

INTRODUCTION

The deep gray matter nuclei include the basal ganglia and thalamus (fig1), they are paired structures that situated at the base of the forebrain and widely connected to the cortex and other parts of the brain.⁽¹⁾

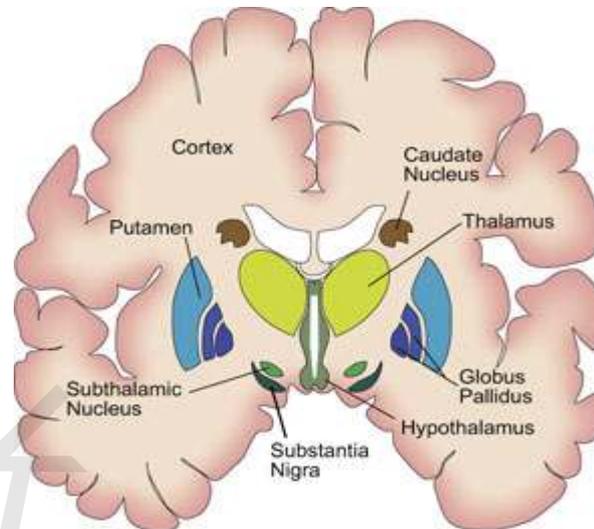


Fig1: Drawing showing the deep gray matter nuclei.⁽²⁾

There are 4 major nuclei (fig2): (1) Corpus striatum (divided into the caudate nucleus, the putamen, and the ventral striatum); (2) Globus pallidus or palladium (divided into the internal and external segments); (3) Substantia nigra (divided into the pars compacta and the pars reticulata); and (4) Sub thalamic nucleus. The term lentiform nucleus is a descriptive term for the putamen and globus pallidus. The claustrum, amygdaloid complex and olfactory tubercle are also included.^(3, 4)

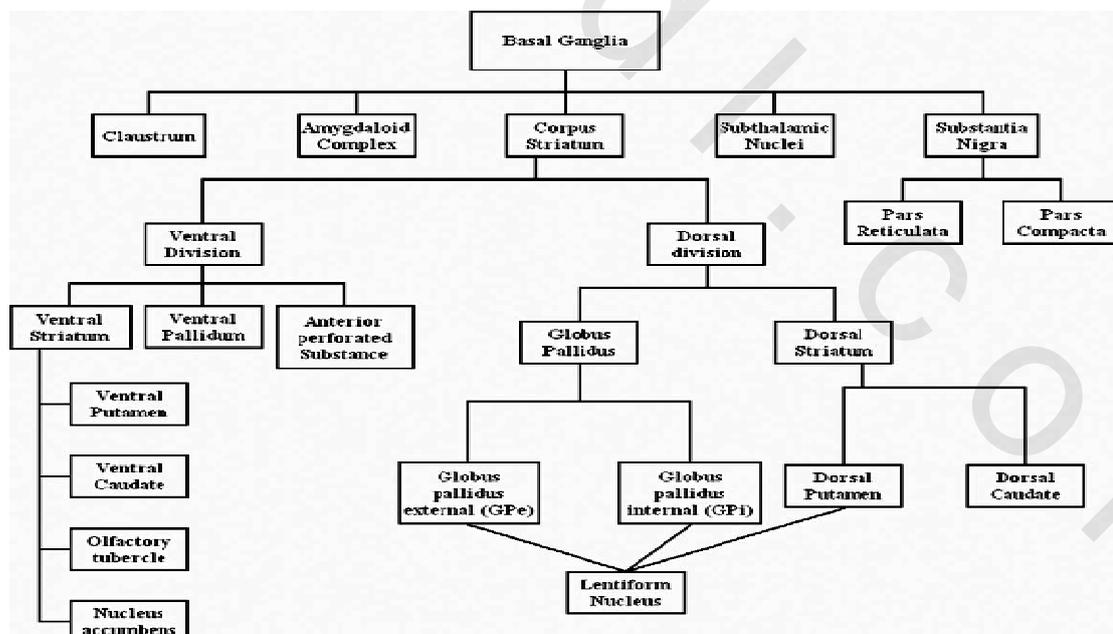


Fig2: Schematic diagram for the divisions of the basal ganglia⁽³⁾.

The following table(1)demonstrates the developmental classification and traces it to the anatomic structures found in the basal ganglia.⁽⁵⁾

Primary division of the neural tube	Secondary subdivision	Final segments in a human adult
Prosencephalon	1. Telencephalon 2. Diencephalon	Caudate, putamen, globus pallidus, thalamus, hypothalamus and sub thalamic nuclei
Mesencephalon	1. Mesencephalon	Substantia nigra pars compacta and pars reticulata.

Basal ganglia derive their blood supply from the medial and lateral lenticulo striate arteries (fig3), which arise from the anterior and middle cerebral arteries, respectively. The lateral LSA's are deep penetrating arteries of the middle cerebral artery (MCA). Their territory includes most of the basal ganglia. The medial LSA's arise from the anterior cerebral artery (usually the A1-segment)(fig3). Heubner's artery is the largest of the medial LSA's and supplies the antero-medial part of the head of the caudate and antero-inferior internal capsule.^(1, 6)

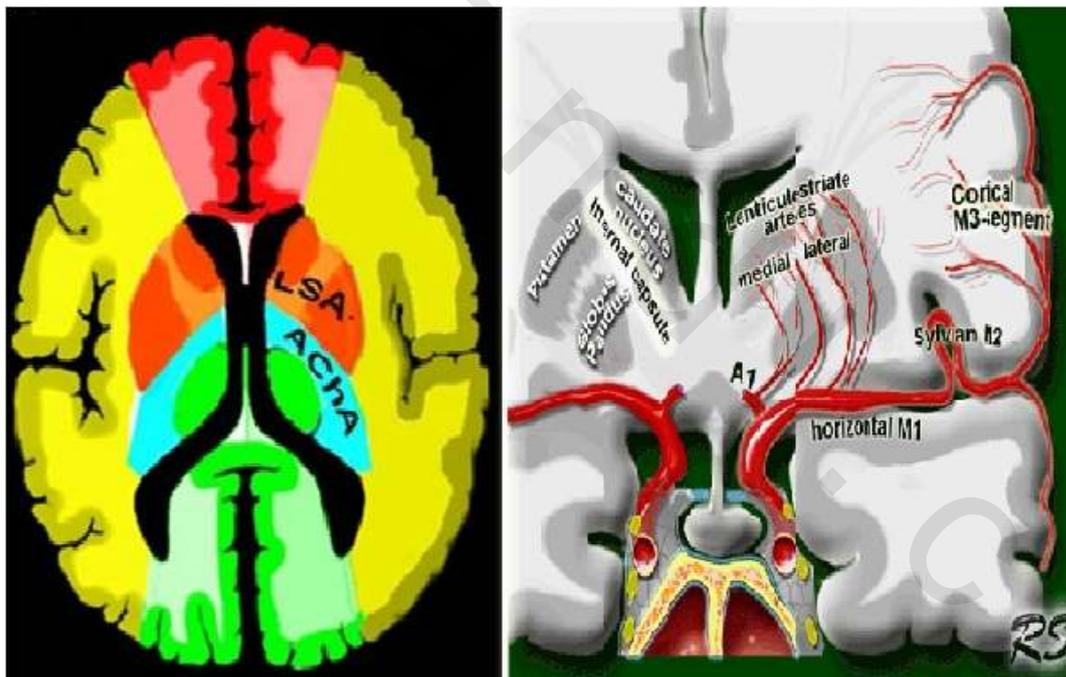


Fig3: Arterial supply of the basal ganglia .⁽⁶⁾

Venous drainage of the basal ganglia and thalamus is into the deep venous system⁽⁷⁾. The superior and inferior thalamostriate veins, along with several smaller surface veins, drain into the paired internal cerebral veins. These join the basal vein of Rosenthal to form the great vein of Galen at a point inferior to the splenium of the corpus callosum, where the great vein of Galen joins the inferior sagittal sinus to form the straight sinus (fig4). The straight sinus then continues backward to the torcula and joins the superficial dural venous sinus system^(1, 7).

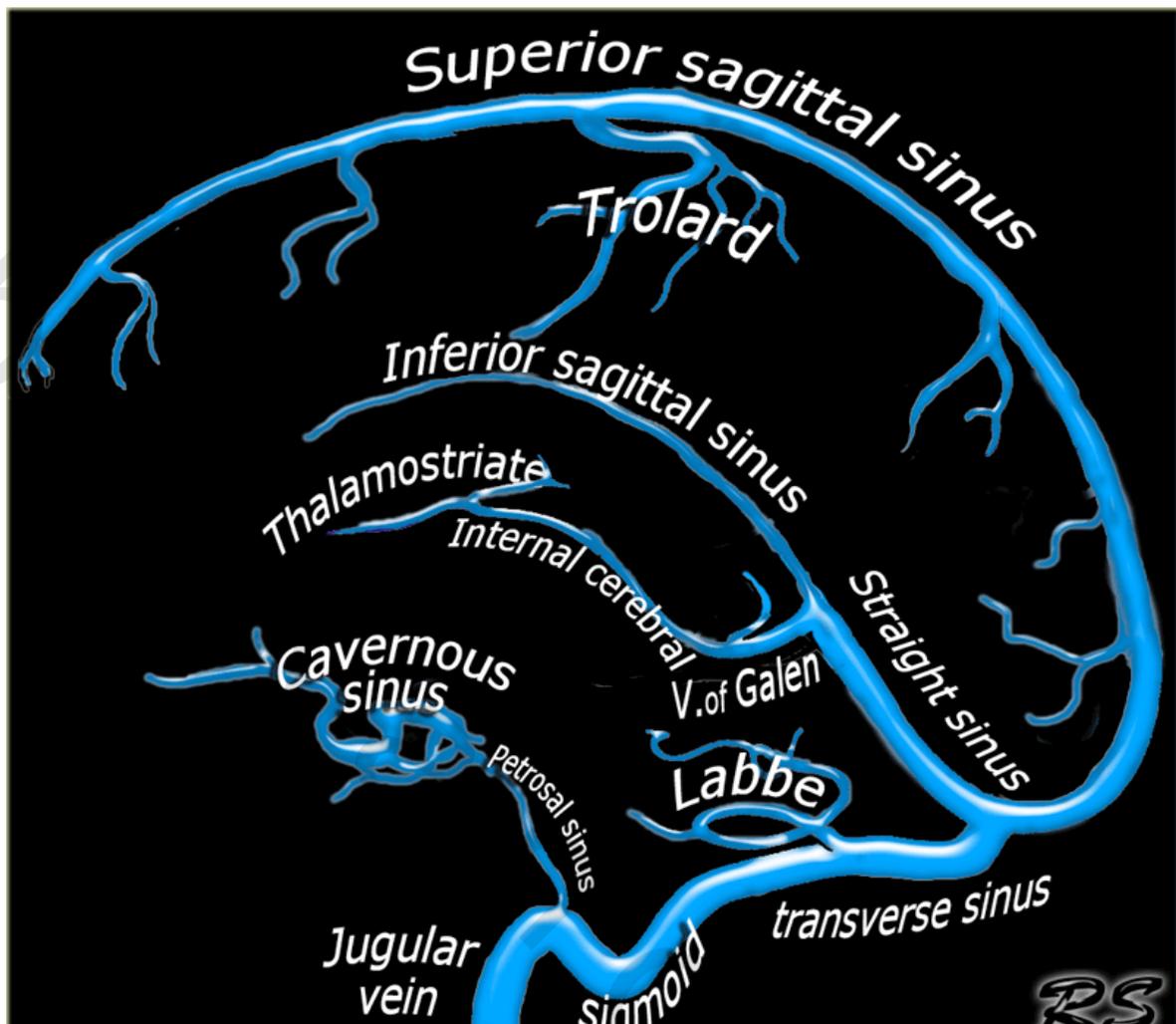


Fig4:Drawing showing the major superficial and deep veins of the brain.⁽⁸⁾

Basal ganglia functions are complex mainly involved in the production of movement and are a part of the extra pyramidal motor system, but they may also be involved in memory, learning, routine behaviors or "habits" such as bruxism, eye movements, emotion, and other cognitive functions.^(5,9)

Experimental studies show that the basal ganglia exert inhibitory influence on the motor system, and that a release of this inhibition permits a motor system to become active. The "behavior switching" that takes place within the basal ganglia is influenced by signals from many parts of the brain, including the prefrontal cortex.⁽¹⁰⁾

The basal ganglia composed of a plethora of pathways, utilizing GABA, dopamine, acetylcholine and glutamine. There are multiple pathways within the basal ganglia with both excitatory and inhibitory functions. Input to the basal ganglia is received from both the cerebral cortex and the thalamus. Because the cerebral cortex acts as both the primary input center and the ultimate output target, it is accepted that a function of the basal ganglia is to take information from the cortex, modify it then pass it back to the cortex. Lesions in the basal ganglia result in uncoordinated and disorganized movement.⁽¹¹⁻¹³⁾

Recent studies identified more distinctive and specialized pathways I- The direct and indirect pathways these two pathways work as a push-pull system that finely control the level of basal ganglia output. All basal ganglia output is thought to be inhibitory and to suppress thalamic activity, which reduces stimulation of inter connecting cortical regions. The direct pathway runs from the striatum to the GPi and suppresses GPi output, thus releasing the thalamus to provide excitation to the cortex (fig5). The indirect pathway from the striatum to the GPe and STN excites the GPi, thereby suppressing the thalamus and withdrawing excitation from the cortex. ⁽¹⁴⁾

II-The nigro-striatal pathway: This dopamine projection is degenerated in PD and has abundant projections to the striatum. Its effect is to increase basal ganglia output by acting on D1 dopamine receptors in striatal neurons that stimulate the direct pathway and on D2 dopamine receptors that stimulate the indirect pathway. III. Basal ganglia loops: the basal ganglia neurons organized within a series of parallel loops. Each loop begun in the cortex with excitation of the striatum followed by input to the GPi, then variably inhibited the thalamus whose projections sent excitation back onto the original cortical source. ⁽¹⁵⁾

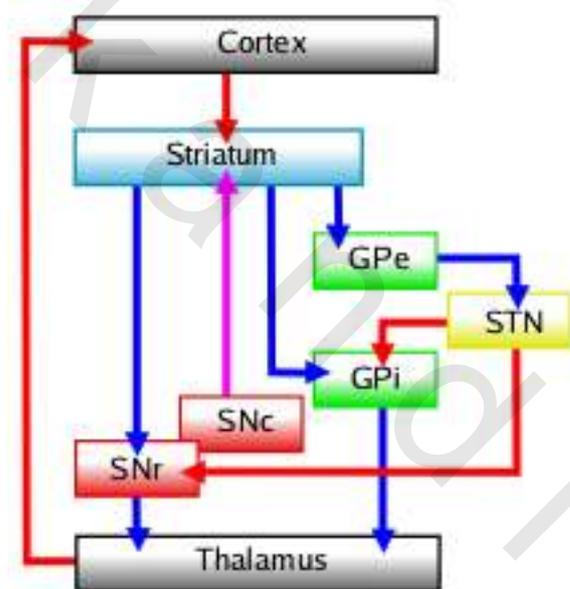


Fig 5: Connectivity diagram ,showing the different pathways.⁽³⁾

The basal ganglia have a limbic sector whose components are: nucleus accumbens, ventral pallidum, and ventral tegmental area (VTA). There is considerable evidence that this limbic part plays a central role in reward learning, particularly a pathway from the VTA to the nucleus accumbens that uses the neurotransmitter dopamine. ⁽¹⁶⁾

At MR imaging anatomy of the basal ganglia is best imaged on proton-density weighted images or T2-weighted images. The caudate nucleus, putamen and thalamus are iso intense to the cortical gray matter (fig6-A) and (fig7) with all pulse sequences. And show no enhancement after contrast injection. The globus pallidus is typically hypointense relative to the putamen, a normal feature attributed to progressive iron deposition with age, and the same refers to substantia nigra (fig6-B). ^{(4, 17, 18).}

In pediatric patients, immature myelination results in indistinct intensity differences.^(19, 20)

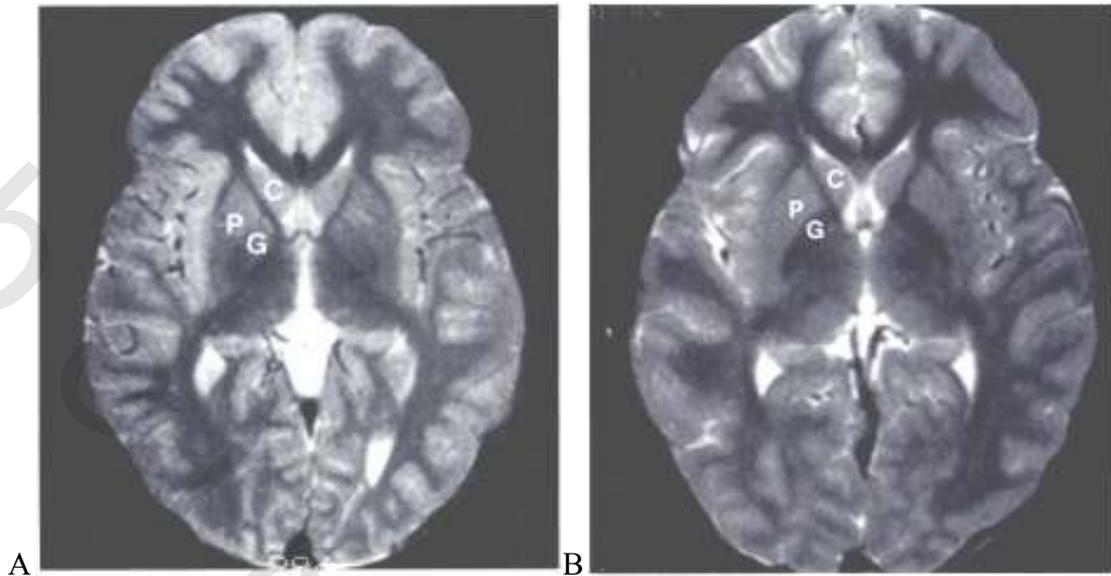


Fig 6: A) Axial T2 of the brain of healthy child 3yrs old ,showing the basal ganglia B) Axial T2 of the brain of healthy child 10yrs old showing the basal ganglia with progressive maturation there is darkening of the basal ganglia this phenomenon occurs first in the globus pallidus due to iron deposition⁽¹⁹⁾

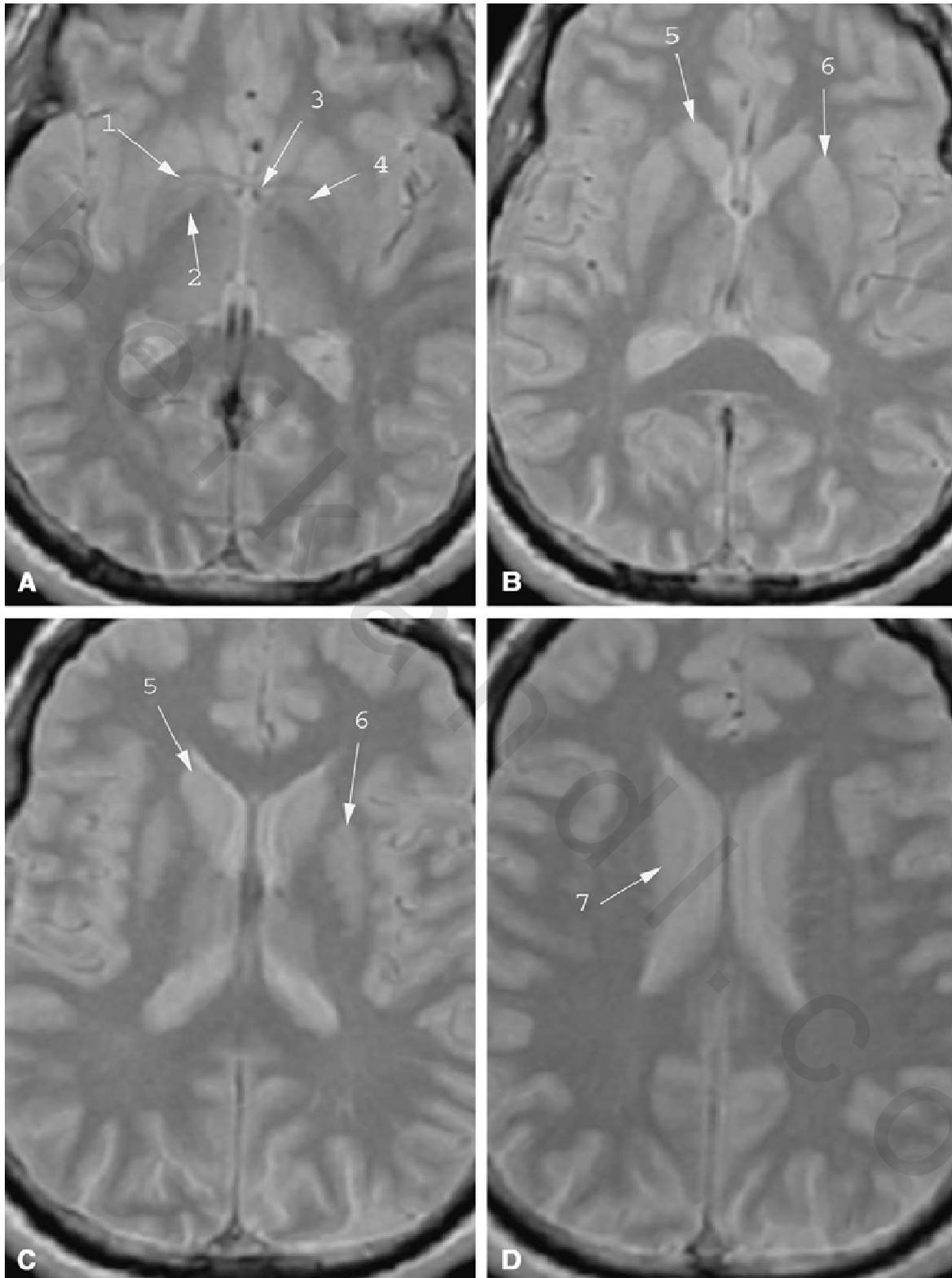


Fig 7: (A-D) External segments of globus pallidus (1); internal segment of globus pallidus (2); anterior commissure (3); internal pallidal lamina dividing the internal segment from the external segment (4); caudate head (5); putamen (6); body of the caudate (7).⁽¹⁷⁾



Fig 8: Coronal T2-weighted image reveals normal-appearing striatum with caudate head (white arrow), putamen (white arrow head), and “stria” (black arrow) between the caudate and putamen⁽¹⁷⁾.

The substantia nigra divisions, with the pars compacta being slightly hyperintense compared with the hypointensity of the pars reticulata (fig 9) and the red nuclei. On high-quality images, the gray-matter bands connecting the caudate and putamen (fig8) may be visualized, and the sub thalamic nuclei can be seen, but it is often a subtle finding.^(17, 18)

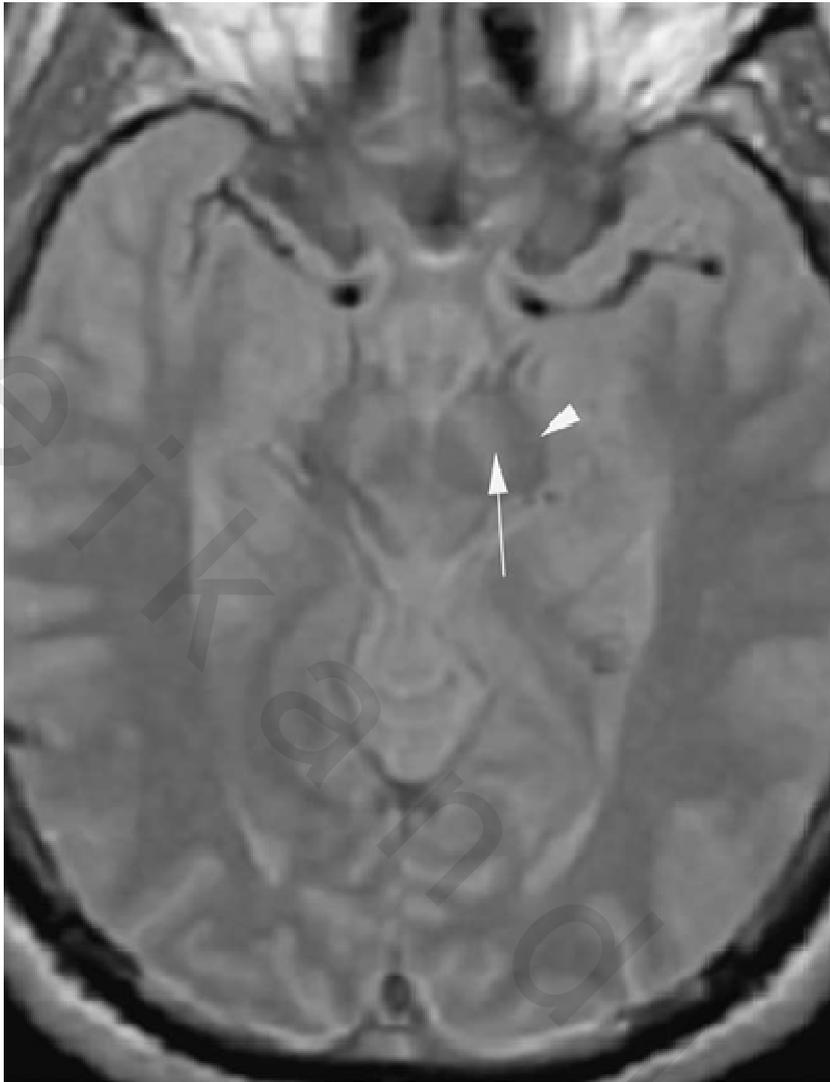


Fig 9: Substantia nigra seen on proton-density weighted axial image. Pars reticulata (arrowhead) and pars compacta (arrow)⁽¹⁷⁾

The lentiform nucleus exhibits dilated Virchow-Robin perivascular spaces(fig10-A) and bilateral symmetric age-related calcification(fig10-B); both considered normal findings and should not be confused with pathologic changes.⁽¹⁾

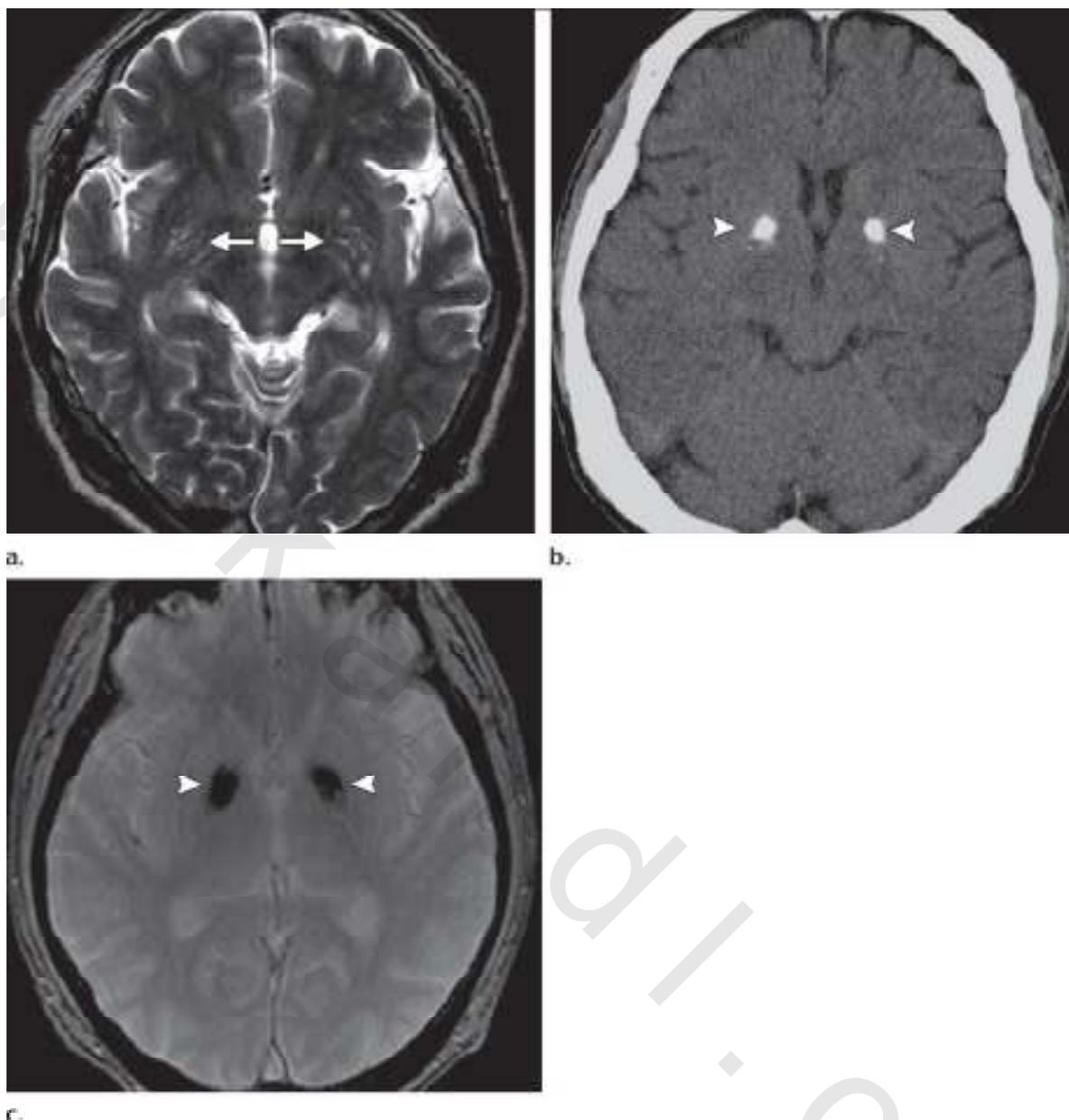


Fig10: A) Axial T2-weighted MR image shows well-defined foci (arrows) iso intense relative to (CSF), findings represent prominent Virchow-Robin (perivascular) spaces. B)CT scan obtained without contrast demonstrates bilateral physiologic calcification (arrow heads) .C) Axial gradient-recalled echo image depicts physiologic iron deposition in the globus pallidus (arrow heads) as symmetric hypointense areas.⁽¹⁾

On axial brain images, the lentiform nucleus and the head of the caudate nucleus visualized as paired symmetric structures located between the lateral ventricle and the insular cortex (fig7) and (fig11). The lentiform nucleus separated from the caudate head and the thalamus by the anterior and posterior limbs of the internal capsule, respectively. The external capsule seen on the lateral aspect of putamen and separates it from the insular cortex. The caudate nucleus situated adjacent to the lateral ventricle.^(4, 18)

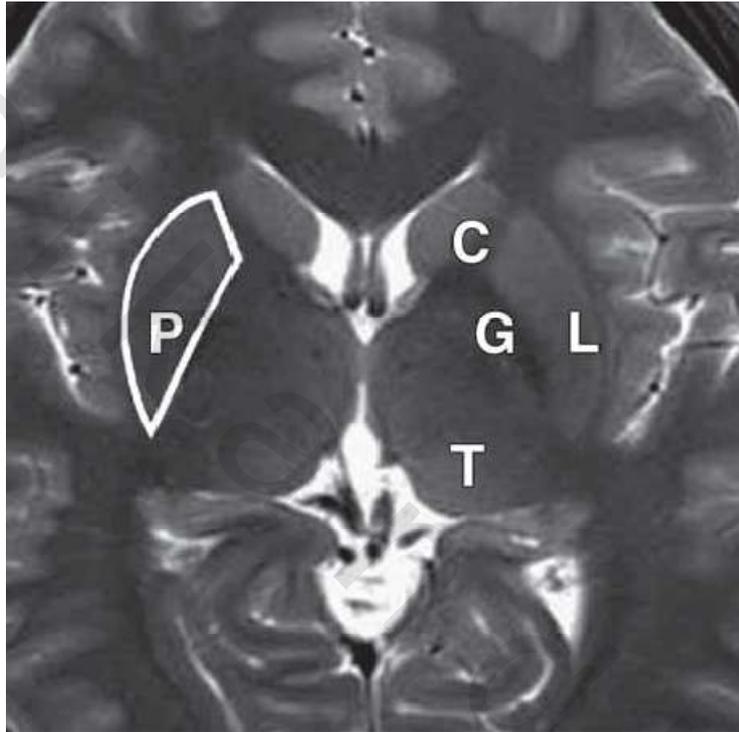


Fig 11: Axial T2-weighted MR image shows the normal anatomy of the deep gray matter structures. C = caudate nucleus, G = globus pallidus, L = lentiform nucleus, P = putamen, T = thalamus⁽¹⁾

For the imaging purposes, structures of importance are: caudate, putamen, globus pallidus, and substantia nigra. At CT imaging the caudate and putamen are easily distinguished; Loss of this distinction should enhance one to search for the cause, such as infarct. (Fig12)With high quality imaging, the separation of the globus pallidus from the putamen can be made, with the globus pallidus being hypo dense.⁽¹⁷⁾

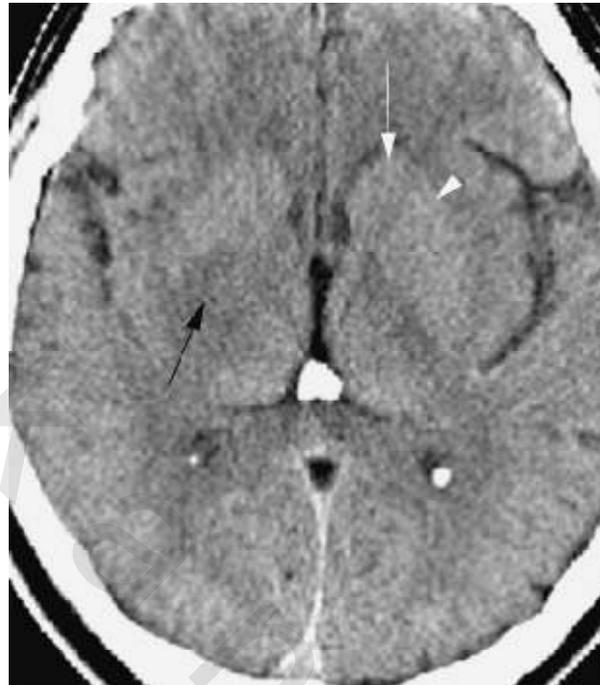


Fig12. Axial CT scan demonstrating normal appearing left-sided caudate (white arrow) and putamen (white arrowhead). On the right there is loss of normal appearance to the posterior putamen, with decreased density indicating early infarct (black arrow).⁽¹⁷⁾

The neuro-transmissive function requires rich blood supply and high energy level. Their high metabolic activity explains the need for trace metals (Fe, Cu and Mn) as enzyme cofactors. That explains their vulnerability to various conditions in which blood/oxygen/energy levels are diminished and lead to their damage. In childhood the metabolic activity of the basal ganglia is greater and they are particularly prone to injury.⁽⁴⁾

The synaptic integration of information requires a ready supply of ATP which necessary to maintain the trans-membrane ion gradients; important for neuronal conduction and to regulate transmitter synthesis, release, and reuptake. Under normal conditions ATP is efficiently produced by aerobic respiration and oxidative phosphorylation within the mitochondria (fig13) so acute deprivation of oxygen or glucose result in insufficient production of ATP via anaerobic respiration and diffuse basal ganglia injury.⁽²¹⁾

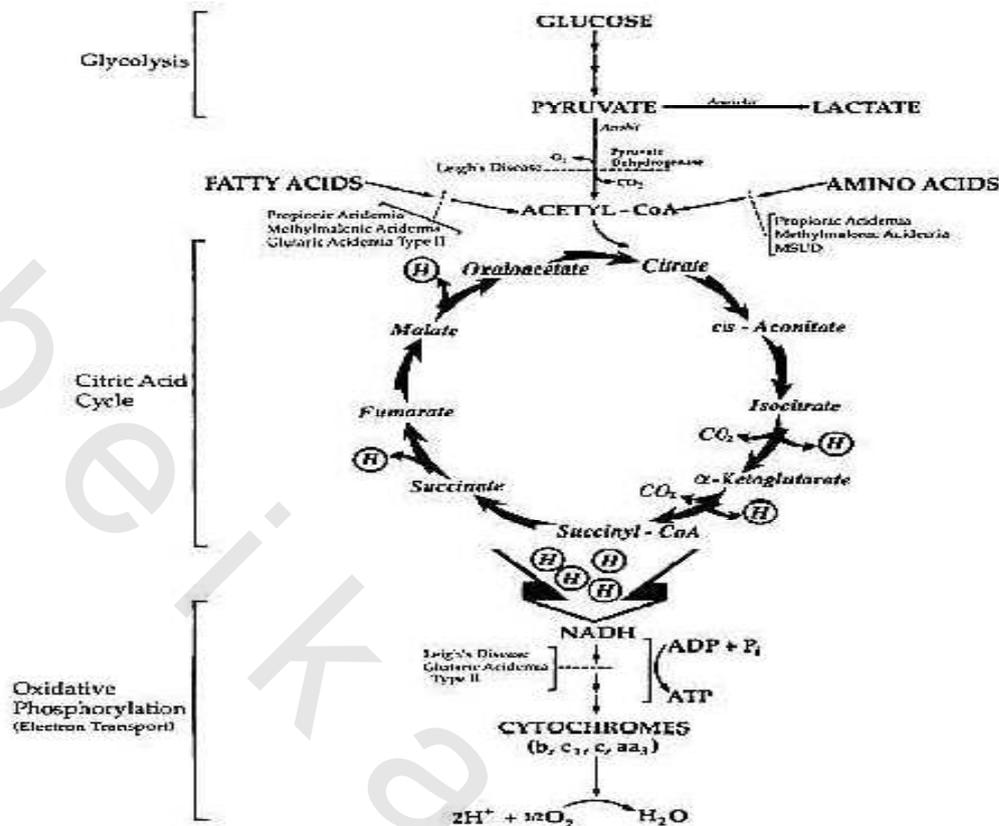


Fig13. Drawing shows that the production of ATP by the mitochondria requires a variety of biochemical pathways. Most entities that preferentially affect the basal ganglia do so by altering basal ganglia metabolism. Dashed lines =the proposed sites of metabolic abnormality (simplified) seen with these disorders, ADP =adenosine diphosphate, CO₂= carbondioxide, H = hydrogen, 1-120 = water, MSUD = maple syrup urine disease, NADH = reduced nicotinamide adenine dinucleotide, O₂= oxygen, Pi inorganic phosphate.⁽¹⁹⁾

Conditions altering the normal mitochondrial structure or elevating mineral deposition injure the basal ganglia. The rich vascular supply to the basal ganglia makes them susceptible to toxins and infectious agents. High metabolic demand of the basal ganglia is similar to that of the cerebellum and cerebral cortex. This is why the cortex and basal ganglia often involved simultaneously. Cell injury result from insufficient production of ATP, increasing intra cellular water and causing the basal ganglia to show abnormal signal hyper intensities on FLAIR, T2 and DW images. If hemorrhage or mineral or protein deposition present the basal ganglia may show T1-weighted signal hyperintensity.⁽¹⁹⁾

Neuronal damage results from disruption of ATP-dependent sodium-potassium pump and the ion gradients that it regulates. The intra cellular retention of sodium leads to increase in intra cellular water and cytotoxic edema. Depletion of ATP results in extra cellular accumulation of glutamate, Glutamate is a potent excito-toxin, through its actions on N methyl D- aspartate receptors, results in the intra cellular influx of calcium. The intra cellular increase in calcium, initiates a series of degradative enzymatic cascades that lead to free radical formation, lipid peroxidation, and ultimately cell death. The basal ganglia, which are richly innervated by the cerebral cortex, contain high concentrations of glutamate and a large number of N-methyl-D-aspartate receptors.⁽²²⁻²⁴⁾

Basal ganglia injury may be

I) Unilateral in:

- 1) Rasmussen encephalitis which is progressive disease due to viral infection and auto immunological response .seizures, cognitive decline and hemiparesis are the most common clinical symptoms.MRI findings are unilateral cortical and subcortical brain atrophy, at the insula, with hyperintense signal or atrophy of the ipsilateral head of caudate nucleus and increased cortical and/or subcortical T2- and FLAIR signal intensity these are included in the diagnostic criteria of RE.
- 2) Diabetes with hemichorea/hemiballism which cause unilateral chorea due to non ketotoxic hyperglycaemia. Characteristic finding is T1 hyperintensity in the contralateral putamen without any significant signal alteration on other MR sequences.
- 3) Unilaterally dilated Virchow Robin spaces frequently in the lentiform nuclei around the lenticulo-striate arteries.
- 4) Infarction the signals are typical of an ischemic focus, with early diffusion restriction followed by T2-/FLAIR hyper intensity and T1-hypointensity. ^(4, 25, 26)

II) Bilateral in:

I .Toxic Poisoning

Carbon monoxide (fig14), methanol (fig15) and cyanide are cellular respiratory toxins resulting in impairment of mitochondrial cellular respiratory enzymes. ^(27, 28)

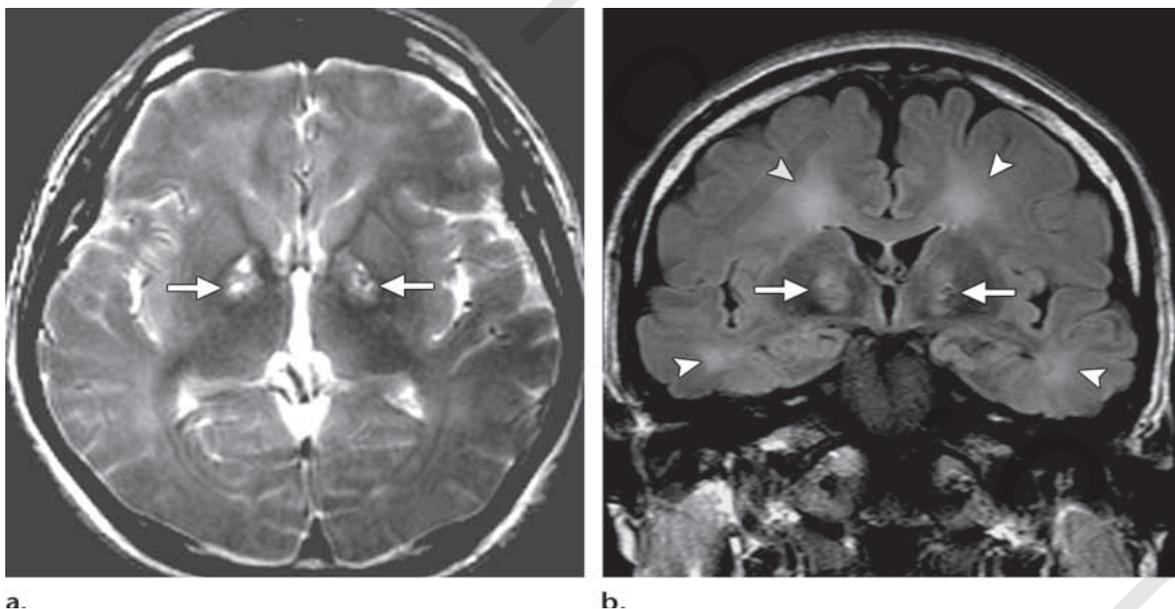


Fig14: Co poisoning in a 33-year man, found in coma after suicide. Axial T2-weighted (A) and coronal FLAIR (B) MR images 4 weeks after depict symmetric hyperintense foci in the globus pallidus (arrows). Symmetric hyperintense areas in the deep white matter (arrow heads in B) are consistent with delayed leukoencephalopathy. ⁽¹⁾

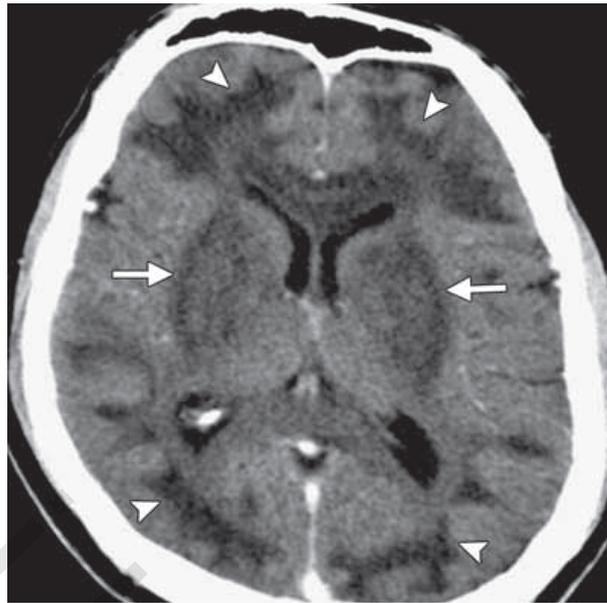


Fig15- Methanol poisoning in 41-year man presented with altered mental status and retro-bulbar pain. Contrast material–enhanced CT demonstrates hypo attenuating areas in the lentiform nuclei (arrows), corpus callosum, and subcortical deep white matter in the frontal and parieto-occipital regions (arrow heads).⁽¹⁾

II-Metabolic

A) Liver disease:

Portal hypertension and porto systemic shunts cause the nitrogenous waste products to cross the blood-brain barrier causing toxic brain damage. MR findings are bilateral hyperintense areas in the globus pallidus and substantia nigra on T1-weighted images(fig16) due to manganese deposition producing pallidal degeneration and elevating glutamine/glutamate peak coupled with decreased myo-inositol and choline signals on MR spectroscopy, acute hyper-ammonemia causes bilateral symmetrical swelling, T2 prolongation, and restricted diffusion in basal ganglia, insular cortex and cingulate gyrus(fig17).⁽²⁹⁻³²⁾.

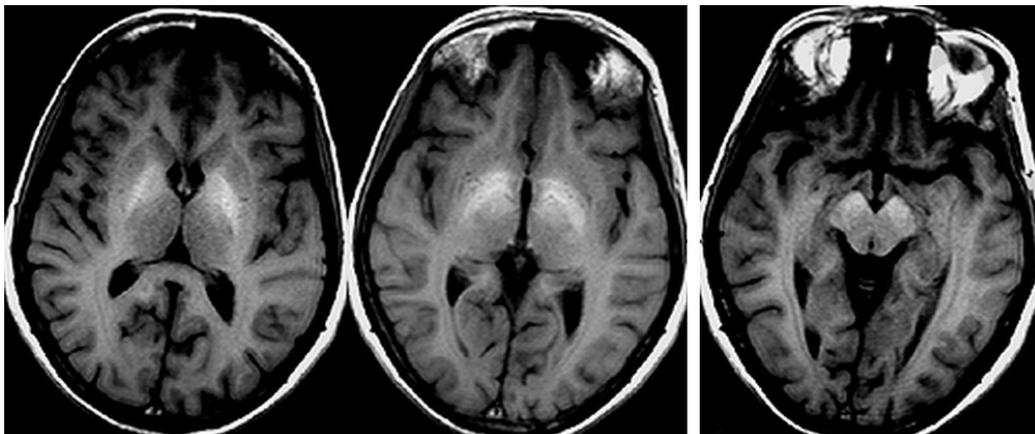


Fig16: Axial T1-weighted MR images of patient with chronic liver failure observe the bilateral and symmetric high T1 signal-intensity change involving the globus pallidus and the anterior midbrain⁽³³⁾.

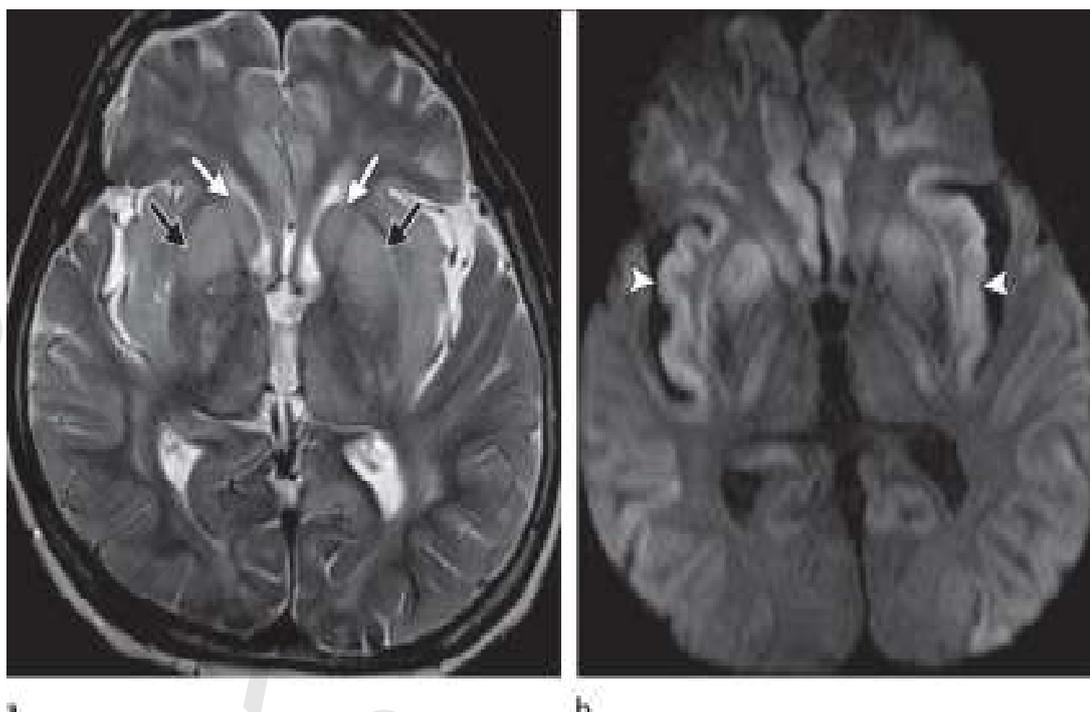


Fig17: Acute hyperammonemia T2-weighted (A) and diffusion-weighted (B) MR images reveal bilaterally symmetric swelling, hyperintensity, and restricted diffusion in the caudate heads (white arrows in a), putamina (black arrows in a), and insular cortices (arrowheads in b).⁽¹⁾

Manganese-related abnormality also described in patients receiving total parenteral nutrition and occupational exposure to manganese. MR changes resolve after discontinuation of manganese intake.⁽³⁴⁻³⁷⁾

B) Hypoxic Ischemic Encephalopathy

Findings depend on the severity and patient age, in neonates present as symmetrical involvement of the basal ganglia (and/or thalami) with signal hyper intensity in all the sequences (T1-, T2-, FLAIR and DWI) and swollen appearance. In adults affect the watershed zones. Severe HIE affects the gray matter including the cerebral cortex, basal ganglia (due to high metabolic activity). The thalamus and cerebellum may be (fig18), the increased volume of basal ganglia not observed in adults. MRI has a prognostic value: extensive lesions, cortical and with restricted diffusion in particular, indicate poor prognosis.⁽³⁸⁾

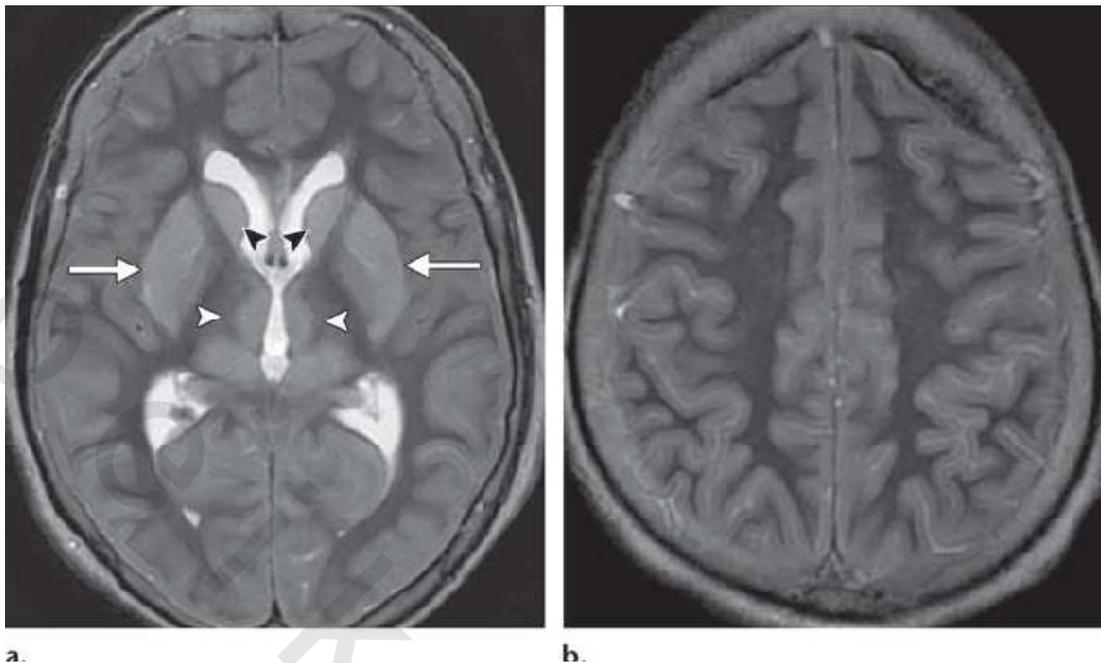


Fig18: HIE in a 38-year woman resuscitated after being involved in a traffic accident. a) T2-weighted MR image demonstrates bilaterally symmetric hyperintense areas in the thalamus (white arrow heads), basal ganglia, and cerebral cortex. Black arrow heads caudate nuclei, arrows = lentiform nuclei. (b) T2-weighted MR image obtained at higher level more clearly depicts diffuse cortical involvement.⁽¹⁾

c) Hypoglycemia

Produce similar injury to hypoxia as lack of glucose may have similar effect on metabolism. Also affected structures are the same: basal ganglia, cortex, substantia nigra, and hippocampus sparing thalami. Lesions in basal ganglia are T2 and DWI hyperintense (fig19). However, in hypoglycemic coma survivors the signal intensity is T1-hyperintense and T2-hypointense. Transient and isolated white matter abnormalities involving the corpus callosum, internal capsules, and corona radiata. However, white matter lesions may be seen in combination with severe gray matter abnormalities. Involvement of the basal ganglia have poor prognosis.^{(39-42).}

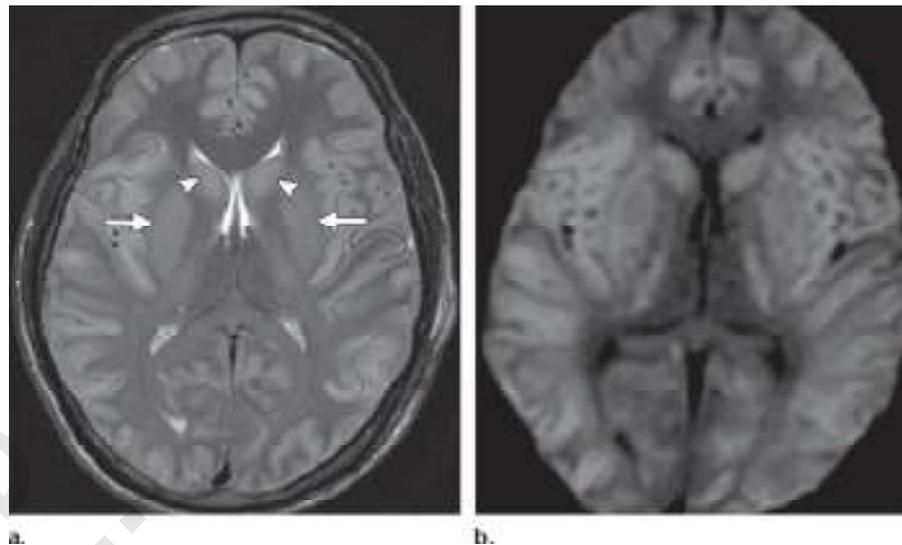


Fig19: Hypoglycemic brain injury in an 18-year-old comatose man with a random blood sugar level of 2.1 mmol/L. Axial T2-weighted (a) and diffusion-weighted (b) MR images demonstrate diffuse hyperintensity and restricted diffusion in the head of the caudate nuclei (arrowheads in a), lentiform nuclei (arrows in a), and cerebral cortex, while sparing the subcortical white matter and thalamus.⁽¹⁾

D) Non ketotic hyper glycvemia

Poorly controlled diabetics present with acute chorea, hemi ballismus, and altered mental status. Hyperglycemia is treatable with good prognosis, and follow-up neuroimaging shows resolution of findings at MR imaging, the abnormal areas are characteristically hyperintense on T1-weighted images (fig20) and of variable intensity on T2-weighted images. The mechanism is deposition of proteins, myelin breakdown products, blood, or calcium.⁽⁴³⁾

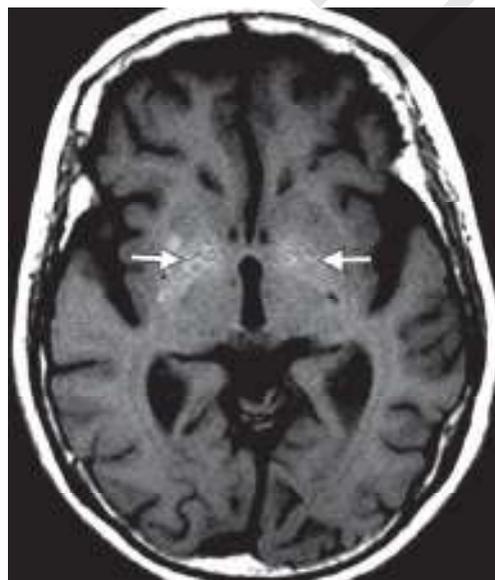


Fig20: Non ketotic hyperglycemia with choreo-athetoid movements. Axial T1-weighted MR image reveals bilateral hyperintense pallidal areas⁽¹⁾

E) Leigh disease (Sub-acute necrotizing encephalomyelopathy)

Mitochondrial disease results from a disorder in the respiratory chain production of ATP affecting children and (rarely) young adults and typically causes central hypotonia, developmental regression or arrest, ophthalmoplegia, respiratory and bulbar dysfunction, and ataxia. MR findings include symmetric areas of T2 prolongation in the basal ganglia, periaqueductal region(fig 21A,B), and cerebral peduncles; (long echo times) MRS reveals high lactate levels(fig21C), together with elevated serum and CSF lactate levels.^(44, 45)

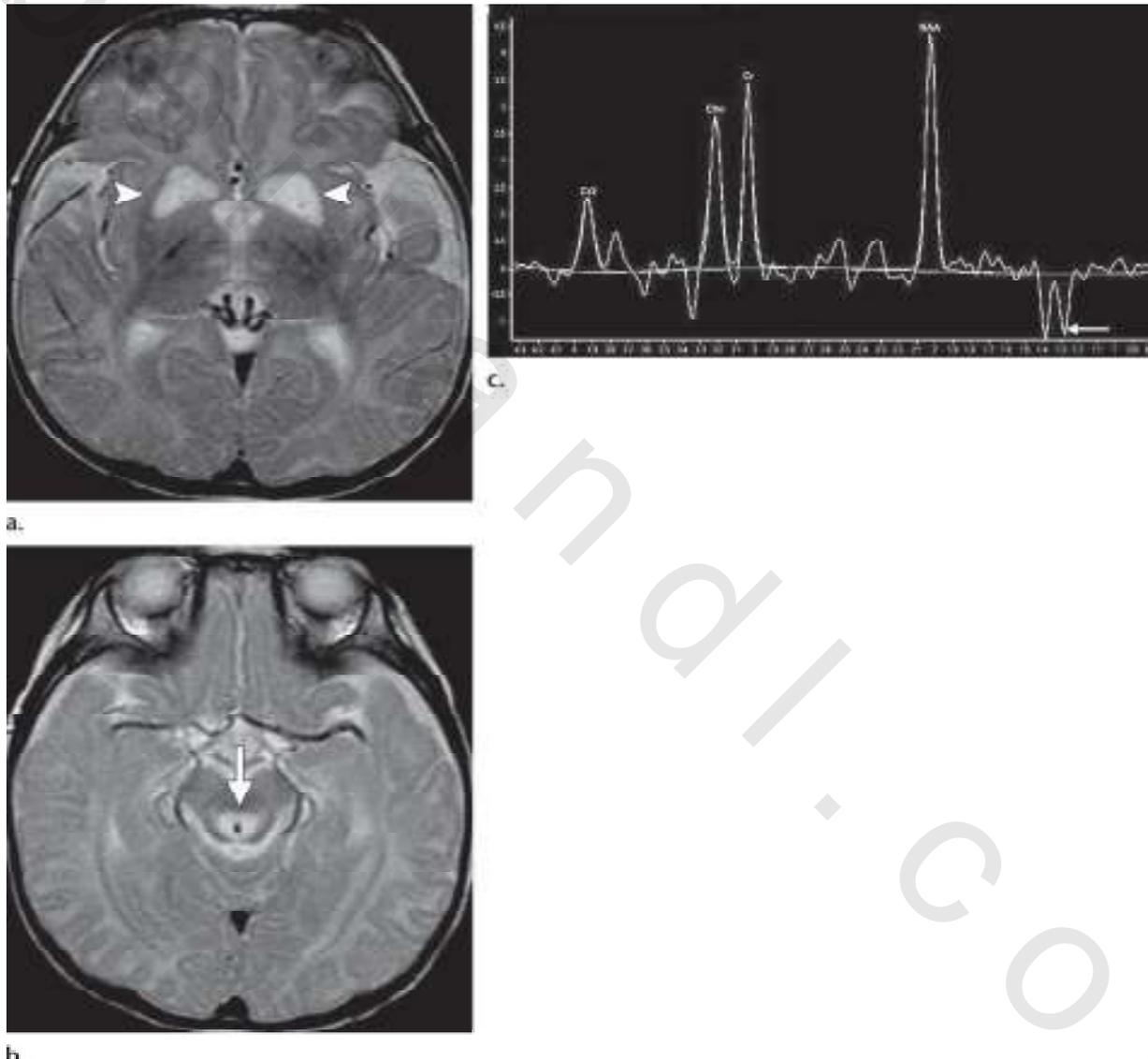


Fig 21: Leigh disease in an 11-month-old boy, presented with irritability and failure to thrive. (A, B) Axial T2-weighted MR images obtained at the level of the deep gray nuclei (A) and through the posterior fossa (B) reveal symmetric areas of hyper intensity in the putamina (arrow heads in A) and periaqueductal region (arrow in B). (C) MR spectroscopy reveals an inverted double peak at 1.33 ppm (arrow), a finding that is characteristic of lactate.⁽¹⁾

F) Canavan disease (CD)

Dysmyelinating disease of infants presenting with spasticity and macrocephaly. Characteristically involves the globus pallidus, sparing the putamen and caudate nuclei. Characterized by early involvement of the peripheral white matter and U-fibers sparing the central white matter until later phases. MRS shows relative high peak of NAA.⁽⁴⁶⁾

G) Osmotic Pontine Myelinolysis (OPM)

Acquired demyelinating disease due to rapid correction of hyponatremia in patients with other disease (e.g. cancer, diabetes, renal insufficiency and alcoholism). MRI shows a centrally located lesion in the pons with sparing of its peripheral rim (fig22). Extra pontine structures such as the cerebral white matter, thalamus, and basal ganglia may be involved. Lesions appear hyperintense on T2-weighted and FLAIR imaging and may show increased signal on diffusion-weighted imaging that is presumably due to cytotoxic edema.^(47, 48)

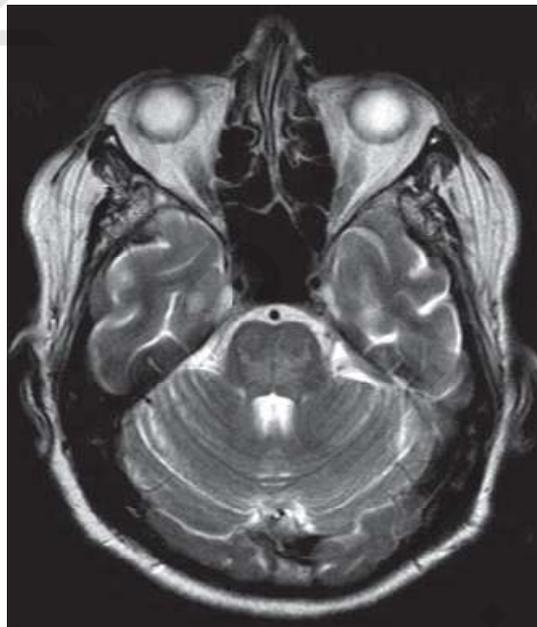


Fig22: Alcohol abuser, with decreased level of consciousness due to osmotic demyelination. Axial T2-weighted images show hyper intensity in pons sparing the periphery.⁽⁴⁹⁾

H) Wernicke encephalopathy

Caused by vitamin B1 deficiency due to chronic alcoholism, gastro-intestinal or hematologic neoplasms, chronic dialysis, bowel obstruction, and hyperemesis gravidarum, with a classic clinical triad of altered consciousness, ocular dysfunction and ataxia. MR findings include symmetric T2 prolongation in the medial thalamus (fig23-A), periaqueductal area (fig23-B), mammillary bodies, and tectal plate, petechial hemorrhage, diffusion restriction, and contrast enhancement. Involvement of the mammillary bodies was most prevalent in chronic alcohol abusers.^(50, 51)

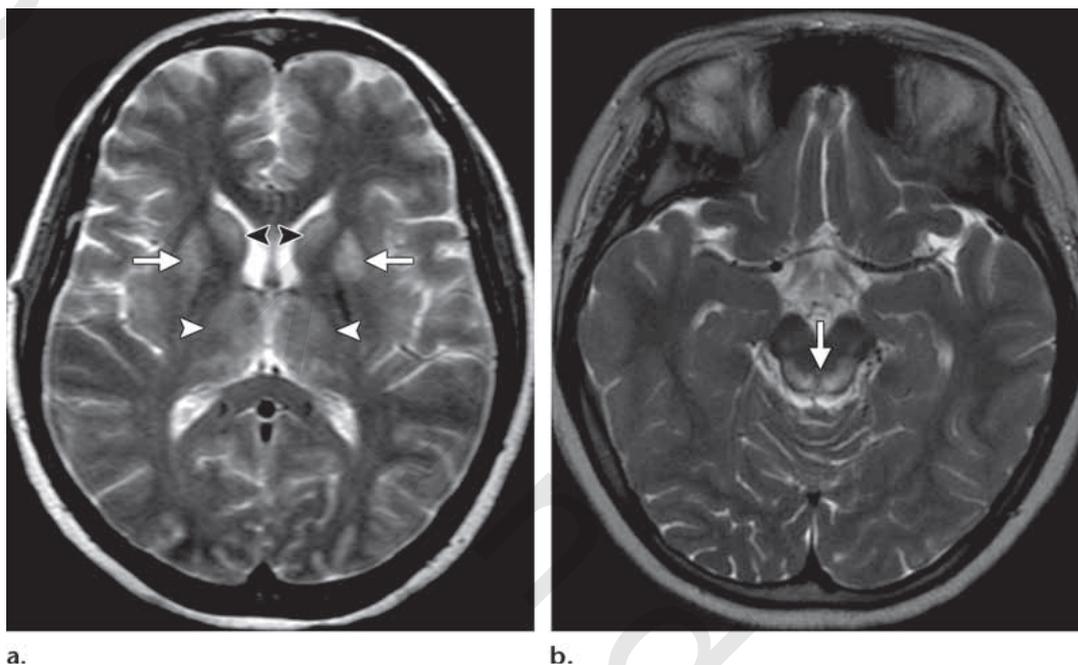


Fig23: Wernicke encephalopathy in a 36-year-old man (A) Axial T2-weighted MR image shows bilaterally symmetric areas of T2 prolongation in the para median thalamus along the third ventricle (white arrow heads), the caudate nuclei (black arrowheads), and the putamina (arrows). (B) Axial T2-weighted MR image shows ill-defined hyperintense areas in the periaqueductal region (arrow).⁽¹⁾

I) Kernicterus (bilirubin encephalopathy)

Rare neurological syndrome complicating the infantile hyper bilirubinemia, resulting from preferential deposition of bilirubin in the globus pallidus (GP), sub thalamic nucleus, hippocampus, putamen, thalamus, and cranial nerve nuclei (III, IV, and VI). (MRI) reveals symmetrical high intensity signal in the globus pallidus bilaterally on T1 and T2 weighted images is the most characteristic finding. Long-term survivors of kernicterus can have athetoid cerebral palsy, deafness or hearing loss, and impairment of upward gaze. Laboratory studies document abnormal or absent brain stem auditory evoked potentials.^(52, 53)

III. Degenerative.

A) Neuro-degeneration with Brain Iron Accumulation

NBIA characterized by brain degeneration and excessive iron deposition in the basal ganglia. Two clinical categories: (a) classic early-onset, rapidly progressive disease; and (b) atypical late onset, slowly progressive disease. In classic NBIA and in one-third of cases of atypical disease, the PANK2 gene is mutated. This gene encodes a pantothenate kinase, and affected patients (known as Hallervorden-Spatz disease) typically present with pyramidal or extra pyramidal signs, dystonia, and dysarthria. In NBIA, the diagnostic MR imaging feature is bilateral hypointensity in the globus pallidus at T2-weighted imaging, due to iron accumulation. Patients with PANK2 mutation demonstrate the “eye-of-the-tiger sign,” with a high-signal-intensity center surrounded by the more hypo-intensity in the globus pallidus (fig24). The eye-of-the-tiger sign is not seen in PANK2 mutation-negative patients.⁽⁵⁴⁻⁵⁶⁾

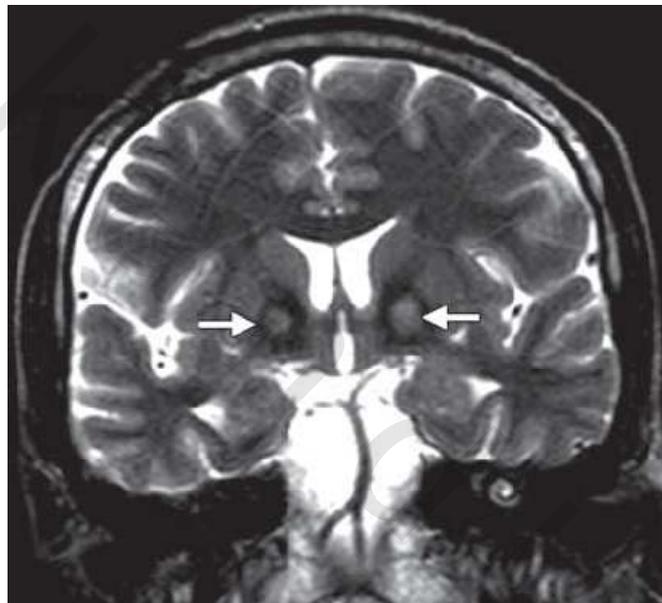


Fig24: (Hallervorden-Spatz disease) in a 24-year-old man with dystonia. Coronal T2-weighted MR image demonstrates bilateral hyperintense pallidal areas on a background areas of T2 shortening (eye-of-the-tiger sign) (arrows).⁽¹⁾

B) Creutzfeldt-Jakob disease (CJD)

Progressive neuro-degenerative disorder, caused deposition of isoform of prion protein PrP^{Sc} in the CNS. The classic triad includes: rapidly progressive dementia, myoclonus and typical EEG findings. Hyperintense MRI signal (more hyperintense in DWI than FLAIR) within caudate nucleus and putamen (fig25) or at least from two areas of the cerebral cortex (temporal, parietal or occipital). Sparing of the pre central gyri is characteristic.^(4, 57)

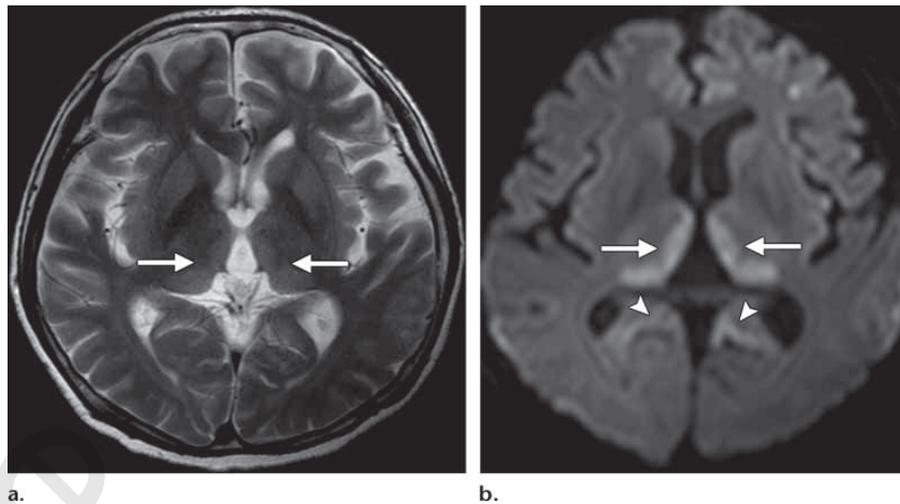


Fig 25: CJD in a 71-year man with rapidly progressive dementia and myoclonus. T2-weighted (a) and diffusion-weighted (b) MR images reveal bilaterally symmetric areas of T2 prolongation and restricted diffusion in the medial pulvinar nuclei of the medial thalamus (“pulvinar sign” or “hockey stick sign”) (arrows). The affected sites are better seen on the diffusion-weighted MR image. Note the high signal intensity of the cingulate gyri (arrow heads in b).⁽¹⁾

c) Fahr disease

Bilateral strio-pallido-dentate calcinosis characterized by: the symmetric deposition of calcium in the basal ganglia, thalamus, dentate nuclei and centrum semi ovale in absence of hypo-para-thyroidism. Presenting with slow onset of non-specific symptoms as headache. Other neurologic deficits include paresis, spasticity, gait disturbance, speech disorders, coma, dementia, Parkinsonism and chorea. At neuroimaging the condition characterized by bilaterally symmetric dense calcifications (fig26). Differential diagnosis for Fahr disease include hypo- para-thyroidism or pseudo- hypo- para-thyroidism (end-organ resistance to parathyroid hormone), confirmed with lab correlation.⁽⁵⁸⁾



Fig26: Fahr disease in a 44-year-old man CT scan shows bilaterally symmetrical high-attenuation calcifications in the thalamus, caudate nuclei, putamina, globus pallidus, and subcortical white matter.⁽¹⁾

D) Huntington disease (HD)

Degenerative disease of the (CNS) caused by expansion of a CGA triplet in the gene IT15 of chromosome 4, which encodes a protein of unknown function called huntingtin. The role of imaging techniques considerably decreased by the availability of a genetic screening test that also enables identification of asymptomatic gene carriers. However, combining the results of imaging studies with the results of molecular genetics improves the genotype-phenotype correlation and has the potential to enable a better understanding of the pathophysiology of the disease. In particular, results of several studies involving MR imaging demonstrated that volume loss in the neostriatum (i.e. the caudate nucleus and the putamen) can be observed in pre symptomatic patients.⁽⁵⁹⁾

The main radiologic feature of HD is caudate atrophy, Caudate atrophy can be quantified by the use of ratios that compare the inter caudate distance (CC) to other internal standards most commonly, frontal horn (FH) width and calvarial width (inner table [IT]) (fig27). In HD, there is an increase in CC out of proportion to FH or IT, which results in a decrease in the FH/CC ratio and an increase in the CC/IT ratio (bi caudate ratio).⁽⁶⁰⁾

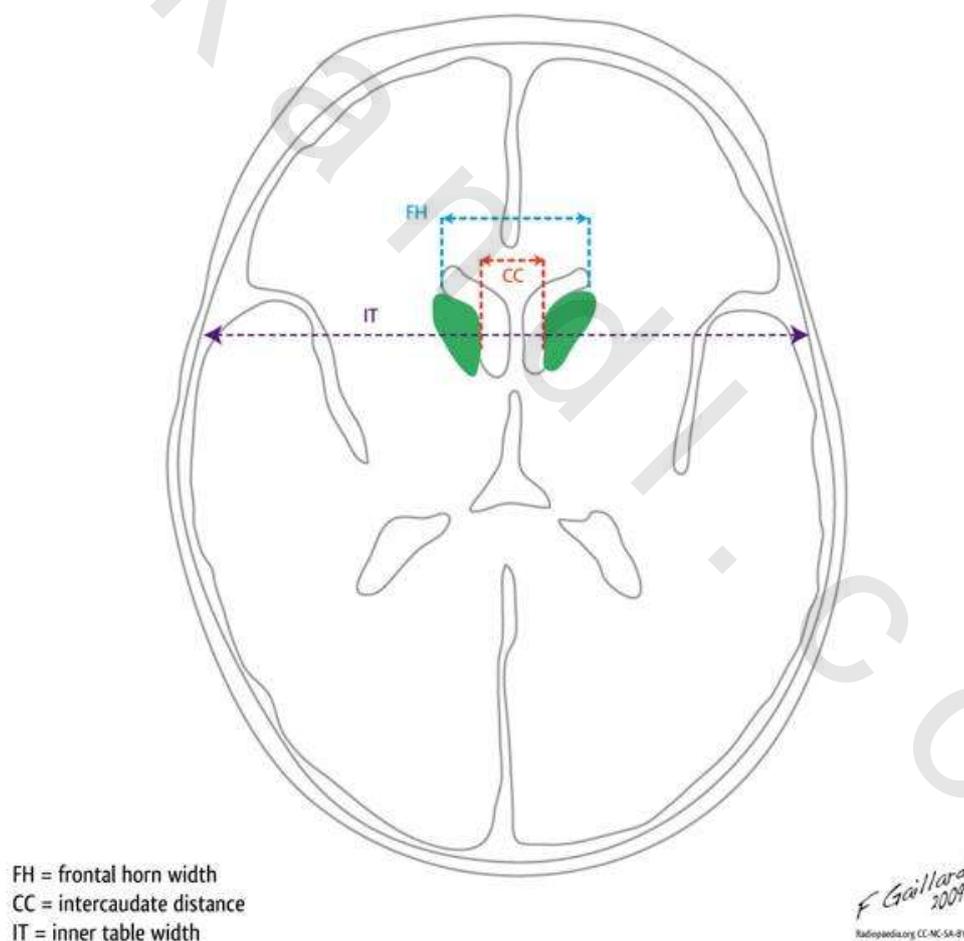


Fig27: Demonstrating how to measure :frontal horn width inter caudate distance inner table width FH/CC ratio :normal mean 2.2 to 2.6.⁽⁶⁰⁾

IV-Vascular.

A) Deep Cerebral Venous Thrombosis

Caused by hyper coagulable state, with involvement of the deep venous system present with acute headache, nausea, vomiting, seizures, and altered mental status. At neuroimaging, cerebral edema with T2 prolongation in the thalamus, internal capsule, basal ganglia, and deep white matter as well hemorrhagic conversion is common. Diffusion restriction is not a consistent feature.^(61, 62)

V- Inflammatory-infection.

A) Neuro-Behçet Disease

Recurrent inflammatory disorder with a triad of uveitis, oral ulcers and genital ulcers. CNS is affected in 4%-49% of patients. Focal or multifocal lesions are common. Commonly involve the brain stem, basal ganglia and thalamus and less commonly, the white matter of the cerebral hemispheres and cervicothoracic spinal cord. Lesions are hyperintense on T2-weighted MR images, are hypointense on T1-weighted images, enhance after contrast administration and associated with vasogenic edema.^(63, 64)

B) Flavivirus encephalitis

Japanese encephalitis, West Nile fever, and Murray Valley fever typically symmetric involvement of the deep gray matter. Definitive serologic diagnosis is the detection of antibodies in serum and CSF. MR finding of Japanese encephalitis is T2 hyperintensity of the posteromedial thalamus intra lesional hemorrhages and restricted diffusion. Other sites include the basal ganglia, substantia nigra, red nucleus, pons, hippocampi, cerebral cortex, and cerebellum. Japanese encephalitis and Murray Valley encephalitis more often involve the thalamus, whereas West Nile fever demonstrates bilateral involvement of the thalamus and the caudate and lentiform nuclei.⁽⁶⁵⁻⁶⁸⁾

C) Cerebral toxoplasmosis

Opportunistic infection caused by toxoplasma gondii, in immune-compromised patients, at imaging multiple focal lesions in the basal ganglia and gray white matter junctions. On T2-weighted images, the lesions are typically hypo- to iso intense with prominent mass effect and vasogenic edema (fig28-A), Hemorrhagic lesions appear hyper intense on T1-weighted images and are hypointense on gradient images. After contrast injection, nodular or ring enhancement typically seen (fig28-B). MR spectroscopy typically demonstrates lipid break down products without elevated choline.^(1, 69)

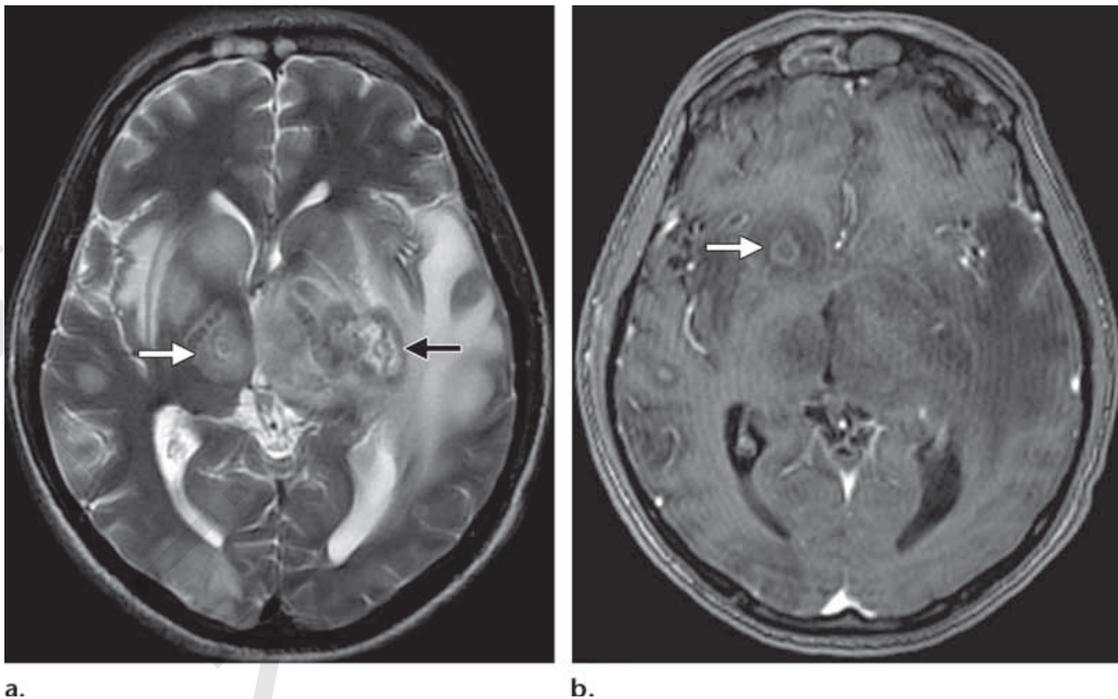


Fig28: CNS toxoplasmosis in a 37-year-old HIV man (A) Axial T2-weighted image shows multiple bilateral hyperintense lesions in the caudate nuclei, left lentiform nucleus (black arrow), and right thalamus (white arrow), with extensive perifocal edema. (B) On an axial contrast-enhanced T1-weighted MR image obtained at a lower level, the lesion in the right caudate nucleus demonstrates rim enhancement (arrow).⁽¹⁾

VI-Neoplasm.

A) Primary CNS Lymphoma

In both immune-competent and immune-compromised patients involve the deep periventricular white matter, corpus callosum, and basal ganglia. Multiple lesions and involvement of the basal ganglia common in HIV-AIDS patients, lesions mimic toxoplasmosis. Periventricular location and sub ependymal spread distinguish it from toxoplasmosis. MR spectroscopy shows elevated choline levels. The high attenuation of primary CNS lymphoma at CT and its iso- or hypo intensity at T2-weighted imaging (Fig29A) attributed to high tumor cellularity. Solid enhancement typically occurs in immune-competent patients (Fig29B), whereas lesions with ring enhancement and central necrosis occur in AIDS patients.⁽⁶⁹⁻⁷¹⁾

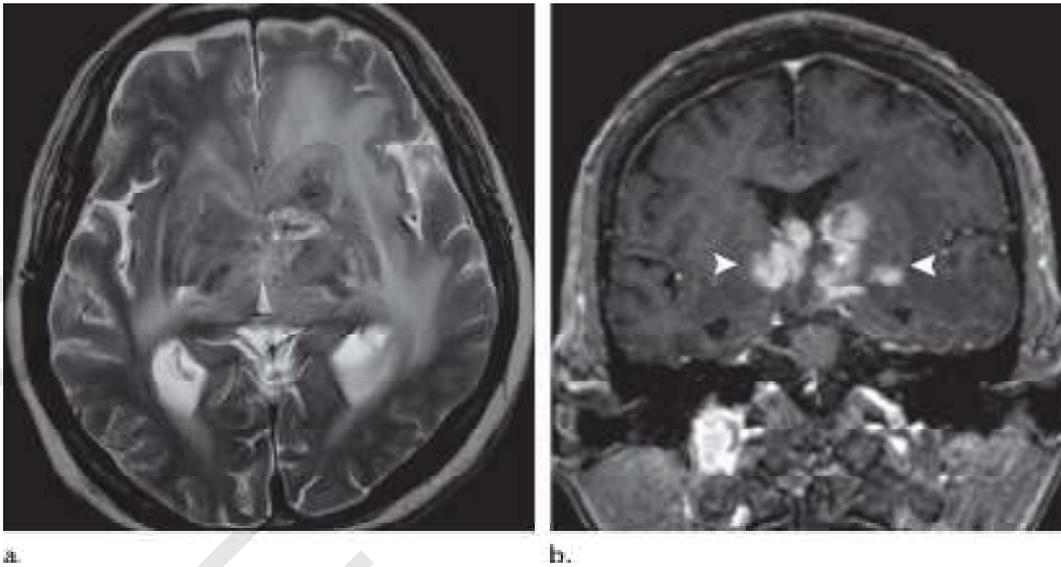


Fig.29: Primary CNS lymphoma in a 55-year AIDS man. (A) Axial T2-weighted MR image depicts Bilateral ill-defined iso intense to hypointense areas involving the basal ganglia and thalamus, with extensive peri focal edema. (B) On a coronal contrast-enhanced T1-weighted MR image, the lesions demonstrate avid enhancement.⁽¹⁾

B) Germinoma of the basal ganglia

Germinoma of the basal ganglia and thalamus account about 4-10% of the intracranial germinoma. MR imaging show a large para-ventricular mass with internal cystic changes and focal hemorrhage and minimal surrounding edema.^(72, 73)

C) Neurofibromatosis Type 1

MR imaging reveal focal areas of increased signal intensity on T2-weighted images (fig30). The globus pallidus is the most common site. Also found in the brainstem and cerebellum. Typically exert no mass effect, are not associated with surrounding edema, and do not enhance, differentiated from gliomas at MR spectroscopy due to their higher N-acetyl aspartate–choline, N-acetyl aspartate–creatine, and creatine–choline ratios.^(74, 75)

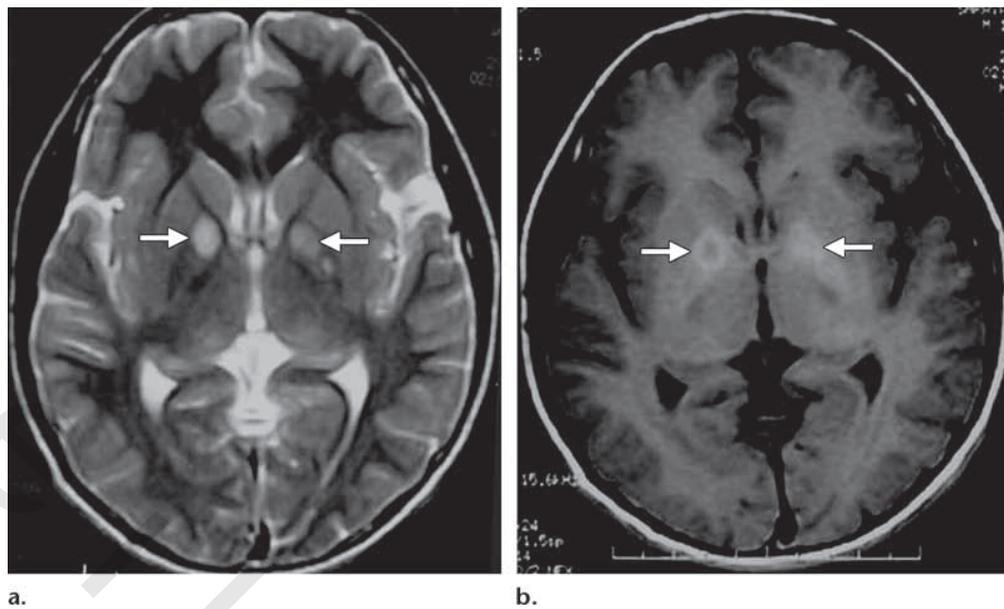


Fig30: Bright objects” in an asymptomatic 21-year woman with NF 1. (A) Axial T2-weighted MR image shows bilateral pallidal areas of hyperintensity (arrows) that have no mass effect. (B) On an axial T1-weighted MR image, the foci (arrows) appear also hyperintense⁽¹⁾.

D) Metastases.

Intracerebral mass in patients with known malignant tumor strongly suggests brain metastases. In 70% imaging demonstrates more than one lesion. The most common sources in order of decreasing frequency are carcinomas of the lung, breast, malignant melanoma, carcinomas of the kidney, and carcinomas of the gastrointestinal tract. Cerebral metastases mostly occur at the junction of cortex and underlying white matter, roughly 80% being located in the arterial distribution zones of the cerebral hemispheres, 3% in the basal ganglia, and 15% in the cerebellum. On MRI examination, most intracerebral metastases show diminished signal on T1 and increased signal on T2-weighted images. T1-weighted with contrast reveals ring, punctate or solid enhancement. Some of them, especially with large size, have central necrosis, and intra tumoural hemorrhage is found in about 20% of cases, more frequent in dissemination of melanomas, choriocarcinomas, carcinomas of the lung, kidney and thyroid, in this order. Calcification rarely found.⁽⁷⁶⁾

Table (2): Differential diagnosis of the diseases on the basis of their MR signals characteristics⁽⁴⁾.

MR signal characteristics	Characteristics Disease
T2-hyperintensity	<ul style="list-style-type: none"> ▪ Rassmussen encephalitis (unilateral). ▪ Infarction. ▪ Hypoxia-ischemia ▪ Carbon monoxide intoxication ▪ Hypoglycemia ▪ Leigh disease and other mitochondrial diseases. ▪ Infantile bilateral striatal necrosis. ▪ Huntington' s disease. ▪ Neurofibromatosis type 1. ▪ HSV-encephalitis and encephalitis due to other causes. ▪ Creutz feldt-Jakob disease. ▪ Extra pontine myelinolysis. ▪ Cyanide, methanol and drugs intoxication.
T2-hypointensity old age	<ul style="list-style-type: none"> ▪ Parkinson' s disease (globus pallidus). ▪ Calcifications. ▪ Hemosiderin (old hemorrhage) or deoxyhemoglobin.
T2-hyper- and hypointensity	<ul style="list-style-type: none"> ▪ Panthotenate kinase-associated neuro degeneration – “eye-of-the-tiger” .
T2-hyper- or hypointensity	<ul style="list-style-type: none"> ▪ Wilson disease
T1-hyperintensity	<ul style="list-style-type: none"> ▪ (Hemi) chorea/ (hemi) ballism. ▪ Hypoxia-ischemia, newborns. ▪ Carbon monoxide (delayed). ▪ Kernicterus. ▪ Manganese intoxication. ▪ Methemoglobin.
T1-hypointensity	<ul style="list-style-type: none"> ▪ Infarction. ▪ Infantile bilateral striatal necrosis.
T1-hyper- and hypointensity	<ul style="list-style-type: none"> ▪ Parkinson variant of multiple system atrophy.
T1-hyper- or hypointensity	<ul style="list-style-type: none"> ▪ Wilson disease. ▪ Calcifications.
DWI-hyperintensity	<ul style="list-style-type: none"> ▪ Recent infarction. ▪ Hypoxia-ischemia. ▪ Carbon monoxide intoxication. ▪ Hypoglycemia. ▪ Leigh disease and other mitochondrial diseases. ▪ Wilson disease. ▪ Encephalitis (Streptococcus, flava virus and Japanese encephalitis.) ▪ Creutz feldt-Jakob disease. ▪ Extra pontine myelinolysis. ▪ Acute hyper amonemia.

Table3: Clinical and neuroimaging features of bilateral abnormalities of the basal ganglia and thalamus ⁽¹⁾.

Cause	Primary Nuclei Affected	Other areas of Involvement	Clinical history and Laboratory features
Toxic Poisoning			
Carbon monoxide	GP (decreased ADC, late T1 shortening).	Delayed white matter leukoencephalopathy	Suicide attempt, elevated serum carboxy hemoglobin.
Methanol	Putamen (hemorrhagic).	WM edema	Accidental ingestion, optic neuritis, toxicity.
Cyanide	Putamen (hemorrhagic).	-----	Industrial accident toxicity.
Metabolic diseases			
Liver disease	GP (T1 hyperintensity)	Substantia nigra	Cirrhotic patients with porto-systemic shunts or history of TIPS.
Acute hyper ammonia	BG (decreased ADC)	Insular cortex, cingulate gyrus	Acute exacerbation of hepatic encephalopathy ,inborn errors of metabolism, elevated serum ammonia levels, or urea cycle metabolites in the serum or urine.
Non ketotic hyperglycemia	Caudate nucleus and GP (T1 hyperintensity).		Diabetic patients with chorea, ballismus, or an elevated blood sugar level.
Hypoglycemia	BG (decreased ADC)	Cortical involvement: hippocampus or diffuse pattern of involvement; WM involvement: commonly in the internal capsule, splenium of the corpus callosum.	Diabetic with a therapeutic over dose, elevated blood sugar level or toxicity.
Hypoxic ischemic encephalopathy	BG and thalamus (decreased ADC)	Cortical involvement: water shed infarcts or diffuse involvement; Delayed leukoencephalopathy.	Cardiac arrest, asphyxia, near drowning.
Leigh disease	BG and thalamus (lactate at MR spectroscopy)	Periaqueductal region, cerebral peduncle.	Elevated serum or CSF lactate levels, muscle biopsy for mitochondrial abnormalities, genetic analysis for specific Mutations.
Wilson disease	BG and ventro-lateral thalamus (decreased ADC)	----	Kayser-Fleischer rings, low serum level of ceruloplasmin, hepatic abnormalities
Osmotic myelinolysis	BG and thalamus (variable ADC)	Pons: “trident sign” or “bat wing sign”.	Alcoholic or malnourished patients, rapid over correction Of hyponatremia.

Table3: Clinical and neuroimaging features of bilateral abnormalities of the basal ganglia and thalamus (cont.)⁽¹⁾.

Cause	Primary Nuclei Affected	Other areas of Involvement	Clinical history and Laboratory features
Vascular disease.			
Deep cerebral vein thrombosis	BG and thalamus (hemorrhagic, variable ADC)	Adjacent WM†	Dehydration, puerperium, oral contraceptive ,infection
Degenerative Diseases			
NBIA	GP (“eye of the tiger” sign [hyperintense center with hypointense rim])		Genetic analysis for PANK2 mutations.
CJD	BG and thalamus (decreased ADC, “pulvinar sign” typical of variant CJD)	Cortex	Rapidly progressive dementia, myoclonus, CSF 14-3-3 protein, generalized periodic sharp wave complexes at electroencephalography, Brain biopsy for definitive diagnosis.
Fahr disease	BG and thalamus (heavy calcification at CT)	Dentate nuclei, subcortical WM	Normal serum calcium and parathyroid hormone levels exclude hypo parathyroidism and pseudohypoparathyroidism
Inflammatory and Infectious Diseases			
Neuro-Behçet disease	BG and thalamus	Brainstem, WM, spinal cord	Patients with uveitis, oro-genital ulcers.
Flavi virus encephalitis	BG and thalamus (hemorrhagic)	Cortex, substantia nigra, red nucleus, pons, cerebellum	Patients in Asia (Japanese encephalitis), Australia (MurrayValley fever), or the Middle East or United States (West Nile fever); detection of antibodies at enzyme-linked Immunesorbent assay of the serum or CSF
CNS toxoplasmosis	BG and thalamus (hemorrhagic, T2 shortening, lipid or lactate at MR spectroscopy)	Adjacent WM	Immuno compromised patients, findings of T Gondii at serologic analysis
Neoplasm			
Primary CNS lymphoma.	BG and thalamus (slightly hyper attenuating at CT, choline at MR spectroscopy, increased uptake at PET and SPECT	Adjacent periventricular WM and sub ependymal Spread.	Immuno-compromised patients.
Metastasis.	Basal ganglia.	GWJ at arterial distribution zones and cerebellum.	Known primary tumor.
NF1.	GP (T2 hyperintensity.)	Cranial neurofibroma and optic glioma.	Café-au-lait spots, plexiform neurofibromas, or bone dysplasia