIC STENOSIS**

a. left VA2: plaque and stenosis
b. spectral Doppler waveform indicates high vel. flow (PSV =108 cm/s.) and turbolences confirming the stenosis
c. VA3: the flow is regular
VA SEGMENT 4 STENOSIS

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

_Cut off stenosis > 50%: PSV > 120 cm./sec. Baumgartner R.W. Stroke 1999_
ATHEROSCLEROTIC STENOSIS OF THE DISTAL VERTEBRAL ARTERY

- distal VA haemodynamic stenoses may manifest themselves as a high resistance waveform in proximal VA segments
VA 4 SEVERE STENOSIS

- angioCT and TCCD: VA4 stenosis
- US: VA2 high resistance pattern (with a normal diameter = 3.7 mm.) indicative of significant distal VA stenosis or occlusion
VA 4 RIGHT SEVERE STENOSIS AND VA LEFT OCCLUSION

- VA right: high resistance Doppler waveform in the intertransverse (a) and V3 (b) segments in AV4 severe stenosis (aliasing) (c)
- VA left: VA 2 occlusion (d) and VA4 inverse flow (red color) from controlateral VA (c)
- in diffuse severe intracranial stenosis
  systolic velocity can be low
vertebral stenosis

VA4 DIFFUSE SEVERE STENOSIS

- low velocity in VA4 diffuse severe stenosis

In diffuse severe intracranial stenosis systolic velocity can be low.

1. SUBCLAVIAN AND EXTRACRANIAL VERTEBRAL ARTERIES NORMAL DOPPLER PARAMETERS

2. SUBCLAVIAN AND EXTRACRANIAL VERTEBRAL ARTERIES Atherosclerosis

a) subclavian artery
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   - stenosis
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ATHEROSCLEROTIC OCCLUSION OF THE VERTEBRAL ARTERY

- detection of a VA with no flow is suggestive of occlusion, particularly if calcified plaque can be identified
- a VA lumen with no flow and filled with echo-poor thrombus (hypoechoic thrombus) is suggestive of a (recent??) occlusion, while the presence of hyperechoic thrombus is suggestive of an (old??) occlusion
vertebral occlusion

VA OCCLUSION

- absence of flow within the vessel
  a. hypoechoic thrombus: suggestive of a recent obstruction
  b. echogenic thrombus not distinguishable from the surrounding structures: suggestive of an old obstruction
VA OCCLUSION

a. the lumen of the intertransverse VA rt. is filled with echo-poor thrombus suggestive of (recent??) occlusion
b. transcranial colorDoppler images the VA4 rt. occlusion and the normal flow of the intracranial VA left and of the BA
VA 2 OCCLUSION

a. the lumen of the intertransverse VA rt. is filled with echo-poor thrombus

b. transcranial color Doppler: the intracranial VVAAs present different colors and directions of the flows (rt. V4 with regular negative blu flow, lt. VA with reverse red flow)
ATHEROSCLEROTIC OCCLUSION OF VA

- in VA occlusion distal VA recanalization is possible for the activation of collateral circulation
- tardus parvus distal VA waveforms are suggestive of significant proximal VA stenosis or occlusion
**ATHEROSCLEROTIC VA1-VA2 OCCLUSION**

a. proximal VA occlusion: no flow in VA1-VA2 and distal VA recanalization (for the activation of collateral circulation)

b. tardus parvus distal VA waveform
VA OCCLUSION

a. absence of flow within the vessel not distinguishable from the surrounding structures
b. tardus distal Doppler waveform distal to the VA proximal occlusion. Distal VA recanalization is possible for the activation of collateral circulation (c)
VERTEBRAL ARTERY OCCLUSIONS
possible collateral flows distal to the VA2 occlusion

a) case 1: VA3 antegrade waveform
b) case 2: VA3 intermittent waveform
c) case 3: VA3 parvus tardus waveform
**VA1-VA2 OCCLUSION: COLLATERAL FLOWS DISTAL TO THE OCCLUSION**

a) Lumen filled with thrombus. SCA is clearly visible
b) VA2-VA3 download: intermittent waveform
c) VA4: intermittent waveform
d) BA: regular waveform
DISTAL VERTEBRAL ARTERY OCCLUSIONS

- distal VA occlusions may manifest themselves as a high resistance waveform in proximal VA segments
- transcranial colorDoppler is able to image the distal VA to the level of the basilar artery
VERTEBRAL ARTERY 4 SEGMENT OCCLUSION

a. VA2-VA3 high resistance pattern (with a normal diameter)
b. TCCD is able to image the distal VA to the level of the BA and this may extend the value of US: VA4 left occlusion and VA4 rt./ BA with normal flow
short videos and playlists on echocolor Doppler study of subclavian and vertebral artery stenosis are available on my youtube channel:
http://www.youtube.com/channel/UCij561sX0bQoEjXlWKnKpKg