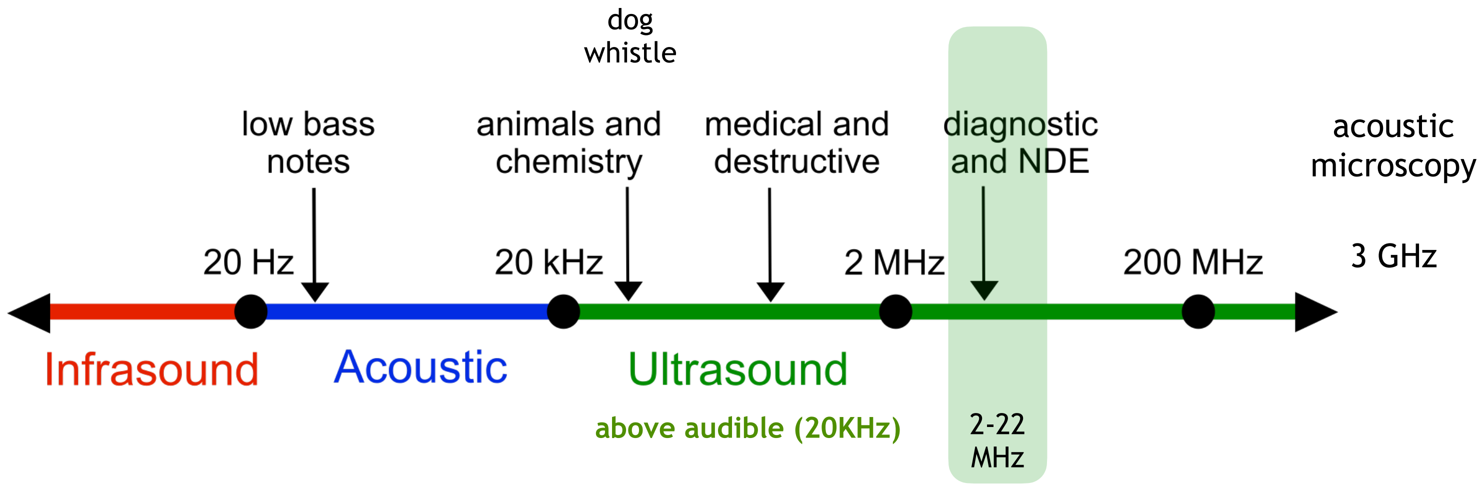
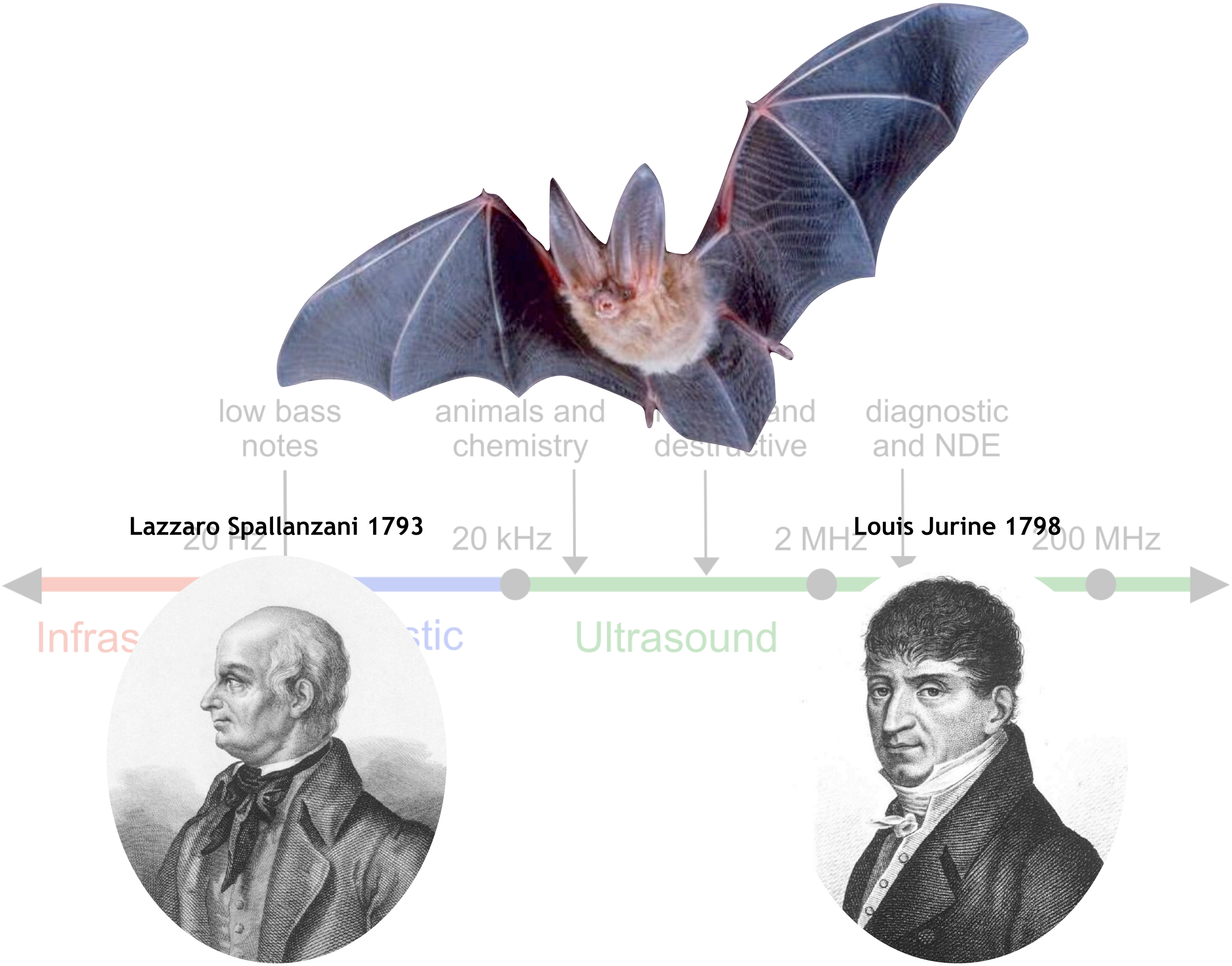


govaert@icloud.com

blinded bats can not navigate without hearing



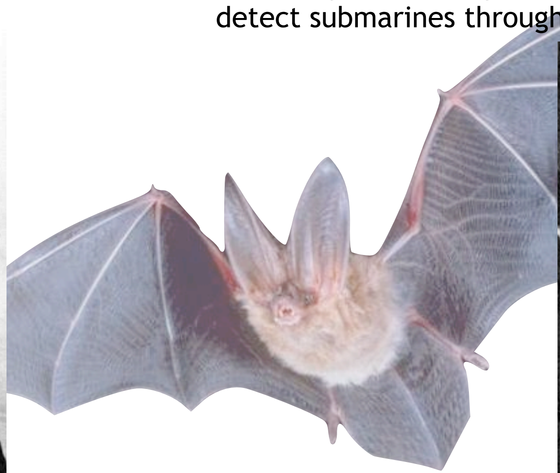
https://en.wikipedia.org/wiki/Louis_Jurine

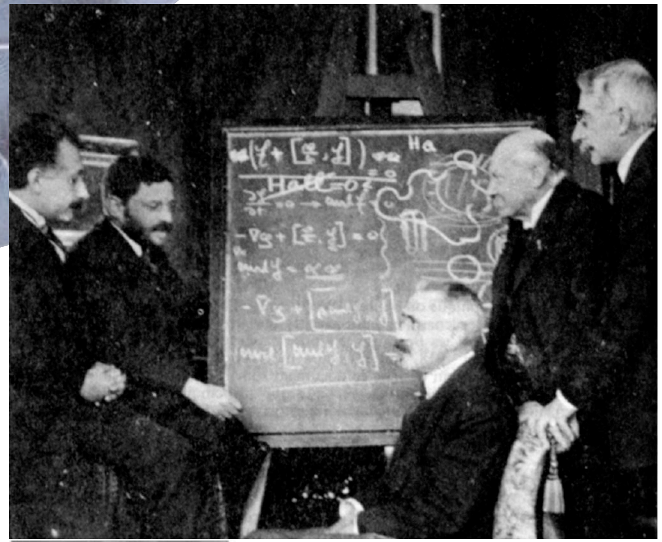
cranial ultrasound

from piezoelectricity to echolocation in submarines

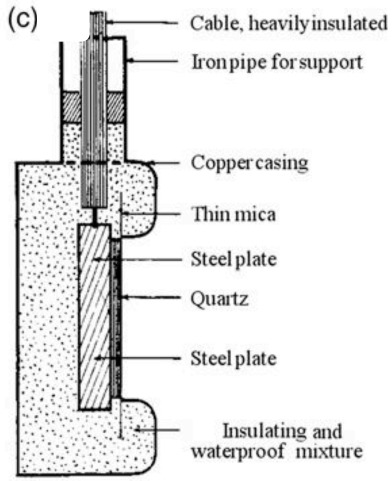
Pierre Curie 1880 piezoelectricity

Paul Langevin: during World War I, work on the use of these sounds to detect submarines through echo location





Paul Langevin
(1872–1946)



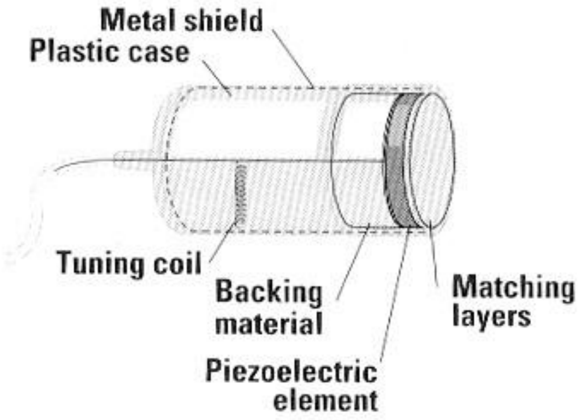
The inverse piezoelectric effect is used in the production of ultrasound waves.

Robert W. Boyle
(1883–1955)

https://en.wikipedia.org/wiki/Paul_Langevin

cranial ultrasound

Pierre Curie 1880 piezoelectricity



each transducer emits a range of frequencies: the bandwidth

the frame rate (inverse to the difference in time between ultrasound pulses) determines temporal resolution

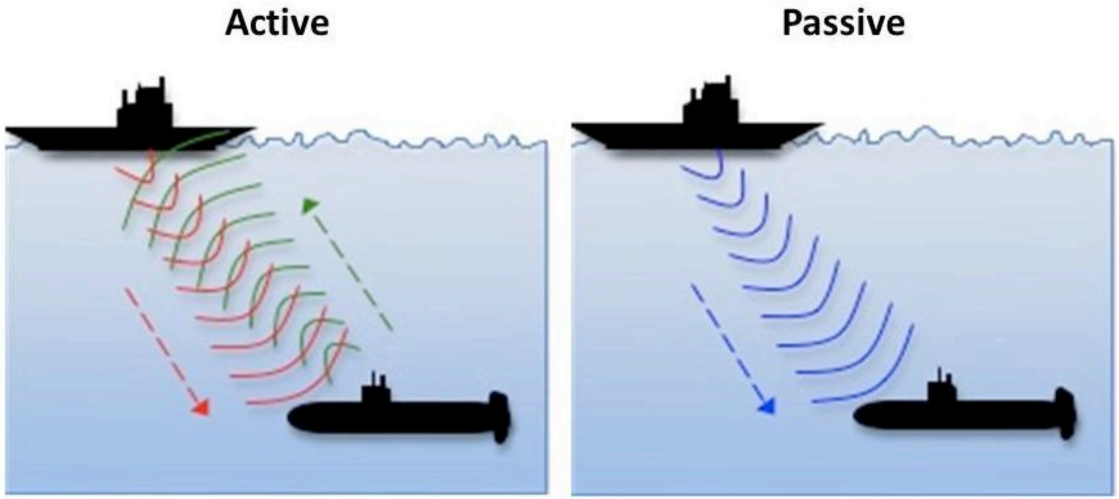
In the transducer scanhead:

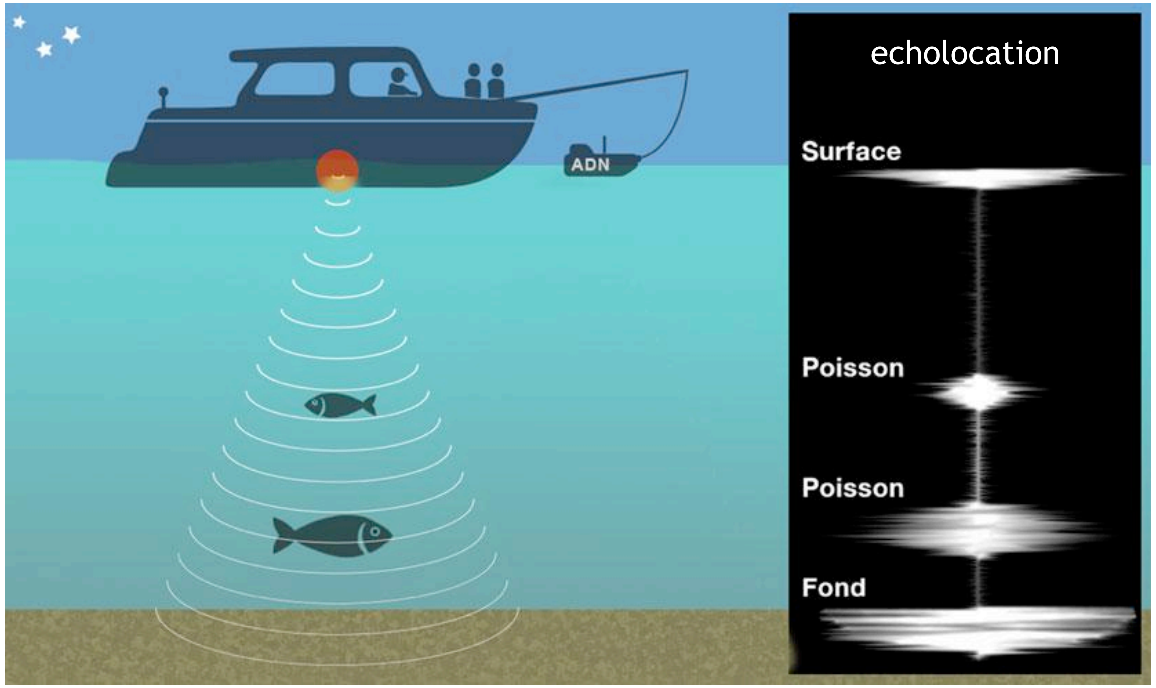
- the **piezo-electric element** (ceramic material) changes electricity into ultrasound and back; the frequency of the sound emitted depends on element thickness (thinner for higher frequencies)
- **backing material**: to dampen the sound waves for reduction of the pulse duration
- **impedance matching layers**: to provide for efficient sound transmission between element and contact tissue
- **probe architecture** determines formation of curved (convexe) or linear waves, both to be steered per cristal

after Zagzebski JA (1996) Essentials of ultrasound physics. Mosby.

Sound Navigation Ranging

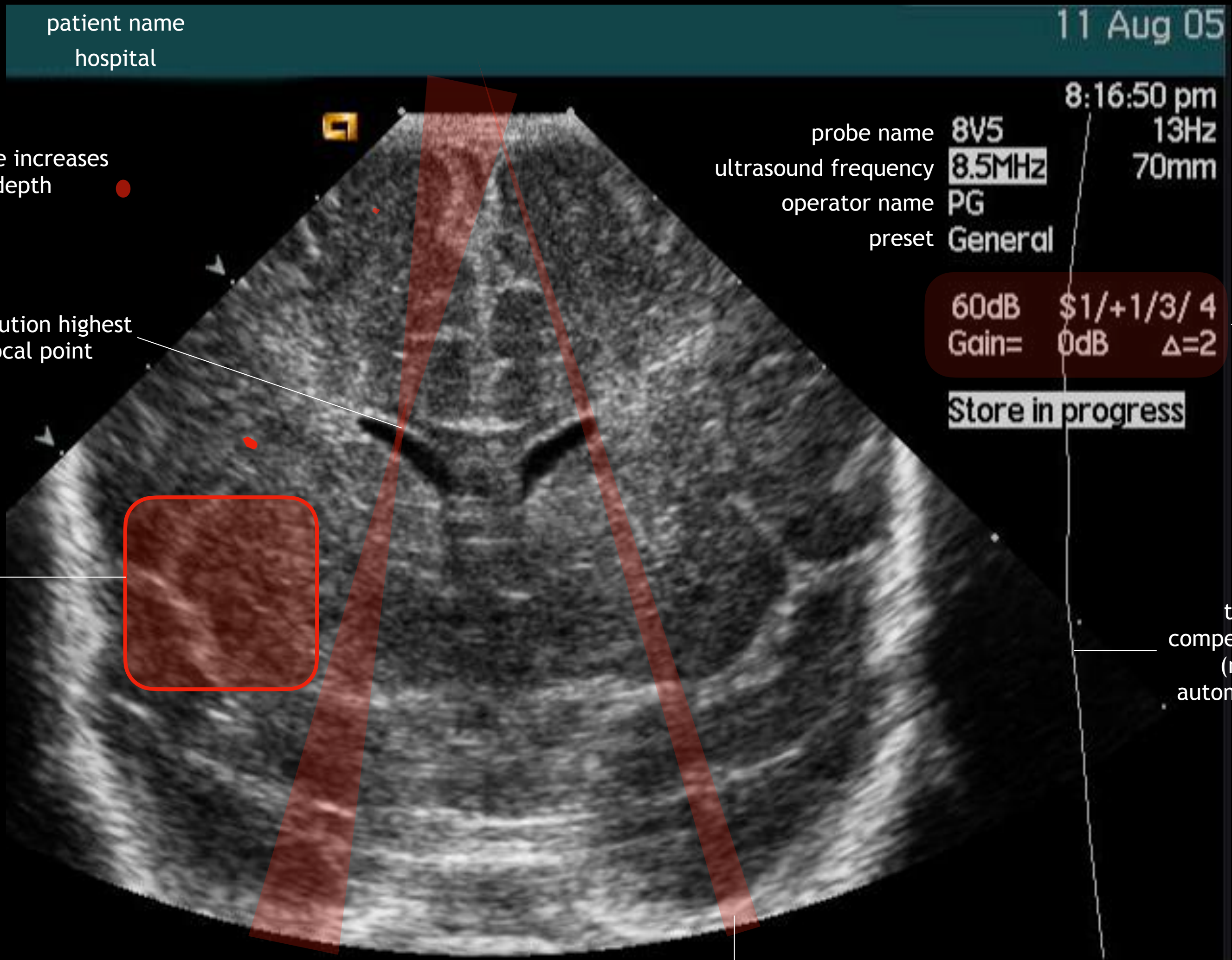
Sonar





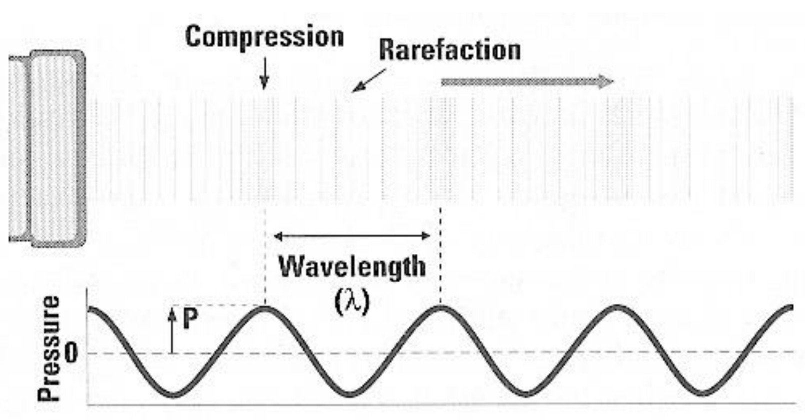
cranial ultrasound

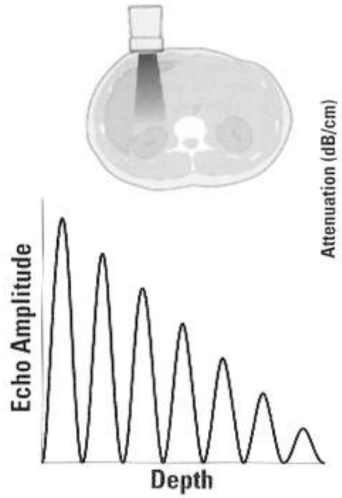
information in the image

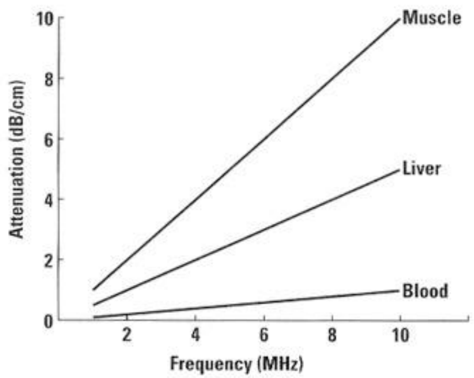


Zagzebski JA (1996) Essentials of ultrasound physics. Mosby.

cranial ultrasound





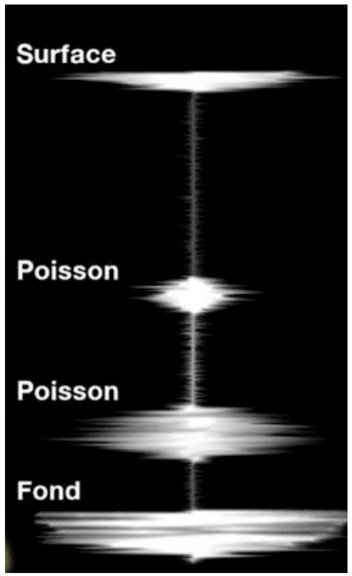


As sound travels to tissue, it is **attenuated** (in dB/cm) by

- reflection (on different types of reflectors), some of which leads to scattering
- absorption (increases with frequency of the wave)
- interference (wavelets may cancel one another).

Ultrasound travels in the form of a **mechanical longitudinal wave**, in which particle motion occurs along the direction the wave is traveling. These waves are generated by an ultrasound transducer.

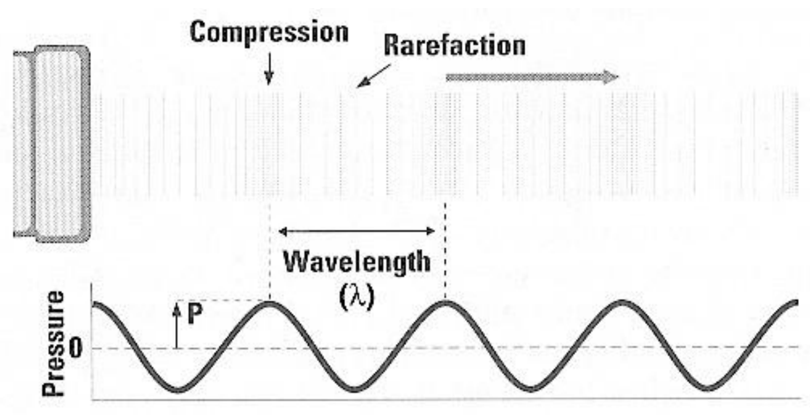
Longitudinal waves transfer energy through the motion of regions of compression (with peak Pressure P in pascals) and rarefaction within the wave.

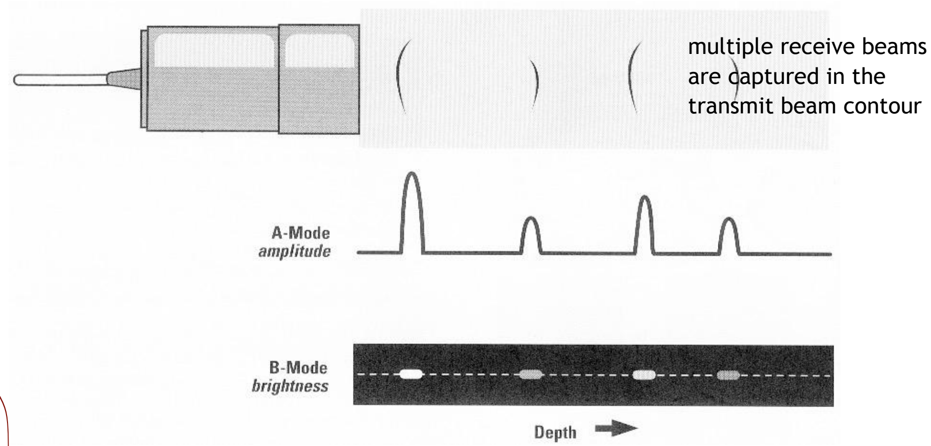


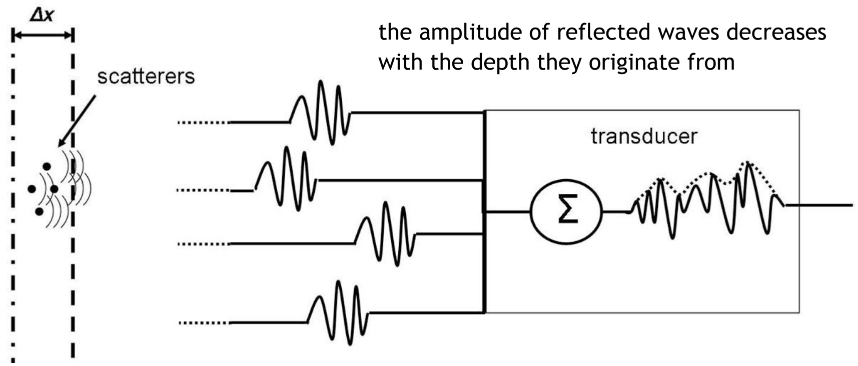
after Zagzebski JA (1996) Essentials of ultrasound physics. Mosby.

ultrasound physics: scanhead, speckle, scatterers

the strength of a reflection determines speckle brightness
the delay of a relfection determines speckle depth







Interference of backscattered sound waves from 4 scatterers within the critical axial resolution Δx (Source: Thijssen and Oosterveld, 1990).
Upon reception, the transducer will transform the echoes in an electrical Radio-Frequency signal **(RF-signal) that is the algebraic sum of the instantaneous sound pressures of the backscattered waves**. This algebraic sum is the interference pattern of the four different scatterers and the dashed line in the figure represents the peaked demodulated echogram.
This peaked interference pattern is called **speckle**. Neither the number nor the amplitude of the peaks is directly related to the number of scatterers in the tissue. They rather reflect the distribution of the scatterers within the resolution cell (Δx).

A- mode= amplitude mode, depicts sound amplitude versus time

B-mode = brightness mode, depicts echodots to represent scattered sound waves arriving within the same package at the scanhead

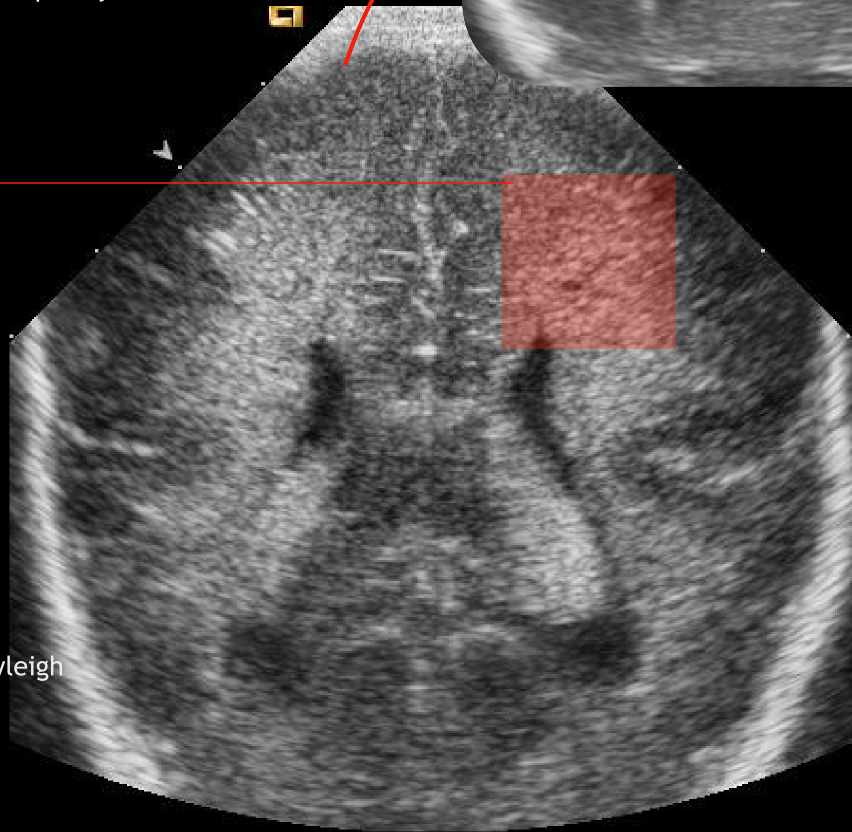
after Zagzebski JA (1996) Essentials of ultrasound physics. Mosby.

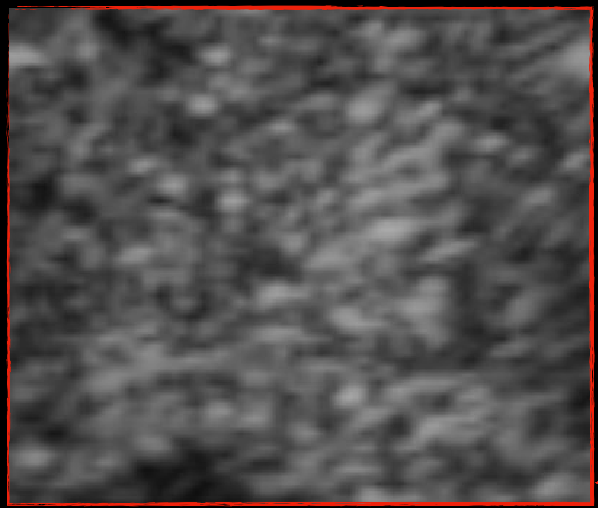
speckle and resolution

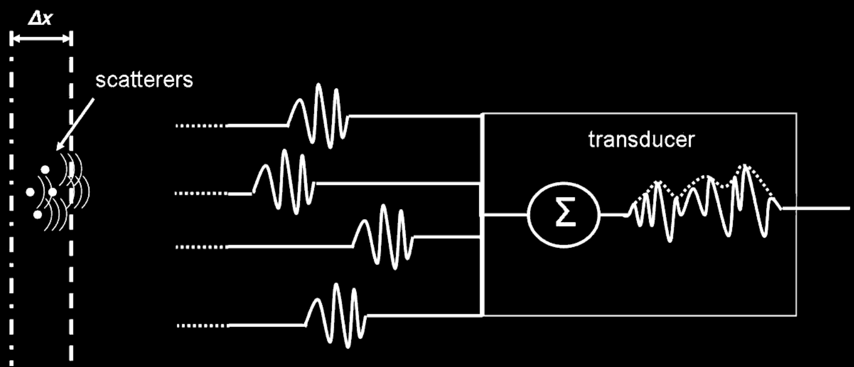
by spatial compounding, multiple images of the same target by phased array probes are averaged to reduce coherent noise (the graininess from speckles)

each image must contain uncorrelated speckle patterns:
ways to obtain uncorrelated speckle patterns:

- divide the transducer into small sub-apertures
- change the steering angle of the beams
- physically translate the transducer
- change the transmit frequency







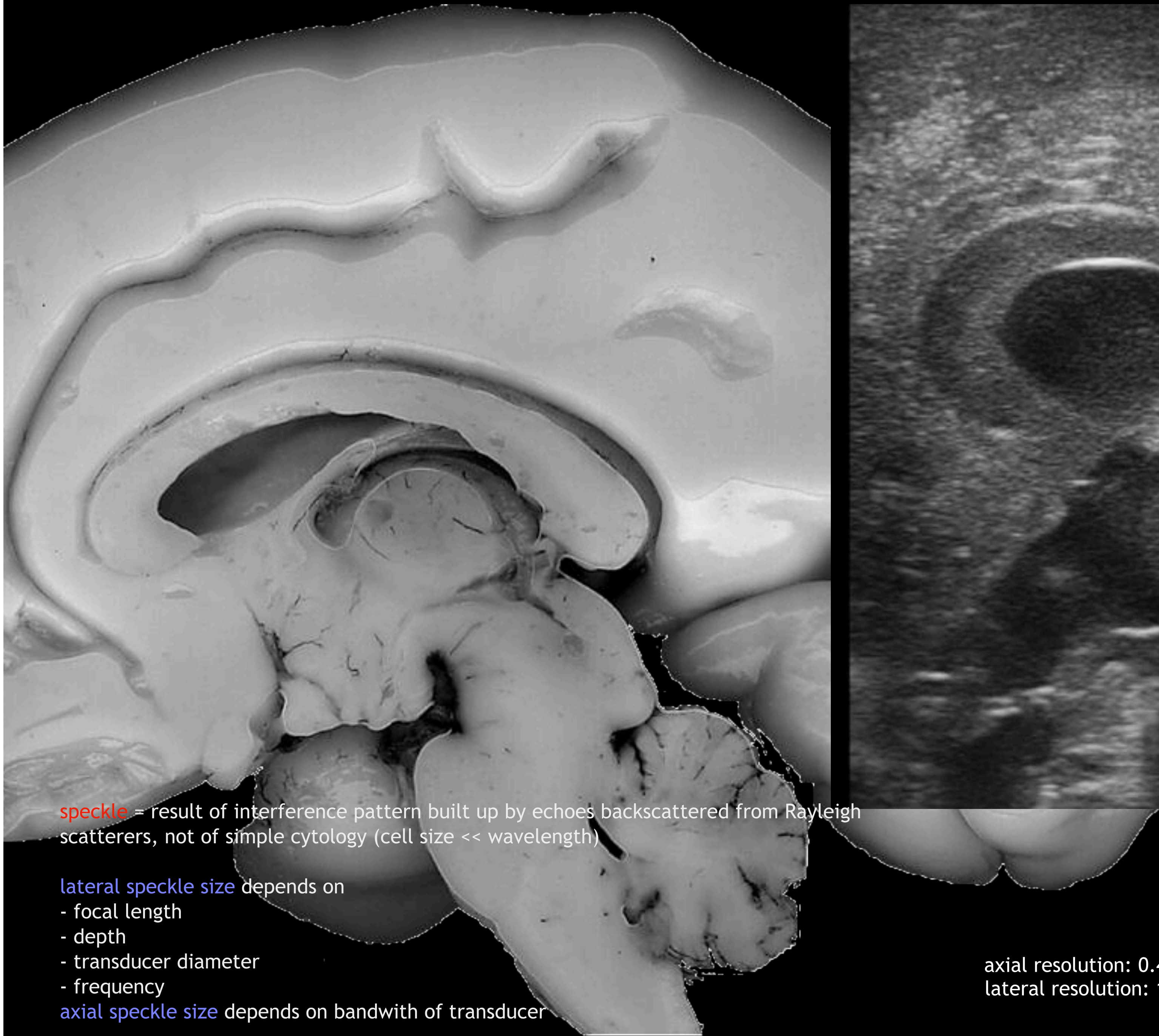
speckle = result of interference pattern built up by echoes backscattered from Rayleigh scatterers, not of simple cytology (cell size << wavelength)

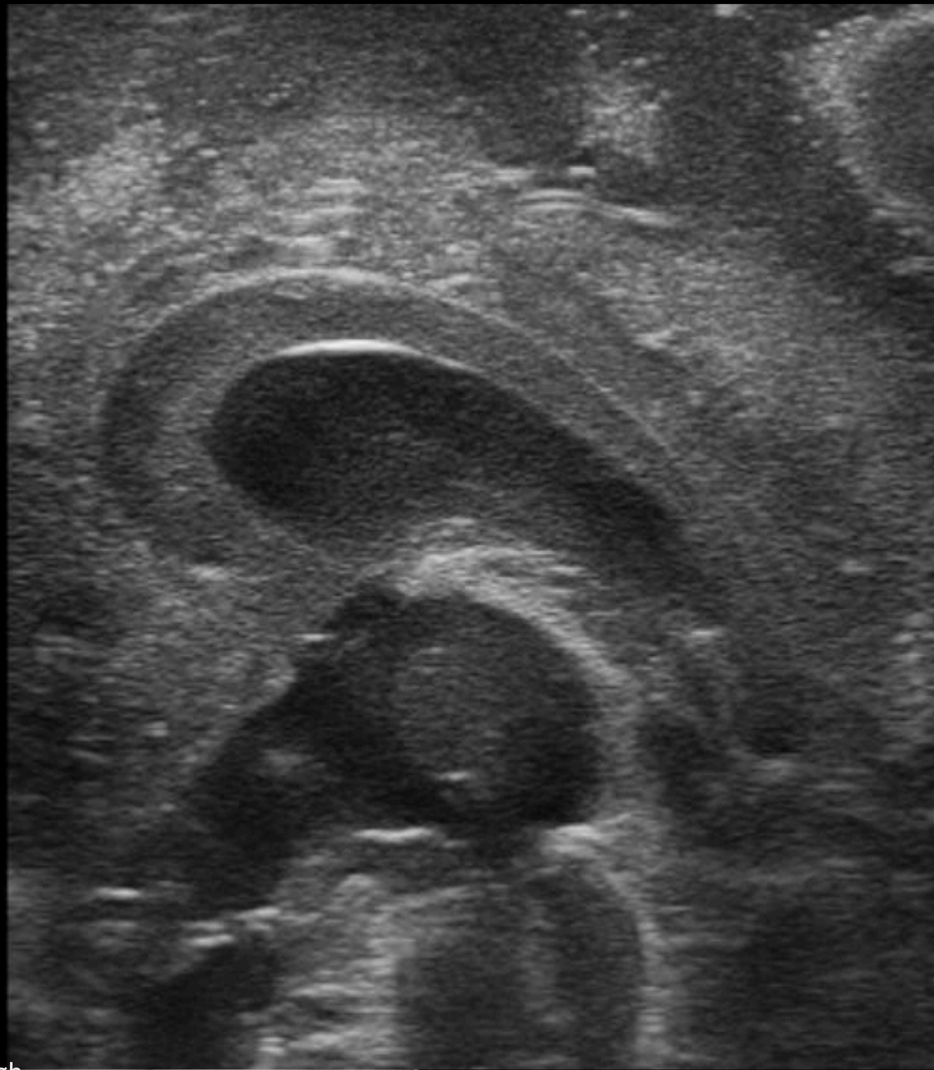
lateral speckle size depends on
- focal length
- depth
- transducer diameter
- frequency

axial speckle size depends on bandwith of transducer

axial resolution: 0.4 mm at 7.5-10 MHz
lateral resolution: 1 mm at 7.5-10 MHz
0,1 mm at 20 MHz

speckle and resolution





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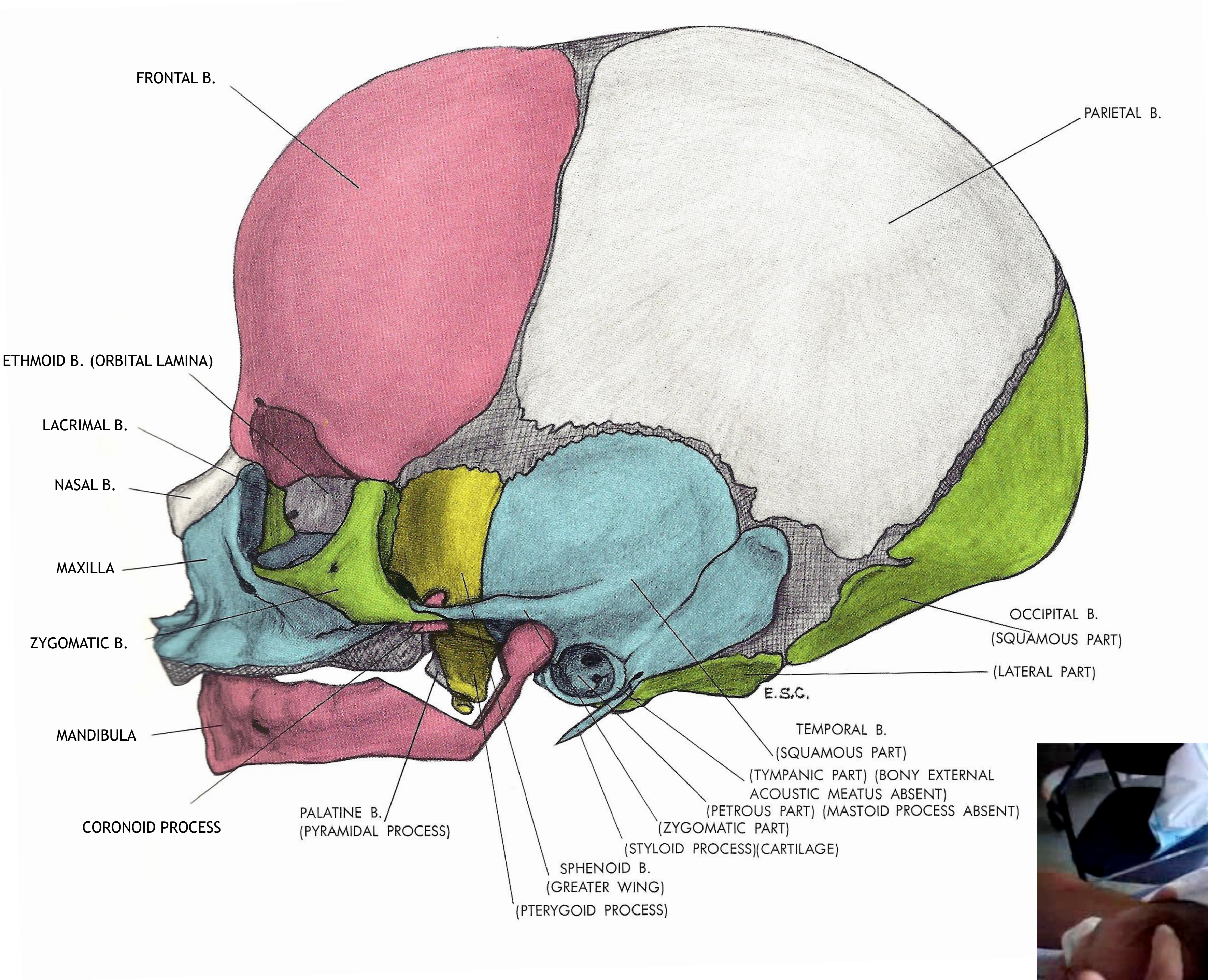
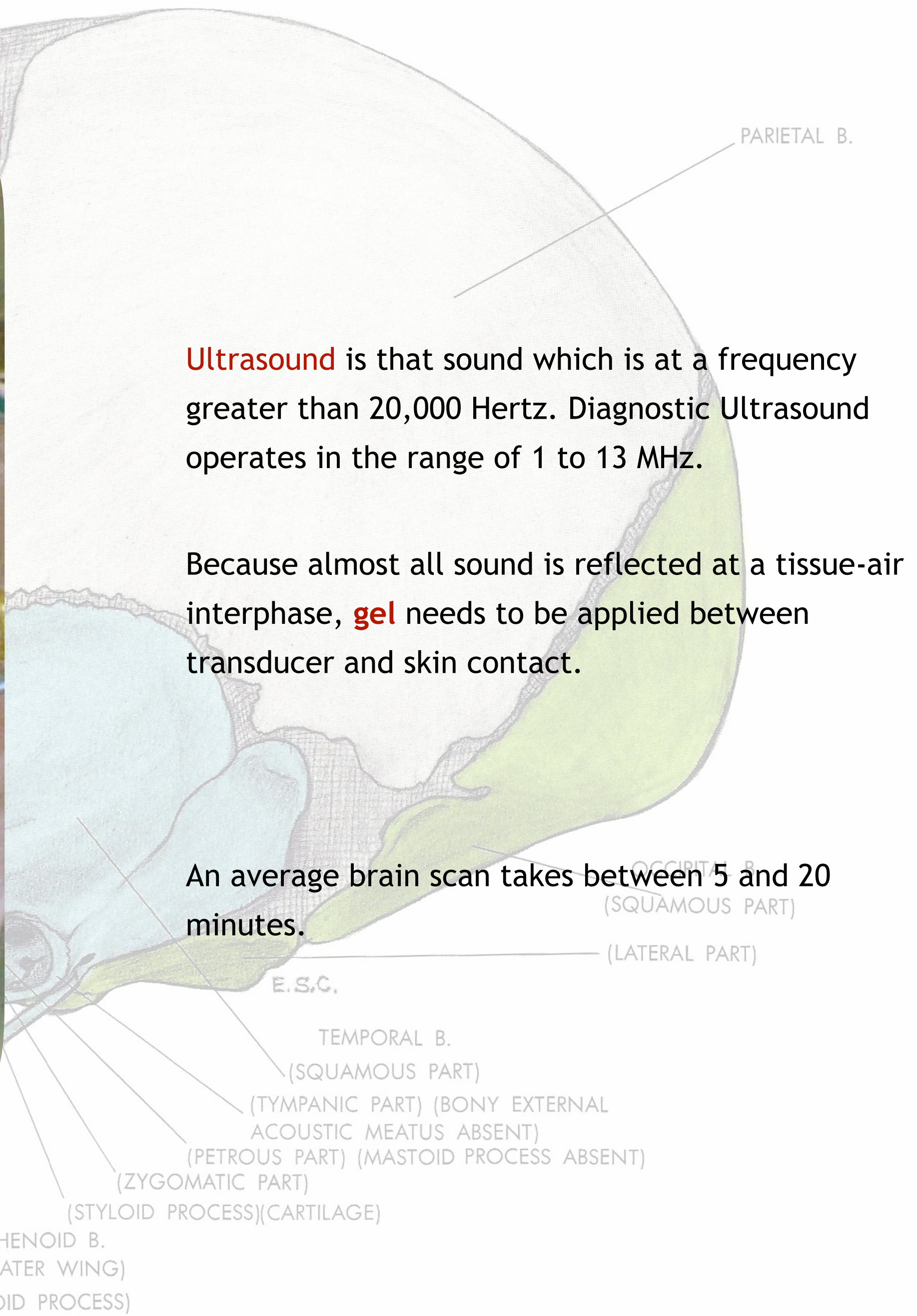
0,1 mm at 20 MHz

sectional planes and fontanels available for insonation



cranial ultrasound



Ultrasound is that sound which is at a frequency greater than 20,000 Hertz. Diagnostic Ultrasound operates in the range of 1 to 13 MHz.

Because almost all sound is reflected at a tissue-air interphase, **gel** needs to be applied between transducer and skin contact.

An average brain scan takes between 5 and 20 minutes.

practical routine: a good quality scan takes planning and time

neonatologist

radiologist

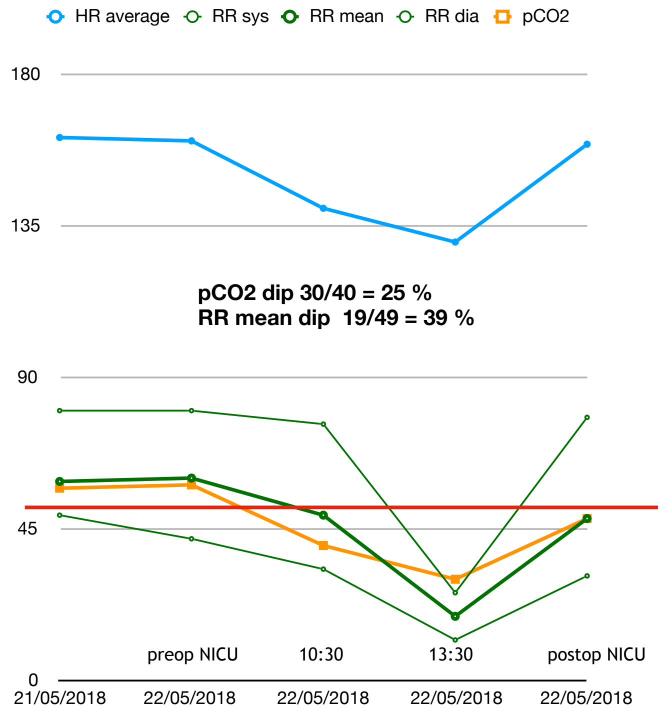
diagnosis

management

research

prognostication and end of life decision making

serial ultrasound findings complete the clinical findings

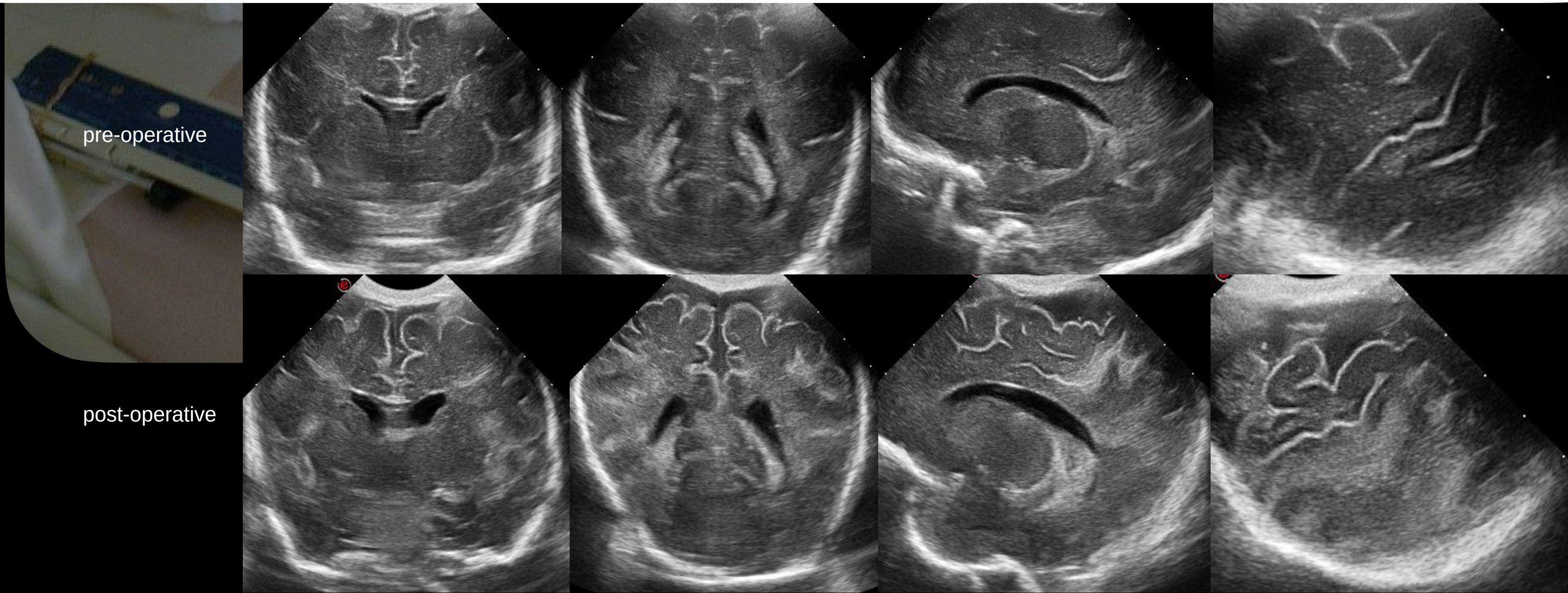


SPA intraoperative hypotension

Nafiu OO, Voepel-Lewis T, Morris M, et al. How do pediatric anesthesiologists define intraoperative hypotension? Paediatr Anaesth. 2009;19(11):1048-1053

reconstruction of gut following NEC, surgery at 25w + 10 w

intraoperative encephalopathy: after an abdominal intervention with low intraoperative systemic perfusion, the brain was affected by cortical necrosis in posterior frontal, parietal, limbic and insular areas



practical routine: a good quality scan takes planning and time

<u>Indication</u>

Antenatal – Perinatal – Postnatal

<u>Timing</u>

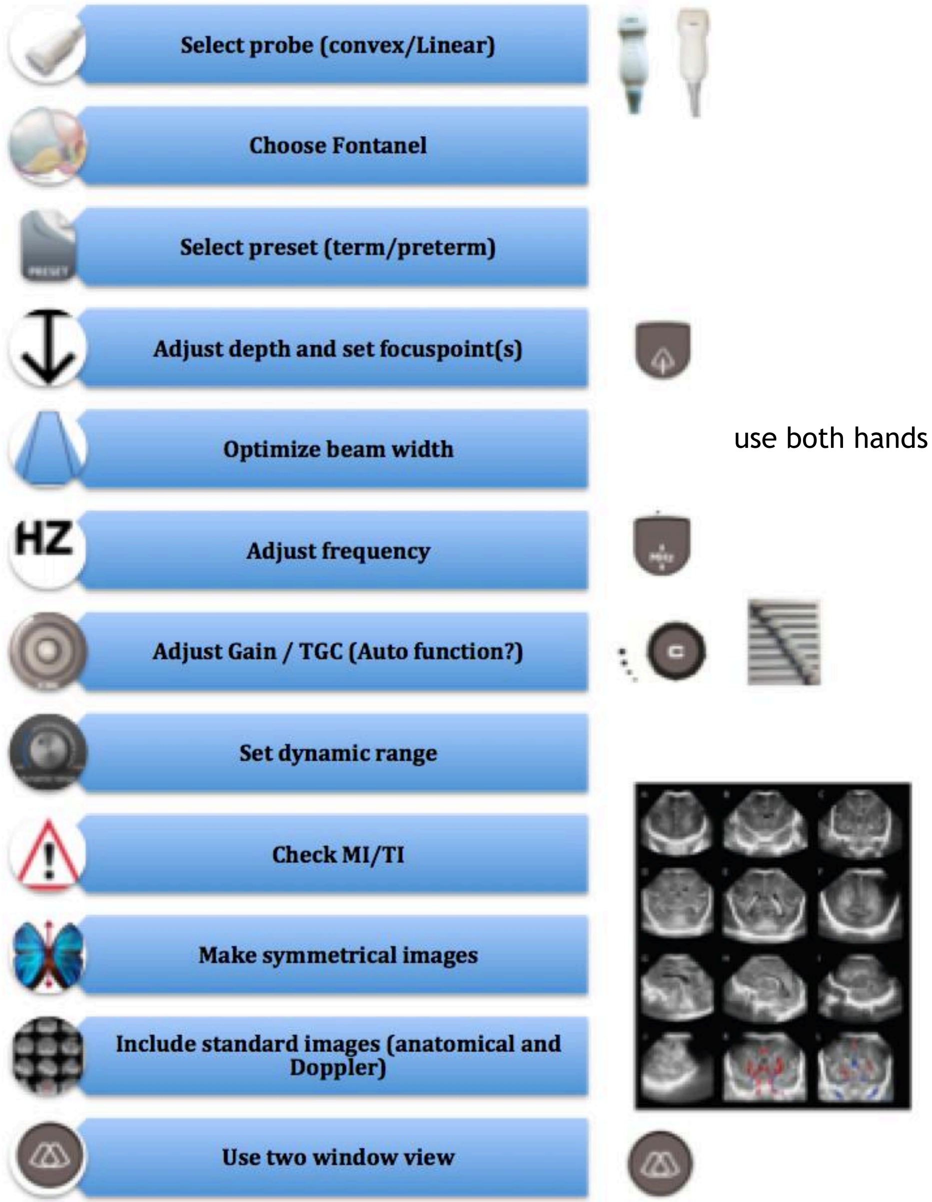
e.g. extremely preterm: day 1, 3, 7, 14, 21 and 28 next every 1-2 weeks

Parental or nursing <u>support</u>

<u>ALARA</u> principle

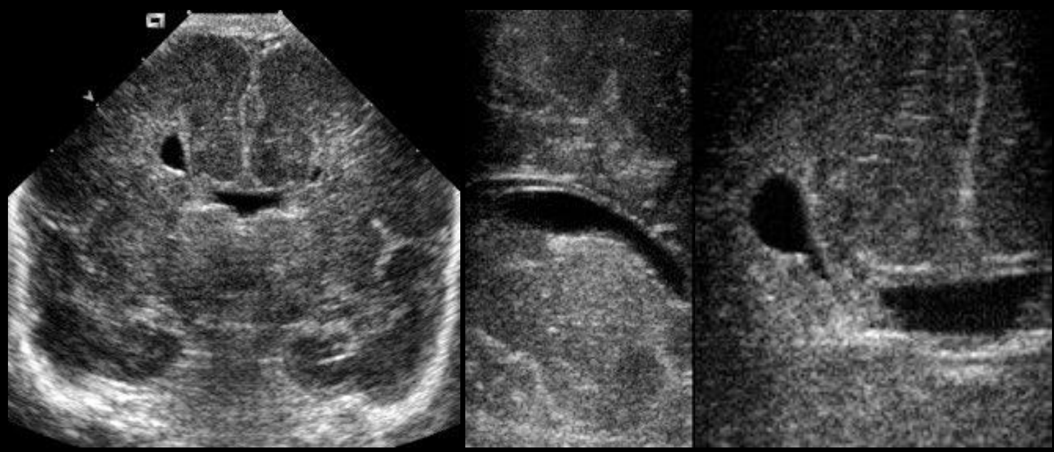
MI and TI warnings

Structured <u>reporting</u>

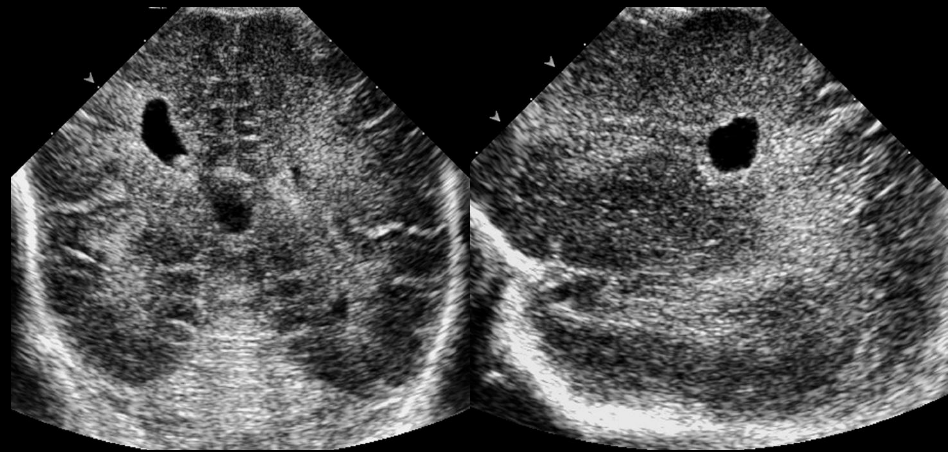


(courtesy of J Dudink UMCUtrecht)

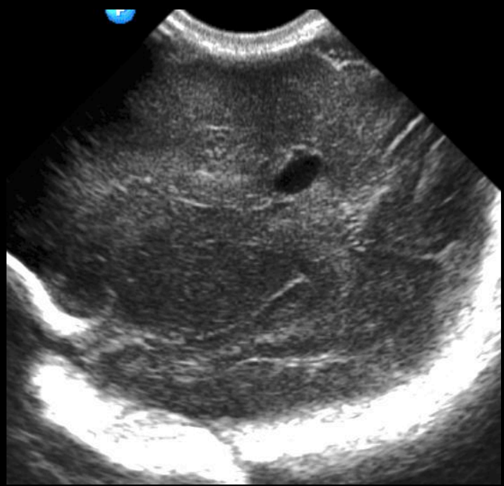
porencephaly



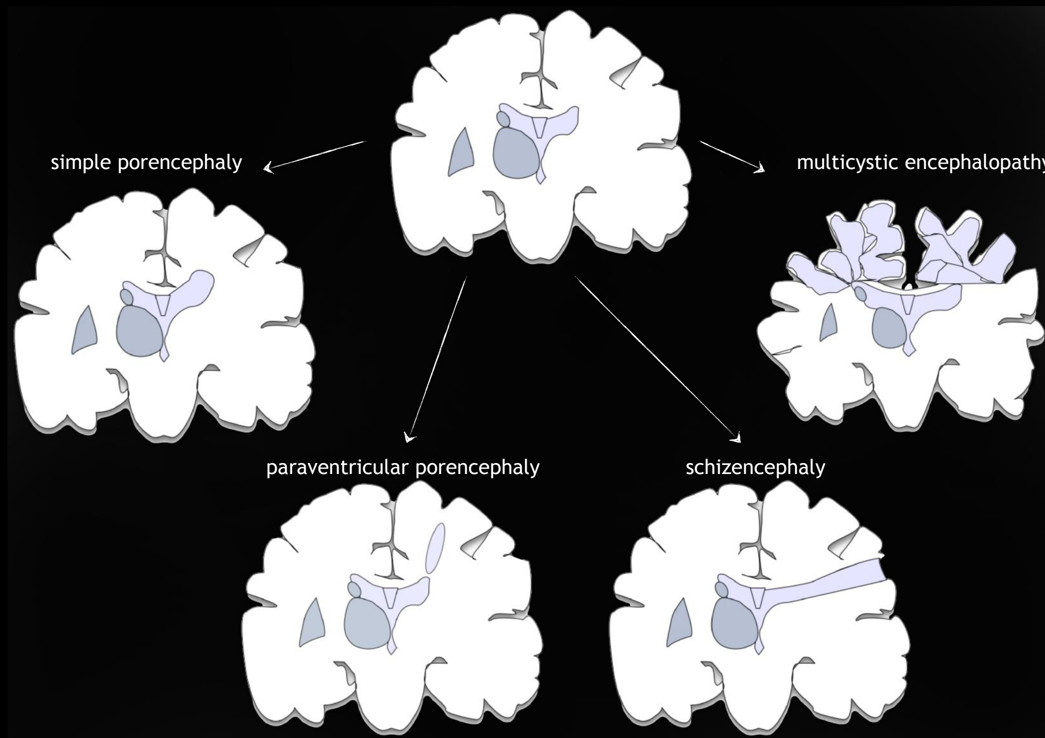
routine scan in preterm at 28w GA on CPAP from birth; first day scan; simple right posterior frontal porencephaly with thinning of the corpus callosum at the same level



routine first day sonogram in a ventilated 32 weeker; simple porencephaly (arrows) at the posterior frontal part of the right lateral ventricle, subjacent to the rolandic area



incidental day 1 sonographic finding at 25w GA of simple porencephaly



practical routine: probes, symmetry and window

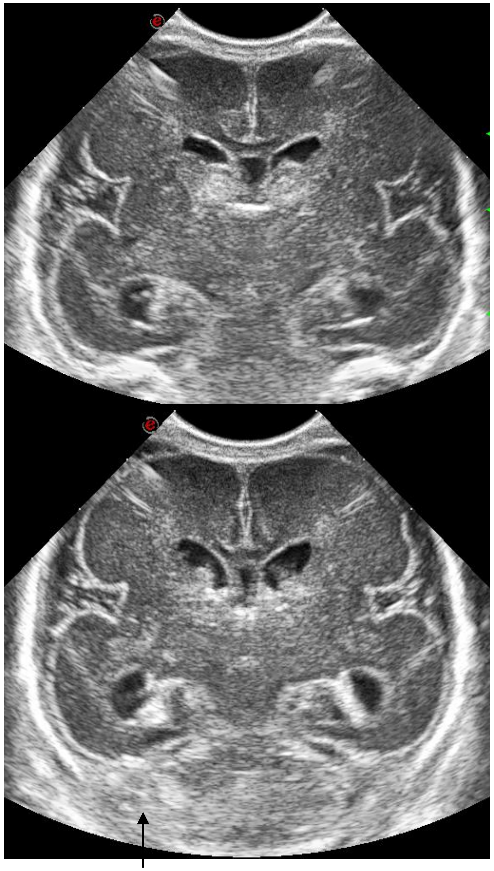
choose probe and presets

Convex probe ~ 8Mhz

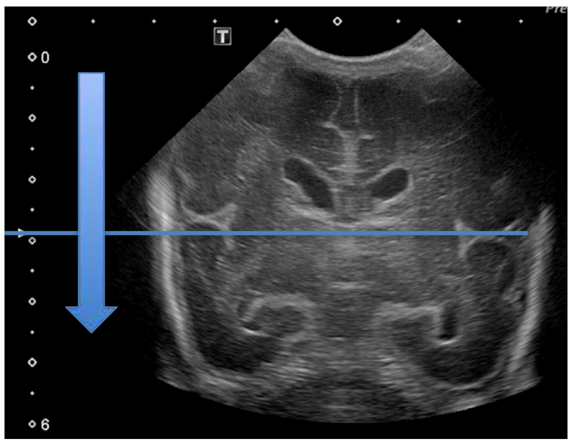
Linear probe ~ 18Mhz

trade-off between overview (depth) and resolution

cover the entire cranium

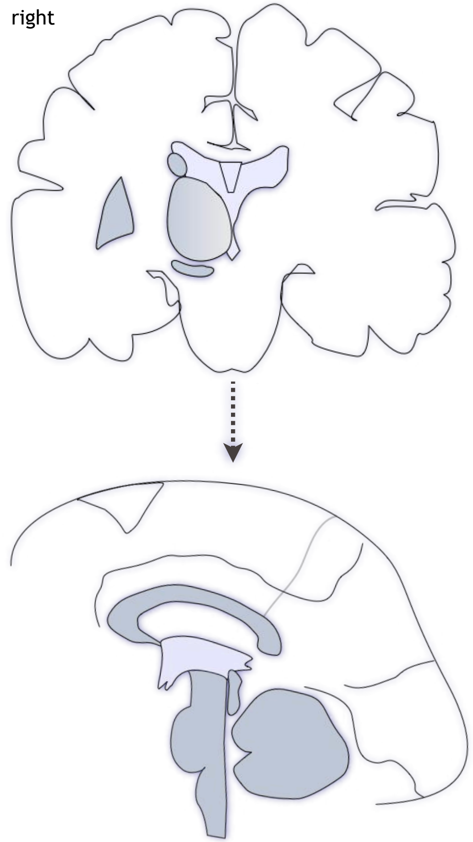


cerebellar haematoma



cranial ultrasound

start with symmetrical coronal images



choose appropiate frequency and place focal point(s)

increase of number of Focus Points leads to reduction of Frames Per Second: Images can appear disjointed

ultrasound energy and doppler: limitations of use

Thermal Index	recommended maximum time for transcranial and spinal scanning
< 0.7	unlimited
0,7 - 1	60 minutes
1 - 1.5	30 minutes
1.5 - 2	15 minutes
2 - 2.5	4 minutes
2.5 - 3	1 minute
≥ 3	not recommended
caution	TI value on machine may understimate biological temperature change TI of 1 means you heat the interrogated tissue up with 1 °C after about 120 seconds heating effect largest near bone 5 minutes in static B mode scanning may heat brain surface by up to 4 °C

during contrast agent application thermal index above 0.7 not advised

TIS assumes that only soft tissue is insonated.
TIB assumes bone is present at the depth where temporal intensity is greatest.
TIC assumes bone is very close to the front face of the probe.

	colour doppler	power (spectral) doppler
physical principle	moving RBC shift doppler frequency	moving scatterers between pulse trains
angle dependency	yes, unreliable velocities > 20° (> 6% error), no visualisation at angle 90°	not
energy		higher sound pressures (about double of colour doppler)
artefacts		more sensitive to low velocities but also to motion artefacts

- *ultrasound travels through brain in 0,00006493506494 sec = in 0,065 msec*
- *only one % is reflected to the probe, the rest is lost in tissue by attenuation*
- *ultrasound is attenuated by scattering, but the main attenuation is by absorption of the waves by tissue, which is then converted to heat*
- ***MI** is an on-screen indicator of the relative potential for ultrasound to induce an adverse bio effect by a non-thermal mechanism including cavitation*

practice: doppler scanning no longer than 15 minutes and not fixing a probe on one vessel continuously for more than 1 minute, especially during spectral doppler imaging

continued need for research with advancing techniques; safety provided by limiting scan duration; caution in use of contrast agents

Schneider ME, Lombardo P. Brain Surface Heating After Exposure to Ultrasound: An Analysis Using Thermography. Ultrasound Med Biol. 2016 May;42(5):1138-44.
Duggan PM, Murcott MF, McPhee AJ, Barnett SB. The influence of variations in blood flow on pulsed doppler ultrasonic heating of the cerebral cortex of the neonatal pig. Ultrasound Med Biol. 2000 May;26(4):647-54.
Taylor GA, Barnewolt CE, Dunning PS. Neonatal pig brain: lack of heating during Doppler US. Radiology. 1998 May;207(2):525-8.
Lalzad A, Wong F, Schneider M. Neonatal Cranial Ultrasound: Are Current Safety Guidelines Appropriate? Ultrasound Med Biol. 2017 Mar;43(3):553-560.

Guidelines for the safe use of diagnostic ultrasound equipment, prepared by the Safety Group of the British Medical Ultrasound Society. 2009
https://www.bmus.org/static/uploads/resources/BMUS-Safety-Guidelines-2009-revision-FINAL-Nov-2009.pdf
https://journals.sagepub.com/doi/pdf/10.1177/1742271X0000800311 and https://doi.org/10.1258/ult.2010.100003

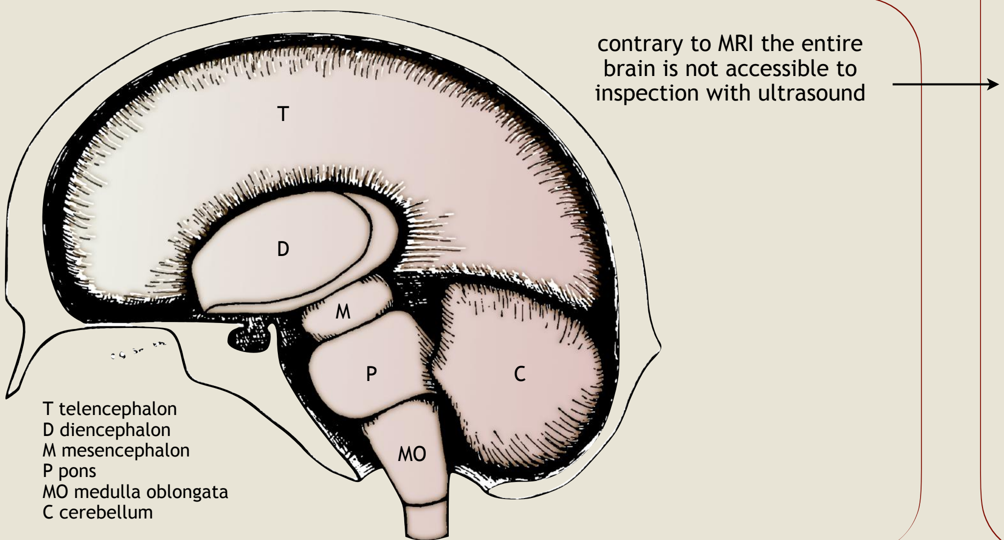
AIUM 2008. American Institute of Ultrasound in Medicine Consensus Report on Potential Bioeffects of Diagnostic Ultrasound. J Ultrasound Med; 27:503-515.

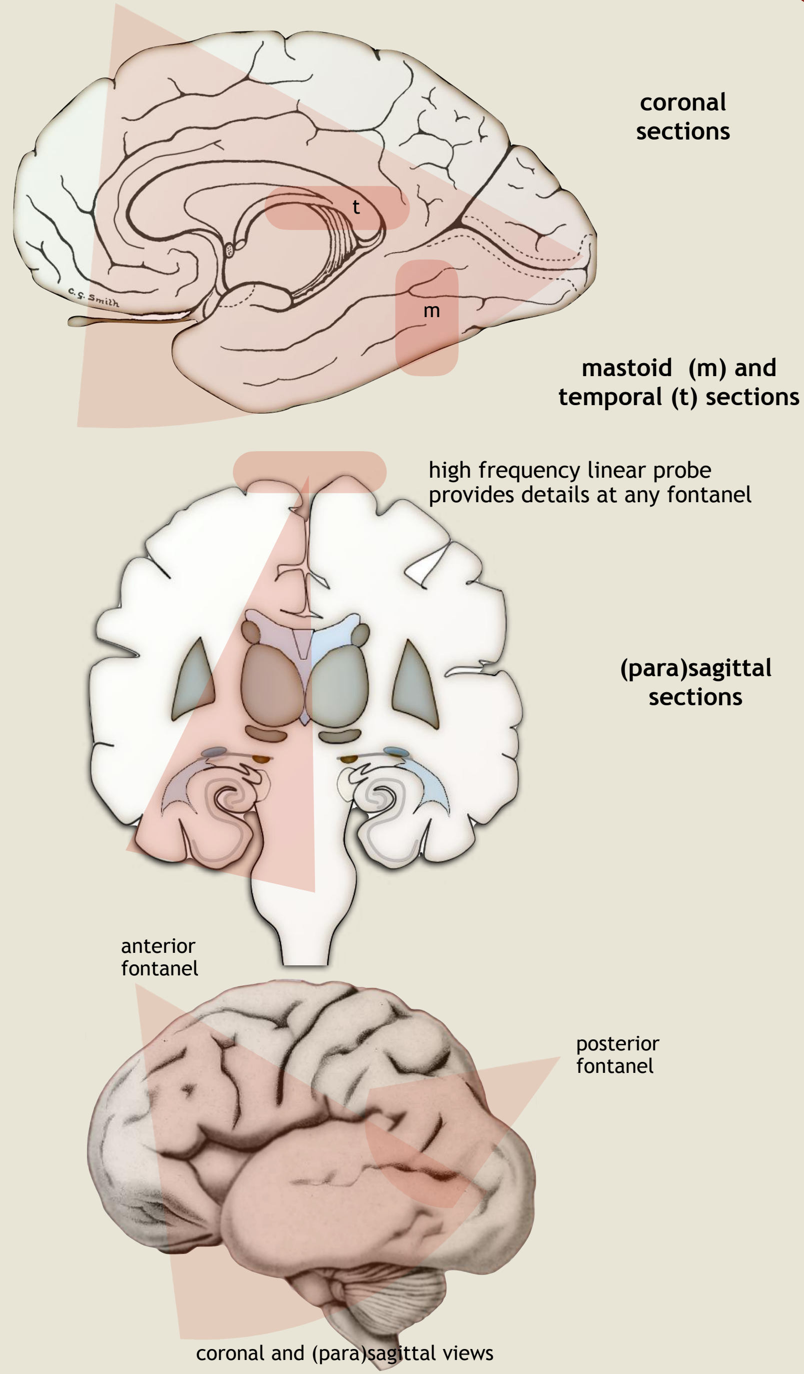
conditions we can study well with ultrasound

- ☑ there are conditions we can (only) study well with ultrasound

location	echo-aspect	disorder
around ventricles	**cavitation**	germinolysis
		midline cavities
		plexus cyst
	hypercellularity	arteriopathy
		stroke
	motion	DVA
		AVM
	fibrin deposition	
	calcification	
subdural space	details under fontanels	sinus thrombosis, subdural haematoma
IH fissure		
mastoid window		

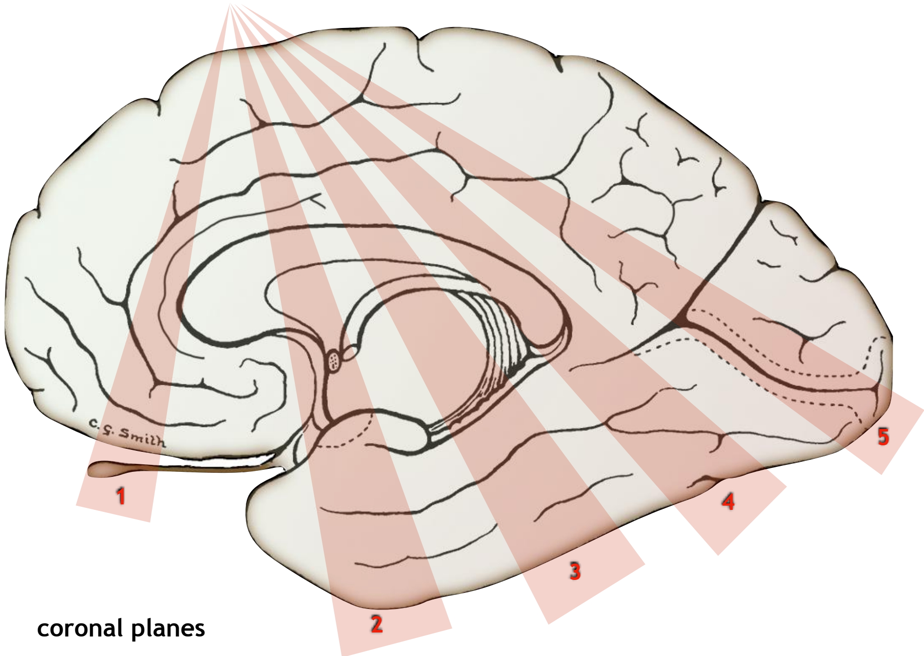
sectional planes and fontanels available for insonation



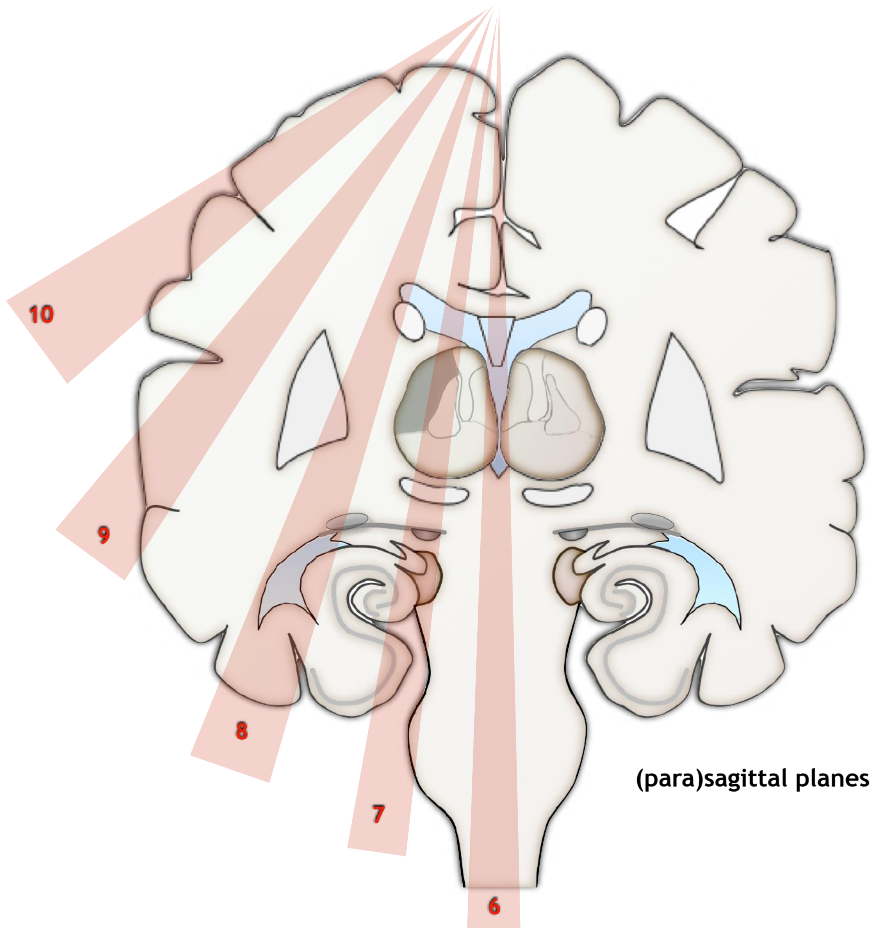


cranial ultrasound

“standard” sectional planes



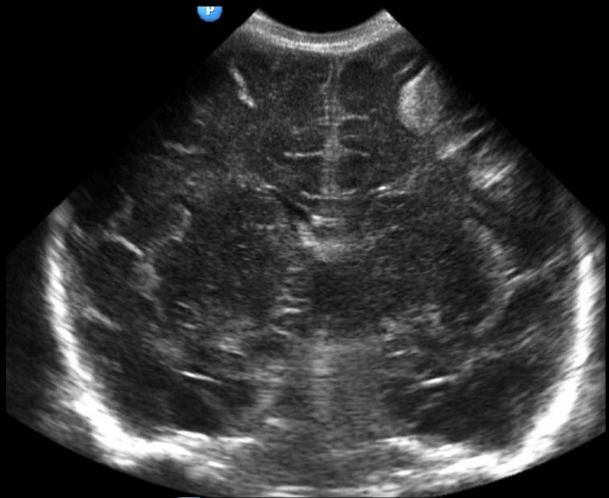
coronal planes

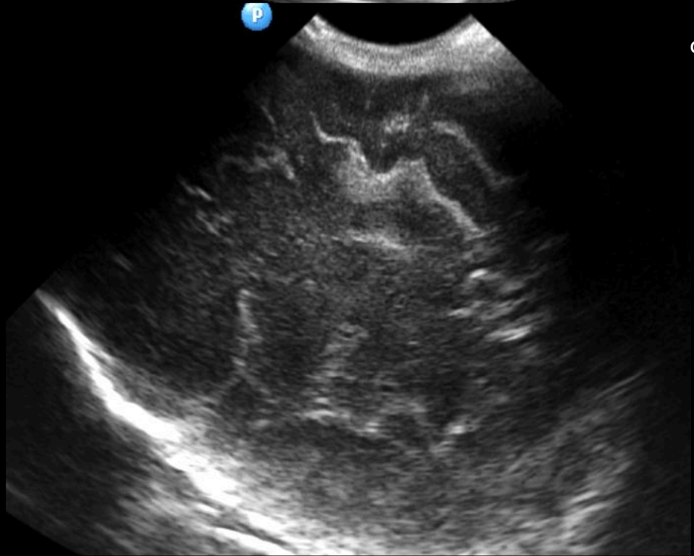


(para)sagittal planes

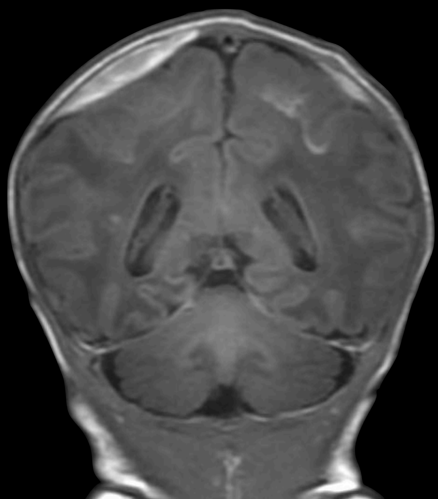
1 anterior to the foramen of Monro at olfactory level
2 near the foramen of Monro
3 through ventrolateral thalamus
4 through ventricle atrium and glomus choroideum
5 posterior to the lateral ventricles

midsagittal 6
through the caudothalamic groove 7
through thalamus and basal ganglia 8
through insula 9
through fronto-parietal cortex 10
repeat 7-10 for the other side 11-14





contusion

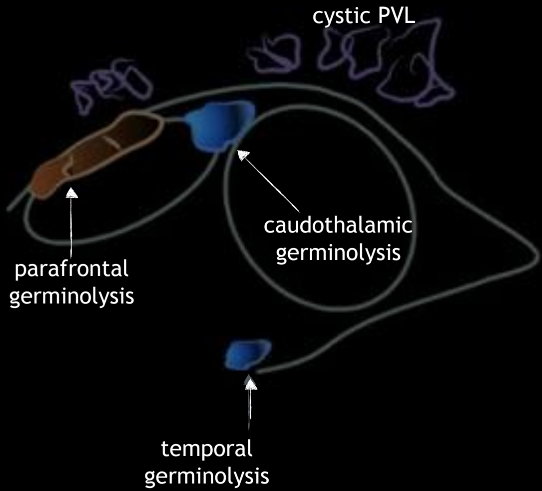


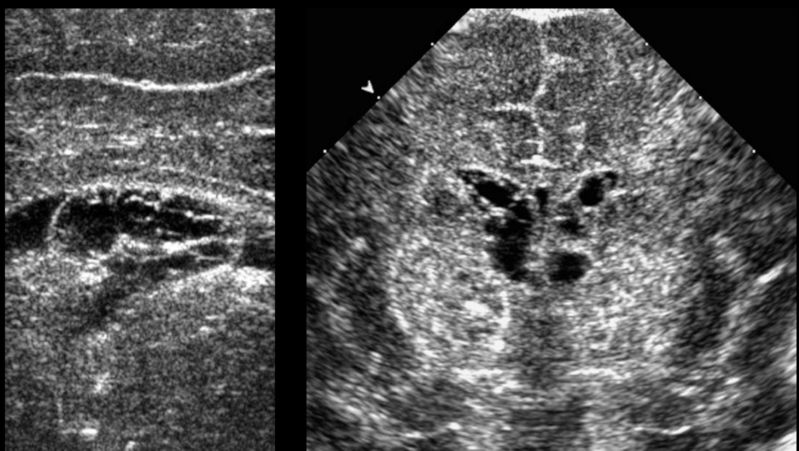
CEREBROCORTICAL GREY MATTER

24w PMA

a divided sulcus centralis

CEREBROCORTICAL GREY MATTER

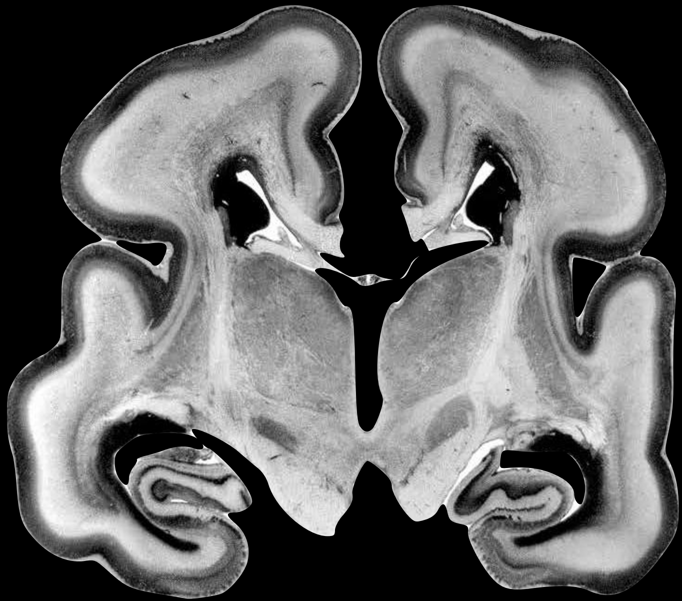


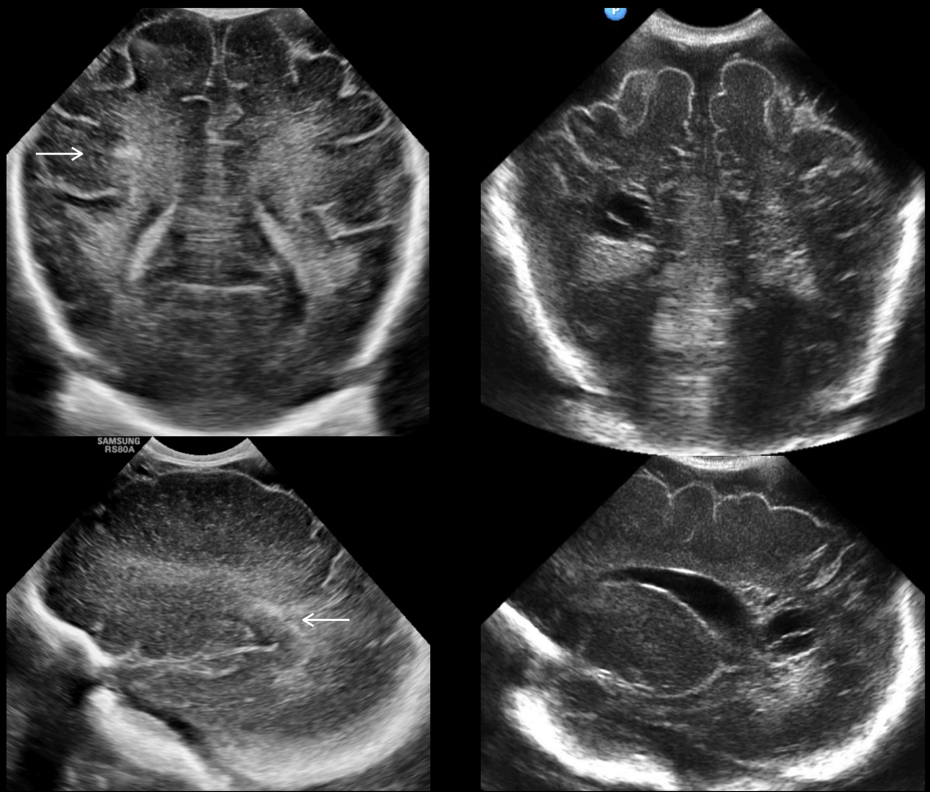


congenital rubella syndrome, caudothalamic germinolysis

GERMINAL MATRIX

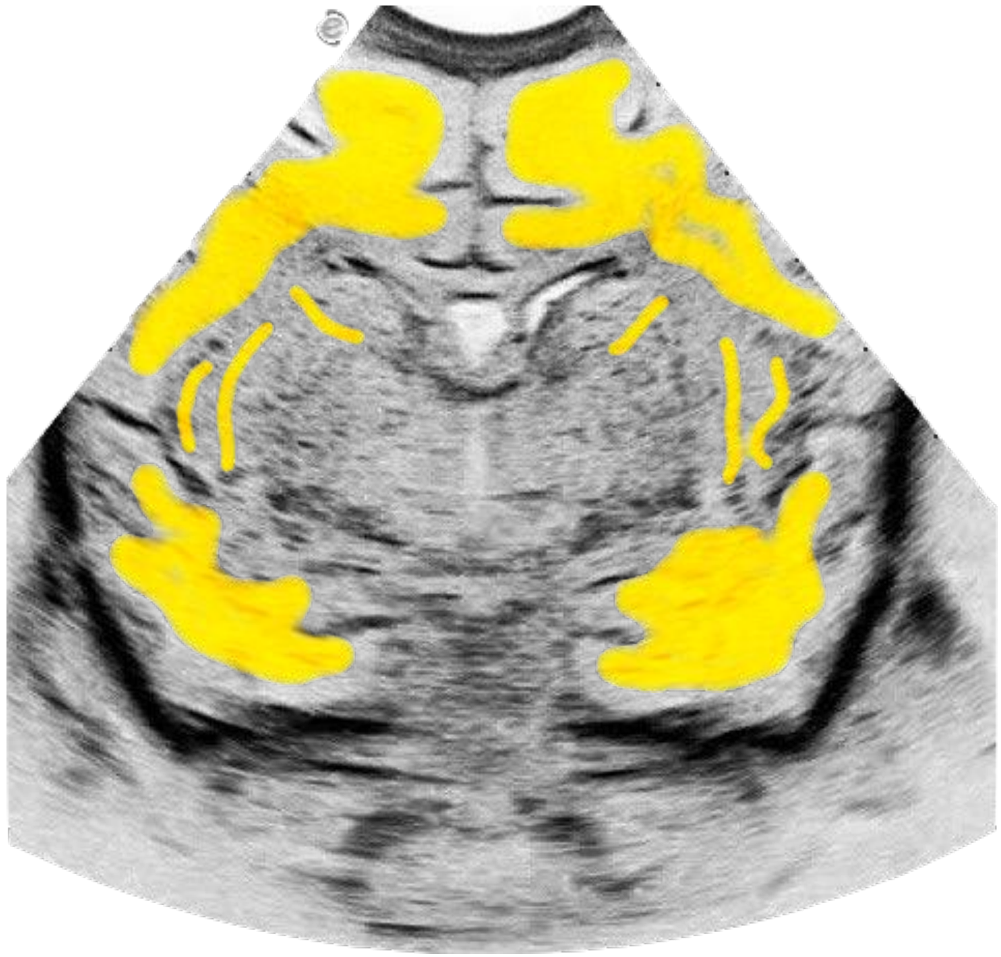
GERMINAL MATRIX



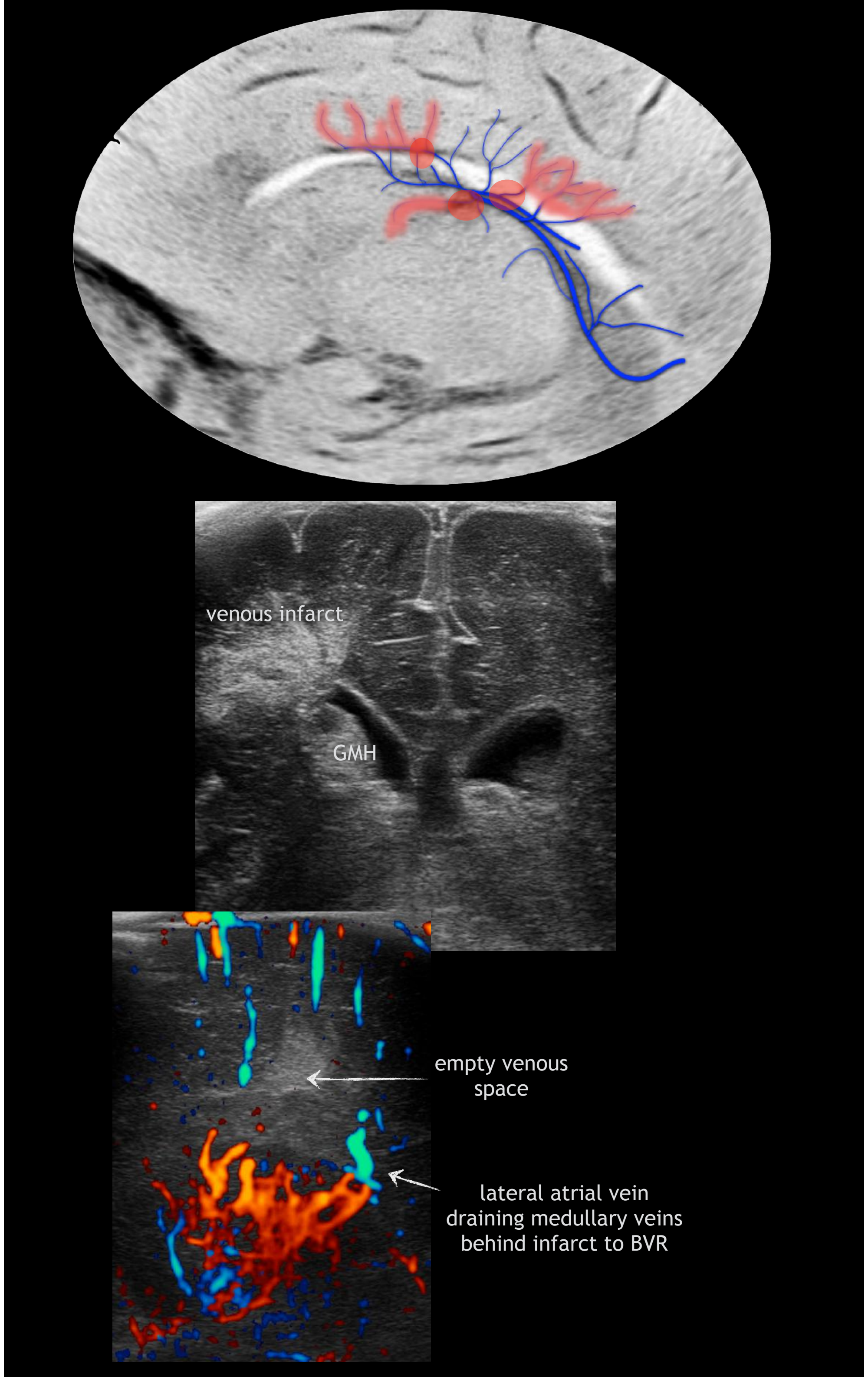


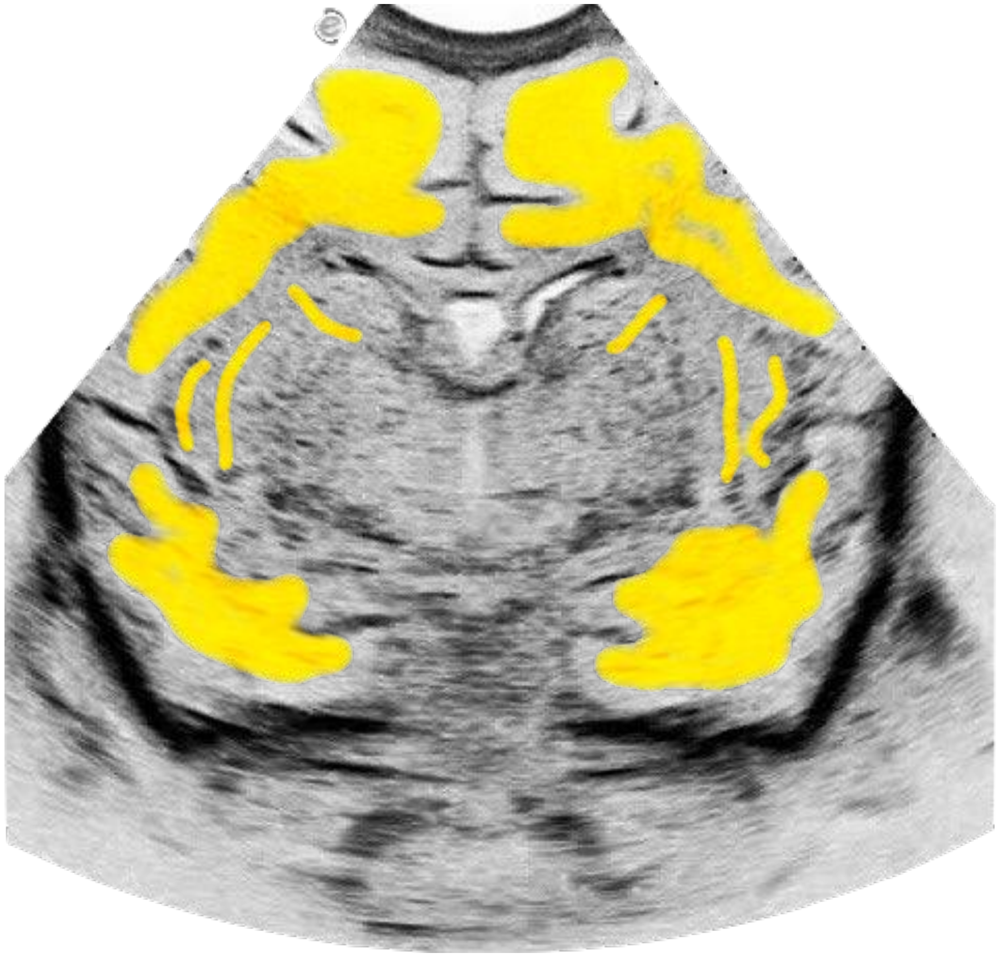
non-cystic (gliotic) leukomalacia

cystic leukomalacia

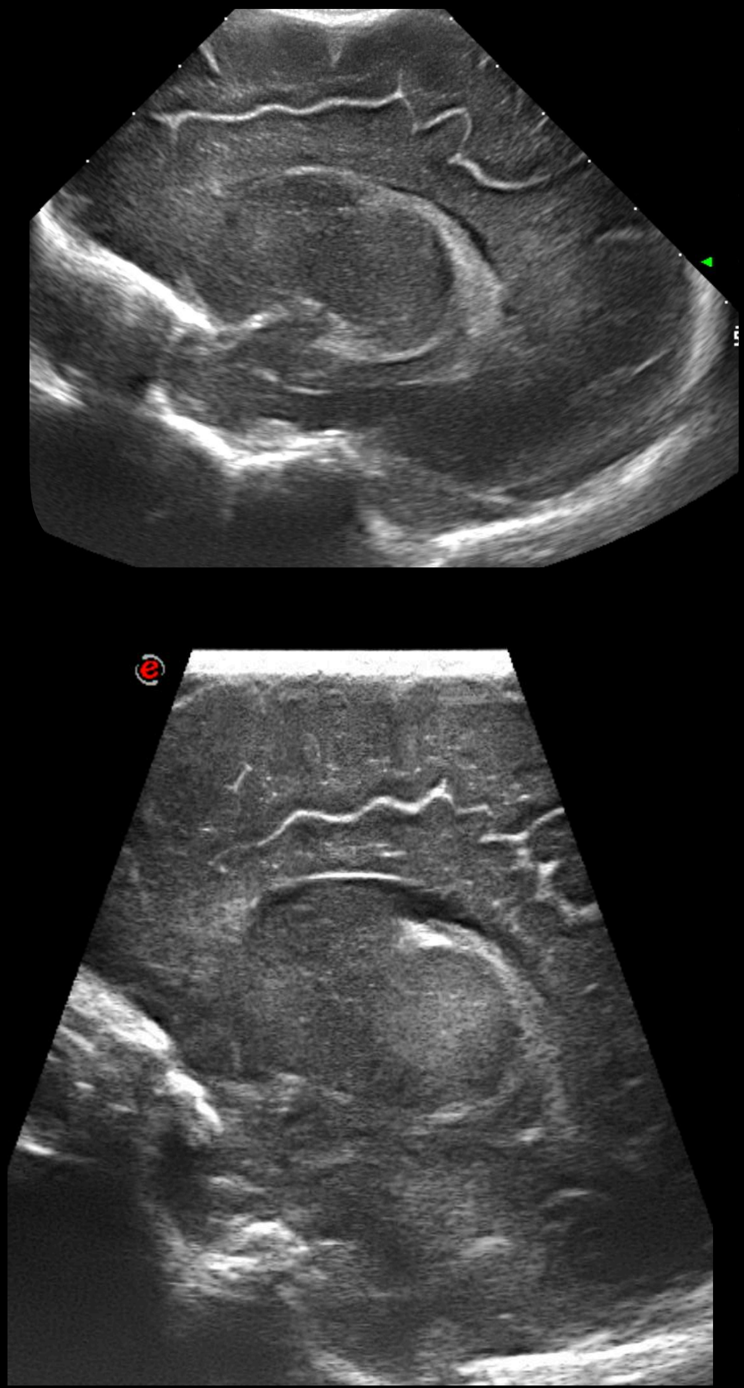


WHITE MATTER



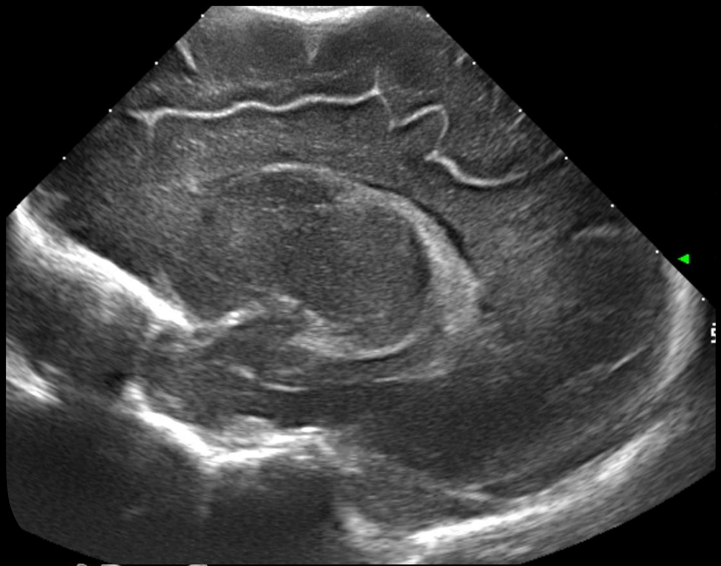


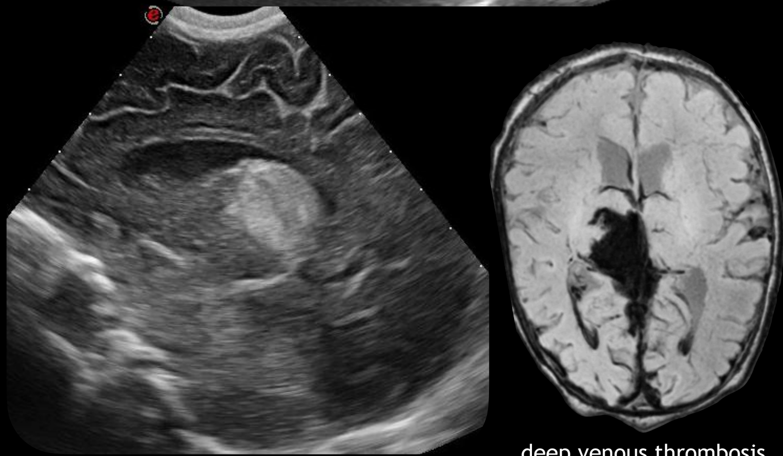
WHITE MATTER



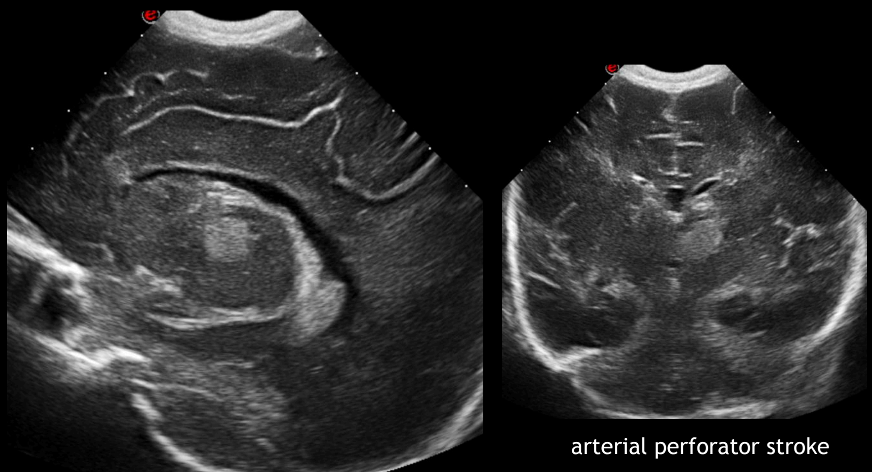
acute total asphyxia

DEEP GREY MATTER



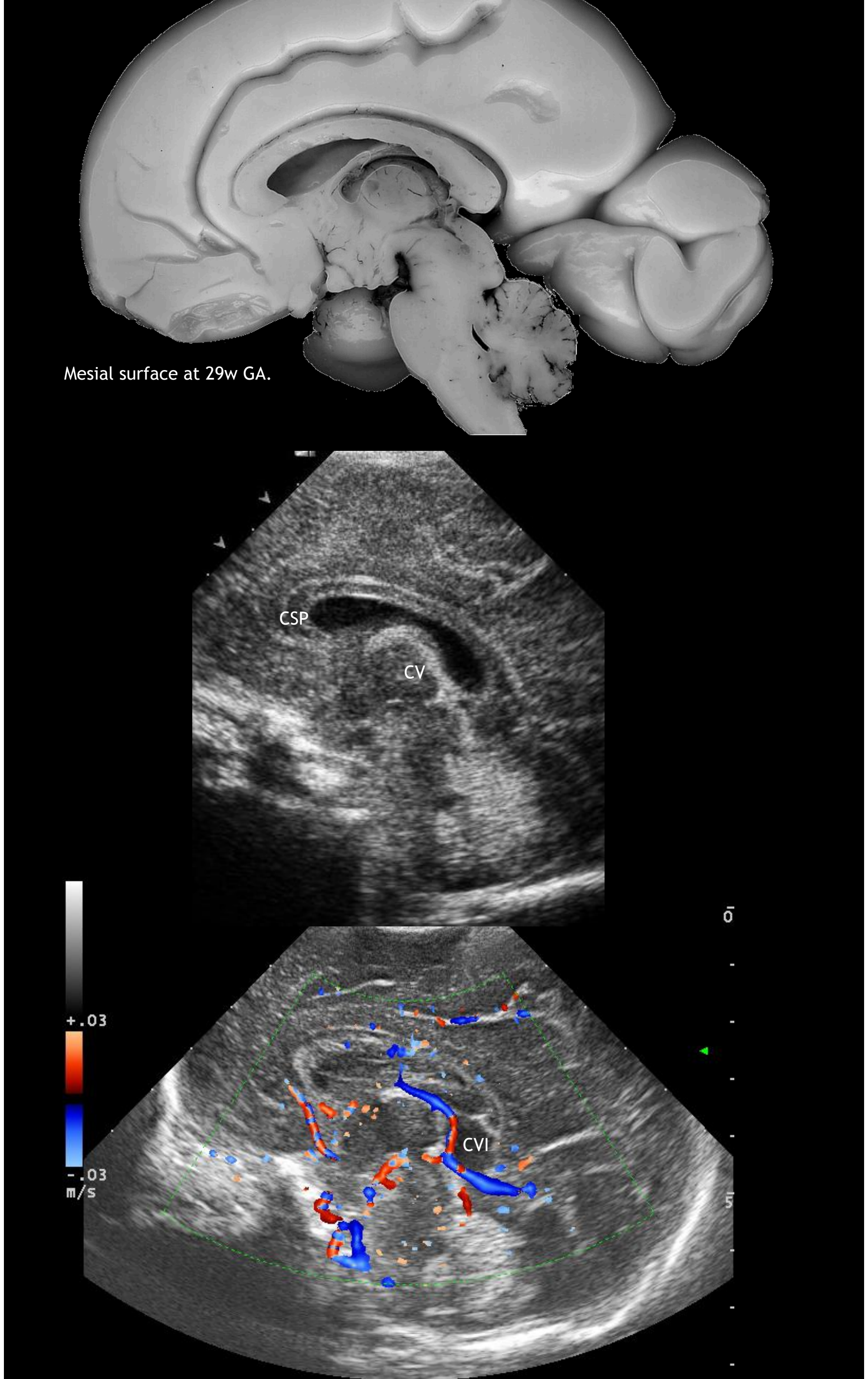


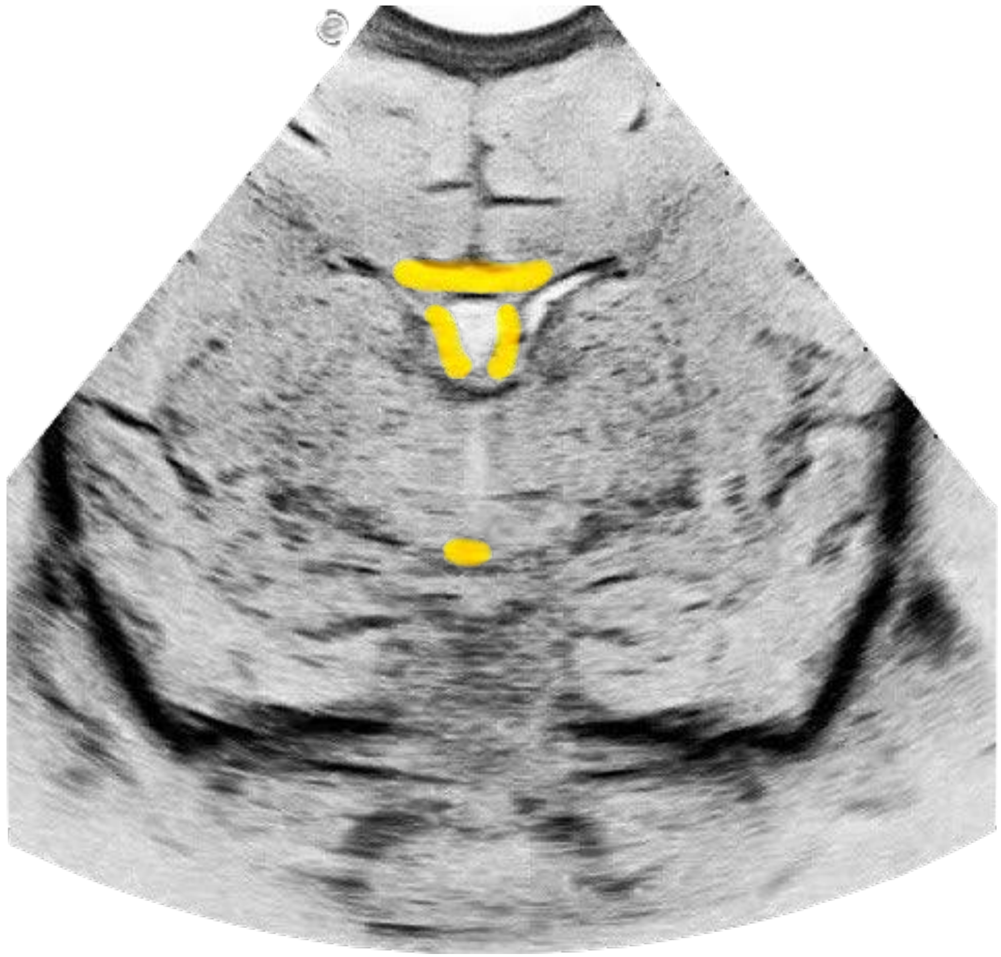
deep venous thrombosis



arterial perforator stroke

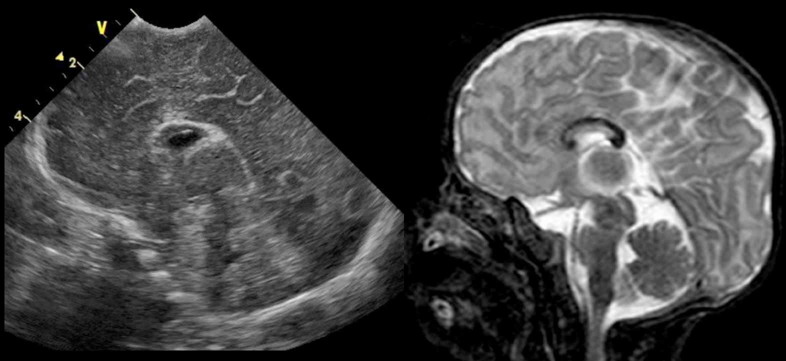
DEEP GREY MATTER



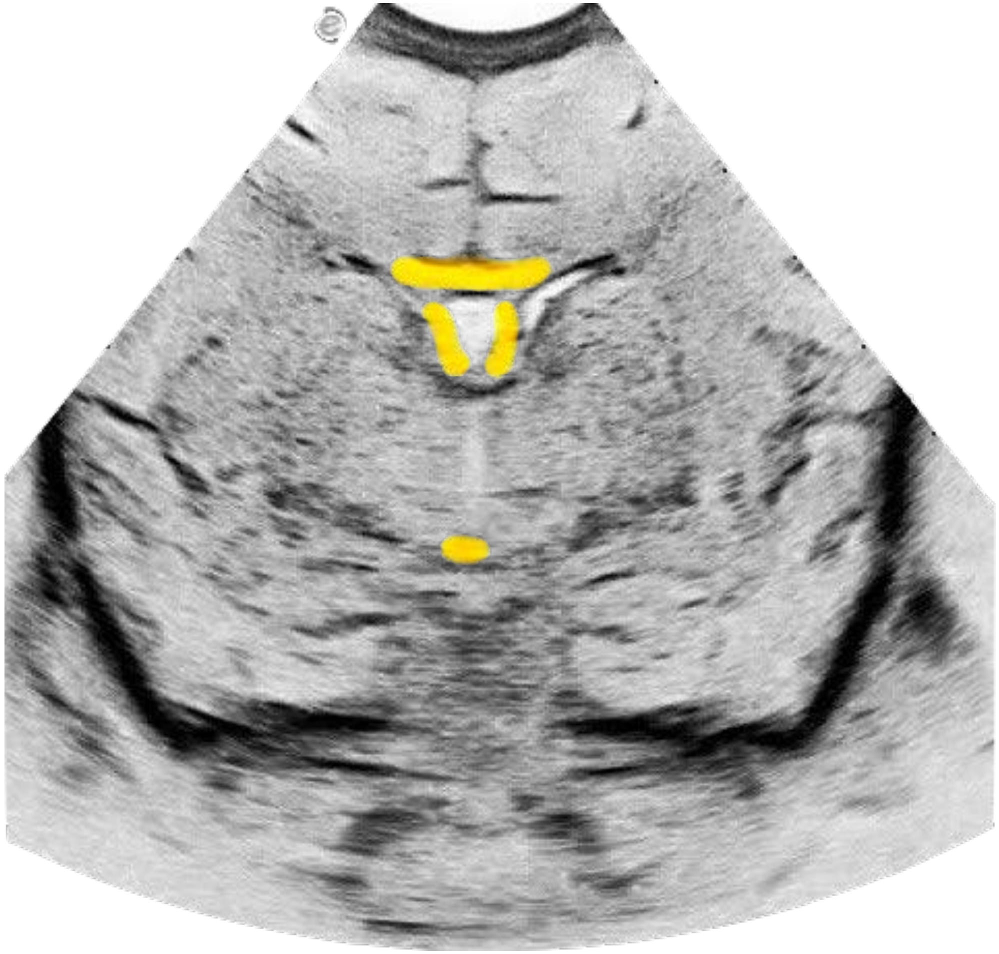


MIDLINE

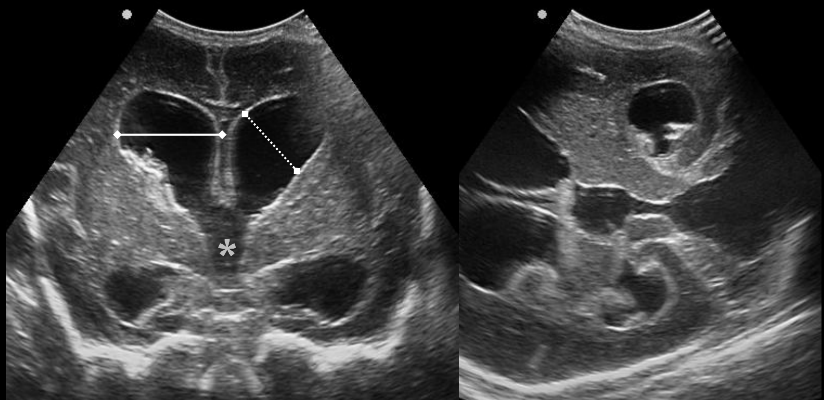
callosal agenesis

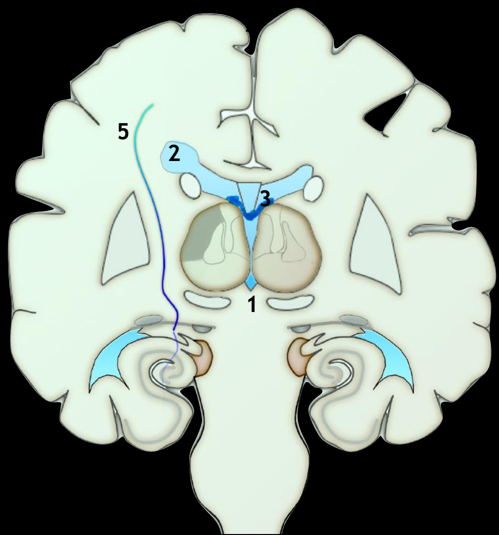


callosal lipoma



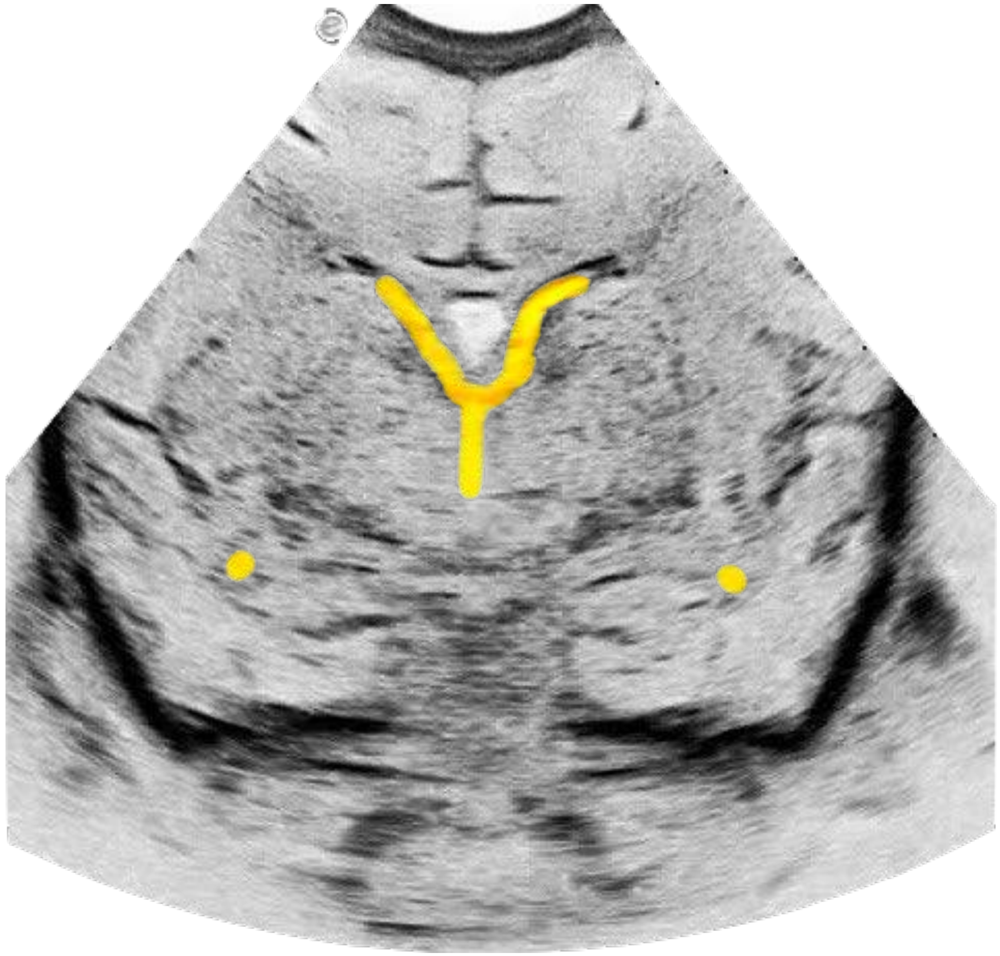
MIDLINE



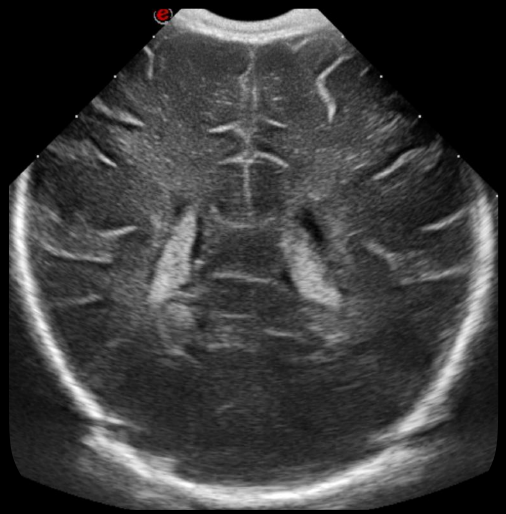


mechanisms behind ventricular dilatation

1 intraventricular obstruction
2 ex vacuo
3 overproduction
4 disturbed resorption
5 abnormal glymphatic drainage

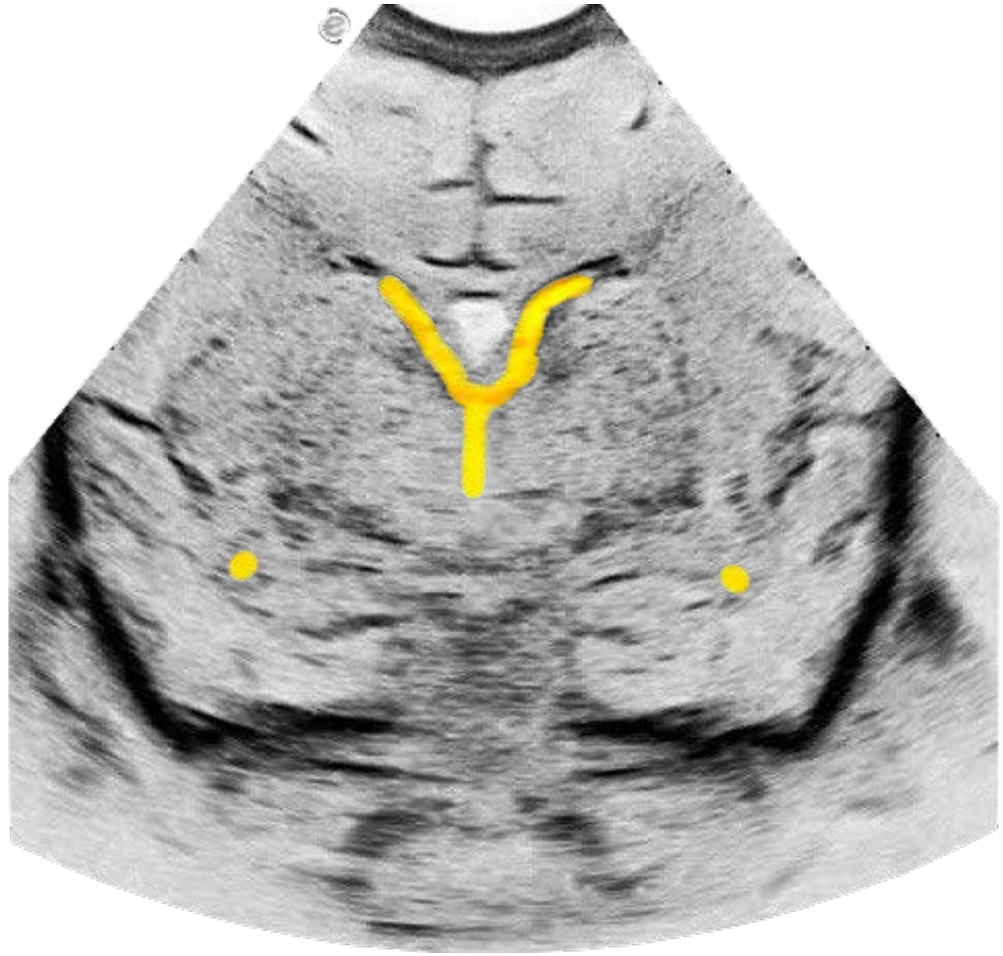


VENTRICLES AND PLEXUS

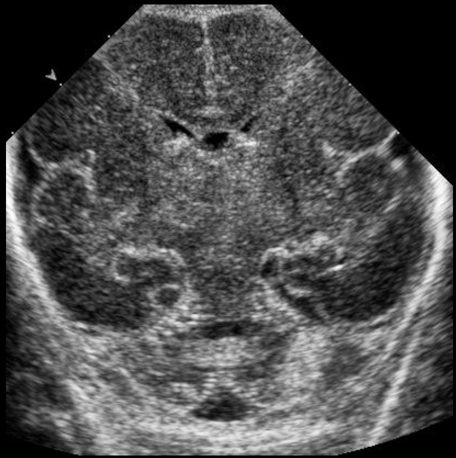


plexus haemorrhage

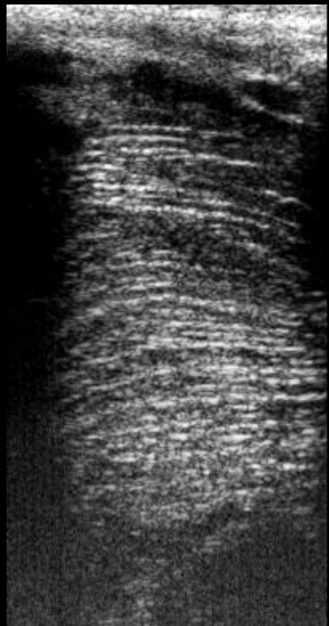
plexus hypertrophy

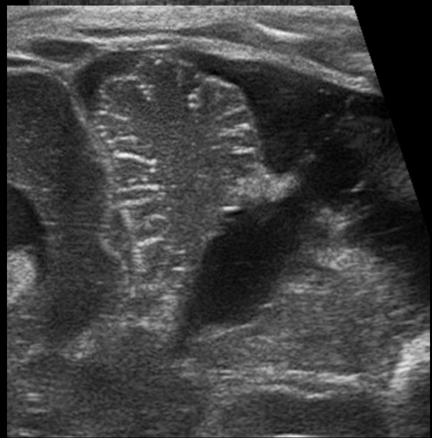


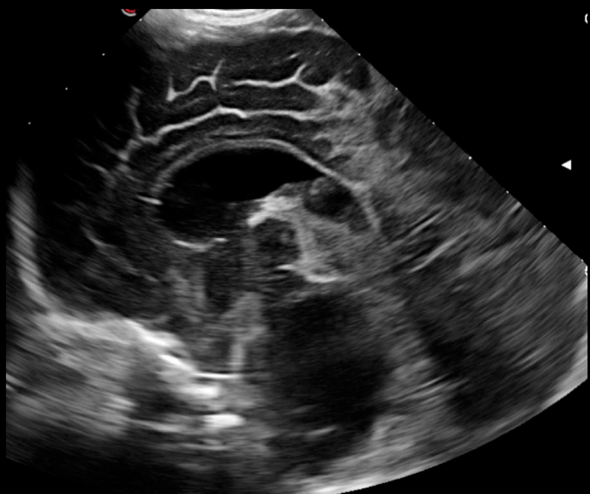
VENTRICLES AND PLEXUS



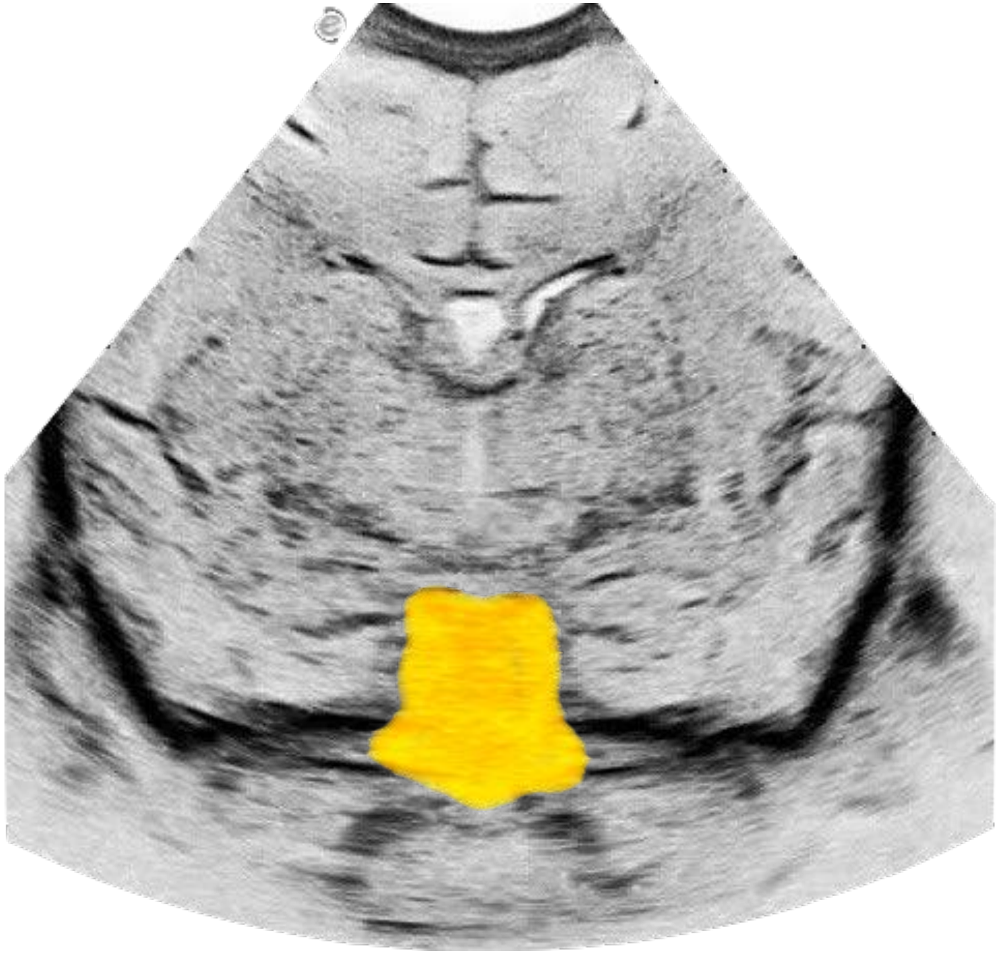
cerebellar haematoma





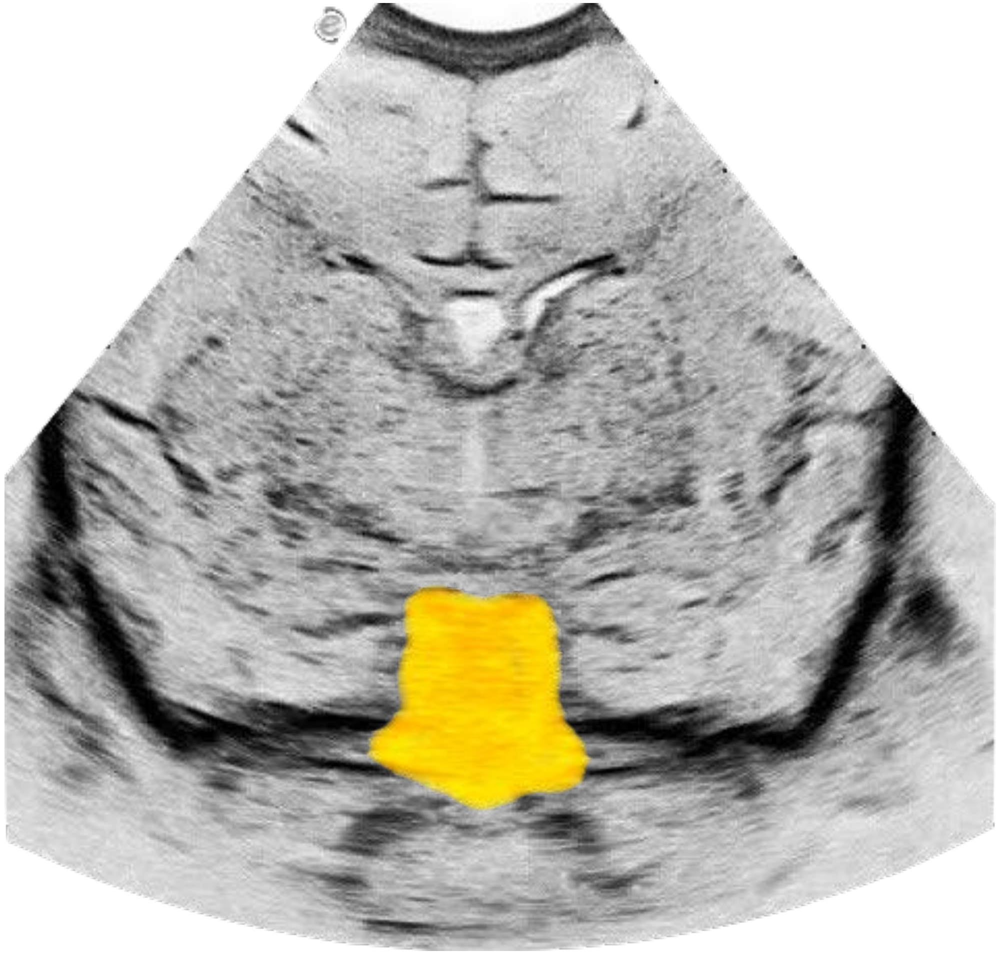


isolated fourth ventricle



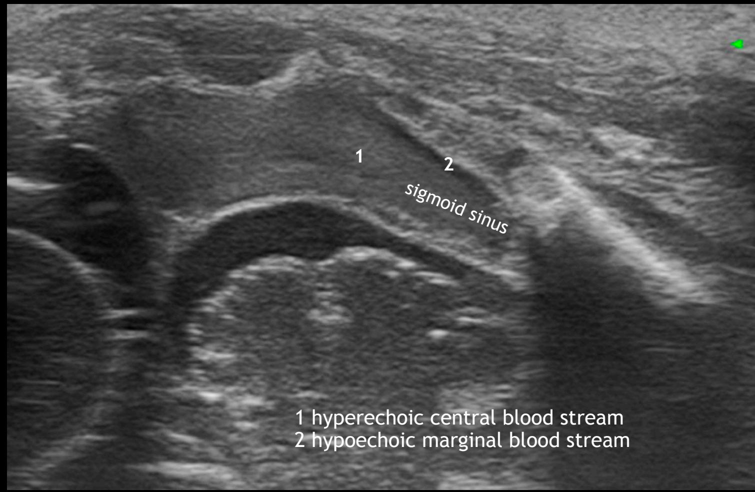
HINDBRAIN

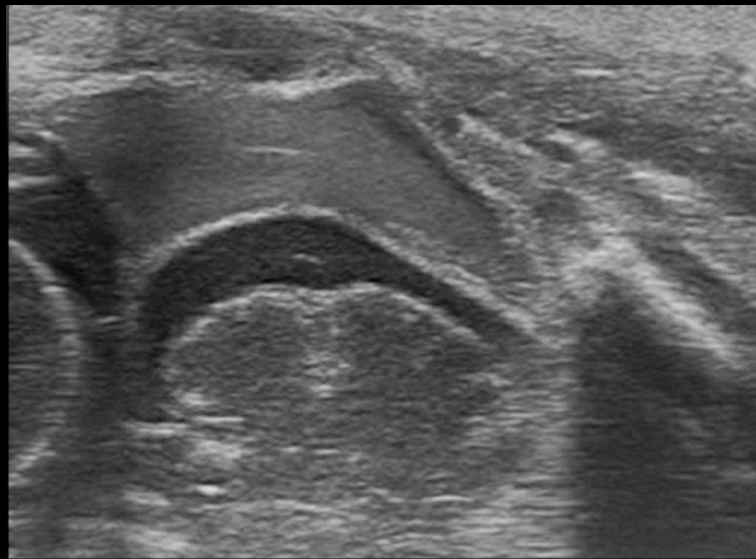
1 hyperechoic central blood stream
2 hypoechoic marginal blood stream



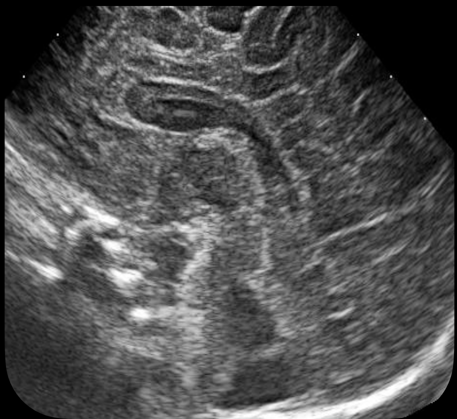
HINDBRAIN

mastoid section: early transverse sinus thrombosis (sludging)

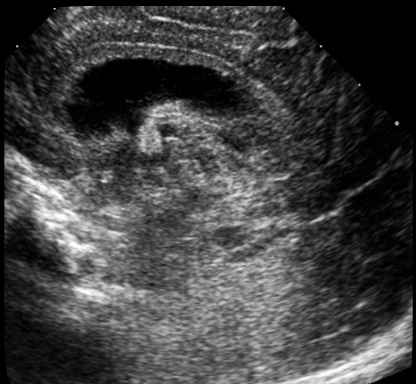




posthemorrhagic destruction of cerebellum in utero: large fourth ventricle and cisterna magna

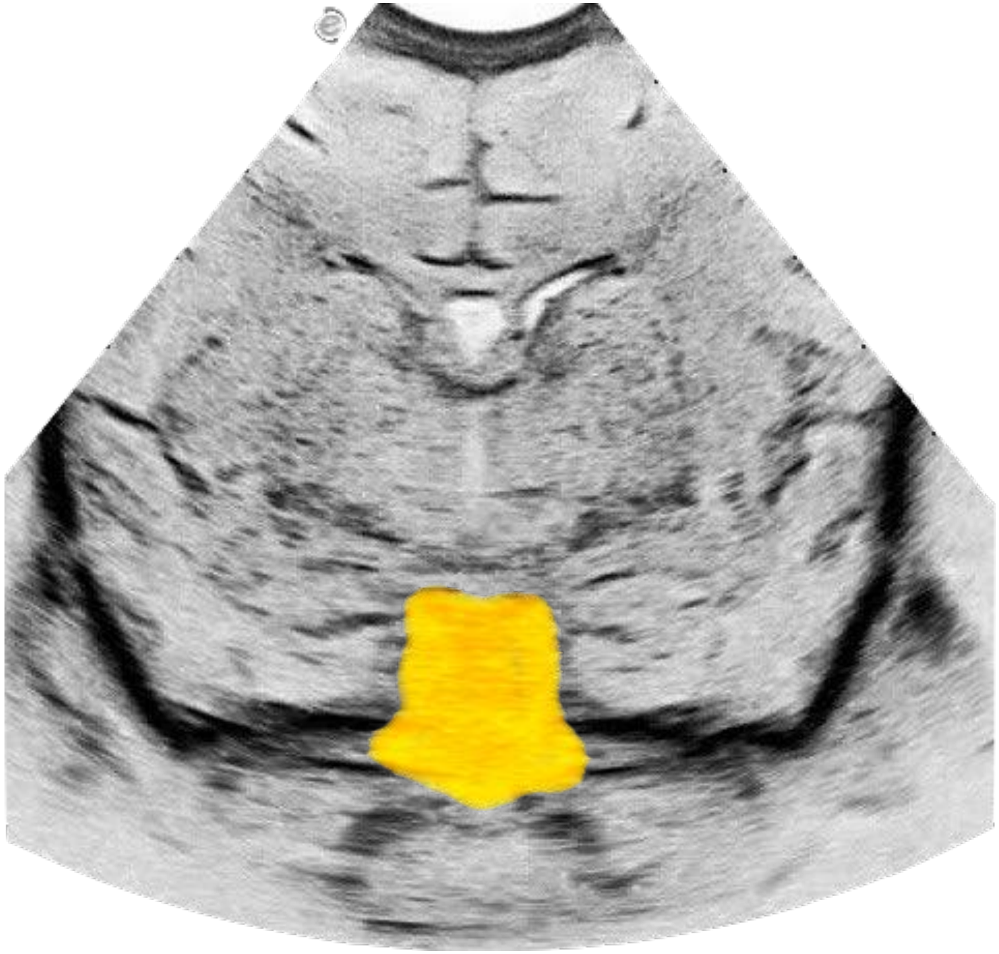


pontocerebellar hypoplasia: small vermis and large cisterna magna



central tentorial tear with subdural bleeding: obscure vermis margins and closed cisterna magna; foruth ventricle absent

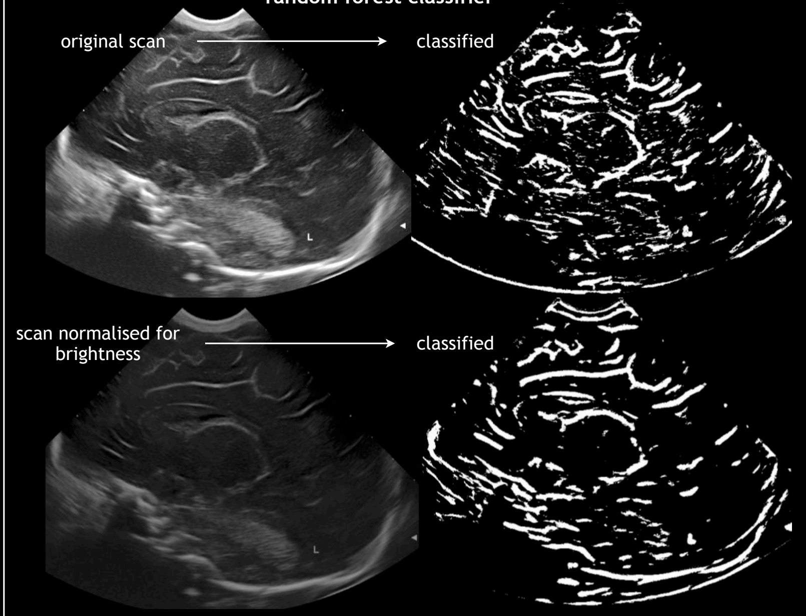
intracerebellar haematoma: elevated sharp superior margin and closed cisterna magna; foruth ventricle absent



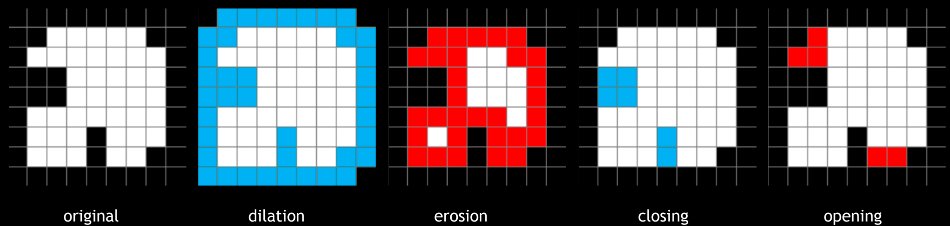
HINDBRAIN

automatic analysis of cerebral sulci in ultrasound images

random forest classifier

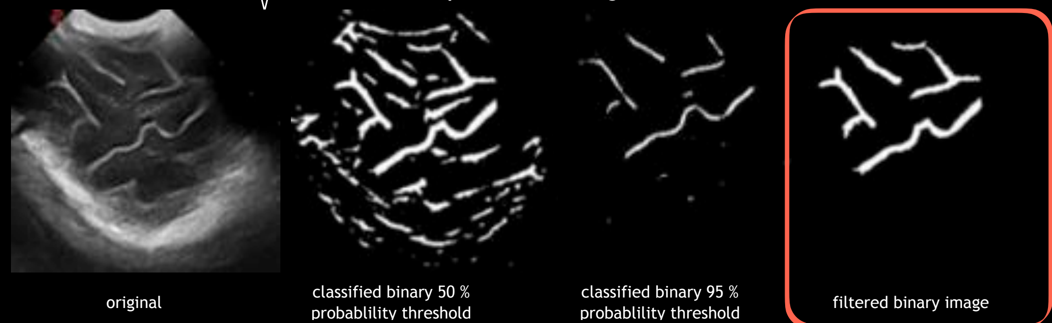


morphological operations to reduce noise



foreground pixels white, background pixels black; blue new foreground, red deleted foreground pixels

importance filtering

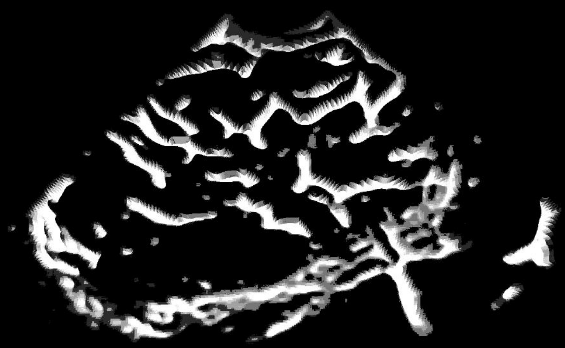


region properties

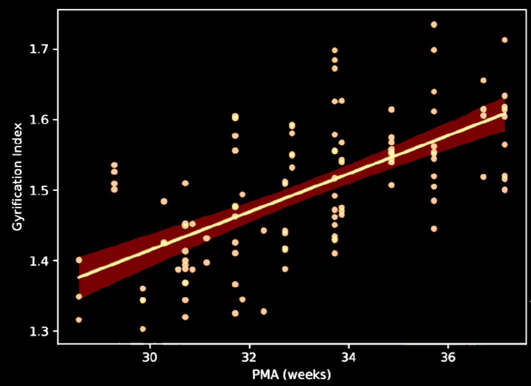
skeletonisation

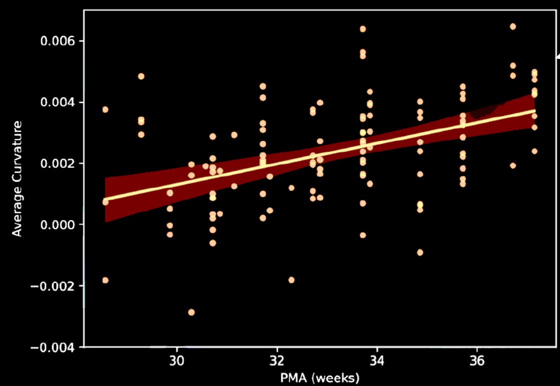
curvature

3D rendering based on random forest classifier with estimation of surface area to visualise sulcus depth



results for correlation of GI and AC in parasagittal image through frontal sulci





degree of correlation

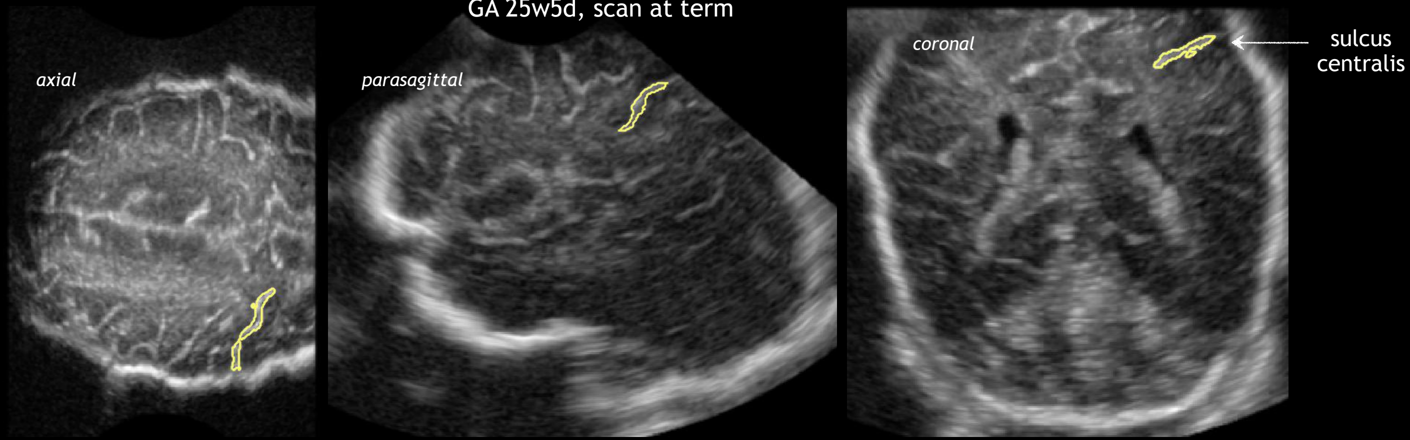
	GI (%)	AC (%)
Both planes	41.6	24.7
Parasagittal plane	64.3	45.6
Midsagittal plane	9.5	19.7

	correlation with PMA in %
Gyrification Index	45.0
Branch Count (intersection to endpoint)	30.4
Average Curvature (3D)	28.8
Solidity	-28.8
Mean Curvature of Skeleton	28.7
Max Local Contrast	27.8
Mean EDT	-27.7
Mean Branch Distance	-26.0
Mean Curvature of Contour	25.0
Max Branch Distance (isolated branch)	-24.8

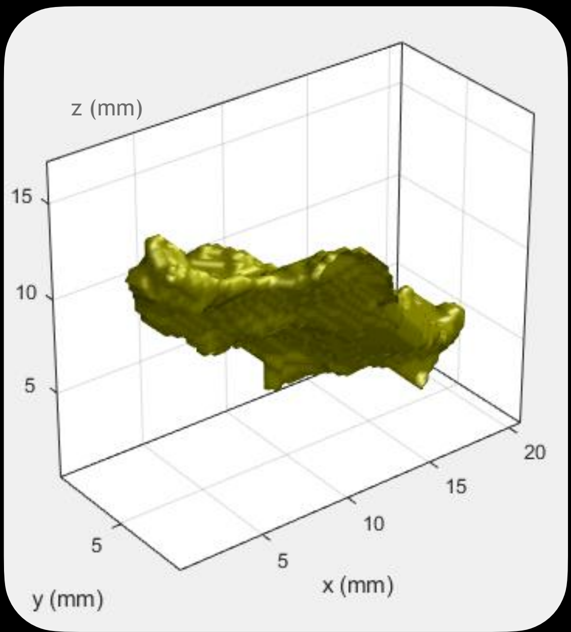
thesis Ghent University, De Mulder S 2022

3D visualisation of the sulcus centralis

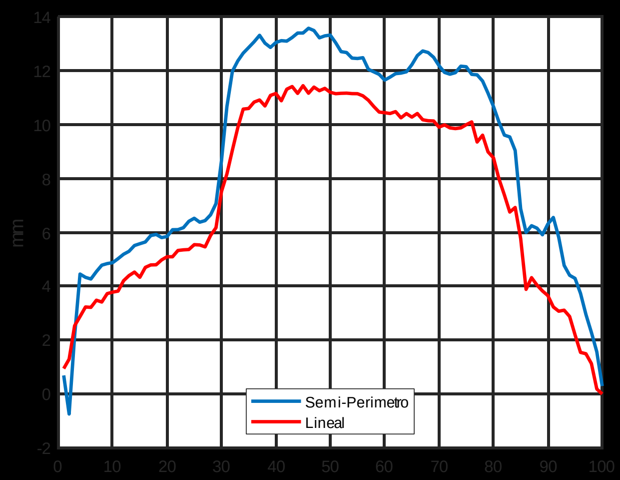
GA 25w5d, scan at term



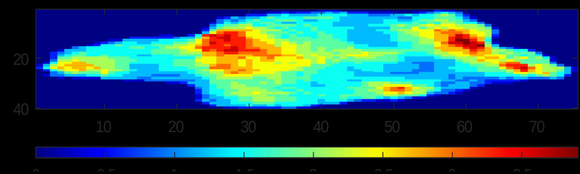
- volume acquisition : 4D option in the 3D/4D Voluson ultrasound system (GE Healthcare)
- transducer situated in the third coronal plane, beam moving from anterior to posterior planes using a center frequency of 6.5 MHz with a scan angle set at 90°
- analysis performed off-line: developed in Matlab (UCA academic license, version R2021a) department of computer engineering of the School of Engineering, University of Cádiz



some metrics of the segmented mesh:
tortuosity = 1,26
volume = 0,28 ml
surface area = 4,46 cm2

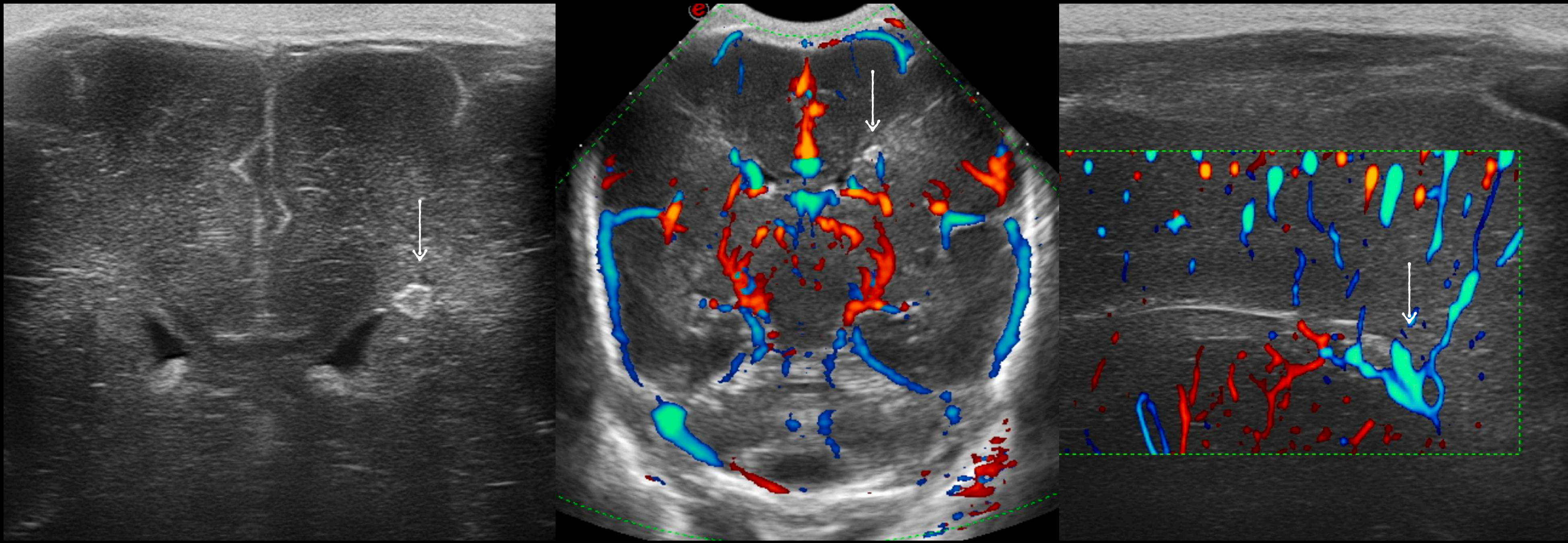


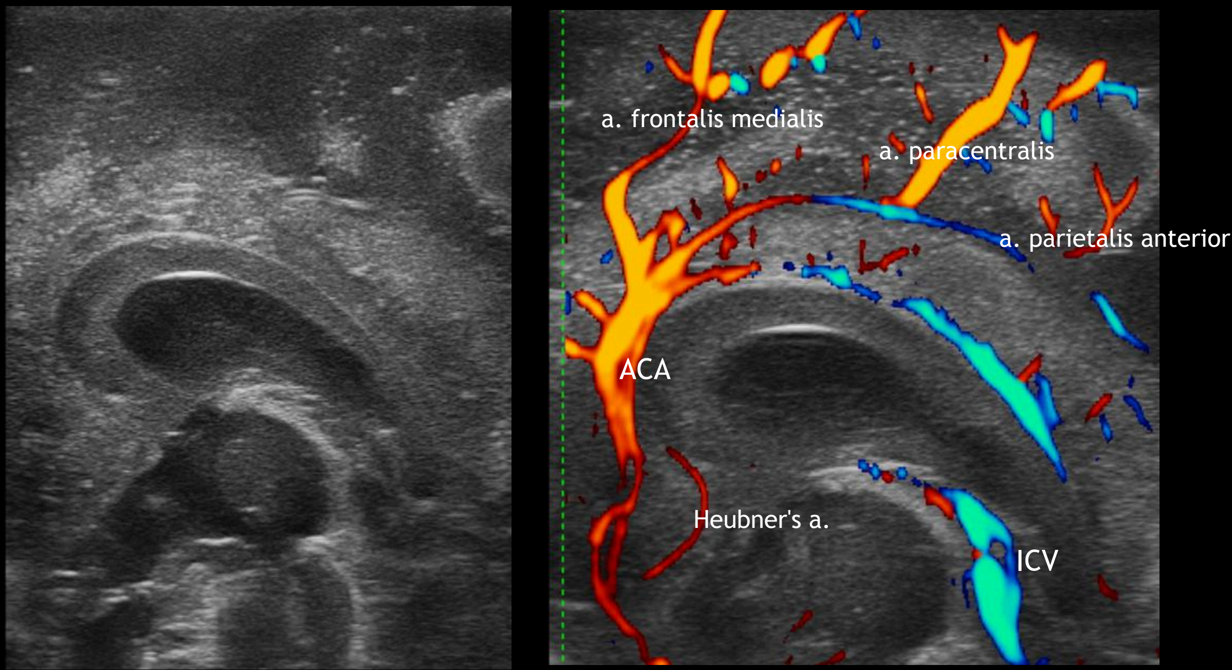
depth of sulcus centralis



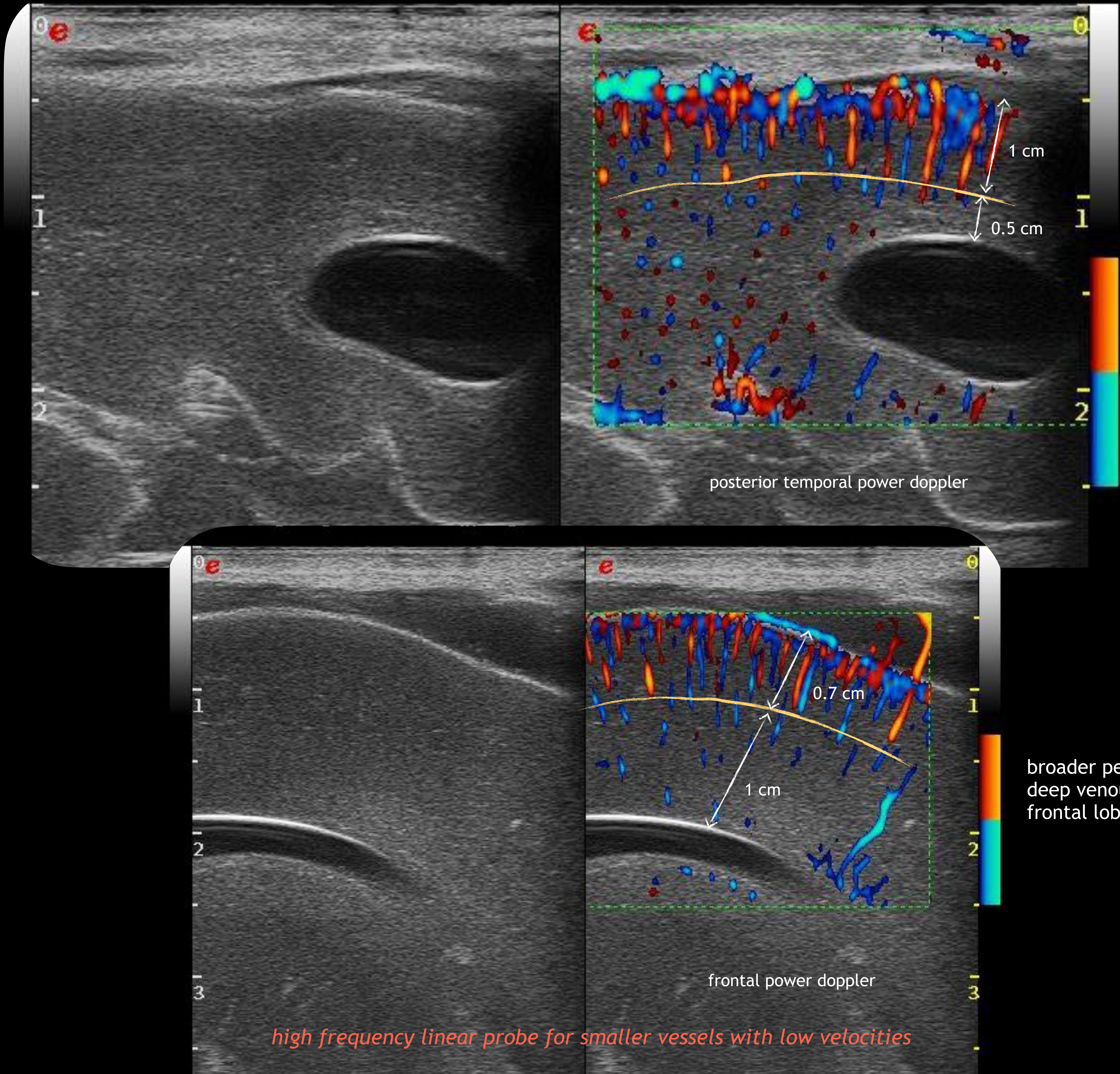
width of sulcus centralis

courtesy Isabel Benavente Fernandez, Cadiz, Spain





combining different frequency probes to visualise vessels around a lesion



broader periventricular deep venous drainage in frontal lobe

high frequency linear probe for smaller vessels with low velocities