

# MRI OF THE THALAMUS

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## Objectives:

The thalamic nuclei can be involved in a wide variety of conditions. A systematic imaging approach would be useful for narrowing the differential diagnosis of thalamic abnormalities. This presentation will review the imaging patterns of thalamic involvement. Along with anatomic-clinical correlations, it is hoped that this review will help in improving diagnostic accuracy of abnormalities in these regions.

## Functional Anatomy:

The thalamus consists of large midline paired symmetrical ovoid deep grey mass of nuclei positioned in each hemisphere on each side of the third ventricle. They are located above the brainstem and are interconnected by the inter-thalamic adhesion.

The thalamus has multiple functions.

1. Acts as a relay between a number of subcortical areas and the cerebral cortex. The thalamus is believed to both process and relay sensory information.
2. Plays an important role in regulating states of sleep and wakefulness. Thalamic nuclei have strong reciprocal connections with the cerebral cortex, forming thalamo-cortico-thalamic circuits that are believed to be involved with consciousness.
3. Plays a major role in regulating arousal and the level of awareness. Damage to the thalamus can lead to permanent coma.
4. Forms the main relay station for sensory impulses from the spinal cord, brainstem, cerebellum and other parts of the cerebrum to the cortex.

The several different thalamic nuclei are divided from one another by laminae or thin walls of tissue. The thalamic nuclei can be divided into four groups based on their functions; the **specific relay nuclei**, the **association nuclei**, the **non-specific nuclei**, and a **subcortical nucleus**.

Table 1. Thalamic relay nuclei

NUCLEUS	FUNCTIONS
VPM	Relay station for impulses from face, head and taste buds
VPL	Relay station for exteroceptive and proprioceptive from all body <i>except</i> head and face
VA	Relay station for striatal impulses (attention and recent memory )
VL (VI)	Relay station for cerebellar impulses
MGB	Relay station for auditory impulses
LGB	Relay station for visual (optic) impulses

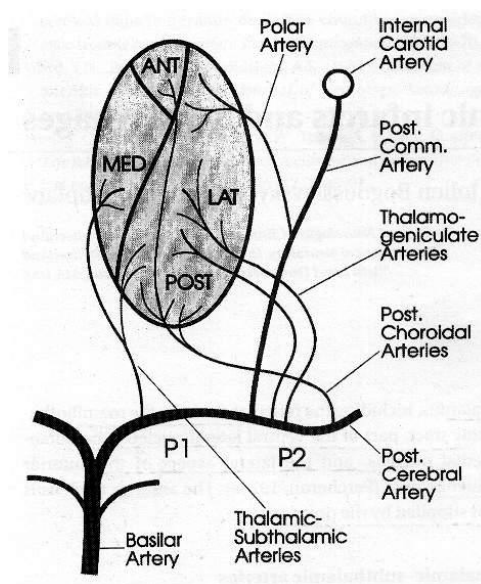
Table 2. Thalamic nuclei (association and non-specific)

NUCLEUS	FUNCTIONS
Reticular	Attention and recent memory
Medial dorsal	Associated with mood and emotional balance
Lateral dorsal	Integrates sensory information
Lateral posterior	Integrates sensory information
Pulvinar	Correlates auditory and visual information with sensations
Intralaminar (Including centromedian)	Awareness of painful stimuli at thalamic level

One portion of the thalamus, the **reticular nucleus**, is classified as **subcortical**. Its input is from other thalamic nuclei and its output is also to thalamic nuclei.

## Vascular Supply:

The thalamus derives its blood supply from the posterior cerebral and posterior communicating arteries. Normally there are paired thalamic and midbrain perforators. The artery of Percheron (AOP) is a rare variant of the posterior cerebral circulation. This anatomic variant refers to a solitary arterial trunk that branches from one of the proximal segments of either posterior cerebral artery (PCA). It supplies blood to the paramedian thalami and the rostral midbrain bilaterally.



## Regional patterns of involvement

There are host of conditions that can involve the thalamus selectively, as part of deep gray matter disease or combined with white matter involvement.

It is helpful to look at a regional pattern of involvement and focus on conditions that have unilateral versus bilateral involvement.

### Unilateral thalamic lesions:

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- ☐ Infarct
  - ☐ Hypertensive hemorrhage
  - ☐ Tumors:
    - Diffuse Astrocytoma, low Grade
    - Glioblastoma Multiforme
    - Anaplastic Astrocytoma
    - Germinoma
  - ☐ ADEM
  - ☐ Multiple Sclerosis – rare
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## Infarcts

Vascular lesions involve different combinations of nuclei in different combinations and produce sensorimotor and behavioral syndromes.

Table 3. Vascular syndromes

Location	Clinical features
Tuberothalamic	Impairments of arousal and orientation, learning and memory, personality, and executive function
Paramedian infarcts	Decreased arousal, impaired learning and memory
Inferolateral infarcts	Contralateral hemisensory loss, hemiparesis and hemiataxia
Posterior choroidal infarcts	Visual field deficits, variable sensory loss, weakness, dystonia, tremors

## Thalamic infarct mimics:

- ☐ Artery of Percheron infarct
  - Occlusion of a common vascular trunk that arises from one P1 segment
  - Supplies bilateral thalami
- ☐ Internal cerebral vein thrombosis
- ☐ Hypoxic-Ischemic Encephalopathy –solely involving deep gray nuclei.

## Nontraumatic intracerebral hemorrhage

This most commonly results from vascular damage (eg, hypertension, eclampsia, drug abuse) Sites of predilection include the basal ganglia (40-50%), lobar regions (20-50%), thalamus (10-15%), pons (5-12%), cerebellum (5-10%), and other brainstem sites (1-5%).

Intraventricular hemorrhage occurs in one third of patients from extension of thalamic bleeding into the ventricular space.

## Tumors

Thalamic Gliomas comprise about 1 % of all intracranial neoplasms- low-grade astrocytomas (WHO I and II) and higher-grade gliomas (WHO III and glioblastomas have been described. The diffuse astrocytomas appear hyperintense on T2-weighted and FLAIR sequences, and usually show no contrast enhancement.

Germinomas are often very large at the time of diagnosis. They appear iso- to hyperintense on the T2-weighted sequences. Cystic (T2-hyperintense) areas may be seen.

Acute disseminated encephalomyelitis (ADEM) – Thalamic involvement is common and maybe asymmetric

## Bilateral thalamic lesions

Bilateral thalamic lesions are uncommon with limited differential diagnosis

The differential diagnosis can be further narrowed with the patient history, imaging characteristics, and presence or absence of lesions outside the thalami.

Table 4. Bilateral thalamic lesions:

Vascular causes
Metabolic and toxic processes
<ul style="list-style-type: none"> <li>• Osmotic myelinolysis</li> </ul>
<ul style="list-style-type: none"> <li>• Wilson's disease</li> </ul>
<ul style="list-style-type: none"> <li>• Wernicke s encephalopathy</li> </ul>
Infection
<ul style="list-style-type: none"> <li>• Encephalitides</li> <li>• West Nile encephalitis</li> <li>• Japanese encephalitis</li> <li>• Eastern Equine encephalitis</li> <li>• Murray Valley</li> <li>• Epstein-Barr Virus</li> </ul>
Neoplasia
Uncommon – Fabry's disease

## **Vascular causes**

Internal cerebral vein thrombosis generally results in bilateral thalamic edema, venous infarction (50% of cases) and even haemorrhage.

The clinical presentation can be highly variable and range from being essentially asymptomatic to coma and death.

Symptoms include headaches, decreased or altered conscious state, decreased or altered vision, nausea and vomiting. Signs include papilloedema, cranial nerve palsies, focal neurological deficits, seizures and coma.

Imaging findings: Bilateral thalamic T2/FLAIR hyperintensity and variable DWI signal changes (elevated ADC values from vasogenic edema in the early stages) are noted.

## **Osmotic myelinolysis**

This occurs from rapid shifts in serum osmolality- eg. rapid correction of hyponatremia. The most common site of involvement is the central pons (central pontine myelinolysis). Other lesions affect the basal ganglia, thalami, and white matter (extrapontine myelinolysis). Acute T2 hyperintensity and T1 hypointensity occur in the affected regions. Contrast enhancement is uncommon, and there may be restricted diffusion.

## **Wilson Disease**

Hyperintensity in lentiform nuclei and mesencephalic regions on T1-weighted images have been described as most common *initial* MR abnormality.

T2 hyperintensity is also seen typically involving basal ganglia (putamen, globus pallidus, caudate nucleus) and the ventrolateral thalamus.

Axial T2 MR at midbrain level can show a "face of the giant panda sign", a characteristic imaging feature of Wilson disease.

## **Wernicke's encephalopathy**

Results from Vitamin B1 deficiency often from chronic alcohol abuse. The classical triad consists of changes in consciousness, ocular abnormalities, and ataxia. The imaging findings include high signal on T2-weighted images in the dorsal medial nucleus of the thalamus and in some cases restricted diffusion. Enhancement is not common. There may be associated abnormalities in the midbrain and mammillary bodies.

## Infections

Encephalitides: There are several forms of encephalitis that may involve the thalami eg . West Nile Virus, Japanese, Eastern Equine. Bilateral T2 hypertensity may be seen in the thalami, midbrain and basal ganglia regions.

Creutzfeldt-Jakob disease: *Key imaging findings are-*

*The pulvinar sign*—refers to high T2 signal intensity in the pulvinar. This sign has a sensitivity of 68–90% for variant CJD and can also occur in sporadic CJD.

The *hockey stick sign* (symmetric pulvinar and dorsomedial FLAIR hyperintensity) is characteristic of variant CJD.

*Cortical ribbon sign* (restricted diffusion in the cortical grey matter) - may be an early sign in the sporadic type and is rarely seen in variant CJD.

## Bilateral thalamic glioma

This is a rare neoplasm and is usually a diffuse low-grade astrocytoma (WHO grade II), occurs in both children and adults.

Bilateral thalamic glioma has a poor prognosis due to the location of the lesions.

## Rare causes

Fabry disease is an X-linked disorder of glycosphingolipid metabolism leading to accumulation of glycosphingolipids in the vascular endothelium, smooth muscles, heart, and brain. This can lead to renal, cardiac dysfunction and stroke. On T1- weighted images, hyperintensity may be seen in the pulvinar.

## CONCLUSION

The differential diagnosis of thalamic lesions is limited. However, knowledge of characteristic and common imaging abnormalities involving these deep grey matter structures would be of great value in making the right diagnosis non-invasively.