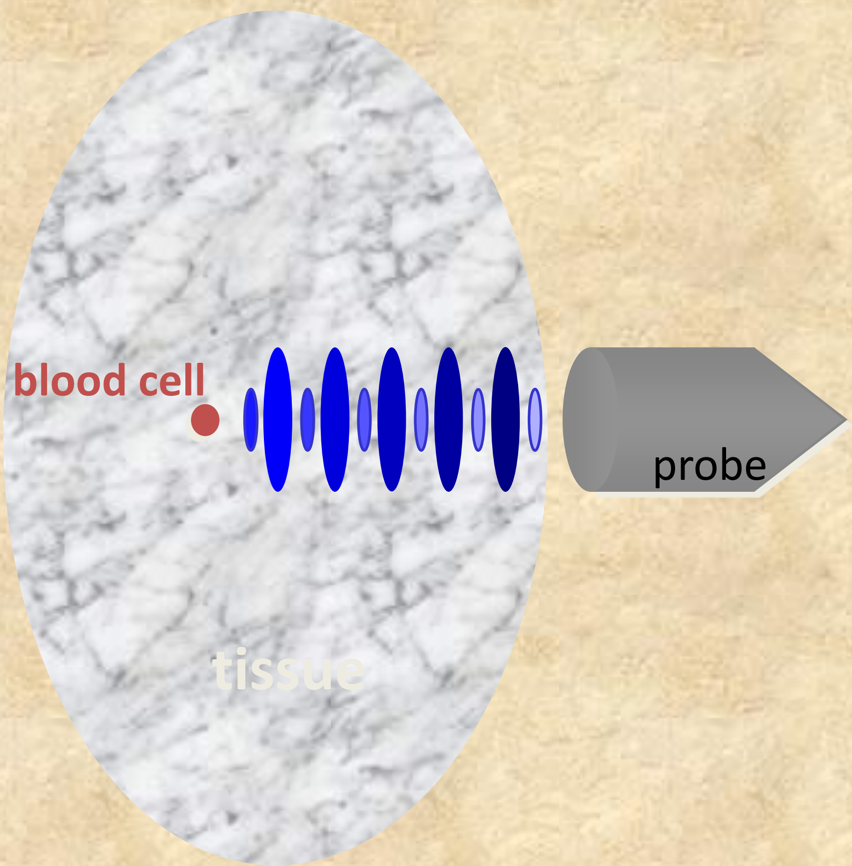
Monitoring of Cerebral Blood Flow

Transcranial Doppler
Laser Doppler Flowmetry
Thermal dilution method (Hemedex)

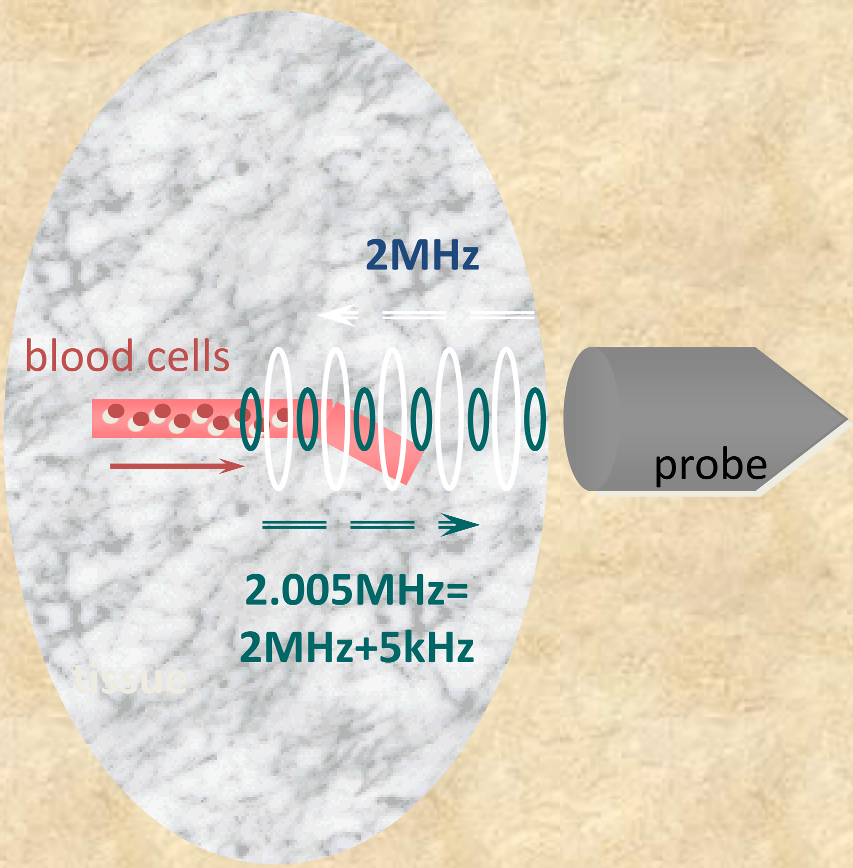
Ultrasound in Tissue



Some Facts:

- ultrasound travels at a constant speed of 1540m/s in tissue.
- ultrasound is reflected at the boundary of two media.
- ultrasound is backscattered n heterogenous tissues.
- the higher the ultrasound fequency the higher the attenuation and the hallower the penetration depth.

Doppler Principle in Sonography



- a ultrasound signal is used to insonate the vessels, e.g. 2MHz.
- this signal is reflected and backscattered from moving objects (e.g. blood cells) with a positive or negative frequency shift.
- the frequency shift is also called Doppler shift or Doppler signal.
- the faster the blood cells are moving the higher Doppler shift.

Doppler Formula

Doppler Frequency Shift:

$$f_d = \frac{2*f_t*v*\cos ß}{v_0}$$

Velocity:

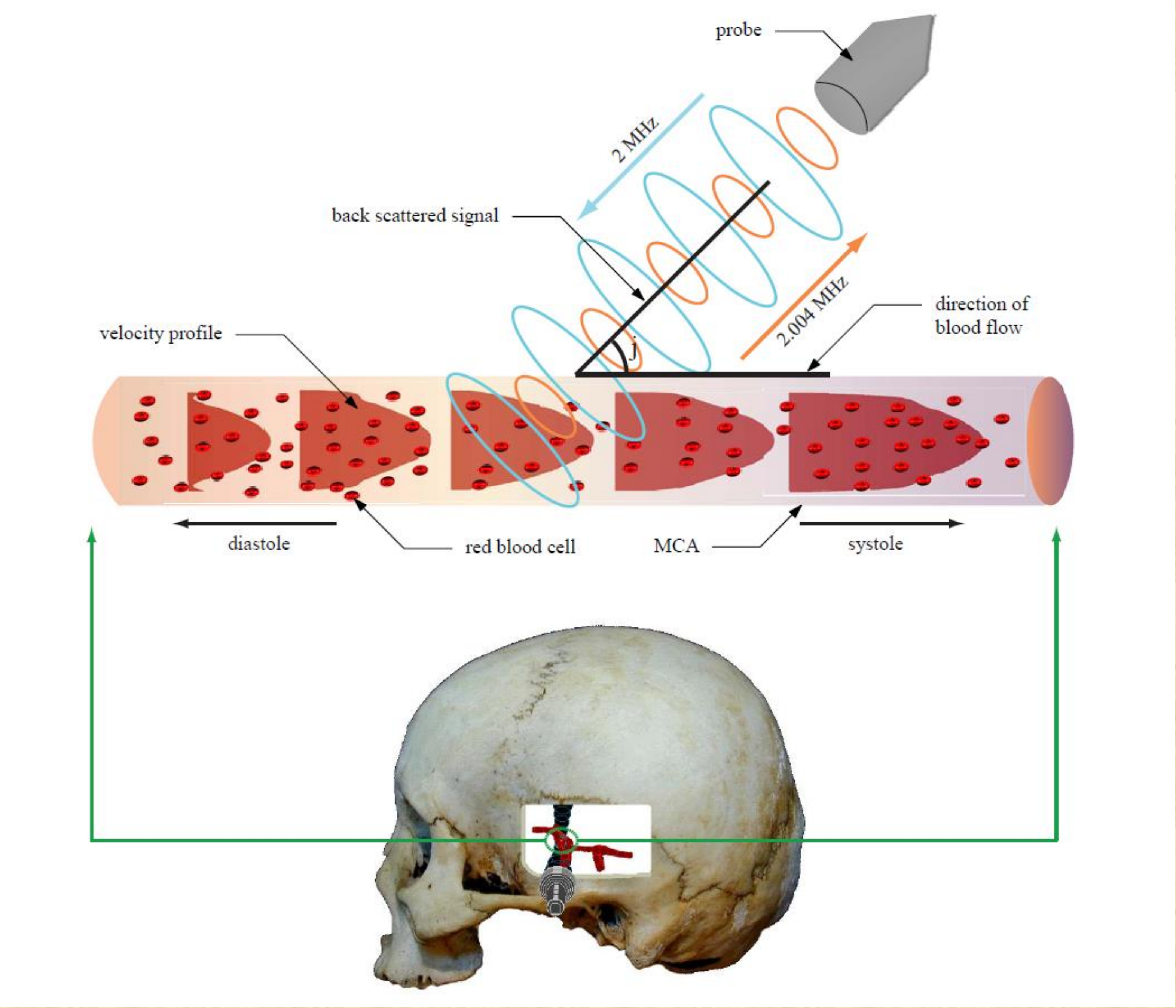
$$v = \frac{v_0*f_d}{2*f_t*\cos ß}$$

simplified:

$$v = f_d * \frac{1540m/s}{2*2MHz*1}$$

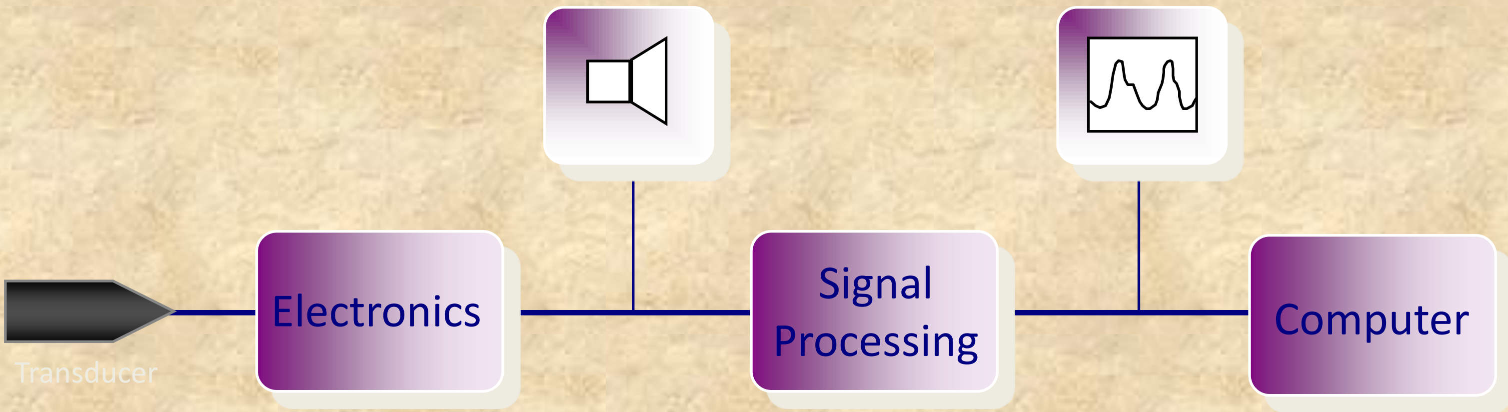
f_d: Doppler frequency shift
f_t: ultrasound frequency, e.g. 2MHz
v: velocity of the moving blood cells
v_0: velocity of ultrasound in tissue (1540m/s)
ß: angle of insonation

The Doppler frequency shift is the only variable in the above shown formula, therefore we have a linear relationship between blood flow velocity and Doppler frequency shift.



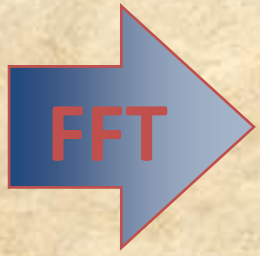
Thanks to Dr.DJ Kim

Doppler System



Audio Doppler Signal:

- ❑ Doppler signal
- ❑ time signal
- ❑ audio output
- ❑ difficult to analize

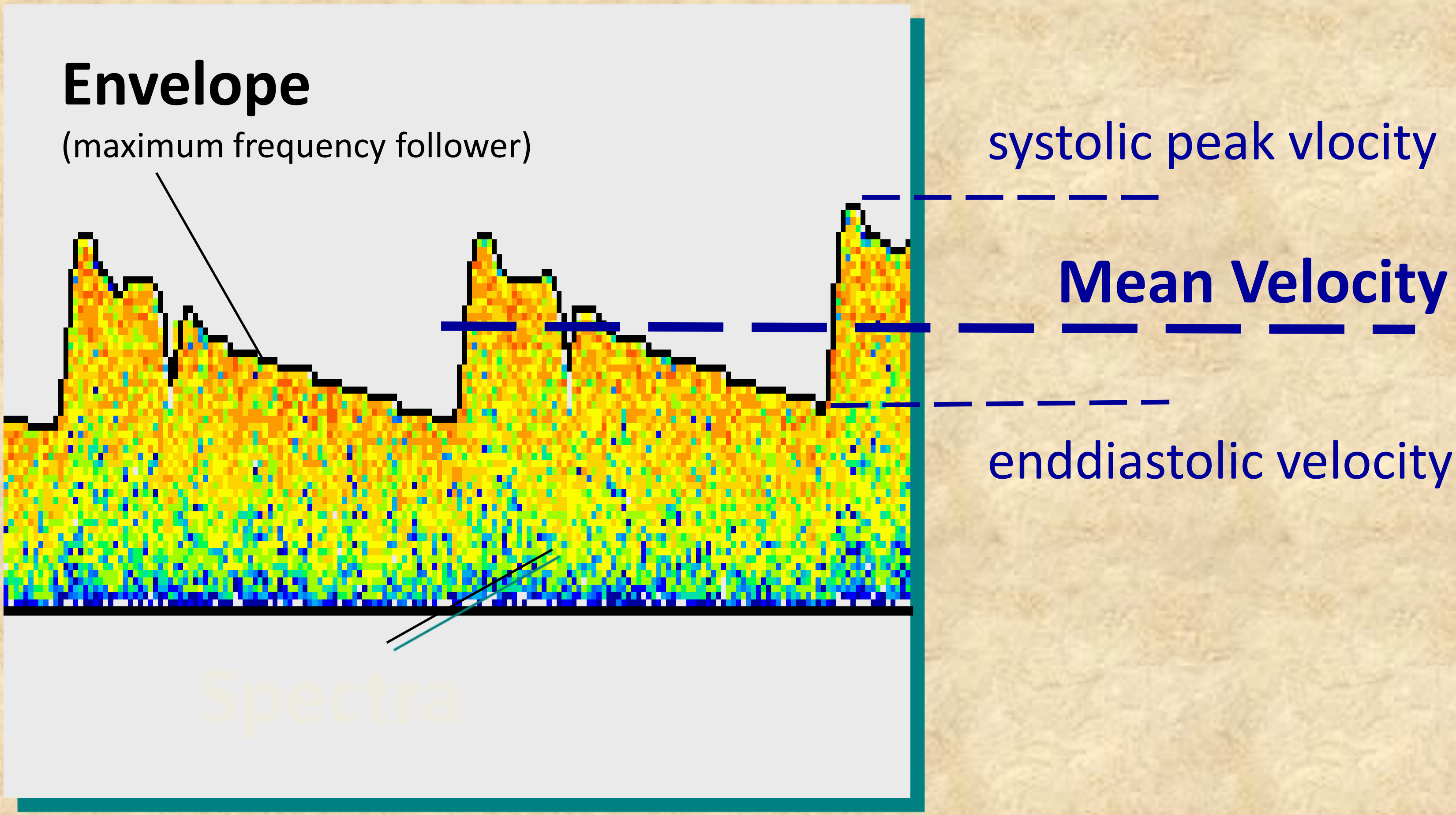


Fast Fourier Transform

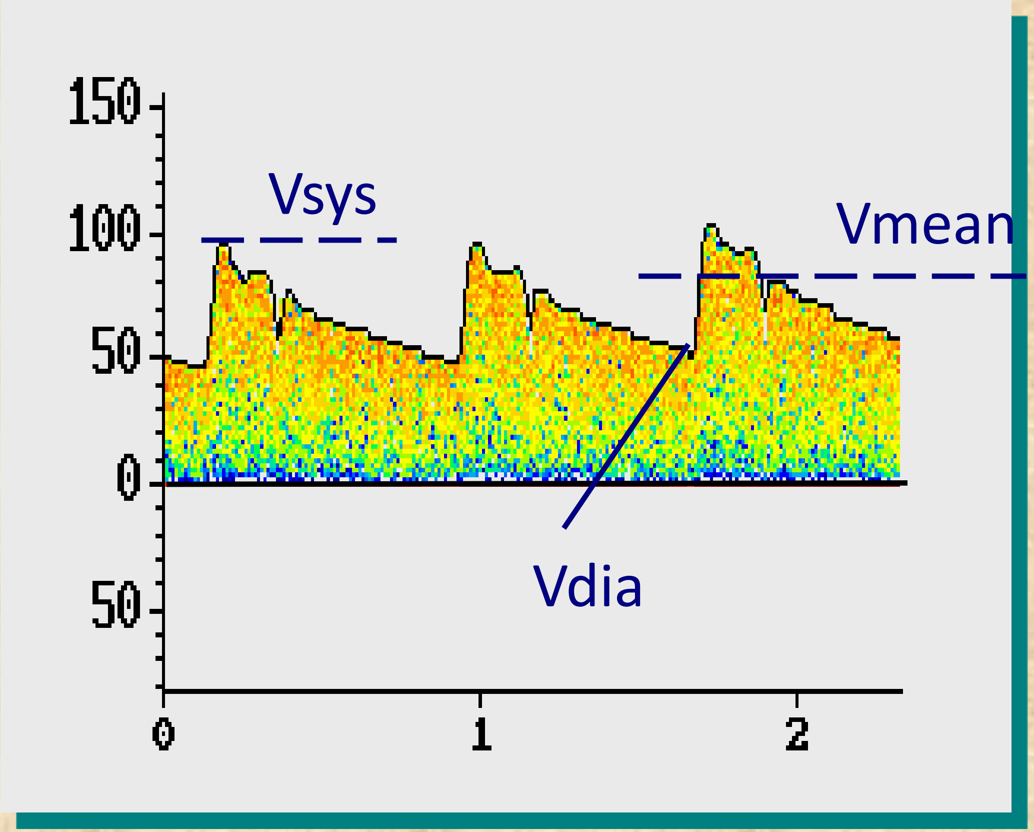
Spectral Display:

- ❑ frequencies and velocities
- ❑ spectral display
- ❑ parameters like envelope, PI
- ❑ easier to analize

Spectral Display, Indices



Pulsatility Indices



Gosling's Pulsatility Index

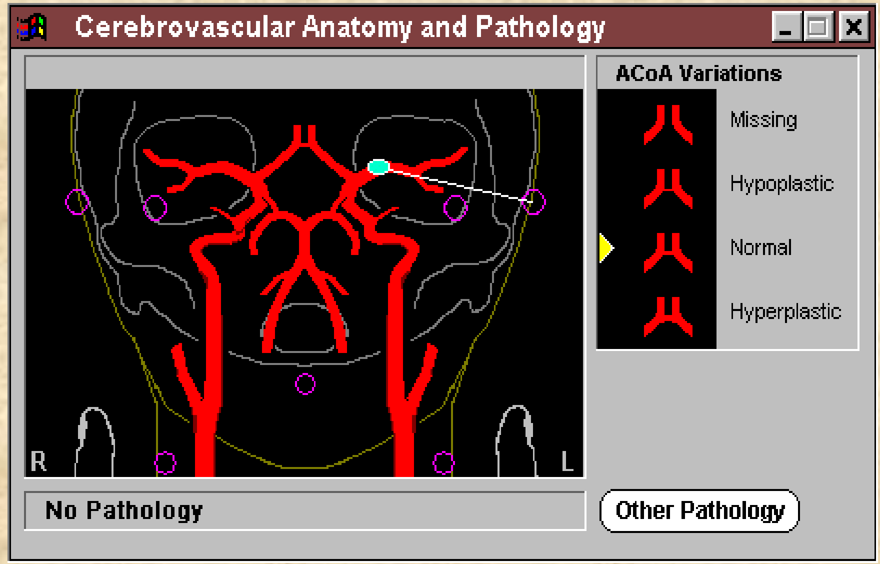
$$PI = \frac{Vsys - Vdia}{Vmean}$$

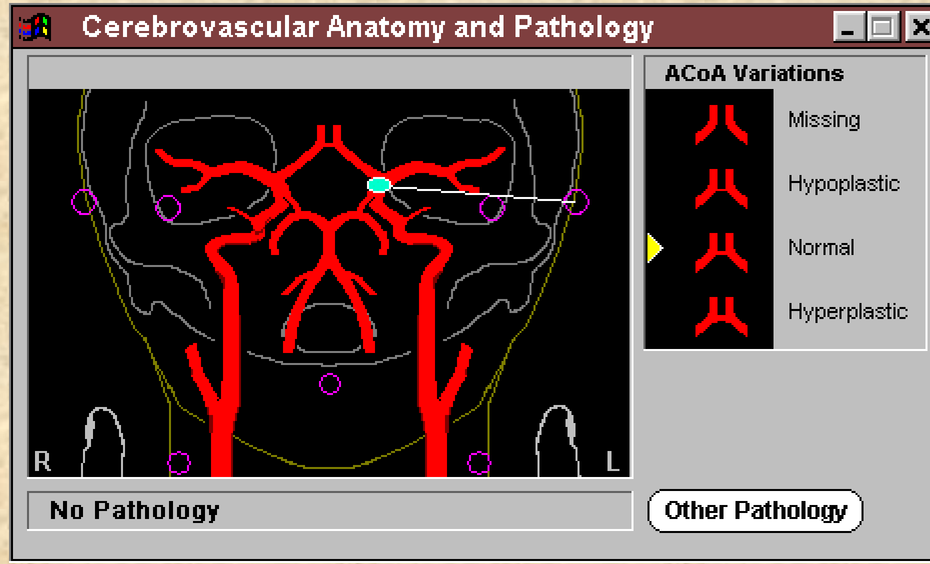
Pourcelot's Resistance Index

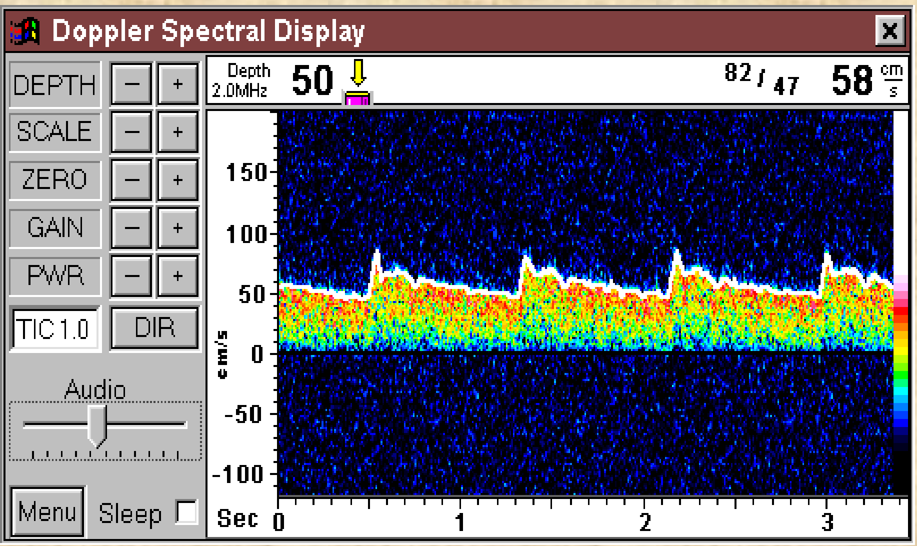
$$RI = \frac{Vsys - Vdia}{Vsys}$$

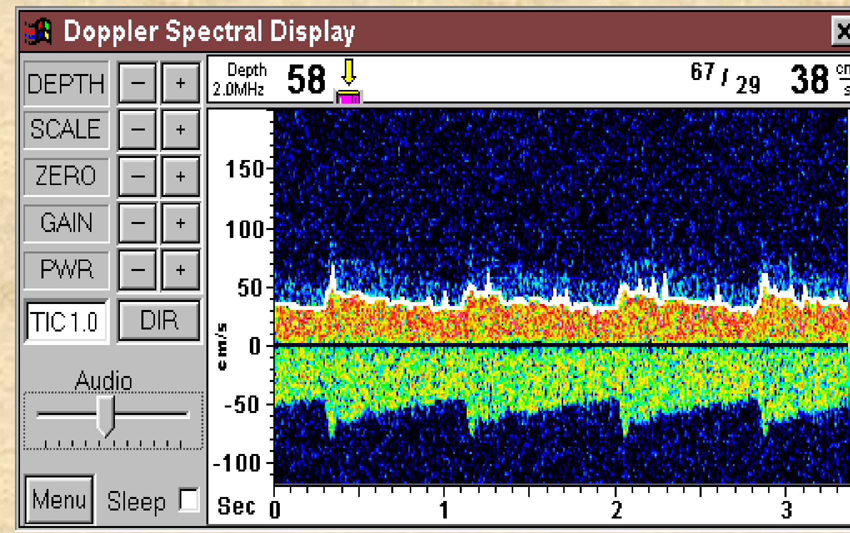
MCA

Bifurcation

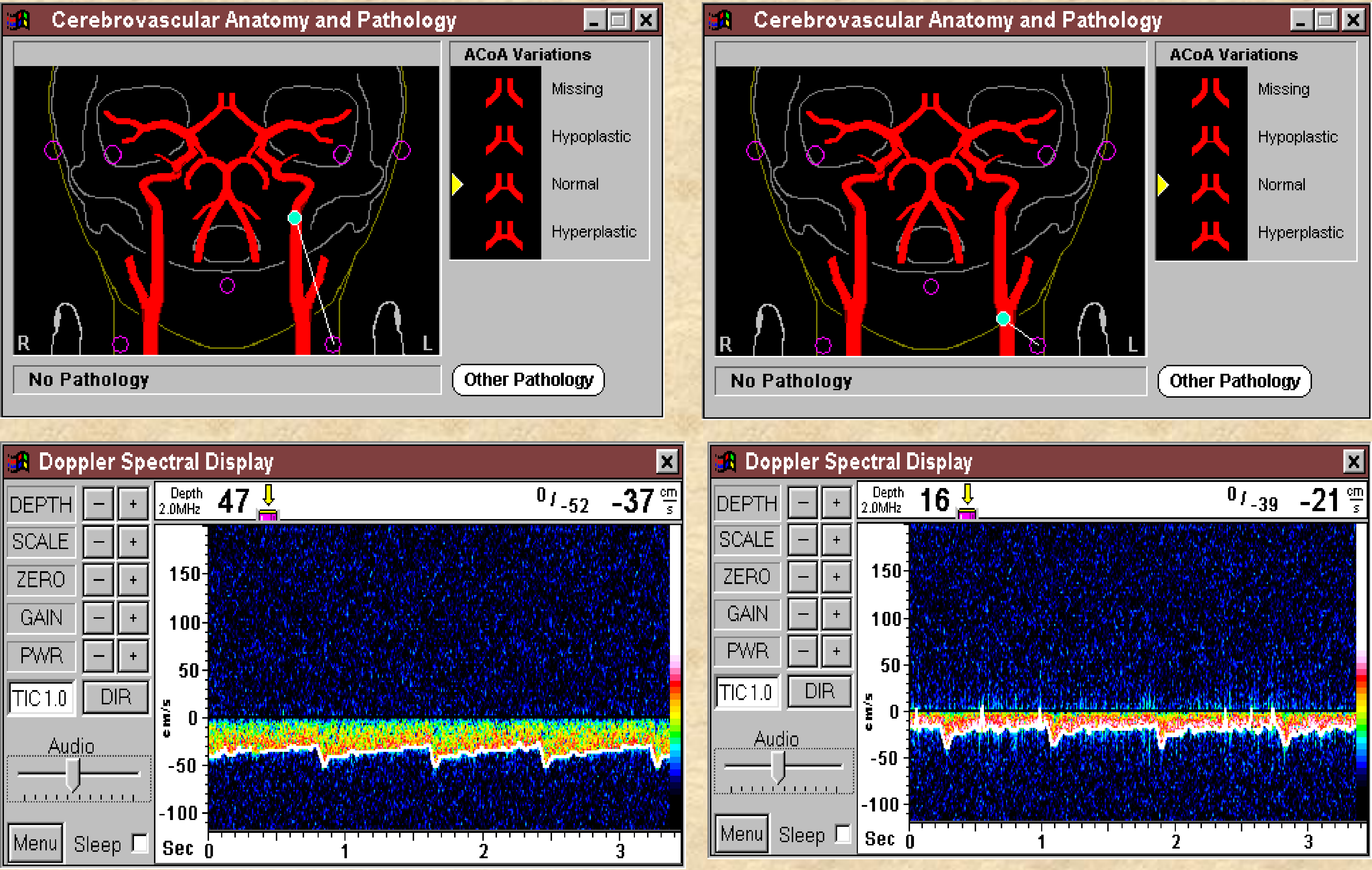




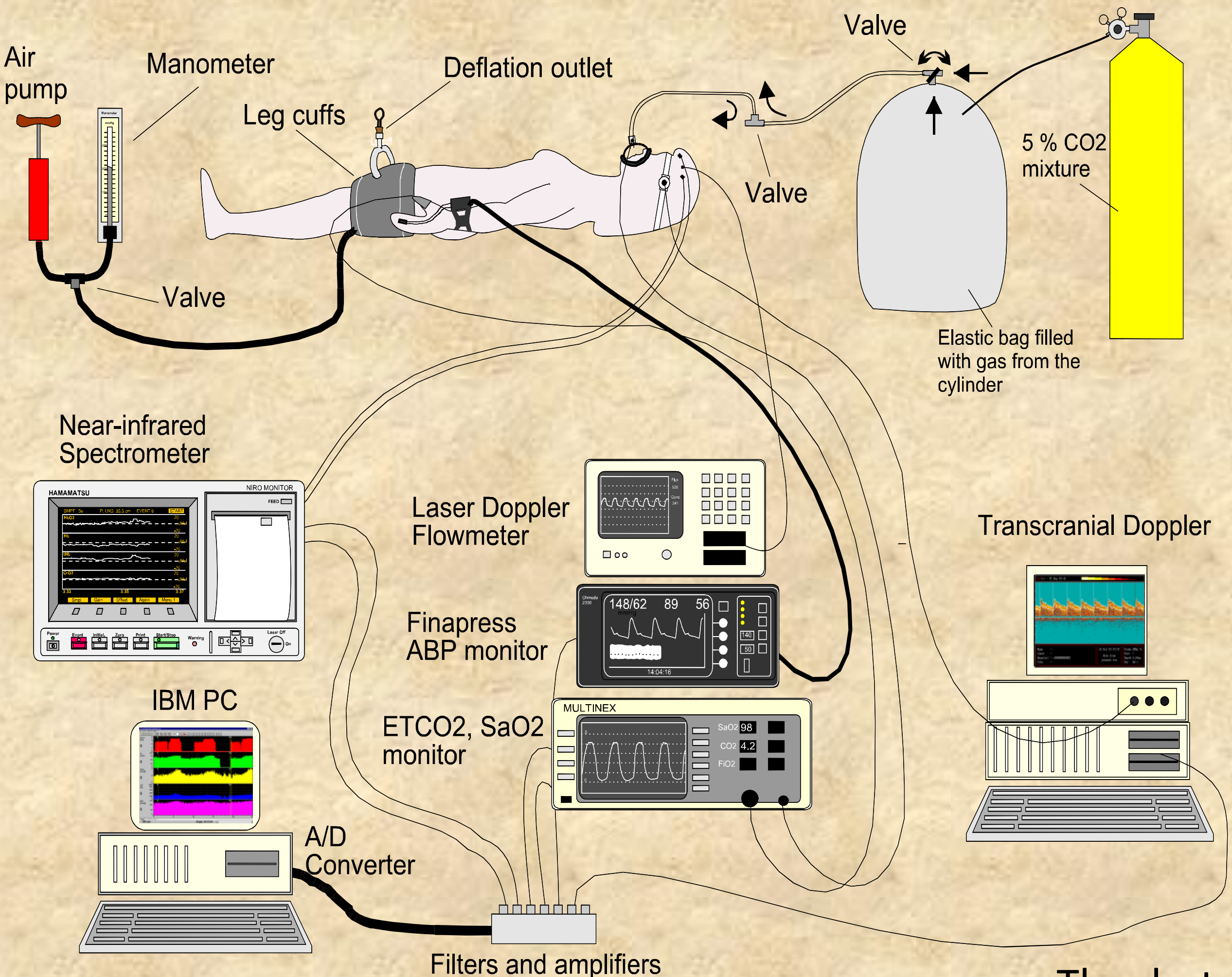




Investigation of ICA



Cerebrovascular Laboratory



Thanks to Dr.P.Smielwski

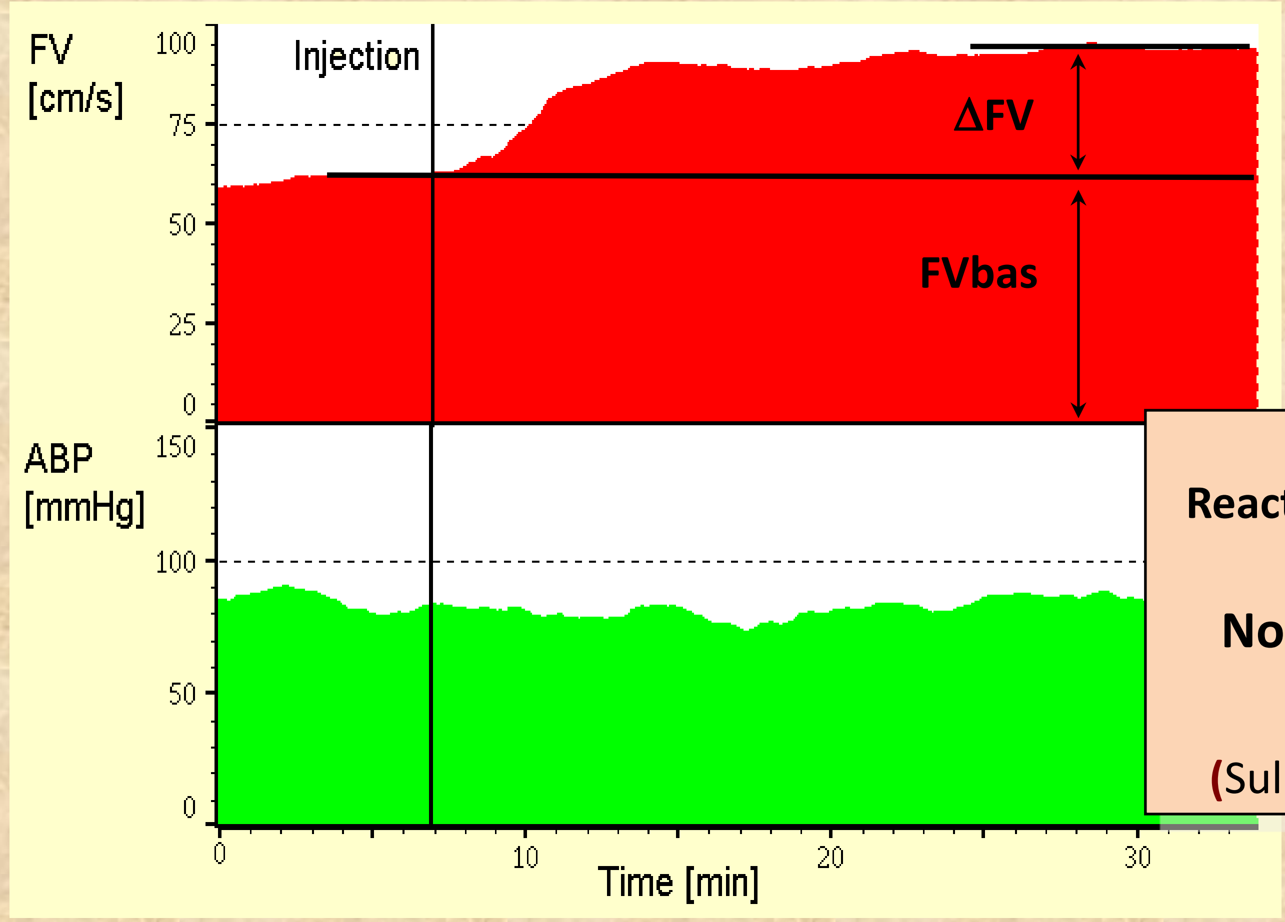
Testing of Cerebrovascular Reactivity using TCD

Acetazolamide test

- Inhibitor of carbonic anhydrase in red cells.
- Intravenous administration of 1 g of acetazolamide causes normally 30%-60% increase in CBF.
- Advantages:
  - does not change ABP,
  - does not require patient’s co-operation.
- Disadvantages: 2-h duration of action.

Thanks to Dr.P.Smielwski

Acetazolamide test



Reactivity $= \dfrac{\Delta FV}{FVbas}$

Normal values :

30-60 %

(Sullivan *et al.*, 1987)

Thanks to Dr.P.Smielwski

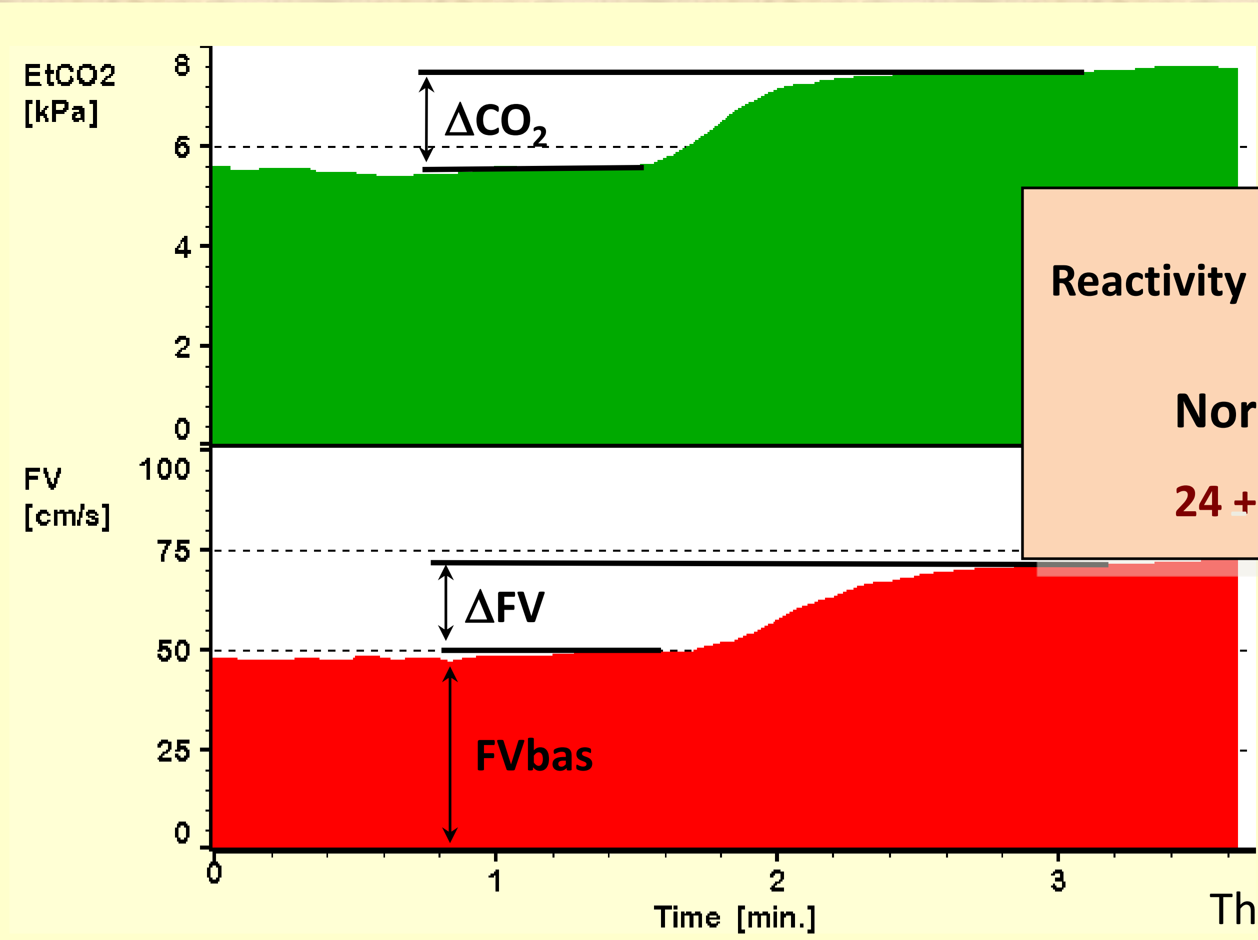
CO_2 reactivity test

- Change in CO2 concentration of the inspired gas
- Breath holding
- Manipulation of ventilation in sedated patients

Thanks to Dr.P.Smielwski

CO_2 Reactivity Methods of assessment

Change in FV to change in $PaCO_2$ ratio



$$\text{Reactivity} = \frac{\Delta FV}{\Delta CO_2} \cdot \frac{1}{FVbas}$$

Normal values :

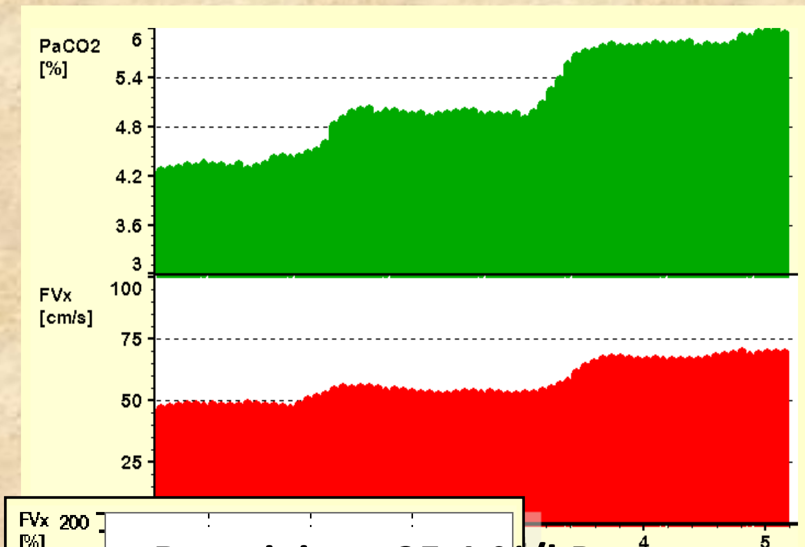
24 + 4.1 %/kPa

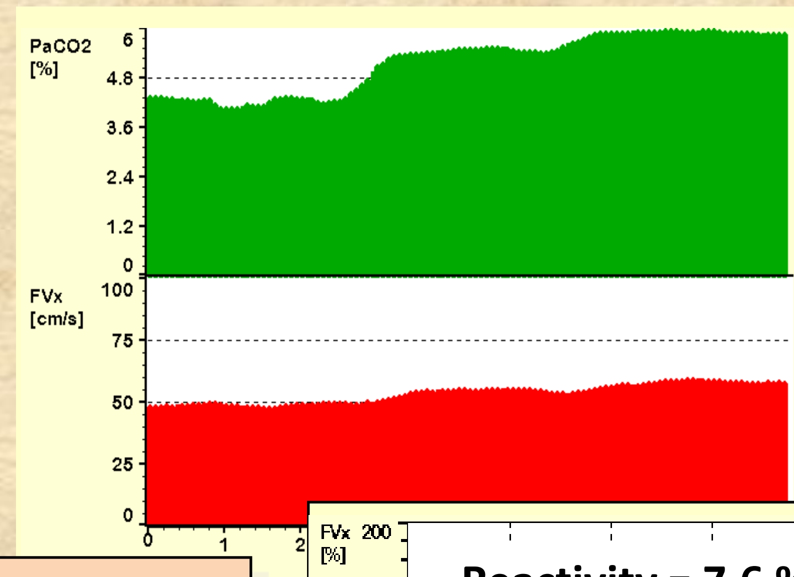
Thanks to Dr.P.Smielwski

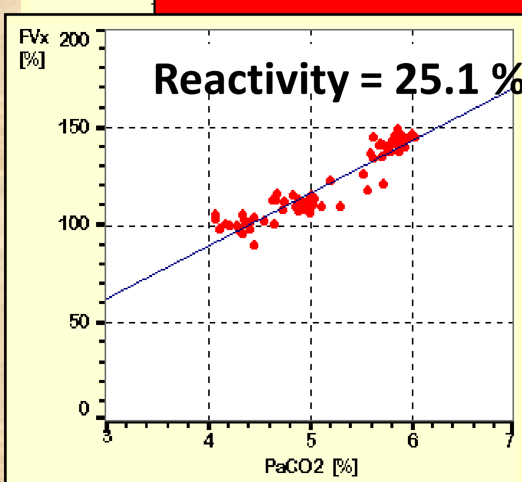
Thanks to Dr.P.Smielwski

CO_2 Reactivity Methods of assessment

Linear regression



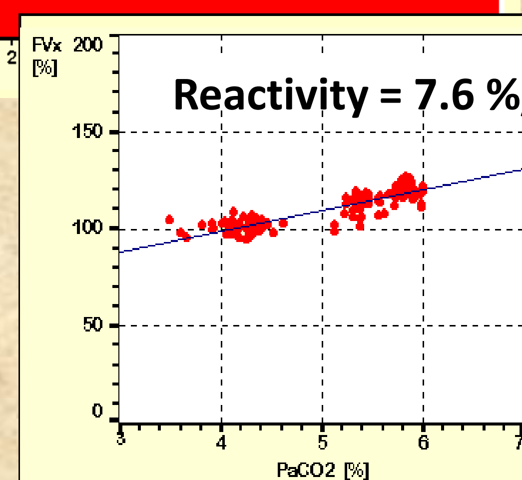




Reactivity = Slope of regr.

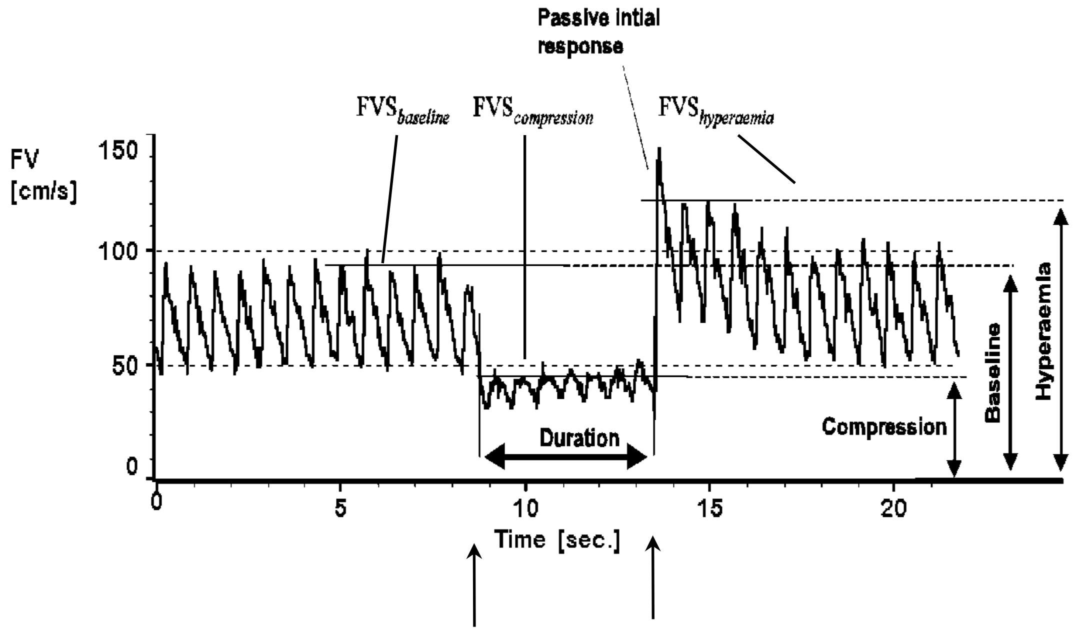
Normal values :

24 + 4.1 %/kPa



Transient Hyperaemic Response Test
Definition

Carotid compression



compression release

Transient hyperaemic response ratio

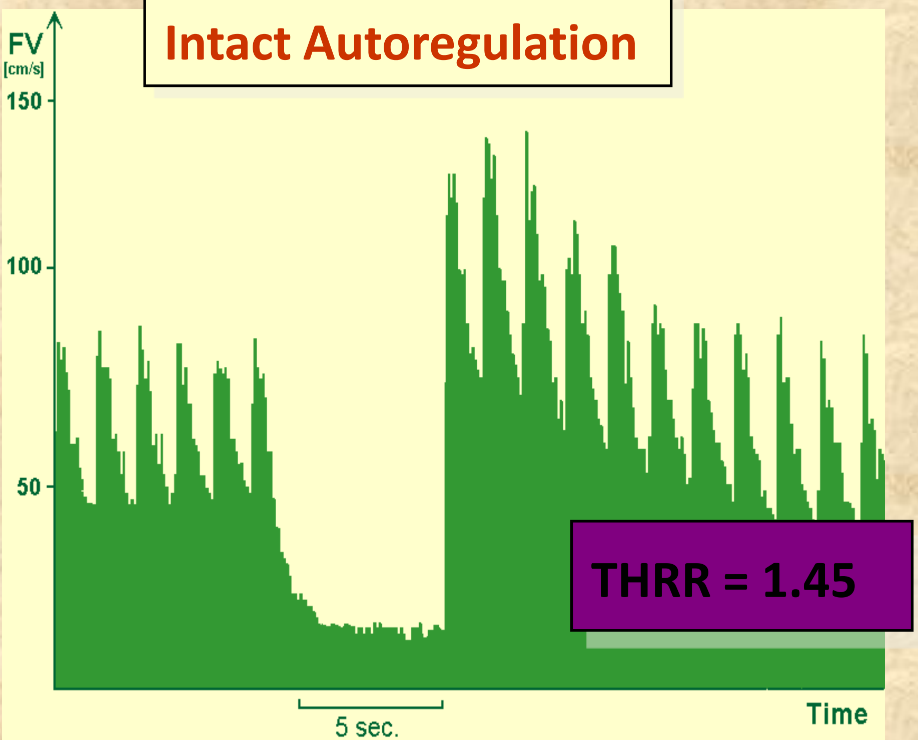
$$THRR = \frac{FVS_{hyperaemia}}{FVS_{baseline}}$$

Thanks to Dr.P.Smielwski

Transient Hyperaemic Response Test

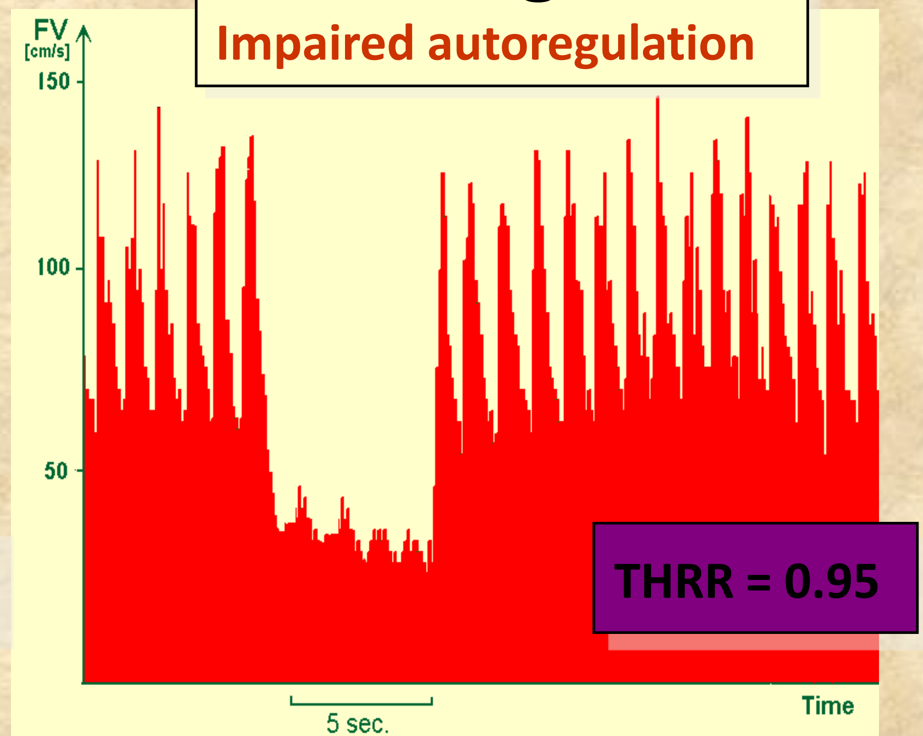
THRT Positive

Intact Autoregulation



THRT Negative

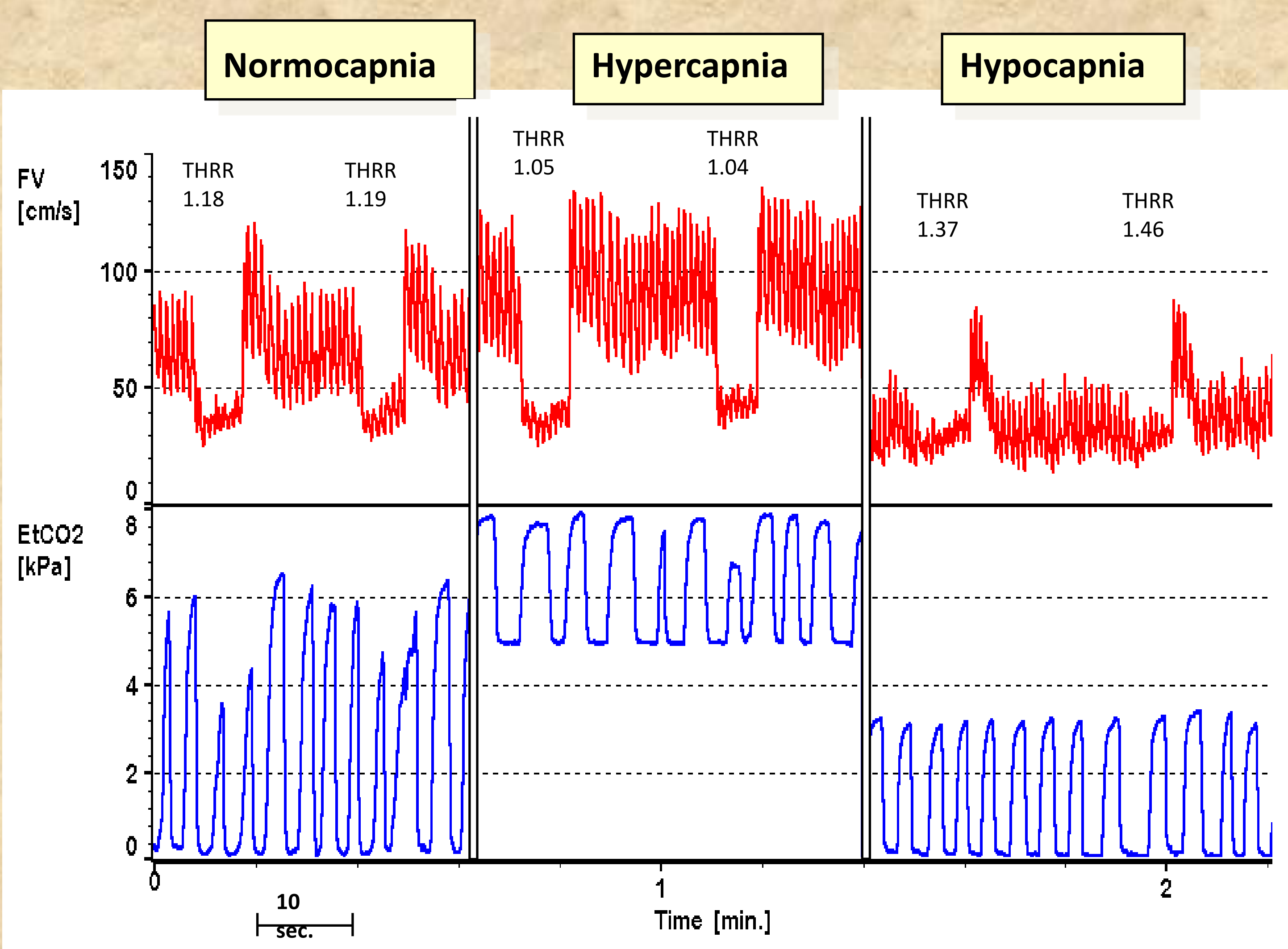
Impaired autoregulation



Thanks to Dr.P.Smielwski

Transient Hyperaemic Response Test Test

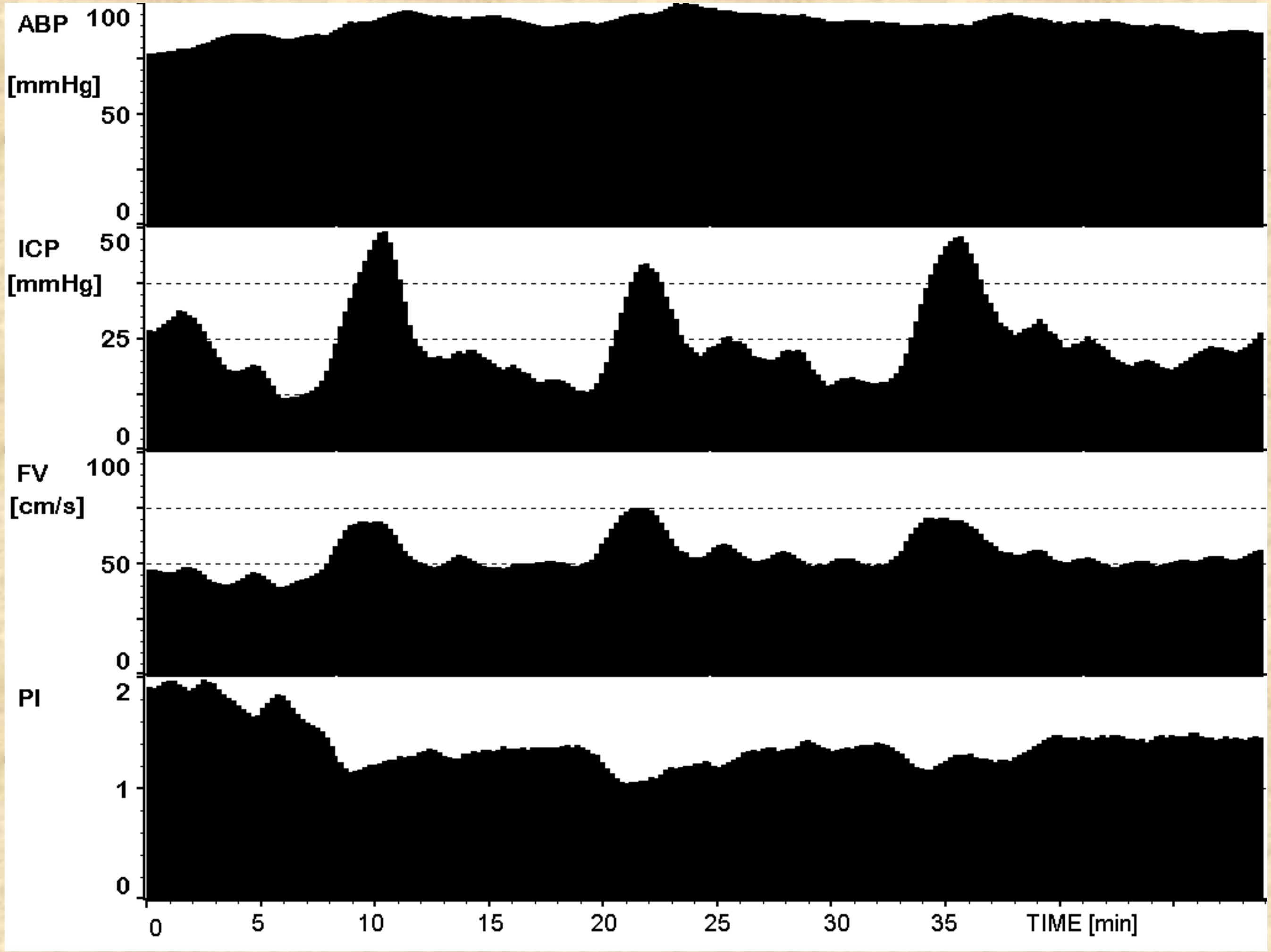
repeated at different CO_2 levels



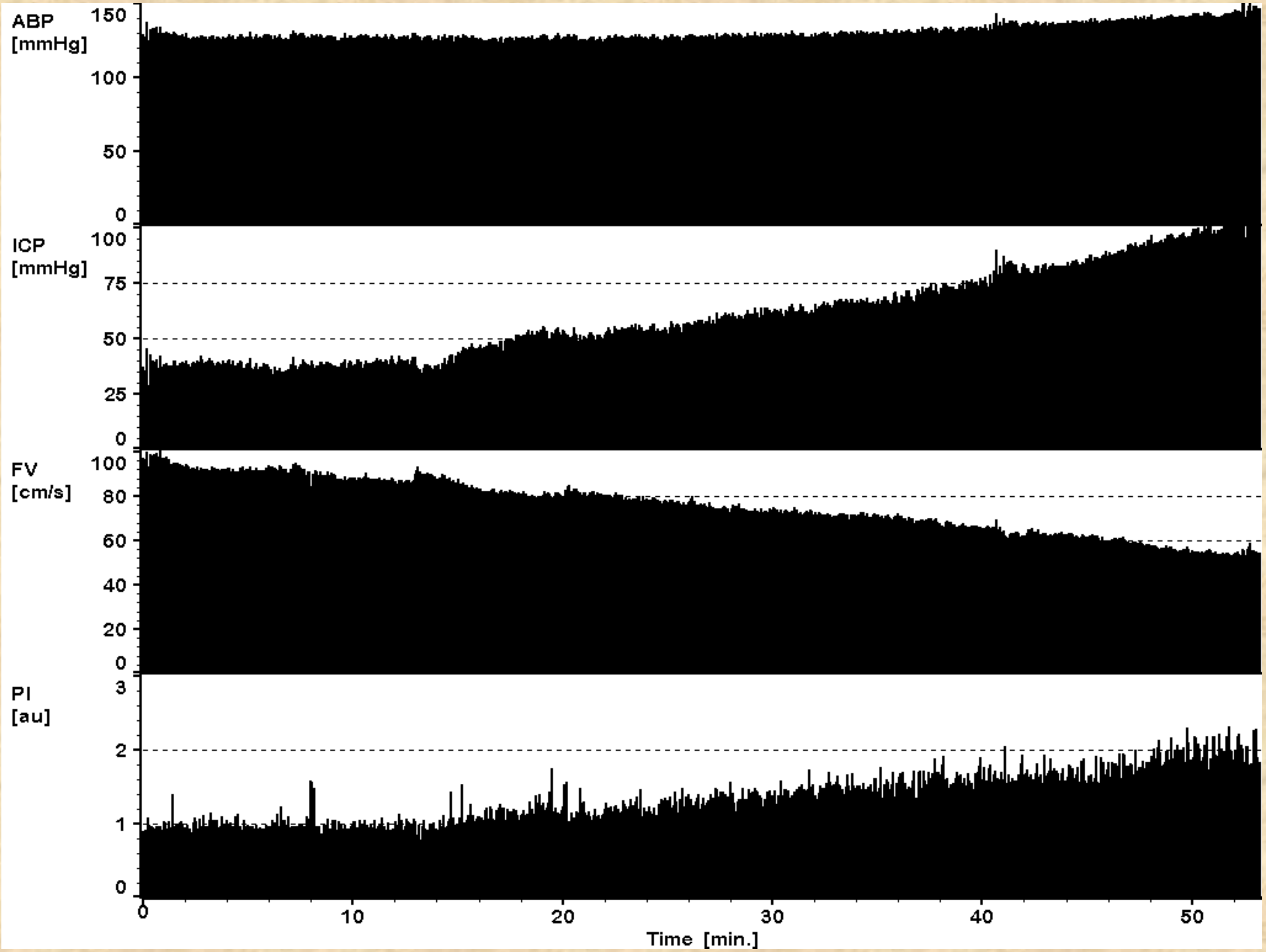
Thanks to Dr.P.Smielwski

Brain monitoring on NCCU

Continuous monitoring of CBF: 'Hyperaemic' waves of ICP



Refractory intracranial hypertension:



Multimodal CBF monitoring

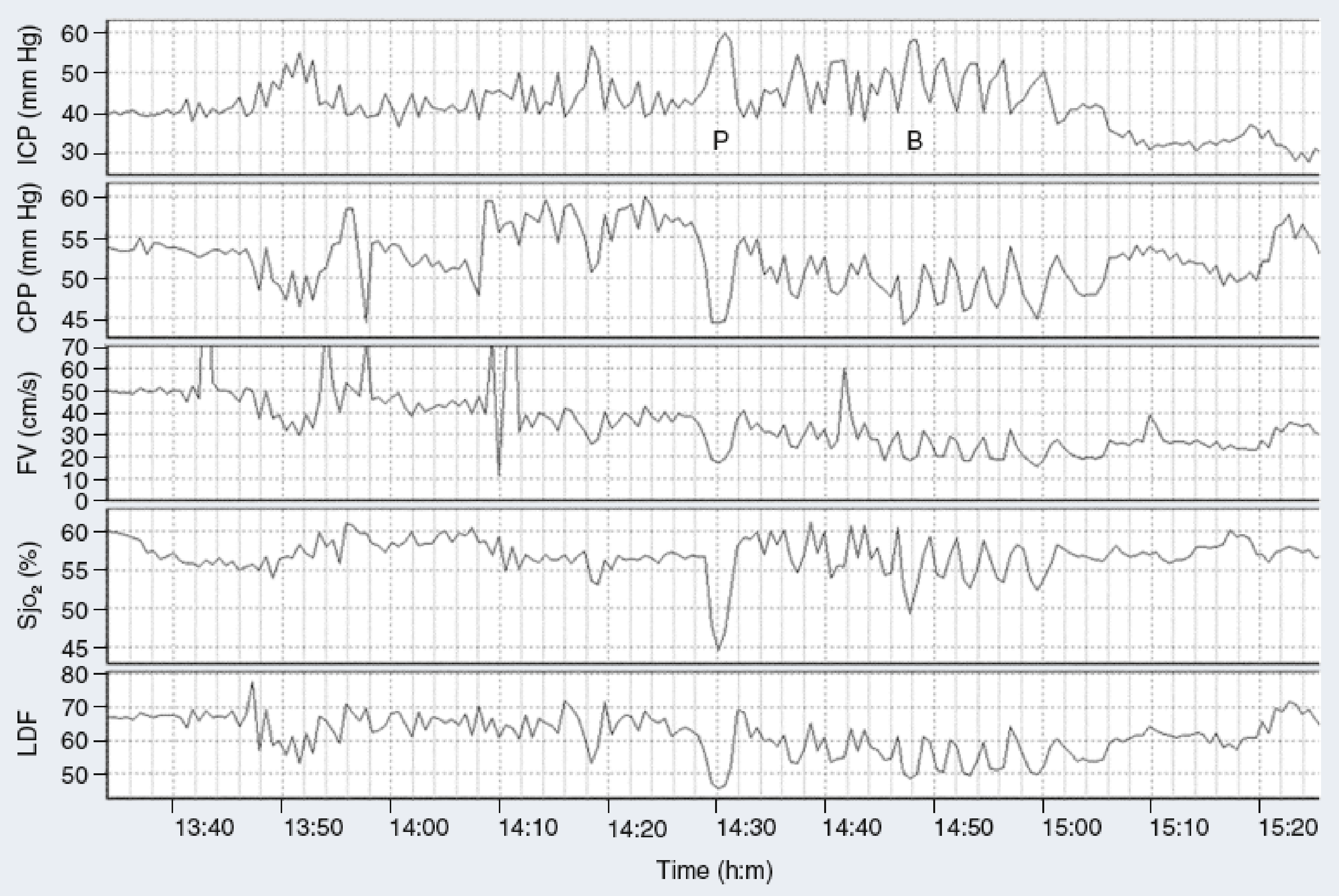


Figure 8–8 Recording of events characterized by intracranial hypertension in a head-injured patient receiving intensive care. Using multimodality monitoring makes it possible to identify the cause of this increase. Increase in intracranial pressure (ICP) (plateau wave [P]) is secondary to a fall in cerebral perfusion pressure (CPP), as the blood velocity (FV), the jugular bulb oxygen saturation values (Sjo_2) and cortical blood flow (LDF, in arbitrary units) also fall, indicating hypoperfusion. Repetitive vasogenic waves of ICP (B waves [B]) are secondary to fluctuations of cerebral blood flow as Sjo_2, and FV, and LDF increase and decrease in phase with ICP.

Laser Doppler Flowmetry

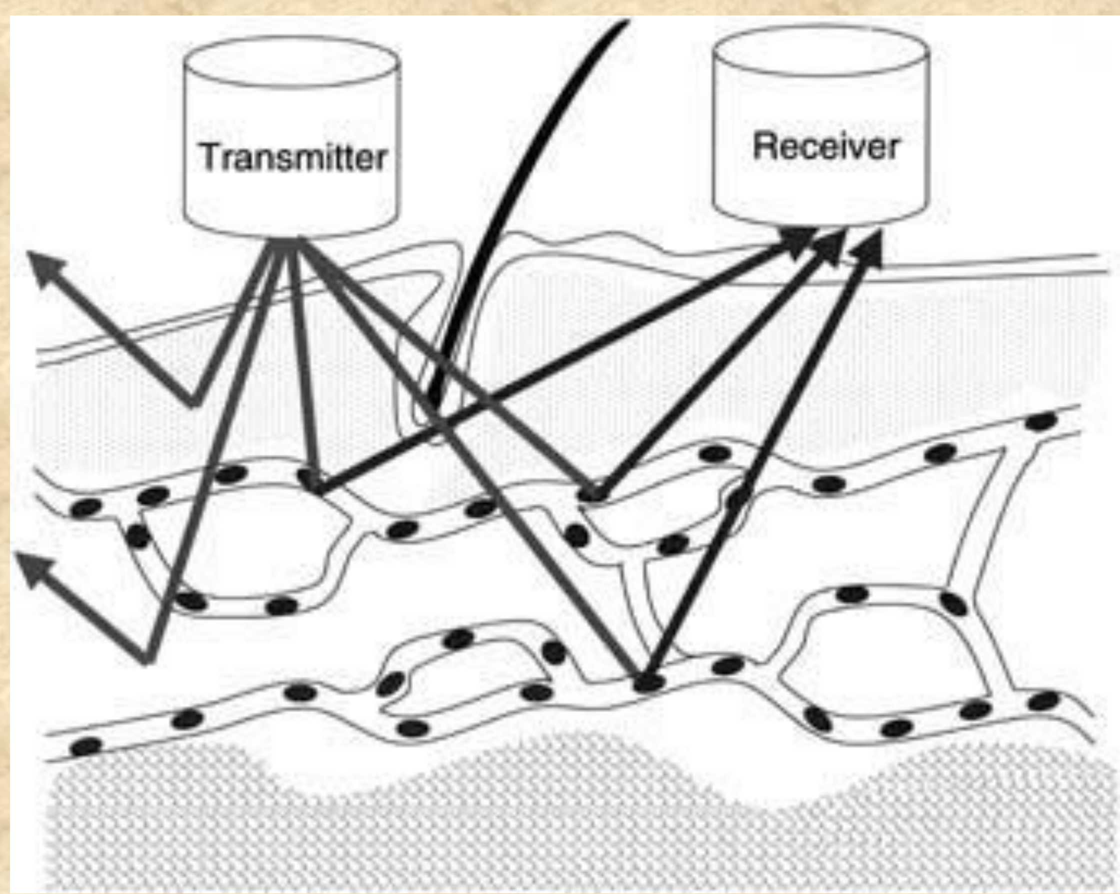
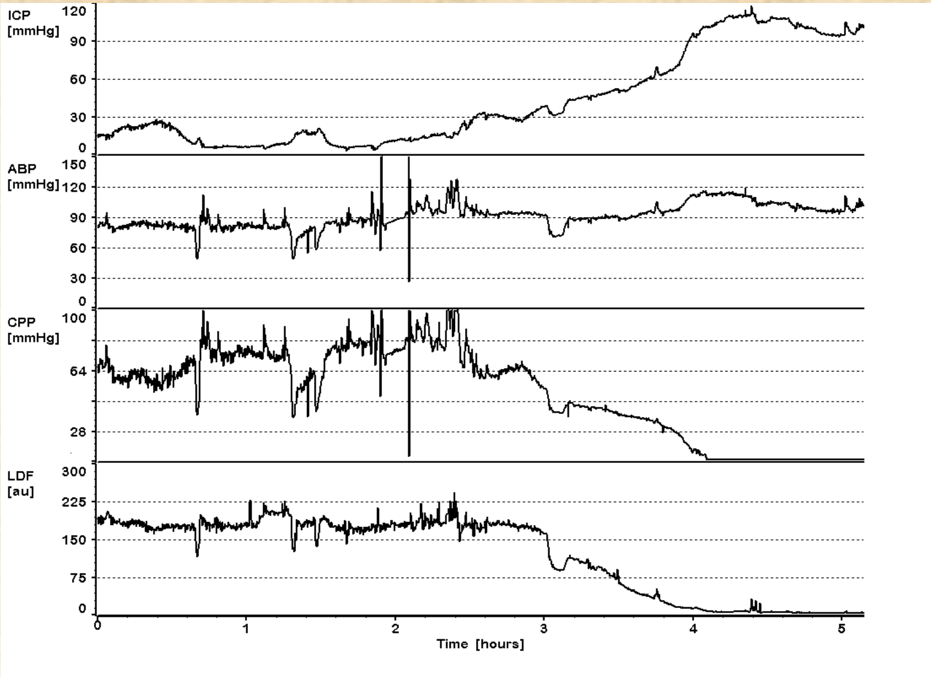
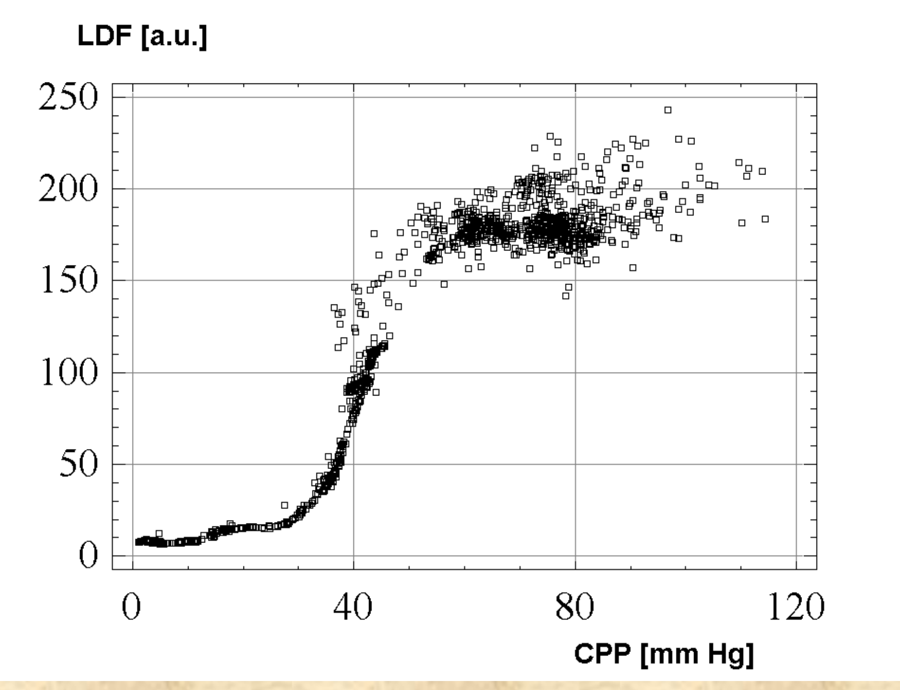


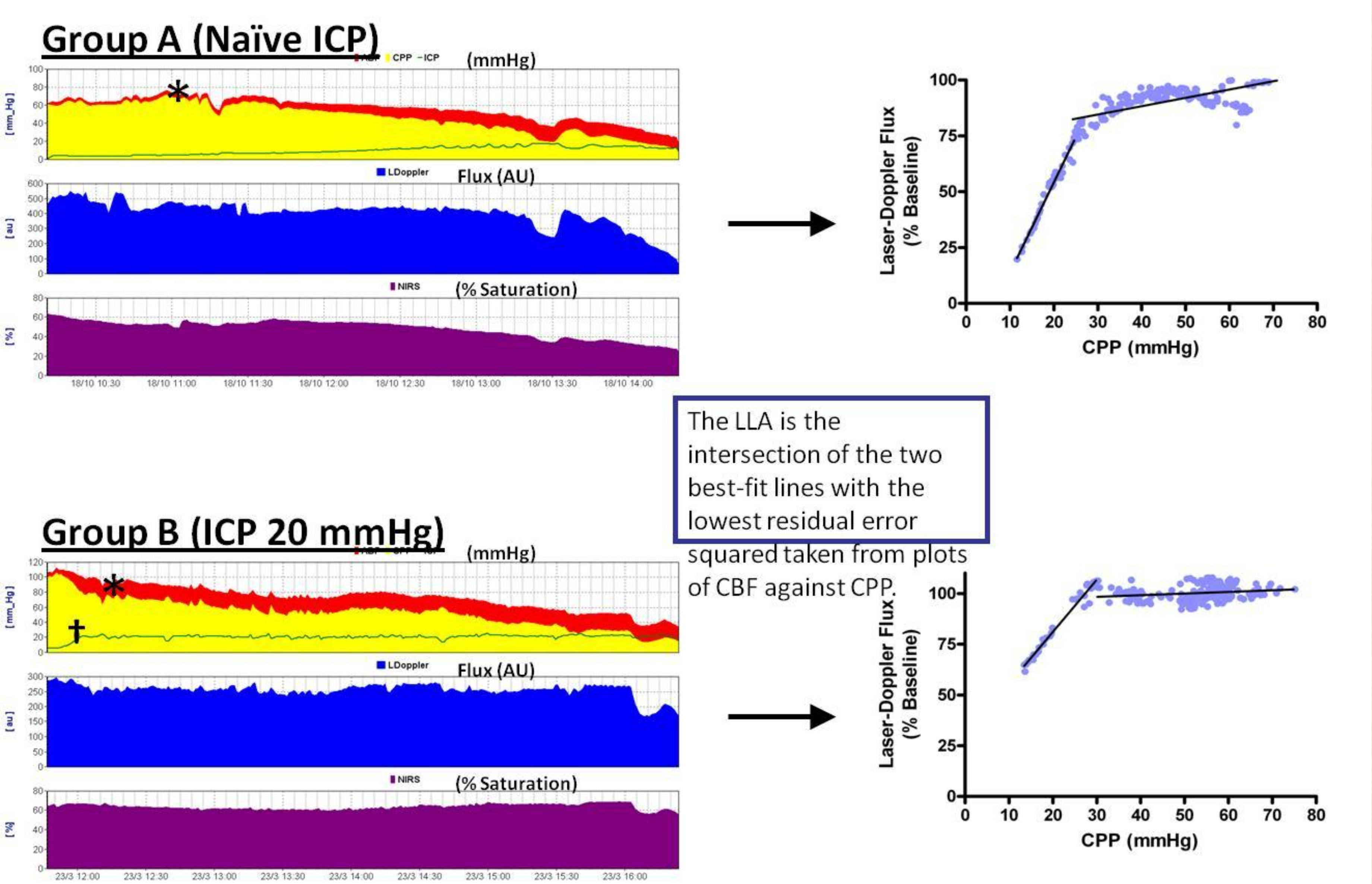
Figure 1 Basic operating principles of laser Doppler flowmetry. A laser beam is directed to an area of tissue. Upon contact with red blood cells in the target tissue, light waves are reflected and scattered, resulting in broadening of the light wave frequency, which is detected and received by a photodector.

Clinical monitoring of rCBF using LDF





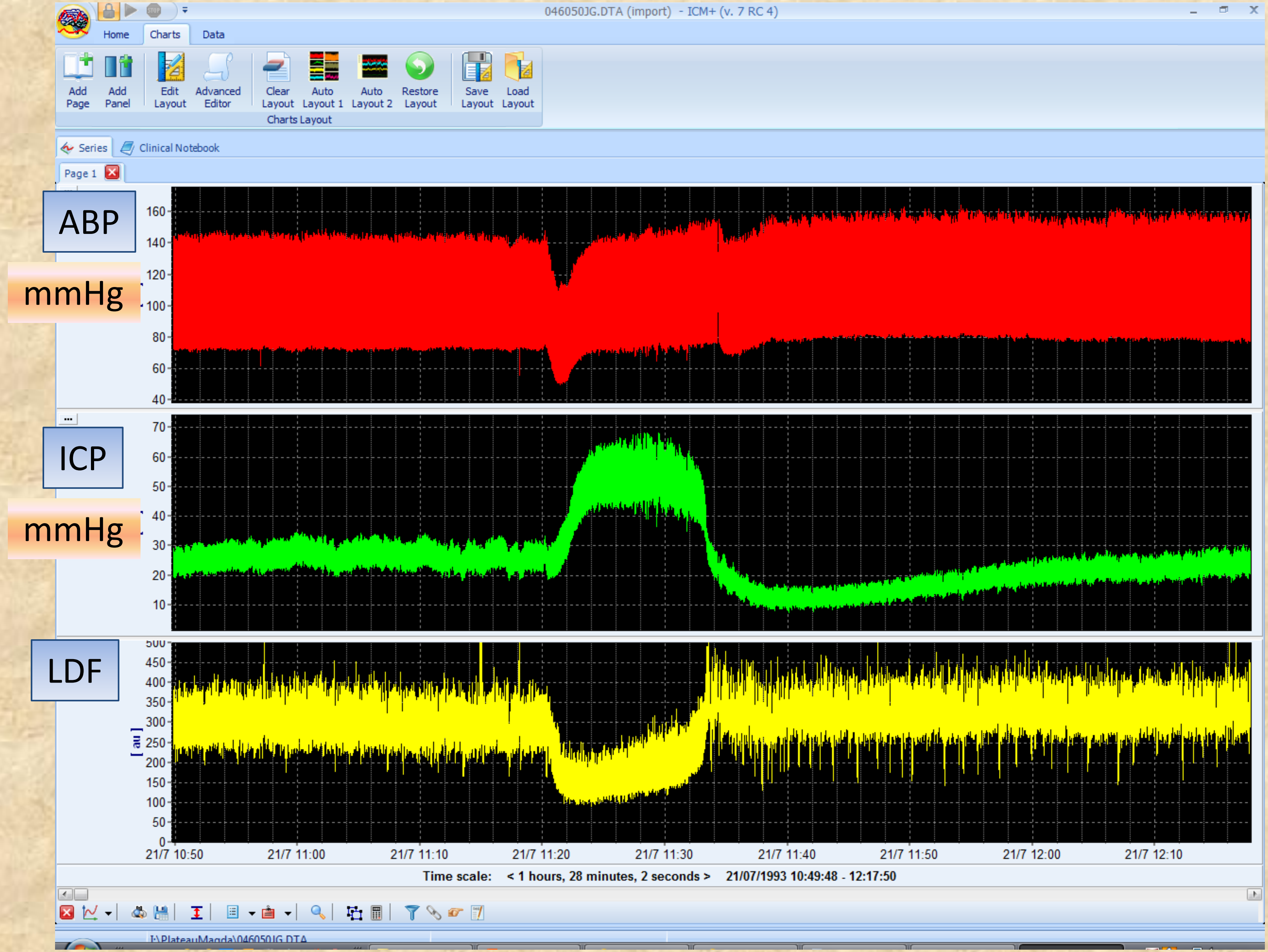
Experimental monitoring



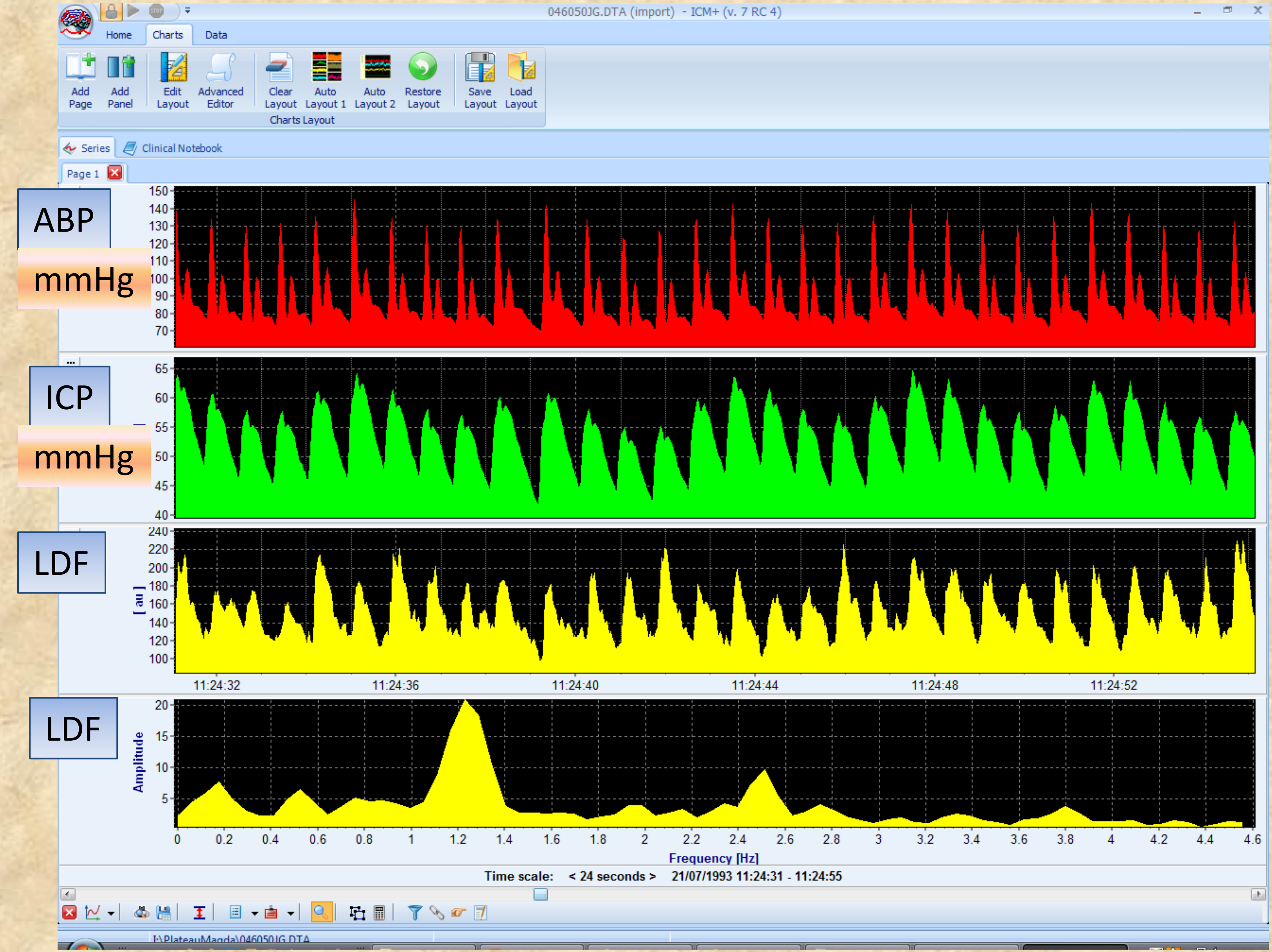
The LLA is the intersection of the two best-fit lines with the lowest residual error squared taken from plots of CBF against CPP.

Thanks to Dr. K.Brady

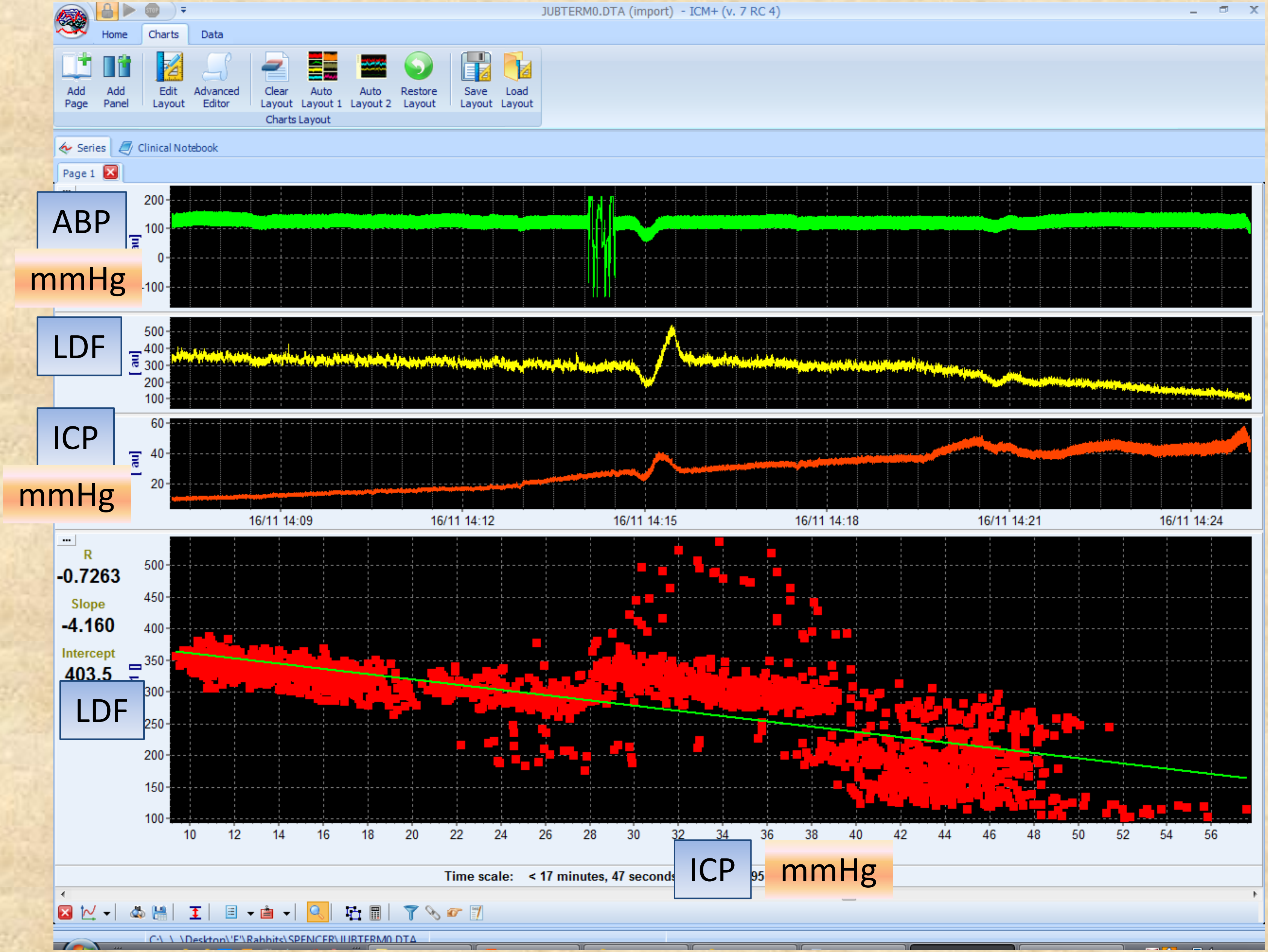
LDF flux during plateau elevation of ICP

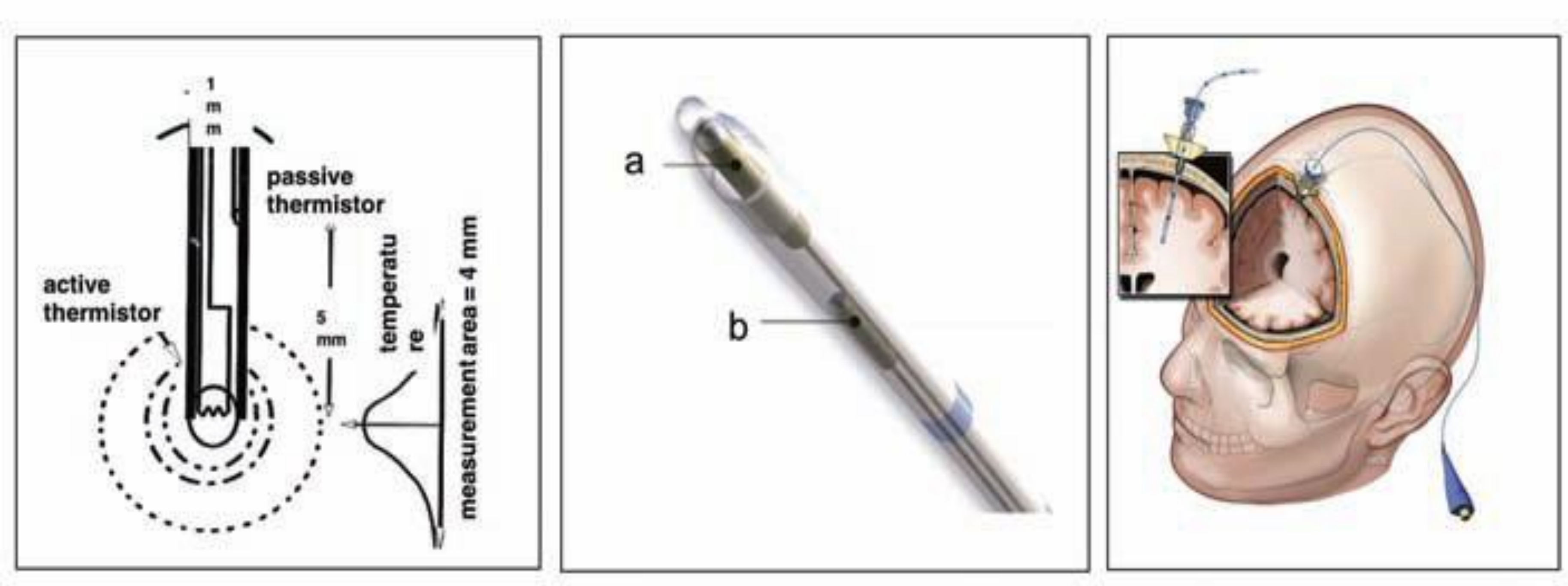


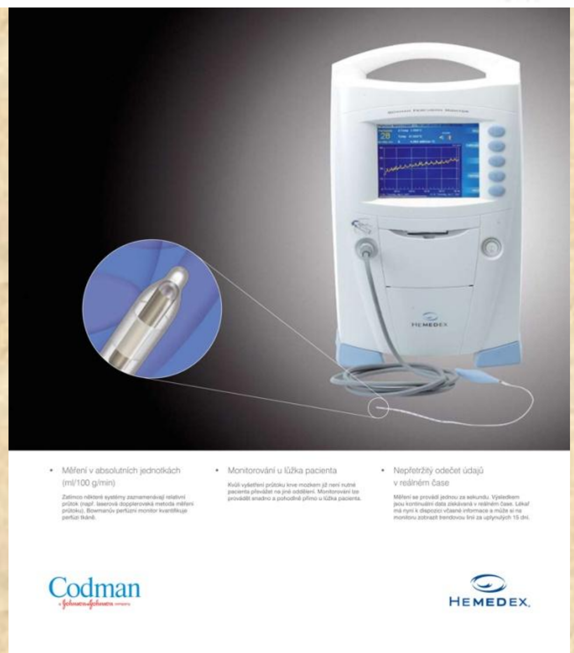
‘Pulse wave’ of LDF flux



LDF during refractory elevation of ICP

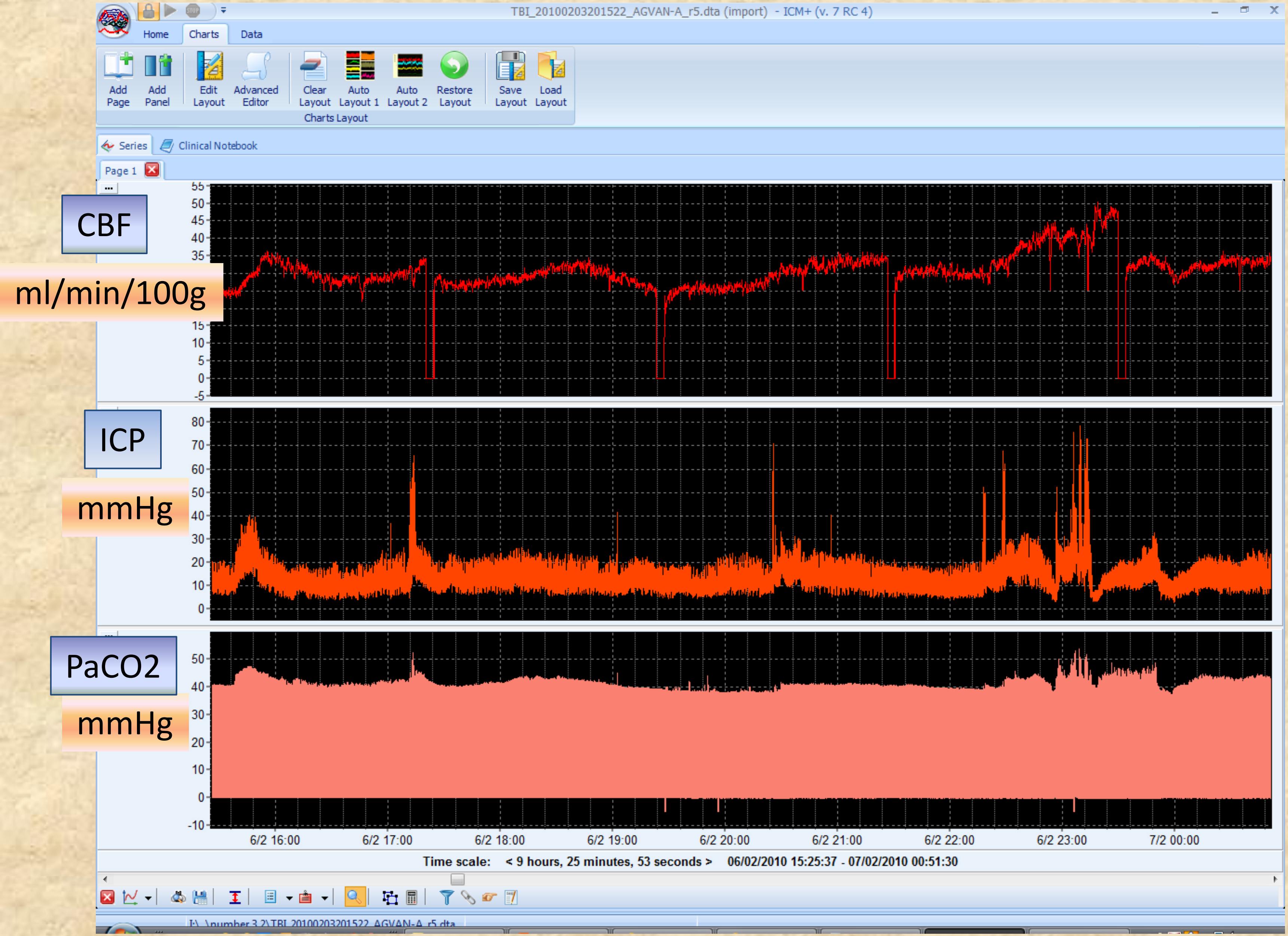






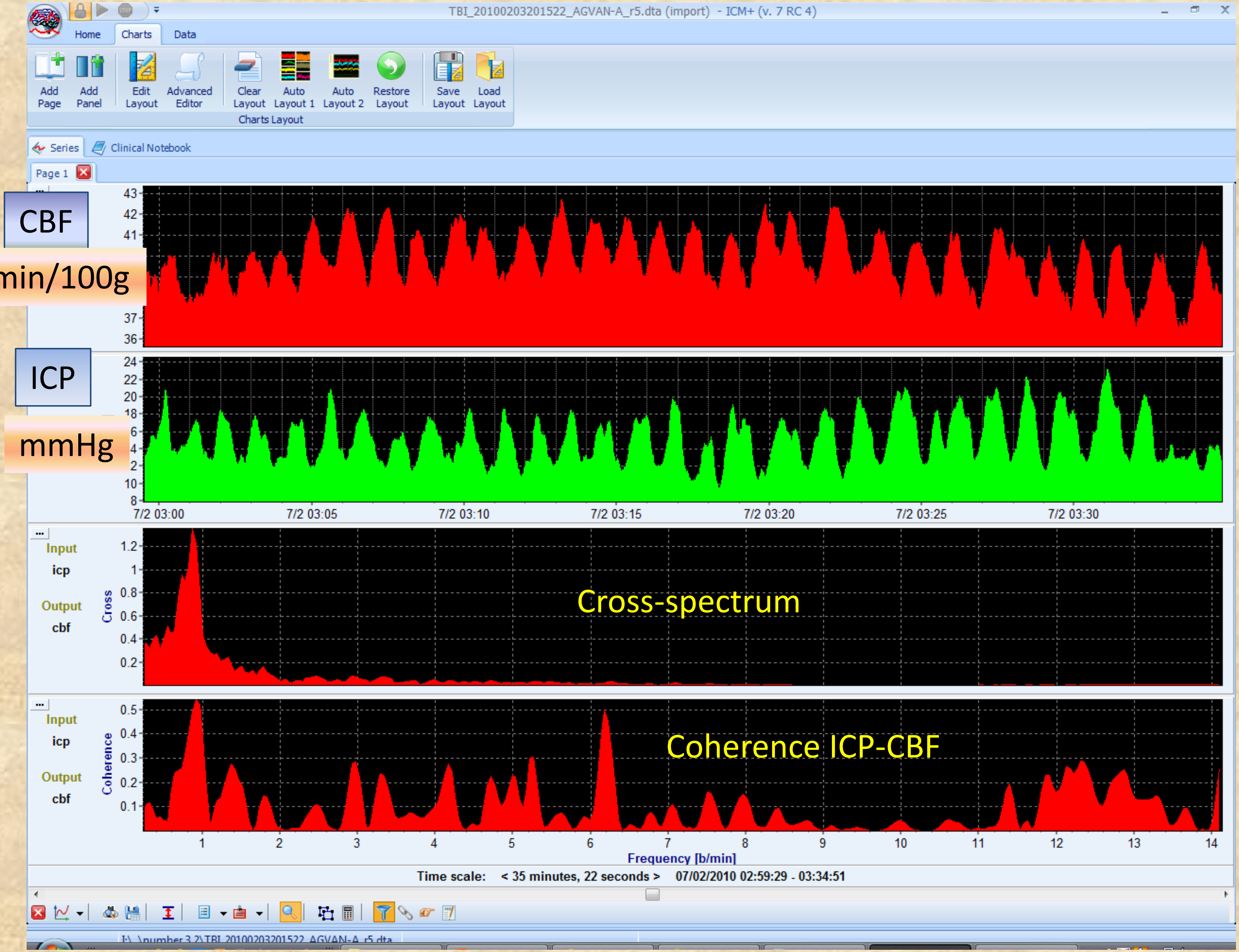
Hemedex- rCBF measurement using thermal dilution method

Changes in Hemedex CBF related to changes in EtCO2

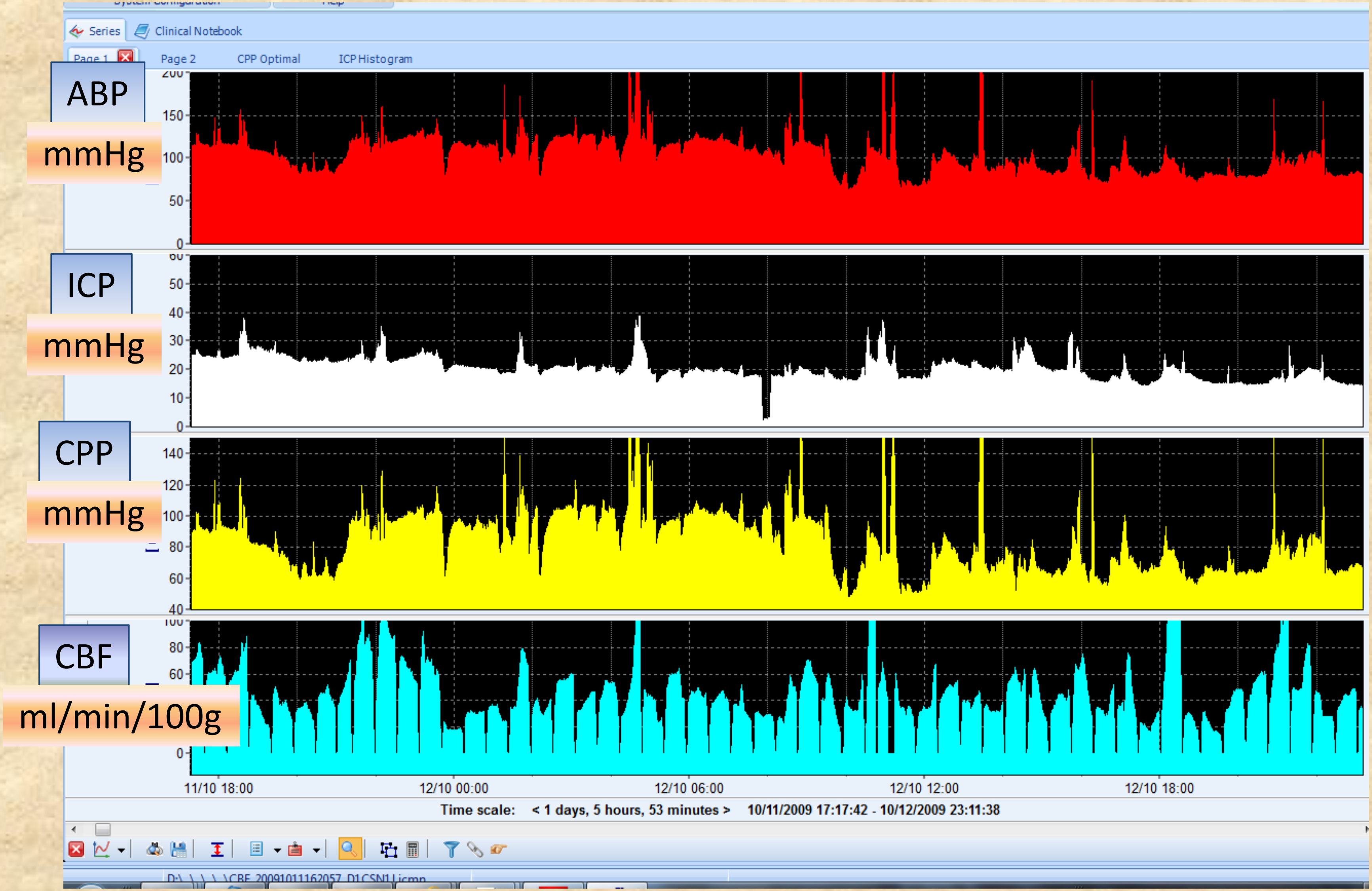


Thanks to Dr A.Oshorov

Slow waves in Hemedex CBF and ICP



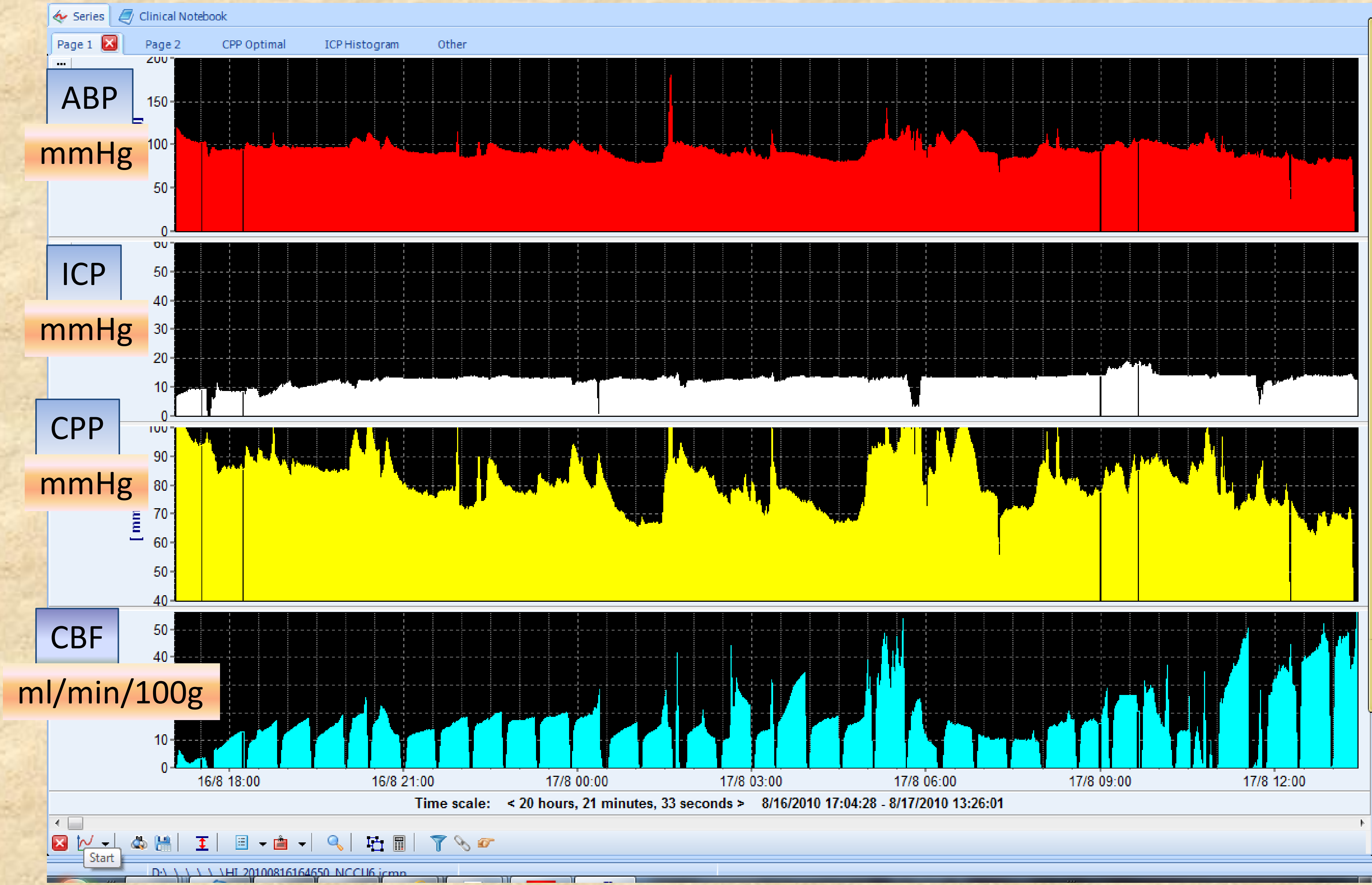
Head injury- CBF fluctuates independently on CPP



But not always: example of homogenous Lassen's curve; 3 days monitoring , TBI

Thanks to Dr. N. De Riva Solla

Calibration gaps- main source of variation in measured CBF



Typical…

Thanks to Dr. N. Der Riva Solla

Message to take home

TCD- non-invasive, indirect and difficult in continuous monitoring
TCD- information included in mean velocity and waveform
TCD- very good dynamical response

LDF- invasive, indirect
LDF- rarely used in clinical practice
LDF- biological zero

Hemedex- invasive, direct
Hemedex- lot of fluctuations which seem to be artificial