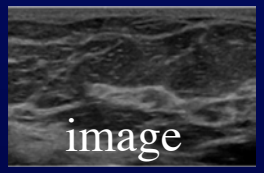
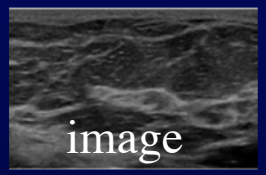
Ultrafast Imaging

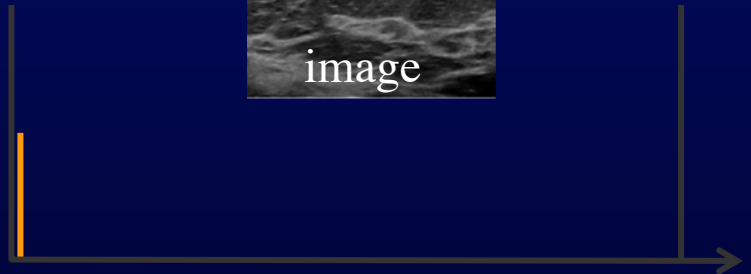
Conventional



256 transmits for one ultrasound image

Ultrafast Imaging



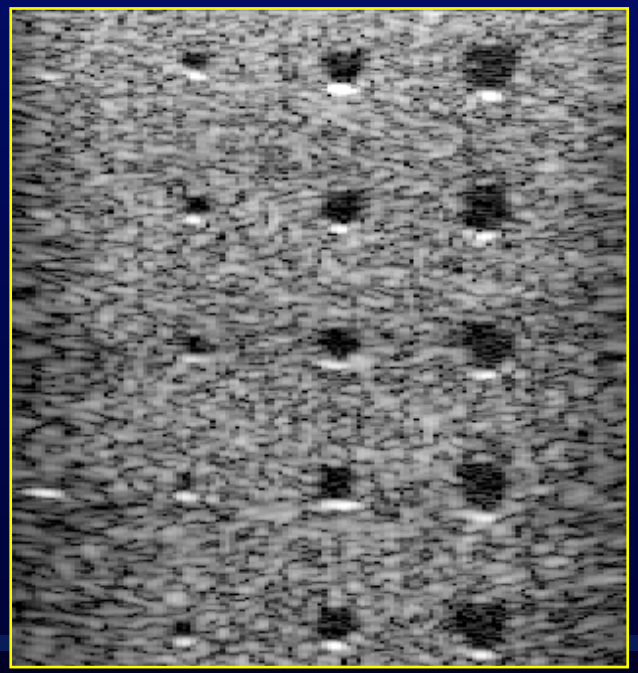


1 single transmit per image

Ultrafast Imaging

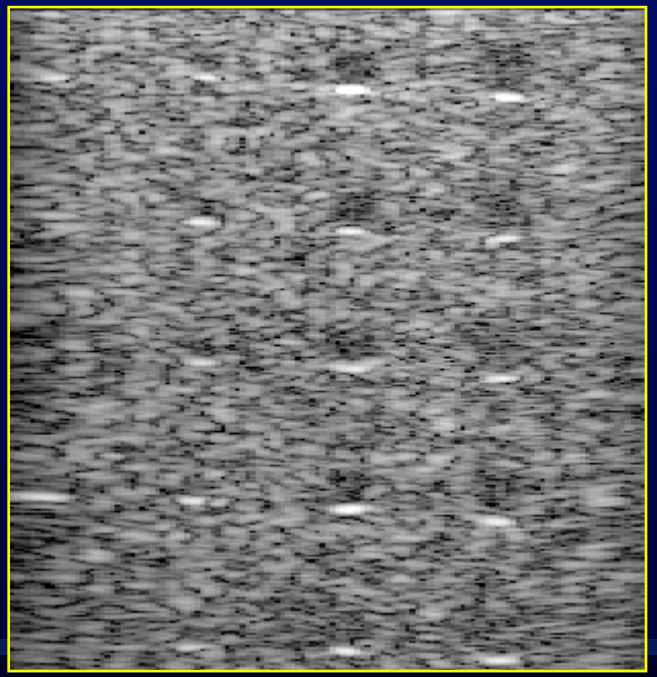
Conventional
4 focal depths
512 beams

25 fps



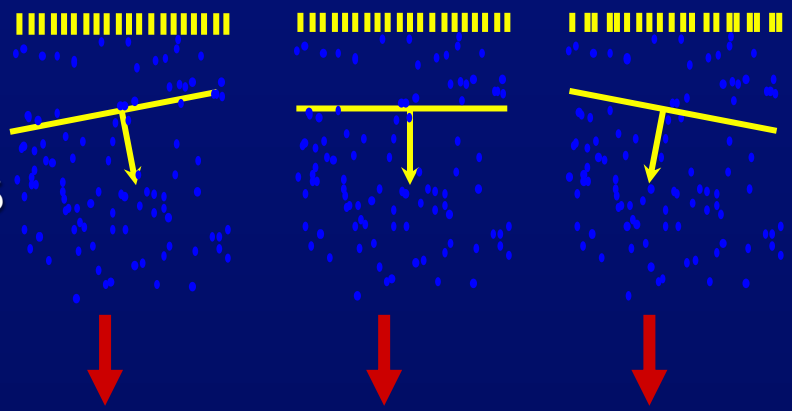
Ultrafast Imaging
One single unfocused
plane wave

18 000 F/s

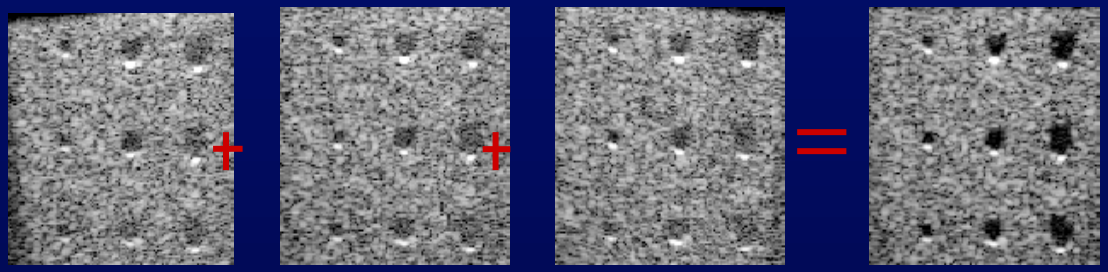


Ultrafast Imaging with coherent plane wave compounding

Illumination with a set of
Plane Waves
with DIFFERENT ANGLES



Each plane wave gets
a LOW QUALITY IMAGE



The coherent addition generates a
HIGHER QUALITY IMAGE

Coherent plane-wave compounding for very high frame rate ultrasonography and transient Elastography. G. Montaldo et coll. IEEE Trans. On Ultr. Ferr. Freq. Ctrl, March 2009

A Trade-off between Frame Rate and Image Quality

Conventional
4 focal depths

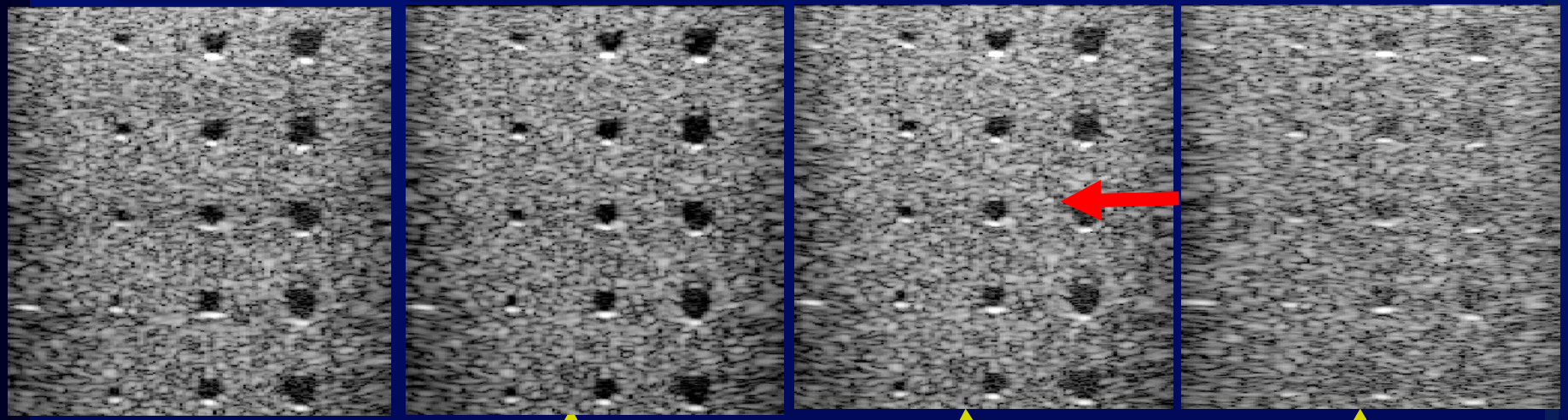
Ultrafast Compound

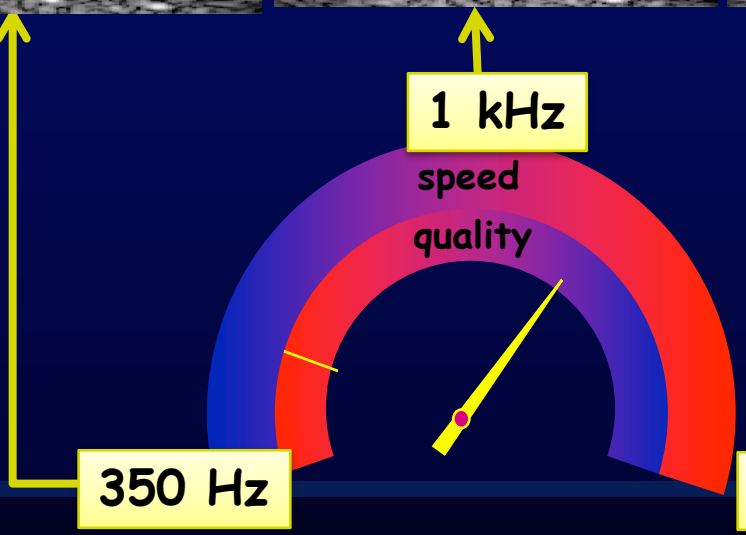
25 fps

40 angles 350 fps

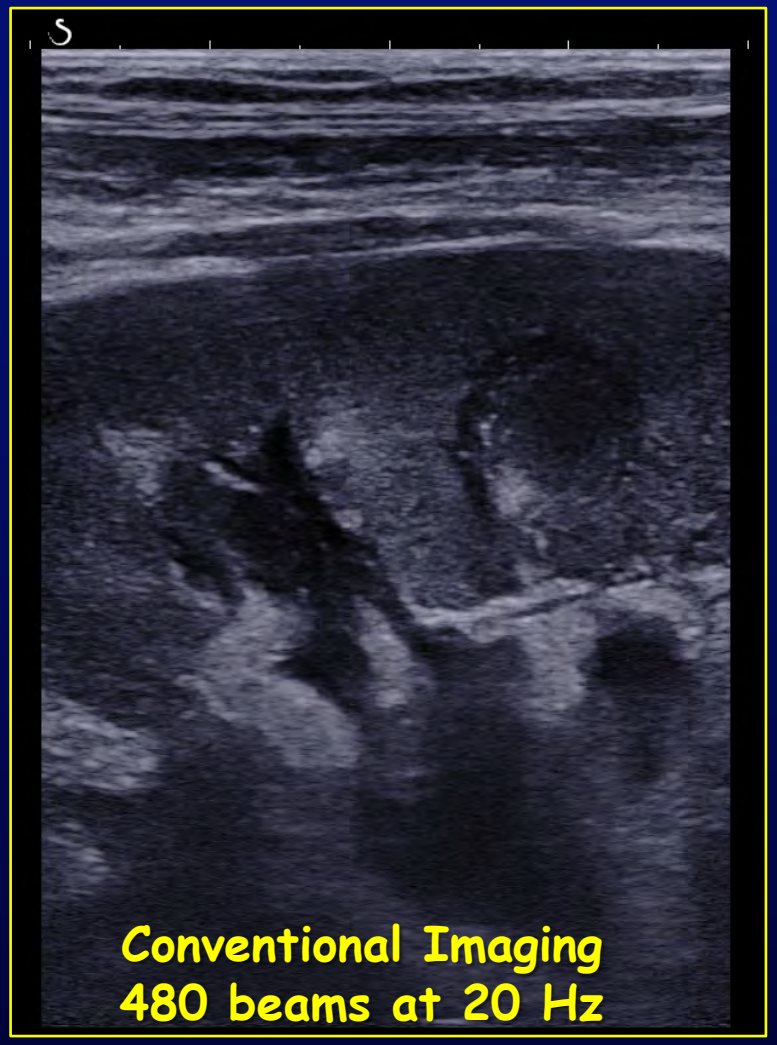
17 angles 1000 fps

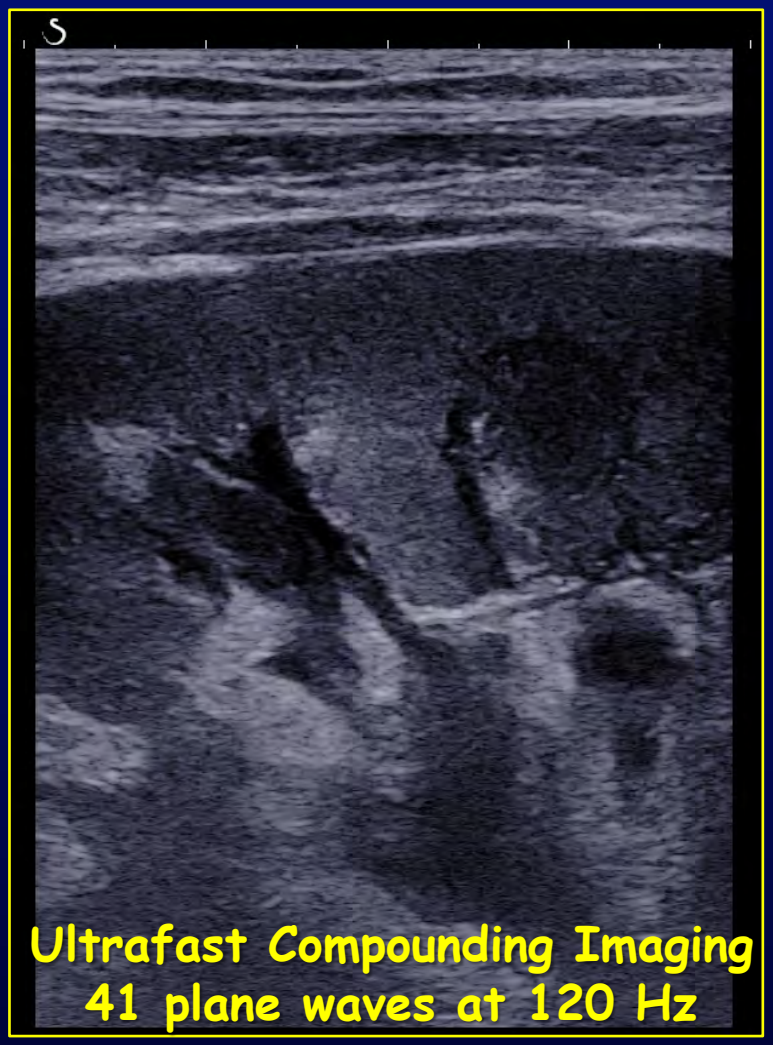
1 angle 18000 fps





A Trade-off between Frame Rate and Image Quality

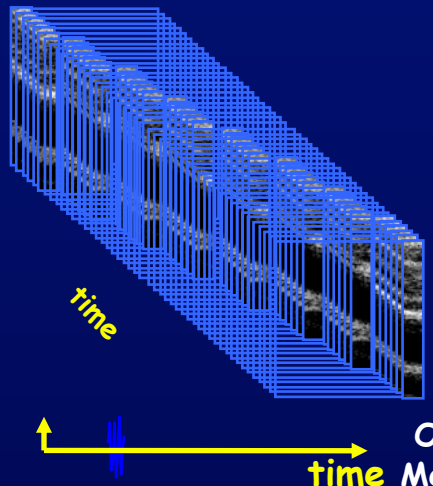




Micro-Doppler US techniques

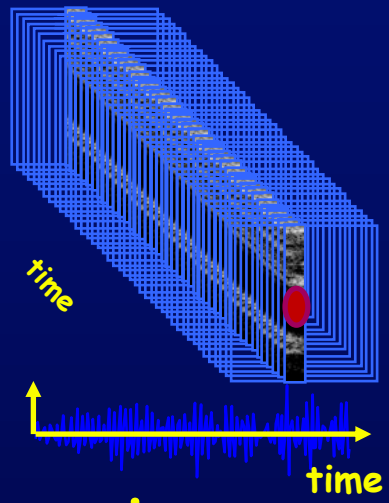
Conventional vs Ultrafast Doppler

Conventional CFI



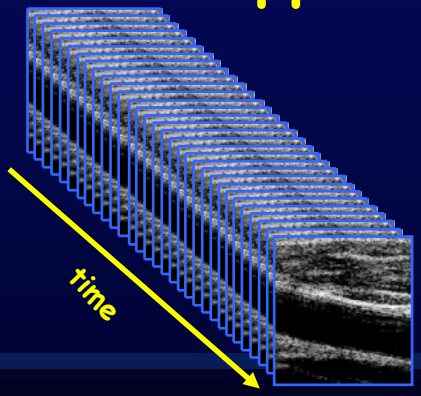
Only 10 points per pixel
Mean Velocity estimation

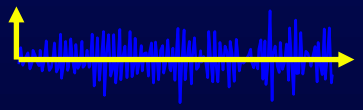
Conventional PW



50- 150 points per pixel at a given sample volume

Ultrafast Doppler





50- 150 points per pixel all over the image

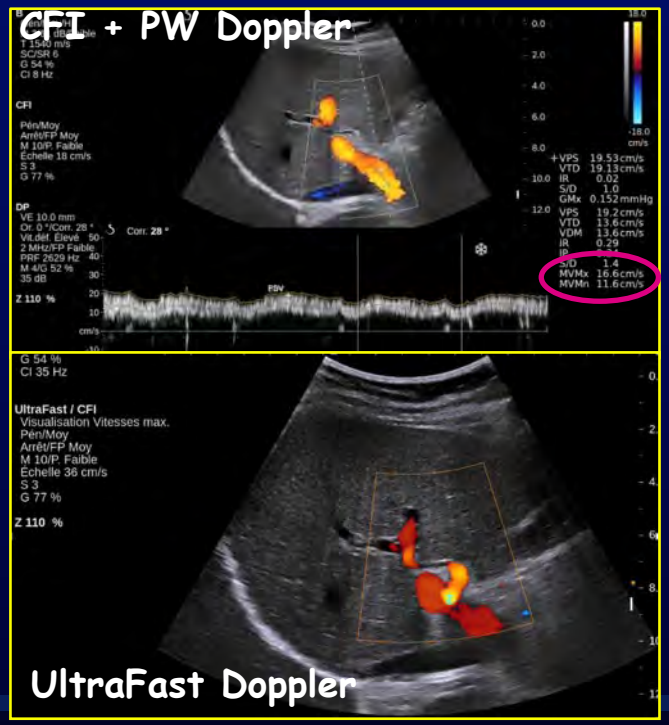
Ultrafast allows gathering of complete Doppler information for all pixels

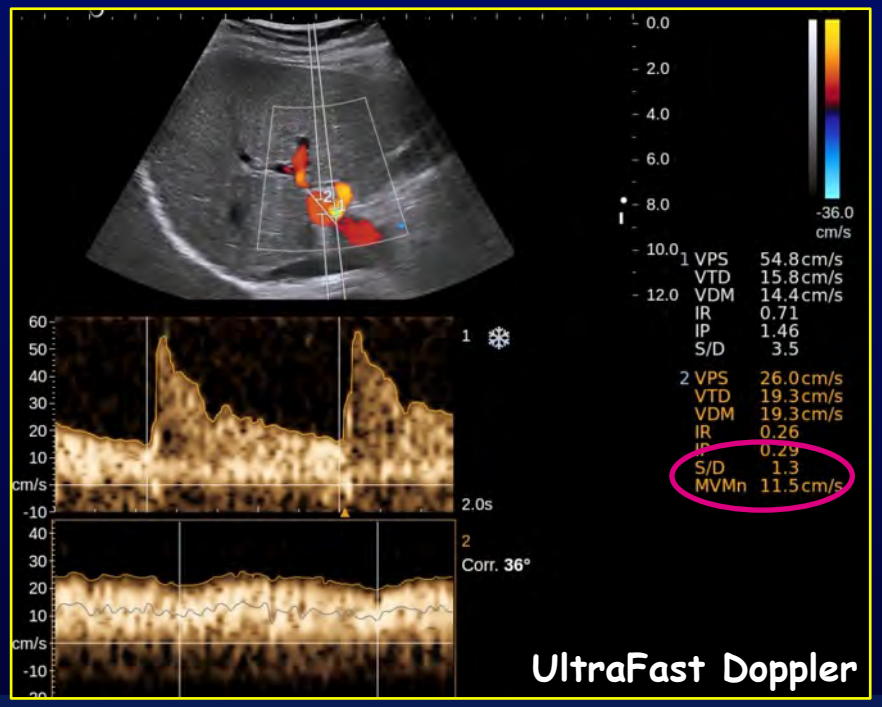
Courtesy Dr. Berkoff

Micro-Doppler US techniques

Ultrafast Doppler: clinical benefits

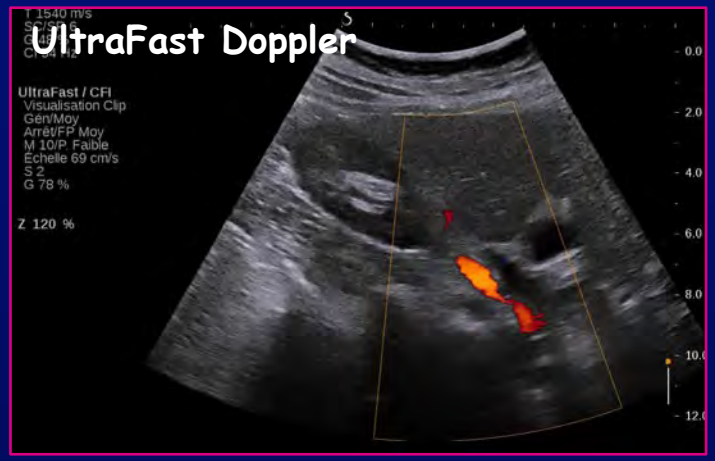
- Reduction of examination duration
- Improved diagnostic capability with additional vessels recorded
- Quantitative Spectral Doppler anywhere
- Save Ultrafast data=> further review new Doppler measurements

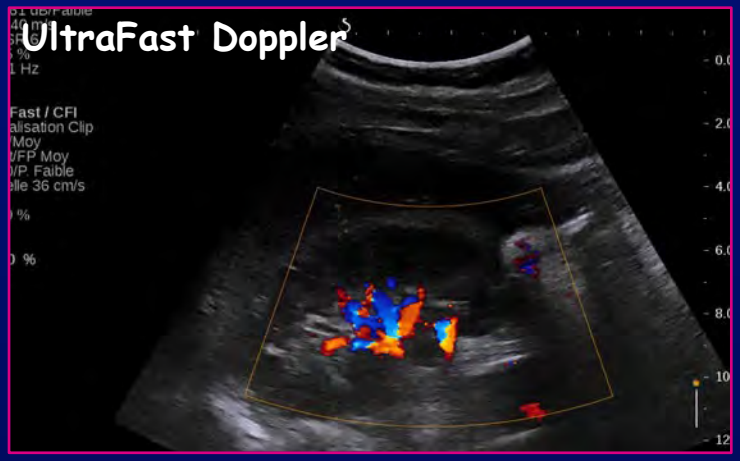


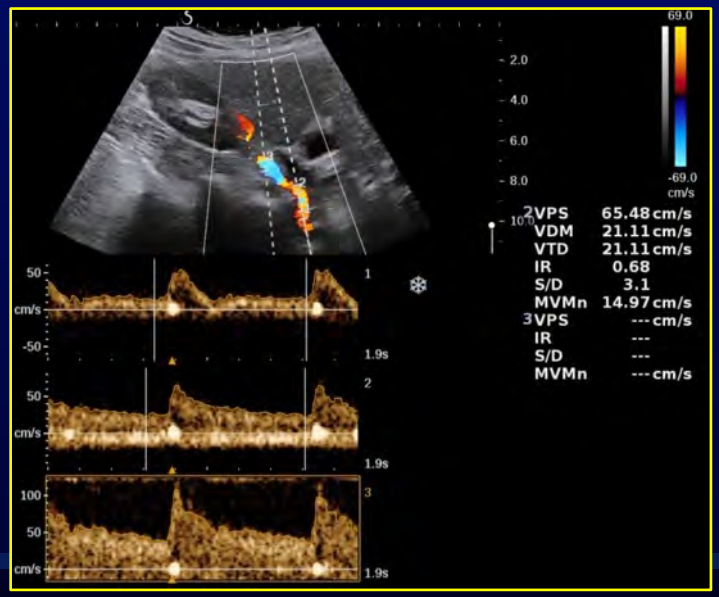


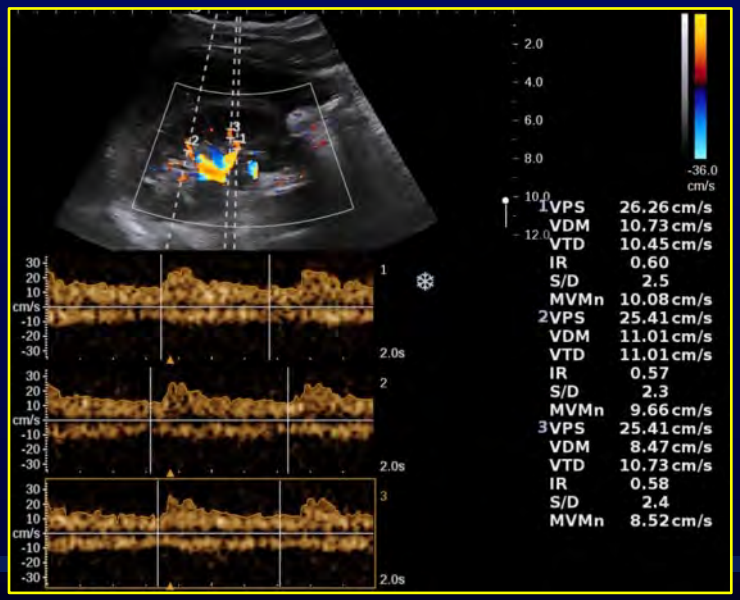
Micro-Doppler US techniques

Ultrafast Doppler: clinical benefits





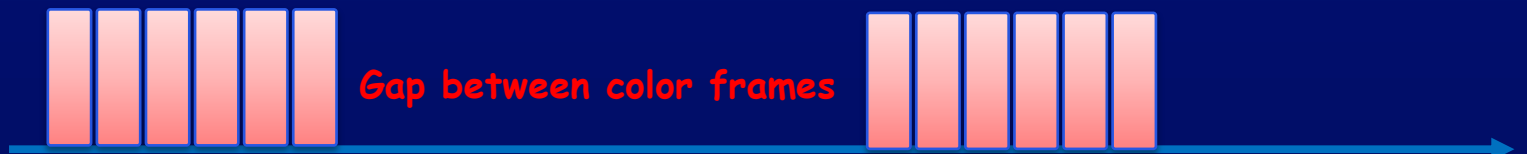




Micro-Doppler US techniques

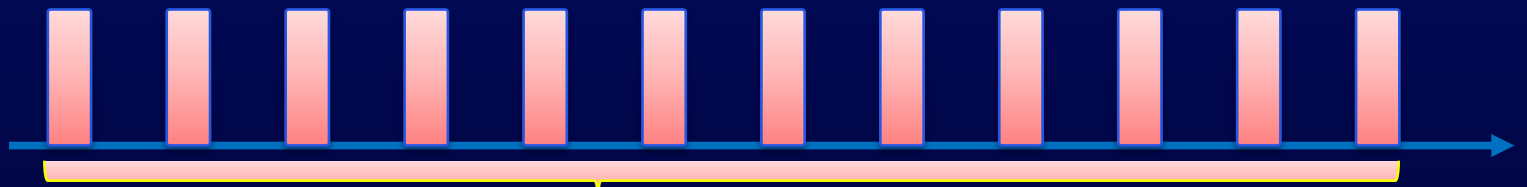
Conventional vs UltraSensitive Doppler

Conventional Color and Ultrafast:



- Ensemble Length small
- Imposed by sequence structure
- No overlap possible

Ultrasensitive sequence:

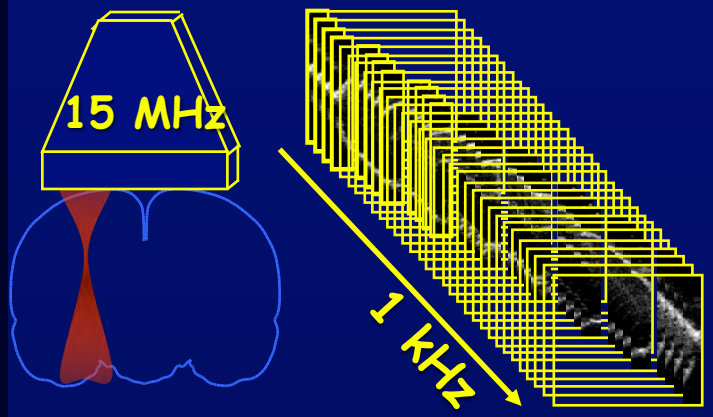


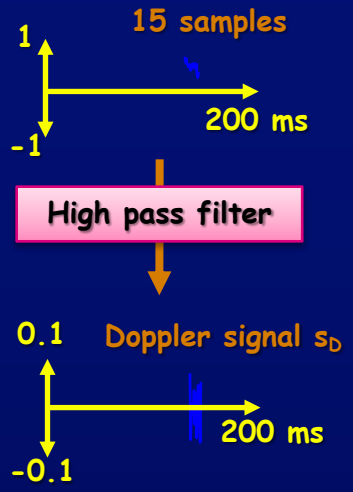
- Ensemble Length as large as wanted
- Settable
- Overlap between Ensemble Length

Courtesy SuperSonic Imagine

The concept of μDoppler based on Ultrafast Imaging

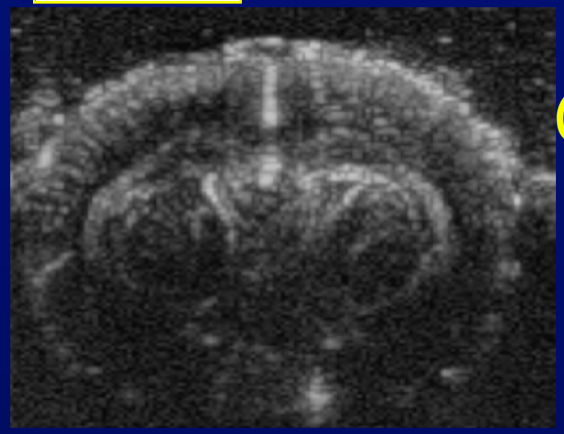
Conventional Doppler



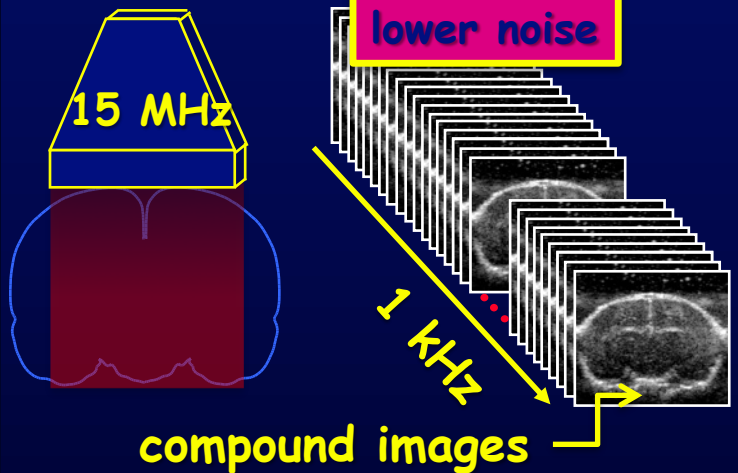


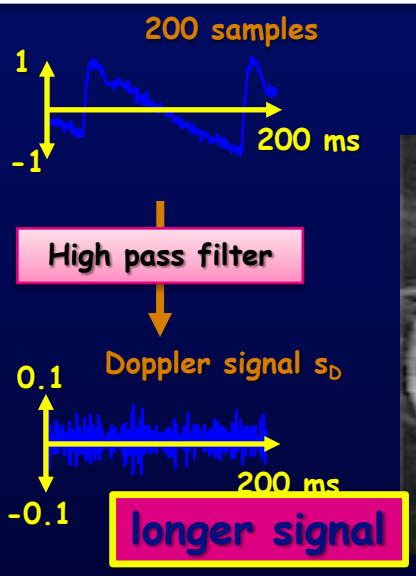
$$I = \int s_D^2(t)\, dt$$

Power Doppler



μDoppler





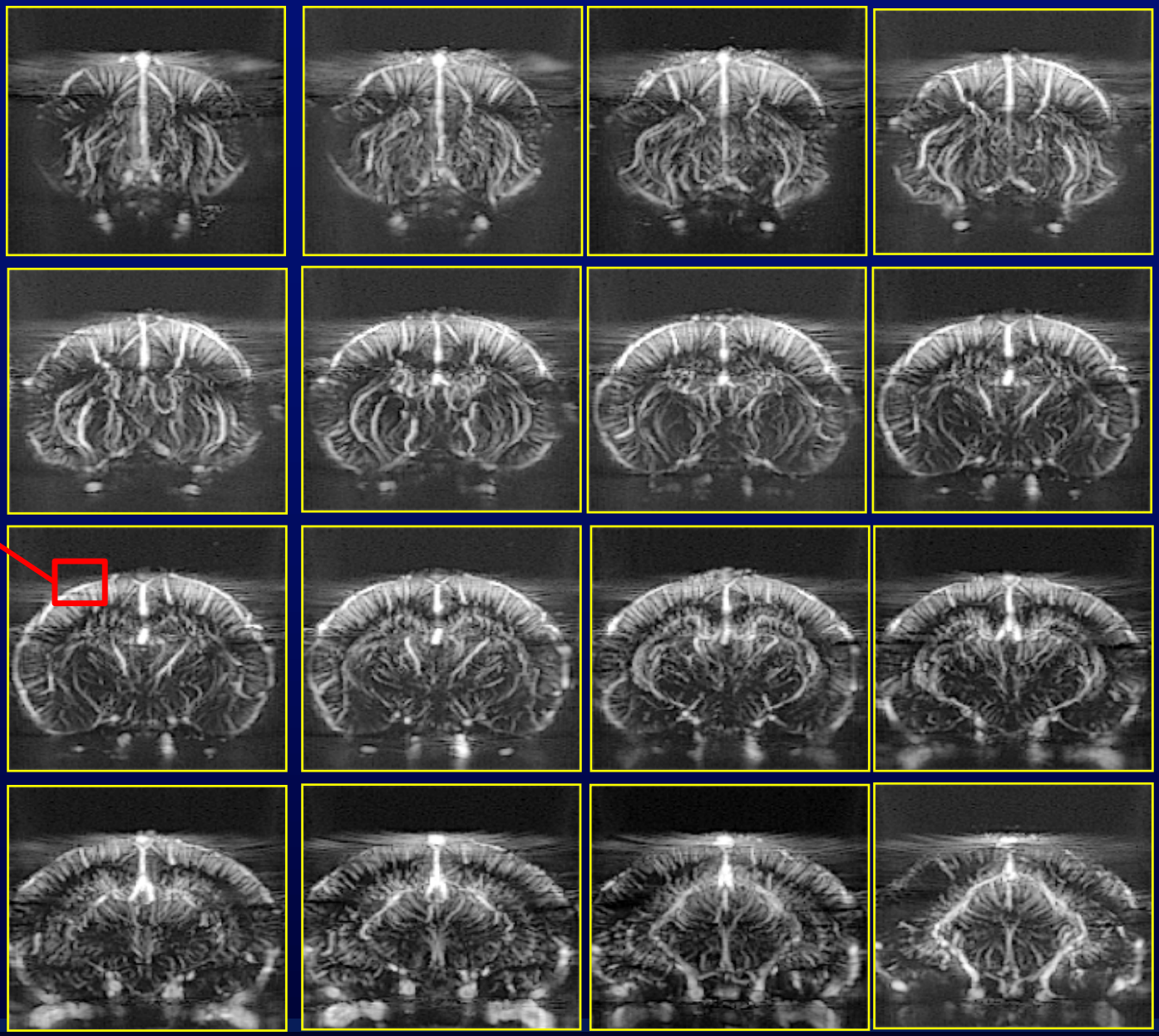
$$I = \int s_D^2(t)\, dt$$

Power Doppler

E. Macé et coll. Functional Ultrasonic Imaging of Brain Activity, *Nature Methods*, July 2011

3D Ultrafast Doppler scan of rat cerebral blood flow

Mesure des flux locaux



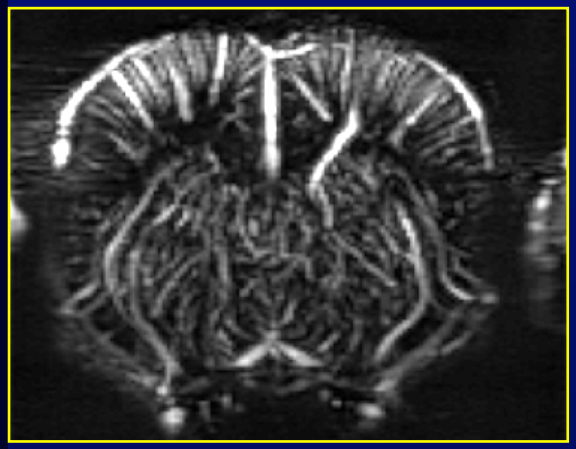
E. Macé
PhD Thesis

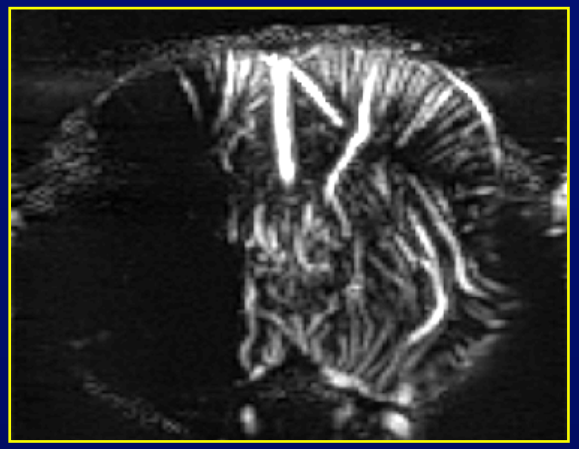
Monitoring rat brain vessel occlusion

before

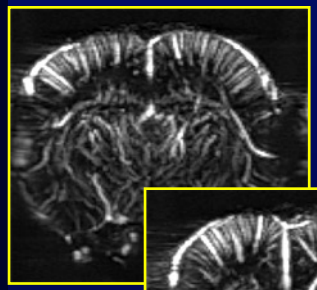
during

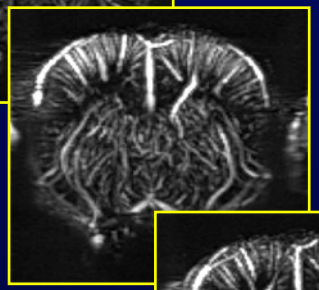
after

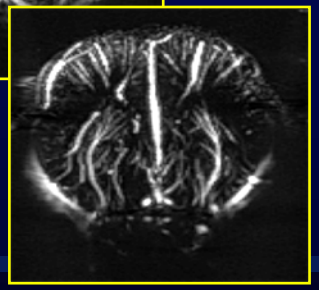


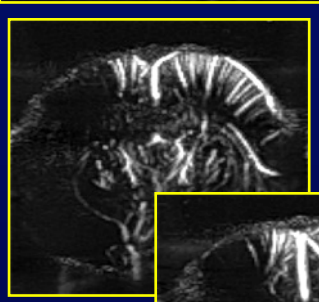


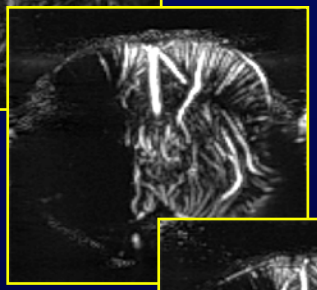
in 3D

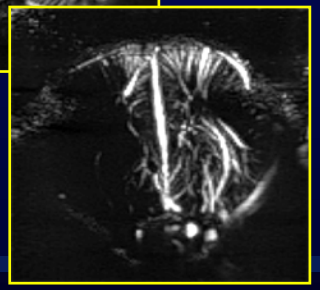


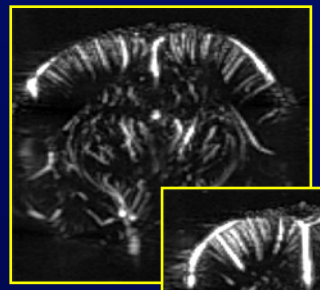


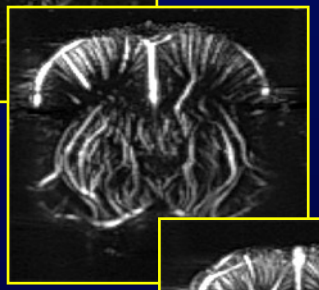


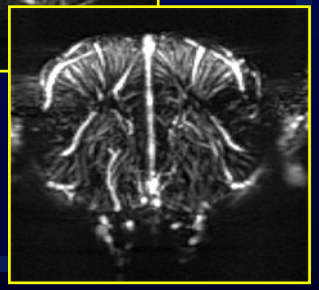






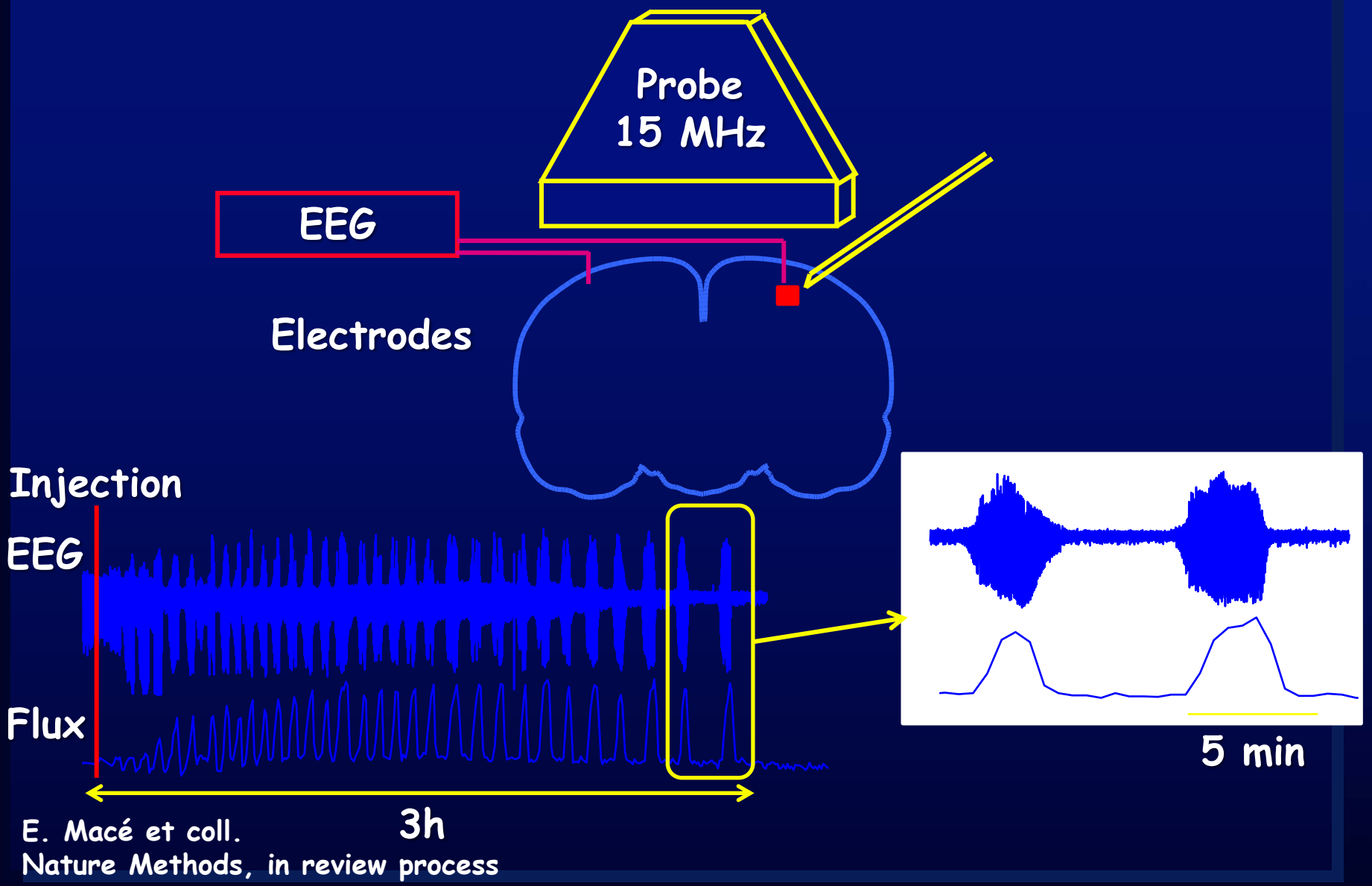






E. Macé
PhD Thesis

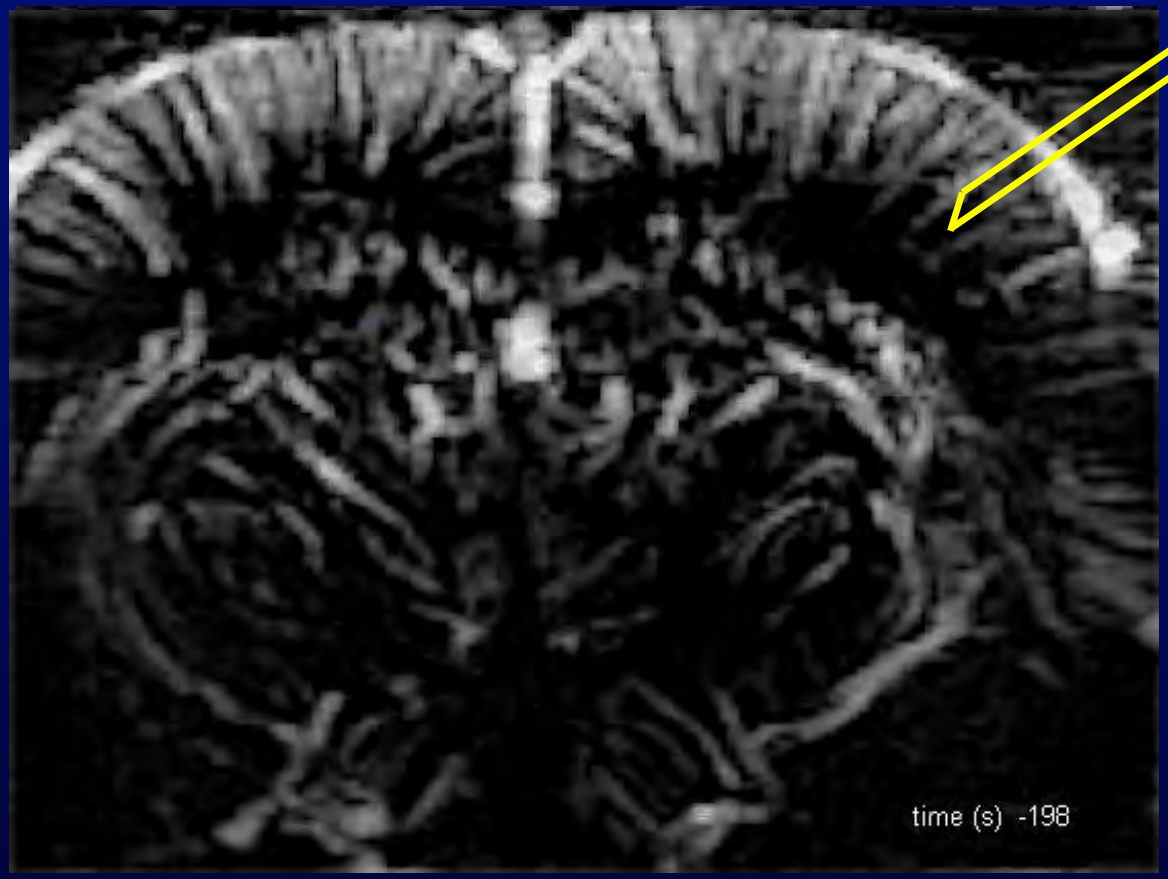
Ultrasensitive Functional Ultrasound imaging

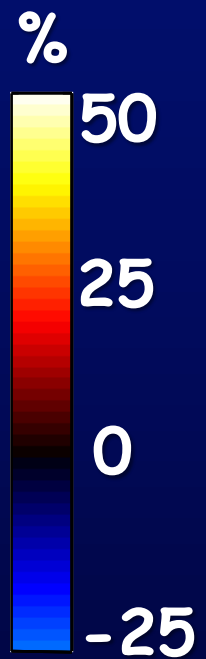


E. Macé et coll.
Nature Methods, in review process

Spatio-temporal dynamics of seizure

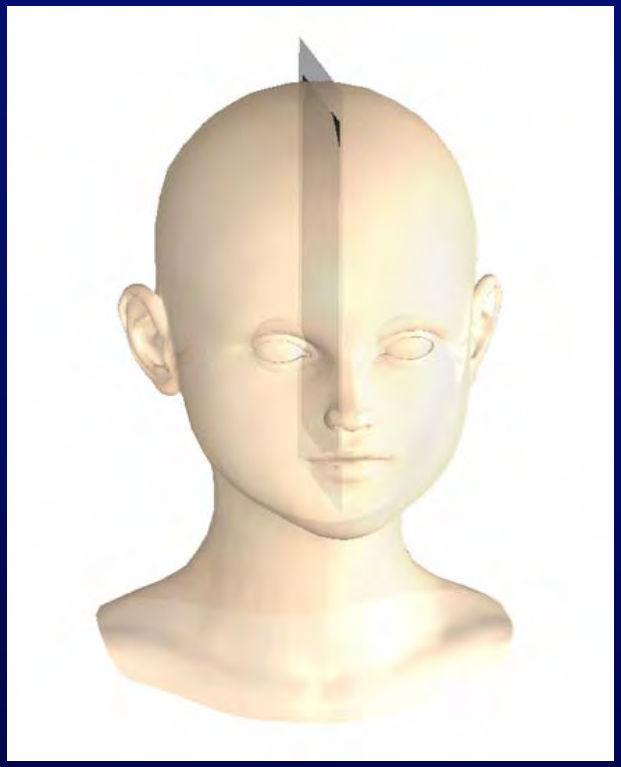
B-mode

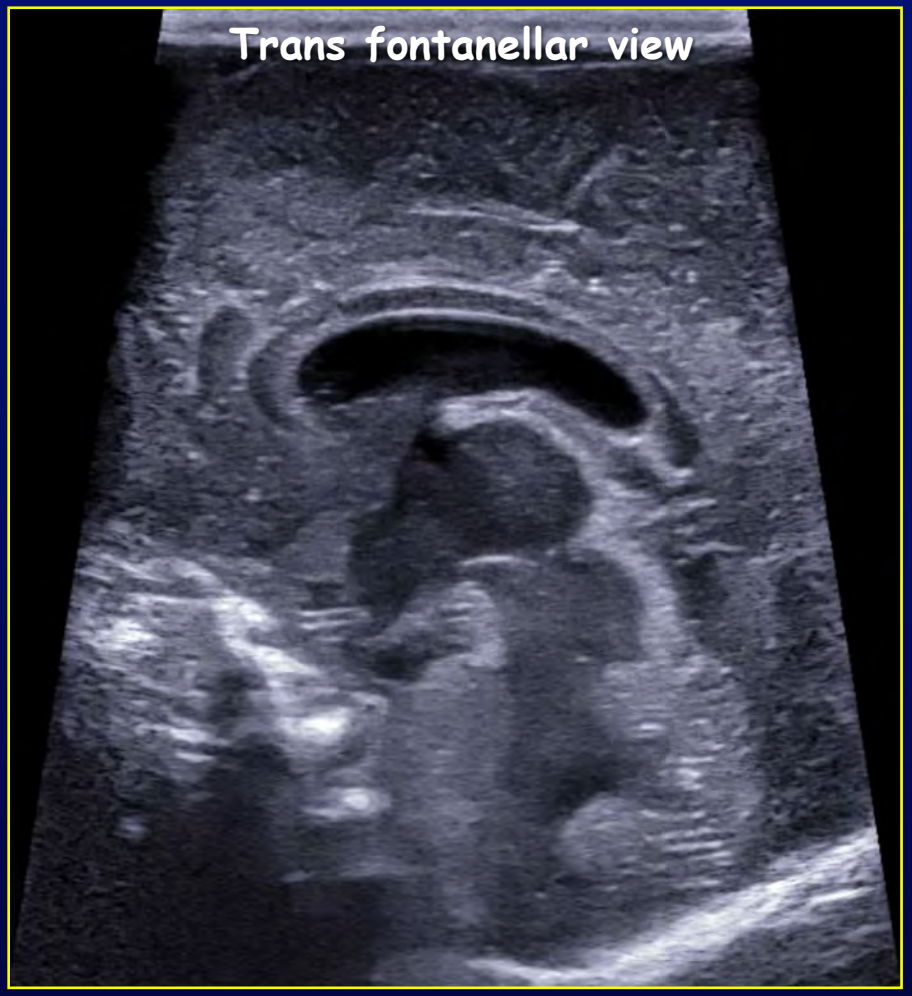




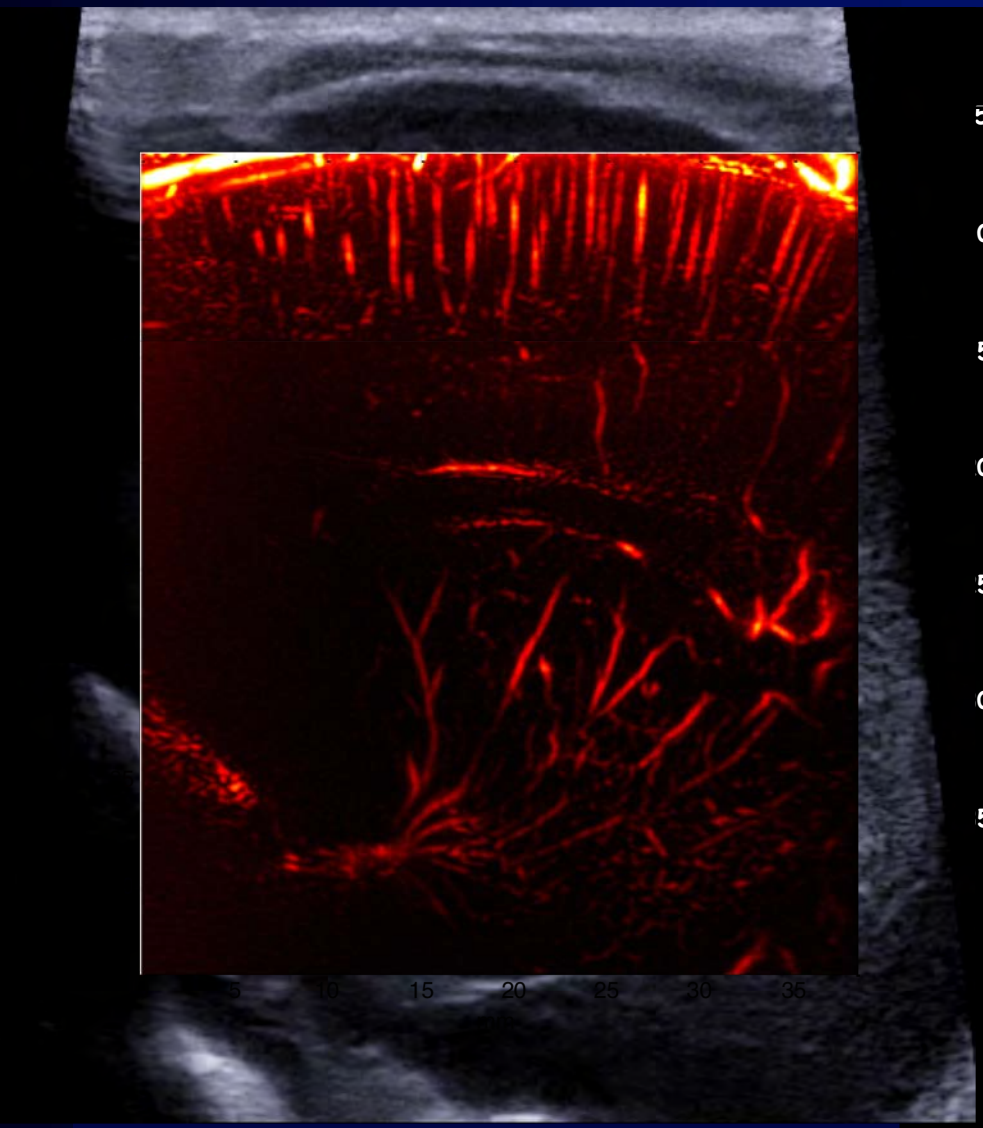
E. Macé et coll.
Nature Methods, in review process

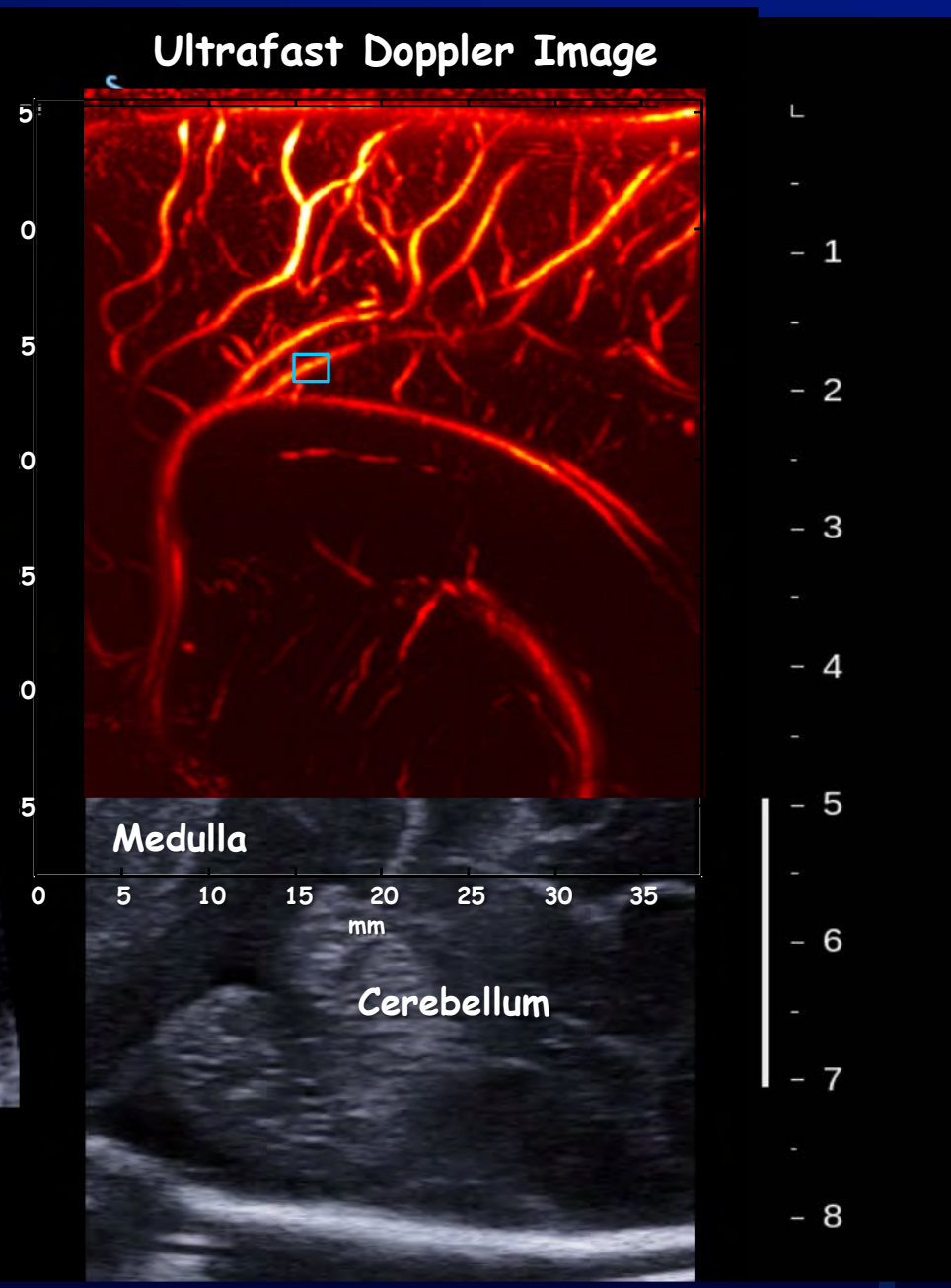
Towards clinical fonctional US on preterm infants



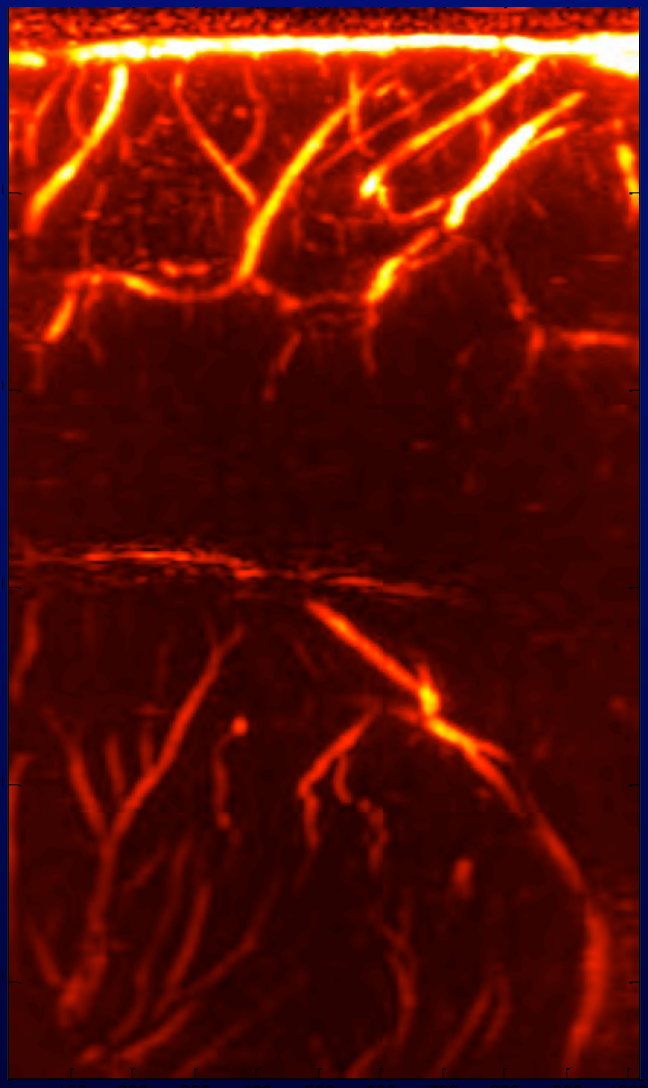


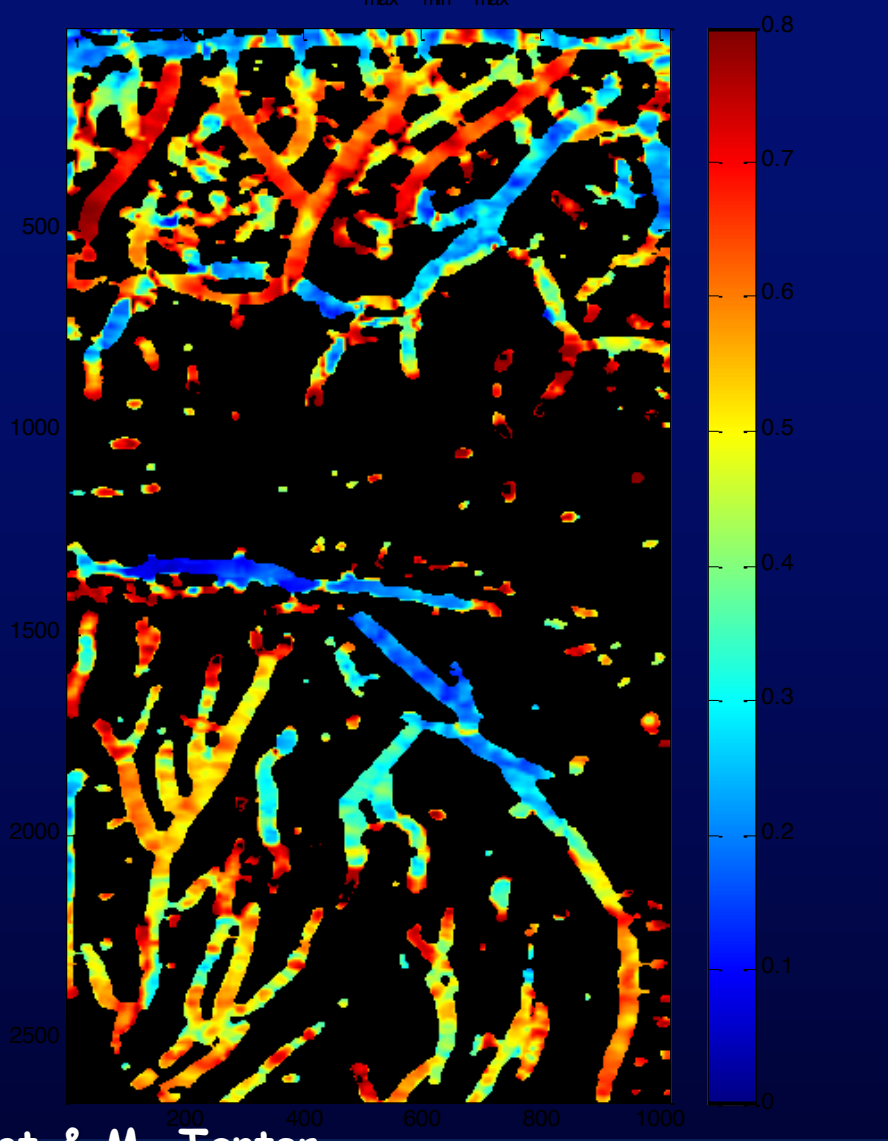
Collaboration between the Langevin Institute & Robert Debré Hospital, Paris (C. Demené et coll.)




Ultrafast Doppler Image
Medulla
Cerebellum
0 5 10 15 20 25 30 35
mm

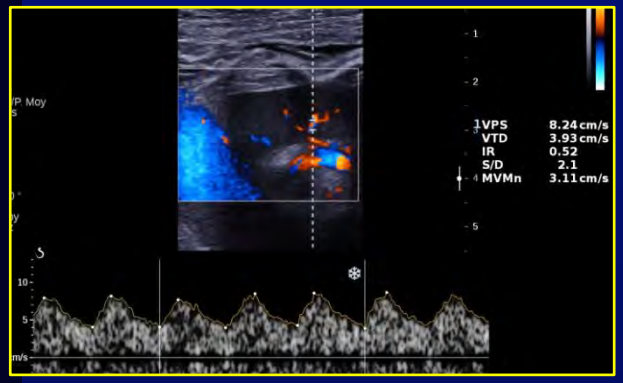
Imaging the resistivity index map

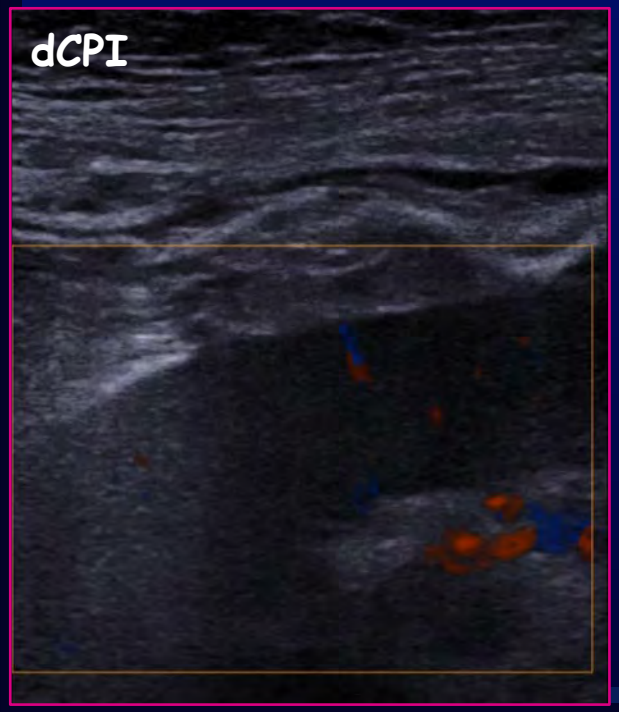


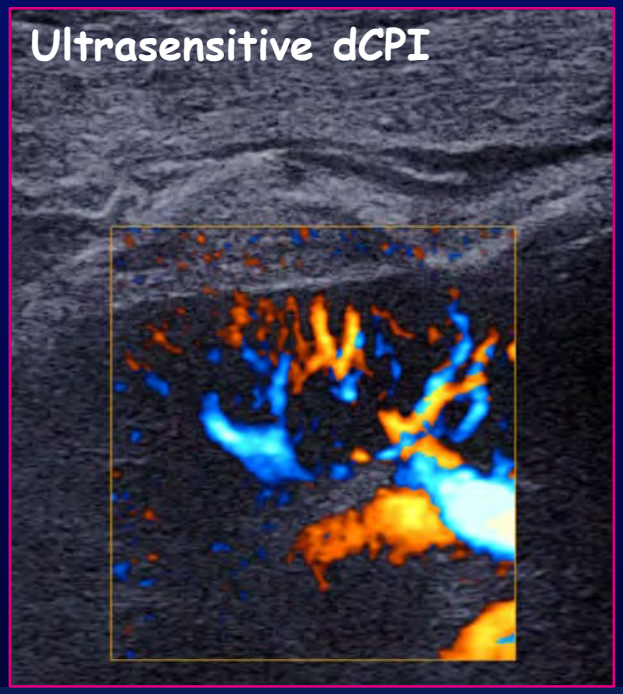


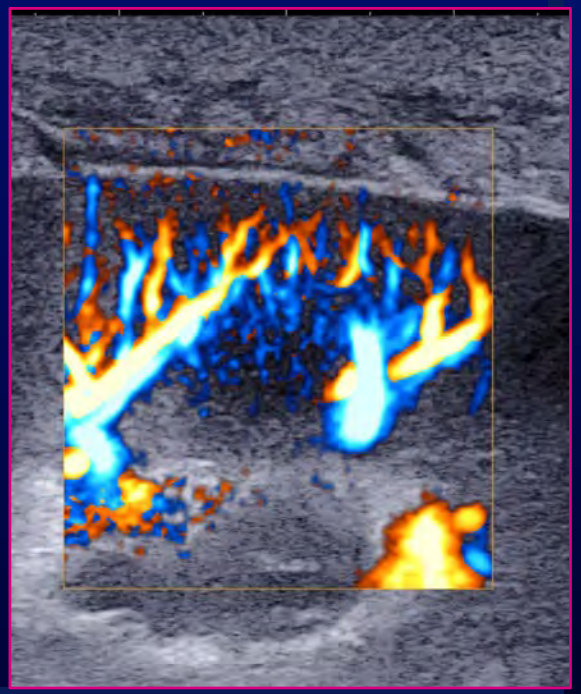
C. Demené, O. Baud, V. Biran, M. Pernot & M. Tanter

Renal transplantation, acute renal failure at day 5
Suspicion of cortical necrosis

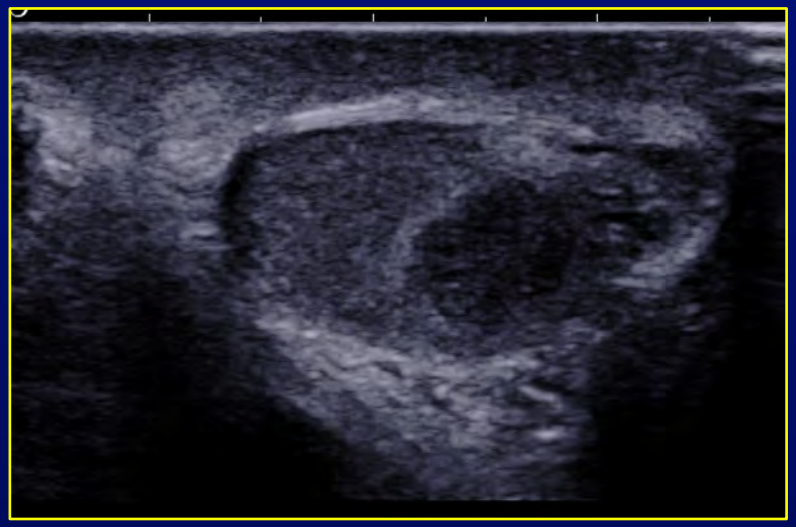




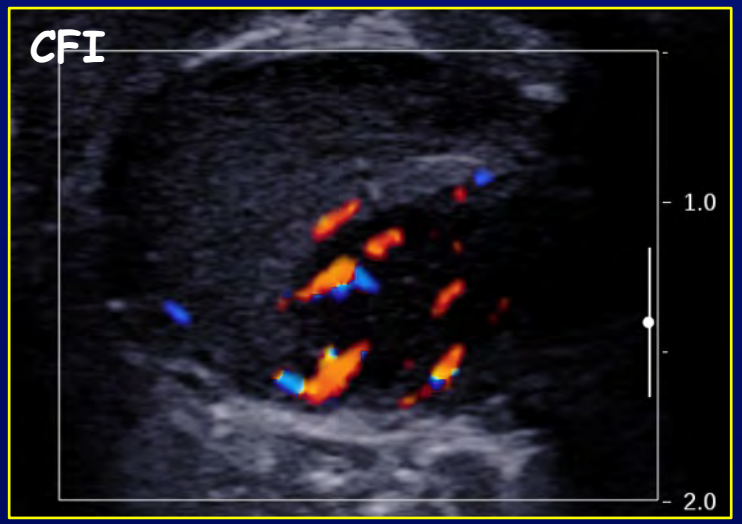


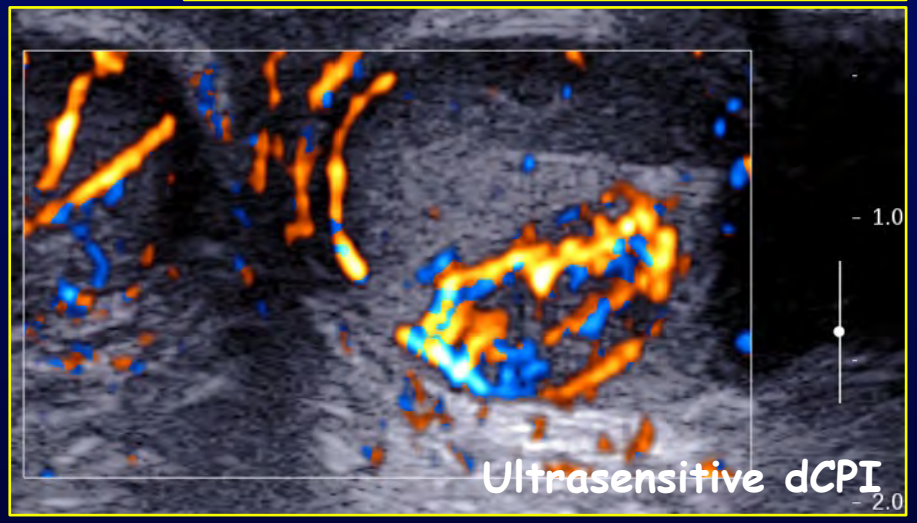


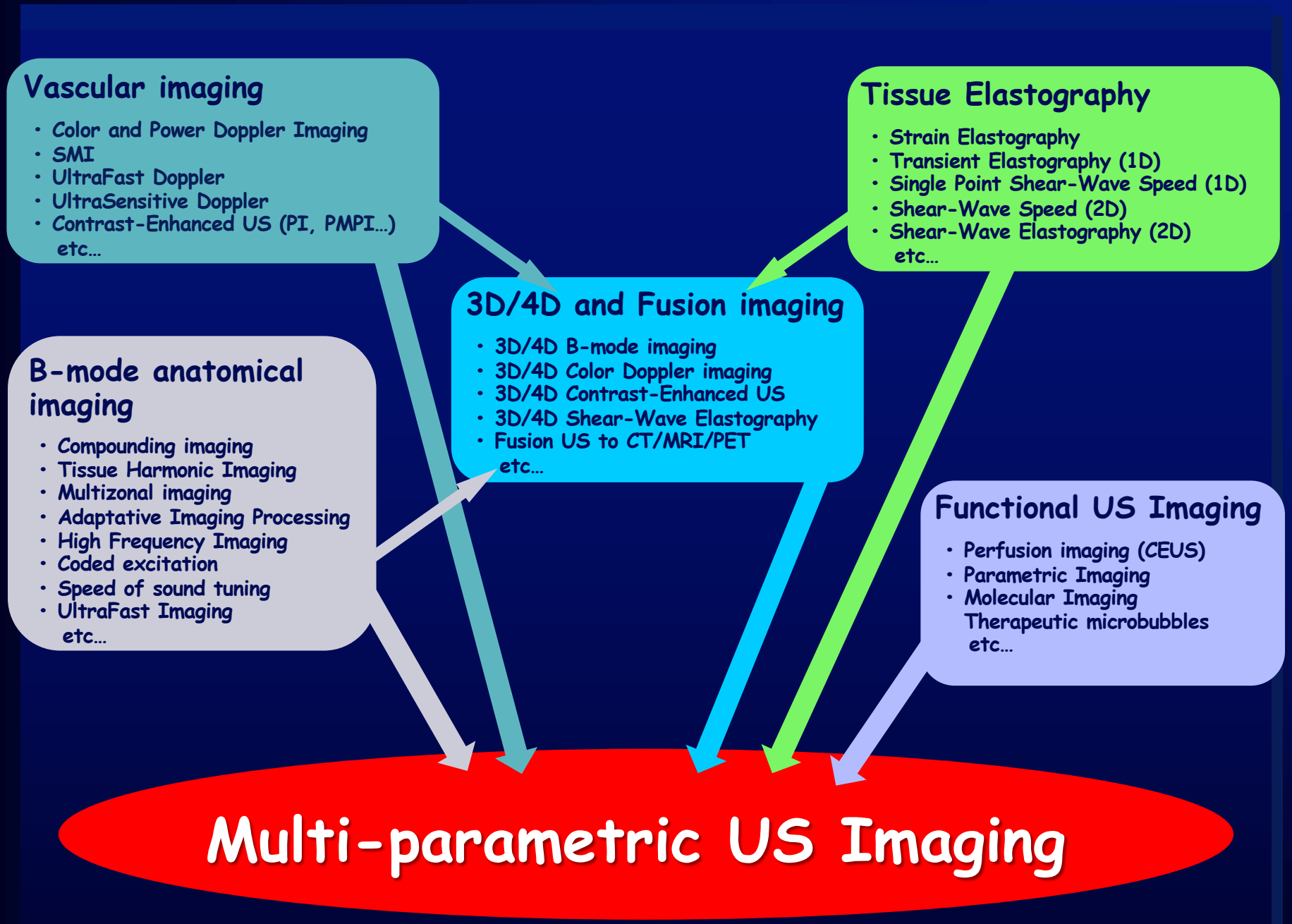
9 year-old boy with precocious puberty
4 mm testis tumor corresponding to a Leydig cell tumor



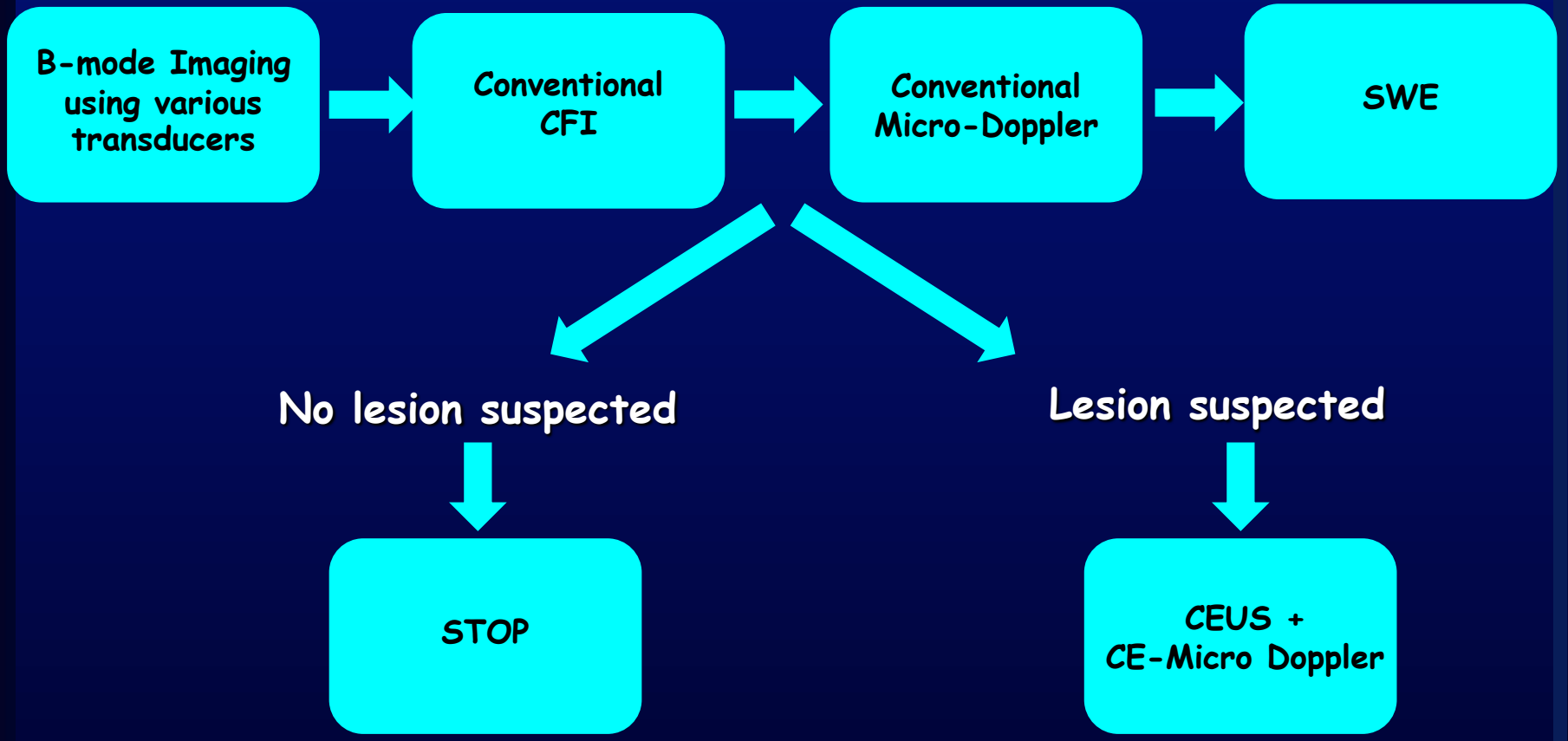
Courtesy Dr S Franchi






Vascular imaging
• Color and Power Doppler Imaging
• SMI
• UltraFast Doppler
• UltraSensitive Doppler
• Contrast-Enhanced US (PI, PMPI…)
etc…
Tissue Elastography
• Strain Elastography
• Transient Elastography (1D)
• Single Point Shear-Wave Speed (1D)
• Shear-Wave Speed (2D)
• Shear-Wave Elastography (2D)
etc…
3D/4D and Fusion imaging
• 3D/4D B-mode imaging
• 3D/4D Color Doppler imaging
• 3D/4D Contrast-Enhanced US
• 3D/4D Shear-Wave Elastography
• Fusion US to CT/MRI/PET
etc…
B-mode anatomical imaging
• Compounding imaging
• Tissue Harmonic Imaging
• Multizonal imaging
• Adaptative Imaging Processing
• High Frequency Imaging
• Coded excitation
• Speed of sound tuning
• UltraFast Imaging
etc…
Functional US Imaging
• Perfusion imaging (CEUS)
• Parametric Imaging
• Molecular Imaging
Therapeutic microbubbles
etc…
Multi-parametric US Imaging

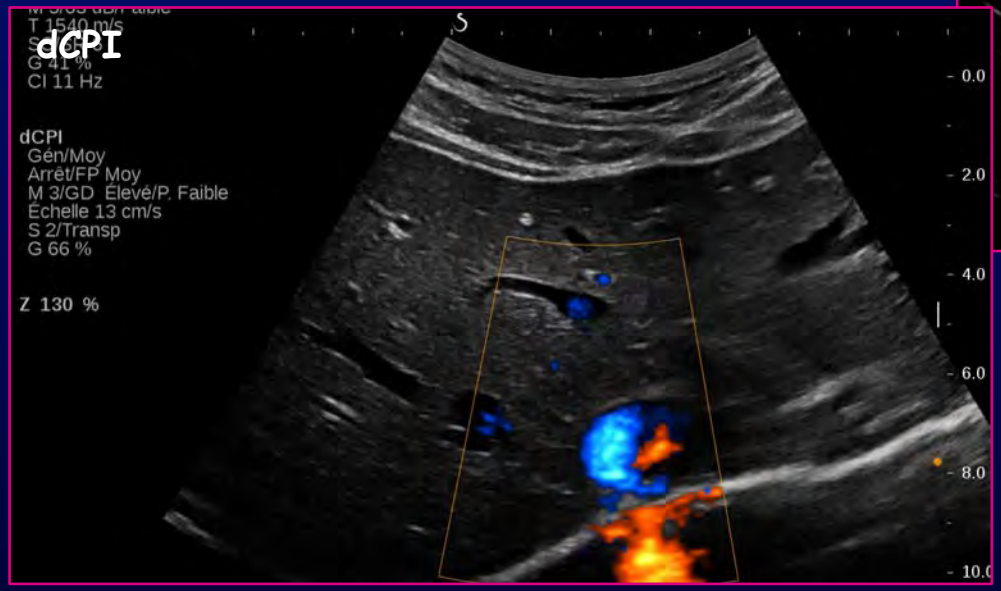
Multi-Parametric US



A new paradigm: mp-US

Characterization of a focal liver lesion

Mrs K., 33 year-old woman
- pre-operative assessment of a small adenoma
- incidental discovery at US
- diagnosis confirmed by MRI



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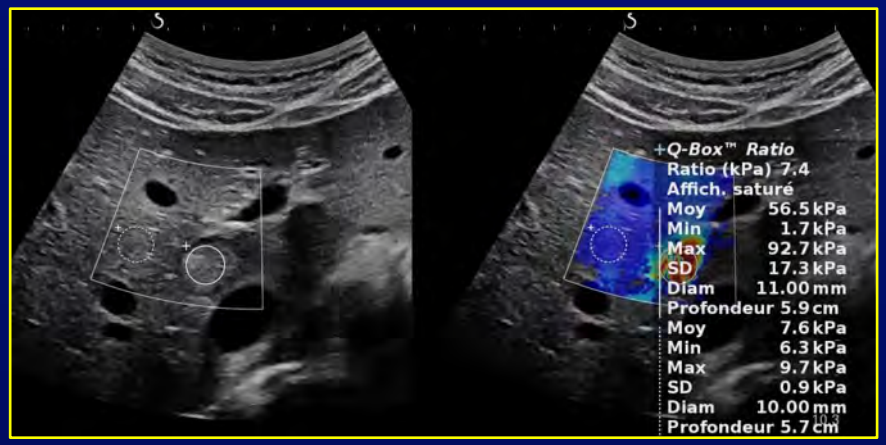
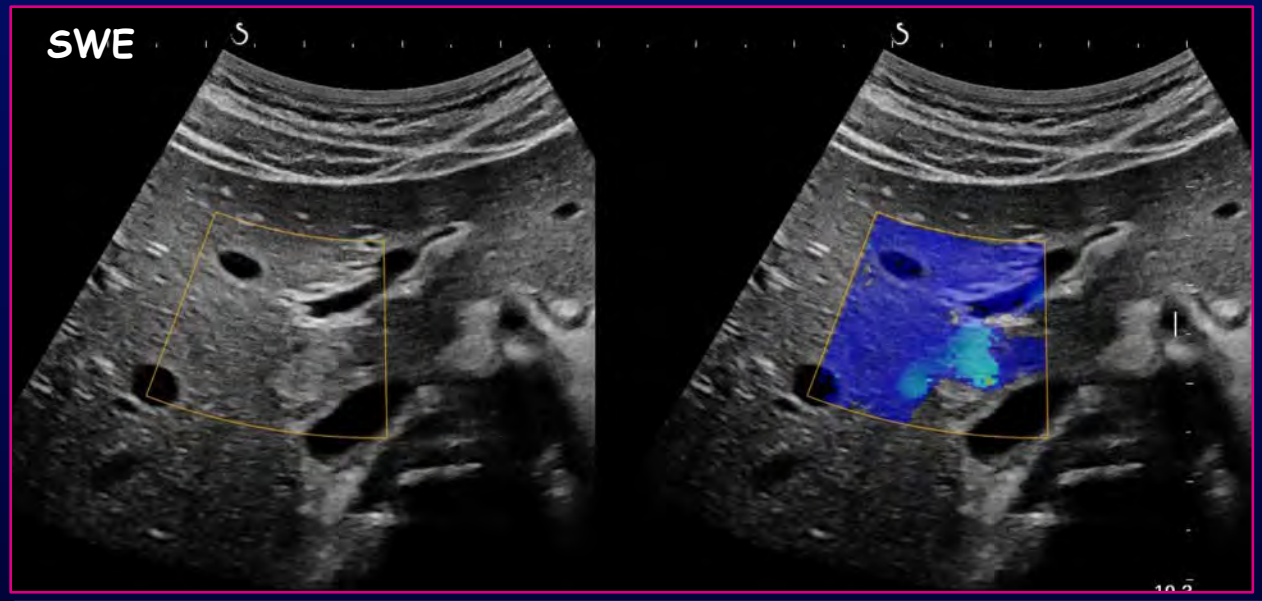
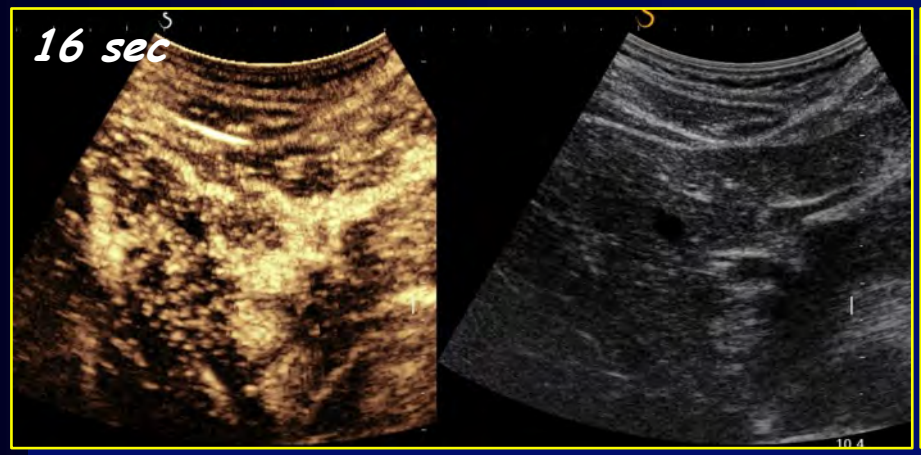
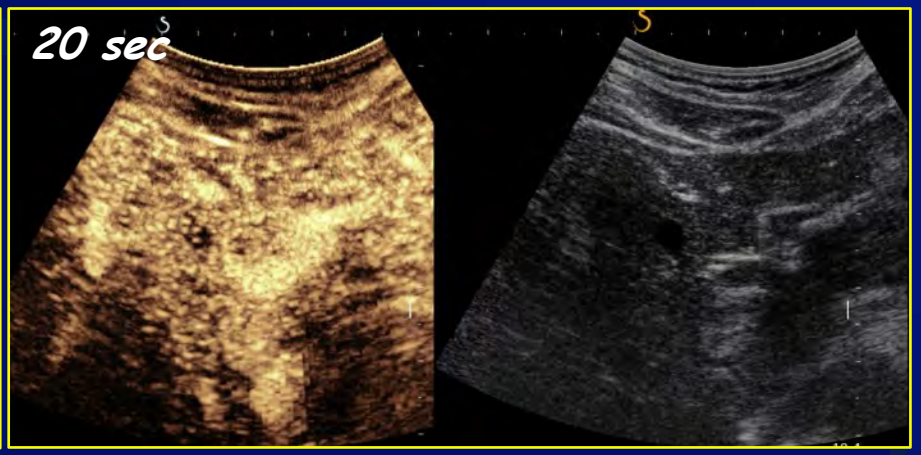
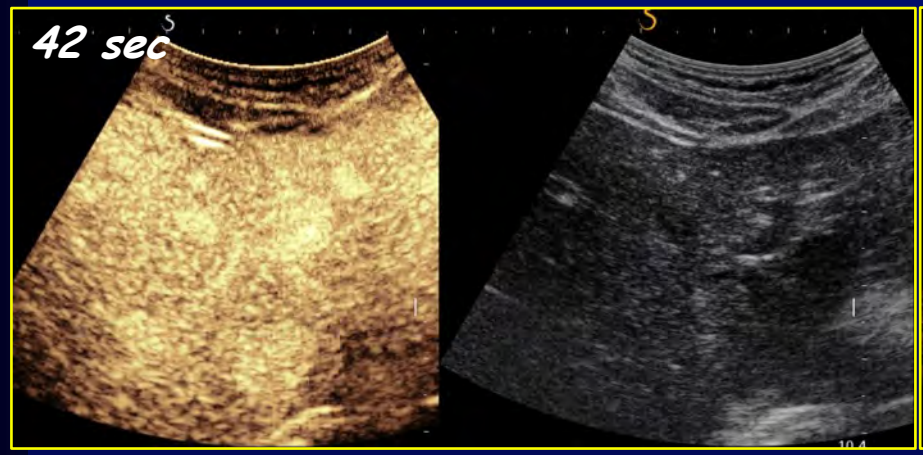


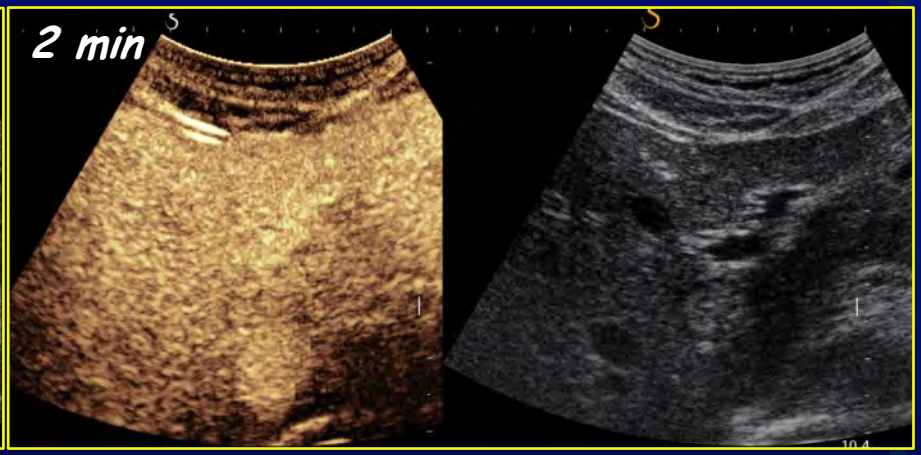


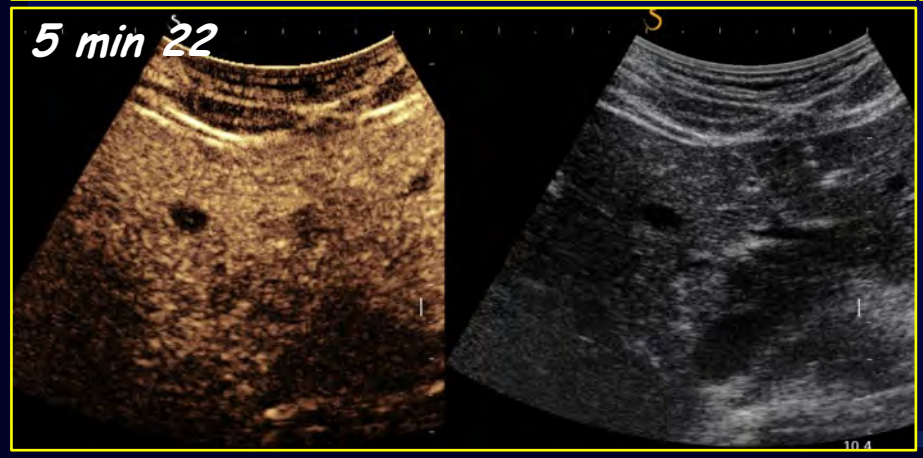
Real-time
ShearWave Elastography
(SuperSonic Imagine)











Contrast-enhanced US
Slow injection SonoVue® 0.3 ml

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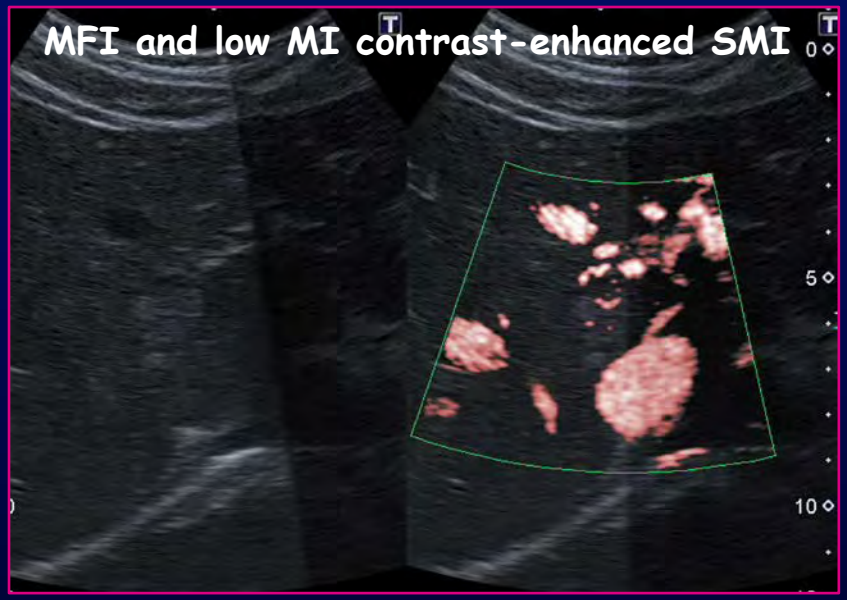
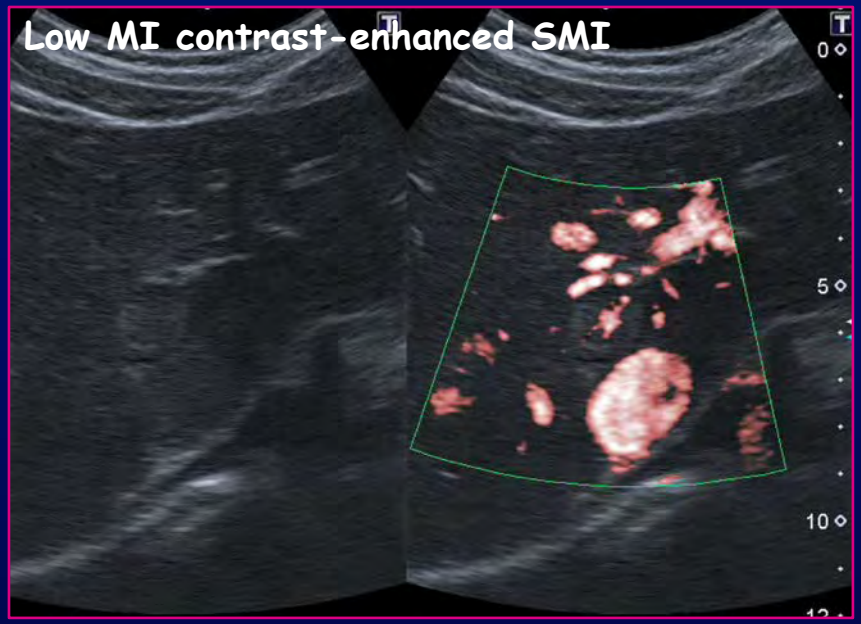




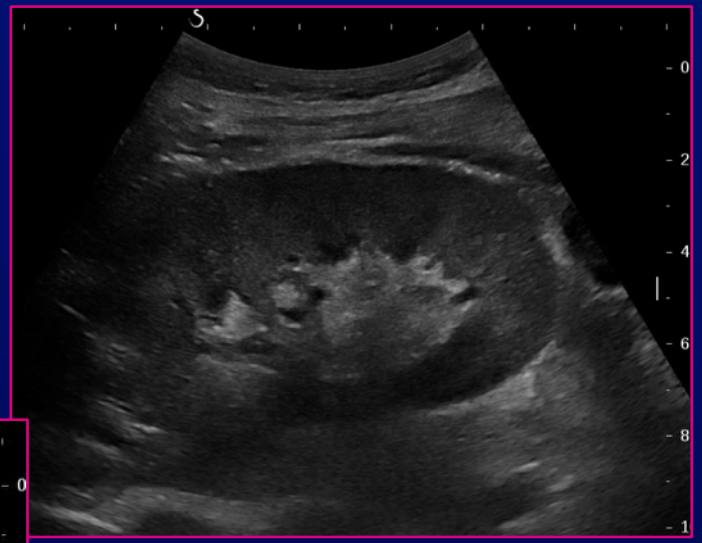
SonoVue® 0.3 ml; 1min 40 sec after injection

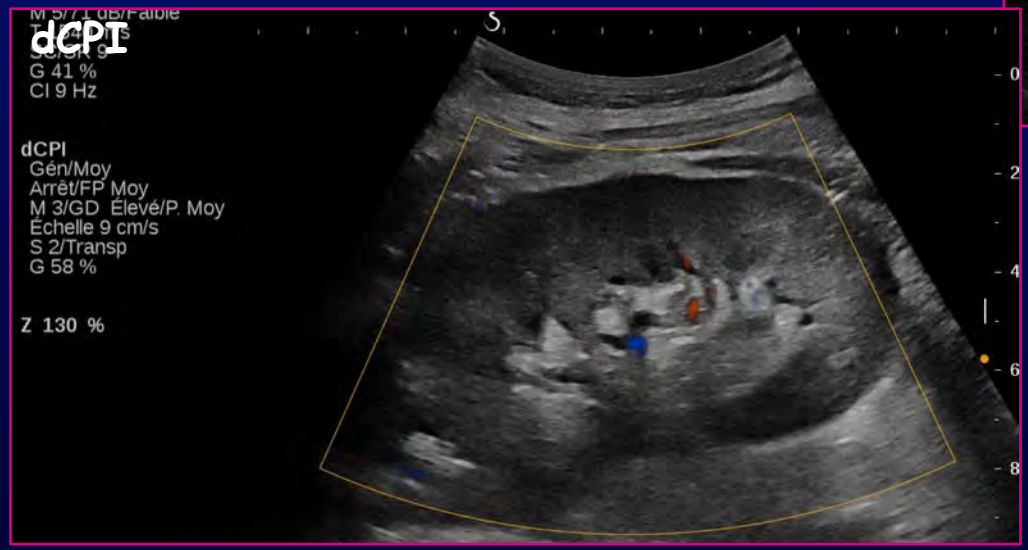
A new paradigm: mp-US

Diagnosis of renal ischemia

Mrs C., 42 year-old woman
- living donor renal pre-emptive transplantation
- 2 arteries re-anastomosed during surgery after acute bleeding
- good coloration of the graft but poor diuresis

US examination 6 hours after the surgical procedure





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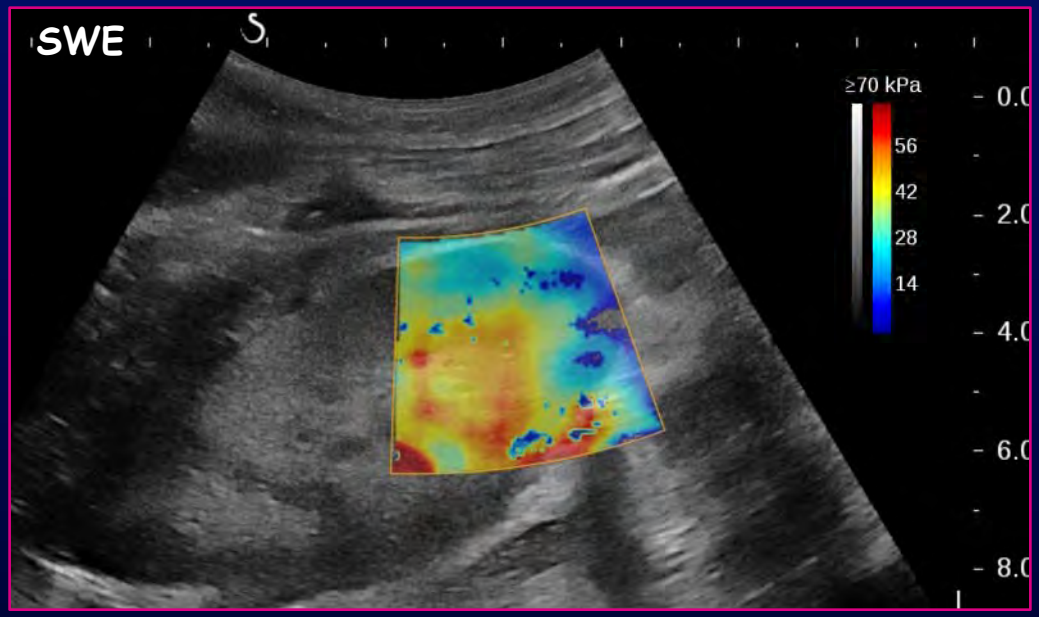

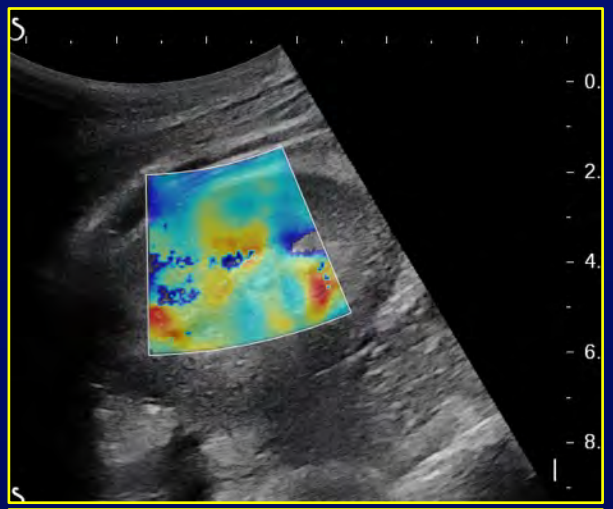

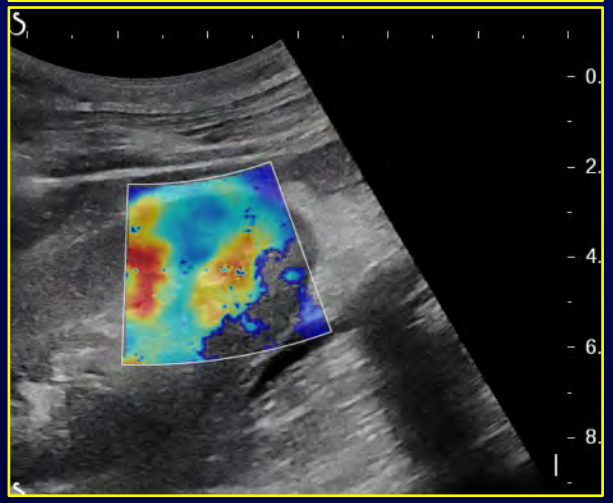

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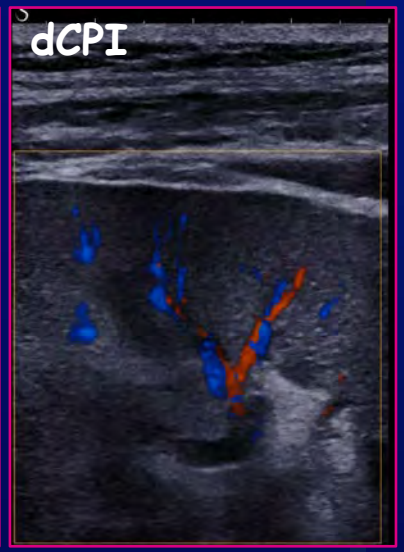

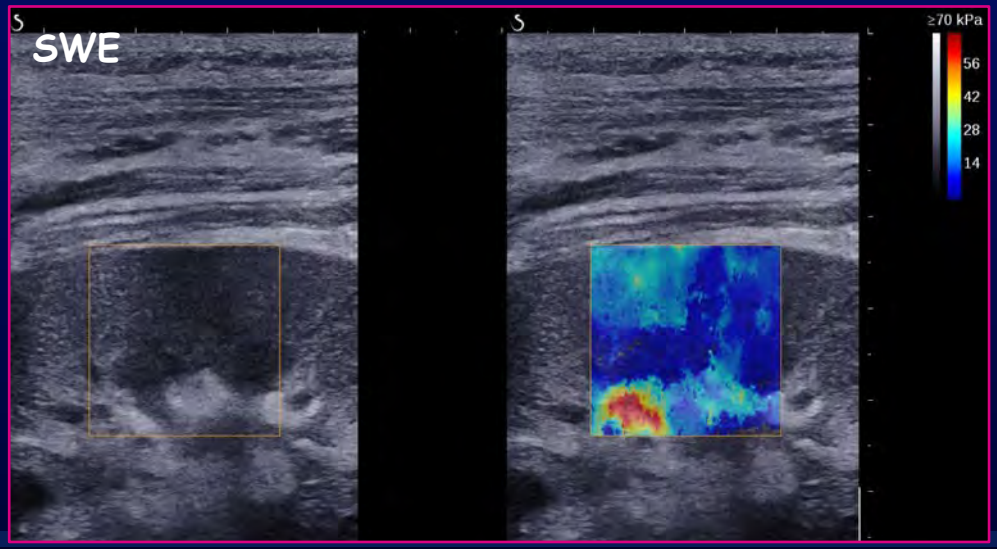

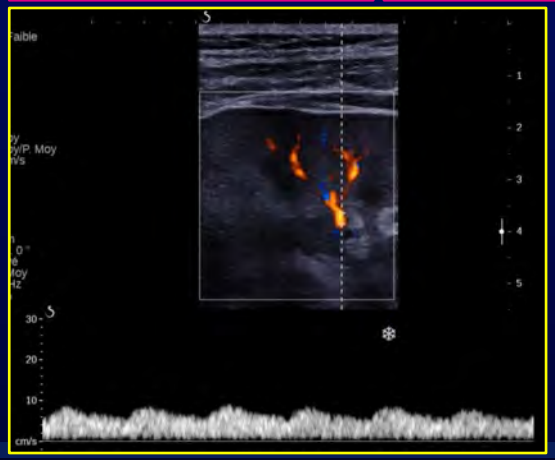

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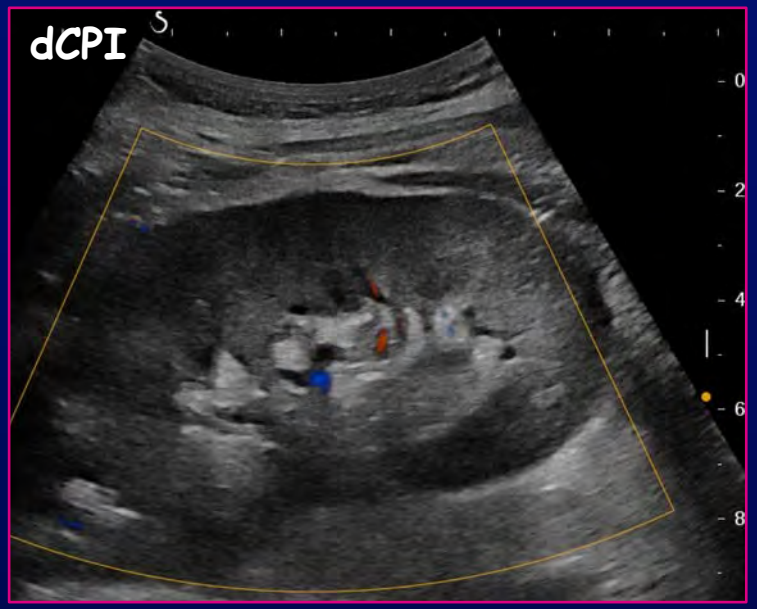

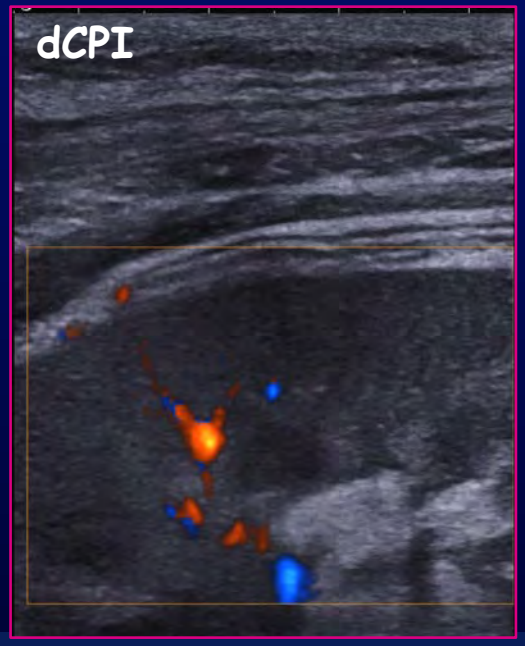

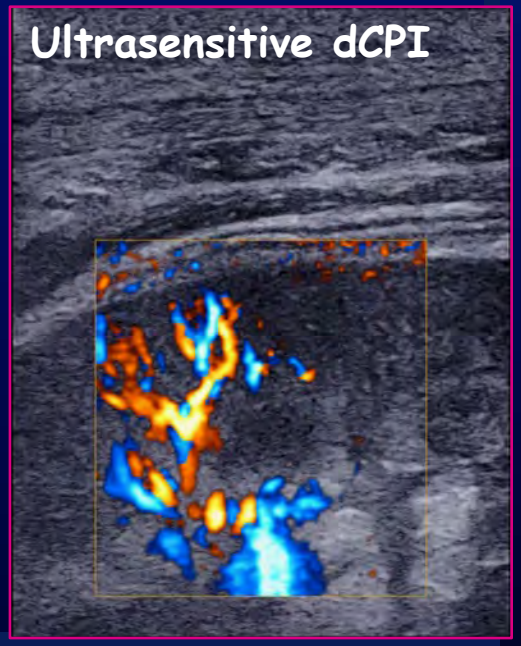

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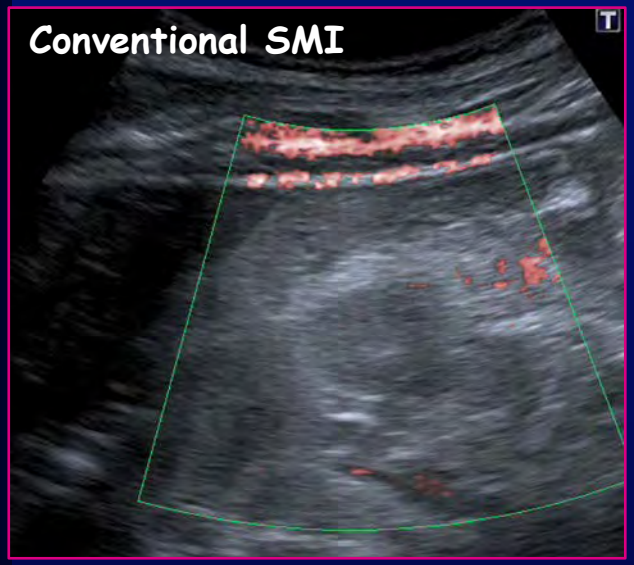
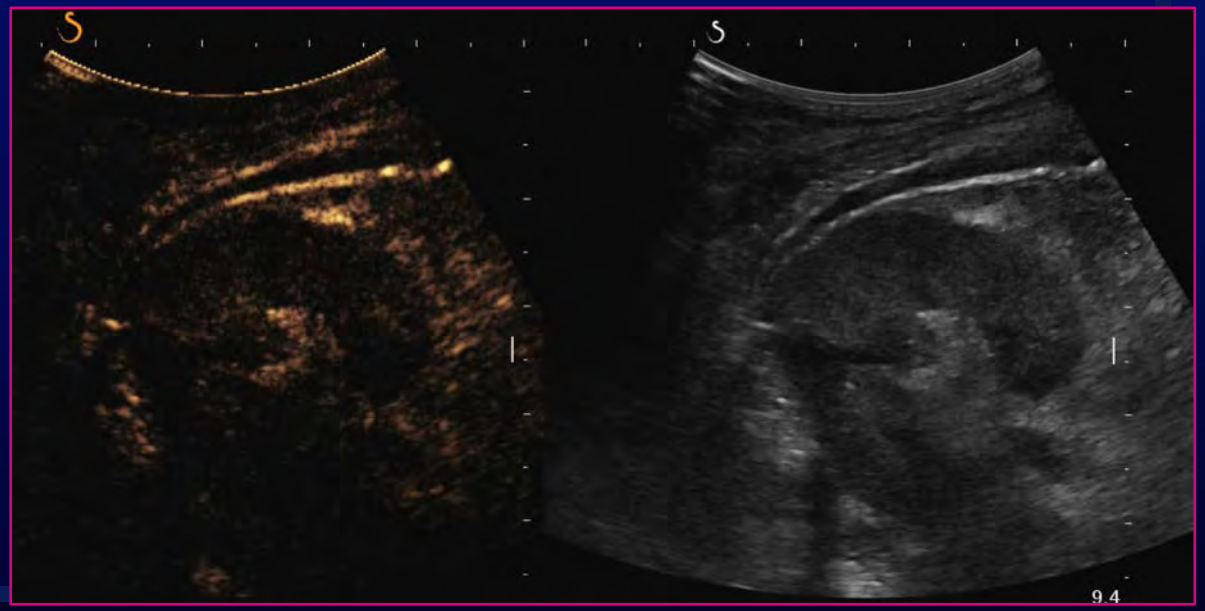
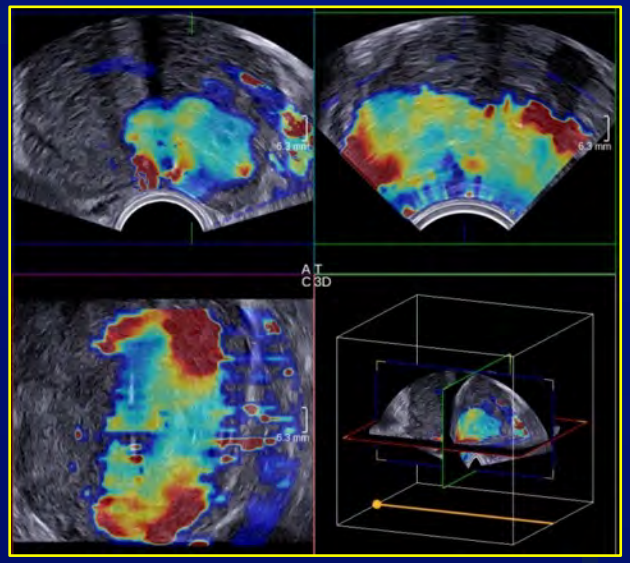


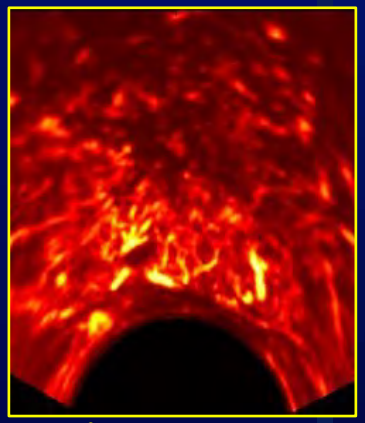
SonoVue® 1.2 ml



Conclusion



- Micro-Doppler US: a new tool for diagnosis of vascular disorders
- Ultrafast Imaging: opening the door to completely new capabilities including:
  - B-mode imaging improvements
  - functional imaging
  - and 2D/3D/4D SWE



- Mp-US has become a reality: high resolution B-mode, CDUS and Micro-Doppler, SWE, CEUS and CE Micro-Doppler
- Continuous improvements: quantitative SMI, real-time UltraSensitive Doppler and resistivity maps

Many thanks to my friendsand colleagues from the research lab.

US elastography
The different approaches

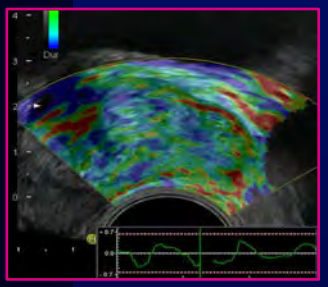
- **Two different techniques:**
  - Static/ Quasi Static Elastography
    - using an external stimulation (alternative pushes)
    - using an internal stimulation (cardiac beats…)
  - ShearWave Elastography
    - using an external push (Transient E, FibroScan®); NO image (1D)
    - using an US push (ARFI)
      - anatomical ref. (B-mode), « single point » quantification (1D)
      - anatomical ref.(B-mode), 2D elasticity map, single frame acq.
      - anatomical ref. (B-mode), 2D elasticity map, real time acq.

US Elastography

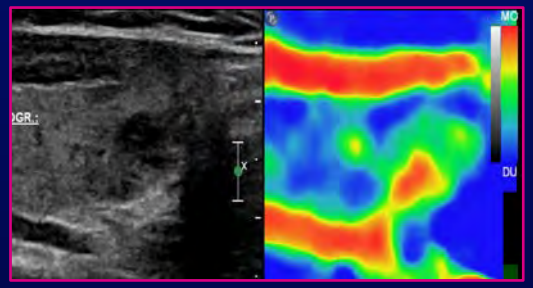
The different approaches

Quasi-static Elastography

- External alternative compressions
- Internal deformation (cardiac beats, breathing…)



Strain Elastography ("Hitachi Real-time Tissue Elastography HI-RTE…")



Strain Elastography ("Philips Nanometer tissue strain tracking Elastography…")

Shear-Wave based Elastography

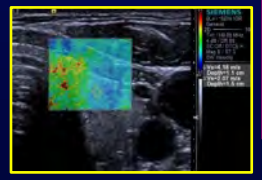
- External pressure (piston) No Image
  - 1D Single Point Quantification

Transient Elastography Fibroscan® (EchoSens)

- Internal acoustic pressure (ARFI) Anatomical 2D image
  - 1D Single Point Quantification

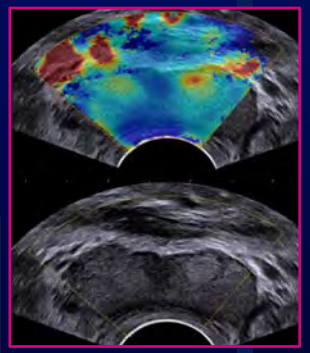
Point Quantification® (Philips)

  - 2D Color map
    - Single frame Acquisition



Virtual Touch IQ® (Siemens)

    - Real Time Acq.



Shear Wave E. SuperSonic Imagine