Intracranial Pressure Monitoring in Intracranial Hypotension

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• Continuous ICP Monitoring Setup
• cICP in skull based CSF leaks
• cICP normative data in upright position
• cICP in spontaneous spinal CSF leaks
• cICP guided percutaneous intervention

• Units: 1 mm Hg = 1.3 cm of Water
Limitations of measuring opening pressure during lumbar puncture

• Improper positioning, especially when performed under fluoroscopic guidance

• Diurnal variation, increased pressure with sleep-disordered breathing (apnea or hypopnea)

• Hyperventilation due to anxiety and/or pain lower ICP

• Pressures often normal in lateral decubitus position – not surprising since the majority of leak patients have abnormal pressures only during upright position when they are most symptomatic
Direct measurement and graphic recording of intracranial pressure through a trephined opening was described by LEYDEN in 1866.

KEY & RETZIUS (1875) were the first to measure CSF pressure in animals, and KNOLL (1886) produced the first graphic records CSF pressure.

Lumbar puncture as a clinical method introduced by QUINCKE in 1891.
Bedside continuous CSF pressure monitoring

Then…
Heart rate, EKG, respirations, and oxygen saturation are recorded in addition to CSFP referenced to the external auditory meatus. Signals are amplified and conditioned using a standard physiology monitoring system (Solar 8000M, GE Healthcare, Waukesha, WI).

Analog voltages are sampled at 100 Hz and digital data are logged on a bedside computer (PowerLab data acquisition system and LabChart Pro software; ADInstruments, Colorado Springs, CO).
# CSF Pressure values in mm H2O measured @ LP*

<table>
<thead>
<tr>
<th></th>
<th>Acute IIH</th>
<th>Chronic IIH</th>
<th>Normal Obese</th>
<th>Normal Lean</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average</strong></td>
<td>343.9</td>
<td>253</td>
<td>167 SD 36.46</td>
<td>136 SD 37.6</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>200-550 (100%)</td>
<td>&gt;250 (90%)</td>
<td>200-250 (44%)</td>
<td>200-250 (25%)</td>
</tr>
<tr>
<td></td>
<td>&gt;250 (28%)</td>
<td>&lt;200 (28%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*no sedation, local, 22-gauge needle, <1 ml of CSF loss, left lateral decubitus, head and legs extended, pressure recorded for 1'*

Revised Criteria: Adults: 5-25 cm, Children: 5-28 cm
Normal continuous Intracranial Pressure
Continuous ICP Monitoring – IIH (LP opening pressure: 19 cm H2O)

Mean ICP > 20 mm Hg (26 cm H2O) for over 35 minutes
IIHWOP, multiple shunts: Headache – 10/10, no papilledema, normal cICP recording

Chart Window

Heart Rate

EKG (mV)

Respirations (mm Hg)

ICP (mm Hg)

SaO2 (%)
Skull based CSF Leaks

- CSF otorrhea and rhinorrhea can be congenital, post blunt head trauma, cranial or endoscopic surgery, or spontaneous

- Spontaneous idiopathic CSF leaks are 25–87% more likely to recur after surgical closure

- Pseudotumor cerebri and spontaneous CSF leak share common risk factors
CSF Otorrhea & Rhinorrhea

- Non-traumatic cases have higher incidence of surgical failure
- Some have findings of empty sella - ?forme fruste of PTC
CSF Otorrhea & Rhinorrhea - preop

Chart Window

EKG (m...-1000
-500
0
500
1000

Respiration...-1000
-500
0
500
1000

ICP (mm Hg) (mmHg)

SaO2 (%)
25% need Diamox postop and 5% shunts

Perioperative ICP management of spontaneous skull based CSF Leaks

- Neuro-ophthalmology assessment
- Lumbar puncture
- Sleep study – mandibular advancement device for OSA, NOT CPAP
- Lumbar continuous ICP Monitoring pre-op and post-op

What are normal intracranial (not lumbar) pressures when upright?
11 patients with hydrocephalus, posterior fossa tumors and aqueductal stenosis etc

Body position and cerebrospinal fluid pressure

Part 1: Clinical studies on the effect of rapid postural changes

Bjørn Magnaes, M.D.
Department of Neurosurgery, Rikshospitalet, Oslo University Hospital, Oslo, Norway

J. Neurosurg. / Volume 44 / June, 1976
Location matters

Ventricular Catheter (Ventriculostomy)

To monitor

Subarachnoid Screw (bolt)

To monitor

3-4 cm
<table>
<thead>
<tr>
<th>Author</th>
<th>N</th>
<th>Subjects</th>
<th>Reference</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chapman-Cossman</td>
<td>8</td>
<td>patients</td>
<td>Foramen of Monro</td>
<td>-5 to +5 cm H2O</td>
</tr>
<tr>
<td>Loman</td>
<td>13</td>
<td>normals</td>
<td>Cisterna magna</td>
<td>-8.5 to +4.5 cm of H2O</td>
</tr>
<tr>
<td>Bradley</td>
<td>1</td>
<td>patient</td>
<td>Convexity</td>
<td>-16.5 cm H2O</td>
</tr>
<tr>
<td>Fox</td>
<td>18</td>
<td>patients</td>
<td>Foramen of Monro</td>
<td>-14 to +7 cm</td>
</tr>
<tr>
<td>Andresen</td>
<td>4</td>
<td>normals</td>
<td>Convexity</td>
<td>-10 to 0 mm Hg</td>
</tr>
<tr>
<td>Juhler</td>
<td>4</td>
<td>normals</td>
<td>Convexity</td>
<td>-9 to 0 mm Hg</td>
</tr>
</tbody>
</table>
What is low pressure?

Less than -10 mm Hg when monitored by a parenchymal transducer in the cortex.
Effect of postural changes on ICP in healthy and ill subjects

Morten Andresen · Amer Hadi · Lonnie G. Petersen · Marianne Juhler
Normal ICP change with position

Supine  Sitting  Standing  Supine

ICP (mm Hg) (mmHg)

SaO2 (%)


2:19:00 PM 2:19:30 PM 2:20:00 PM 2:20:30 PM 2:22:00 PM 2:22:30 PM 2:23:00 PM 2:26:00 PM

28 29 30 32 33

Normal ICP change with position
ICP changes with sitting in a EDS patient with no classic MRI brain findings over 60 mins
Severe orthostatic headaches; negative imaging
Sitting up in bed
CSF Leak s/p multilevel epidural blood/fibrin patches with persistent orthostatic symptoms
Multi-level perineural cysts  Day 1 baseline monitoring, sitting up
Day 2 after 4 multilevel blood/fibrin patches
Day 3 after an additional 2 levels were targeted
Spinal CSF Leak – baseline Day 1 monitoring - supine
Day 2 – post patch rebound hypertension - supine

Mean CSFP was greater or equal to 19 mm Hg (about 25 cm water) for 27 mins (8.7% of the recording) and greater or equal to 15 mm Hg (about 20 cm water) for 64 (20.5%). Mean peak CSFP ranged from 9.3 to 42.5, with average mean peak CSF of 16.1. Mean peak CSFP was greater or equal to 25 for 25 minutes (8.0%). Mean waveform amplitude was 5.6, and ranged from 2.9 to 18.5. Mean waveform amplitude was greater than or equal to 5 for 142 minutes (45.5%).
Skull based CSF leak
A 61 year-old male with beta-2 transferrin positive left-sided rhinorrhea
BMI was 26.6, no clinical history of obstructive sleep apnea, meningitis, trauma, or sinonasal/cranial surgery.

Prior to endoscopic endonasal repair, a lumbar spinal catheter was inserted.
Overnight CSF pressure monitoring revealed CSF pressure greater or equal to 19 mm Hg 11% of the time.
Mean CSF pulse waveform amplitude was greater than 5 mm Hg for 53.4% of the time.
Lumbar drainage was performed for 3 days.
Overnight post-operative CSF pressure monitoring showed CSF pressure greater than 19 mm Hg only 5.6% of the time.
Positional CSF pressure testing was done…

• High-resolution CT showed left sided planum sphenoidale defect
• T2-weighted MR demonstrated left sided meningoencephalocele extending into the left sphenoid sinus
Supine CSF Pressure Recordings

Head right = 32.5 mm Hg (44.2 cm H₂O)

Head left = 36.8 mm Hg (50 cm H₂O),
Angiography demonstrates focal transverse venous sinus stenosis

Pre stent

Post stent
Pre-stent

Post- Left transverse sinus stent
One year following surgical leak repair he underwent a diagnostic angiogram with cerebral venous sinus manometry

Bilateral transverse sinus pressure gradient of 6.7 mm Hg across the areas of stenosis.

Eight months following stenting, the patient was weaned off acetazolamide and he remains asymptomatic at 30 months follow up.

A 6 x 40 mm right transverse sinus stent was then deployed in the right transverse sinus. Pressure gradients decreased to 0.4 mm Hg right and 2.3 mm Hg left.

# ICP Monitoring in large Tarlov Cysts with no radiographic signs of leak

<table>
<thead>
<tr>
<th>Age</th>
<th>Diagnoses</th>
<th>Upright pressure (mm Hg)</th>
<th>Orthostatic headache</th>
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<tbody>
<tr>
<td>58</td>
<td>Tarlov cyst.</td>
<td>-13</td>
<td>Yes</td>
</tr>
<tr>
<td>49</td>
<td>Sacral dural cyst</td>
<td>-16</td>
<td>Yes</td>
</tr>
<tr>
<td>41</td>
<td>Sacral cyst</td>
<td>-14</td>
<td>Yes</td>
</tr>
<tr>
<td>49</td>
<td>Marfan syndrome, Sacral dorsal ectasias</td>
<td>-25</td>
<td>Yes</td>
</tr>
<tr>
<td>25</td>
<td>Tarlov cyst</td>
<td>-10.7</td>
<td>Yes</td>
</tr>
<tr>
<td>36</td>
<td>Tarlov cysts</td>
<td>-7</td>
<td>Yes</td>
</tr>
<tr>
<td>39</td>
<td>Tethered cord syndrome, Tarlov cyst</td>
<td>-20</td>
<td>Yes</td>
</tr>
<tr>
<td>31</td>
<td>Sacral cyst</td>
<td>-12</td>
<td>Yes</td>
</tr>
<tr>
<td>66</td>
<td>Large sacral internal meningocele</td>
<td>-5</td>
<td>Yes</td>
</tr>
<tr>
<td>42</td>
<td>chronic low back pain, sacral dural cysts, infertility, bicornuate uterus.</td>
<td>-13</td>
<td>Yes</td>
</tr>
<tr>
<td>34</td>
<td>Occult spina bifida Meningocele</td>
<td>-4</td>
<td>Yes</td>
</tr>
</tbody>
</table>
cICP Implications post-treatment –

No straining……
Effects of Coughing
Sleep Apnea related ICP elevations
Practical Implications of cICP for SIH post-treatment

- Sleep Apnea
- Body position
- Rebound intracranial hypertension
- Venous Stenosis
- Avoid futile treatment
- Guide appropriate treatment
Complications

• Scalp infection: <1%
• Seizures: <1%
ICP during a GTC Seizure – exceeds CPP, O2 Sat drops
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• Dr. Aruna Rao
• Dr. David Solomon

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