Hypointensities in the brain on T2* weighted gradient echo MR imaging: what radiologist should know.

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Learning objectives

Investigate the meaning of the images punctate of low signal on magnetic susceptibility sequences "black dots" and consider the differential diagnosis of the various causes of cerebral microbleeds, illustrating all with images collected over asistencial activity developed in our center.
Background

"Hot spots" in the sequence T2 * and currently in the most modern magnetic susceptibility sequences are hypointense lesions less than half centimeter of diameter, that go unnoticed in other MR sequences.

These images are derived from a ferromagnetic artifact produced by accumulation of hemosiderin inside macrophages after microhemorrhages. Ruled out other etiologies of "black dots" like air bubbles or microcalcifications normally easily identifiable in previous CT studies and vascular structures that would be displayed as signal void in several cutting planes continuos.

We will study other coexisting lesions on MRI.
Findings and procedure details

The T2* gradient echo sequence and the most recent magnetic susceptibility onset sequences, show the presence of punctate hypointense lesions not visible on other sequences. We will consider hypointensities hemorrhagic causes and discarding images due to air bubbles and microcalcifications identifiables in previous studies of computed tomography (CT) and those produced by empty signal of vascular structures that would be identified as contiguous vacuum signal at various cutting planes.

Amiloid angiopathy

The microangiopathy is characterized by amyloid deposition of congophilic materials (defined as affinity for Congo red) in the cerebral vessels of small and medium size and in the leptomeninges. In severe stages, amyloid deposits cause rupture of the wall of the blood vessel causing bleeding. Cerebral amyloid deposits in the sporadic form are biochemically similar to the senile plaques of Alzheimer's disease.

Although the most common clinical manifestation of amyloid microangiopathy is spontaneous lobar cerebral hemorrhage, in a considerable number of patients, the radiologist may be the first physician to suggest the diagnosis, incidentally suggestive image data by identifying small subclinical bleeds. Brain microbleeds or petechial hemorrhages also called "microbleeds" are relatively common in amyloid microangiopathy and are detected as punctate areas of no signal of 2-5 mm in sequence T2 * gradient echo and other sequences of magnetic susceptibility, images correspond to focal hemosiderin deposits.

The most frequent location of microbleeds secondary to amyloid microangiopathy is the cortical or cortico-subcortical area and are usually punctate and very numerous, (along with larger intraparenchymal) and differentiating of hypertensive microhemorrhage often affect basal ganglia thalamus and pons. The cerebellum is rarely affected.

Other radiological findings, although nonspecific are frequently associated involvement of the subcortical white matter secondary to small vessel disease and atrophic-involutive changes the brain parenchyma. These findings along with personal and clinical neurological examination data (which may be normal or occasional focal symptoms may appear) help to make a correct diagnosis of this disease.

Hypertensive angiopathy

Hypertension is the most common cause of intracranial hemorrhage of traumatic origin in adults.
Under the name of hypertensive angiopathy are described multiples morphological and inflammatory changes of the arterial wall as intimal hyperplasia, hialinosis, sclerosis and possible bleeding consequences.

These alterations are more frequent at level of perforating arteries such as recurrent artery of Heubner, and lenticulostriate, talamogeniculadas and consequently the most common location of hypertensive hemorrhage angiopathy are the basal ganglia. In order of frequency: putamen and internal capsule (40-50%), thalamus (10-20%), caudate nucleus (8%), lobar involvement, brain stem and cerebellum.

These locations are opposed to the typical location of amyloid angiopathy where hemorrhagic involvement is predominant to cortico-subcortical level, facilitating orientation of radiological diagnosis.

**Axonal diffuse injury**

Diffuse axonal injury is a disorder characterized by diffuse or multifocal involvement of axons following a head injury secondary to direct trauma, inertial acceleration and deceleration forces or shear without direct traumatic impact.

The most common radiographic findings are the presence of multiple small punctate images from 1 to 15 mm of decrease signal in magnetic susceptibility sequences, typically located in the gray-white matter union, corpus callosum and posterior-lateral regions of the brainstem.

The most affected are the frontal and temporal lobes and the corpus callosum. These injuries often go unnoticed in brain CT and the majority of other MRI sequences, only some of these lesions may present as small hiperintesidades in the FLAIR sequence and long TR sequence.

The findings refered with a history of head trauma and suspected diagnosis by neurologic examination, coma or autonomic symptoms allow the diagnosis of diffuse axonal injury with high sensitivity and specificity.

**Multiple cavernomatosis**

Cavernomas are low-flow vascular malformations that can occur isolated way or be multiple and sporadic or familial.

Classically cavernomas were described as congenital lesions resulting from an alteration in the development of arteriolo capillary network, but modern studies have shown this to be dynamic lesions which can vary in size.

Cavernomas consist of dilated vascular channels of different sizes which are lined by a thin and weak epithelium, lacking in muscular and elastic layers which predisposes to bleeding. They may have internal calcifications. Most cavernomas will present a less than 3 cm in size, with many of them of a few millimeters.
However, there may be large lesions called giants cavernomas.

Its main histological feature is that there is no brain parenchyma between them, this the difference with capillary telangiectasia.

With respect to the clinical presentation cavernomas may be asymptomatic and diagnosis may be performed incidentally or presents as seizures or symptoms arising from its major complication, bleeding.

Supratentorial cavernomas are the most common, accounting for about 80%. Mainly affect the subcortical region being the frontal and temporal lobes most frequently affected. In the posterior fossa, cavernomas most often affecting the pons and cerebellar hemispheres.

Magnetic resonance imaging (MRI) is the main technique for diagnosing and assessing image cavernomas. Its radiographic appearance is variable depending on the stage of hemorrhage. The typical image in uncomplicated cavernomas is known as "popcorn." This is a central area of heterogeneous signal on T1-weighted images and T2 (due to phenomena of thrombosis, hemorrhage, fibrosis and calcification), surrounded by a ring full hemosiderin, less intense signal in weighted sequences T2. The most sensitive sequence to detect cavernomas is the gradient echo T2*. Due to the effect of magnetic susceptibility of the products generated by degradation of hemoglobin, the injury is more evident in this sequence.

In case of recent hemorrhage, which often have clinical expression, cavernoma may lose their typical appearance in different image modalities and presenting atypical radiologic features: mass effect on adjacent structures associated with an halo of vasogenic edema, loss of peripheral ring of low intensity hemosiderin, liquid-liquid level inside or presence of a perilesional hemorrhage.

**CADASIL**

CADASIL is defined ("Cerebral Autosomal-Dominant Arteriopathy with Subcortical Infarcts and Leukoencephalopathy") as cerebral autosomal dominant arteriopathy with subcortical infarcts and leukencephalopathy a secondary systemic genetic disease mutation of NOTCH3 gene on chromosome 19.

The first clinical manifestations of the disease in patients usually begin during the third decade of life, death often occurring during the sixth decade of life. Clinical manifestations of the disease are ischemic stroke, dementia, migraine with aura and mood disorders. Histopathological studies reveal deposit high density granular material near the membrane of vascular smooth muscle cells, as well as loss of the same in small and medium arteries leptomeningeal.
The main findings of MRI in patients with CADASIL are diffuse areas of hyperintensity of white matter occur predominantly in subcortical areas and lacunar infarcts present in the centrum semiovale, thalamus, basal ganglia and pons.

Recent findings described in MRI studies are the presence of microbleeds or punctate in subcortical region.

Cerebral Vasculitis
Vasculitis are characterized by inflammation and necrosis of the vessel wall and are usually differentiated according to the involvement of vessels of large, medium and small size and the presence or absence of anti neutrophil cytoplasmic antibodies (ANCA ). Primary central nervous system vasculitis is a rare disorder that affects the vessels of small and medium size being the main stroke symptoms, headache and encephalopathy.

The diagnosis is based on laboratory findings and radiological findings. Radiological findings are not specific to a particular type of vasculitis and although MRI may suggest the diagnosis, greater diagnostic sensitivity test is the digital cerebral angiography. Images most frequently observed are irregularities, vascular stenosis and occlusions with an atypical distribution for atherosclerotic disease.

There may be arterial and venous involvement in any location and size of the vessel.

In the different MRI sequences the most frequent findings cortico- subcortical hypointensities areas in T1, T2 weighted sequences and multifocal hyperintensities in FLAIR, sometimes restricted diffusion, findings all secondary to areas of cerebral infarct. In the enhanced magnetic susceptibility sequences smalls hypointense foci may be visible in relation microbleeds.

Metastatic microbleeds
Although any brain tumor can bleed, tumor hemorrhage is often associated with malignant tumors. Malignant tumors most commonly associated with intracerebral hemorrhage include glioblastoma multiforme, lymphoma and metastasis of melanoma, choriocarcinoma, lung and renal cell carcinoma.

Sometimes the presence of small bleeds within micrometastases determined early detection of metastases, when they still would not reach a sufficient size to make them detectable in conventional sequences.

A particular case is the metastatic melanoma, for is chemical composition injuries usually have high signal intensity on T1-weighted images and loss of signal intensity on T2 *, even in the absence of bleeding.

Metal embolisms
There have been reports of cases showing multiple small or isolated hipointensities in the brain parenchyma of new onset in patients undergoing heart valve replacement surgery.

These results may be due to metal embolism associated with preoperative angiography derivatives perfusion circuit used for cardiac intervention or from the metal valve itself.
Images for this section:

Fig. 1: 81 year old patient admitted for status epilepticus. Multiple peripheral rounded images in left frontoparietal region and right temporal, of different sizes, and heterogeneous hypointense on T1-T2 compatible with hemorrhagic foci in relation to amyloid angiopathy. See next image.

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**Fig. 2:** Same patient of the previous image. 81 year old patient admitted for status epilepticus. Multiple peripheral rounded images in left frontoparietal region and right temporal, of different sizes, and heterogeneous hypointense on T1-T2 compatible with hemorrhagic foci in relation to amyloid angiopathy.

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![Fig. 2](image)

**Fig. 3:** Patient 81 years old with symptoms of vascular dementia. In the gradient echo T2 sequences multiple punctate foci of marked hyposignal and millimeter of corticosubcortical location and the pial surface of the entire supratentorial convexity and both cerebellar hemispheres consistent as the first diagnostic possibility with massive microbleeds identified by amyloid angiopathy.

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![Fig. 3](image)
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Fig. 5: Chronic hypertensive patiente of 54 years old. In CT imaging identifies acute hematoma in left basal ganglia. On MRI performed 3 days after the normal evolution of the hematoma is seen with a halo of T1 hyperintense methemoglobin without other findings are identified. In the axial gradient echo sequence also T2 lesion left basal ganglia, there are uncountless number hypointense lesions mainly concentrated in basal ganglia, brainstem, and white matter of cerebellar hemispheres, remains compatible with hemosiderin from chronic bleeding in the context of hypertensive microangiopathy. See next image.

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Fig. 7: 56 year old patient hospitalized for hypertensive crisis and nauseas. Identified in the axial T2-weighted gradient echo sequence images punctate signal absence in basal ganglia of pseudonodular morphology, of few millimeters, consistent with focal microhemorrhages hemosiderin derived in the context of hypertensive vasculopathy. In the pons of brainstem an image of similar but larger semiology is appreciated. Lesions are more abundant in deeper regions of the brain and more scarce in peripheral locations, which corresponds to hemorrhage due to hypertension.

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Fig. 8: 19 year old male patient who suffered a severe head injury with cerebral TC unaltered. In the sagittal T1 collection, extra axial hyperintense subacute epidural hematoma support is displayed behind the cerebellar vermis. There are punctate hyperintense images on long TR sequences affecting the subcortical white matter of the right frontal lobe and in several other locations not shown on the pictures. In gradient echo sequences T2 these lesions become hypointense and appear in greater numbers, pinpoint, magnetic susceptibility phenomena affecting the gray white junction and splenium of corpus callosum. Given the support neurological examination and history these findings are consistent with diffuse axonal injury. See next picture.

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Fig. 9: Same patient of previous image. 19 year old male patient who suffered a severe head injury with cerebral TC unaltered In the sagittal T1 collection, extra axial hyperintense subacute epidural hematoma support is displayed behind the cerebellar vermis. There are punctate hyperintense images on long TR sequences affecting the subcortical white matter of the right frontal lobe and in several other locations not shown on the pictures. In gradient echo sequences T2 these lesions become hypointense and appear in greater numbers, pinpoint, magnetic susceptibility phenomena affecting the gray white junction and splenium of corpus callosum Given the support neurological examination and history these findings are consistent with diffuse axonal injury.

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**Fig. 10:** Patient under study because of familiar history of multiple cavernous. In both hemispheres, stem and cerebellar hemispheres multiple focal images of heterogeneous signal on T1 identified in some cases presenting central punctate hyperintense areas. In sequences susceptibility greater number of lesions in the remaining sequences and appear hypointense markedly detected. Images are compatible with cavernomatosis familiar with possible multiple small foci of bleeding.

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Fig. 11: Patient age 21, without pathological antecedents that debuted with a tonic-clonic seizure. A supratentorial level, in both hemispheres, multiple space-occupying lesions are observed, all of very low signal intensity on T2 sequences, becoming even more hypointense on gradient echo sequence T2, a larger (2.5 cm) with regard to "popcorn" on the right base ganglia, findings consistent with multiple cavernous. See next two pictures.

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**Fig. 12:** Same patient of previous picture. Patient age 21, without pathological antecedents that debuted with a tonic-clonic seizure. A supratentorial level, in both hemispheres, multiple space-occupying lesions are observed, all of very low signal intensity on T2 sequences, becoming even more hypointense on gradient echo sequence T2, a larger (2.5 cm) with regard to "popcorn-" on the right base ganglia, findings consistent with multiple cavernous.

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Fig. 13: Same patient of previous pictures. Patient age 21, without pathological antecedents that debuted with a tonic-clonic seizure. A supratentorial level, in both hemispheres, multiple space-occupying lesions are observed, all of very low signal intensity on T2 sequences, becoming even more hypointense on gradient echo sequence T2, a larger (2 5 cm) with regard to “popcorn-” on the right base ganglia, findings consistent with multiple cavernous.

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**Fig. 14:** 56 year old patient with a history of heart valve disease and aortic valve replacement and mitral mechanical prosthesis and atrial fibrillation. In the sequence of magnetic susceptibility SWI, hypointense images punctate ("black dots") supratentorial in both cerebral hemispheres, adjacent to Red nucellus and boss, that given the clinical setting midbrain are compatible with metal microembolisms from artificial heart valves are displayed. See next picture.

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Fig. 15: Same patient of previous image. 56 year old patient with a history of heart valve disease and aortic valve replacement and mitral mechanical prosthesis and atrial fibrillation. In the sequence of magnetic susceptibility SWI, hypointense images punctate ("black dots") supratentorial in both cerebral hemispheres, adjacent to Red nucellus and boss, that given the clinical setting midbrain are compatible with metal microembolisms from artificial heart valves are displayed.

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Fig. 16: 54 years female patient with lung neoplasia. In neuronavigator sequence after administration of paramagnetic contrast hypercaptant multiple lesions of different size located predominantly in the gray-white junction compatible with metastasis identified. Some of them (arrows) phenomena occur in the magnetic susceptibility in the gradient echo sequence T2, which is compatible with the presence of bleeding inside.

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**Fig. 17:** Same patient of previous picture. 54 years female patient with lung neoplasia. In neuronavigator sequence after administration of paramagnetic contrast hypercaptant multiple lesions of different size located predominantly in the gray-white junction compatible with metastasis identified. Some of them (arrows) phenomena occur in the magnetic susceptibility in the gradient echo sequence T2, which is compatible with the presence of bleeding inside.

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**Fig. 18:** Same patient of previous picture. 54 years female patient with lung neoplasia. In neuronavigator sequence after administration of paramagnetic contrast hypercaptive multiple lesions of different size located predominantly in the gray-white junction compatible with metastasis identified. Some of them (arrows) phenomena occur in the magnetic susceptibility in the gradient echo sequence T2, which is compatible with the presence of bleeding inside.

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Conclusion

With magnetic susceptibility sequences we identify black spots not visible in other sequences. Considering its distribution, morphology, other MRI findings and the clinical context of the patient, we can guide a differential diagnosis between various pathologies that may determine it.
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5. Malformaciones cavernosas intracraneales: espectro de manifestaciones neurorradiológicas

*Cerebral cavernous malformations: spectrum of neuroradiological findings*

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