Infusion studies in clinical practice

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‘infusion study’ + hydrocephalus

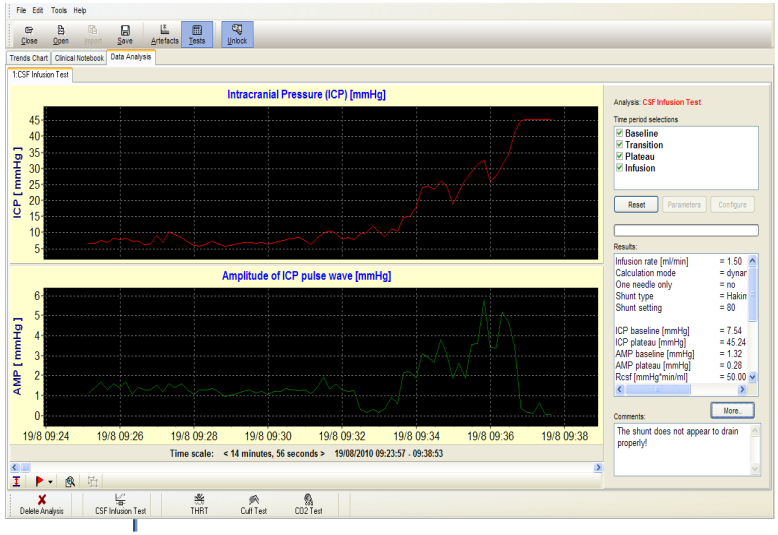
216 publications

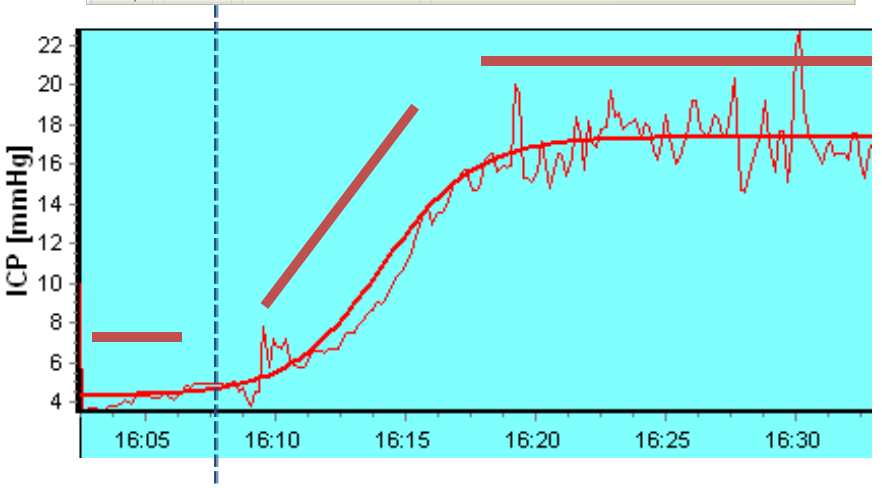
Clinical indications

- Normal pressure hydrocephalus
- Evaluation of CSF diversion
  - Shunt function
  - ETV function

Infusion test – general principles

- Two 25 G needles – ventricular access device or shunt reservoir (if proximal to valve)
- Pressure transduced to patient monitor and ICM+
- Evaluation of baseline ICP
- Infusion of 1.5 mL / min of normal saline
- Constant flow rate – syringe driver
- Infusion continued until plateau reached





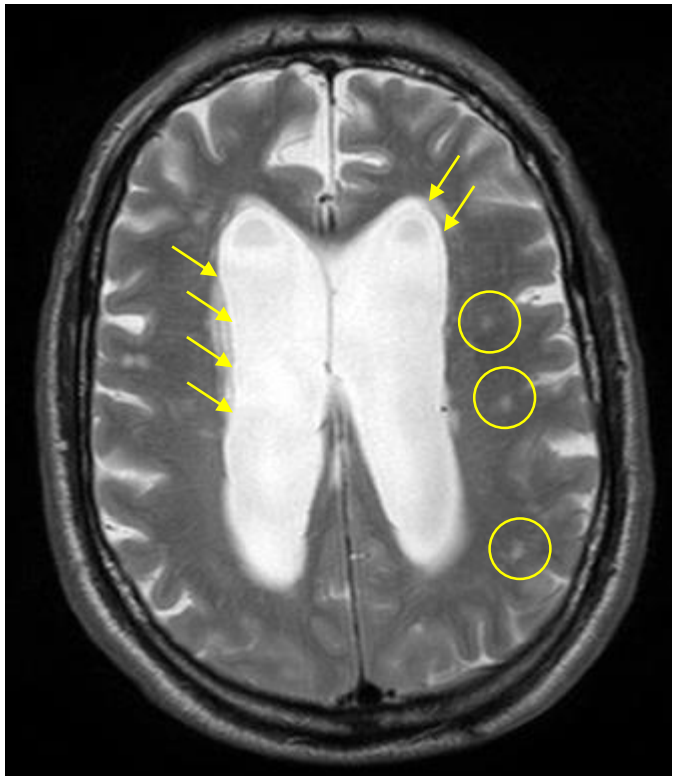
Idiopathic normal pressure hydrocephalus

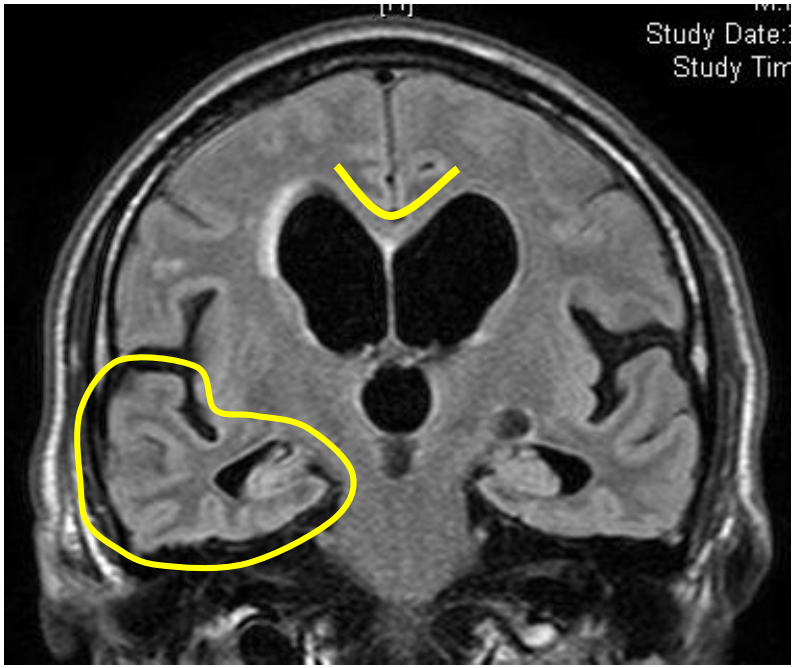
- Adam's triad
  - Ataxia
  - Urinary incontinence
  - Cognitive impairment

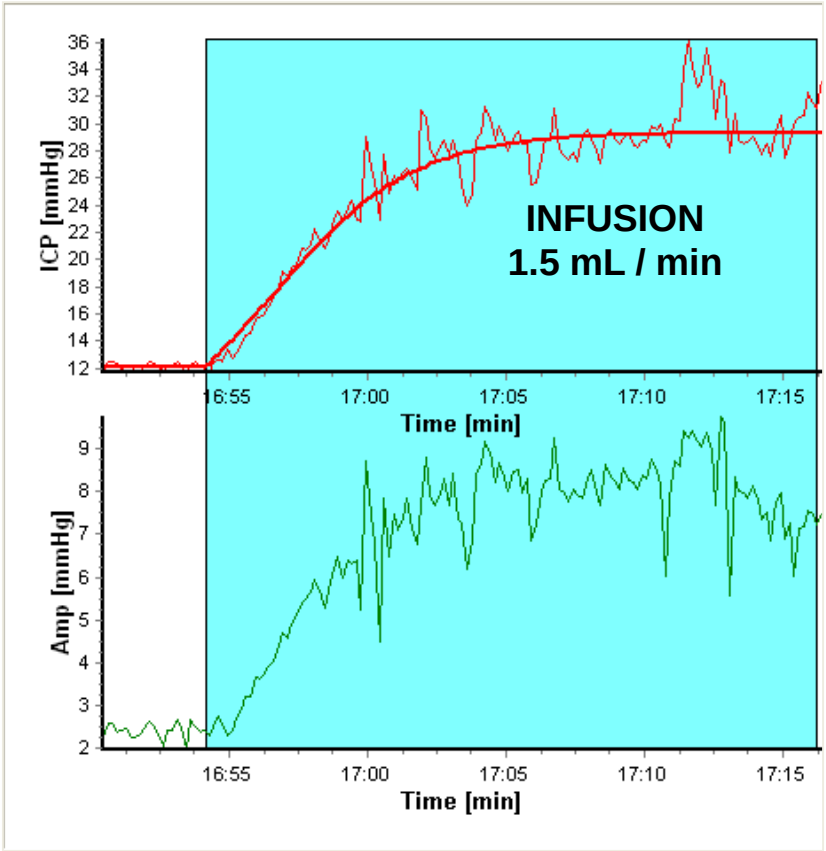
Decreased production and absorption of CSF
Decreased elasticity of periventricular tissue
Small vessel disease in deep periventricular white matter
Decreased clearance of metabolic waste products
? Overlap with Alzheimer's disease

- Investigations
  - Determination of R_{out}
  - Improvement in symptoms with prolonged CSF drainage

Imaging - MR







R_{out}
12 mmHg / mL / min

Rise in R_{out} with age

20 years	12
40 years	14
60 years	16
80 years	>18

Czosnyka M et al J Neurosurg 94:482-6, 2001

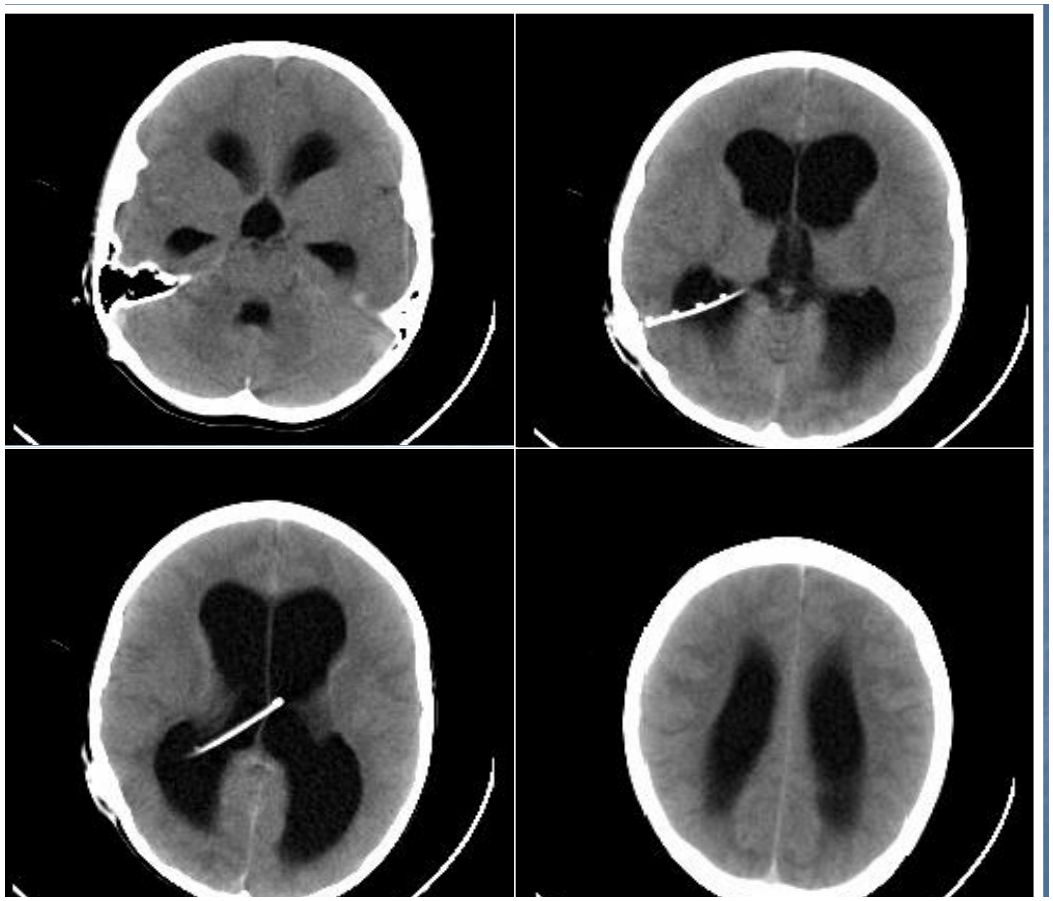
- R_{out} of 18 mmHg / mL / min
- PPV 92 %
- NPV 34 %

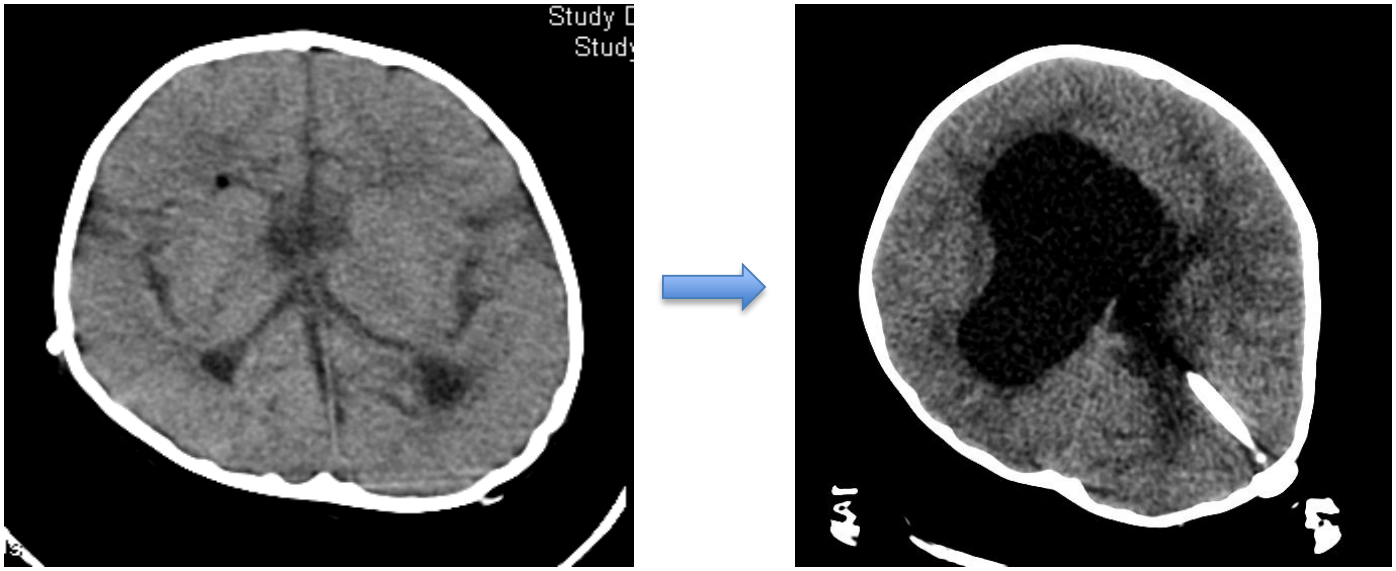
Boon A, Tans JT, Delwel EJ et al. Dutch normal pressure hydrocephalus study: prediction of outcome after shunting by resistance to outflow of cerebrospinal fluid. J Neurosurg 87:687 – 693, 1997. (n=101)

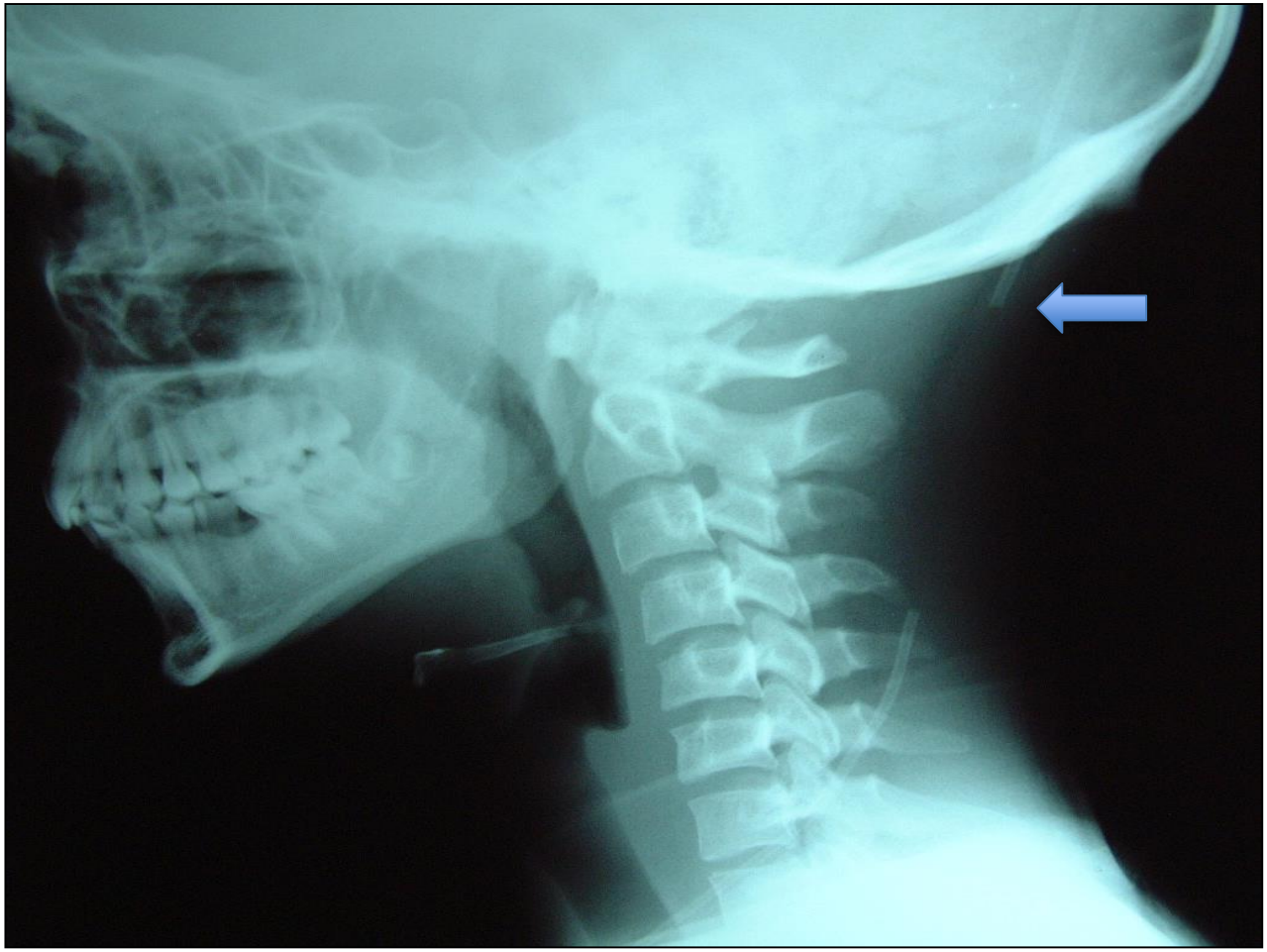
Diagnosis of shunt malfunction

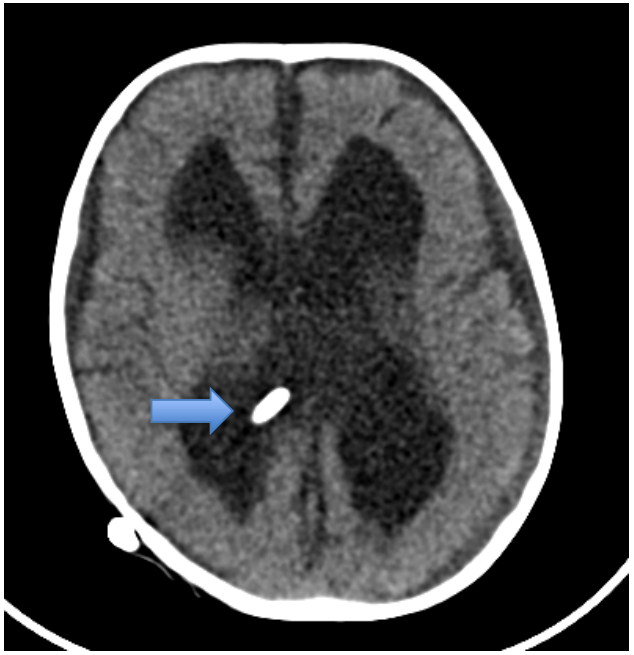
- Clinical
  - Headache, nausea, vomiting, drowsiness
  - Abdominal pain
  - Increasing head circumference

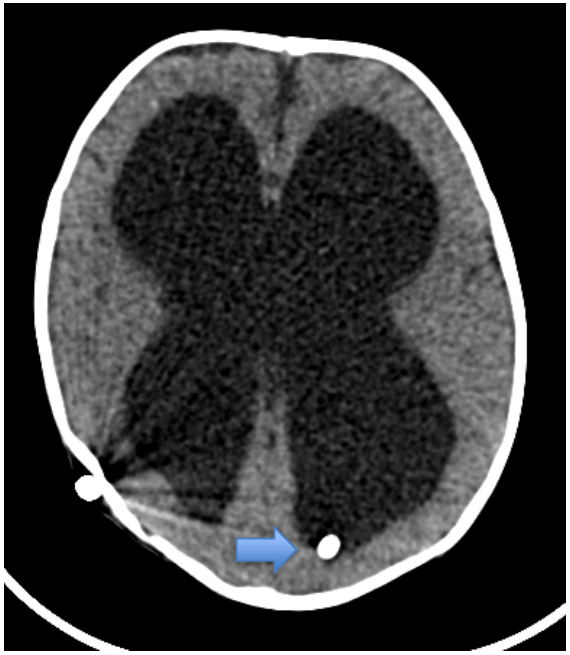
- Radiological
  - Increase in ventricular size
  - Reduction in subarachnoid space

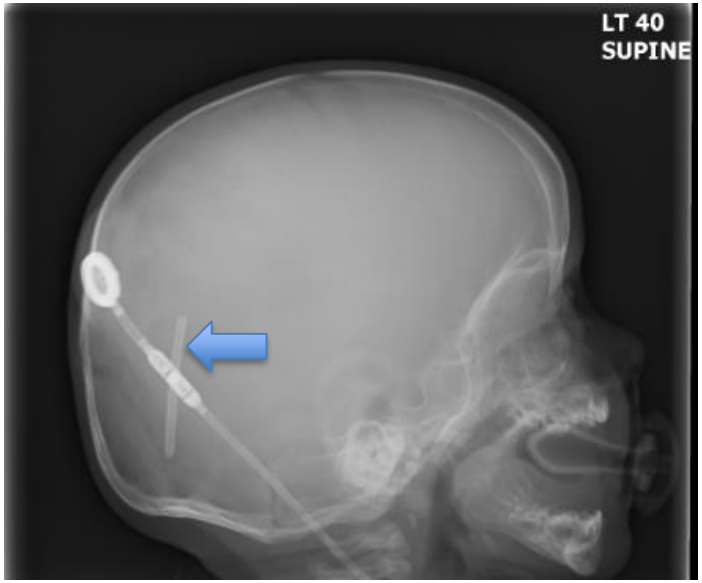








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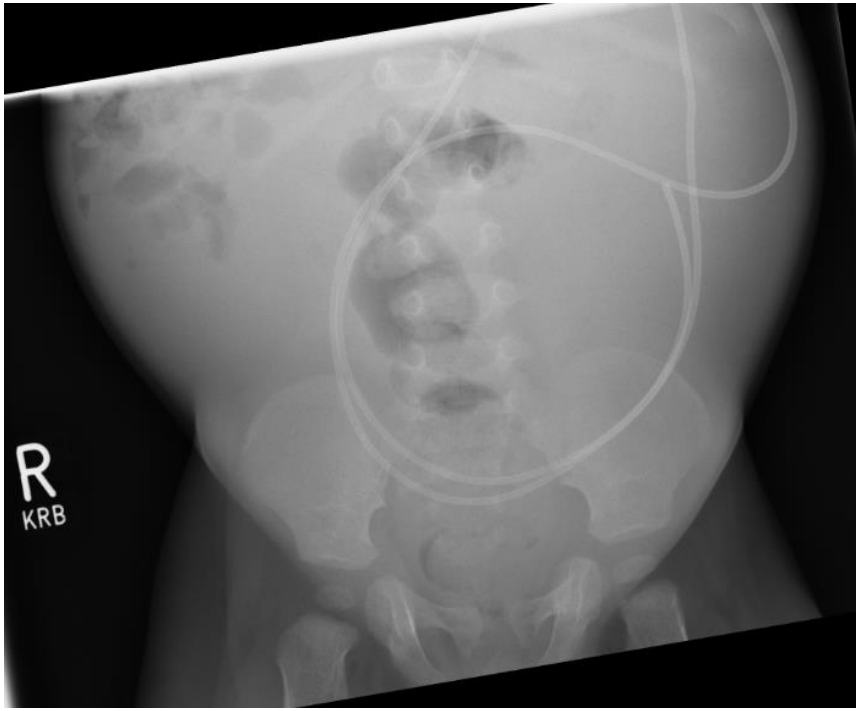

R
KRB

Pleural complications

- Breathlessness
- Pleural effusion

Acta Neurologica Scandinavica

Acta Neurol Scand 2011: 124: 85–98 DOI: 10.1111/j.1600-0404.2010.01467.x

ACTA NEUROLOGICA SCANDINAVICA

Clinical assessment of cerebrospinal fluid dynamics in hydrocephalus. Guide to interpretation based on observational study

Weerakkody RA, Czosnyka M, Schuhmann MU, Schmidt E, Keong N, Santarius T, Pickard JD, Czosnyka Z. Clinical assessment of cerebrospinal fluid dynamics in hydrocephalus. Guide to interpretation based on observational study.
Acta Neurol Scand: 2011: 124: 85–98.

Objectives – The term hydrocephalus encompasses a range of disorders characterised by clinical symptoms, abnormal brain imaging and derangement of cerebrospinal fluid (CSF) dynamics. The ability to elucidate which patients would benefit from CSF diversion (a shunt or third ventriculostomy) is often unclear. Similar difficulties are often encountered in shunted patients to predict the scope for improvement

R. A. Weerakkody[1], M. Czosnyka[1], M. U. Schuhmann[2], E. Schmidt[3], N. Keong[1], T. Santarius[1], J. D. Pickard[1], Z. Czosnyka[1]

[1]Academic Department of Neurosurgery, University of Cambridge, Cambridge, UK; [2]Department of Neurosurgery, University of Tübingen, Tübingen, Germany; [3]Neurosurgery, Hôpital Purpan, Toulouse, France

- Largest observational study of the infusion test
- Routine use over 17 years – 1992 to 2009
- 1423 patients, 2665 studies; all adults
- 47 % NPH

Interpretation

- Shunt pre-chamber required
- Ventricular catheter patency
- Opening pressure - > 5 mmHg above shunt operating pressure
- Comparison with critical threshold for shunt (in vitro tests)

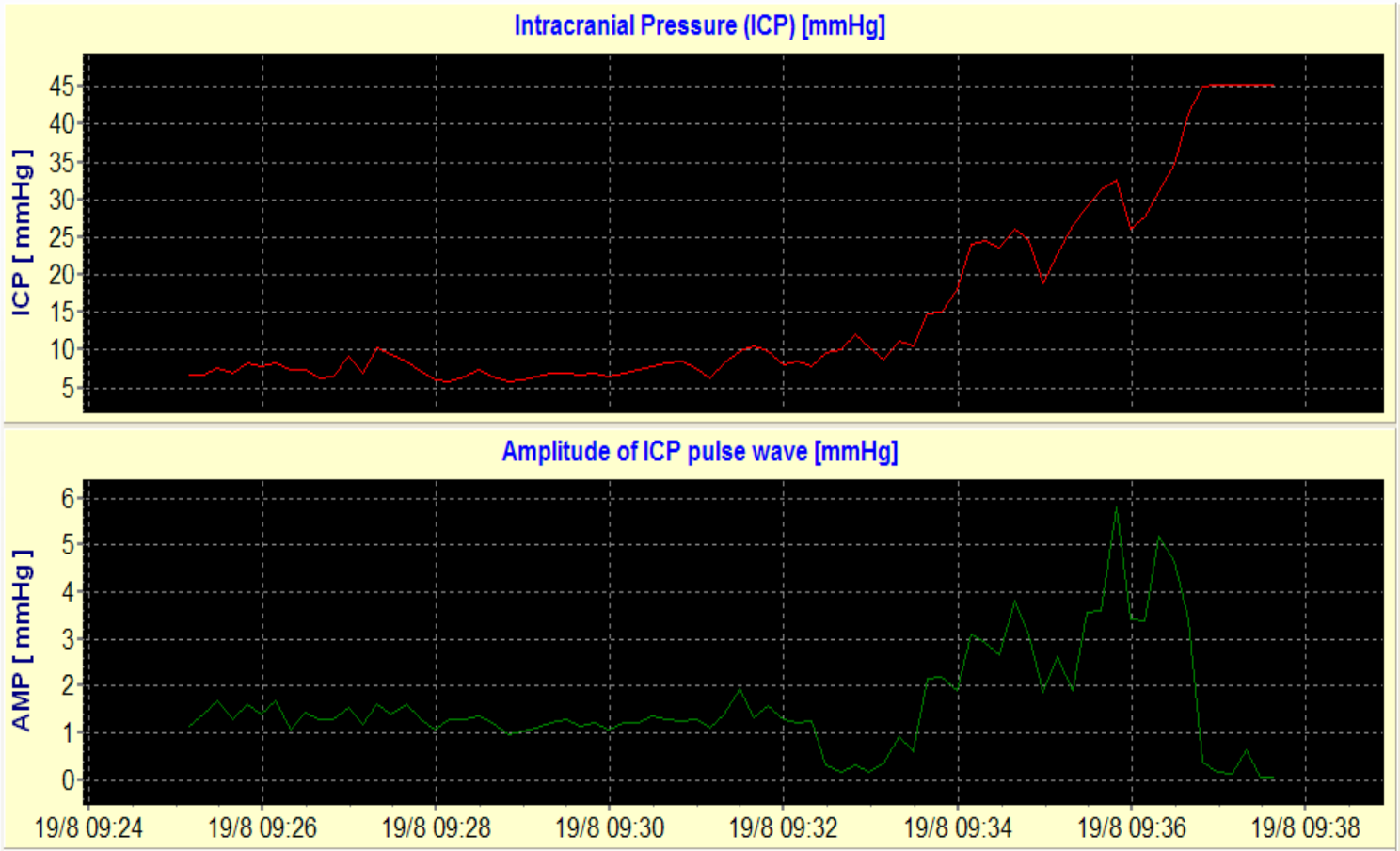
  - High baseline pressure
  - High R_{out}
  - High RAP (> 0.6)
  - High AMP (> 2 – 4 mmHG)
  - High E (> 0.20 L / mL)

File Edit Tools Help

Close Open Import Save Artefacts Tests Unlock

Trends Chart | Clinical Notebook | Data Analysis

1:CSF Infusion Test



Time scale: < 14 minutes, 56 seconds > 19/08/2010 09:23:57 - 09:38:53

Analysis: CSF Infusion Test

Time period selections

- [x] Baseline
- [x] Transition
- [x] Plateau
- [x] Infusion

Reset | Parameters | Configure

Results:

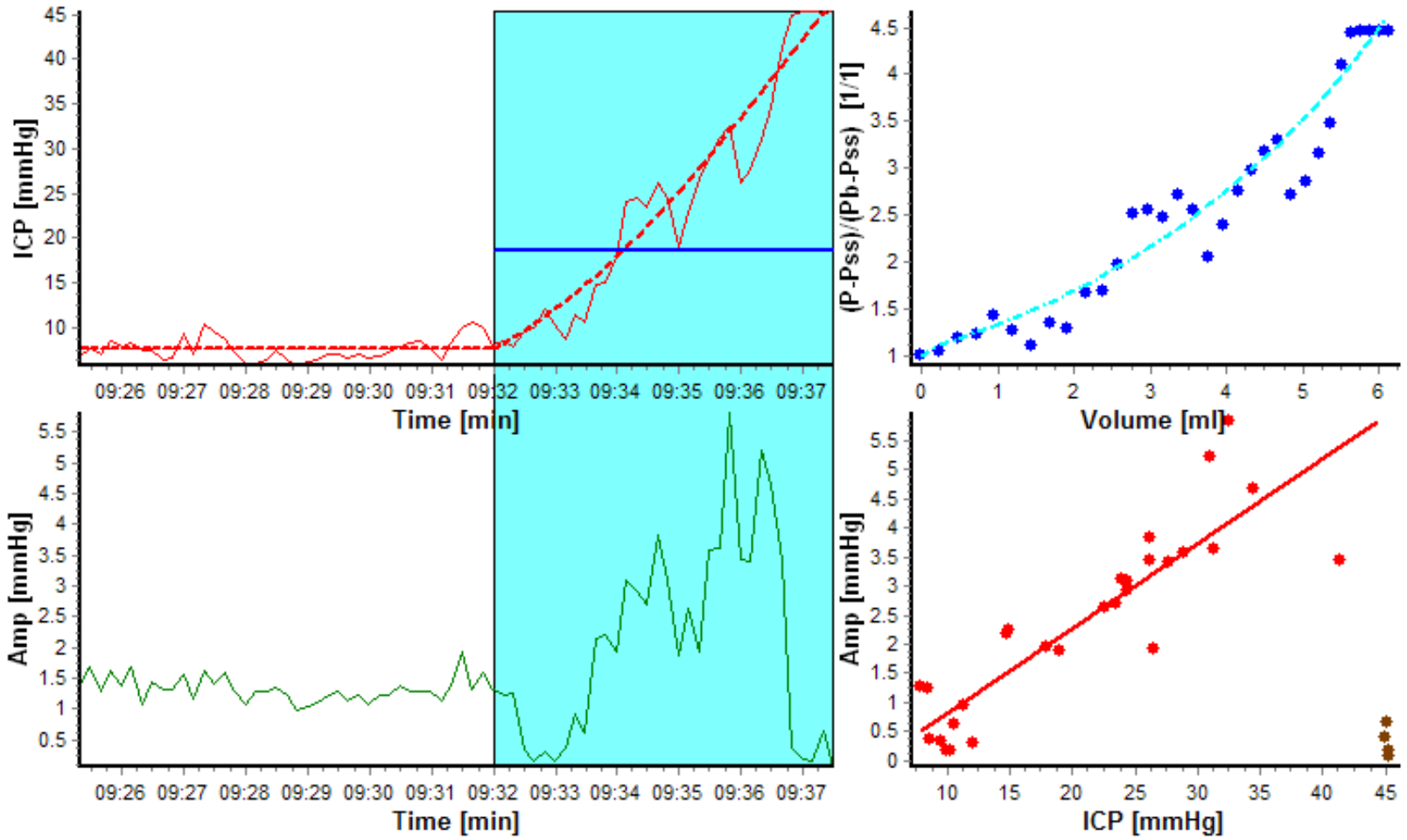
Infusion rate [ml/min]	= 1.50
Calculation mode	= dynar
One needle only	= no
Shunt type	= Hakin
Shunt setting	= 80
ICP baseline [mmHg]	= 7.54
ICP plateau [mmHg]	= 45.24
AMP baseline [mmHg]	= 1.32
AMP plateau [mmHg]	= 0.28
Rcsf [mmHg*min/ml]	= 50.00

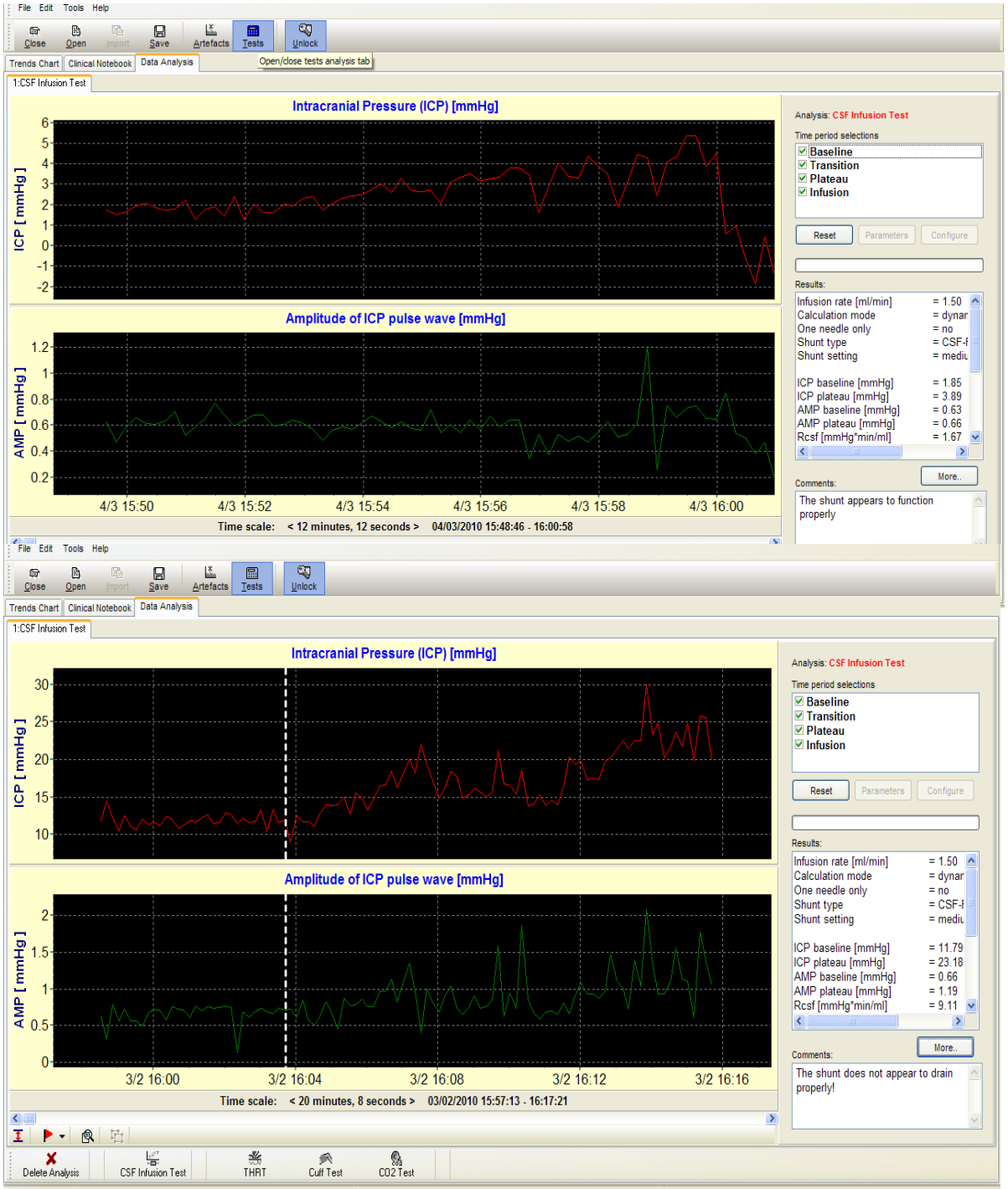
More..

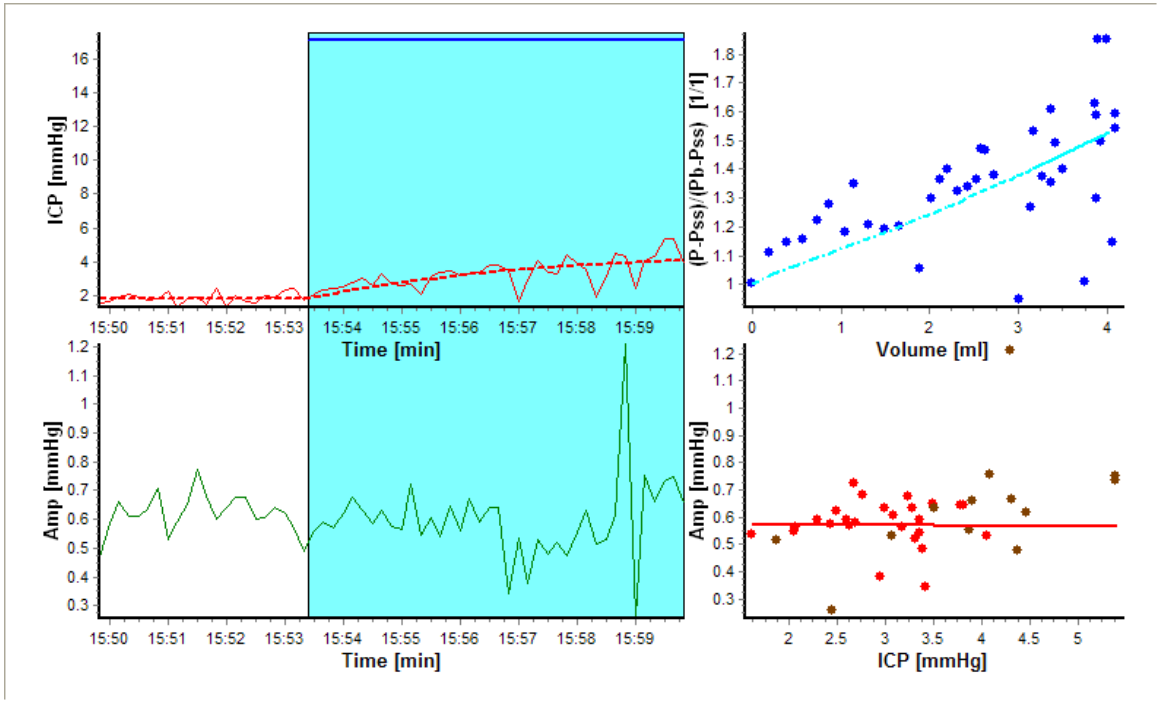
Comments:

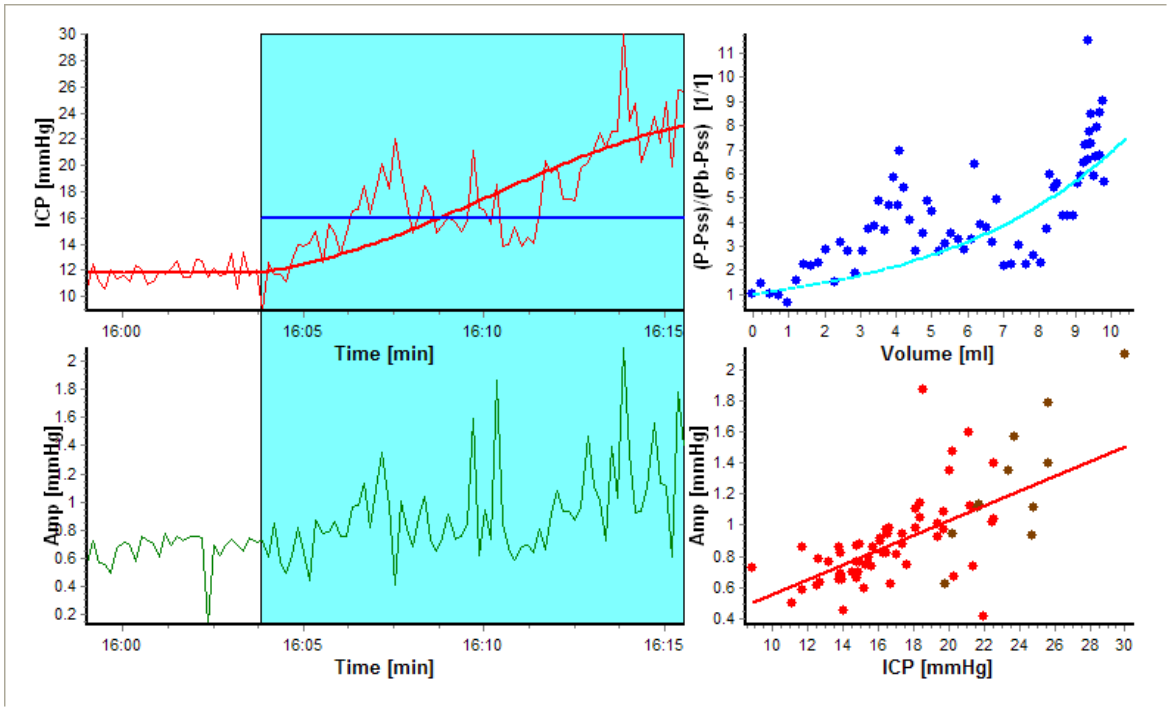
The shunt does not appear to drain properly!

Delete Analysis | CSF Infusion Test | THRT | Cuff Test | CO2 Test


ICP [mmHg]
Time [min]
09:26 09:27 09:28 09:29 09:30 09:31 09:32 09:33 09:34 09:35 09:36 09:37
(P-Pss)/(Pb-Pss) [1/1]
Volume [ml]
Amp [mmHg]
Time [min]
Amp [mmHg]
ICP [mmHg]


File Edit Tools Help
Close Open Import Save Artefacts Tests Unlock
Trends Chart Clinical Notebook Data Analysis
Open/close tests analysis tab
1:CSF Infusion Test
Intracranial Pressure (ICP) [mmHg]
ICP [mmHg]
Amplitude of ICP pulse wave [mmHg]
AMP [mmHg]
4/3 15:50 4/3 15:52 4/3 15:54 4/3 15:56 4/3 15:58 4/3 16:00
Time scale: < 12 minutes, 12 seconds > 04/03/2010 15:48:46 - 16:00:58
Analysis: CSF Infusion Test
Time period selections
Baseline
Transition
Plateau
Infusion
Reset Parameters Configure
Results:
Infusion rate [ml/min] = 1.50
Calculation mode = dynar
One needle only = no
Shunt type = CSF-
Shunt setting = mediu
ICP baseline [mmHg] = 1.85
ICP plateau [mmHg] = 3.89
AMP baseline [mmHg] = 0.63
AMP plateau [mmHg] = 0.66
Rcsf [mmHg*min/ml] = 1.67
More..
Comments:
The shunt appears to function properly
File Edit Tools Help
Close Open Import Save Artefacts Tests Unlock
Trends Chart Clinical Notebook Data Analysis
1:CSF Infusion Test
Intracranial Pressure (ICP) [mmHg]
ICP [mmHg]
Amplitude of ICP pulse wave [mmHg]
AMP [mmHg]
3/2 16:00 3/2 16:04 3/2 16:08 3/2 16:12 3/2 16:16
Time scale: < 20 minutes, 8 seconds > 03/02/2010 15:57:13 - 16:17:21
Analysis: CSF Infusion Test
Time period selections
Baseline
Transition
Plateau
Infusion
Reset Parameters Configure
Results:
Infusion rate [ml/min] = 1.50
Calculation mode = dynar
One needle only = no
Shunt type = CSF-
Shunt setting = mediu
ICP baseline [mmHg] = 11.79
ICP plateau [mmHg] = 23.18
AMP baseline [mmHg] = 0.66
AMP plateau [mmHg] = 1.19
Rcsf [mmHg*min/ml] = 9.11
More..
Comments:
The shunt does not appear to drain properly!
Delete Analysis CSF Infusion Test THRT Cuff Test CO2 Test


ICP [mmHg]
Time [min]
Amp [mmHg]
Time [min]
(P-Pss)/(Pb-Pss) [1/1]
Volume [ml]
Amp [mmHg]
ICP [mmHg]

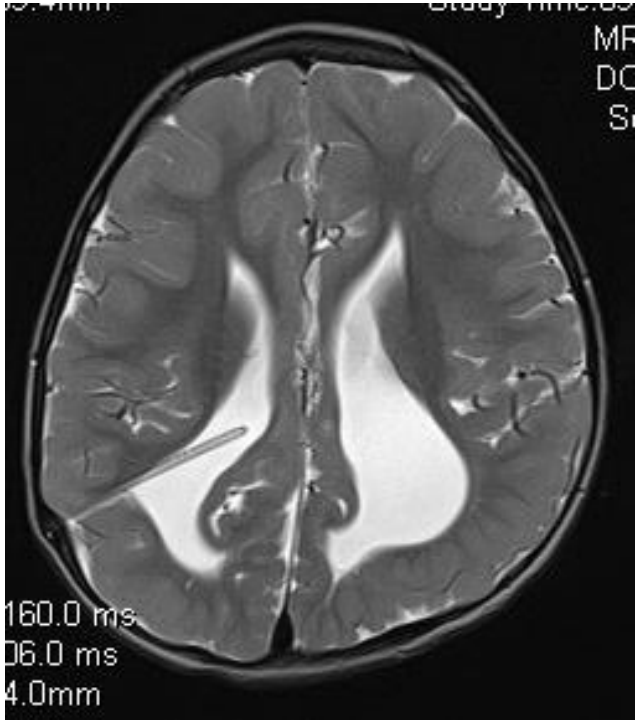

ICP [mmHg]
Time [min]
Amp [mmHg]
Time [min]
(P-Pss)/(Pb-Pss) [1/1]
Volume [ml]
Amp [mmHg]
ICP [mmHg]

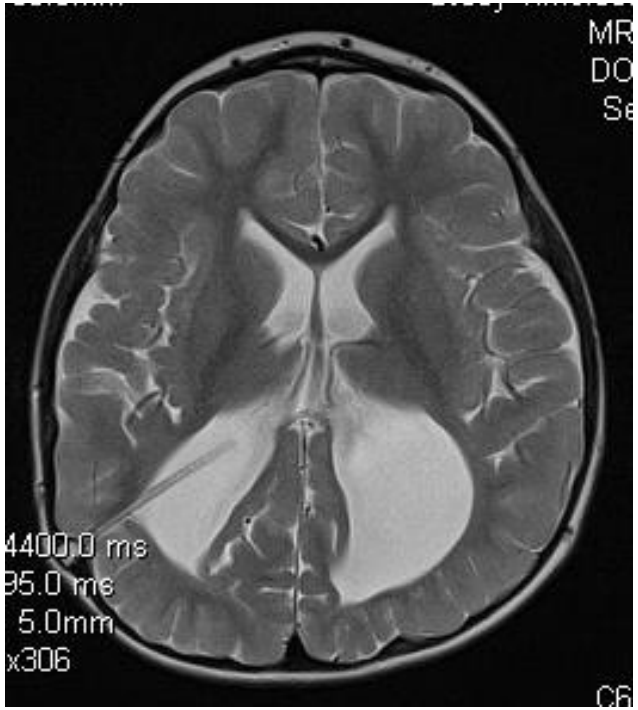
Proximal catheter block

- Complete occlusion
  - No pulse waveform (sometimes respiratory only)
  - Rapid rise in recorded pressure to shunt pressure on infusion
  - Distal occlusion – very rapid rise
- Partial occlusion
  - Low amplitude pulse waveform
  - May vary with increasing infusion
- Slit ventricle syndrome
  - No pulse waveform
  - Improves on infusion or distal occlusion
  - High ICP

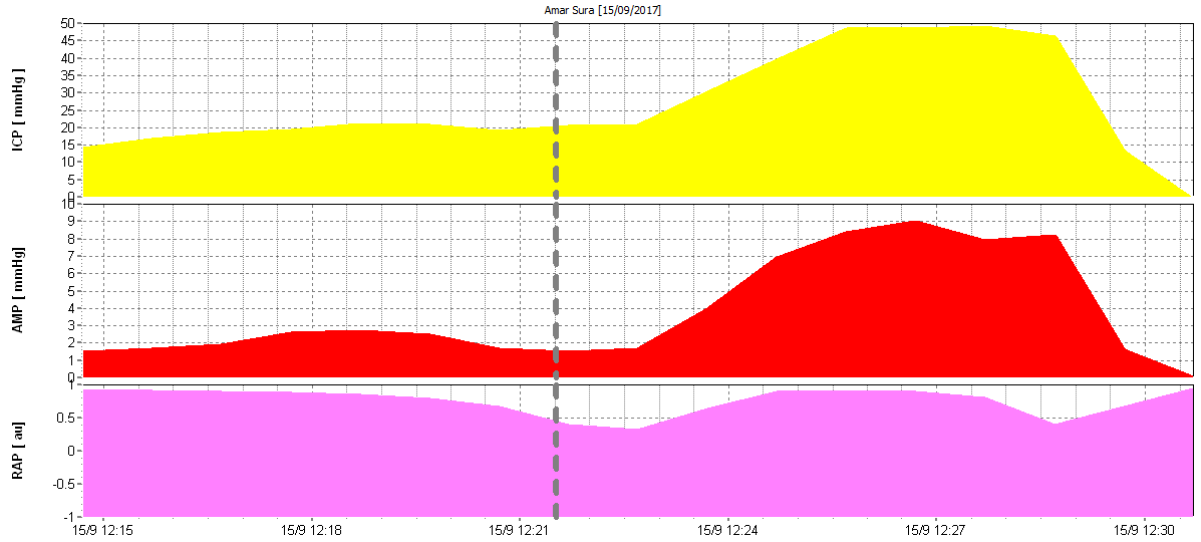
Czosnyka Z, Sinha R, Morgan J et al. Shunt testing in vivo: observational study of problems with ventricular catheter. Acta Neurochir Supple 2016; 122-353-6.

- 20 children in three years
- Definitive results in all of them
- All difficult patients
  - Cerebral palsy
  - Equivocal radiological change
  - Chronic symptoms
  - Surgery of careful follow-up
  - Close ophthalmological surveillance


160.0 ms
06.0 ms
4.0mm


4400.0 ms
35.0 ms
5.0mm
x306

Infusion Study
Date: 15/09/17



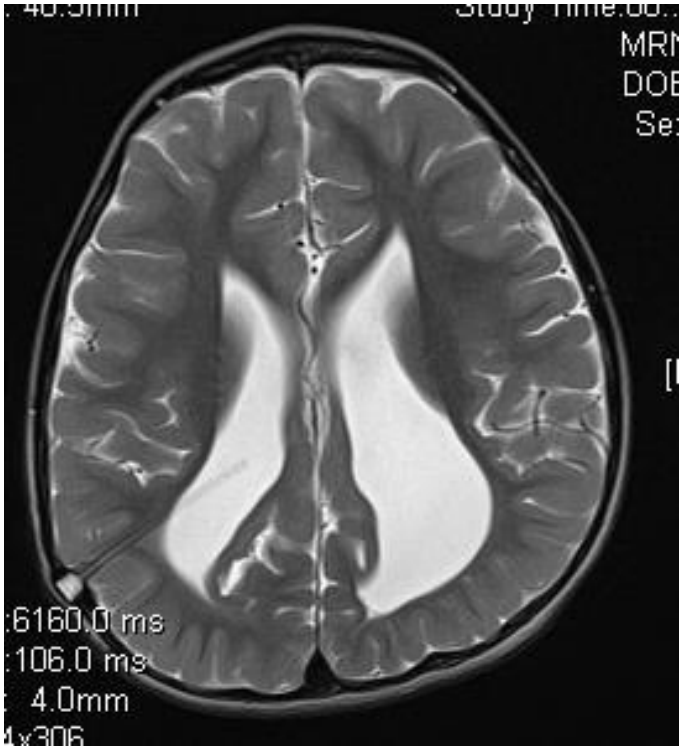
Tests Results:

[CSF Infusion Test]

Infusion rate [ml/min]	1.50	Calculation mode	dynamic
One needle only	no	Shunt type	Miethke - PediGav
Shunt setting	8		
ICP baseline [mmHg]	19.13	ICP plateau [mmHg]	48.41
AMP baseline [mmHg]	2.02	AMP plateau [mmHg]	8.38
Rcsf [mmHg*min/ml]	22.27	Elastance [1/ml]	0.10
PVI [ml]	23.04	Pss [mmHg]	-77.87
CSF production rate [ml/min]	4.36	Volume infused [ml]	9.78
Infusion duration [min]	6.52	Normalised Error [%]	1.659
Shunt critical ICP [mmHg]	19.85	Shunt resist. [mmHg*min/ml]	5.50

Opening pressure 15 mmHg with a good waveform. Plateau pressure >50 mmHg.

Results indicative of shunt malfunction. Patient admitted for shunt revision.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:4920.0 ms
:101.0 ms
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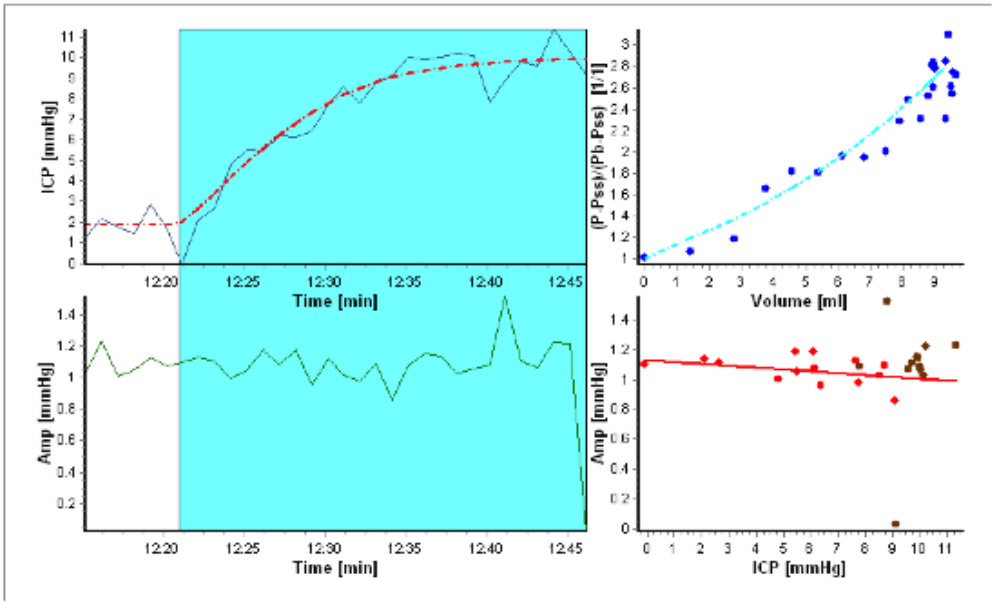
Study Date:



Tests Results:

[CSF Infusion Test]

Infusion rate [ml/min]	1.50	**Calculation mode**	dynamic
One needle only	no	**Shunt type**	Sophy-Programmable
Shunt setting	70		
ICP baseline [mmHg]	1.86	**ICP plateau [mmHg]**	9.75
AMP baseline [mmHg]	1.09	**AMP plateau [mmHg]**	1.06
Rcsf [mmHg*min/ml]	5.42	**Elastance [1/ml]**	0.10
PVI [ml]	23.15	**Pss [mmHg]**	-2.69
CSF production rate [ml/min]	0.84	**Volume infused [ml]**	42.36
Infusion duration [min]	28.24	**Normalised Error [%]**	2.061
Shunt critical ICP [mmHg]	82.95	**Shunt resist. [mmHg*min/ml]**	5.30

Comments

The shunt appears to function properly

DOI: 10.3171/2011.10.JNS1140

The constant flow ventricular infusion test: a simple and useful study in the diagnosis of third ventriculostomy failure

Clinical article

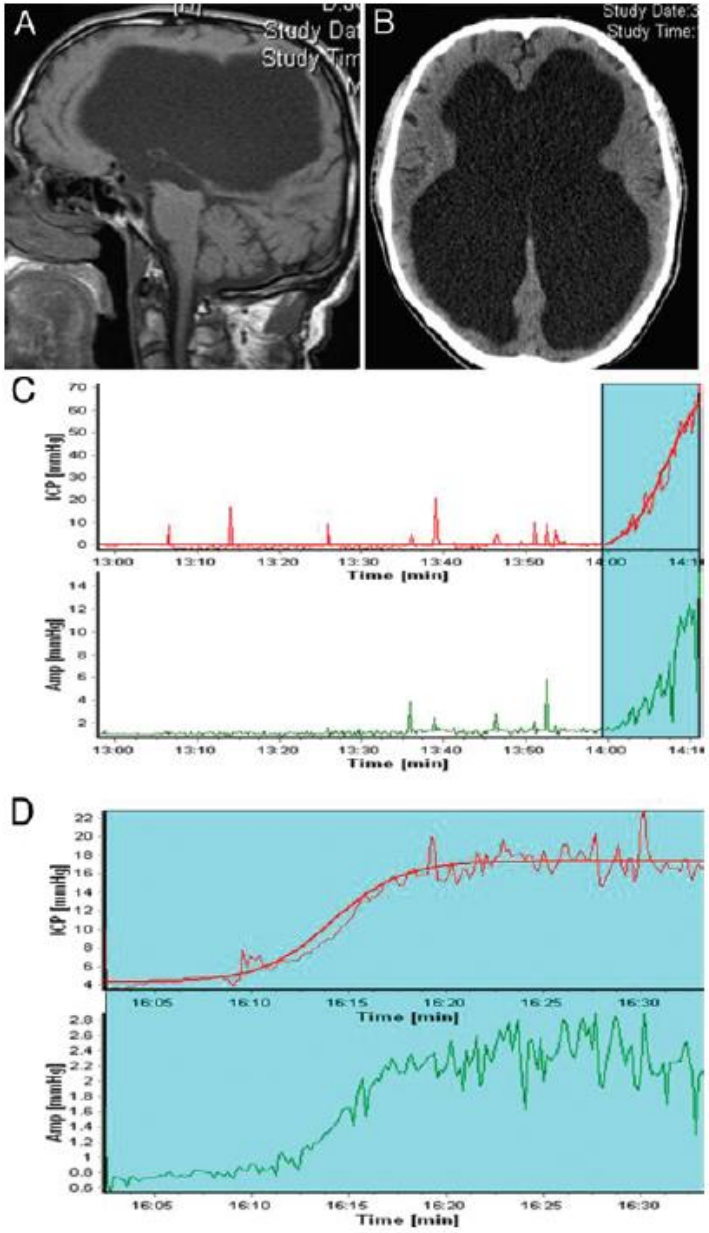
Kristian Aquilina, F.R.C.S.(SN), Ian K. Pople, M.D., Jenny Sacree, R.S.C.N., Michael R. Carter, F.R.C.S.(SN), and Richard J. Edwards, M.D.

Department of Neurosurgery, Frenchay Hospital, Bristol, United Kingdom

TABLE 3: Comparison between functioning and nonfunctioning ETVs

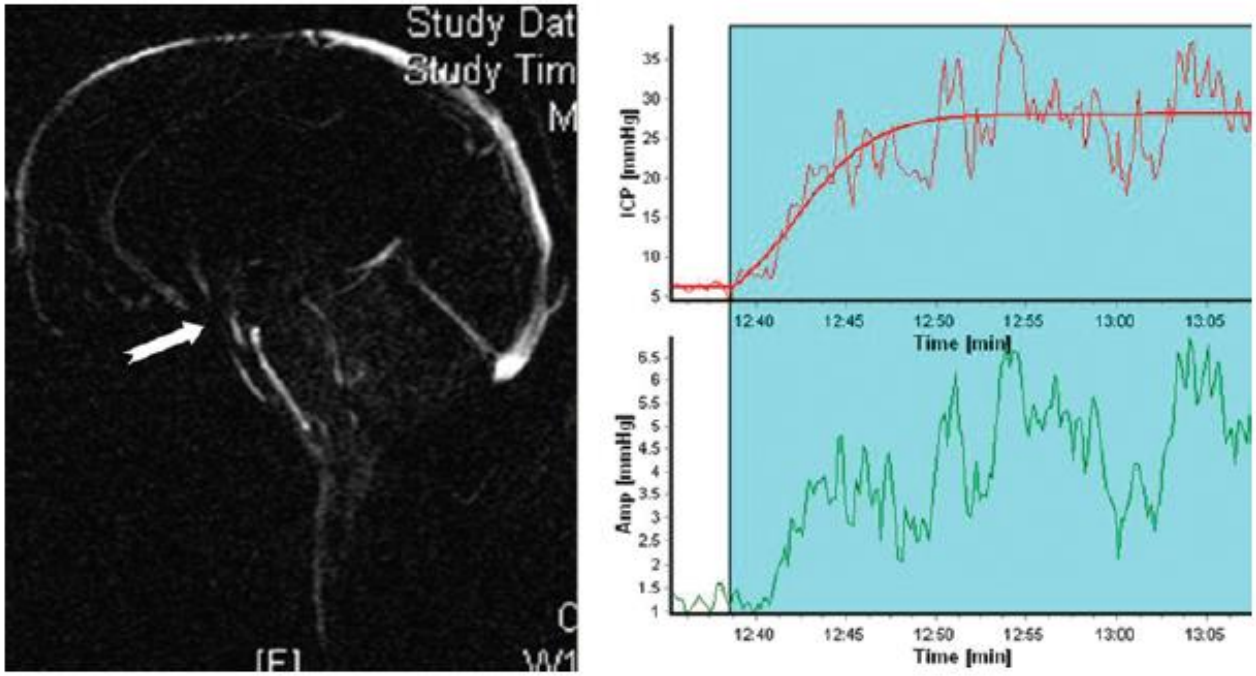
Variable	Mean ± SD		p Value (unpaired t-test)
	Functioning ETV	Nonfunctioning ETV	
R_{out} (mm Hg/ml/min)	7.25 ± 2.9	17.04 ± 7.4	0.00*
ICP (mm Hg)			
baseline	9.84 ± 4.9	8.10 ± 5.3	0.29
plateau	21.03 ± 7.4	32.57 ± 9.9	0.00*
amplitude			
baseline (mm Hg)	1.27 ± 0.6	1.21 ± 0.6	0.79
plateau (mm Hg)	2.66 ± 1.6	4.50 ± 3.2	0.13
difference (%)	132.39 ± 129.8	293.30 ± 218.5	0.06
RAP			
baseline	0.57 ± 0.3	0.56 ± 0.2	0.94
plateau	0.76 ± 0.1	0.81 ± 0.1	0.47
difference (%)	139.07 ± 263.7	92.79 ± 140.4	0.52
slow waves (mm Hg)			
baseline	1.33 ± 0.9	1.20 ± 0.5	0.64
plateau	2.43 ± 1.1	6.33 ± 2.7	0.01*
follow-up (mos)	20.60 ± 14.1	15.53 ± 12.2	0.20

* Statistically significant ($p < 0.05$).



Failed ETV

After shunt insertion

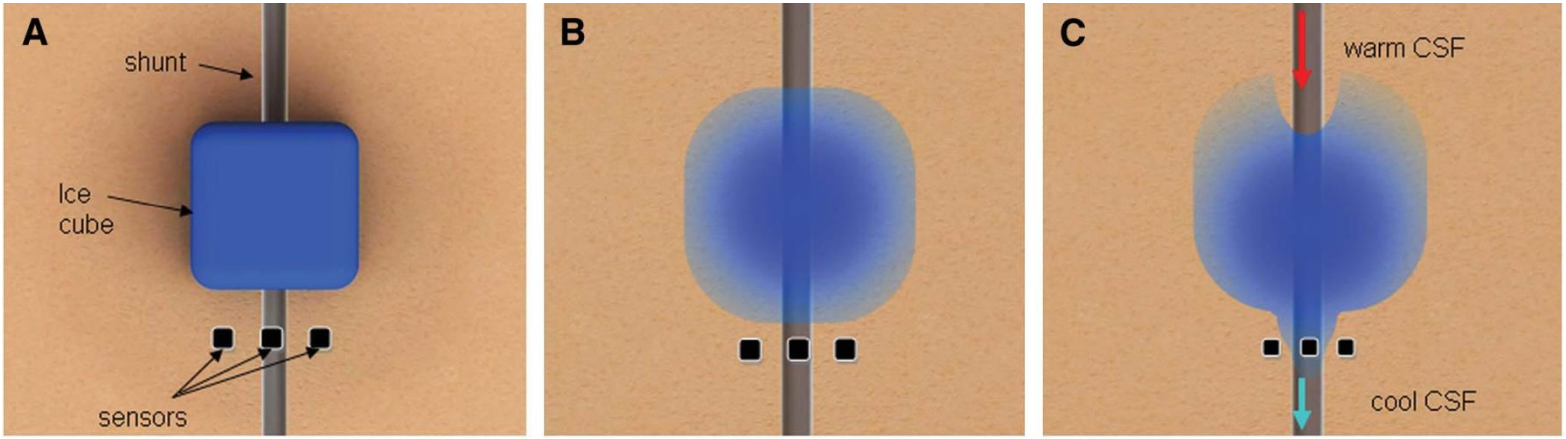


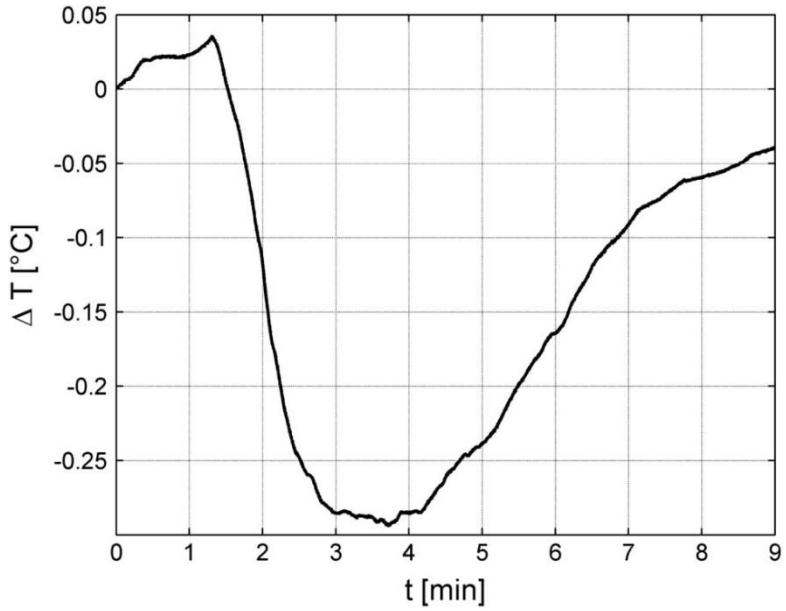
Bulk flow across the stoma, or evidence of global CSF absorptive capacity?

Conclusions

- The infusion study remains an important method in the evaluation of CSF dynamics
- It is particularly useful in paediatric practice to determine shunt malfunction in difficult cases
- It is also helpful in ETV when ventricular change is minimal

Thank you





Madsen JR, Abazi G, Fleming L, Proctor M, Grondin R, Magge S, Casey P, Anor T. Evaluation of the ShuntCheck noninvasive thermal technique for shunt flow detection in hydrocephalic patients. Neurosurgery 68:198–205, 2011