HARVARD MEDICAL SCHOOL
TEACHING HOSPITAL

Subclavian and Vertebral Artery Ultrasound

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Disclosures

- No disclosures on this presentation.

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Topics of Discussion

- Normal anatomy of the subclavian and vertebral arteries.
- Abnormal anatomy of the subclavian and vertebral arteries.
- Proper ultrasound imaging of the subclavian and vertebral arteries.
- Normal imaging of the subclavian and vertebral arteries.
- Abnormal imaging of the subclavian and vertebral arteries.

Topic 1

Normal anatomy of the subclavian and vertebral arteries.

Subclavian artery anatomy

- The subclavian arteries are a paired set of arteries of the thorax, that supply blood flow to each arm.
- The right and left arteries have different origins.
- The right subclavian artery originates from the brachiocephalic trunk where is splints into the subclavian and common carotid arteries.
- The left subclavian artery originates directly from the aortic arch
- The subclavian arteries terminate upon reaching the lateral border of the first rib on each side, where they become the axillary arteries.

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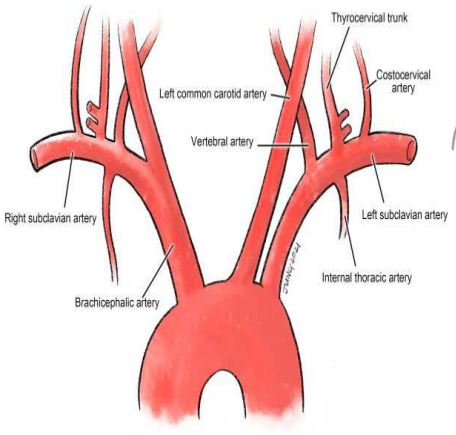
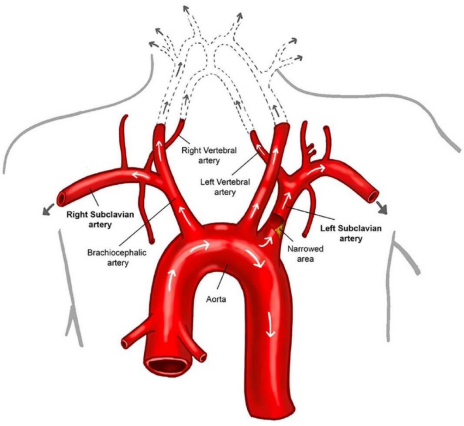
Subclavian artery anatomy (cont'd)





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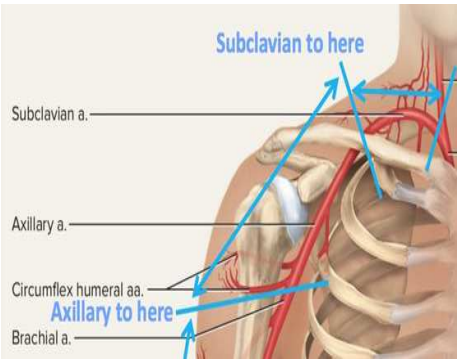
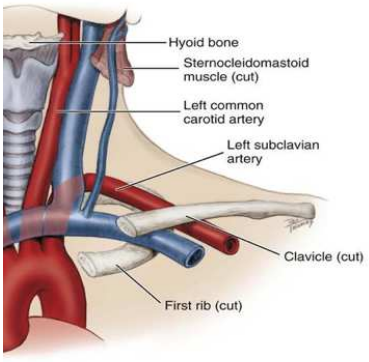
Subclavian artery anatomy

Right Subclavian Artery



Left Subclavian artery



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Vertebral artery anatomy

- The vertebral artery is a major artery in the neck. It branches from the subclavian artery, where it arises from the posterosuperior portion of the subclavian artery.
- It ascends though the foramina of the transverse processes of the cervical vertebrae, usually starting at C6 but entering as high as C4. It winds behind the superior articular process of the atlas, which is also known as C1.
- It enters the cranium through the foramen magnum where it unites with the opposite vertebral artery to form the basilar artery.

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Vertebral artery anatomy

- It supplies 20% of blood to the brain, mainly the posterior aspect or hindbrain, along with the internal carotid artery which supplies 80%.
- Inside the skull, the two vertebral arteries join to form the basilar artery at the base of the pons. The basilar artery is the main blood supply to the brainstem and connects to the Circle of Willis to potentially supply the rest of the brain if there is occlusion to one of the carotid arteries.

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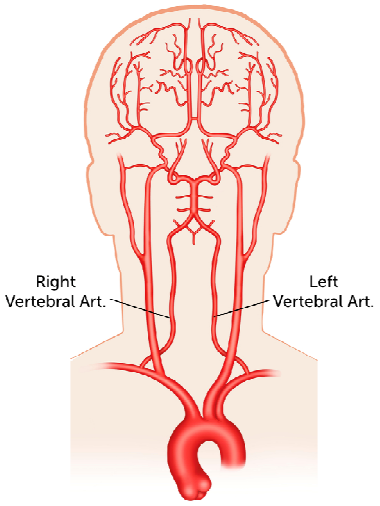
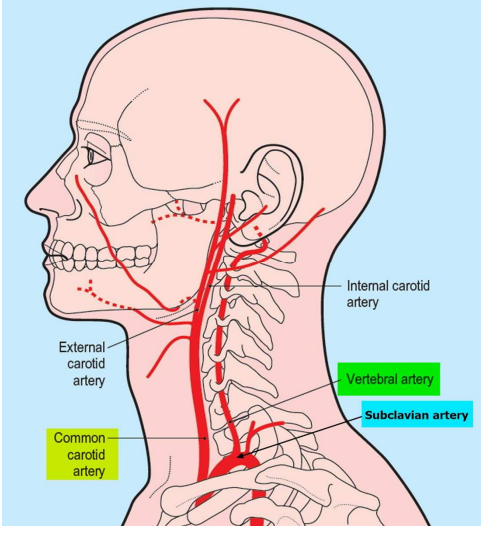
Vertebral artery anatomy





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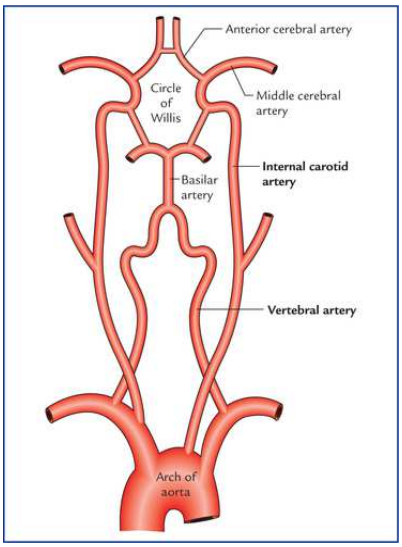
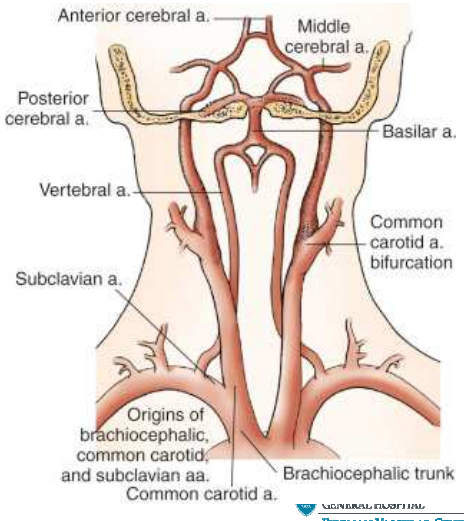
Vertebral artery anatomy





Topic 2

Abnormal anatomy of the subclavian and vertebral arteries

Subclavian artery anatomy variants

- Aberrant right subclavian artery (ARSA) is a rare anomaly, in which the right subclavian artery arises directly from the aortic arch instead of originating from the brachiocephalic artery. This is found in 0.5% to 1% of the population. It can compress on the trachea and/or the esophagus.
- Common symptoms of an aberrant right subclavian artery are difficulty swallowing, difficulty breathing or chest pain, which are usually associated with evident compression of the appropriate structure.

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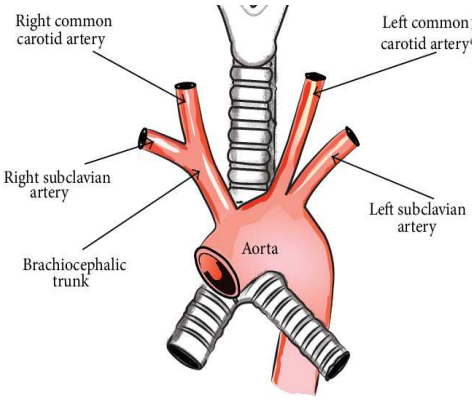
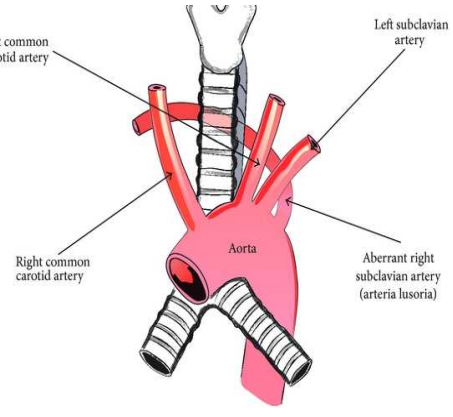
Aberrant right subclavian artery

Normal right subclavian artery



Aberrant right subclavian artery



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Aberrant left subclavian artery

- An aberrant left subclavian artery takes its origin from a right sided aortic arch and a prominent Diverticulum of Kommerell at the distal end of aortic arch. This causes compression on the trachea and esophagus due to the ligamentum arteriosum (previously the fetal ductus arteriosum, which becomes of no use as an adult).
- Symptoms include difficulty swallowing, shortness of breath and can cause compression of the left subclavian artery.

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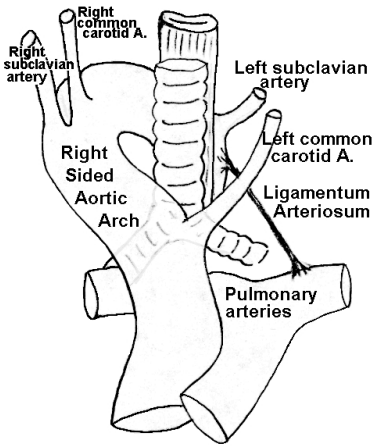
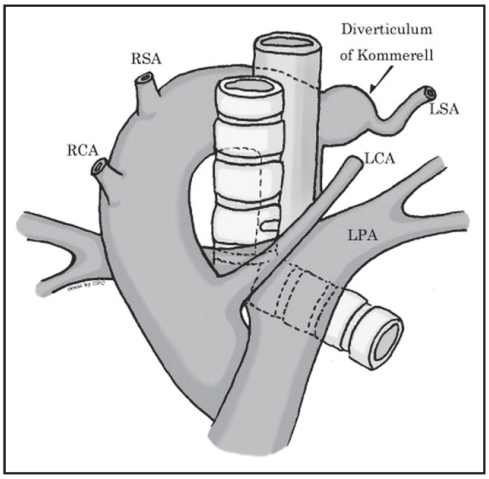
Aberrant left subclavian artery





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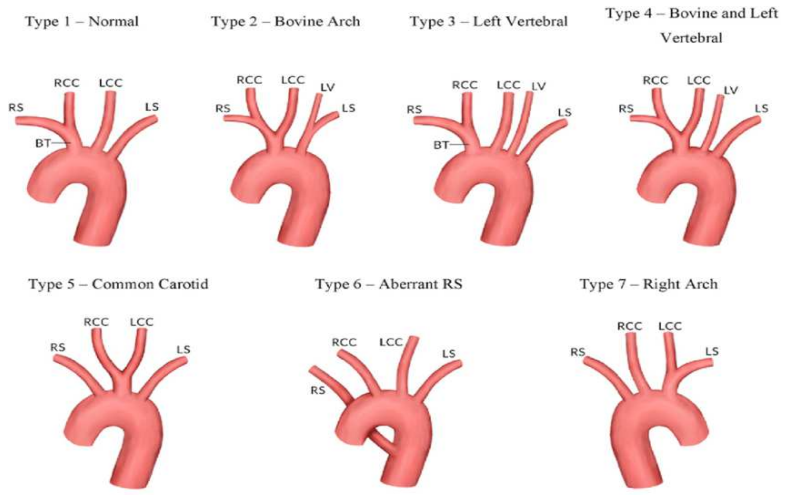
Aortic arch congenital abnormalities

- There are multiple types of congenital aortic arch abnormalities that can affect the right or left subclavian arteries.
- These can vary in type and may include a variant of either subclavian or vertebral arteries.
- Symptoms vary between variants which may be asymptomatic to difficulty swallowing, shortness of breath and decreased arm pressures from subclavian compression.

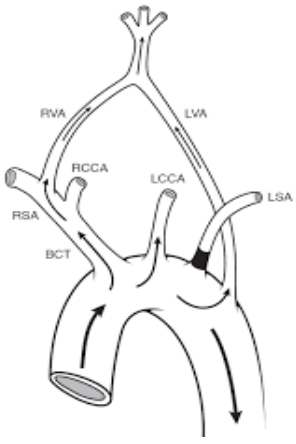
Types of aortic arch congenital abnormalities

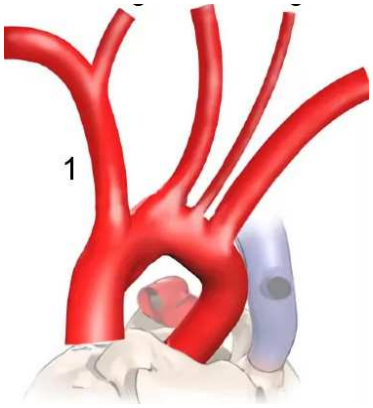


Vertebral artery anatomy abnormalities

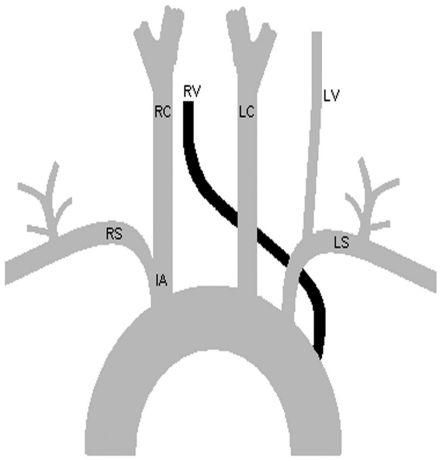
- Left vertebral aortic arch is when the left vertebral artery originates from the aortic arch instead of the left subclavian artery.
- Right vertebral aortic arch is when the right vertebral artery originates from the aortic arch instead of the right subclavian artery. This can be due to an absence of the brachiocephalic trunk or the artery may originate later in the arch and curve over to the right side.

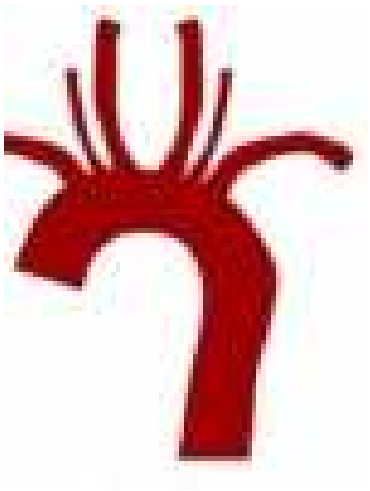
Left vertebral aortic arch





Right vertebral aortic arch





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Topic 3

Proper ultrasound imaging of the subclavian and vertebral arteries.

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Subclavian artery imaging

- There are multiple ways you can image the subclavian arteries with ultrasound:

- Regular pulse wave and color doppler
- Pulse volume recordings and segmental pressures
- Thoracic outlet maneuvers such as Adson's maneuver, raising arms, etc.

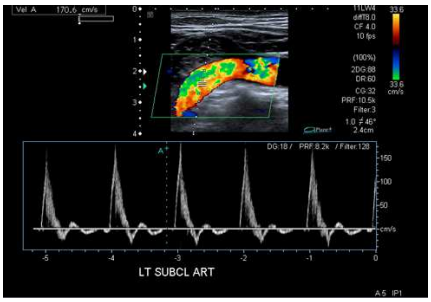
Color doppler / pulse wave ultrasound

- Vertebral and subclavian artery ultrasound uses high frequency sound waves to assess the blood vessels of the body, which are called the veins and arteries. These exams are often ordered to check the flow of blood to brain and assess the risk for a stroke.
- Color doppler is used to show wall to wall color filling and the pulse wave doppler is used to show the waveform of the artery.
- The probe is placed on the side of the neck and on top of the clavicle to image the proximal aspect, and from below the clavicle to image more distal.

Color doppler / pulse wave ultrasound

Probe placement for proximal subclavian artery

Ultrasound image with color doppler and pulse wave



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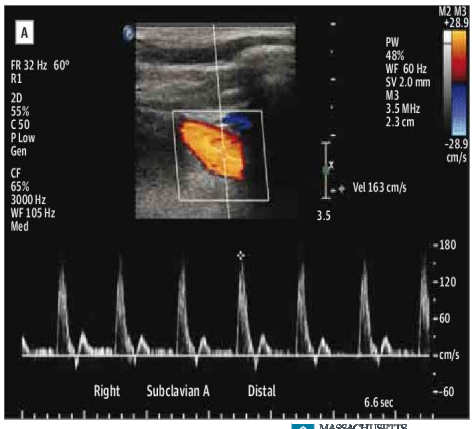
Color doppler / pulse wave ultrasound

Probe placement for mid and distal subclavian artery

Ultrasound image with color doppler and pulse wave



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Subclavian color doppler / pulse wave

Proper subclavian artery protocol requires the following:

- Longitudinal B mode (black and white) images of the proximal, mid and distal aspects of the subclavian artery.
- Color doppler and pulse wave images of the proximal, mid and distal subclavian artery.
- Any area of abnormality should be imaged with both B mode and color/pulse wave imaging.
- Any areas of stenosis should be measured before, in and after the stenotic area.

Subclavian color doppler / pulse wave

Stents and bypass grafts can be seen in the subclavian artery, the following protocol should be followed:

- For stents the inflow aspect or area before the stent, the proximal, mid and distal aspects of the stent and the outflow or the vessel after the stent.
- For a bypass graft the inflow aspect or area before the graft, the proximal anastomosis or the area the graft attaches to the native artery, the proximal, mid and distal aspects of the graft, the distal anastomosis or the area the graft attaches back to the native artery and the outflow or the vessel after the attachment of the bypass graft.
- Any areas of abnormality should be documented as well.

Subclavian color doppler / pulse wave

Normal velocity values of pulse wave ultrasound that our vascular lab uses:

- Proximal Subclavian artery: A PSV (peak systolic velocity) of >275 cm/s with associated distal turbulent flow equates to a > 50% stenosis, with changes in the waveform pattern from triphasic/biphasic to monophasic waveform.
- Mid and distal subclavian artery PSV should be <275cm/s or less than 2 times the adjacent segments.

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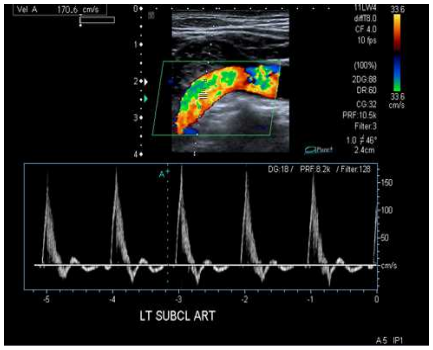
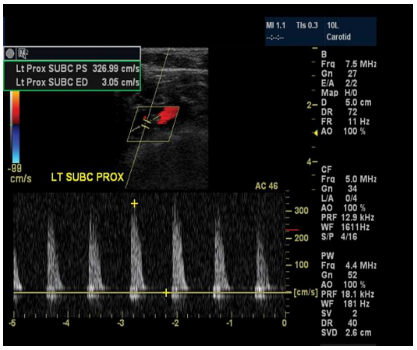
Subclavian color doppler / pulse wave

Triphasic waveform with normal velocity



Monophasic waveform with elevated velocity



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Pulse volume recordings and segmental pressures

- Pulse volume recordings with segmental pressures can also tell if there is a possibility of subclavian artery stenosis.
- This is done by using blood pressure cuffs on the arms at the brachial level (distal upper arm), the forearm level, the wrist level and the digital level.
- The pulse volume recording tells you the amount of blood flowing through that specific segment.
- The segmental pressures compared the highest brachial pressure and compares it to all other levels.

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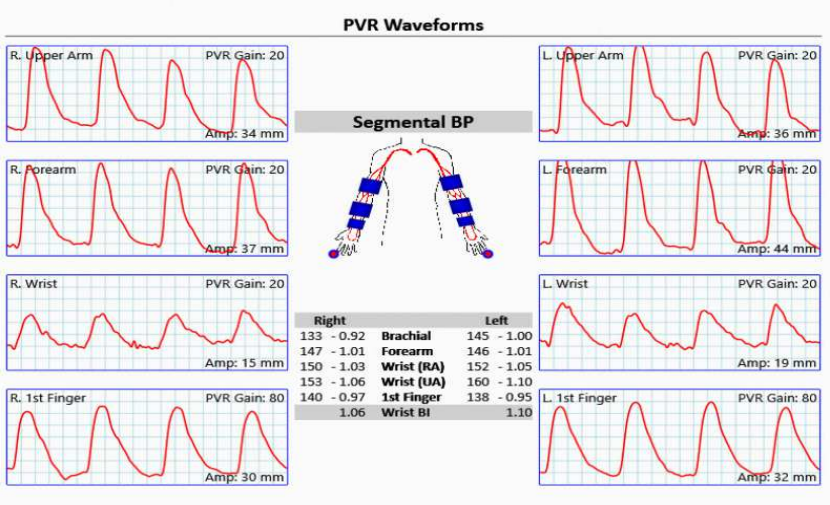
Pulse volume recordings and segmental pressures



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Pulse volume recordings and segmental pressures for TOS

- For thoracic outlet testing, you do the same PVR (pulse volume recordings and segmental pressure.
- You add multiple maneuvers to the test by putting a PPG sensor on the index finger.
- You test in the neutral position, arms 90 degrees, arms 180 degrees, military position (Parade rest) which is arms behind the back to pull shoulders back and turning the head to the left and then to the right. Lastly any position that causes numbness, tingling or pain in the arm.

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Pulse volume recordings and segmental pressures for TOS

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Vertebral artery testing

- Ultrasound of the vertebral arteries is done with 2 different methods depending on which parts of the vertebral artery you are testing for.
- First is with color doppler and pulse wave imaging which can see the extracranial vertebral arteries, commonly done with carotid artery testing.
- The other is by doing TCD or transcranial doppler which looks at the intracranial vertebral arteries as they terminate into the basilar artery.

Vertebral artery testing color and pulse wave doppler ultrasound

- Testing the vertebral arteries with conventional color/pulse wave doppler the probe it placed on the right or left side of the neck with a slight head turn.
- Locate the carotid artery and slide more posterior or angle towards the back of the neck. The vertebral artery should show up in segments between the cervical vertebrae, unless you look at the proximal aspect which arises from the subclavian artery before it goes through the foramen of the transverse process of each cervical vertebrae.

Vertebral artery testing color and pulse wave doppler ultrasound

- In most normal circumstances, the vertebral artery is a low resistance vessel. The Doppler waveform is monophasic with prominent diastolic flow and spectral broadening.
- Spectral broadening in normal vessels can be seen as a result of a large sample volume relative to the small diameter of the vessel.
- Spectral broadening is the filling of the systolic window when pulse wave doppler is obtained.

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Vertebral artery testing color and pulse wave doppler ultrasound

Vertebral artery segments between the cervical vertebrae

Proper probe placement and color doppler imaging

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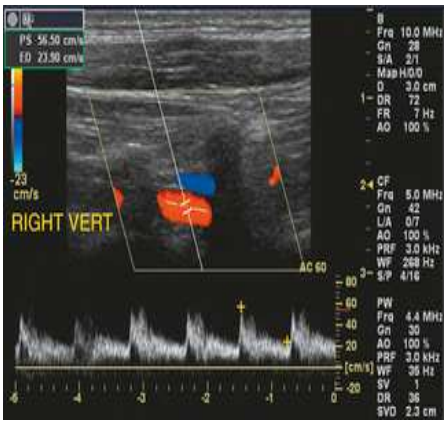
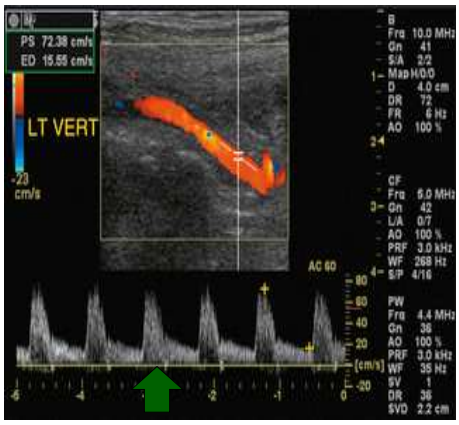
Vertebral artery testing color and pulse wave doppler ultrasound

Color and pulse wave doppler of the artery



Proximal vertebral artery with spectral broadening



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Vertebral artery testing by TCD

- Transcranial doppler which is continuous wave ultrasound or pulse wave ultrasound with no color picture guidance.
- Imaging is done with a “blind” approach meaning you are not seeing the artery you are sampling, it is done by probe placement, direction of flow and depth measurements.
- The vertebral arteries are sampled in the posterior aspect of the skull and imaged through the foramen magnum, where at specific depths as in our labs protocol we use 60mm to 75 mm depths in 5 mm increments. Meaning we sample at 60, 65, 70, 75 mm depth from the probe.

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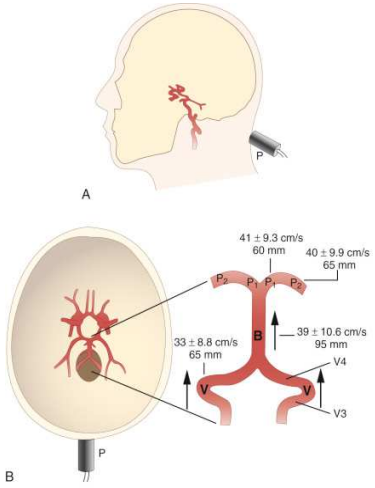
Vertebral artery testing by TCD



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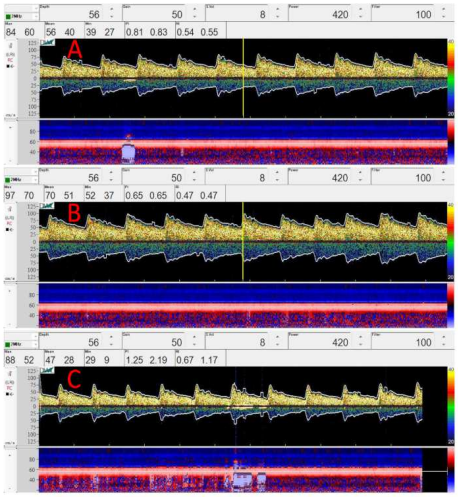
Vertebral artery testing by TCD



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Dept.: Neurologie Patient ID: Created on: 05.04.2018
Exam. No: Not implemented

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MCA_L	←	60	97	58	37	1.02	0.61	2.59
MCA_R	←	50	74	48	32	0.88	0.57	2.32
MCA_R	←	55	94	54	35	1.07	0.62	2.65
MCA_R	←	60	93	58	37	0.98	0.60	2.52
ACA_L	←	65	73	44	22	1.15	0.70	3.29
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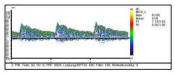

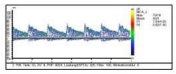

Comment:
Kein Hinweis für hämodynamisch releveante Stenosen der transkraniellen Gefäße.
(Warning: the results are for reference only and not as a diagnostic conclusion)
Created by: Report Date: 05.04.2018

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Topic 4

Normal and abnormal subclavian artery imaging by pulse wave doppler and PVR / segmental pressures.

Normal and abnormal subclavian artery doppler imaging criteria

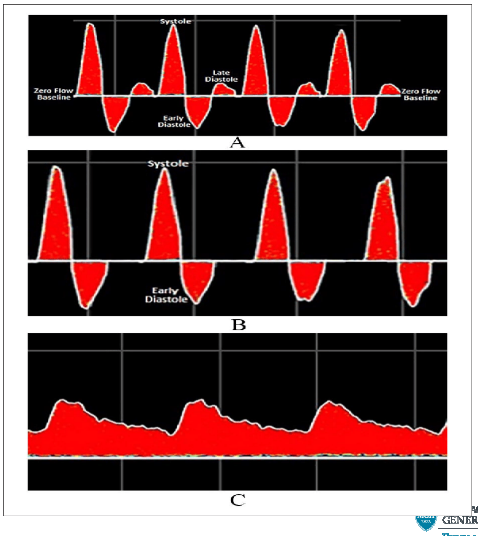
- Normal subclavian artery waveforms should be triphasic in appearance, meaning each waveform goes in 3 phases peak systolic, early diastole and late diastole.
- As an artery becomes more narrowed or stenotic the waveform changes to biphasic in which loses the late diastole component.
- Significant stenosis or narrowing the waveform becomes monophasic and loses it early diastole and late diastole components.
- Velocities are elevated in a stenotic subclavian artery which is >275 cm/s and an increase in velocity of > 2 times the adjacent segment

3 types of waveforms in the subclavian artery

Triphasic (normal)

Biphasic

Monophasic



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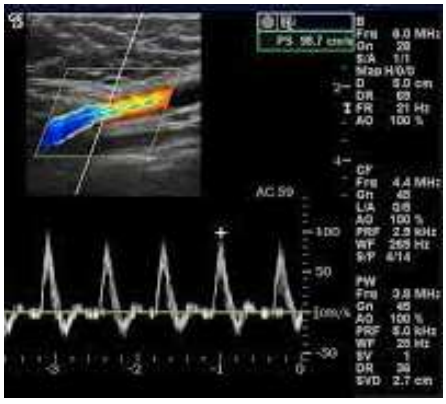
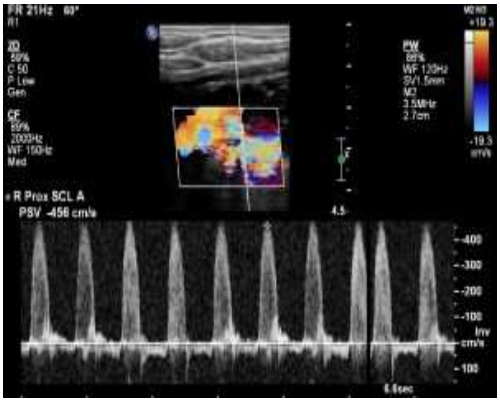
Waveform analysis of the subclavian artery

Normal subclavian waveform



Subclavian stenosis waveform



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Subclavian steal syndrome

- Subclavian steal syndrome (SSS), also known as subclavian-vertebral artery steal syndrome, is a phenomenon causing retrograde flow in an ipsilateral (same sided) vertebral artery due to stenosis or occlusion of the subclavian artery, proximal to the origin of the vertebral artery.
- In this case, the subclavian artery steals reverse-flow blood from the vertebrobasilar artery circulation to supply the arm during exertion, resulting in vertebrobasilar insufficiency and retrograde flow in the vertebral artery.
- Symptoms include:
- Hearing loss / Tinnitus (ringing in ear)
- Blurred Vision
- Dizziness / vertigo / fainting
- Ataxia (loss of muscle coordination)

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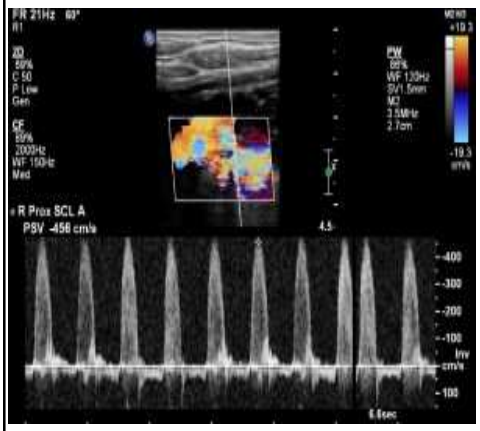
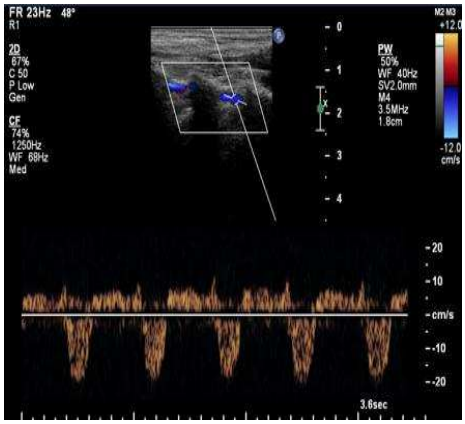
Subclavian steal syndrome

Subclavian artery with high grade stenosis proximal to vertebral artery takeoff



Ipsilateral Vertebral artery with retrograde flow (toward the heart)



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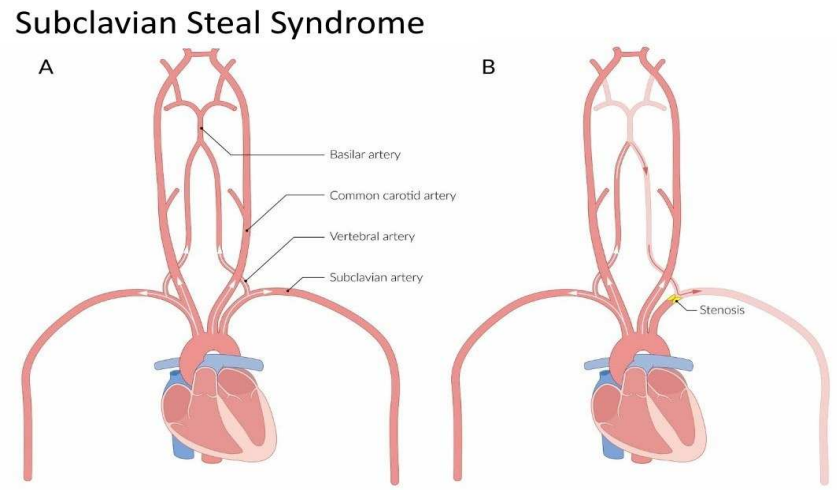
Subclavian steal syndrome



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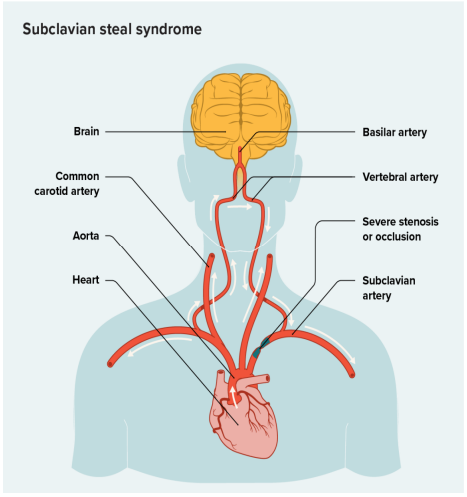
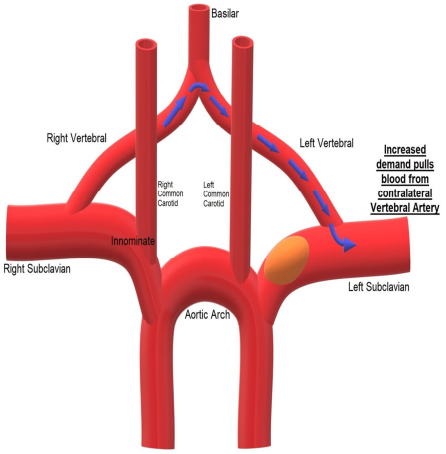
Subclavian steal syndrome





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Thoracic outlet syndrome

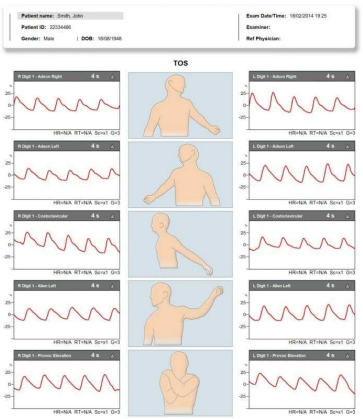
- Arterial thoracic outlet syndrome is a result of compression of the subclavian artery as it branches off of the aortic arch and travels, alongside the brachial plexus, between the anterior and middle scalene muscles, over the first rib and underneath the clavicle. TOS usually occurs in young patients and athletes who are involved in repetitive overhead motion, such as swimming or baseball.
- Symptoms in the upper extremity are a result of thromboembolization (clot formation & dislodgement of the clot), and include arm fatigue, distal ischemia (lack of blood supply) of part of the hand in more than 50% of cases, Raynaud's phenomenon, or stroke.
- A bony abnormality causes trauma to the subclavian artery from compression that occurs with arm movement, especially repetitive overhead activities. The bony abnormalities could be a cervical rib, long C7 transverse process, articulated first rib, or a rib or clavicle fracture.

Thoracic outlet imaging by PVR / segmental pressures and digit PPG

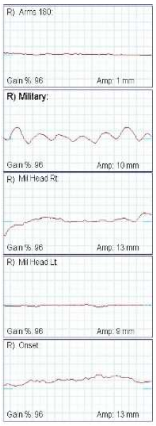
- Thoracic outlet syndrome can be diagnosed by using PVR and segmental pressures with digital PPG (Photoplethysmography) with multiple different maneuvers.
- In thoracic outlet syndrome certain maneuvers compress the subclavian artery and cause decreased or total occlusion of blood flow to the arm and digits.
- You test in the neutral position, arms 90 degrees, arms 180 degrees, military position (Parade rest) which is arms behind the back to pull shoulders back and turning the head to the left and then to the right. Lastly any position that causes numbness, tingling or pain in the arm.
- You record digital PPG in both arms, in a positive exam 50% to complete obliteration of the waveform in a specific position.

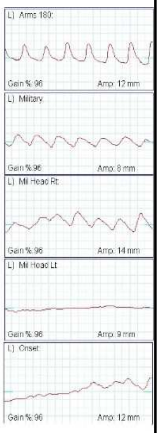
Thoracic outlet imaging by PVR / segmental pressures and digit PPG

Normal TOS testing



Positive TOS testing





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Topic 5

Normal and abnormal vertebral artery imaging by pulse wave doppler and transcranial doppler imaging (TCD).

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Vertebral artery imaging with color and pulse wave doppler

- Color and pulse wave doppler imaging for the vertebral artery should include images of the common carotid and vertebral artery to show direction of flow.
- Normal vertebral artery color flow should be in the same direction as the carotid artery when imaged in the same plane/direction.
- Normal velocities of the vertebral artery should be < 100 cm/s and low resistant in nature.
- There are abnormal appearing waveforms which include retrograde flow, bidirectional flow or “bunny ear” flow.

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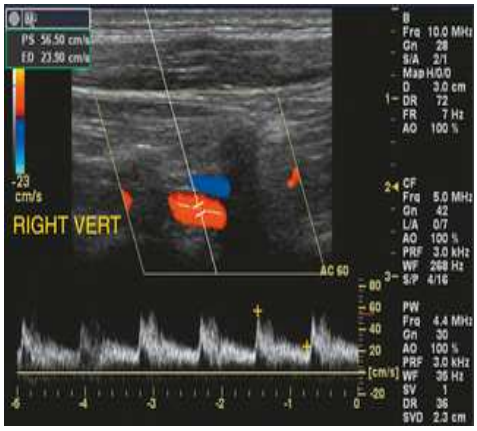
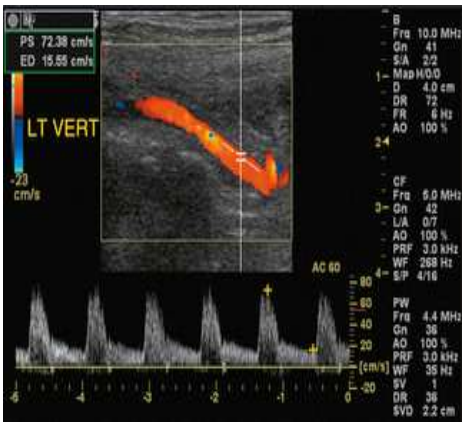
Normal vertebral artery waveforms





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Retrograde vertebral artery flow

- Retrograde vertebral artery flow occurs in cases of subclavian steal syndrome and some cases of carotid artery occlusion.
- When flow is compared to the common carotid artery it is shown to flow in the opposite direction.
- The retrograde flow occurs to provide blood flow to the arm in cases of occlusion or significant stenosis in the proximal subclavian artery before the vertebral artery takeoff.

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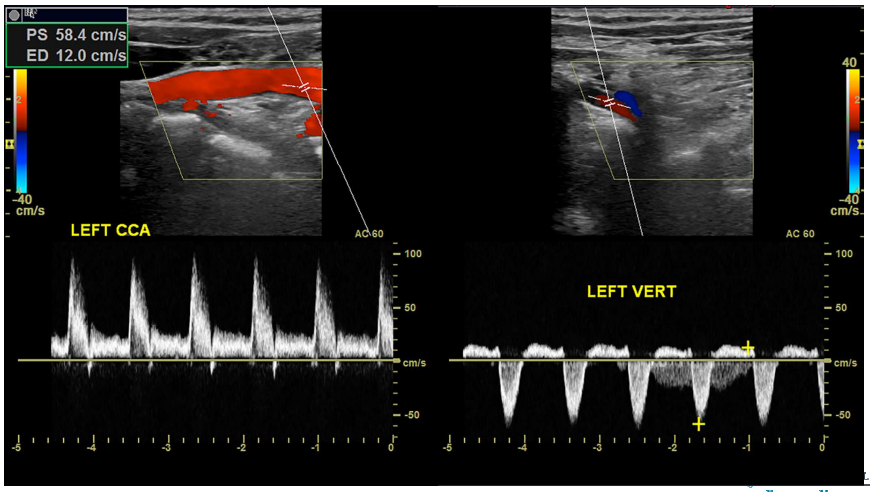
Retrograde flow in the vertebral artery



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Bidirectional “bunny” vertebral flow

- The bunny waveform resembles a rabbit's profile. It is thought to be caused by post-stenotic pressure decrease resulting from high-velocity turbulent flow through the stenosis during systole. The degree of mid systolic velocity decrease, which is associated with the severity of subclavian stenosis, indicates a “pre-steal” state that precedes systolic flow reversal seen in more advanced disease.
- Bidirectional flow can occur, although this is rare in occurrence, from physiological variants of the vertebrobasilar circulation like a vertebral artery hypoplasia or proximal ICA-ending vertebral artery might also cause the above type of VA flow pattern.

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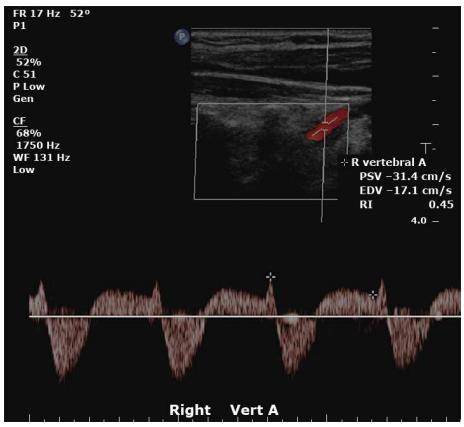
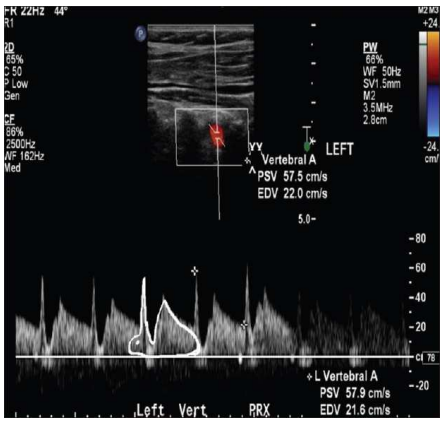
Bidirectional “bunny ear” vertebral flow





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Vertebral artery stenosis

- Vertebral artery stenosis occurs when the artery becomes narrowed from plaque build up. Velocities over 100 cm/s may indicate a >50 % stenosis.
- Symptoms, which may be delayed include:
- vertigo
- nausea
- tinnitus
- drop attacks
- visual disturbances
- in rare cases stroke or death

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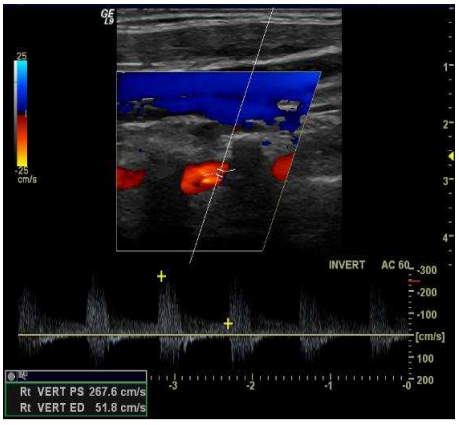
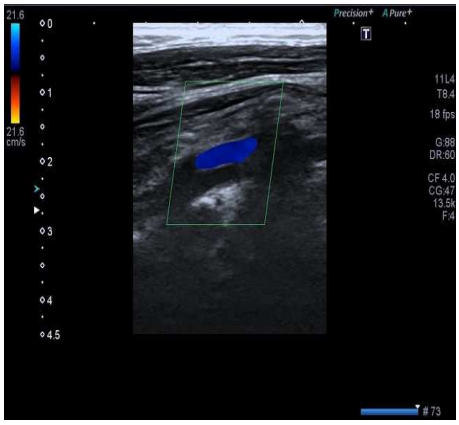
Vertebral artery stenosis

Vertebral artery stenosis with elevated velocities



Vertebral artery occlusion with absent color flow



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Conclusion

- In conclusion there are a few different ways to test for vertebral and subclavian artery issues, some with conventional ultrasound and some with out it.
- Subclavian and vertebral artery symptoms are not anything to ignore as in some cases it can be a precursor to a significant problem or can even result in a stroke.
- Knowing you cross section anatomy and landmarks for specific vessels is always a great way to help in making these exams easier.
- Thank you and have a great day