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
Infusion 1 ml/min
What we need?
Hardware
Pressure transducer, tubing, needles

Essential: sterile preparation of transducer and tubing
Measurement set-up

- Pressure Transducer
- Manometer lines filled with saline
- 2 25G Butterfly needles
- Ommaya Reservoir
- Syringe drive (50 ml syringe with normal saline)

Reservoir

Computer running INFUSION TEST software

Lumbar
Checking the waveform of ICP signal
When the pulse waveform is weak, looking at the spectrum of ABP helps.
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

\[ I_{\text{ext}}(t) = \frac{1}{E \ast (P - P_0)} \ast \frac{dp}{dt} + \frac{P - P_b}{R_{\text{csf}}} \]

\[ I_b = \frac{P_b - P_{ss}}{R_{\text{csf}}} \quad P_{ss} \approx P_0 \]

\[ P_m(t) = \frac{(I_b + I_{\text{inf}}) \ast (P_b - P_0)}{I_b + I_{\text{inf}} \ast e^{-E \ast (I_b + I_{\text{inf}}) \ast t}} + P_0 \]
Click ‘more’ and you see:

Interpolation of ICP trend with modelling curve

Exponential pressure-volume curve

Trend of amplitude in time

Amplitude – pressure line

I use this screen to assess visually **quality of identification** of the model.
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
R = 77 mmHg/(ml/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
**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

Review: Cerebrospinal fluid dynamics

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.
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 (1 ml/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 int 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 dissapear
Partially blocked ventricular end
by in-growing choroid plexi – ICP waveform diminishes after start of infusion
Happy infusion studies!