ECHOCOLORDOPPLER LESSONS

SUBCLAVIAN AND VERTEBRAL ARTERY ATHEROSCLEROTIC DISEASE: US PARAMETERS

SUBCLAVIAN ARTERY STEAL WITH AND WITHOUT BASILAR ARTERY PATHOLOGY

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SCA and VA atherosclerotic disease: ultrasound parameters. 
SCA steal with and without basilar artery pathology.

INTRODUCTION

In presence of subclavian artery (SCA) steno-occlusion proximal to the origin of the vertebral artery (VA), the most important natural by-pass is represented by the ipsilateral VA: the blood is stolen by the VA from the contralateral VA (SCA steal phenomenon). This is a compensatory mechanism to increase flow to the affected extremity.

The SCA steal is a graded system showing a progressive change in the ipsilateral VA waveform: in the grade I lesions the VA flow is antegrade (with a diminished peak systolic velocity), while in the grade II lesions the VA waveform is bidirectional, and in the grade III lesions the VA waveform is completely retrograde, regardless of cardiac contractility.

While the SCA steal without a pathologic flow in the basilar artery (BA) seems only a marker of generalized atherosclerosis, the SCA steal with pathologic flow in the BA (post-stenotic, bidirectional or reverse flow) may be associated with a high risk of developing cerebrovascular accidents.

In this lesson the ultrasound parameters of the SCA with and without BA pathology are presented.
SUBCLAVIAN STEAL PHENOMENON

- In presence of subclavian artery steno-occlusion proximal to the origin of the vertebral artery the most important natural bypass is represented by ipsilateral vertebral artery

- Blood is stolen by the vertebral artery from the contralateral vertebral artery. This is a compensatory mechanism to increase flow to the affected extremity
SUBCLAVIAN STEAL PHENOMENON

- although the bidirectional or complete reversal waveform of the of vertebral artery correlates with severe subclavian artery stenosis or occlusion, it does not indicate the presence of related neurologic symptoms
- the subclavian steal phenomenon seems only a marker of generalized atherosclerosis
SUBCLAVIAN ARTERY STEAL

US IN

SCA STENO-OCCLUSIVE DISEASE
SUBCLAVIAN ARTERY STEAL

SUBCLAVIAN STEAL FROM THE VERTEBRAL ARTERY
a graded system showing a progressive change
in the ipsilateral VA waveform

1. grade I lesions: VA antegrade flow with a diminished peak systolic velocity

2. grade II lesions: bidirectional VA waveform (retrograde flow during systole and antegrade flow during diastole)

3. grade III lesions: VA waveform is completely retrograde, regardless of cardiac contractility
1. grade I lesion: VA antegrade flow with a diminished peak systolic velocity
2. grade II lesion: bidirectional VA waveform (retrograde flow during systole and antegrade flow during diastole)
3. grade III lesion: VA waveform is completely retrograde, regardless of cardiac contractility
SUBCLAVIAN ARTERY STEAL

US IN SCA STENO-OCCCLUSIVE DISEASE:

the presence of

I. ipsilateral vertebral artery flow reversal with a

II. stenotic/poststenotic waveform in the ipsilateral subclavian artery

confirms the diagnosis of subclavian steal phenomenon
SUBCLAVIAN ARTERY STEAL

1. WITHOUT BASILAR ARTERY PATHOLOGY
2. WITH BASILAR ARTERY PATHOLOGY
SUBCLAVIAN ARTERY STEAL

1. WITHOUT BASILAR ARTERY PATHOLOGY
2. WITH BASILAR ARTERY PATHOLOGY
B) SCA STENOSIS/OCLUSION: VA WAVEFORM CHANGE

GRADE 1. 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

GRADE 2. SIGNIFICANT SCA STENOSIS (> 80%):

VA to-and-fro/bidirectional waveform
- VA waveform with initial antegrade flow and subsequent retrograde flow each cardiac cycle

GRADE 3. PRE-VERTEBRAL SCA OCCLUSION OR HIGH GRADE STENOSIS:

VA completely retrograde waveform
B) SCA STENOSIS/OCCLUSION: VA WAVEFORM CHANGE

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GRADE 3. PRE-VERTEBRAL SCA OCCLUSION OR HIGH GRADE STENOSIS:

VA completely retrograde waveform
SUBCLAVIAN ARTERY STEAL (MODERATE SCA STENOSIS)

a) SCA Lt. stenosis: turbulent and high velocity flow
b) Lt VA2: “bunny” waveform; c) Lt VA4 bidirectional waveform
d) AB regular flow; e) rt. VA4 regular flow
B) SCA STENOSIS/OCCCLUSION: VA WAVEFORM CHANGE

GRADE 1. 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

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GRADE 3. PRE-VERTEBRAL SCA OCCLUSION OR HIGH GRADe STENOSIS:
VA completely retrograde waveform
SUBCLAVIAN ARTERY STEAL (SIGNIFICANT SCA STENOSIS)

a, b) proximal SCA lt. stenosis: aliasing and significantly elevated velocity (=241 cm/s), change from the normal triphasic to monophasic waveform; c) VA2 lt.: bidirectional waveform; d, e) intracranic VAs: VA lt. with completely retrograde waveform, VA rt. with antegrade flow; f) different colors in intracranic VAs; g) BA with antegrade flow
SUBCLAVIAN ARTERY STEAL

a) proximal lt. SCA stenosis: aliasing and significantly elevated velocity on the stenosis and (b) parvus tardus waveform in the distal lt. SCA; c) lt. VA2 and (d) intracranic lt. VA: bidirectional waveform; e) rt VA2 and (f) rt. VA4: anterograde regular waveform; g) BA with antegrade, but turbulent flow
B) SCA STENOSIS/OCCLUSION: VA WAVEFORM CHANGE

GRADE 1. 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

GRADE 2. SIGNIFICANT SCA STENOSIS (> 80%):

VA to-and-fro/bidirectional waveform
- VA waveform with initial antegrade flow and subsequent retrograde flow each cardiac cycle

GRADE 3. PRE-VERTEBRAL SCA OCCLUSION OR HIGH GRADE STENOSIS:

VA completely retrograde waveform
SUBCLAVIAN ARTERY STEAL

(PRE-VERTEBRAL SCA OCCLUSION OR HIGH GRADE STENOSIS)

a) SCA rt: aliasing in proximal SCA and parvus tardus waveform (prolonged systolic acceleration time with decreased PSV) in the distal SCA
b), c) rt. and lt. VA with different colors (red and blu) and directions (lt. antegrade flow; rt. retrograde flow); d) intracranic VAs with different colors (different directions), e) BA: antegrade flow
IN SUBCLAVIAN ARTERY STENO-OCCCLUSIVE DISEASE:

- reactive hyperemia provoked by blood pressure cuff maneuver and arm exercise exaggerates this waveform change (subclavian steal test)
SUBCLAVIAN ARTERY STEAL

a) SCA lt. stenosis: turbulent and high velocity flow; b, c) lt VA2-4 bidirectional flow; d) AB regular flow; e) rt. VA4 regular flow

f) blood pressure cuff maneuver: change in the lt. VA2 waveform contour (from systolic deceleration to alternating flow)
US IN SUBCLAVIAN ARTERY STEAL

- US has the possibility to compare the color code of the ipsilateral carotid artery with the color of the vertebral artery and to identify the direction of flow
- In the antegrade vertebral artery flow, the color is the same as that of the carotid artery.
- In the SCA steal, the color code of the carotid artery and the AV are different because these arteries have the opposite direction.
- To highlight the different color of the vessels is useful transverse scan.
a) trasverse scan: normal flows
CCA and VA antegrade flow, with the same color

b) trasverse scan: SCA steal
with different directions and colors (red and blu)

SUBCLAVIAN ARTERY STEAL
a) CCA and VA have physiologically the same direction thus have the same color
b) SCA steal: CCA and VA with different colors to the opposite direction of the flows
SUBCLAVIAN ARTERY STEAL

a) SCA lt. stenosis: a monophasic waveform replaces the usual triphasic Doppler signal; b) SCA rt.: regular flow; c), d) VAs flows in opposite directions (antegrade right., reversal left.); e) the inversion of the VA lt. flow is also evident by comparing its color (blue) with the color of the ipsilateral common carotid artery (red); f) the intracranial VAs present different colors and flows
a) SCA rt. with turbulent flow (steno-occlusion); b) SCA lt. with regular triphasic flow; c, d) completely retrograde waveform in extra-intracranial VA rt. (CCA and VA with different colors to the opposite direction of the flows); e,f) extra-intracranial VA with regular flow); g) intracranic VAs: flows in opposite directions and different colors; h) BA with regular antegrade flow
SUBCLAVIAN ARTERY STEAL

1. WITHOUT BASILAR ARTERY PATHOLOGY

2. WITH BASILAR ARTERY PATHOLOGY
SUBCLAVIAN STEAL WITH THE ASSOCIATION WITH PATHOLOGIC FLOW IN THE BASILAR ARTERY

1. SCA steal, without the association with pathologic flow in the BA, seems only a marker of generalized atherosclerosis

2. Pathologic flow in the BA is associated with high risk to develop cerebrovascular accidents

3. Transcranial color Doppler is effective screening test for pathologic flow in the BA artery and useful to define a subgroup of SCA syndrome with high risk of cerebrovascular accidents
BASILAR ARTERY FLOW IN SUBCLAVIAN STEAL

- in most cases of SCA steals the BA flow is normal
- in the case of SCA steno-occlusion associated with steno-occlusion of controlateral SCA and/or of controlateral VA, the BA flow can be:

  1. antegrade, but poor/post-stenotic
  2. bidirectional (intermittent BA steal)
  3. reverse (permanent BA steal)
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2. bidirectional (intermittent BA steal)
3. reverse (permanent BA steal)
SCA STEAL AND BA FLOW ANTEGRADE, BUT POOR

a), b) bilateral SCAs post stenotic flow: monophasic waveforms replace the usual triphasic Doppler signals; c) lt. VA with completely retrograde waveform; d) rt. VA antegrade waveform; e) intracranic VAs with different colors (red and blu); f) BA with antegrade but post stenotic flow
in the case of SCA steno-occlusion associated with steno-occlusion of controlateral SCA and/or of controlateral VA, the BA flow can be:

1. antegrade, but poor/post-stenotic
2. bidirectional (intermittent BA steal)
3. reverse (permanent BA steal)
INTERMITTENT BA STEAL:
presence of an alternating flow directed toward the arm in the systolic phase and towards the brain in the diastolic phase
BA BIDIRECTIONAL FLOW

BASILAR ARTERY INTERMITTENT STEAL in Lt. SCA stenosis

a) proximal SCA Lt. stenosis: elevated velocity and aliasing; b) regular the SCA rt. flow; c) Lt VA2 and VA3 intermittent flow; d) rt VA2 and VA4 regular flow; e) BA (origin) with intermittent flow
BA BIDIRECTIONAL FLOW

BASILAR ARTERY INTERMITTENT STEAL in bilateral SCA stenosis

a), b) bilateral SCAs stenosis; c) lt. VA2 bidirectional waveform (retrograde flow during systole and antegrade flow during diastole); d) rt. VA2 antegrade flow with a sharp first systolic peak and a more rounded second systolic peak; e) BA (origin) with intermittent flow
BA BIDIRECTIONAL FLOW

BASILAR ARTERY INTERMITTENT STEAL in lt. SCA stenosis and rt. VA1-2 occlusion

a) SCA lt. stenosis: monophasic waveform; b) lt VA2: intermittent flow; c) proximal rt. VA occlusion; d) different colors (red/blu) in intracranic VAs to opposite direction and BA intermittent flow (origin)
BA BIDIRECTIONAL FLOW

BASILAR ARTERY INTERMITTENT STEAL
in Lt. SCA stenosis and rt. VA0 stenosis

a) occlusion of the proximal SCA and post stenotic waveform in distal Lt. SCA b) rt. VA0 stenosis and post stenotic waveform in V2 segment; c) Lt. VA2 with reverse flow; d, e) opposite direction of VAs intracranial flow (antegrad but post stenotic waveform in VA rt. (d) and reverse waveform in VA lt. (e); f) BA with intermittent flow
CASE REPORT: BASILAR ARTERY INTERMITTENT STEAL

a) angiography: rt. VA0 stenosis and proximal Lt. SCA stenosis, with reverse flow in Lt. VA

b) US: rt VA2 with antegrade, but stenotic flow and Lt. VA2 with reverse flow;

e) BA with intermittent flow
CASE REPORT: BASILAR ARTERY INTERMITTENT STEAL

d) Lt. VA reverse flow (angiography) and BA intermittent steal (TCCD) before stenting in Lt. SCA; e) antegrade Lt.VA flow (angiography) and BA regular flow (TCCD) after stenting in Lt. SCA
in the case of SCA steno-occlusion associated with steno-occlusion of controlateral SCA and/or of controlateral VA, the BA flow can be:

1. antegrade, but poor/post-stenotic
2. bidirectional (intermittent BA steal)
3. reverse (permanent BA steal)
BA COMPLETELY REVERSE FLOW

BASILAR ARTERY PERMANENT STEAL

a, b) stenosis of rt. ant lt. SCA; c, d) right VA with reversed flow in V2 and V4 segments; e, f) left VA (AV2-AV4) present antegrade but post stenotic flow; g) different colors (red and blue) in intracranial VAs to the opposite direction of flow; h) BA with reversed flow
ANONYMOUS TRUNK STENOSIS

- in presence of hemodynamic stenosis of the trunk anonymous, is involved:

1. the ipsilateral vertebral artery

2. the ipsilateral common carotid artery: in this artery it is possible to record a post stenotic waveform for the presence of a stenosis "upstream" of the origin of the common carotid artery
ANONYMOUS TRUNK STENOSIS

a), b) anonymous trunk: aliasing and turbulent flow; c) rt. SCA post stenotic waveform; d), e) rt. CCA and rt. ICA with post stenotic waveforms; f) rt. VA3 with intermittent flow
PITFALLS

I. VA4 flow reversal in proximal VA occlusion, without SCA pathology
II. SCA steno-occlusive disease not associated with VA flow reversal
III. VA bidirectional flow without SCA pathology
PITFALLS

I. VA4 flow reversal in proximal VA occlusion, without SCA pathology

II. SCA steno-occlusive disease not associated with VA flow reversal

III. VA bidirectional flow without SCA pathology
VA4 FLOW REVERSAL IN PROXIMAL VA OCCLUSION, WITHOUT SCA PATHOLOGY.

PITFALL!

I. proximal VA occlusion can cause VA4 flow reversal, without subclavian steno-occlusive disease.

II. in this syndrome posterior fossa symptoms can occur with a normal triphasic subclavian waveform and normal upper extremity blood pressures
VA 4 FLOW REVERSAL WITHOUT SCA PATHOLOGY

VA4 FLOW REVERSAL RELATED TO PROXIMAL VA OCCLUSION WITHOUT SCA PATHOLOGY

a) SCA lt. regular triphasic waveform; b) proximal lt. VA occlusion; c) presence of flow in AV2-3 lt; e) V4 lt. reverse flow; f) V4 rt. regular flow
VA 4 FLOW REVERSAL WITHOUT SCA PATHOLOGY

a) rt SCA normal triphasic waveform; b) proximal rt. VA occlusion; c) lt. VA4 antegrade, regular waveform; d) intermittent waveform in rt. VA4; e) regular waveform in BA
VA4 FLOW REVERSAL RELATED TO PROXIMAL VA OCCLUSION WITHOUT SCA PATHOLOGY

a, b) lt. VA2-VA4 antegrade, regular waveforms; c) rt. VA2 occlusion; d) intermittent waveform in rt. VA4; e) different colors in intracranial VAs to opposite direction; f) regular waveform in BA
VA 4 FLOW REVERSAL WITHOUT SCA PATHOLOGY

VA3-4 FLOW REVERSAL RELATED VA1-2 OCCLUSION WITHOUT SCA PATHOLOGY
a) VA0-1-2 occlusion (VA lumen filled with thrombus. SCA is clearly visible)
b) VA2-VA3 download flow: “bunny” waveform
c) VA4: intermittent waveform
d) BA: regular waveform and PSV
PITFALLS

I. VA flow reversal in proximal VA occlusion, without SCA pathology

II. SCA steno-occlusive disease not associated with VA flow reversal

III. VA bidirectional flow without SCA pathology
SCA STENO-OCCCLUSIVE DISEASE NOT ASSOCIATED WITH VA FLOW REVERSAL.

PITFALL!

I. SCA steno-occlusive disease distal to the VA origin or
II. left SCA steno-occlusive disease associated with left VA origin directly from the aorta
cannot be associated with VA flow reversal
VA 4 FLOW REVERSAL WITHOUT SCA PATHOLOGY

SCA OCCLUSIVE DISEASE NOT ASSOCIATED WITH VA FLOW REVERSAL

a) rt SCA occlusion (cardioembolism)
b) rt VA2 with regular waveform
PITFALLS

I. VA4 flow reversal without SCA pathology

II. SCA steno-occlusive disease not associated with VA flow reversal

III. VA bidirectional flow without SCA pathology
VA BIDIRECTIONAL FLOW WITHOUT SCA PATHOLOGY

BIDIRECTIONAL FLOW WITHOUT SUBCLAVIAN ARTERY PATHOLOGY

A bidirectional flow in the V4-segment of the vertebral artery cannot prove a subclavian steal syndrome.

It seems that:

i. variations of the VB circulation like PICA-ending vertebral artery
ii. hypoplasia of the vertebral artery
iii. and fetal-type PCA

might also cause a biphasic intracranial flow pattern

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I. variations of the VB circulation like PICA-ending vertebral artery

II. hypoplasia of the vertebral artery

might also cause a biphasic intracranial flow pattern
VA BIDIRECTIONAL FLOW WITHOUT SCA PATHOLOGY

bidirectional flow of the vertebral artery in PICA-ending vertebral artery

e) blood pressure cuff maneuver: no change in the Lt. VA4 waveform contour

BIDIRECTIONAL FLOW OF THE RT VA IN PICA-ENDING VA
a) subclavian artery with regular flow; b, c) rt VA2-4 systolic deceleration in PICA-ending vertebral artery; d) regular the BA flow; e) no change in the Lt. VA4 waveform contour after provocative maneuvers
It seems that:

1. variations of the VB circulation like PICA-ending vertebral artery
2. hypoplasia of the vertebral artery

might also cause a biphasic intracranial flow pattern
RT VA HYPOPLASIA WITH BIDIRECTIONAL FLOW

a) right VA hypoplasia (=1.4 mm.) with (b) VA2 systolic deceleration (PSV = 15 cm/s.); c) rt VA3 bidirectional flow pattern; d) different direction of the flows in the intracranial VVAAs; e) different colors in the intracranial VVAAs (red and blu); f) BA with regular flow; f) rt VA (=5.1 mm.) with regular flow (PSV = 59 cm/s.)
LEFT VERTEBRAL ARTERY (SEGMENT 4) FLOW REVERSAL RELATED TO LEFT VERTEBRAL ARTERY HYPOPLASIA

a) normal rt. VA2 (diam. = 4,1 mm.)
b) hypoplastic lt. VA2 (diam. = 1,3 mm.) with antegrade but low and high resistance flow
c) the intracranial VAs present different colors and and directions of the flows (rt.V4 with regular blu flow, lt. VA with reverse red flow)
short videos and playlists on echocolor Doppler study of subclavian artery steal are available on my youtube channel: http://www.youtube.com/channel/UCij561sX0bQoEjXIWKuPnKg