Brain Abscess in Children

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Purpose

To show the imaging findings of central nervous system (CNS) abscesses in the pediatric patient by means of US, MRI and CT, evaluating their utility in the presurgical planning in surgical patients and follow-up when conservative treatment is required.
Methods and Materials

We reviewed 15 cases of brain abscesses that were admitted in our hospital during the last 5 years (2006-2011).
We analyzed the pathogenesis of each case and presented the diagnostic images obtained by US, MRI and, in just a few cases, CT.
The etiology was possible to confirm in most of cases from blood cultures and samples taken from surgical drains.

The list of the cases was:

A. Abscess due to neonatal meningitis by Citrobacter koserii: 3 (cases 1, 2, 3)
B. Abscess due to neonatal meningitis (non-isolated pathogen): 1 (case 4)
C. Abscess due to neonatal Candidiasis: 2 (cases 5, 6)
D. Abscess due to neonatal sepsis (klebsiella, Enterobacter): 1 (case 7)
E. Abscess due to meningitis in older child (Streptococcus): 1 (case 8)
F. Abscess due to foreign body (Peptostreptococcus): 1 (case 9)
G. Abscess as a complication of sinusitis (non-isolated pathogen): 2 (cases 10, 11)
H. Abscess as a complication of dermal sinus (non-isolated pathogen): 1 (case 12)
I. Abscess due to tuberculosis: 2 (cases 13, 14)
J. Abscess due to cysticercosis: 1 (case 15)
Results

A CNS abscess is an intra- or extraparenchymatous infection that begins as an area of cerebritis that progresses to an encapsulated collection of purulent material going through different phases. Cerebritis is the earliest manifestation of a cerebral infection that may progress to the formation of a brain abscess and occurs 2-3 days following pathogen inoculation. It is a rare infection during childhood, but has an important morbidity (comitial crisis, development alterations, hydrocephalus…) and a high mortality rate (5-10%), especially in immunocompromised patients, presenting multiple abscesses or with a ventriculitis secondary to the rupture of an abscess into the ventricular system. [1, 2]

The infectious pathogen depends on [2, 3]:

- The origin of the infection: Streptococcus, Enterobacter, and anaerobes are usually present in the middle ear, mastoid, and oropharinx. In a high percentage of cases, the infection is caused by mixed flora (25-50%).
- Immunitary state: in immunocompromised patients there is a predisposition to fungal and parasite infections.
- Age: during the neonatal period, it is more frequent to observe cerebral abscesses secondary to meningeal infections (1-18%). These infections are caused by pathogen such as Citrobacter, Proteus, Enterobacter, and Serratia.

The middle ear, sinusal and mastoid infections have classically been the most relevant risk factors for CNS abscesses. Seeding of the brain presumably occurs via transit of infectious bacteria through the valveless emissary veins that drain into these regions, and permit either direct or retrograde flow into the venous drainage systems of the brain. Nevertheless, recent studies have published that the most relevant risk factor is the presence of congenital cyanotic cardiac disease (left-to-right shunt), due to the improvement of antibiotic treatment in ORL infections. It is also important to consider that the incidence of these infections is increasing in immunocompromised patients and in neonates. Up to 25% of cases have no predisposing risk factor. [2,3]

Imaging:

- US findings [4]:
The cerebral parenchyma shows a heterogeneous and increased echogenicity in phases previous to the formation of the abscess. This finding corresponds to cerebritis. The cerebritis area progresses to an abscess by the liquefaction of its content during the evolution of the lesion. In intermediate stages, the lesion shows solid and cystic components.
The abscess is a lesion with a hyperechogenic and hyperemic well-defined wall that present liquid inside and sometimes can show air bubbles or a detritus liquid-liquid level. It produces mass effect and secondarily can secondarily collapse a ventricle or produce midline shift.

- **MRI findings** [1, 5, 6]:
  During the stage of cerebritis the affected area is seen on T1 weighted images as an ill-defined area of decreased signal intensity. It shows important restriction on diffusion weighted images (that in abscence of purulent fluid may be attributed to hypercellularity, brain ischemia or cytotoxic edema), and usually does not present enhancement on gadolinium-enhanced T1 weighted images. On FLAIR and T2 weighted images, the infected tissue is hyperintense. The abscess is a parenchymatous lesion hypointense on T1-weighted images and hyperintense on T2-weighted images. It has a rough wall that enhances after contrast administration. The abscess shows an important restriction to diffusion and a secondary low signal intensity in ADC maps. The pus contained inside the abscess presents a high quantity of inflammatory cells, bacteria and high-viscosity necrotic and proteinaceous tissue. These are manifested on diffusion weighted sequences as a marked restriction to diffusion (high intensity signal). When the abscess is drained or removed, this signal disappears, unlike the enhancement of the affected tissue after contrast administration that can stay up to 8 months in spite of effective treatment. This information is essential in monitoring the effectiveness of treatment of the abscess as the high intensity signal in diffusion weighted sequences indicates an active abscess, and in these cases it may suggest the ineffectiveness of conservative treatment. Diffusion weighted sequences are useful for the differential diagnosis of the abscess, as well as other signs observed on different sequences. The signal differences between abscess and necrotic or cystic tumors are due to physical and biochemical differences of their contents (serous fluid does not show restriction to diffusion). In case of doubt it is useful to use spectroscopy because inside the abscess a lipid/lactate peak is observed without a choline peak, unlike tumors.

**REVIEW OF THE CASES:**

A. **Cerebral abscess in the context of neonatal meningitis due to Citrobacter koseri (diversus). Cases 1, 2, 3.**

Citrobacter koseri is a rare cause of neonatal meningitis, but up to 77% of infants infected with this germ develop brain abscesses. The major pathological feature of Citrobacter meningitis is vasculitis followed by infarction, with necrosis and liquefaction of large portions of the white matter [4, 7]

**Case 1**
A 7-day newborn that presented with a meningitis caused by Citrobacter koseri. The infection progressed to the formation of 3 abscesses (two frontal, and one parietooccipital) that drained spontaneously into the ventricular system causing a secondary ventriculitis. US (Fig 1) and MRI (Fig 2) findings are shown.

Fig. 1: Coronal (A) and sagittal (B) US images. Compression of the left frontal horn caused by an abscess. The abscess has a smooth echogenic wall and a CSF-pus level inside (red arrows).

References: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES

Fig. 1 on page 49
Fig. 2: Axial T2 (A), Axial T1-Gd (B), Axial Diffusion (C). Left parietooccipital and frontal abscesses presenting cystic and solid components appreciated on T2-w images. Ring enhancement is appreciated after the administration of intravenous gadolinium. Enhancement of the occipital horn corresponding to ventriculitis (long arrow, image B), can be noticed, as well as a CSF-pus level inside the ventricle (short arrow, image A), due to drainage of the pus to the ventricular system. In diffusion-w images the solid areas show restriction.

References: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES
Fig. 2 on page 49

Case 2

An Eighteen day old neonate, that presents with fever of a few hours duration. No focus of infection was identified. According to our hospital protocols, a lumbar puncture was performed. CSF was compatible with bacterial meningitis, and cultures were positive to Citrobacter koseri.

A brain ultrasonography was performed on the first day after admission, showing a left hyperechogenic frontoparietal lesion (Fig. 3) suggestive of cerebritis. An MRI was performed (Fig. 4), observing a hypointense frontoparietal lesion that produced a mass effect and collapse of the frontal horn.
This lesion showed later liquefaction and progressed to an abscess (Fig. 5).

Fig. 3: Coronal (A) and sagittal (B) ultrasound images performed on the first day after admission, showing a left frontoparietal lesion with diffuse hyperechogenicity of white matter, also presented more hyperechoic areas inside. Edema and mass effect that produced ventricular collapse was also noticed.

References: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES

Fig. 3 on page 50
Fig. 4: Sagittal T1-weighted image (A), axial FLAIR image (B) and diffusion weighted image (C). Left frontoparietal lesion with mass effect that produce secondary collapse of left frontal horn, suggestive of cerebritis. This lesion showed generalized restriction to diffusion.

References: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES
Fig. 4 on page 51
Fig. 5: Coronal (A) and sagittal (B) ultrasound images showing progression of the cerebritis area to an abscess. Notice the liquefaction of the lesion, resembling a multicystic lesion.

References: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES

Fig. 5 on page 52

Case 3

An eight-day-old neonate presenting with weight loss, irritability, and refusal to feed. He was admitted due to severe hypernatremic dehydration. During hospitalization the patient showed signs of infection and cultures of blood, urine and CSF were taken. CSF culture was positive to Citrobacter koseri. Antibiotic treatment was started and a brain ultrasonography was performed (Fig. 6), showing hyperechogenic lesions suggestive of abscesses. Later, these lesions presented necrosis and liquefaction (Fig. 7)
Fig. 6: Coronal (A, B) and sagittal (C, D) ultrasound images obtained on the first day of hospitalization. Three hyperechogenic lesions are observed, two of them in the right hemisphere (frontal and occipital 3.2cm to 2cm) and one in the left hemisphere (frontal lesion of 2cm diameter). These lesions, in the context of a bacterial infection due to Citrobacter, are suggestive of abscesses.

References: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES

Fig. 6 on page 53
Fig. 7: Coronal (A, B, C) and sagittal (D) ultrasound images obtained on the seventh day of hospitalization. The lesions described in the first ultrasonography have now a lower echogenicity in relation to areas of necrosis. Notice a discrete mass effect.

References: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES
Fig. 7 on page 54

Case 4

A neonate who presented with a clinical picture of meningitis that started a few days after birth. No pathogens were isolated from blood, CSF, or from the drained pus. The ultrasound images showed a left parietooccipital abscess (Fig. 8), hydrocephalus and left temporal horn entrapment (Fig. 8-image C). These lesions were confirmed by standard MRI sequences with and without contrast administration, and by diffusion sequences (Fig. 9). In the subsequent follow-up, despite antibiotic treatment and abscess drainage, the restriction to diffusion persisted (Fig. 10). These suggested that the infection was not eradicated and highlighted the need for a surgical intervention to remove the abscess. In later MRI studies, the hyperintensity in diffusion disappeared, suggesting that the surgical
treatment was effective (Fig. 11). Notice the importance of diffusion weighted sequences to make treatment decisions.

**Fig. 8**: Coronal (A, B) and sagittal (C) US images. Left parieto-occipital lesion (between marks) that shows a well defined wall and an echogenic content (image A), as well a peripheral hyperemia, corresponding to an abscess. Subsequently complications of the meningitis, producing hydrocephalus (image B) and left temporal horn entrapment (red arrow, image C) are shown.

**References**: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES

**Fig. 8** on page 55
Fig. 9: Axial T2 (A), Axial T1-gd (B), Axial diffusion (C), Axial ADC map (D) MRI shows the parieto-occipital lesion with hyperintensity on T2-w images and a hypointense wall, that enhances after gadolinium administration (image B). Restriction is observed on diffusion weighted images, presenting a low intensity signal on ADC map images due to its high viscosity (pus). Notice the difference between the fronto-parietal cystic lesion (corresponding with the trapped ventricle, blue arrow) that did not show restriction to diffusion, and the abscess (red arrow), that shows restriction

References: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES

Fig. 9 on page 56
**Fig. 10:** Axial T2W (A), axial diffusion weighted image (B) and ADC map (C) after antibiotic treatment and drainage. The lesion showed restriction to diffusion (B) and a low intensity signal in ADC maps, what meant that treatment was not effective.

**References:** radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES
Fig. 11: Axial diffusion image (A) and ADC map (B). After surgical removal of the abscess a MRI was performed, observing a left postoperative extra-axial collection (image A) that did not show restriction to diffusion, what meant that treatment was effective. Left temporal horn size had decreased.

References: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES
Fig. 11 on page 58

C. Candidiasis in preterm neonates. Cases 5, 6.

Neonatal fungal infection is much less common than bacterial meningitis. There is CNS involvement in the 70% of systemic fungal infections, being the target organs CNS and kidney. The most common pathogen is Candida albicans, which lives in the GI tract and oral cavity. Knowing risk factors are immunosuppression, prematurity, endovascular catheters, antibiotics and steroids [8, 9].

Candidal abscesses in CNS are less common than meningitis. A variable clinical picture consists of fever, altered level of consciousness, seizures, and focal manifestations depending on the size and site of the abscess. In newborns and especially, premature babies, respiratory distress is a common manifestation of Candida meningitis. It
is undistinguishable to bacterial meningitis or sepsis, and has a poor prognosis. Hydrocephalus results from obstruction of cerebrospinal fluid pathways. [9] The definitive diagnosis is made with the isolation of the pathogen in CSF or blood culture in case of infection in other part of the body, in addition to the presence of symptoms suggestive of CNS involvement and/or a suggestive imaging test. [8, 9] The most common imaging findings in brain candidiasis are multiple microabscesses (<3 mm), distributed in the subcortical and periventricular regions, thalami, basal ganglia, brain stem, and cerebellum. Other findings in CNS candidiasis are meningitis, ventriculitis, and ventricular dilatation, or macroabscesses. Ultrasound should be the preferred initial imaging method, given its portability, lack of required sedation, avoidance of radiation, and easy follow-up. At US the microabscesses are small, echogenic rimlike lesions with hypoechogenic centers scattered in the brain parenchyma. MRI is best to depict infratentorial lesions. Contrast-enhanced MRI shows enhancing-ring lesion and diffusion weighted images show restriction to diffusion. [10, 11]

Case 5

In case 5, the patient was a 26-week preterm neonate who presented positive urine and blood cultures to Candida Albicans. Following the protocols of our hospital, a cerebral ultrasonography was performed (fig 12) confirming brain involvement.
Fig. 12: Sagittal (image A, B) and coronal (image C) ultrasound images showing numerous hyperecogenic lesions disseminated diffusely. In the clinical context of candidemia, these lesions are compatible with cerebral candidiasis.

References: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES

Fig. 12 on page 59

Case 6

Preterm neonate admitted at the ICU due to immaturity who suffered clinical deterioration. Cerebral ultrasound was performed showing hyperechogenic images suggestive of embolic or fungal CNS involvement (Fig. 13). The diagnosis was subsequently confirmed by detecting Candida in urine.
**Fig. 13**: Sagital (image A), Coronal (image B, C) ultrasound images showing hyperecogenic lesions distributed diffusely. Some of them presented a hypoecogenic center. Disseminated cerebral candidiasis was suggested as the most probable diagnosis in the context of the patient. As a casual finding, ventricular coartation cysts are observed next to the frontal horns.

**References**: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES Fig. 13 on page 60

**D. Abscess in the context of sepsis in preterm neonate. Case 7.**

**Case 7**

This case is a preterm neonate with a patent ductus arteriosus, presenting with sepsis, subsequent development of osteomyelitis (fig. 16) in the right hand and left foot, and a frontal brain abscess (fig. 14, 15). Klebsiella and Enterobacter were isolated in blood cultures, and Serratia was isolated in the soft tissue abscesses of hand and foot.
Fig. 14: Sagittal (image A, B) and coronal (C) ultrasound images showing a right frontal well-defined heterogeneous lesion corresponding to an abscess.

References: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES
Fig. 14 on page 61
**Fig. 15:** Axial T1-gd enhanced weighted image (image A) showing a frontal ring mural enhanced lesion. It presented restriction on diffusion weighted images (image B) that showed the corresponding low signal intensity on ADC map (image C), confirming the clinical suspicion and the ultrasound images.

**References:** radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES

*Fig. 15 on page 62*
**Fig. 16**: Radiological signs of osteomyelitis on the first metatarsal of the left foot and on the proximal phalanx of the second finger of the right hand in the same patient. 

**References**: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES  

**Fig. 16** on page 63

**E. Abscess in the context of meningitis in a 5 year-old child due to Streptococcus.**  

**Case 8.**

This patient was diagnosed of meningitis (Streptococcus pyogenes isolated in CSF) with normal unenhanced CT scan at diagnosis. 15 days later the patient presented headache and vomiting without fiber. A second CT scan was performed, showing a cerebellar abscess (Fig. 17). This finding was confirmed by MRI study (Fig. 18). Cerebellar abscesses are rare and usually single. They often appear secondary to a middle ear infection. The most common complication, due to its location, is hydrocephalus.  

After surgical resection of the abscess, including the capsule included, cultures confirmed the same pathogen, and there was a significant clinical improvement (Fig. 19).
Fig. 17: Axial unenhanced CT image (A) showing an hypodense area on the left cerebellar hemisphere that produces mass effect with deformation of the fourth ventricle and dilatation of the supratentorial ventricular system. Axial contrast enhanced CT image (image B) showing ring enhancement of the lesion.

References: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES

Fig. 17 on page 64
Fig. 18: Sagittal T1 weighted image (A) showing a well defined lesion on the left cerebellar hemisphere. On axial T2 weighted image (B) it presented a liquid signal. Perilesional edema extending to cerebellar folia was also observed on this sequence.

References: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES
Fig. 19: Coronal (image A) and sagital (B) contrast enhanced T1-w images showing an intense ring enhancement of the cerebellar lesion. These image characteristics where suggestive of cerebellar abscess.

References: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES Fig. 19 on page 66

F. Abscess due to foreign body. Case 9.

Case 9

The prevalence of abscesses due to neurosurgery or penetrating mechanism is relatively low (2-14%).

A 3 year-old child who presented with a sudden onset spastic tetraparesia. The family reported that the child suffered from an injury in the oral cavity caused by a penetrating foreign body (a pen) a few days earlier, the foreign body was extracted by a relative, and the child remained asymptomatic until admission. MRI was performed showing a
cerebellar abscess with the cap of the pen inside (Fig. 20, 21). CT after surgery was also performed (Fig. 22).

Culture after drainage was positive for Peptostreptococcus.

Fig. 20: Sagittal and coronal gadolinium enhanced T1-w images (A, B, C) showing an hypointense right cerebellar lesion that enhanced after the administration of gadolinium. A foreign body (pen cap) inside the abscess is also observed (blue arrow, A). An hypointense oval image, located under the tentorium (B, C), also showed contrast enhancement and corresponded to a supracerebellar empiema.

References: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES
Fig. 20 on page 67
Fig. 21: Axial diffusion weighted image showing a hyperintense lesion due to restriction to diffusion.

References: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES

Fig. 21 on page 68
Fig. 22: Axial unenhanced CT images obtained after surgical treatment showing hydrocephalus (A). An external ventricular derivation was performed after obtaining negative cultures (B).

References: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES
Fig. 22 on page 69

G. CNS abscess as a complication of sinusitis. Cases 10, 11

It is usually produced by a delay in the onset of antibiotic treatment, incomplete treatment or resistance of microorganisms. Intracranial complications of sinusitis are usually secondary to frontal sinusitis. In this case the route of spread is by contiguity due to communication through the abundant veins of the diploe with the meninges. [2]
Because of significant morbidity complications of sinusitis, patients presenting intra and/or extracranial complicated sinusitis should undergo a contrast study of the orbits and sinuses.

Case 10
Our case is a 14 year old girl with frontal sinusitis, headache and vomiting, finding in the contrast-enhanced CT scan a frontal abscess (fig. 23, 24).

**Fig. 23:** Axial contrast enhanced CT images (bone window). Occupation of both maxillary sinuses and the left frontal sinus was observed, as well as destruction of the posterior wall of the frontal sinus and the presence of a bone fragment inside it (red arrow, C).

*References:* radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES

*Fig. 23* on page 70
Fig. 24: Axial contrast enhanced CT images (brain window). Hypoattenuated left frontal lesion with peripheral enhancement was observed (B). It presented surrounding edema that produced significant mass effect with midline shift (A). The brain abscess showed a close relationship with the frontal sinus.

References: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES

Case 11

This case is a ten-year-old girl presenting with 13-day headache, malaise and fiber. She had previously been diagnosed with sinusitis and had undergone a 10-day antibiotic treatment. An unenhanced CT scan was performed, observing a well-defined right frontal extraaxial lesion that showed an epidural morphology (fig. 25). No parenchymatous lesion was observed, but the frontal sinus was occupied by liquid and the ethmoidal sinus showed mucosal thickening. These findings were suggestive of epidural abscess in the clinical context of a frontal sinusitis. The same day a MRI was performed (fig. 26). The right frontal extraaxial lesion was hypointense on T1 weighted images and hyperintense on T2 weighted images,
and showed restriction on diffusion weighted sequences. On gadolinium-enhanced T1 weighted images the lesion presented a ring-like enhancement, and an inflammatory meningeal reaction was observed next to the lesion. In addition the ipsilateral frontal sinus was occupied. These findings confirmed the suspicion of frontal extraaxial abscess secondary to a frontal sinusitis.

The patient was hospitalized and antibiotic treatment was started. A follow-up MRI was performed 20 days later (fig. 27), observing persistence of the lesion with restriction to diffusion, what meant that the medical treatment was not effective. There was also a septum inside the abscess with a liquid-liquid level, suggestive of a non-communicated compartment of the abscess, what would explain the persistence of the lesion despite the antibiotic treatment. This finding was essential to decide surgical treatment. [12]

Fig. 25: Unenhanced CT scan showing a hypodense right frontal extraaxial lesion (A, blue arrow) with epidural morphology. Notice the occupation of the right frontal sinus (B, red arrow), what suggests an epidural abscess secondary to frontal sinusitis.

References: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES

Fig. 25 on page 72
Fig. 26: Axial T1 weighted image (A), axial T2 weighted image (B, C), and sagittal (E), axial (F) and coronal (G, H) gadolinium-enhanced T1 weighted images, diffusion weighted image (Fig. D) A right frontal extraaxial lesion is observed, showing low intensity of signal on T1 weighted images and hyperintensity on T2 weighted images. This lesion presented ring-enhancement. It showed restriction on diffusion weighted images (D) due to its high viscosity content (pus). Inflammatory meningeal reaction with enhancement was seen next to the lesion (H, red arrow). Notice the hyperintense content of the rudimentary right frontal sinus, compatible with sinusitis (C, blue arrow). These findings are highly suggestive of extraaxial abscess secondary to sinusitis.

References: radiology, Hospital regional universitario Carlos Haya - Malaga/ES

Fig. 26 on page 73
Fig. 27: Follow-up MRI performed 20 days after diagnosis. Coronal T2 weighted image (A) showing a liquid-liquid level of nodular morphology limited by a septum, what was suggestive of a non-communicated compartment inside the abscess (red arrow). This image was also seen in the sagittal gadolinium-enhanced T1 weighted image (B). Restriction on diffusion weighted images persisted along this time (C). These two findings indicated that antibiotic treatment had not been effective, and surgical removal was decided.

References: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES

Fig. 27 on page 74

H. CNS abscess as a complication of a congenital lesion of head and neck (dermal sinus). Case 12

The dermal sinus is a congenital defect of the neural tube closure causing a communication between the skin and the CNS (from nose root to cone) being the most common site affected at lumbar level. Its most common presentation is in the form of "dimpled skin" that may ooze, or in the form of vascular lesion (hemangioma). However in general they are hidden and should be suspected if the patient presents a skin lesion, specially with occipital location. [13]
This pathology is associated in 50% of cases with dermoid or epidermoid tumor, being more rare the association with meningocele or encephalocele. The patient usually presents with symptoms of an intracranial infection. Age of presentation is usually between 2 and 5 years. [13]

Treatment is controversial, some clinicians prefer to remove the abscess in order to avoid complications, but it is often very attached to adjacent structures such as the venous sinuses. It is generally recommended to control the infection first and then to dry the collection.

Case 12

Our case is a two-year-old girl with clinical history of occipital hemangioma and dermal sinus presenting meningitis complicated with a cerebellar abscess (Fig. 28, 29). After surgical removal, it was analyzed showing association with a dermoid cyst that presented hair inside.

Cerebellar abscess as a result of a dermoid tumor associated with dermal sinus is a rare entity (30 cases in the literature between 1949 to 2007).

All cultures were negative. It was no possible to isolate the pathogen.
Fig. 28: Sagittal T1 weighted image (A) showing a hypointense lesion next to a dermal sinus of the scalp. Supratentorial hydrocephalus and herniation of the cerebellar tonsils were also observed. On axial FLAIR T2 weighted images (B), an occipital bone defect is observed, allowing the communication between the posterior fossa and the skin (dermal sinus path).

References: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES

Fig. 28 on page 75
Fig. 29: Coronal gadolinium enhanced T1 weighted image (B) showing two cerebellar lesions that presented ring enhancement, corresponding to abscesses. Axial T2 weighted image (A), with two posterior fossa hyperintense lesions are observed, showing surrounding edema and mass effect on the fourth ventricle. These lesions, as well as the dermal sinus path, showed restriction on diffusion weighted images (C) due to high viscosity purulent content.

References: Radiology, Hospital regional universitario Carlos Haya - Malaga/ES
Fig. 29 on page 76

I. CNS abscess due to tuberculosis. Cases 13, 14.

Only 2-5% of patients with tuberculosis have CNS involvement.

Cerebral manifestations are meningitis (most common), tuberculomas, abscesses (10% of tuberculosis in CNS) and cerebritis (very rare). The infection is caused by hematogenous spread of a pulmonary focus.

The most frequent CNS parenchymal lesion of tuberculosis is tuberculoma (tuberculous granuloma). Tuberculomas are clusters of granulomas inside areas of cerebritis.
(containing caseum). Its location is rarely medular (2 in 100,000 cases of TB). The most common site is the gray-white junction.[14, 15]

This lesion may be solitary, multiple, or milliar and may be seen anywhere within the brain parenchyma, although it most commonly occurs within the frontal and parietal lobes. MR imaging depend on whether the tuberculoma is caseating, and if so, whether the centre is liquid or solid. It is thought that there is a progression from noncaseating to caseating and then from a solid to a liquid centre.[14, 15]

A noncaseating tuberculoma is hypointense relatively to gray matter on T1-weighted images and hyperintense on T2-weighted images, with homogeneous gadolinium enhancement.[14]

- Caseating tuberculomas with a solid centre are isointense to hypointense on both T1 and T2 weighted images. They usually have a variable amount of surrounding edema.
- Caseating tuberculomas with a liquid centre are hypointense on T1 weighted images and centrally hyperintense on T2 weighted images, with a peripheral hypointense rim on T2 weighted images that represents the capsule. Rim enhancement is usually seen at gadolinium-enhanced MR imaging.
- After treatment, tuberculomas can completely resolve; however, calcification is seen in up to one-fourth of the cases and is identified most clearly at CT.

Tuberculosis abscesses are rarely seen and can be similar in appearance to liquid-centred caseating tuberculomas, although they tend to be larger and are more often multiloculated. In contrast to tuberculoma, the abscess contains a high concentration of bacteria. Drainage and cultures are required for diagnostic confirmation, because radiologic imaging may be indistinguishable from tuberculomas.

Tuberculosis involvement of the spinal cord is much less common than brain affection. The spinal cord tuberculomas are extremely rare. The lesion appears mostly in dorsal level but can be located at other levels. The incidence of intramedullary tuberculomas is low and the combination of intramedullary and intracranial tuberculomas is extremely rare. [14]

The management of a tuberculoma is pharmacological treatment (tuberculostatics and steroid) but when a neurological deficit exists surgical decompression is required, allowing further histological examination of the lesion.

**Case 13**
14 year-old girl diagnosed of pulmonary milliary tuberculosis, with negative CSF and blood cultures, presenting with multiple brain lesions in the gray-white junction and in the spinal cord (fig. 30). These lesions showed ring-enhancement on gadolinium-enhanced T1 weighted images and surrounding edema. These lesions were suggestive of tuberculomas/abscesses. Medullar involvement was also observed as a hypointense lesion on T2 weighted images that showed contrast-enhancement on T1 weighted images (fig. 31).

These lesions resolved completely after 6 months of pharmacological treatment for tuberculosis.

**Fig. 30:** Coronal FLAIR (A) and coronal contrast enhanced T1 weighted images (B). Multiple hypointense nodular and diffuse lesions, most of them located at the grey-white matter junction, suggesting hematogenous spread. There was also edema visible on FLAIR T2-w image, and ring enhancement after contrast administration on T1-w image. In the clinical context of a tuberculosis infection, these images suggest tuberculomas or abscesses, indistinguishable by image.

**References:** radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES

**Fig. 30** on page 77
Fig. 31: Sagittal T2 weighted image (A) and contrast-enhanced T1 weighted image (B). Hypointense lesion on sagittal T2-w image with surrounding medullar edema, that showed ring enhancement after contrast administration on sagital T1-w images. These findings correspond to a dorsal medullar tuberculoma/abscess, a very rare finding that disappeared after treatment.

References: radiology, Hospital regional universitario Carlos Haya - Malaga/ES

Fig. 31 on page 78

Case 14

Tuberculous meningitis is usually due to hematogenous spread but can also be secondary to direct extension from cerebrospinal fluid infection.

The typical radiographic finding is abnormal meningeal enhancement, usually most pronounced in the basal cisterns, although some degree of involvement of the meninges within the sulci over the cerebral convexities and in the Sylvian fissures is also seen in most cases. These findings are better seen at gadolinium-enhanced MR imaging than at CT. This appearance is nonspecific and has a wide differential diagnosis that includes...
meningitis from other infective agents; inflammatory diseases and neoplastic causes, both primary and secondary.

This case is a seven-year-old boy presenting with altered level of consciousness, fever and hemiparesis.

Unenhanced CT was performed, not finding any alteration. CFS was suggestive of tuberculous meningitis, and the patient was hospitalized. Chest radiography showed a micronodular pattern.

A MRI was performed four days later, showing millimeter nodular intraparenchymatous lesions that presented enhancement on gadolinium-enhanced T1 weighted images. In the context of a tuberculous meningitis, these lesions are suggestive of noncaseating or caseating solid tuberculomas (fig.32).

Tuberculostatic treatment was started, and a follow-up MRI was performed showing intraparenchymatous nodules and meningeal nodes (fig.33) that presented contrast enhancement and surrounding edema (fig.34). These lesions were compatible with intraparenchymal tuberculomas and tuberculous meningitis due to hematogenous spread of tuberculosis.
**Fig. 32**: Axial and coronal gadolinium-enhanced T1 weighted images. There are various nodular lesions that present enhancement after contrast administration. The signal is uniform, what means that is a noncaseating tuberculoma or a caseating solid tuberculosis.

**References**: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES

Fig. 32 on page 79
**Fig. 33:** Axial gadolinium-enhanced T1 weighted images showing meningeal tuberculomas.

*References:* radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES

**Fig. 33** on page 80
**Fig. 34:** FLAIR T2 weighted images showing surrounding edema (red arrows).

**References:** radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES

**Fig. 34** on page 81

**J. Neurocysticercosis. Case 15.**

Neurocysticercosis is an endemic disease worldwide, and the most common CNS parasitic infection in the world.[16]

The causative agent is T. solium cysticerci, intermediate form of the parasite that reaches various organs (brain, muscle, heart ...) after being ingested with pork contaminated with eggs.[16]

When reaching the CNS, the parasites are housed in the subarachnoid space, as meningeal form, in the cerebral ventricles, ventricular form, or in the medulla or brain parenchyma, parenchymal form, existing also mixed forms of involvement. Intraparenchymal lesions elicit a higher immune response from the host and are easily reached by antiparasitic medications, and thus these patients have a good prognosis.[16]
Neurocysticercosis has been classified into active and nonactive forms on the basis of clinical presentation, results of CSF analysis (ie, hypoglycorrhachia, eosinophils in sediment, and cisticercus-specific immunoglobin G antibody level), and imaging findings. The active forms include arachnoiditis with or without ventricular obstruction and vasculitis with or without infarction.[17, 18]

The diagnosis is based on clinical findings (children usually present with seizures in most of cases, less commonly with intracranial hypertension), CSF (pleocytosis with eosinophilia in 50% of cases) and imaging findings. The definitive diagnosis is made by biopsy or autopsy and rarely require surgical intervention, when necessary is usually due to hydrocephalus.[16]

The most common finding in children on CT images often is only a single parenchymal lesion with perilesional edema (unlike adults who have multiple cysts and ventricular system dilatation due to obstruction of the aqueduct of Sylvius in the meningeal form of the disease).[17, 18]

MRI improves the visualization of intraventricular cysts and intramedular lesions. It can even show the scolex (head, seen as a nodule) within the cyst, which is pathognomonic of cisticercosis and corresponds to the active parenchymal form of NC.[17, 18]

Parenchymal cysticercosis has been classified into five stages according to radiologic findings in MRI [17, 18]:

1. Noncystic stage: asymptomatic with negative imaging findings. It is an active stage.
2. Vesicular stage: thin capsule that surrounds the viable larva and its fluid-containing bladder. On imaging studies the larva appears as a cyst containing a small, mural nodule that represents its scolex and it is located usually near the gray-white matter junction. The scolex may show some enhancement. The mural nodule is best seen on FLAIR images. Little or nule edema is seen. It is an active stage.
3. Colloidal vesicular stage: when the larva dies, the fluid becomes turbid, and its capsule thickens. Edema and contrast enhancement are seen in this stage. Degenerating cyst may be hyperintense on both T1 and T2 weighted images due to their contents. Ring-like enhancement is seen in two third of cases.
4. Granular nodular stage: as the parasite dies, the cyst begins to collapse, the capsule thickens and the scolex calcifies. There is intense contrast enhancement of the cyst walls. The cyst is isointense compared to brain on T1-weighted images.
5. Nodular calcified stage: in this stage the granulomatous lesion y completely mineralized. There is no active immune response from the host. A small, calcified lesion measuring between 2 and 10 mm is typical. Usually there is no contrast enhancement.
Antiparasitic treatment is controversial in children (considering also that sometimes the disease disappears without treatment) and is administered in non-calcified cystic stage (active form).

**Case 15**

Our case is an 11 year old Bolivian girl presenting seizures and intracranial hypertension symptoms.

CT scan and gadolinium-enhanced MRI were performed (fig 35) showing a predominantly cystic single lesion located at left temporal cortex, which presented with ring-enhancement and significant perilesional edema.

Spectroscopy dismissed tumoral lesion. CSF cultures and serologies were negative. Steroid therapy and antihelmintic treatment was administrated, with subsequent favourable follow-up.

Although definitive diagnosis has not been carried out due to the absence of complications (no surgical removal was needed, so there was no material to analyze), epidemiology, clinical and imaging findings are highly suggestive of this diagnosis.
Fig. 35: Unenhanced (A) and contrast enhanced (B) CT, showing a cortical hypodense nodular lesion located at the left temporal lobe. It was not calcified, showed ring enhancement after contrast administration and perilesional edema, and presented an inner millimetrical nodule, suggesting an active infection.

References: radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES

Fig. 35 on page 82
**Fig. 36:** Coronal FLAIR T2W (A), axial T2W (B), axial FLAIR T2W (C) and contrast-enhanced T1W (D). Milimetre single lesion, hyperintense on T2 weighted images and surrounded by vasogenic edema. The lesion showed ring enhancement after contrast administration. Cysticercus are located typically on the most vascularized regions, gray matter and subcortical nuclei.

**References:** radiodiology, Hospital regional universitario Carlos Haya - Malaga/ES

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**DIFFERENTIAL DIAGNOSIS OF CNS ABSCESS**

- Cystic or necrotic brain tumors: to differentiate them from an abscess it is necessary to use diffusion weighted sequences and, sometimes, spectroscopy, as commented before. Cystic tumors present low signal intensity in diffusion weighted images and a high signal in ADC maps.
- Metastasis: the presence of an incomplete ring on an unenhanced CT image is more typical of metastasis than an abscess. The symptoms and the medical history play an important role.
• Lymphoma in immunocompromised patients: Sometimes the image characteristics are indistinguishable from abscesses.
• Stroke: although stroke has a similar behaviour to abscess showing high signal intensity in diffusion weighted sequences and low signal intensity in ADC maps during acute phase, the vascular distribution of ischemic lesions can help to differentiate these two entities. In addition ADC maps value are 50% lower in an abscess than in a stroke.
• Pseudotumoral form of multiple sclerosis: more infrequent.
Fig. 1: Coronal (A) and sagittal (B) US images. Compression of the left frontal horn caused by an abscess. The abscess has a smooth echogenic wall and a CSF-pus level inside (red arrows).

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Fig. 2: Axial T2 (A), Axial T1-Gd (B), Axial Diffusion (C). Left parietooccipital and frontal abscesses presenting cystic and solid components appreciated on T2-w images. Ring enhancement is appreciated after the administration of intravenous gadolinium. Enhancement of the occipital horn corresponding to ventriculitis (long arrow, image B), can be noticed, as well as a CSF-pus level inside the ventricle (short arrow, image A), due to drainage of the pus to the ventricular system. In diffusion-w images the solid areas show restriction.

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**Fig. 3:** Coronal (A) and sagittal (B) ultrasound images performed on the first day after admission, showing a left frontoparietal lesion with diffuse hyperechogenicity of white matter, also presented more hyperechoic areas inside. Edema and mass effect that produced ventricular collapse was also noticed.

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Fig. 4: Sagittal T1-weighted image (A), axial FLAIR image (B) and diffusion weighted image (C). Left frontoparietal lesion with mass effect that produce secondary collapse of left frontal horn, suggestive of cerebritis. This lesion showed generalized restriction to diffusion.

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Fig. 5: Coronal (A) and sagittal (B) ultrasound images showing progression of the cerebritis area to an abscess. Notice the liquefaction of the lesion, resembling a multicystic lesion.

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Fig. 6: Coronal (A, B) and sagittal (C, D) ultrasound images obtained on the first day of hospitalization. Three hyperechogenic lesions are observed, two of them in the right hemisphere (frontal and occipital 3.2cm to 2cm) and one in the left hemisphere (frontal lesion of 2cm diameter). These lesions, in the context of a bacterial infection due to Citrobacter, are suggestive of abscesses.

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Fig. 7: Coronal (A, B, C) and sagittal (D) ultrasound images obtained on the seventh day of hospitalization. The lesions described in the first ultrasonography have now a lower echogenicity in relation to areas of necrosis. Notice a discrete mass effect.

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Fig. 8: Coronal (A, B) and sagittal (C) US images. Left parieto-occipital lesion (between marks) that shows a well defined wall and an echogenic content (image A), as well a peripheral hyperemia, corresponding to an abscess. Subsequently complications of the meningitis, producing hydrocephalus (image B) and left temporal horn entrapment (red arrow, image C) are shown.

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Fig. 9: Axial T2 (A), Axial T1-gd (B), Axial diffusion (C), Axial ADC map (D) MRI shows the parieto-occipital lesion with hyperintensity on T2-w images and a hypointense wall, that enhances after gadolinium administration (image B). Restriction is observed on diffusion weighted images, presenting a low intensity signal on ADC map images due to its high viscosity (pus). Notice the difference between the fronto-parietal cystic lesion (corresponding with the trapped ventricle, blue arrow) that did not show restriction to diffusion, and the abscess (red arrow), that shows restriction.
Fig. 10: Axial T2W (A), axial diffusion weighted image (B) and ADC map (C) after antibiotic treatment and drainage. The lesion showed restriction to diffusion (B) and a low intensity signal in ADC maps, what meant that treatment was not effective.

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Fig. 11: Axial diffusion image (A) and ADC map (B). After surgical removal of the abscess a MRI was performed, observing a left postoperative extra-axial collection (image A) that did not show restriction to diffusion, what meant that treatment was effective. Left temporal horn size had decreased.

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**Fig. 12:** Sagittal (image A, B) and coronal (image C) ultrasound images showing numerous hypercogenic lesions disseminated diffusely. In the clinical context of candidemia, these lesions are compatible with cerebral candidiasis.

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Fig. 13: Sagital (image A), Coronal (image B, C) ultrasound images showing hyperecogenic lesions distributed diffusely. Some of them presented a hypoecogenic center. Disseminated cerebral candidiasis was suggested as the most probable diagnosis in the context of the patient. As a casual finding, ventricular coartation cysts are observed next to the frontal horns.

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**Fig. 14:** Sagittal (image A, B) and coronal (C) ultrasound images showing a right frontal well-defined heterogeneous lesion corresponding to an abscess.

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**Fig. 15:** Axial T1-gd enhanced weighted image (image A) showing a frontal ring mural enhanced lesion. It presented restriction on diffusion weighted images (image B) that showed the corresponding low signal intensity on ADC map (image C), confirming the clinical suspicion and the ultrasound images.

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Fig. 16: Radiological signs of osteomyelitis on the first metatarsal of the left foot and on the proximal phalanx of the second finger of the right hand in the same patient.

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**Fig. 17:** Axial unenhanced CT image (A) showing an hypodense area on the left cerebellar hemisphere that produces mass effect with deformation of the fourth ventricle and dilatation of the supratentorial ventricular system. Axial contrast enhanced CT image (image B) showing ring enhancement of the lesion.

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Fig. 18: Sagital T1 weighted image (A) showing a well defined lesion on the left cerebellar hemisphere. On axial T2 weighted image (B) it presented a liquid signal. Perilesional edema extending to cerebellar folia was also observed on this sequence.

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Fig. 19: Coronal (image A) and sagital (B) contrast enhanced T1-w images showing an intense ring enhancement of the cerebellar lesion. These image characteristics where suggestive of cerebellar abscess.

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Fig. 20: Sagittal and coronal gadolinium enhanced T1-w images (A, B, C) showing an hypointense right cerebellar lesion that enhanced after the administration of gadolinium. A foreign body (pen cap) inside the abscess is also observed (blue arrow, A). An hypointense oval image, located under the tentorium (B, C), also showed contrast enhancement and corresponded to a supracerebellar empiema.

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Fig. 21: Axial diffusion weighted image showing a hyperintense lesion due to restriction to diffusion.

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Fig. 22: Axial unenhanced CT images obtained after surgical treatment showing hydrocephalus (A). An external ventricular derivation was performed after obtaining negative cultures (B).

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Fig. 23: Axial contrast enhanced CT images (bone window). Occupation of both maxillary sinuses and the left frontal sinus was observed, as well as destruction of the posterior wall of the frontal sinus and the presence of a bone fragment inside it (red arrow, C).

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**Fig. 24:** Axial contrast enhanced CT images (brain window). Hypoattenuated left frontal lesion with peripheral enhancement was observed (B). It presented surrounding edema that produced significant mass effect with midline shift (A). The brain abscess showed a close relationship with the frontal sinus.

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Fig. 25: Unenhanced CT scan showing a hypodense right frontal extraaxial lesion (A, blue arrow) with epidural morphology. Notice the occupation of the right frontal sinus (B, red arrow), what suggests an epidural abscess secondary to frontal sinusitis.

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Fig. 26: Axial T1 weighted image (A), axial T2 weighted image (B, C), and sagittal (E), axial (F) and coronal (G, H) gadolinium-enhanced T1 weighted images, diffusion weighted image (Fig. D) A right frontal extraaxial lesion is observed, showing low intensity of signal on T1 weighted images and hyperintensity on T2 weighted images. This lesion presented ring-enhancement. It showed restriction on diffusion weighted images (D) due to its high viscosity content (pus). Inflammatory meningeal reaction with enhancement was seen next to the lesion (H, red arrow). Notice the hyperintense content of the rudimentary right frontal sinus, compatible with sinusitis (C, blue arrow). These findings are highly suggestive of extraaxial abscess secondary to sinusitis.

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Fig. 27: Follow-up MRI performed 20 days after diagnosis. Coronal T2 weighted image (A) showing a liquid-liquid level of nodular morphology limited by a septum, what was suggestive of a non-communicated compartment inside the abscess (red arrow). This image was also seen in the sagittal gadolinium-enhanced T1 weighted image (B). Restriction on diffusion weighted images persisted along this time (C). These two findings indicated that antibiotic treatment had not been effective, and surgical removal was decided.

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**Fig. 28:** Sagittal T1 weighted image (A) showing a hypointense lesion next to a dermal sinus of the scalp. Supratentorial hydrocephalus and herniation of the cerebellar tonsils were also observed. On axial FLAIR T2 weighted images (B), an occipital bone defect is observed, allowing the communication between the posterior fossa and the skin (dermal sinus path).

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Fig. 29: Coronal gadolinium enhanced T1 weighted image (B) showing two cerebellar lesions that presented ring enhancement, corresponding to abscesses. Axial T2 weighted image (A), with two posterior fossa hyperintense lesions are observed, showing surrounding edema and mass effect on the fourth ventricle. These lesions, as well as the dermal sinus path, showed restriction on diffusion weighted images (C) due to high viscosity purulent content.

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Fig. 30: Coronal FLAIR (A) and coronal contrast enhanced T1 weighted images (B). Multiple hypointense nodular and diffuse lesions, most of them located at the grey-white matter junction, suggesting hematogenous spread. There was also edema visible on FLAIR T2-w image, and ring enhancement after contrast administration on T1-w image. In the clinical context of a tuberculosis infection, these images suggest tuberculomas or abscesses, indistinguishable by image.

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**Fig. 31**: Sagittal T2 weighted image (A) and contrast-enhanced T1 weighted image (B). Hypointense lesion on sagittal T2-w image with surrounding medullar edema, that showed ring enhancement after contrast administration on sagital T1-w images. These findings correspond to a dorsal medullar tuberculoma/abscess, a very rare finding that disappeared after treatment.

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**Fig. 32:** Axial and coronal gadolinium-enhanced T1 weighted images. There are various nodular lesions that present enhancement after contrast administration. The signal is uniform, what means that is a noncaseating tuberculoma or a caseating solid tuberculoma.

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**Fig. 33:** Axial gadolinium-enhanced T1 weighted images showing meningeal tuberculomas.

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**Fig. 34:** FLAIR T2 weighted images showing surrounding edema (red arrows).

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**Fig. 35:** Unenhanced (A) and contrast enhanced (B) CT, showing a cortical hypodense nodular lesion located at the left temporal lobe. It was not calcified, showed ring enhancement after contrast administration and perilesional edema, and presented an inner milimetric nodule, suggesting an active infection.

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Fig. 36: Coronal FLAIR T2W (A), axial T2W (B), axial FLAIR T2W (C) and contrast-enhanced T1W (D). Milimetallic single lesion, hyperintense on T2 weighted images and surrounded by vasogenic edema. The lesion showed ring enhancement after contrast administration. Cysticercus are located typically on the most vascularized regions, gray matter and subcortical nuclei.

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Conclusion

CNS abscesses in children are an infrequent pathology with an important morbidity and mortality, which need early diagnosis and adequate treatment.

The evaluation of this pathology by using imaging techniques (US and MRI) allows us to identify the location and number of lesions, diagnose the possible complications, and make the follow-up after the surgical intervention as well as evaluating the efficacy of the conservative treatment, facilitating an early diagnosis and improving the prognosis of these patients.
References
