

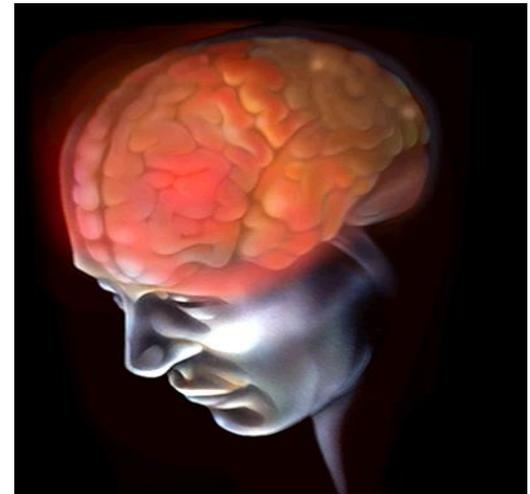
# **Mechanisms of Headache in Intracranial Hypotension**

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# *Overview*

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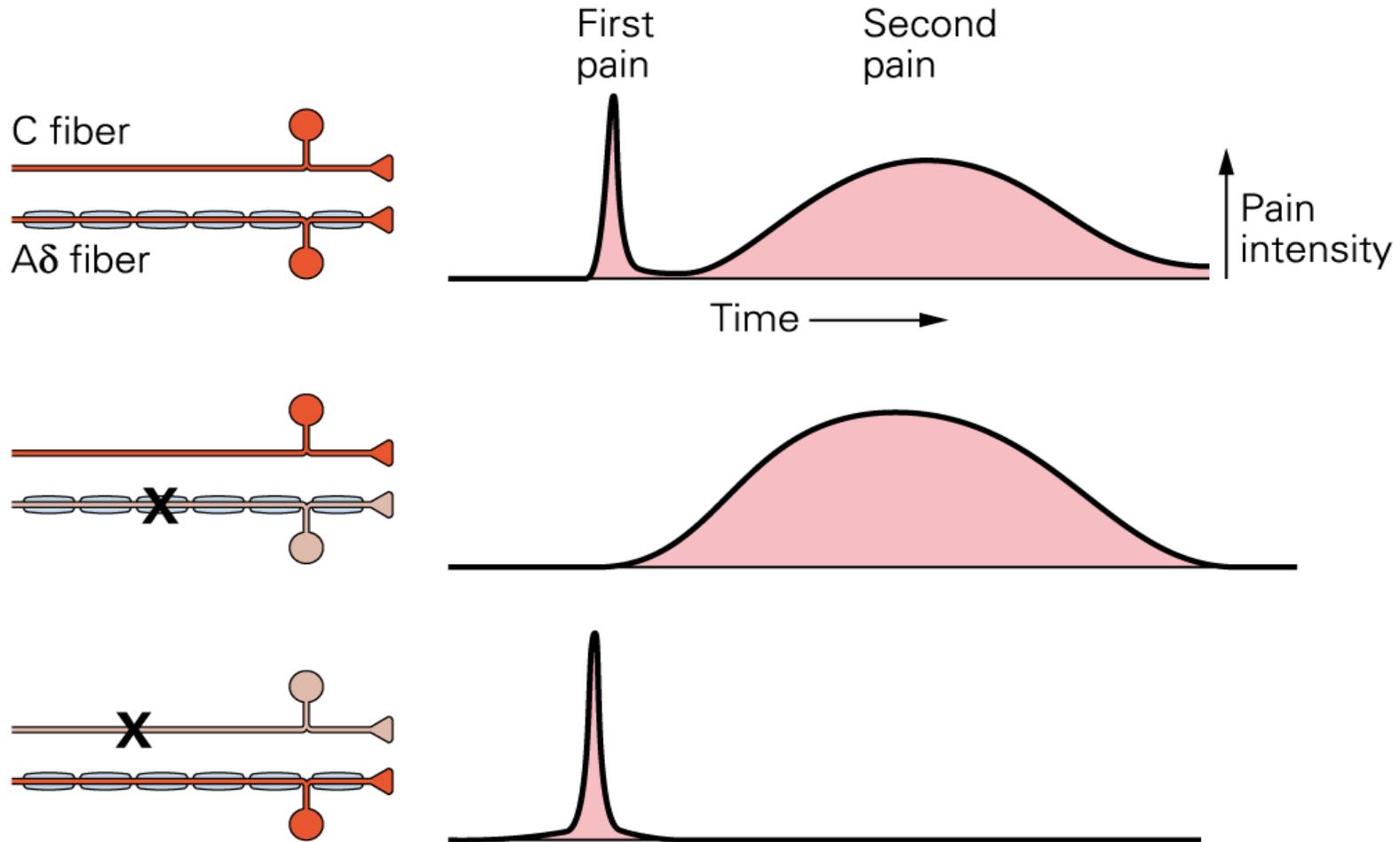
- What are the different pain fibers?
- Which are involved in pain transmission?
- What role does sensitization play in pain and headache?
- What causes headache?
- What causes low CSF pressure?
- What causes low CSF pressure headache?
  - Increased compliance?
    - HIP drift?

# *Sensory Nerve Fibers*

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<b>Fiber type</b>	<b>Myelinated</b>	<b>Conduction velocity (meters/sec)</b>	<b>Sensory Information</b>	<b>Neurotransmitters</b>
<b>A-<math>\beta</math></b>	Yes	30-100	Touch, vibration	EAA (NPY, GAL, CCK, SP, following activation or injury)
<b>A-<math>\delta</math></b>	Yes	12-30	Initial sharp pain, touch, pressure	EAA
<b>C</b>	No	0.5-2	Dull pain, temperature	Glutamate, <b>SP</b> , <b>CGRP</b> , NKA

# Acute Pain

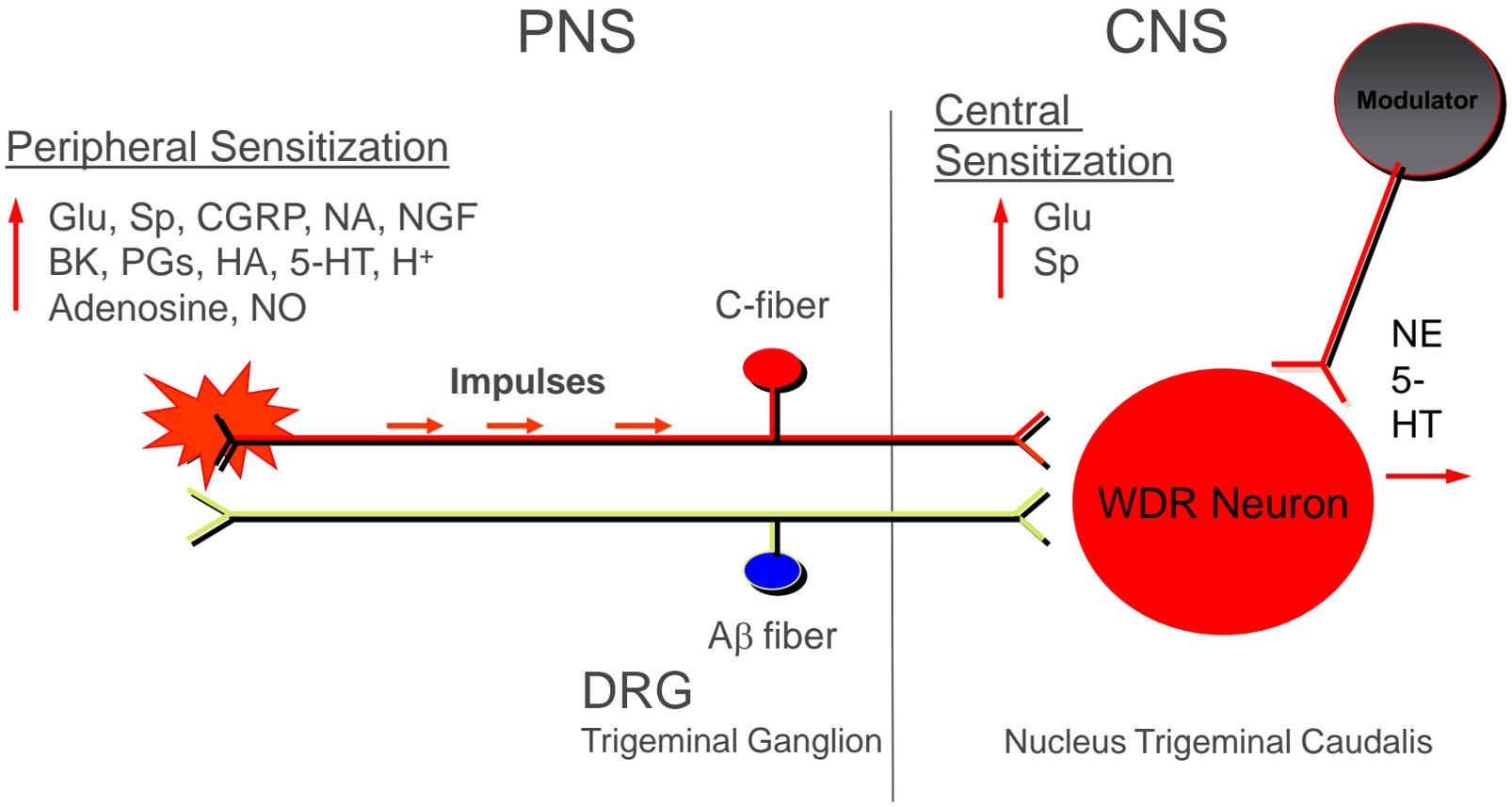


# *Sensitization*

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- Increased responsiveness to stimuli
  - **Hyperalgesia:** Increase in pain sensitivity
  - **Allodynia:** Nonpainful stimuli now painful
- Peripheral sensitization
  - Increased sensitivity of nociceptive receptor
- Central sensitization
  - Increased spontaneous neuronal discharge
  - Expanded nociceptive receptive fields

# Sensitization



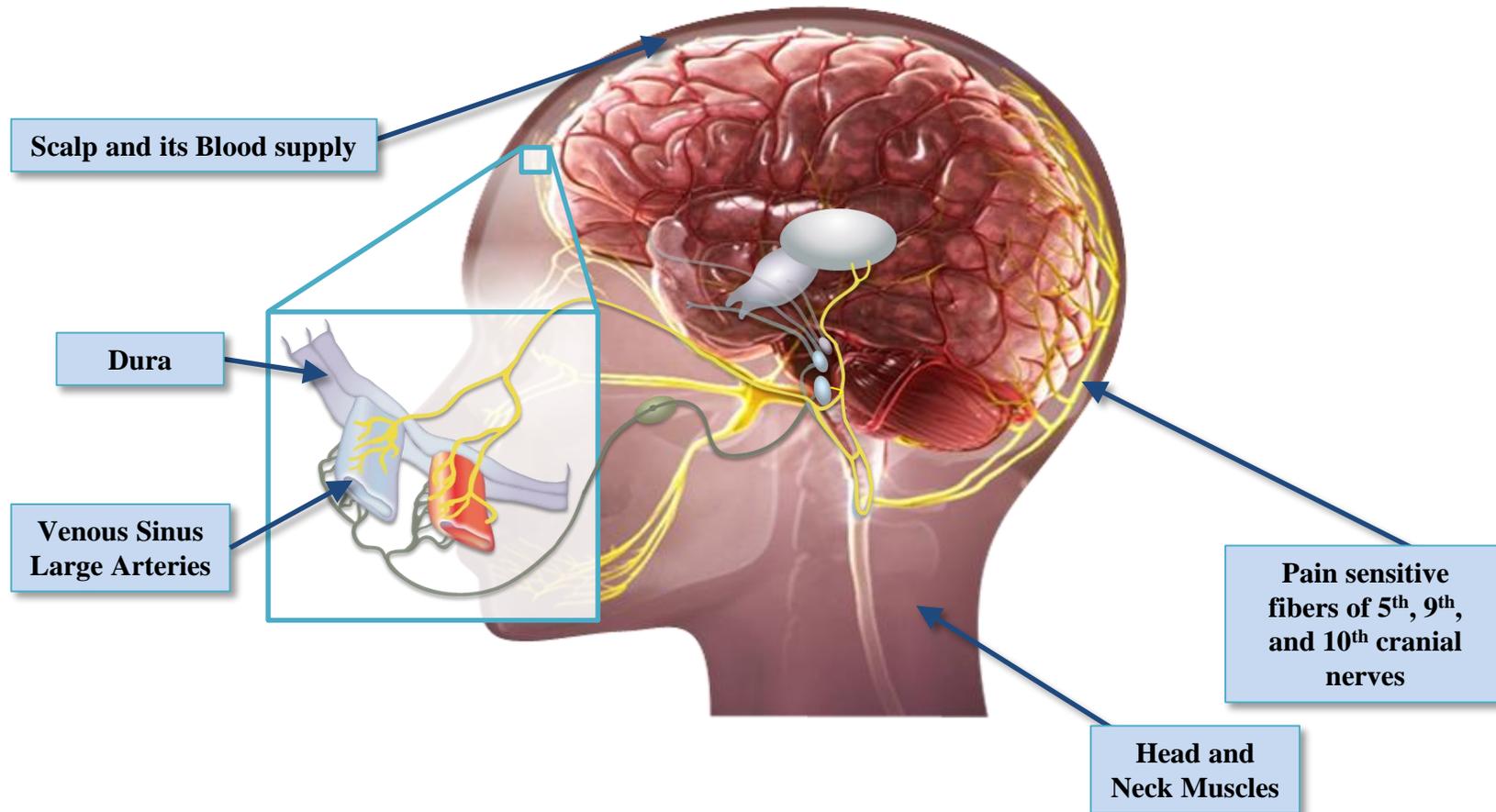
# *What Causes Headaches?*

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1. Traction, tension, or displacement of pain-sensitive structures
2. Distention/dilation of intracranial arteries, **veins or venous sinuses**
3. Inflammation of pain-sensitive structures
4. Obstruction of CSF pathways
5. Primary central pain: involvement of pain-modulating systems

# Anatomy of Headache Pain

## Pain Sensitive Cranial Structures



# *Intracranial Pressure*

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- Normal pressure:
  - 70 to 200 (or 250?) mm H<sub>2</sub>O
- Intracranial hypotension/hypovolemia
  - Symptoms with pressures < 70 mm H<sub>2</sub>O
    - At times pressure not measurable
    - At times pressure normal
  - Most common cause LP

# *Intracranial Hypotension: Causes*

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- A. LP:** diagnostic, myelography and spinal anesthesia
- B. Traumatic:** head or back trauma ( $\pm$  CSF leak)
- C. Postoperative:** craniotomy, spinal surgery, postpneumonectomy
- D. Malfunctioning** CSF shunt
- E. Spontaneous** CSF leak
- F. Systemic illness:** dehydration, diabetic coma, hyperpnea,  
meningoencephalitis, uremia, severe systemic infection

# *Intracranial Hypotension Headache Mechanisms*

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1. Downward brain displacement due to loss of **CSF buoyancy?**
  - Could cause traction on pain-sensitive structures (esp. dura)
2. Intracranial CSF volume loss
  - Can cause compensatory dilation pain-sensitive intracranial venous structures

But Headache aggravated by jugular compression

- Increases intracranial pressure and venous dilatation
- Headache not caused by intracranial hypotension alone

# *Headache Mechanisms: Buoyancy Loss*

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- CSF cushions the brain
  - Does loss ↓ upward buoyant force and cause brain sag when patient is erect?
  - Sag increases tension on veins that anchor brain to dural venous sinuses
- But no evidence to support this
  - Despite CSF loss, brain remains surrounded by fluid, so no decrease in upward buoyant force

Levine DN, Rapalino O. The pathophysiology of lumbar puncture headache. *J Neurol Sci* 2001;192:1–8.

## *Headache Mechanisms: Monroe-Kellie hypothesis*

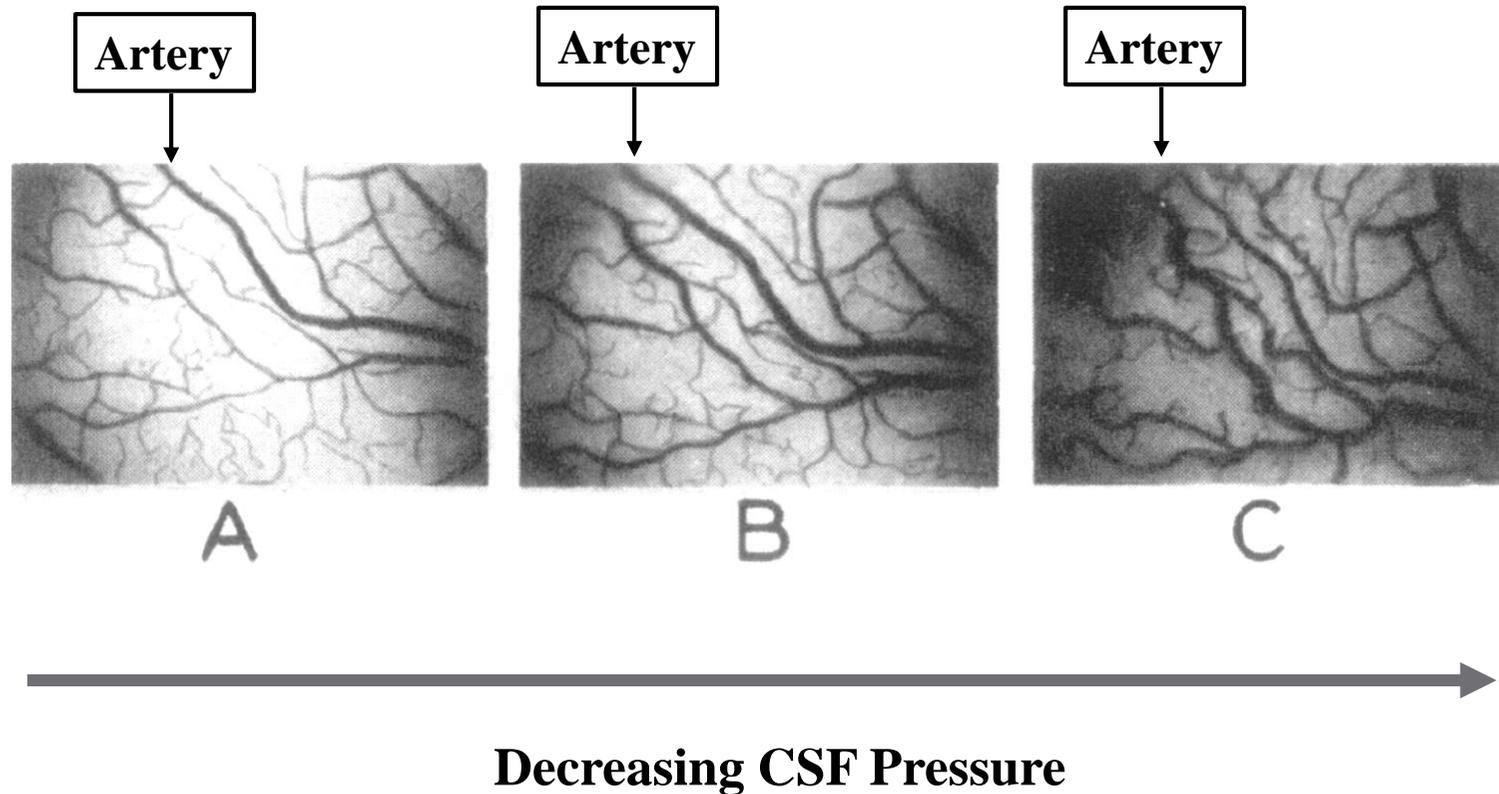
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- Sum of brain, CSF, and *intracranial* blood volume constant
  - ↓ in one causes ↑ in one or both of remaining two.
- CSF loss → ↓ CSF pressure but not venous pressure
  - Pressure difference causes veins to dilate
    - More dilatation in upright posture
- Dilatation of pain sensitive intracranial venous structures
  - → orthostatic headache
- Evidence:
  - Pial veins of anesthetized cat dilate with CSF removal
  - Jugular venous compression increases headache intensity
  - Acute venous sinuses distension produces pain

Forbes HS, Nason GI. Vascular responses to hypertonic solutions and withdrawal of CSF  
Arch Neurol Psychiatry 1935;34:533–47.

# *Pial Vessels Dilate as CSF Pressure Decreases*

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Forbes HS, Nason GI. Vascular responses to hypertonic solutions and withdrawal of CSF  
Arch Neurol Psychiatry 1935;34:533-47.

# *Intracranial Hypotension or Intracranial Hypovolemia or Neither?*

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## **CSF Pressure**

- Orthostatic headache can occur with normal pressure
- No correlation between CSF pressure and headache
- Jugular compression raises pressure and worsens headache

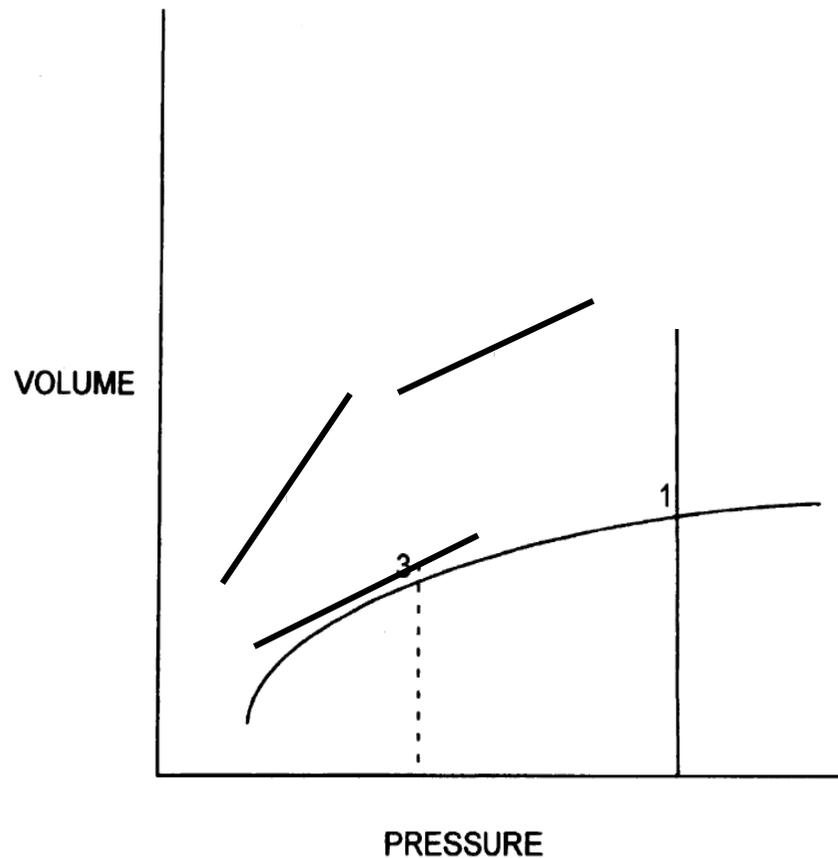
## **CSF Volume**

- Loss correlates to post-LP headache

## **Craniospinal Elasticity (Compliance)**

- Altered distribution due to spinal loss of CSF

# *Pressure Volume Curves and Compliance*

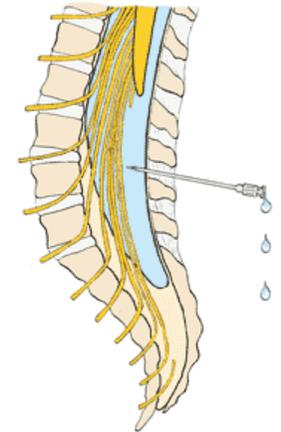
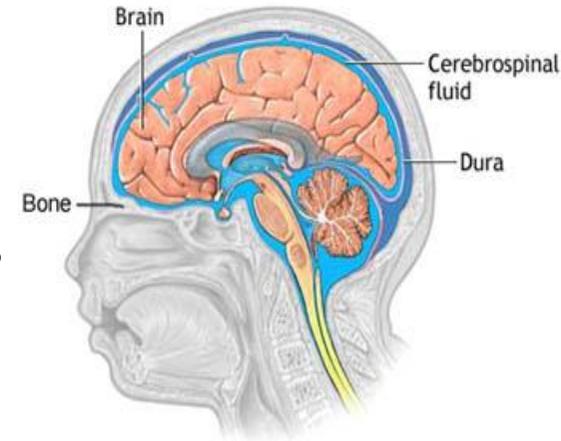


- — volume - pressure curve (less compliant)
- ---- pressure-volume curve (more compliant)
- Distensibility: slope of volume-pressure curve.
  - ↑ Compliance → ↑ Distensibility
  - ↓ pressure → ↑ Compliance

# Compliance of Membranes Enclosing CSF

## Different throughout system

- Rostral component (covered by rigid skull)
  - Depends upon compressibility of intracranial venous and capillary vessels
- Caudal component
  - Depends on degree of filling of spinal dural sac
- Increased lumbar compliance (more give) causes **HIP** to be displaced caudally



Levine DN, Rapalino O. The pathophysiology of lumbar puncture headache. J Neurol Sci 2001;192:1–8.

# *Hydrostatic Indifferent Point (HIP)*

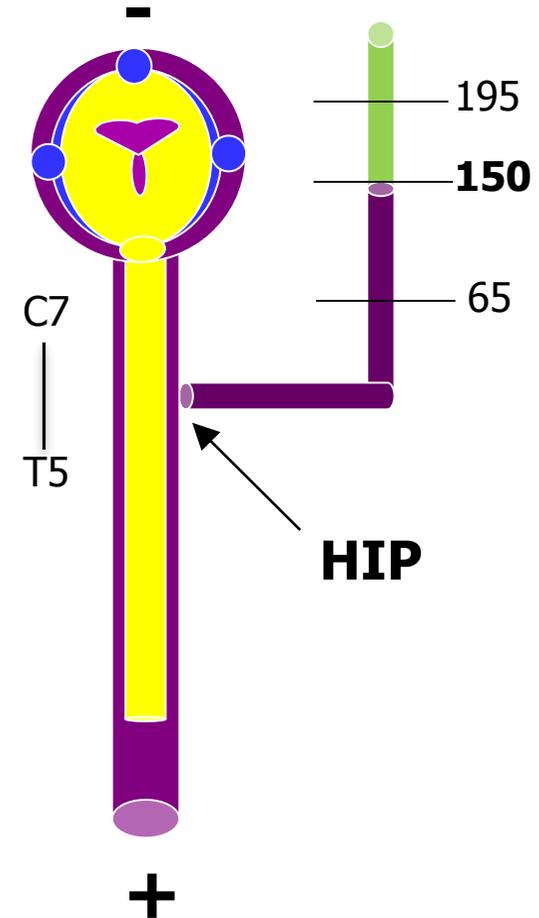
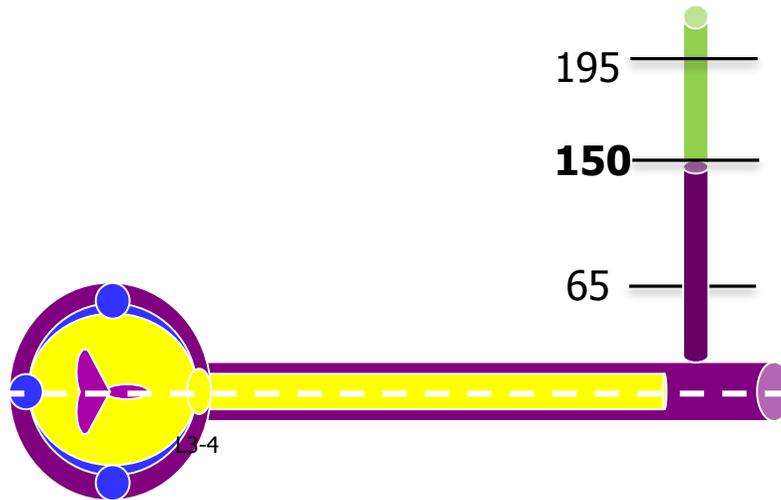
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- Point where upright CSF pressure = CSF recumbent pressure
  - Normally between C7 and T5
- CSF leak may increase lumbar compliance (more give)
  - Increased lumbar compliance shifts HIP downward
  - Independent of decreased CSF volume or opening pressure
- Upright ICP more negative: equals distance HIP displaced
  - Decrease in addition to that resulting from loss of filling pressure
- Change in lumbar compliance alone (without CSF leak) could cause orthostatic headache

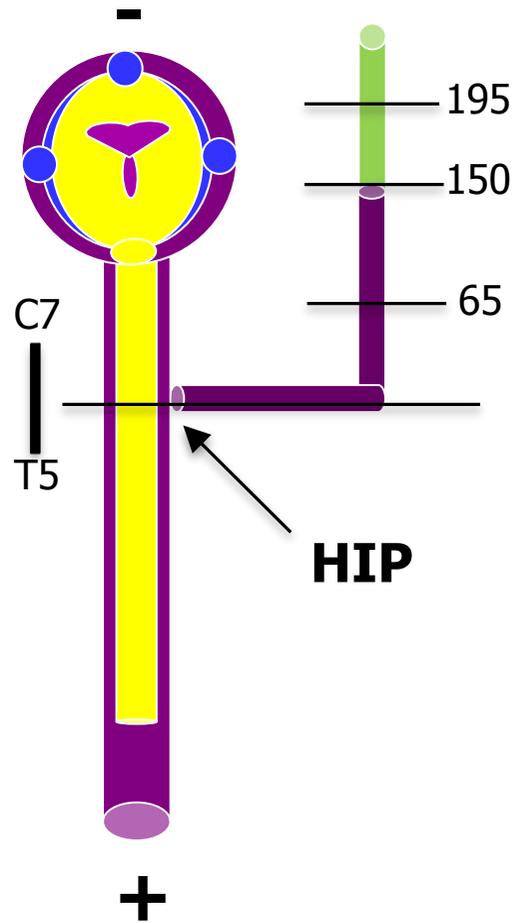
Levine DN, Rapalino O. The pathophysiology of lumbar puncture headache. J Neurol Sci 2001;192:1–8.

## Hydrostatic Indifferent Point

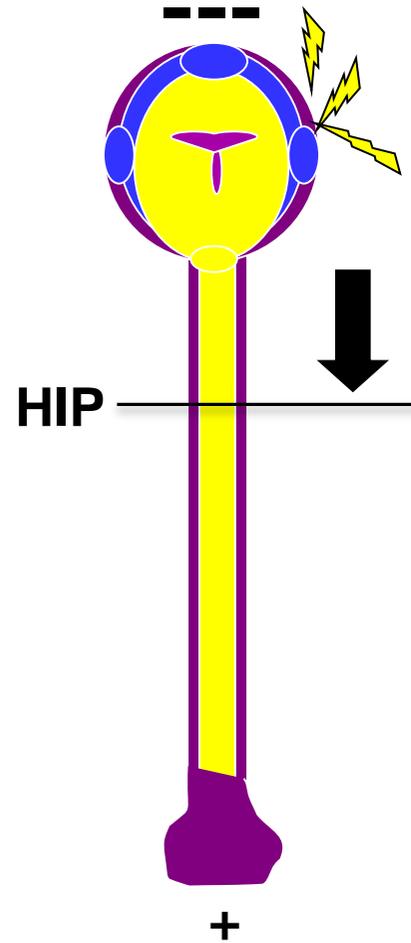
Located along upright CSF axis  
where CSF pressure = supine  
CSF opening pressure



Levine DN, Rapalino O. The pathophysiology of lumbar  
puncture headache. J Neurol Sci 2001;192:1-8.



Normal



Increased compliance of lower CSF space

Levine DN, Rapolino O. The pathophysiology of lumbar puncture headache. *J Neurol Sci* 2001;192:1-8.

# *CSF Leak: Increased Caudal Compliance of CSF Space Relative To Cranial End*

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- **Lumbar dural sac compliance increases with CSF leak**
  - Causes caudal HIP displacement
  - Upright ICP more negative equal to distance HIP displaced
  - Decrease in addition to that due to loss of filling pressure
- **Cranial compliance decreases with CSF leak**
  - Cerebral veins normally slightly collapsed, because CSF pressure exceeds dural sinuses pressure
  - ↓ CSF pressure → venous engorgement
    - Walls become stiffer and less compressible

Levine DN, Rapalino O. The pathophysiology of lumbar puncture headache. J Neurol Sci 2001;192:1–8.

# *CSF Leak and Dural Compliance*

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Lumbar dura usually resists stretch

– Limits distensibility of caudal CSF space

1. **Large holes** increase lumbar compliance by

– Exposing CSF to more compliant epidural space

- Epidural veins, epidural fat, and paravertebral soft tissue

2. **↓ filling pressure** increases lumbar compliance

– Lumbar dural sac collapses and becomes more compliant

- Creates space to accommodate CSF when patient upright

Levine DN, Rapalino O. The pathophysiology of lumbar puncture headache. J Neurol Sci 2001;192:1–8.

# *Does CSF Rhinorrhea Produce Headache?*

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## **Rostral CSF leak displaces HIP less than that due to LP**

- Only 9cm caudally

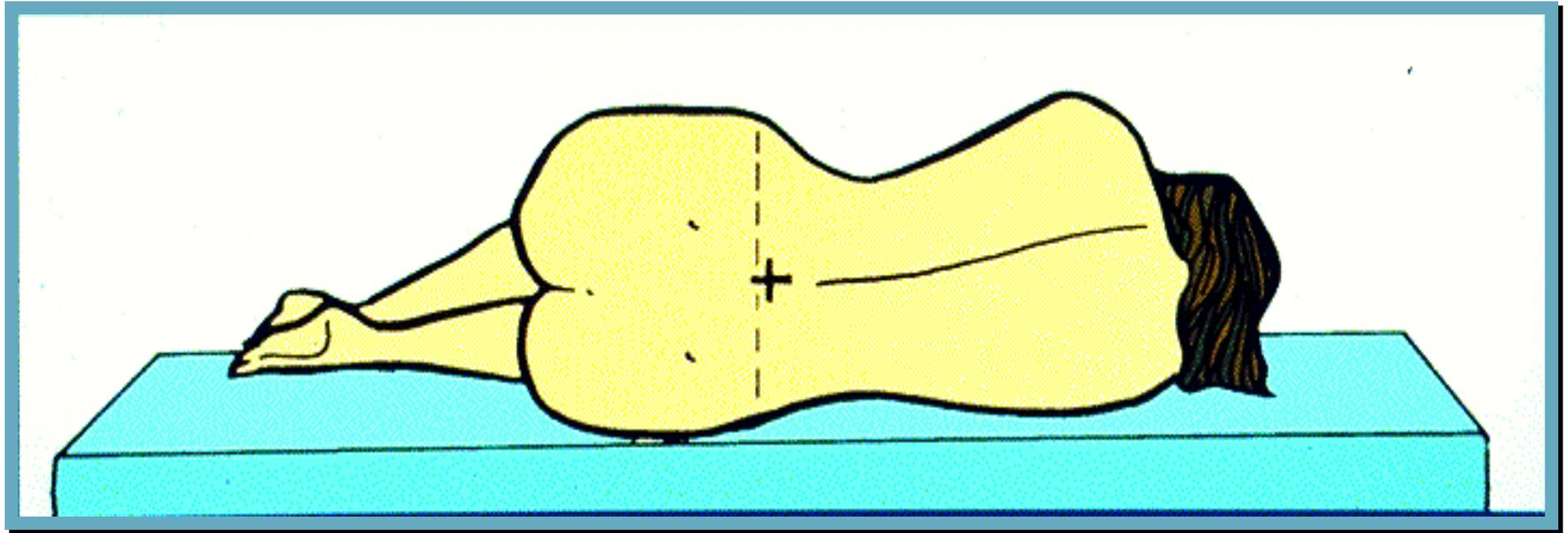
### **WHY?**

- Increased **rostral CSF space** should move HIP rostrally
- But ↓ filling pressure → ↑ **caudal dural sac** compliance
  - Overcomes effects of rostral anatomic change.
  - **Thus rostral leaks may not lower HIP enough to cause headache**

Magnaes B. Body position and cerebrospinal fluid pressure  
J Neurosurg 1976;44:698–705.

# *Lumbar Puncture*

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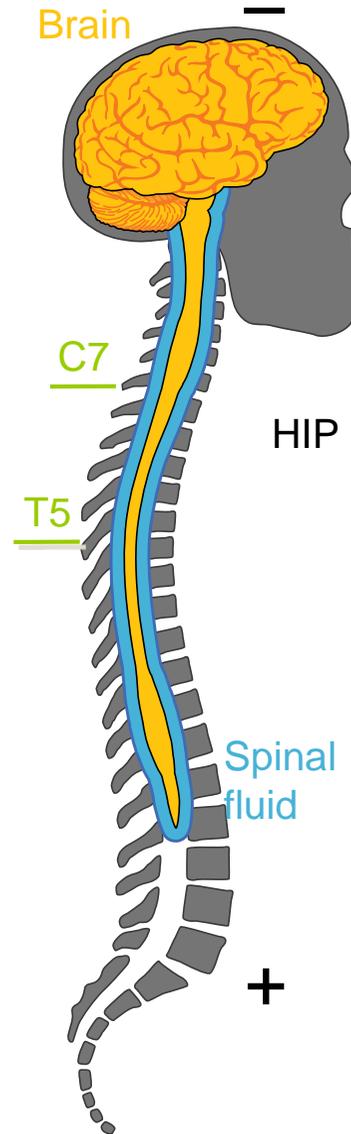
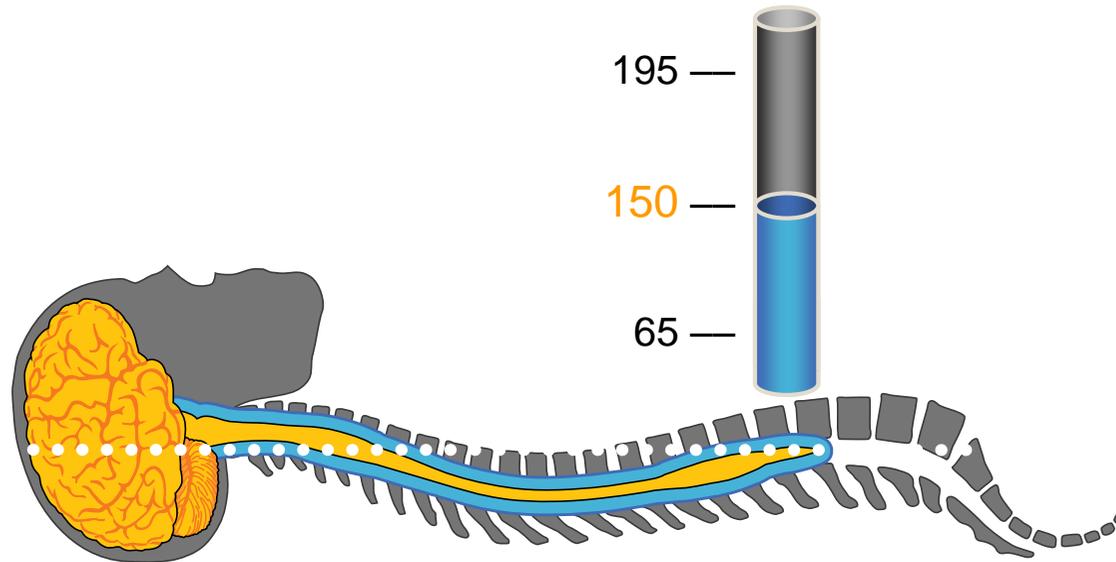
# *LP Causes Caudal Displacement of HIP*

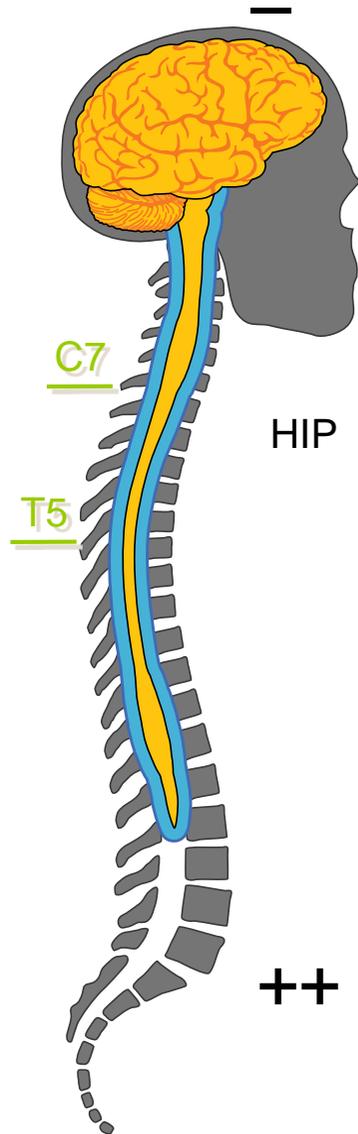
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- **Initial** CSF pressure: 18 cm recumbent and 53 cm sitting
  - HIP **35** cm (53-18)
- **Post LP** CSF pressure: 5.5 cm recumbent and 28 cm sitting
  - HIP now **22.5** cm (28-5.5)
    - HIP displaced 12.5 cm (35- 22.5) caudally
- **Filling pressure** ↓ 12.5 cm (18 -5.5)
- **ICP** ↓ 12.5 cm recumbent, but ↓ 25 cm (12.5+12.5) upright
- **Standing** → **marked** ↑ in **transmural venous pressure**
  - Intracranial veins distend acutely
    - More distension due to loss of filling pressure
- ***Acute orthostatic venous distention causes orthostatic headache***

# Hydrostatic Indifferent Point

Location along the upright CSF axis where CSF pressure = supine CSF opening pressure

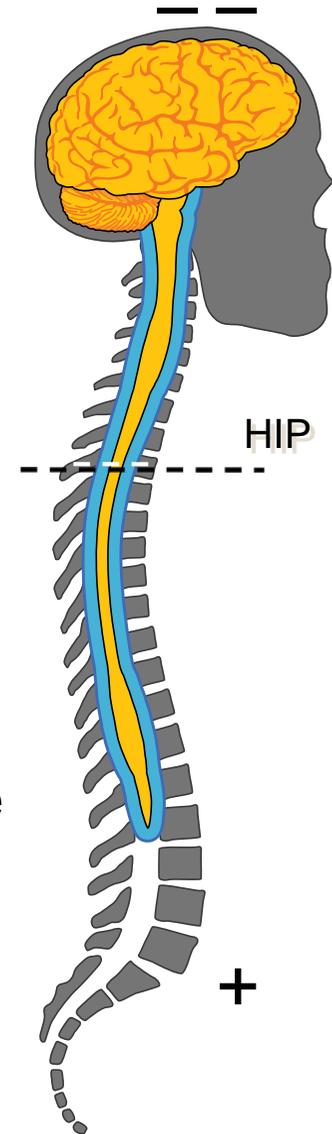


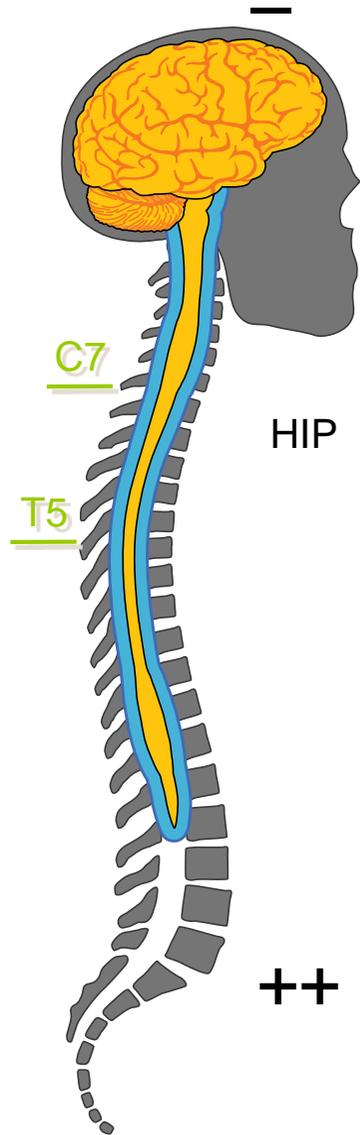


Normal

[Back](#) [Replay](#)

Increased compliance of lower CSF space

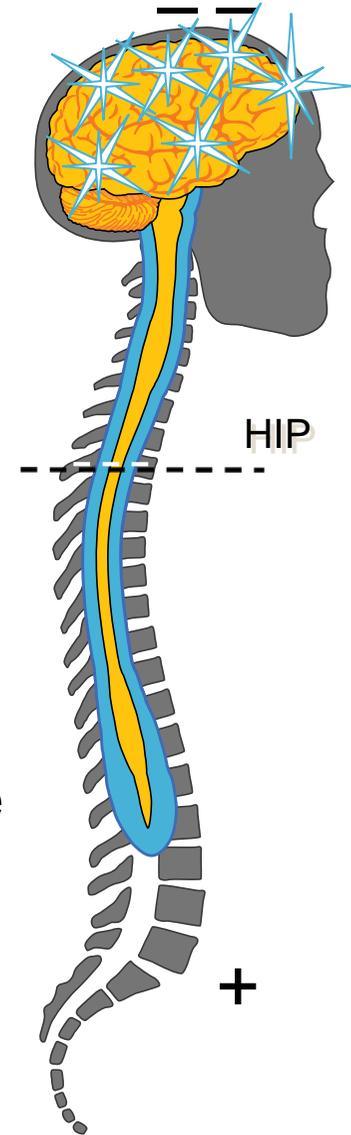




Normal

Back    Replay

Increased compliance of lower CSF space



# *Spinal CSF Compartments: Cervical*

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- Cervical subarachnoid space differs from lumbar
  - Lumbar CSF space collapses but cervical CSF space expands with Valsalva maneuver
  - Opposite may occur in LPH
- Caudal HIP displacement
  - Cervical CSF pressure decreases
  - Cervical dura collapses but cervical epidural veins dilate
- Cervical dura compliance ↓
  - But does not overcome caudal HIP displacement from ↑ lumbar compliance

## *Spinal CSF Compartments : Cervical*

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- Standing: CSF from cervical and intracranial compartments move into more compliant lumbar sac
- Cervical dura partially collapses with compensatory acute distension of cervical **epidural veins**
  - Can cause orthostatic posterior cervical pain
  - **Intracranial veins** dilate causing orthostatic headache
- Young children and older adults: have stiffer caudal space
  - Less increase in caudal compliance with dural tear
    - HIP displaced less and post LP headache less common

## *Intracranial Hypotension Headache: Conclusion*

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- **Cause:** abnormal distribution of craniospinal elasticity
- ↑ lumbar compliance → HIP to move caudally → **more** intracranial hypotension and venous dilation in erect position
- **Can explain:** orthostatic character of headache
  - Spinal not cranial leakage produces headache
  - Imperfect correlation between CSF pressure and headache
  - Near absence in very young and elderly due to ↑ epidural space stiffness at these ages