CSF LEAK ASSOCIATION

Measuring Opening Pressure and Intracranial Pressure (ICP)

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Cerebrospinal Fluid Production and Volume

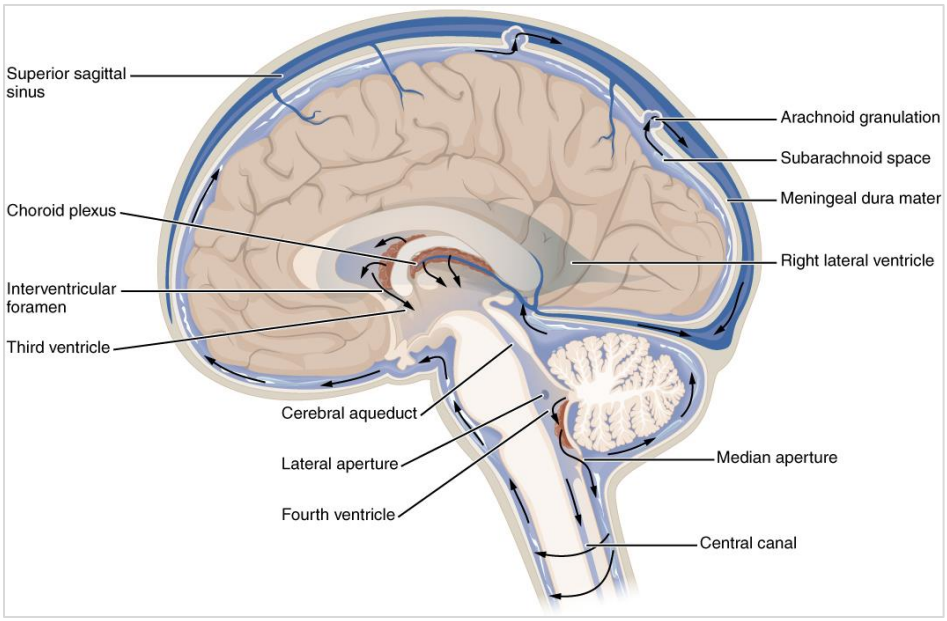

Figure 1: CSF is produced in the choroid plexuses of the ventricles of the brain. [Image: OpenStax / Wikipedia]

The brain and spine are surrounded by clear, colourless fluid known as cerebrospinal fluid (CSF). It acts as a cushion and buffer, bathing the brain and spine and providing basic mechanical and immunological protection.

In an average, healthy adult, about 125-150ml of CSF is present at any one time. CSF is contained within the meninges, of which the dura is the outer layer. It is continuously produced and reabsorbed at a rate of about 0.35 ml/min. The brain produces roughly 500 ml of CSF per day[1].

CSF is held under pressure and when a puncture or tear occurs in the dura, it leaks out of the meninges. As a result of a CSF leak, the volume of CSF drops (CSF Hypovolemia), which may also reduce its pressure.

It is principally this loss of fluid volume that produces many of the symptoms of a CSF leak and can, in some cases, result in a low opening pressure when measured by lumbar puncture, or low intracranial pressure (ICP) when measured through intracranial pressure monitoring (a measure of the pressure of fluid and tissue within the skull), known as intracranial hypotension.

It is important to note, however, that not all CSF leaks result in low opening pressure and, as such, an opening pressure within 'normal' range cannot be used to definitively rule out a CSF leak[2]. A study of 206 consecutive patients known to have a spontaneous CSF leak, published in 2017, demonstrated that only 55.3%[3] also had low opening pressure, while another study from 2015 found the figure to be as low as 34%[4]. BMI and the duration of symptoms may also influence opening pressure.

[1] http://www.neurosurg.cam.ac.uk/pages/brainphys/01-Physics_of_cerebrospinal_fluid_circulation.pdf
[2] Mokri, B. " Spontaneous low pressure, low CSF volume headaches: spontaneous CSF leaks" https://www.ncbi.nlm.nih.gov/pubmed/23808630
[3] Yao LL. "Factors affecting cerebrospinal fluid opening pressure in patients with spontaneous intracranial hypotension." https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5498838
[4] Kranz, PG. "How common is normal cerebrospinal fluid pressure in spontaneous intracranial hypotension?" https://www.ncbi.nlm.nih.gov/pubmed/26682575

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Ways of Measuring CSF Pressure

The pressure at which the cerebrospinal fluid is held within the body, also known as intracranial pressure (ICP) when measured within the skull, is typically measured in two different ways:

1. A pressure sensor can be introduced into the skull to directly measure ICP (normally over a period of hours or days), known as ICP monitoring (see Figure 3), or

2. CSF pressure in the spine (called 'opening pressure') can be monitored via lumbar puncture using a manometer (see Figure 2).

Neither approach uses the same unit of measurement, which can cause some confusion for patients, nor is pressure within the skull always identical to pressure within the spine.

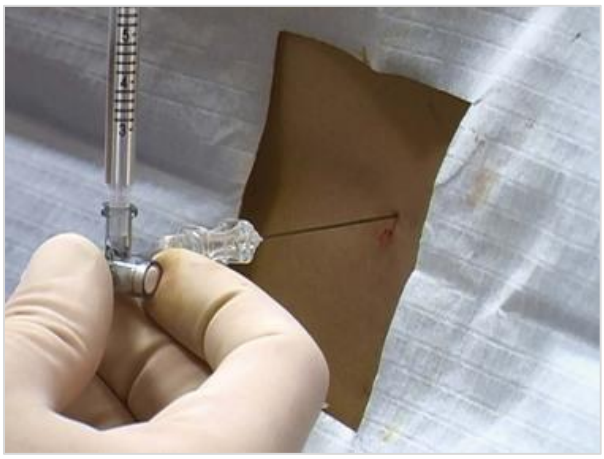

Figure 2: Measuring opening pressure by lumbar puncture brain [Creative Commons]

ICP monitoring is normally carried out over a period of hours and looks at fluctuations, changes and trends during that period, whereas opening pressure via lumbar puncture is a single reading and a snapshot in time.

The measurement of ICP is normally made in mmHg (millimetres of mercury) and opening pressure on lumbar puncture is normally measured in cmH_20 (centimetres of water), or less commonly in mmH_20 (millimetres of water).

Intracranial Pressure Monitoring

The ICP monitoring device (sometimes called an 'ICP bolt') is inserted into the skull during a short surgical procedure, which is normally performed using local anaesthetic (sometimes with mild sedation). Once the device is in place and connected to a computer, readings will be taken at regular intervals to measure the pressure in the skull.

Patients will likely notice a change in the pressure reading if they do anything that alters the pressure inside their head. This can include moving about, changing position in bed, coughing or sneezing or vomiting. A written record of what a patient was doing during the procedure is normally also kept in order to build up a complete picture.

While ICP monitoring is known to be of significant use in determining high ICP states and has a proven track record, its usefulness with spontaneous CSF leak diagnosis is less clear, with a number of leading experts opting not to use it.

In adults, mean normal intracranial pressure whilst standing is considered to be in the region of -10mmHg (max. -15mmHg)[5].

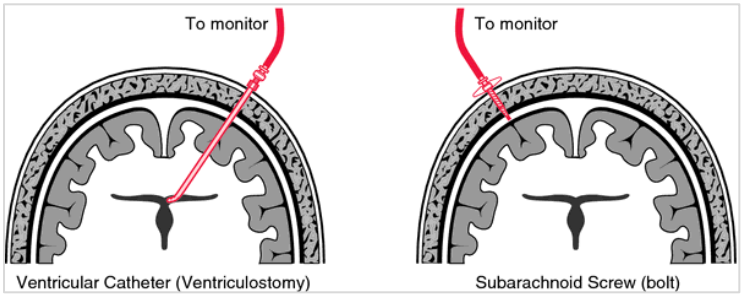

Figure 3: Types of intracranial pressure monitoring device [Polaski and Tatro, 1996]

[5] Czosnyka, M. "Monitoring and interpretation of intracranial pressure" http://jnnp.bmj.com/content/75/6/813.full

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Lumbar Puncture

Lumbar punctures are generally performed under local anaesthetic with the patient fully awake, lying on their left side (see Figure 4). Local anaesthetic is injected into the tissue posterior to the lumbar spine, normally around the L3/4 vertebrae, after which a needle is advanced through the tissue and between the vertebrae until it punctures the dura.

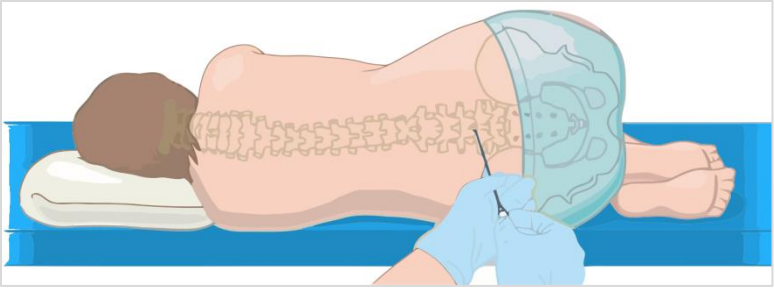

Figure 4: A lumbar puncture procedure

Once the local anaesthetic has taken affect, most patients will not experience any significant pain, but will feel pushing and pressure sensations. Most patients report that the thought of a lumbar puncture is worse than the procedure itself.

Once the needle is in place within the dura, a measuring device called a manometer is attached and used to read the opening pressure. A small amount of CSF may then be withdrawn to send to the laboratory for testing.

Where lumbar puncture is performed, in order to reduce the risk of post-dural puncture headache and more persistent CSF leaks, it is advisable for non-cutting needles (e.g. Gertie Marx) to be used whenever possible[6]. This is particularly important where a patient has symptoms of a connective tissue disorder, such as Ehlers-Danlos or Marfans syndromes.

Patients may wish to query the type of needle to be used with the doctor performing the procedure, as many practitioners - in particular those who carry out the procedure infrequently - may still be in the habit of using cutting needles by default (such as BD Quincke spinal needle).

Opening Pressure Range

What is considered to be within 'normal range' for CSF opening pressure varies noticeably between sources, as well as medical professionals. The physiology of each patient is also different, which can affect pressure, and so too their 'normal' pressure prior to suffering a CSF leak; in reality, it is impossible to state precisely what 'normal' should be for any given person and this, paired with the fact that pressure can be normal despite a CSF leak being present, can pose a problem for correct CSF leak diagnosis.

When measured in left lateral decubitus position (lying on left side), a common definition of 'normal' is an opening pressure range of 7-18 cmH_2O in adults[7], although some also consider the normal range as being 10-20 cmH_2O[8] or 5-25 cmH_2O[9]. Two notable studies examining spontaneous CSF leaks (published in 2015 and 2017) use ≤6 cmH_2O as the lower threshold[10].

While the 'normal range' for opening pressure may more properly be considered an 'average range', it is, however, widely agreed that a pressure reading of ≥25 cmH_2O or ≤6 cmH_2O is unlikely to be normal, and would likely be abnormally high or low respectively. High pressure is known as intracranial ***hyper***tension, while low pressure is known as intracranial ***hypo***tension.

False Positives/Negatives

A number of factors may influence opening pressure and result in an inaccurate or misleading reading being taken. Lumbar punctures are normally carried out with the patient lying on their side with their head supported, and that position is what most opening pressure ranges relate to.

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[6] Engedal, TS. "Changing the needle for lumbar punctures: results from a prospective study." https://www.ncbi.nlm.nih.gov/pubmed/25590665
[7] Reichman E F, Polglaze K, Euerle B. Neurological and Neurosurgical Procedures: Lumbar Puncture. In: *Emergency Medicine Procedures*. McGraw Hill; 2013:747-761.
[8] "Lumbar Puncture (LP) Interpretation of Cerebrospinal Fluid" http://emedicine.medscape.com/article/2172226-overview
[9] Lee S, Lueck C. Cerebrospinal fluid pressure in adults. *J Neuroophthalmol*. 2014;34(3):278-283. [PubMed]
[10] https://www.ncbi.nlm.nih.gov/pubmed/26682575 and https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5498838

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If a patient is sitting up, for example, opening pressure readings will almost certainly be higher. Similarly, if a patient is tense, straining or performing a valsalva manoeuvre, or pulling their knees up excessively tightly towards their chest, it may increase pressure of the cerebrospinal fluid within the thecal sac.

If a patient hyperventilates, this can cause the opening pressure to be lower. Patients who are dehydrated or hypotensive may also have a decreased opening pressure[11]. This is not a false negative per se, because it is a true low, but is likely to be misleading.

Further Information

For more information on CSF leaks and intracranial hypotension, including causes, symptoms, diagnosis and treatment, or to download copies of our other factsheets, please visit our website: www.csfleak.info

[11] Seehusen D, Reeves M, Fomin D. Cerebrospinal fluid analysis. *Am Fam Physician*. 2003;68(6):1103-1108. [PubMed]

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Appendix: Pressure Conversion Table

The following table provides at-a-glance conversion between the two units of measurement used in opening pressure (cmH_20 or mmH_20). While units used for intracranial pressure (mmHg) readings are also provided for information, it is important to note that it is not always possible to directly compare ICP monitoring results with opening pressure.

The reason for this is that lumbar punctures are normally performed lying down, while ICP monitoring involves the patient lying, siting, standing and walking over a period hours, and this materially affects pressure readings. Assessment of ICP readings also involves the collation and comparison of a range of different data sets and pressure patterns, rather than a single reading.

Colour-coding is provided to give a rough indication of pressure ranges relevant to opening pressure readings.

Millimetre of Mercury (mmHg)	Centimetre of Water (cmH_20)	Millimetre of Water (mmH_20)
0	0	0
0.7	1	10
1.5	2	20
2.2	3	30
2.9	4	40
3.7	5	50
4.4	6	60
5.1	7	70
5.9	8	80
6.6	9	90
7.4	10	100
8.1	11	110
8.8	12	120
9.6	13	130
10.3	14	140
11.0	15	150
11.8	16	160
12.5	17	170
13.2	18	180
14.0	19	190
14.7	20	200
15.4	21	210
16.2	22	220
16.9	23	230
17.7	24	240
18.4	25	250
19.1	26	260
19.9	27	270
20.6	28	280
21.3	29	290
22.0	30	300

Pressure Range Key

Low Pressure	Normal or Average Pressure	Moderately High Pressure	High Pressure

*This key is provided as a simple ready reckoner only and is based on a broad average of published ranges for low, normal and high pressure. Physiology and CSF dynamics differ between individuals and what may be unremarkable for one person may not be for another. You must always seek the advice of your medical team to determine the nature and implications of your intracranial or opening pressure readings.

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