

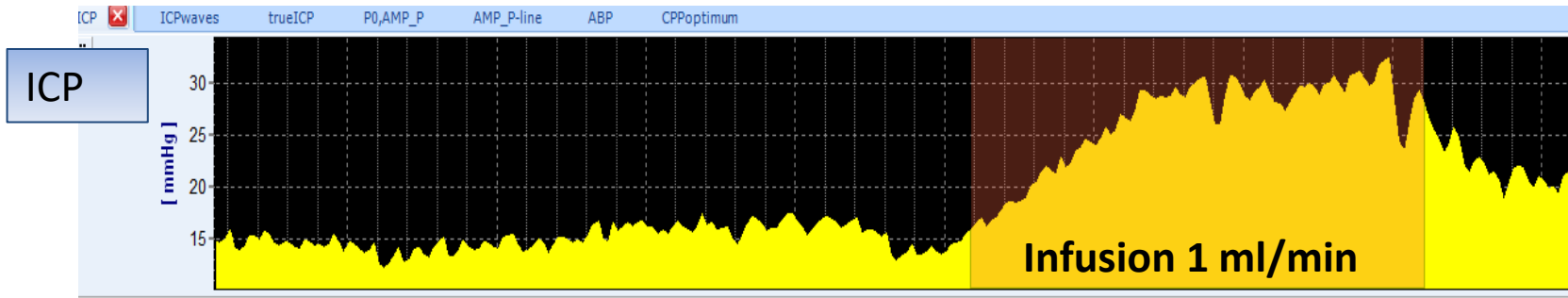
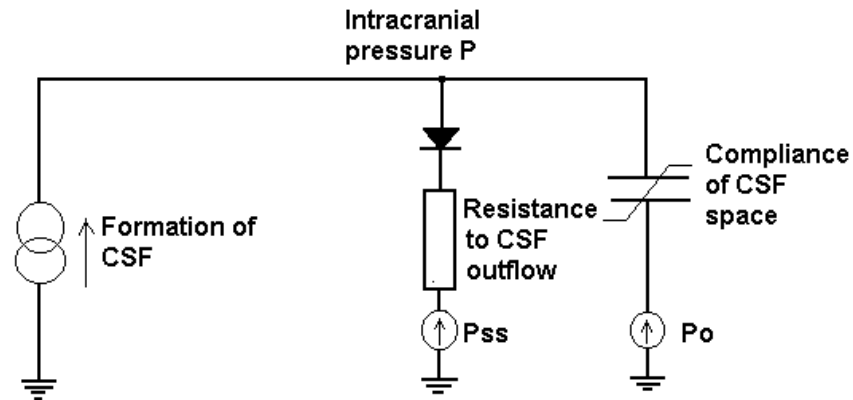
How I do infusion test.

Dr Zofia H. Czosnyka

University of Cambridge, UK



Infusion test: procedure to identify model of CSF compensatory reserve introduced in 1973 by Anthony Marmarou. Essential parameters: Resistance to CSF outflow and compliance of CSF space

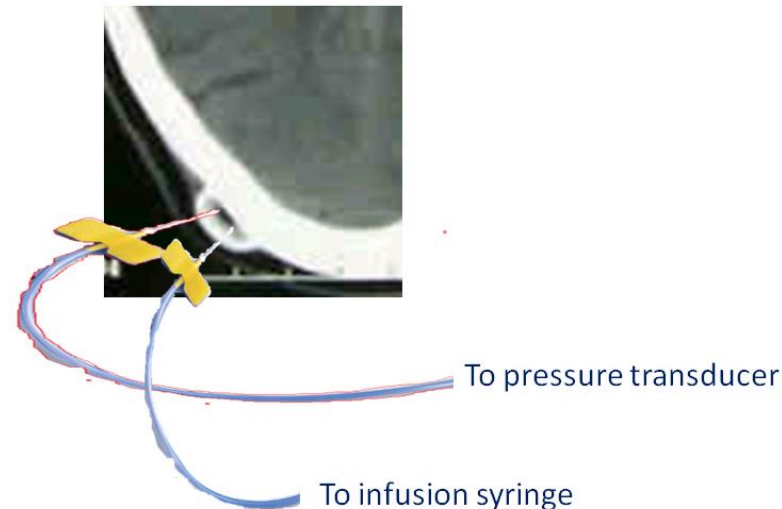


TIME ~30 minutes

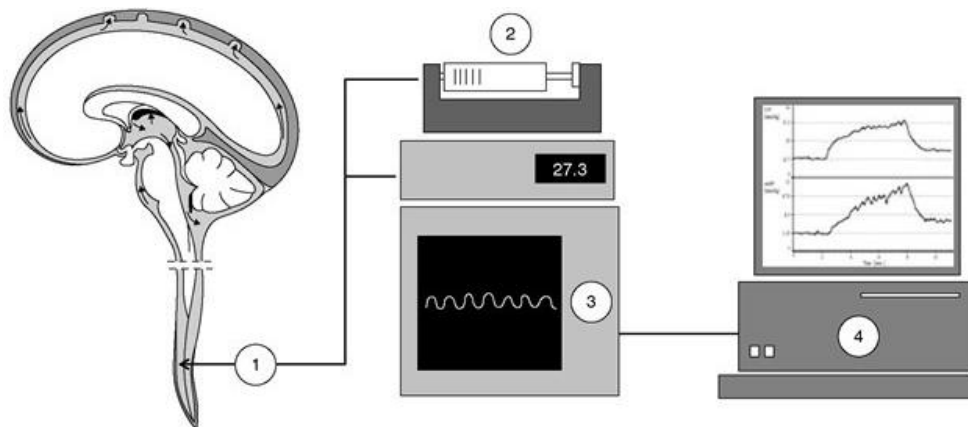
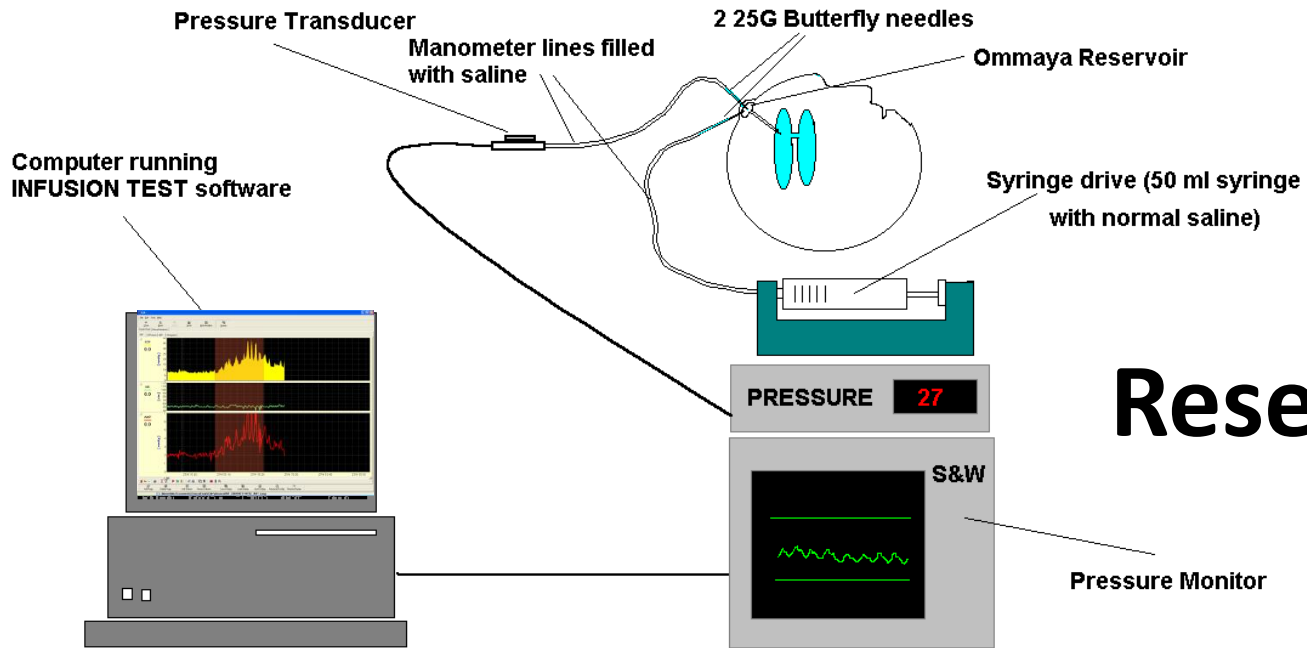


What we need?
Hardware
Pressure transducer,
tubing, needles

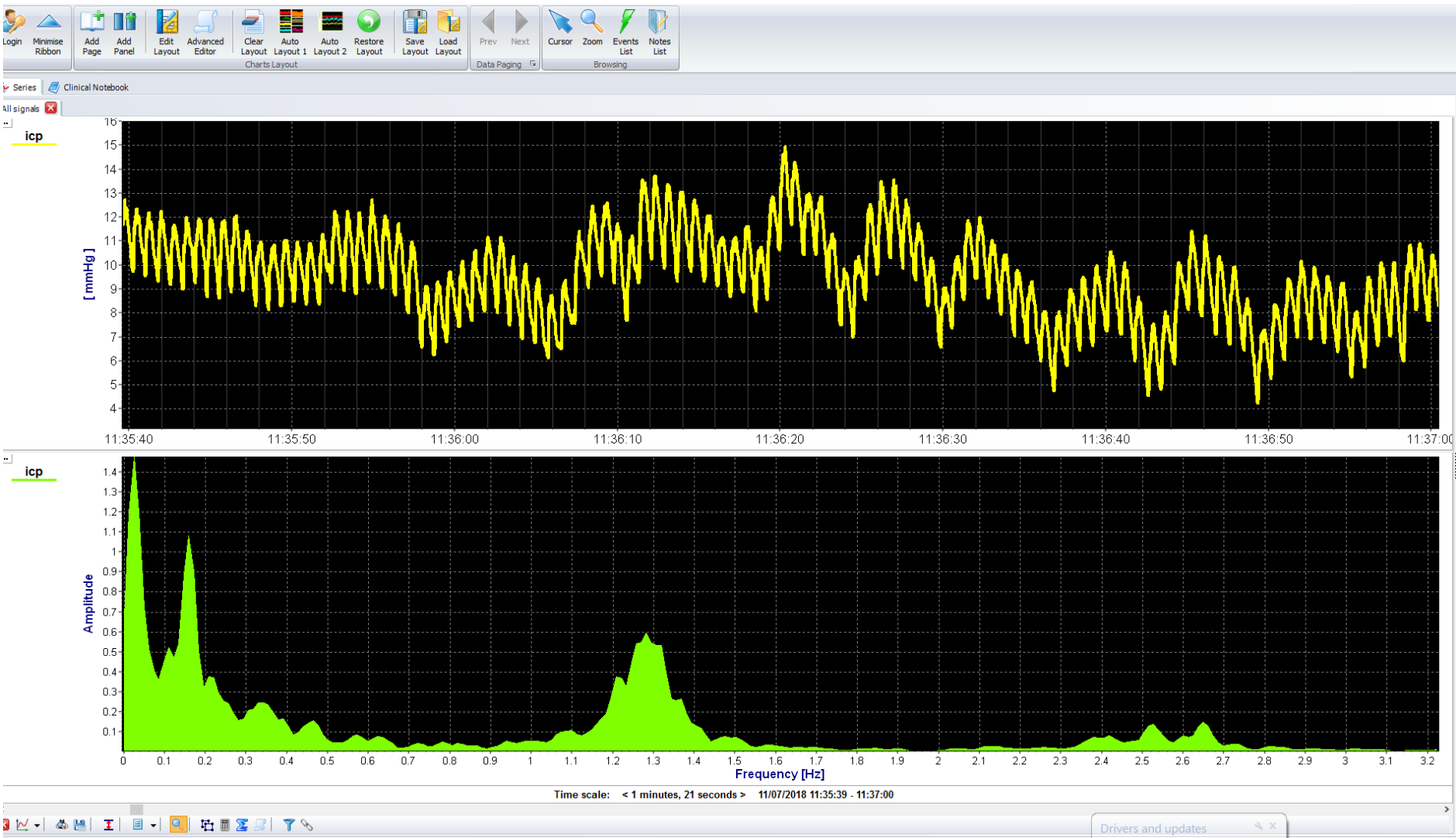
Essential: **sterile preparation** of
transducer and tubing



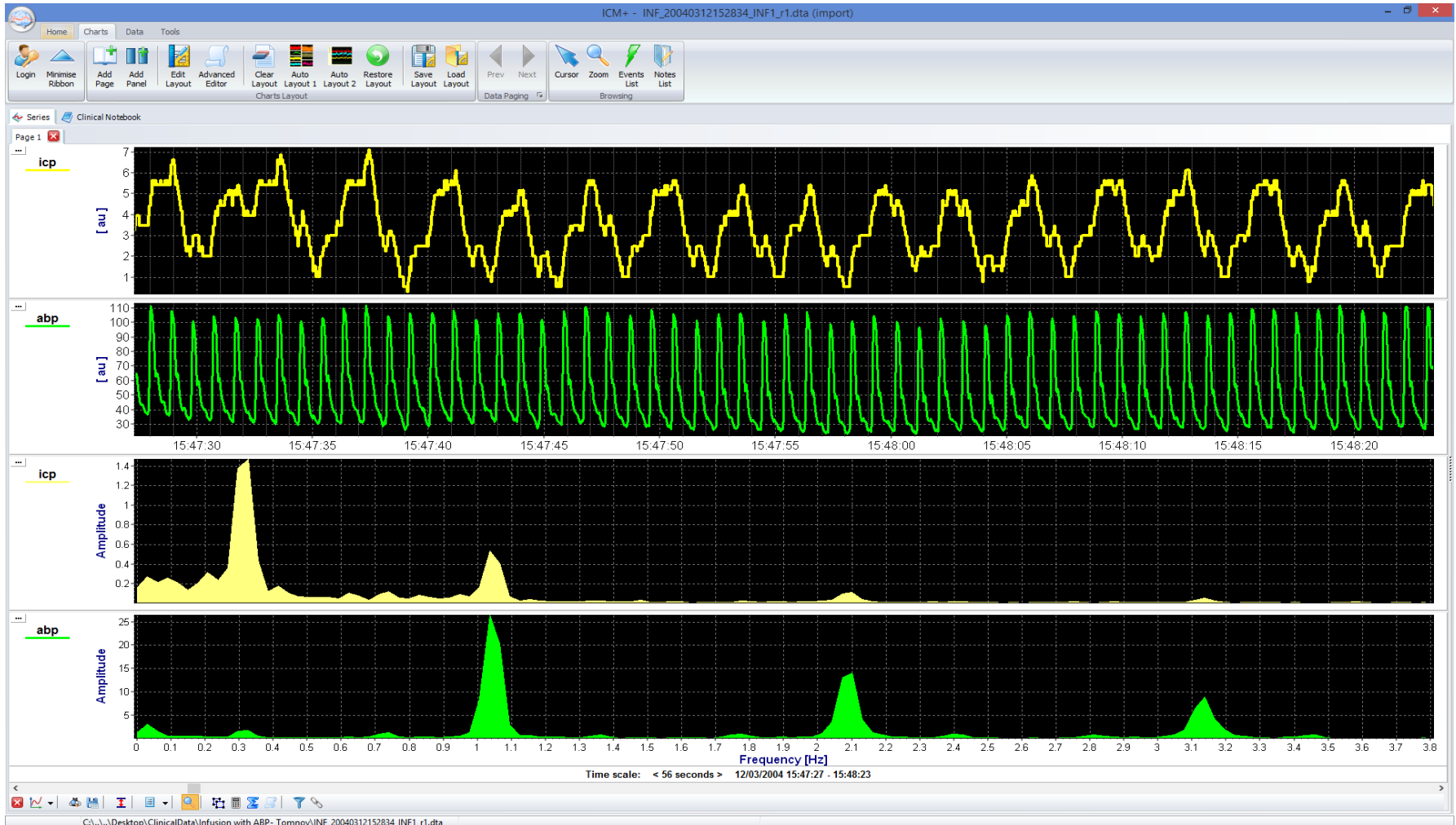
Measurement set-up



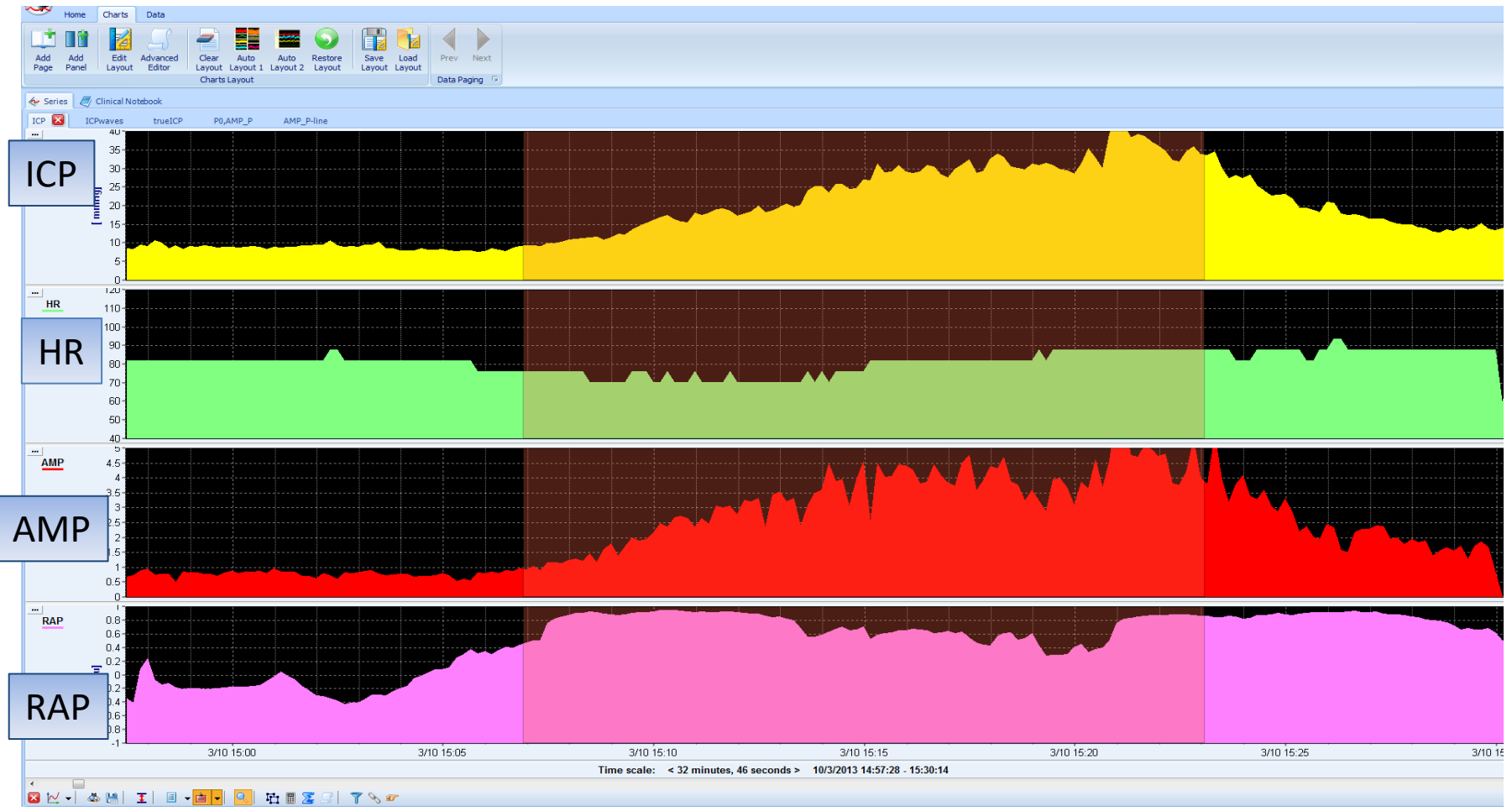
Checking the waveform of ICP signal



When the pulse waveform is weak,
looking at the **spectrum of ABP** helps

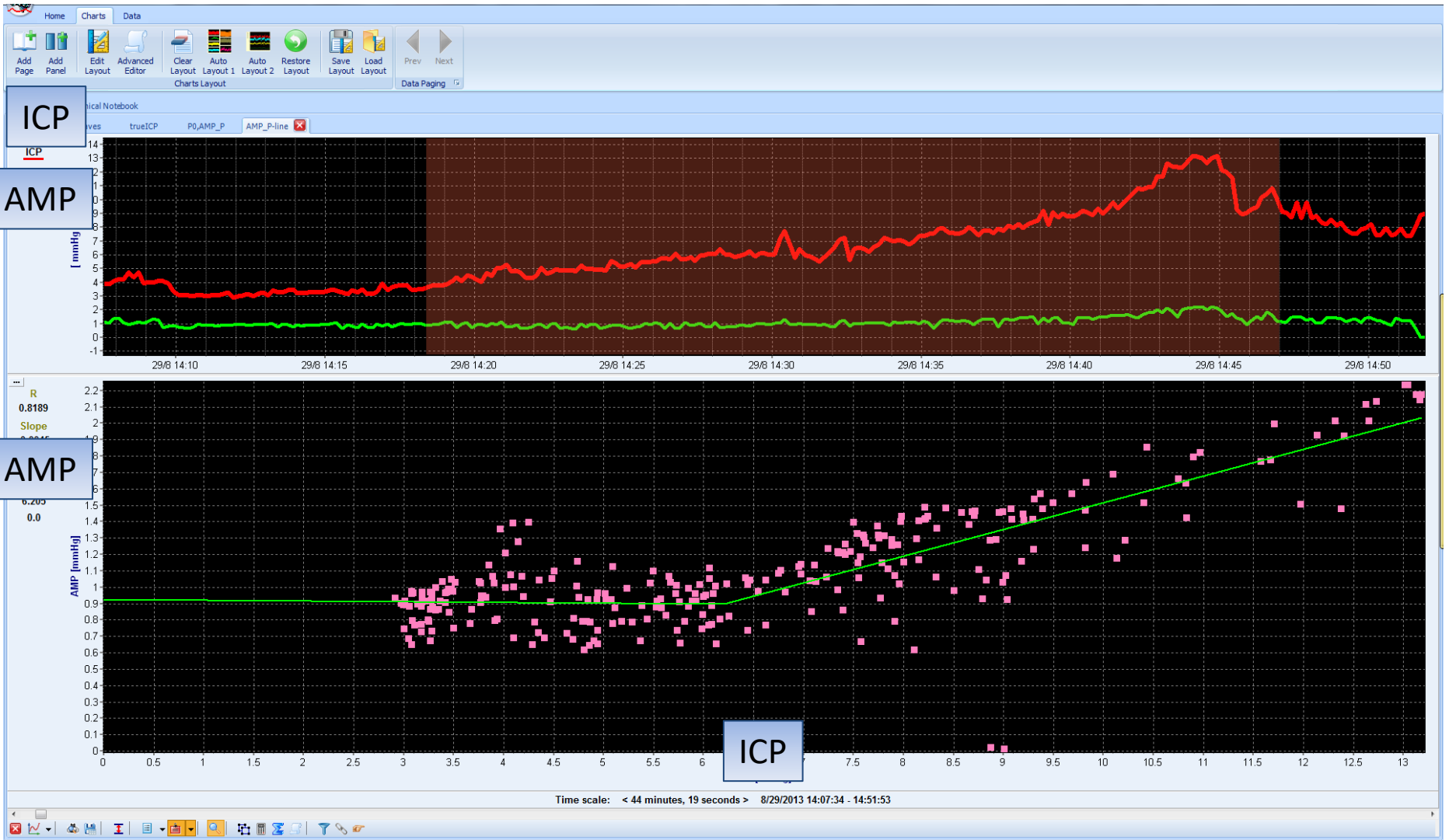


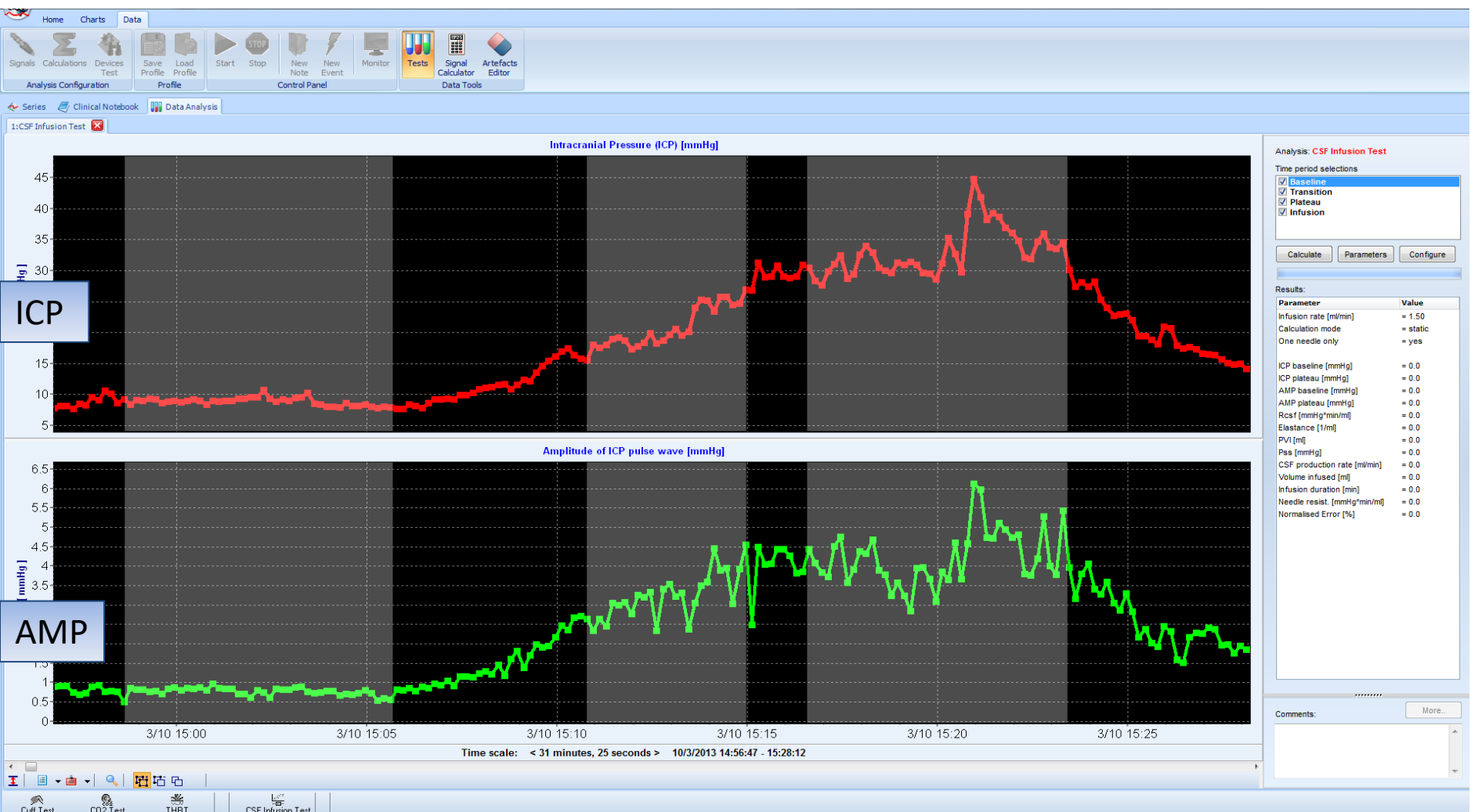
INFUSION TEST



Real time observation of trends of mean ICP, heart rate, pulse amplitude of ICP and RAP index during the study.
Always mark start, end of infusion!

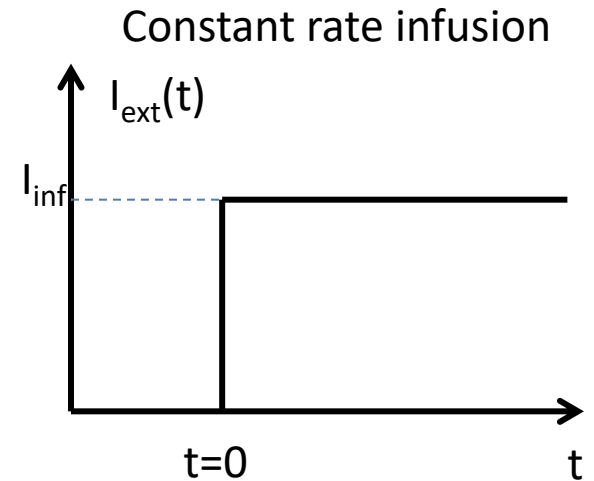
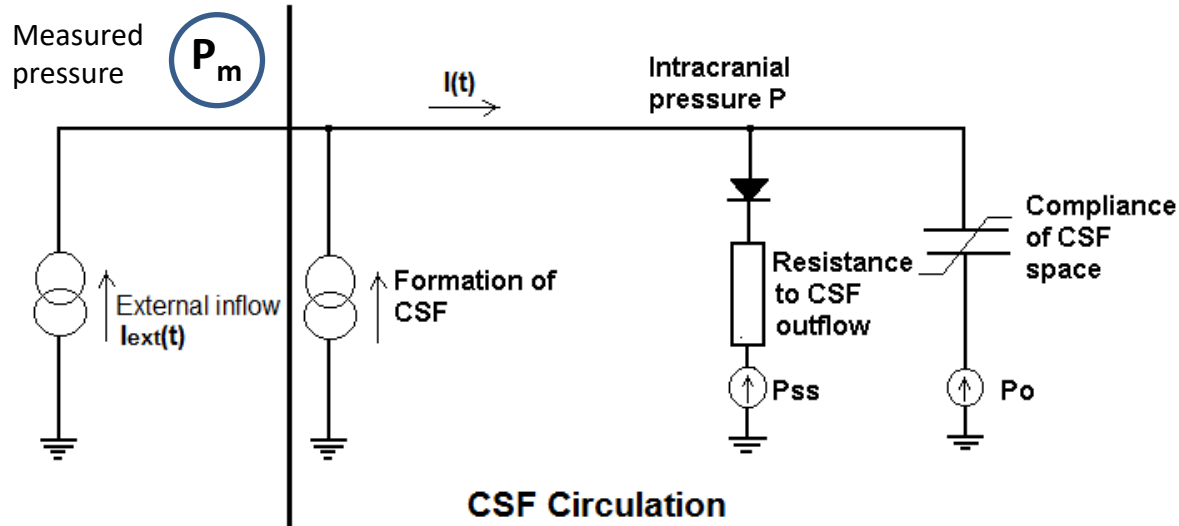
Lower breakpoint of AMP-P characteristic





After study is finished: **Analysis of the Marmarou model**
First: mark baseline, transition and end-plateau periods.
Introduce infusion rate and press 'calculate'

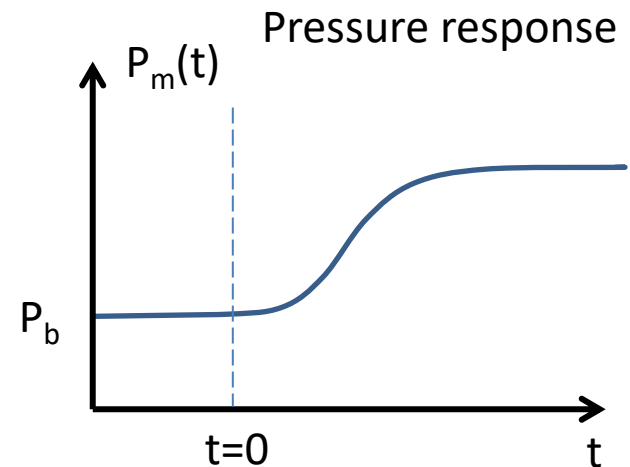
Constant rate CSF infusion challenge



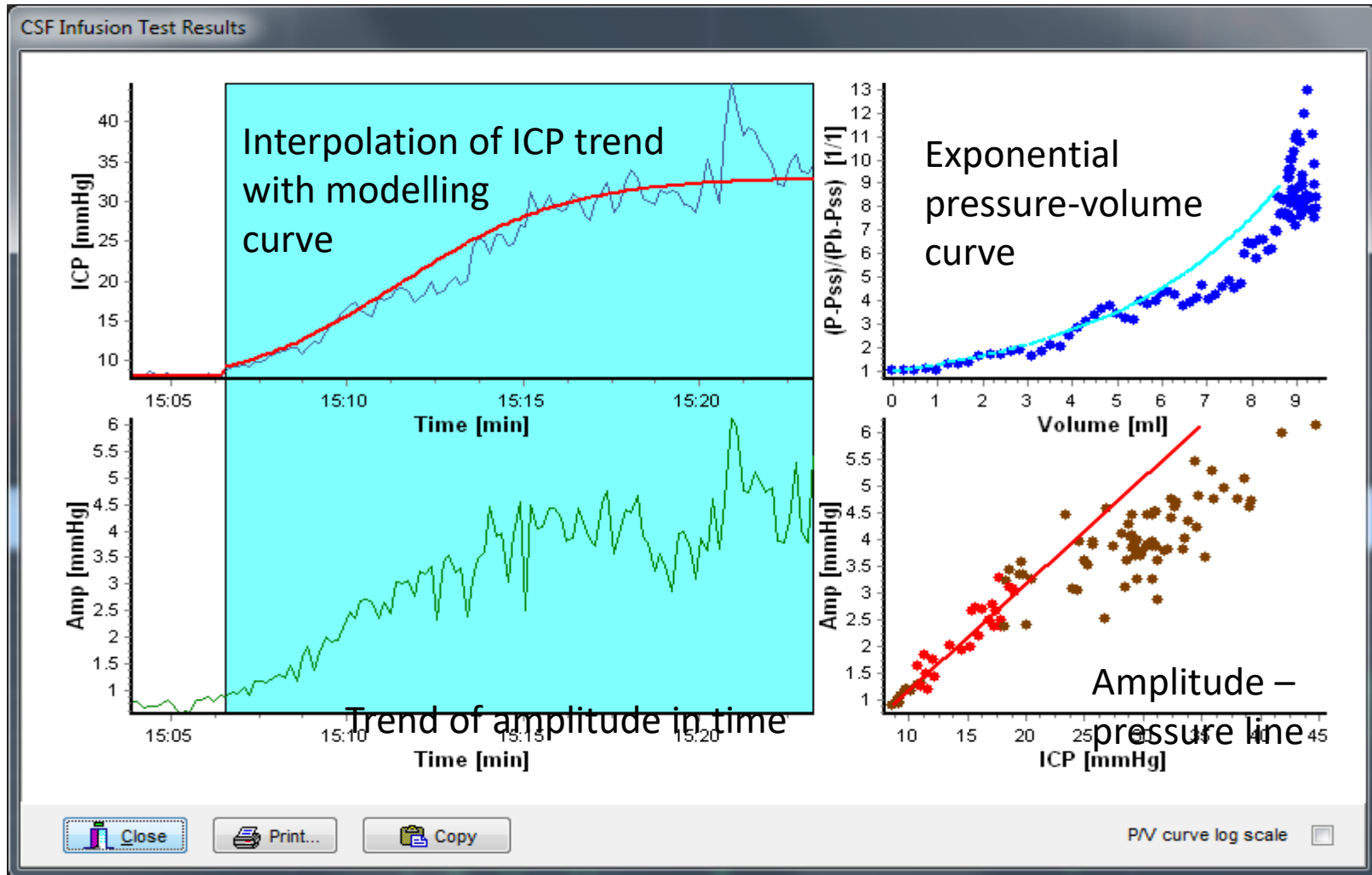
$$I_{ext}(t) = \frac{1}{E * (P - P_0)} * \frac{dp}{dt} + \frac{P - P_b}{R_{csf}}$$

$$I_b = \frac{P_b - P_{ss}}{R_{csf}} \quad P_{ss} \approx P_0$$

$$P_m(t) = \frac{(I_b + I_{inf}) * (P_b - P_0)}{I_b + I_{inf} * e^{-E * (I_b + I_{inf}) * t}} + P_0$$



Click 'more' and you see:



I use this screen to assess visually **quality of identification** of the model

The screenshot shows a software interface with a top navigation bar (Home, Charts, Data) and a toolbar with icons for Signals, Calculations, Devices Test, Save Profile, Load Profile, Start, Stop, New Note, New Event, Monitor, Tests, and Signal Calculator. Below the toolbar are tabs for Series, Clinical Notebook, and Data Analysis. The main content area is divided into sections: Demographics, Project Data, Copy Notes, One Column, Sections, Fonts, and Tabs. The 'Project' section includes a 'Patient description' with fields for Name, Surname, DateOfBirth, DateOfIctus, MidInitial, HospitalNo, Sex, and DateOfAdmission. The 'Clinical background' section contains text about NPH?, Prkinson's disease, Type II diabetes, Hypertension., Macular degeneration (register blind), deaf, Slurred speach, urinary incontinence, cognitive decline, mobilised with a frame. ventriculomegaly, significant white matter changes. Lumbar study , one pink needle. ndrVenessa. Patientis mooving. The 'Tests Results' section includes a sub-section '[CSF Infusion Test]' with a table of test results.

Project:

[Patient description:](#)

Name	[Redacted]	MidInitial	[Redacted]
Surname	[Redacted]	HospitalNo	[Redacted]
DateOfBirth	[Redacted]	Sex	Male
DateOfIctus	03/10/2013	DateOfAdmission	03/10/2013

[Clinical background:](#)

NPH?
 Prkinson's disease. Type II diabetes. Hypertension., Macular degeneration (register blind), deaf.
 Slurred speach, urinary incontinence, cognitive decline, mobilised with a frame.
 ventriculomegaly, significant white matter changes.
 Lumbar study , one pink needle. ndrVenessa.
 Patientis mooving

[Tests Results:](#)

[CSF Infusion Test]

Infusion rate [ml/min]	1.50	Calculation mode	static
One needle only	yes		
ICP baseline [mmHg]	8.99	ICP plateau [mmHg]	32.76
AMP baseline [mmHg]	0.79	AMP plateau [mmHg]	4.19
Rcsf [mmHg*min/ml]	15.85	Elastance [1/ml]	0.22
PVI [ml]	10.67	Pss [mmHg]	4.87
CSF production rate [ml/min]	0.26	Volume infused [ml]	27.28
Infusion duration [min]	18.19	Needle resist. [mmHg*min/ml]	0.14
Normalised Error [%]	1.134		

If everything looks OK, you can **display report** and copy/ paste it to **WORD**

Test 'unfinished'

- if pressure increases to 40 mm Hg without reaching plateau



Calculation Parameters

Infusion rate [ml/min] 1.50

One needle only:

Calculation type
 Static Dynamic

CSF Shunt
 Type
 None

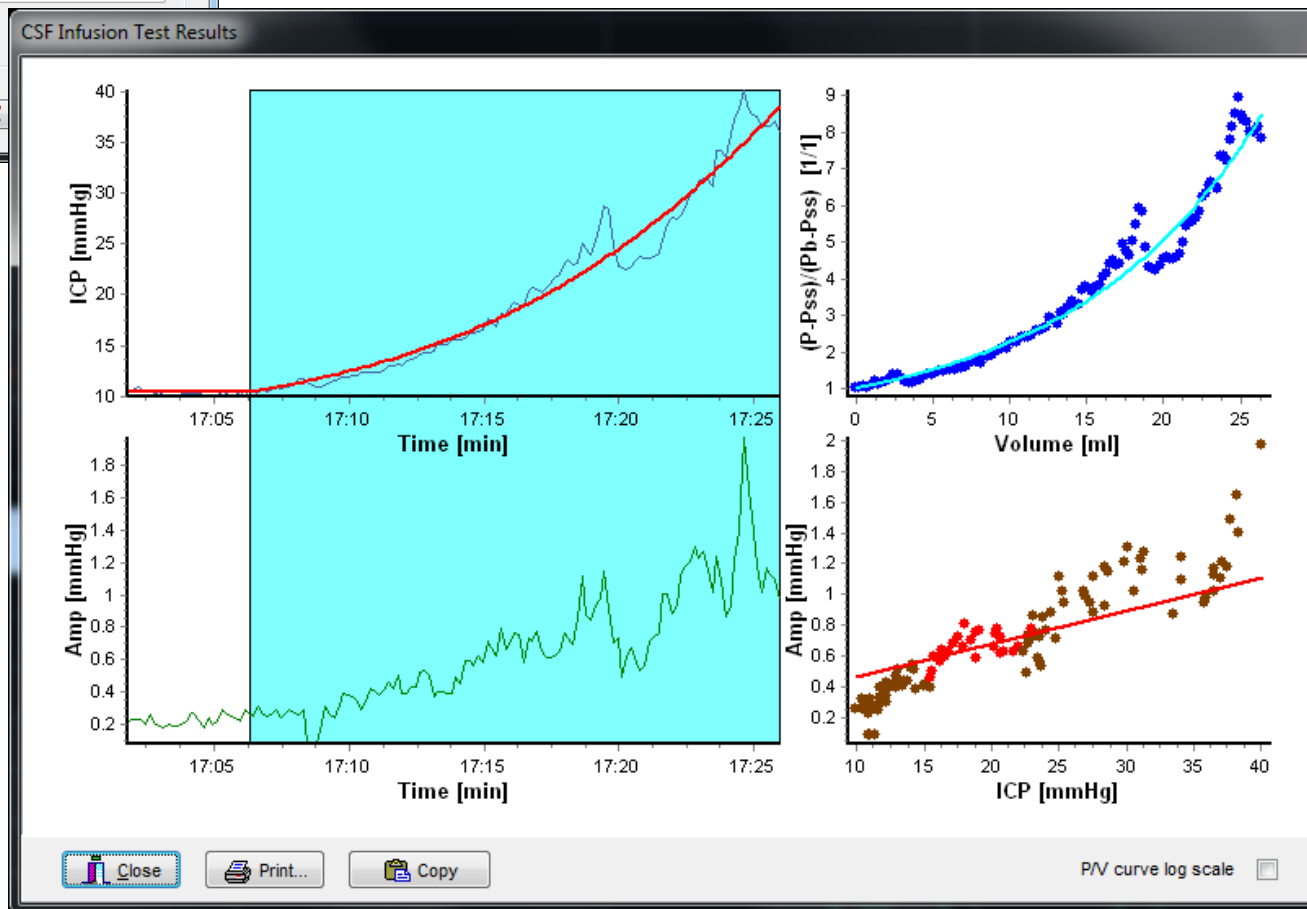
Setting Value [mmHg]
 0.00

Overdrainage test

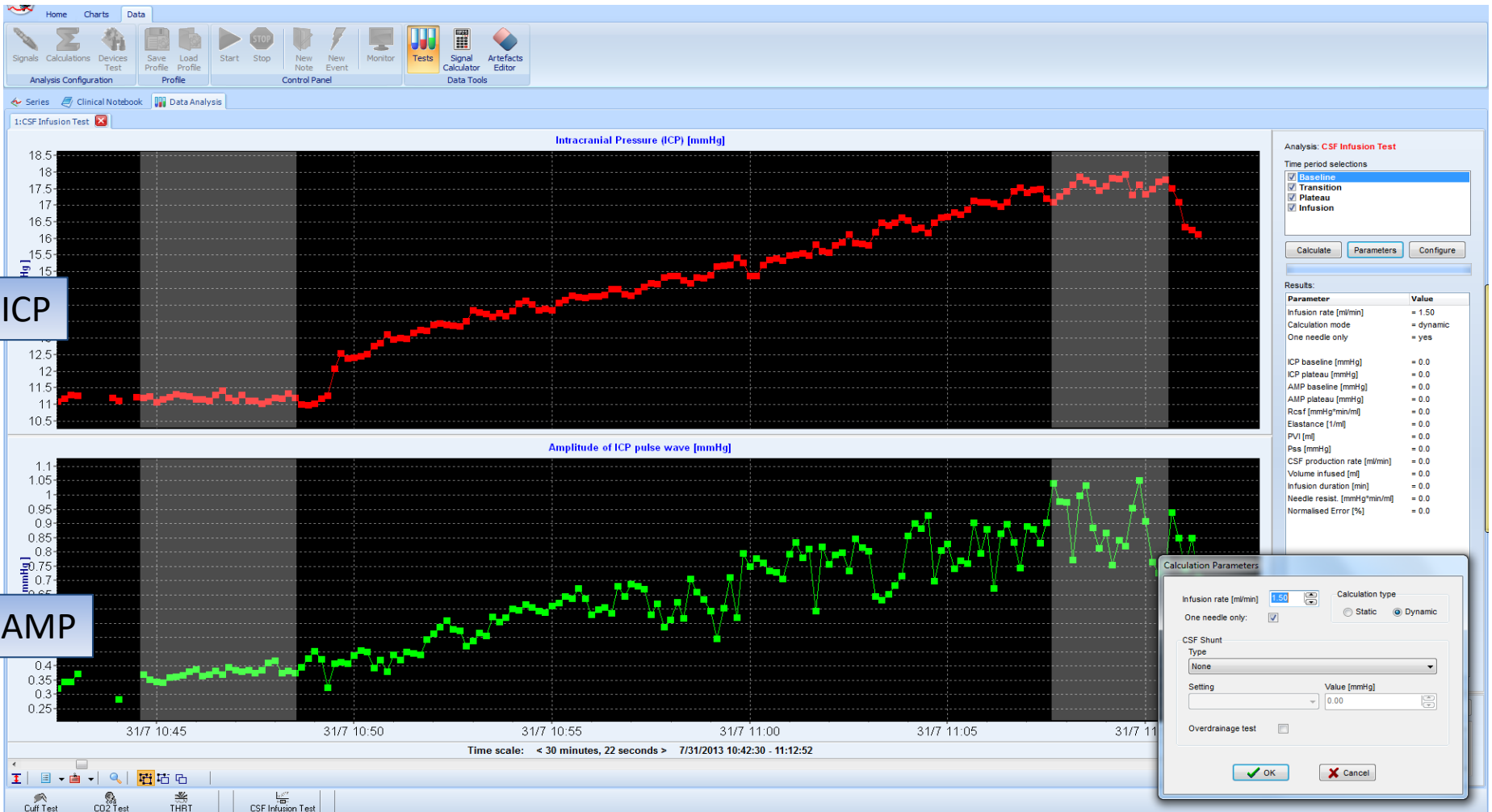
OK X

$$R = 77 \text{ mmHg}/(\text{ml}/\text{min})$$

Automatic analysis may predict plateau



1. I never use 'dynamic' when plateau is good and long
2. I never use 'dynamic' in shunted patients

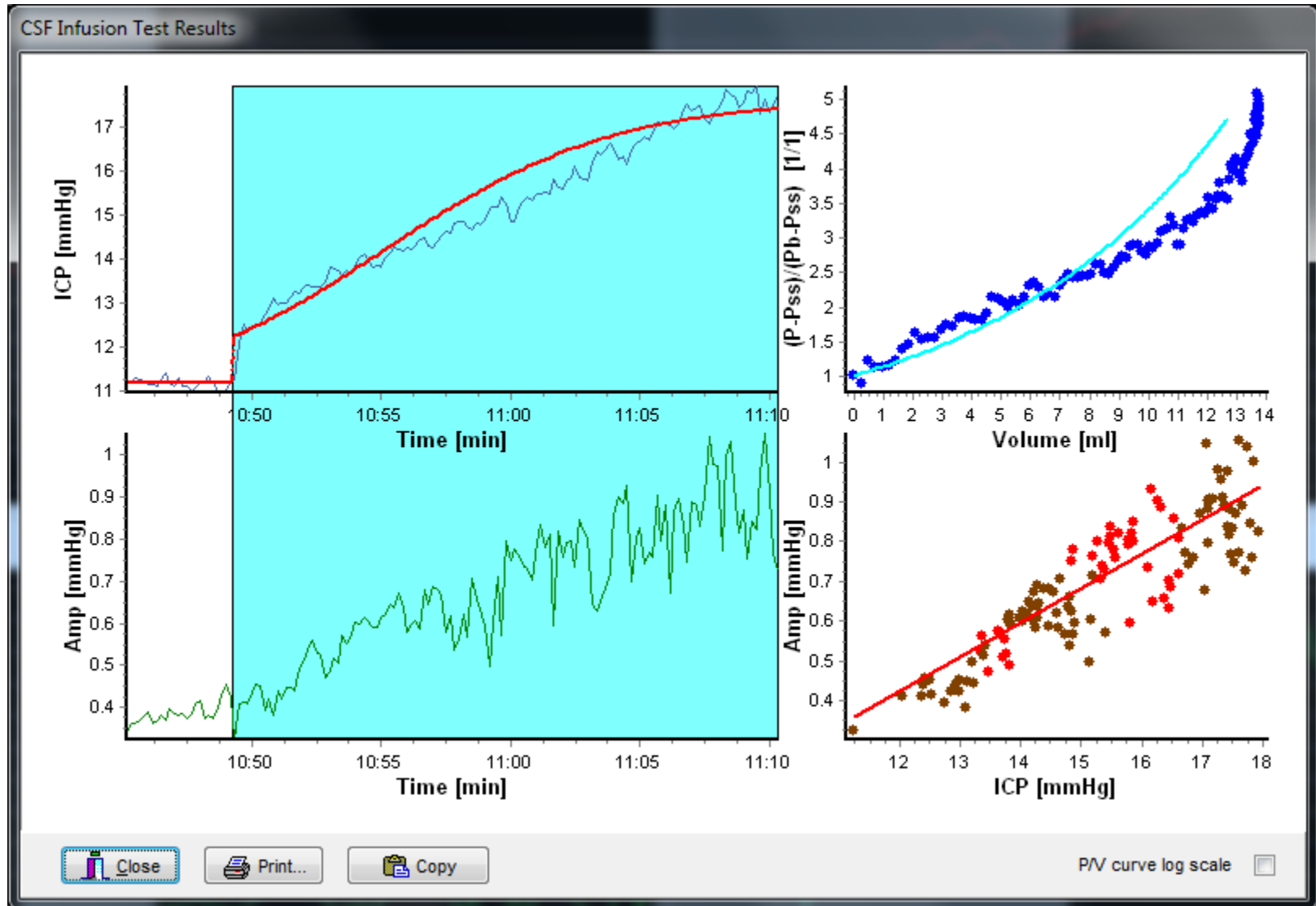


ICP

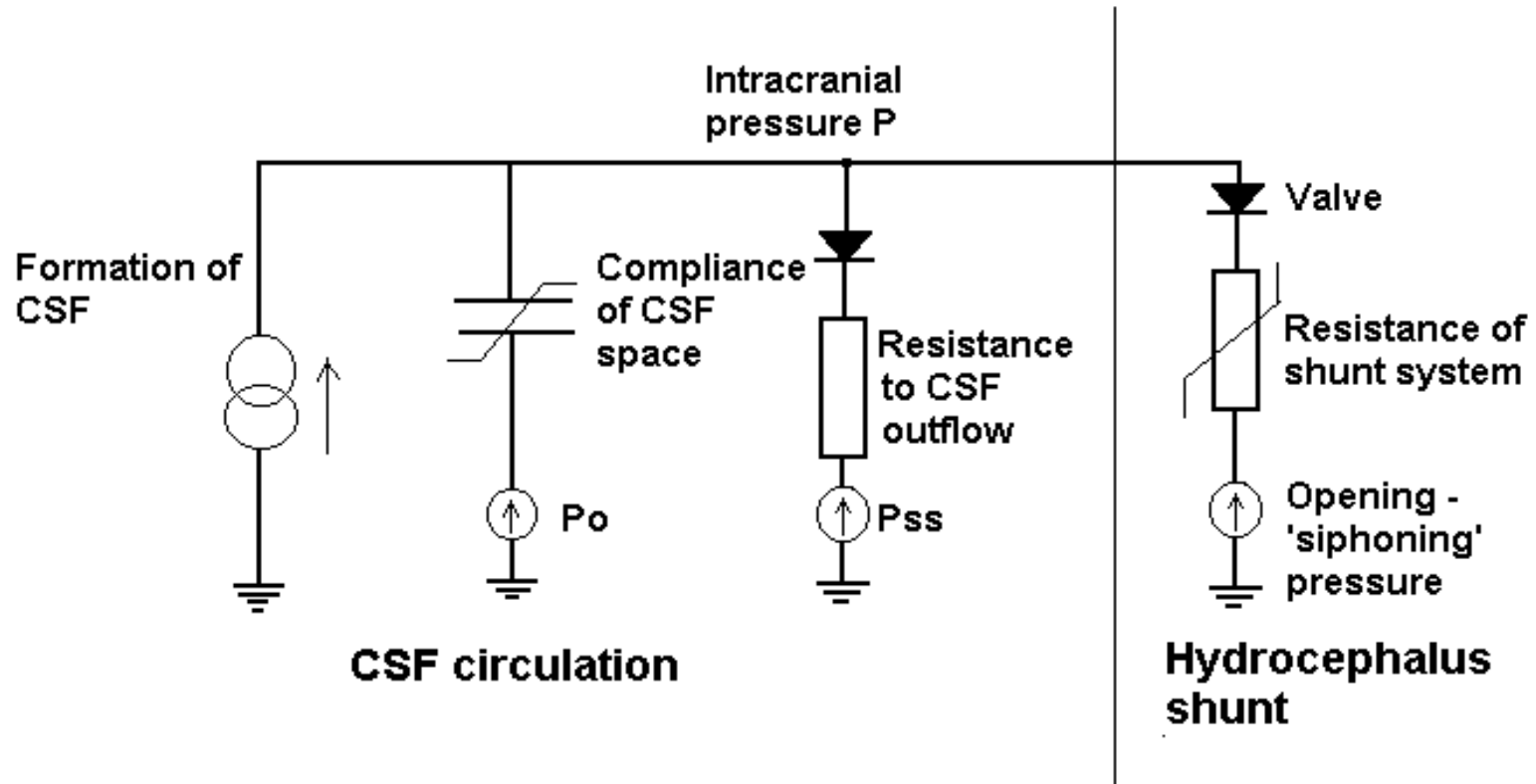
AMP

One needle test: we usually observe rapid increase of ICP just after start of infusion, not reflected by increase in AMP. Tick in 'Parameters' 'one needle' option and problem of higher resistance of the needle may be solved automatically...

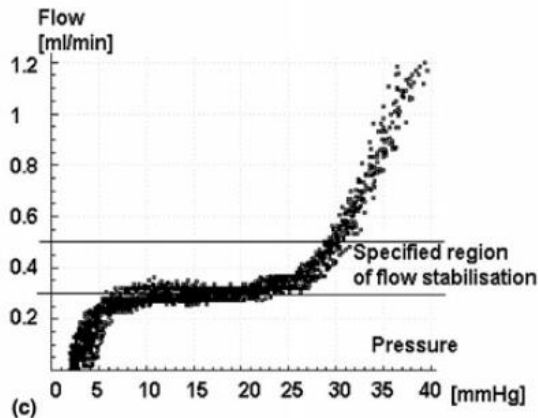
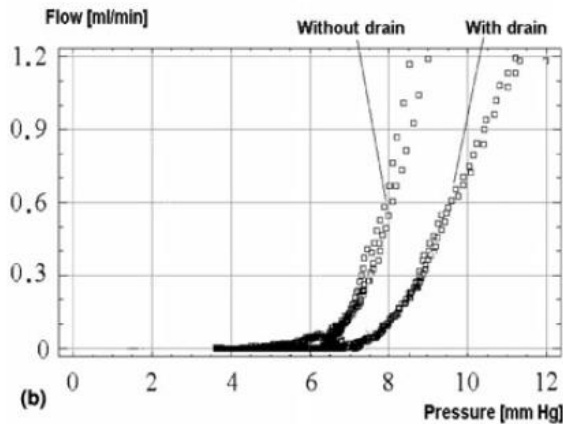
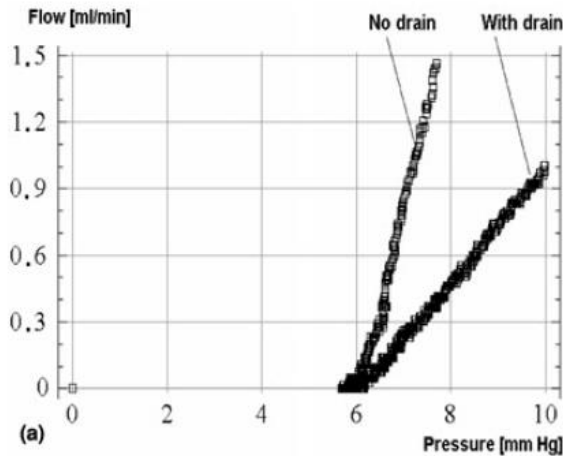
Step-rise of ICP is accounted for and eliminated from its potential influence on CSF compensatory parameters



CSF circulation with shunt in situ



Shunt evaluation laboratory



Cerebrospinal fluid dynamics

Marek Czosnyka¹, Zofia Czosnyka, Shahan Momjian
and John D Pickard

Shunt parameters:

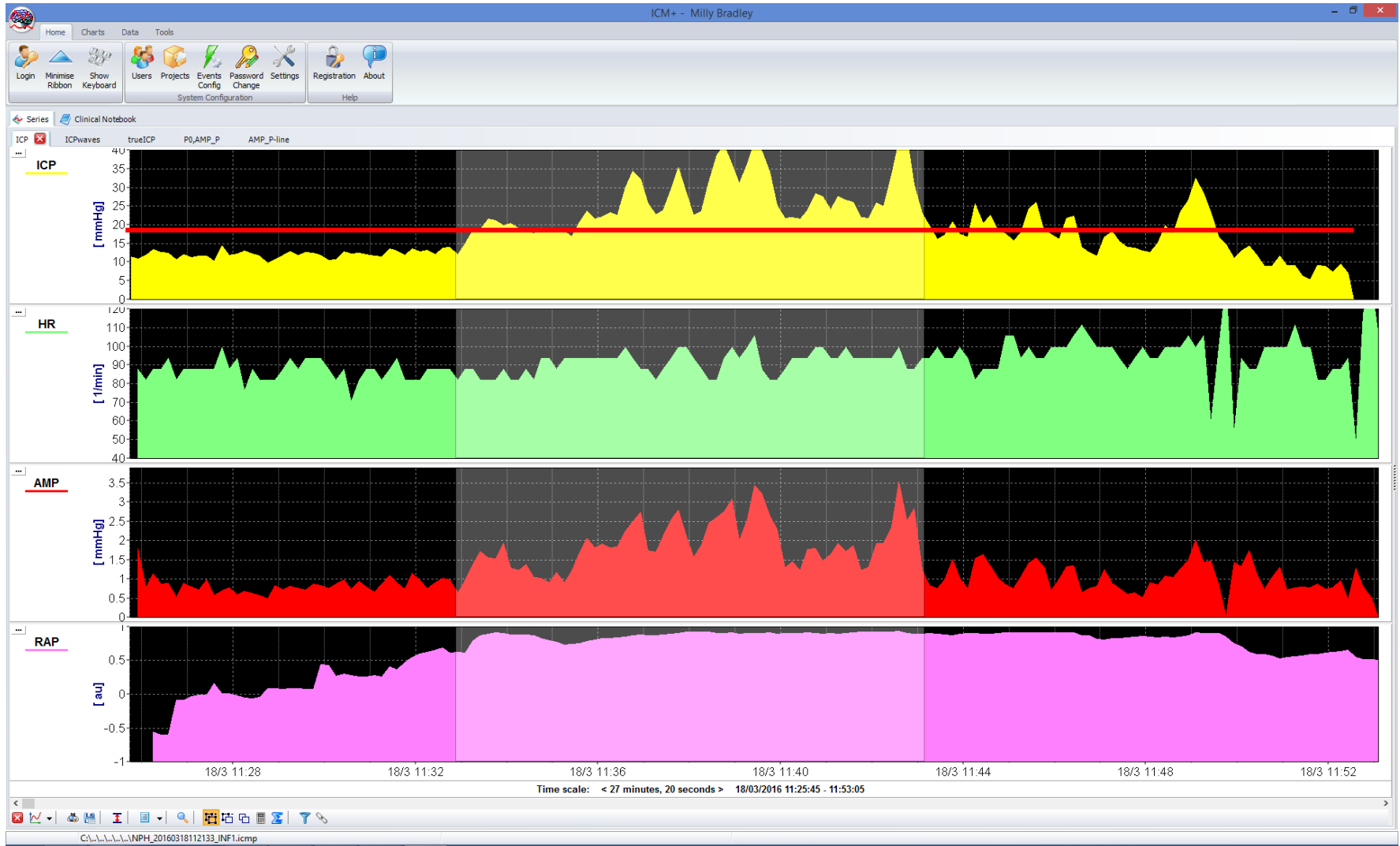
P_{s0} – shunt operating pressure (could be a formula)

R_{eff} – effective resistance

P_{crit} – critical pressure threshold formula

Figure 5. Examples of the pressure–flow curves of three valves: (a) almost linear: ball-on-spring valve; (b) parabolic shape of silicone membrane valve; (c) highly nonlinear ‘autoregulating’ Orbis–Sigma valve.

Shunt tested as **'blocked' distally**. Too high resistance to outflow, prominent vasogenic waves. During the revision broken distal drain (at chest) was found.



Calculation Parameters

Infusion rate [ml/min] 1.50

One needle only:

Calculation type
 Static Dynamic

CSF Shunt
 Type
 Strata

Miethke - PediGav
 Miethke - ProGAV
 Omni-shunt NMT (Cordis)
 Orbis-Sigma NMT
 PS-Medical L-P
 Pudenz-Flushing Heyer-Shulte with ASD
 Sophy-Programmable
 Strata

OK Cancel

Calculation Parameters

Infusion rate [ml/min] 1.50

One needle only:

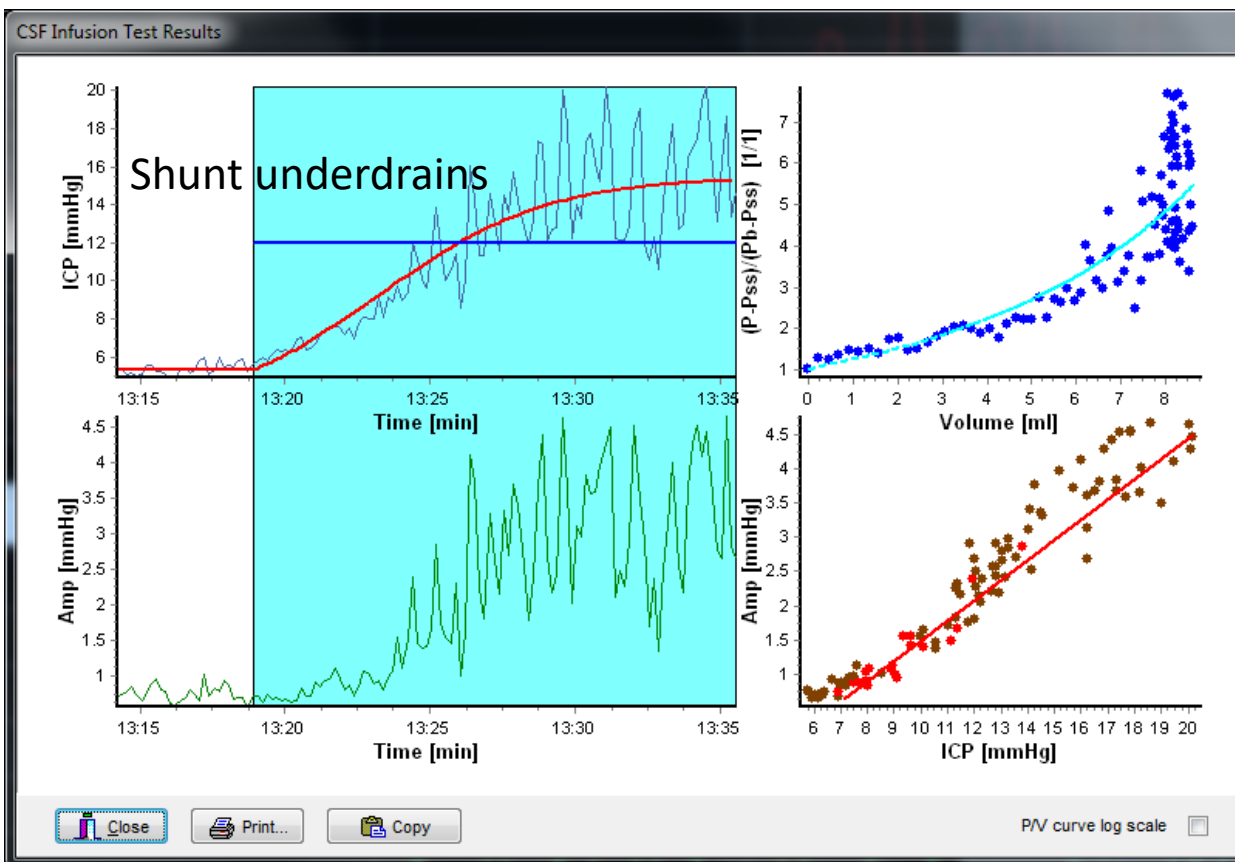
Calculation type
 Static Dynamic

CSF Shunt
 Type
 Strata

Setting Value [performance level]
 programmable 0.50

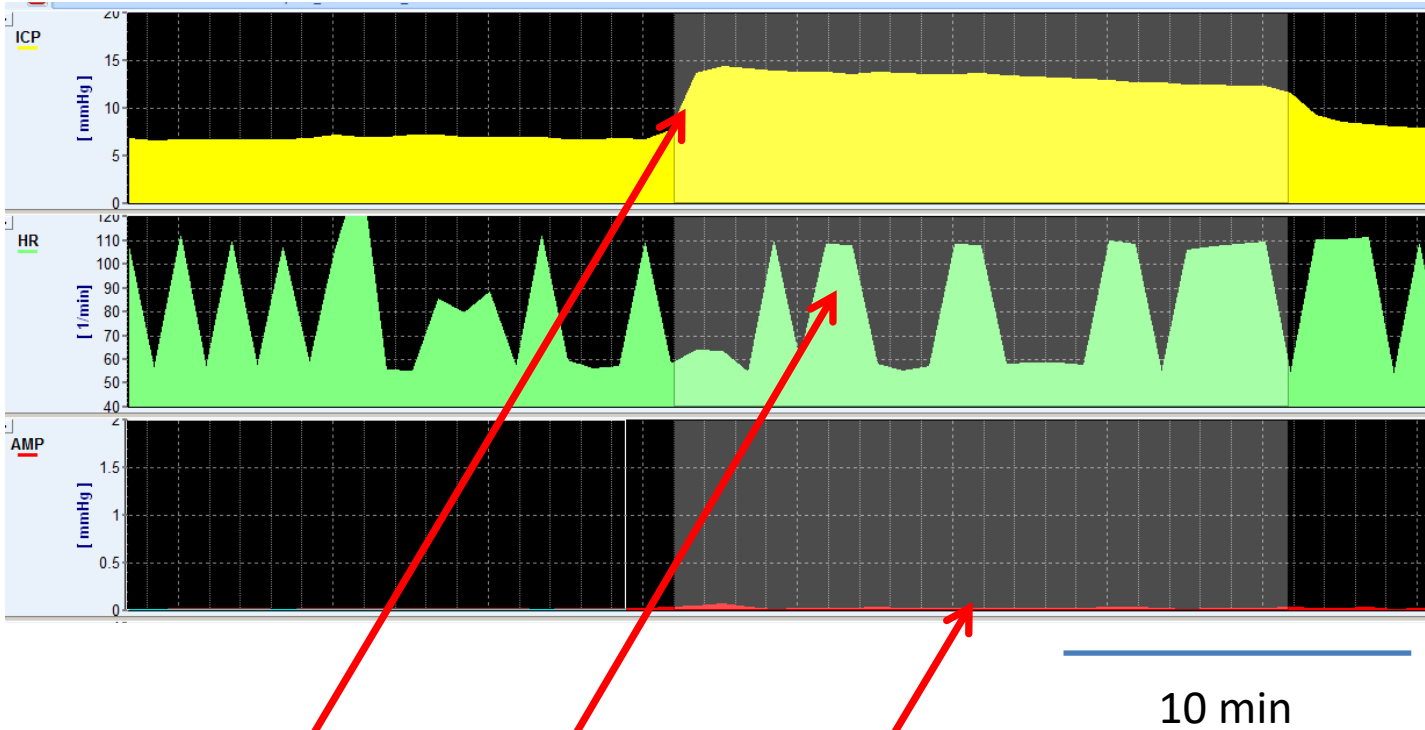
Overdrainage test

OK Cancel



ICM+ has a database of shunt parameters from Cambridge Shunt Lab. Every shunt at given performance level has a limit above which pressure should not rise during infusion of given rate (1ml/min or 1.5 ml/min). If pressure exceeds this limit (blue horizontal line), it indicates that shunt underdrains.

Blockage of ventricular catheter- view of ICM file



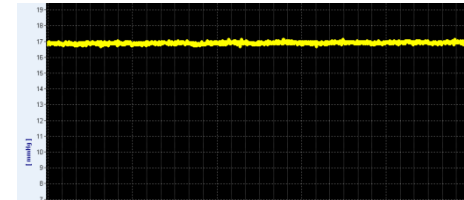
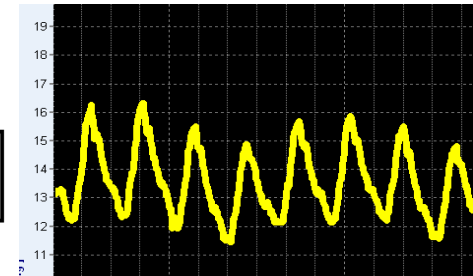
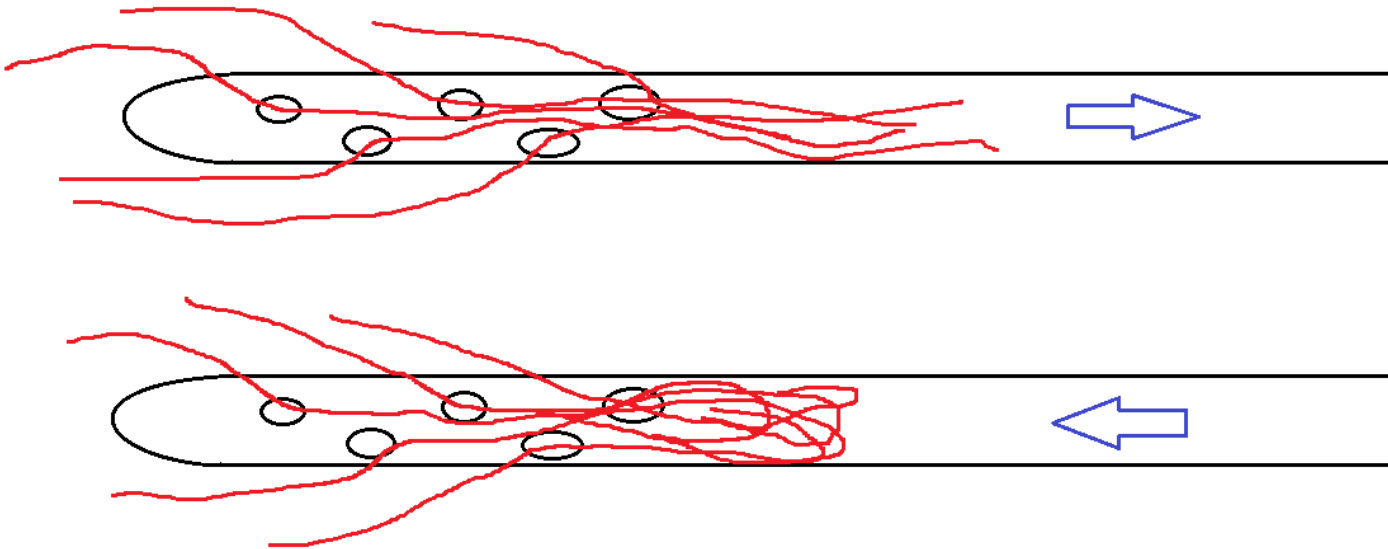
Fast rise of recorded Pressure just after Start of infusion

Invalid detection of heart rate from ICP waveform

Very low (<0.1 mm Hg) pulse amplitude of ICP calculated

Choroid plexus in-growing into ventricular catheter

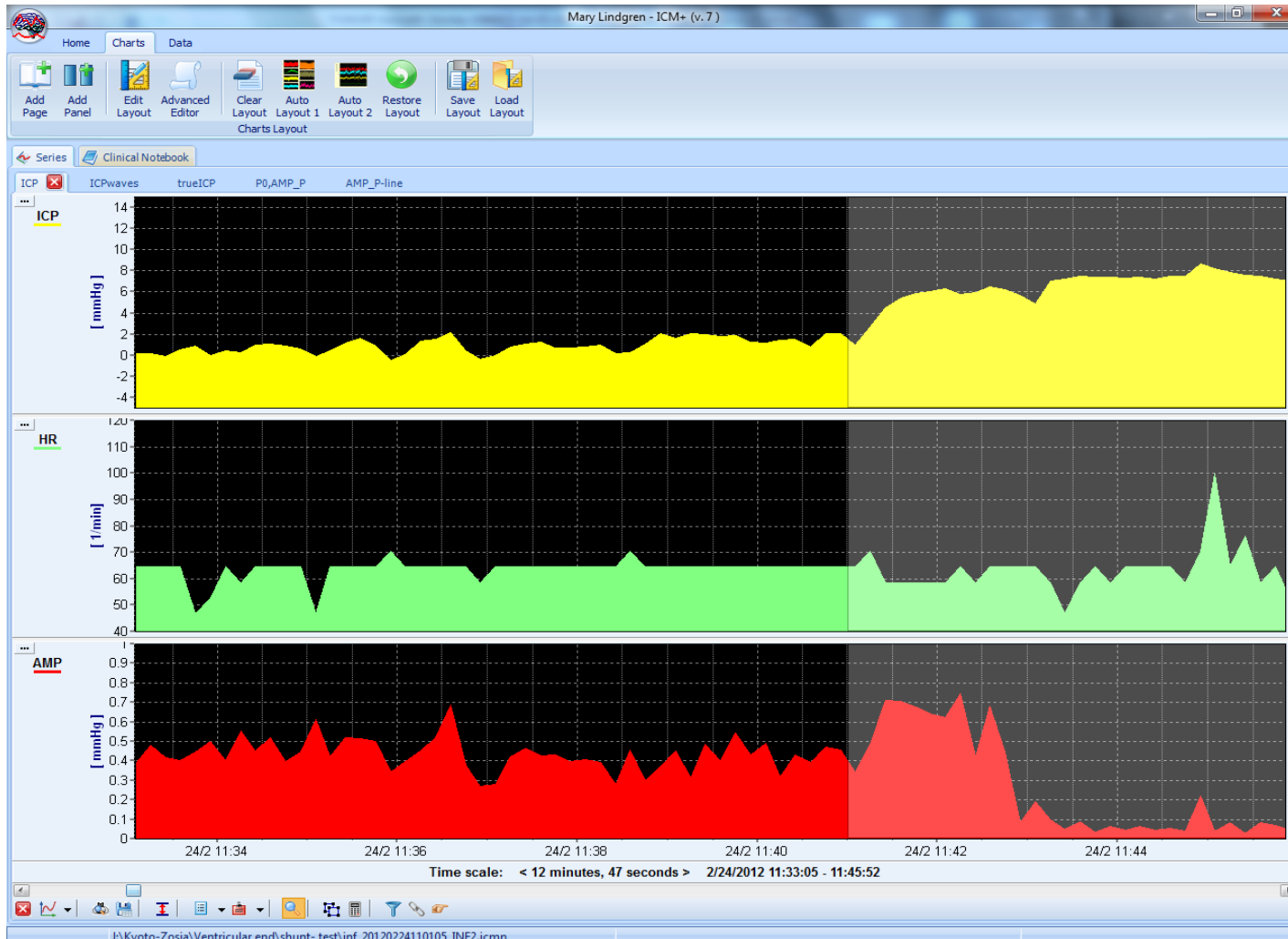
Possibly fluent CSF flow at baseline, aspiration possible, ICP pulsation visible



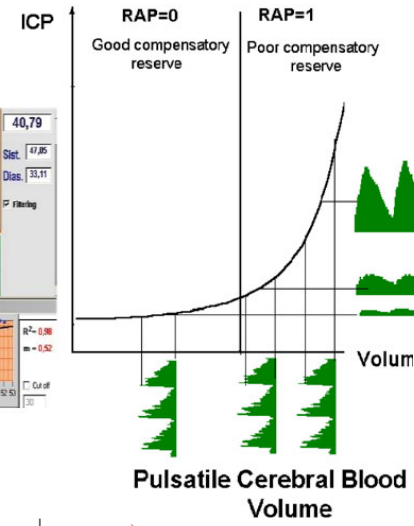
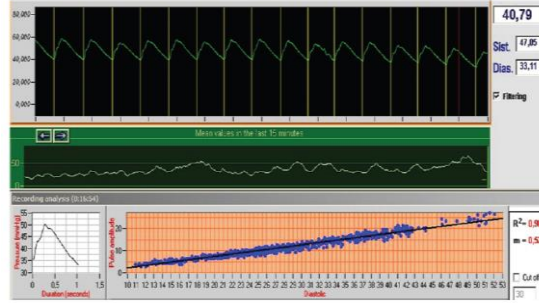
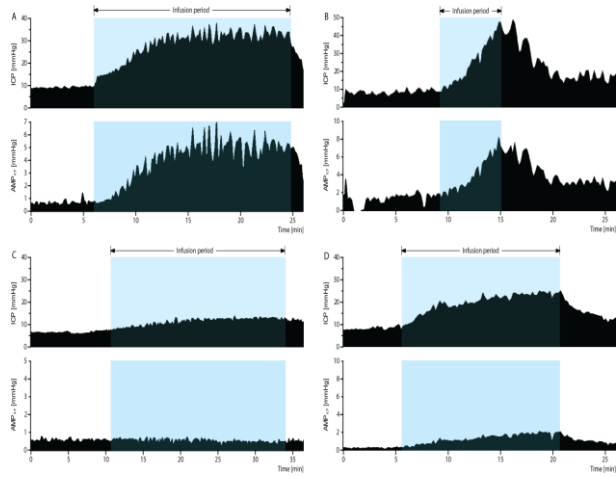
After start of infusion in-growing plexi jam dynamically ventricular catheter, all infused fluid flows distally, pressure pulsations disappear

Partially blocked ventricular end

by in-growing choroid plexi – ICP waveform diminishes after start of infusion



Happy infusion studies!



Pressure response-
ICP pulse amplitude

