

# ICM plus - a Versatile Software for Assessment of CSF Dynamics

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### Introduction

Brain monitoring requires computer support because the recorded signals can be very complex and identification of clinically relevant models is frequently required.

# What is need in order to perform an infusion study ?

- Pressure amplifier/monitor
- Computer running software for data analysis
- Syringe pump
- Trolley with isolation power supply
- Consumables

Total cost of trolley: \$ 16,000



The computerized infusion test is a modification of the traditional constant rate infusion test as described by Katzman and Hussey. The method requires fluid infusion to be made into any accessible CSF compartment proximal to any hypothetical block in the CSF pathway.

There is a low (less than 1.2%) risk of CSF infection following the study if a due care is taken during skin preparation, filling of manometer lines and transducers.



- Baseline ICP is first recorded, pulse amplitude of ICP calculated via spectral analysis and heart rate estimated
- RAP index (moving correlation coefficient between changes in pulse amplitude an mean ICP) is useful for assessment of the compensatory reserve
- Then infusion starts (rate 1.5 ml/min or 1 ml/min), pressure increases and after some time reaches plateau



During the infusion study (or after) full identification of CSF dynamics model is performed (Marmarou 1973). Parameters like baseline pressure, amplitude, resistance to CSF outflow, elasticity, reference pressure, CSF formation rate are calculated.

# Applications

1. Diagnosing types of CSF disorders to support clinical decision-making about shunting/ETV.



- NPH (top left) consider shunting
- Atrophy (bottom left) do not shunt
- Acute hydrocephalus post-SAH (top right) shunt immediately
- Normal CSF circulation (bottom right)

   no shunt, observation with repeated test if clinical symptoms are still persistent is recommended

2. Shunt testing in-vivo: database of all contemporary shunts (from Cambridge Shunt Evaluation Laboratory) is included in software and compared with pattern of the test.



Left: ventricular blockage with sudden rise of pressure after occlusion of SCD. Right: distal obstruction (opening and plateau pressures exceeded lab values).

# Results

Over a 17 year period (1992-2009), 2665 clinical infusion studies and 305 overnight ICP monitoring sessions have been performed in Addenbrooke's Hospital, Cambridge UK in 1423 patients suffering from hydrocephalus of various aetiologies.

All of the patients were referred to the CSF clinic by their treating neurosurgeon, geriatrician or neurologist, based on the presence of ventricular dilatation on brain scan (CT or MRI) and symptoms within Hakim's triad and other clinical presentations like headaches etc.

This group of patients, in addition to the normal clinical and imaging assessment, were investigated with a constant rate infusion study [via the lumbar approach (20%), a pre-implanted Ommaya reservoir (38%), shunt pre-chamber (40%) or open EVD (2%)]. In some, overnight ICP monitoring was performed in addition to or as an alternative to the infusion test.

# Conclusions

Quantitative variables derived from CSF dynamics allow differentiation between clinically overlapping entities such as shuntresponsive normal pressure hydrocephalus and brain atrophy as well as allowing the detection of shunt malfunction (partial or complete blockage) or overdrainage.

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