Brain Herniations into the Dural Venous Sinuses or Calvarium: MRI of a Recently Recognized Entity

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SUMMARY – *Brain herniations into dural venous sinuses (DVS) are rare findings recently described and their etiology and clinical significance are controversial. We describe five patients with brain herniations into the DVS or calvarium identified on MRI, and discuss their imaging findings, possible causes, and relationship to the patient's symptoms. All patients were examined with MRI including high resolution pre- and post-contrast T1- and T2-weighted sequences. With respect to brain herniations we documented their locations, signal intensities in different sequences, and size. We then reviewed clinical records in an attempt to establish if any symptoms were related to the presence of these herniations. Three males and two females were examined (age range, 11-68 years). Three patients had unilateral temporal lobe herniations into transverse sinuses, one had a cerebellar herniation into the skull, and one had bilateral temporal lobe herniations into the transverse sinuses as well as a cerebellar herniation into the sigmoid sinus. In all, the herniated brain and surrounding cerebrospinal fluid (CSF) had normal signal intensity on all MRI sequences. When correlated with clinical symptoms, brain herniations were thought to be incidental and asymptomatic in three patients and two patients had histories of headaches. Brain herniations with surrounding CSF into the DVS/skull should be considered potential sources of filling defects in the DVS. We believe that they are probably incidental findings that may be more common than previously recognized and should be not confused with the more common arachnoid granulations, clots, or tumors. Two patients had headaches, but their relation to the presence of herniated brain was uncertain.*

Introduction

Herniations of brain parenchyma with surrounding cerebrospinal fluid (CSF) into the dural venous sinuses (DVS) or calvarium without apparent bone defects in the outer table of the skull were recently described on MRI^{1,2}. To the best of our knowledge only two such instances have been reported. Descriptions, etiologies, and clinical significances of these herniations varied in those reports. Chan et al.¹ described a focal brain herniation into a giant arachnoid granulation located in a DVS which may have developed spontaneously or was induced by ele-

vated intracranial pressure and cerebral edema resulting from prior head trauma. Coban et al.² described a similar brain herniation as an occult temporal lobe encephalocele into a transverse sinus and suggested that it may have been related to the patient's dizziness, imbalance, and sensation of pressure in one ear.

Recently, we observed five patients showing brain herniation into the DVS or calvarium containing various amounts of cerebral or cerebellar parenchyma surrounded by CSF. Here we aim to present the MRI findings in these patients and discuss possible causes and relationship to symptoms if any.

Figure 1 Brain herniation into the right transverse sinus in an 11-year-old girl. Fat saturated T2-weighted axial (A), contrast-enhanced T1-weighted axial (B) and coronal (C) MR images show a small herniation of temporal lobe parenchyma with surrounding CSF into the right transverse sinus (white arrows). The brain herniation sac is causing moderate stenosis in the right transverse sinus and subtle bone scalloping in the posterolateral temporal bone.

Case Reports

Case 1

An 11-year-old girl with growth retardation due to growth hormone deficiency was examined with brain and pituitary MRI which showed a small herniation of a temporal lobe with surrounding CSF into the right transverse sinus. The sac enclosing herniated brain measured 8×9 mm in size and contained a 5×5 mm brain parenchyma component. This herniation caused moderate narrowing of the transverse sinus and subtle inner table scalloping (Figure 1). The signal intensity of the herniated brain and its surrounding fluid were identical to gray matter and CSF in all sequences. The pituitary gland was normal and no other abnormalities were noted. Review of the clinical record did not reveal any symptoms which could have been related to the brain herniation.

Case 2

A 63-year-old female with hearing loss was examined with MRI which revealed a right and left middle ear and mastoid effusion. There was an 18×10 mm, multilobulated, well-demarcated, fluid intensity lesion in all MRI sequences in the posterior border of the right cer-

ebellar hemisphere which caused scalloping of the inner table of the occipital bone. In it, there was a 9×6 mm focal herniation of the right cerebellar hemisphere (Figure 2). No other abnormalities were noted on MRI and her neurologic examination was normal except for the hearing loss.

Case 3

A 19-year-old male was examined with CT because of syncope and the study revealed a 10×11 mm hypodense structure with an isodense central area in the right transverse sinus with scalloping in the posterolateral temporal bone (Figure 3). No other abnormality was noted. The patient was then evaluated with MRI, which showed an 8×9 mm focal extension of temporal lobe parenchyma with surrounding CSF into the right transverse sinus. Its dimensions were 10×13 mm (Figure 4). The herniated brain and surrounding CSF were isointense to gray matter and CSF in all sequences. No other abnormalities were noted on the MRI, the patient's neurologic examination was normal and up until now he has not had another syncope. Clinical history did not show any findings that may have been associated with the herniated brain.

Figure 2 Cerebellar herniation into the occipital bone in a 63-year-old female. Fat saturated T2-weighted axial (A), CISS axial (B) and contrast-enhanced T1-weighted sagittal (C) MR images show a multilobulated, well-demarcated, fluid intensity structure (arrows) causing prominent scalloping on the occipital bone and focal parenchymal herniation of the right cerebellar hemisphere into the lesion.

Figure 3 Brain herniation into the right transverse sinus in a 19-year-old male. Brain parenchyma window (A) and bone window (B) CT images reveal a hypodense structure with isodense central area in the right transverse sinus (white arrow), and mild scalloping of the posterolateral temporal bone (black arrow).

Case 4

A 56-year-old male with a history of headaches and a CSF leak was examined with maxillofacial CT and brain MRI which confirmed a small ethmoidal bone defect containing an encephalocele. In addition, there were bilateral temporal lobe extensions into the transverse sinuses on the thin slice T1- and T2-weighted MR images. On the right, the herniated sac measured 14×9 mm and contained a 13×8 mm portion of temporal parenchyma. On the left, the herniated sac measured 12×8 mm and contained a 10×8 mm portion of temporal parenchyma. Both transverse sinuses were considered hypoplastic and their lumens narrowed by the herniated brain. There was a third herniation, 12×7 mm in size containing a 10×6 mm portion of left cerebellar hemisphere protruding into the proximal left sigmoid sinus (Figure 5). For all three herniated sacs, their signal intensities were equal to that of gray matter and CSF. Although they caused scalloping in the adjacent temporal bone on CT images, there were no defects.

Case 5

A 68-year-old male underwent brain MRI because of chronic headaches. The study showed multiple non-specific small T2 white matter hyperintensities. In addition, herniation of temporal lobe parenchyma with surrounding CSF into the left transverse sinus was seen on thin section MR images. The herniated sac measured 20×12 mm in size and contained a 12×7 mm portion of temporal lobe. This herniation caused moderate narrowing of the left transverse sinus (Figure 6). Other brain structures were normal.

Discussion

Arachnoid granulations in the transverse and sigmoid sinuses and in the inner table of the skull are considered normal anatomical variants and are commonly encountered³. However, brain parenchyma herniations into a DVS are rare, recently described, and controversial in significance. Arachnoid granulations are also

called pacchionian granulations and are protrusions of arachnoid through the dura mater. These small structures project into a DVS and are thought to provide CSF drainage from the subarachnoid space into the bloodstream. A neck of arachnoid penetrates an aperture in the dura and expands to form the core of the granulation⁴. This core is composed of loose fibrous connective tissues forming a trabeculated network with wide interstices and endothelium-lined channels. Generally, arachnoid granulations have a close relationship with blood vessels into which they enter or protrude⁴. Three giant arachnoid granulations found at autopsy by Mamourian and Towfighi were all contained within relatively large blood vessels⁵. In addition, Browder et al.⁶ reported that the majority of arachnoid granulations observed in the transverse sinuses occur at their junctions with the vein of Labbé. In their patients there were numerous blood vessels within the granulations. Arachnoid granulations may enlarge with age or in response to increased CSF pressure^{1,7,8}. When arachnoid granulations are sufficiently large enough to fill the lumen of a DVS caus-

Figure 4 Brain herniation into the right transverse sinus in a 19-year-old male. Fat saturated T2-weighted axial (A), contrast-enhanced T1-weighted axial (B) and coronal (C) MR images show a herniation of temporal lobe parenchyma with surrounding CSF into the right transverse sinus (arrows). The herniated brain sac is causing narrowing of the right transverse sinus.

A

B

C

Figure 5 Brain herniations into bilateral transverse and left proximal sigmoid sinuses in a 56-year-old male. Coronal contrast-enhanced T1-weighted (A) and CISS (B), and axial CISS (C) MR images show bilateral herniation of temporal lobe parenchyma into bilateral transverse sinuses (arrows). Axial MR image also shows extension of the left cerebellar hemisphere with surrounding CSF into the left proximal sigmoid sinus.

ing local dilation and filling defects they are called “giant”^{1,9}. Giant arachnoid granulations may sometimes be misdiagnosed as thrombus or tumors on imaging studies but rarely cause symptoms of venous hypertension^{1,4}. Nonspecific symptoms such as headaches and tinnitus had been reported with them but no direct relationship or association has been established between these symptoms and arachnoid granulations^{1,9}.

Chan et al. described a unique case of cerebellar parenchymal herniation with surrounding CSF into a transverse sinus and occipital bone and described the finding as a focal brain herniation into the giant arachnoid granulation¹. They suggested that a focal cerebellar herniation into the pre-existing giant arachnoid granulation might have occurred due to elevated intracranial pressure caused by severe head injury.

Recently, a case of temporal lobe parenchymal herniation with surrounding CSF into a transverse sinus was described as an “occult encephalocele” by Coban et al.². This description is different from that used for the well-known temporal lobe encephaloceles. Temporal encephaloceles are parenchymal herniations through the dura mater and bone and involve the middle cranial fossa or lateral temporal cranium. Their major symptoms are epilepsy or disturbances such as hearing loss, otorrhea,

A

B

C

otitis media, rhinorrhea (when they herniate into the sphenoid sinus), and recurrent meningitis^{2,10}. Coban et al. coined the term “occult encephalocele” because its features differed from those of the more usual encephaloceles². Although the exact pathogenesis of spontaneous temporal encephaloceles is unclear, progressive dural and osseous thinning secondary to elevated CSF pressure, osseous variations, inflammation, aging, and erosive arachnoid granulations are among the etiologies thought to be responsible^{2,10,11}. Coban et al. thought that their occult temporal encephalocele may have resulted from intracranial pressure changes².

Brain herniations into the DVS or calvarium have features different from those of arachnoid granulations and classic encephaloceles. Central skull base encephaloceles remain occult until there is a CSF leak, meningitis, seizures, or headaches and when documented they are masses composed of meninges and brain clearly located outside of the confines of the skull. Conversely, the brain herniations we describe here did not occur through a skull base or calvarial defects but through the dura into a venous sinus or calvarium and thus do not meet the criteria for encephaloceles. None of our five patients or the two previously reported ones showed external bony defects that would have been consistent with encephaloceles^{1,2}. On the other hand, arachnoid granulations have a

Figure 6 Brain herniation into the left transverse sinus in a 68-year-old male. T2-weighted coronal (A), contrast-enhanced T1-weighted coronal (B) and sagittal (C) MR images show a herniation of temporal lobe parenchyma with surrounding CSF into the left transverse sinus (arrows). The brain herniation sac narrows the left transverse sinus.

close relationship with blood vessels into which they enter or protrude. Moreover, some giant arachnoid granulations have different signal intensities from that of CSF due to connective tissues and/or vascular structures. In all our patients the herniated brain and surrounding CSF had same signal intensity as normal brain parenchyma and subarachnoid spaces on all MRI sequences. Although the location of the brain herniations into the DVS were in the usual location of arachnoid granulations, none of our cases contained enhancing blood vessels or different signal intensities from brain or CSF. It is, however, possible that venous structures and/or connective tissues into the arachnoid granulations may be tamponed by mass effect from the herniated parenchyma, thereby making them invisible. Based on these findings, it is possible that these brain herniations are different from arachnoid granulations.

It seems reasonable to postulate that the presence of pre-existing arachnoid granulations facilitates the formation of brain herniation into the DVS or adjacent calvarium. Herniations of brain parenchyma into arachnoid granulations are thought to occur spontaneously or as a result of increased intracranial pressure. Although three of our patients did not have findings of increased intracranial pressure, one had an ethmoidal encephalocele which conceivably could have been secondary to increased pressure and this is the same patient who had bilateral transverse sinus hypoplasia with bilateral brain herniation into them

resulting in further narrowing, and another had non-specific and chronic headaches. Since nonspecific symptoms such as headaches and tinnitus had been reported in giant arachnoid granulations, these symptoms could also occur with brain herniations into the DVS. However, no direct relationship or association has been established between these symptoms and giant arachnoid granulations^{1,9}.

Newer MR imaging sequences such as high resolution three-dimensional (3D) gradient echo T1-weighted and T2-weighted sequences such as constructive interference in steady state (CISS) and sampling perfection with application-optimized contrast with different flip-angle evolutions (SPACE) provide the spatial resolution needed to clearly assess the anatomy of brain herniations into the DVS or calvarium. In all of our five patients conventional T1- and T2-weighted sequences were not sufficient for the detection and complete evaluation of the herniations. 3D T1- and T2-weighted sequences were most useful in the detection of herniated brain and its continuity with adjacent parenchyma and CSF-containing compartments.

In conclusion, brain herniations should be considered potential sources of filling defects within the DVS. We believe that this finding is probably incidental, but may be related to headaches, and may be more common than previously recognized. Brain herniation into a DVS should be not confused with the more common arachnoid granulations, clots, or tumor extensions which have different clinical implications.

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