Sunken Eyes, Sagging Brain Syndrome: Bilateral Enophthalmos from Chronic Intracranial Hypotension

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Purpose: To explain the mechanism for acquired enophthalmos after ventriculoperitoneal shunting (VPS).

Design: Case series and a case-control study.

Participants and Controls: Four study patients with bilateral enophthalmos after VPS and 10 control subjects.

Methods: Case description of 4 study patients. Calculated orbital volumes for 2 study patients were compared with controls using the Wilcoxon rank-sum test.

Main Outcome Measures: Exophthalmometry measurements and total orbital and fat volumes.

Results: Patient 1 is a 25-year-old man who presented with progressive enophthalmos 3 years after VPS for traumatic intracranial bleeding. Imaging demonstrated upward expansion of the orbital roof and evidence of intracranial hypotension. The intracranial pressure (ICP) was 20 mm H2O. The enophthalmos improved after shunt revision. Patient 2 is a 19-year-old man who presented with progressive enophthalmos 18 months after VPS for traumatic intracranial hemorrhage. Patient 3 is a 38-year-old woman who presented with bilateral enophthalmos 15 years after VPS after a ruptured aneurysm. Imaging showed orbital expansion. Patient 4 is a 16-year-old man who presented with severe enophthalmos 5 years after a VPS for aneurysm-related hemorrhage. Imaging demonstrated orbital enlargement and findings of intracranial hypotension. Intracranial pressure ranged between −200 and 0 mm H2O. Shunt revision improved the enophthalmos. Total orbital volumes were significantly greater in the study patients than in the controls. Control subjects (5 male, 5 female, ages 23–45 years) had an average right orbital volume of 24.6±3.3 cm3 (n = 10). In comparison, the right orbital volumes of patients 1 and 3 were 32.6 and 32.1 cm3. Similar results were found for the left orbits (23.9±2.7 cm3 [control average] vs. 35.9 and 32.6 cm3). In patient 1, the post-shunt volumes increased 14% (right) and 23% (left) from pre-shunt values. In contrast, orbital fat volume was not statistically significantly different between the control group and enophthalmic patients (right orbit control mean 7.94±3.1 cm3 [n = 10] vs. 7.9 and 9.8 cm3; left orbit control mean 7.88±3.1 cm3 vs. 9.2 and 10.0 cm3).

Conclusions: Enophthalmos after VPS results primarily from chronic intracranial hypotension. Low ICP causes expansion of orbital volume with no fat atrophy. In such patients, shunt revision with a pressure-regulating valve to correct intracranial hypotension should be considered.

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Materials and Methods

Institutional review board/ethics committee approval was obtained, and the research adhered to the tenets of the Declaration of Helsinki. From 1991 to 2010, 4 patients were identified at the University of California San Francisco with progressive enophthalmos after VPS. They are described in detail, with focus on neuro-ophthalmologic, orbital, and radiographic evaluations.

Orbital volumetric analysis was performed on 2 enophthalmic patients (patients 1 and 3) who had adequate imaging studies. Patient 1 also had a pre-shunt computed tomography (CT) scan available for comparison. Patient 2 did not undergo imaging after the development of enophthalmos and therefore could not be included in the volumetric analysis. Patient 4, although imaged with CT, lacked the specific sequences required for volumetric analysis. A control group (5 male and 5 female patients, mean age 35.6 years, range 23–45 years) without orbital pathology was used for comparison. The control group was selected using a reverse chronologic search starting from December 2008 through the radiology database at the University of California San Francisco. Patients with any intracranial or orbital pathology were excluded.

ImageJ software (v 140g, National Institutes of Health, http://rsbweb.nih.gov/ij, accessed July 2009) was used to analyze orbital CT axial images by measuring the orbital area in each slice and multiplying by the slice thickness. Total orbital volume, soft-tissue volume, fat volume, and air volume were all assessed. “Total volume” refers to the volume of the bony orbit. “Soft tissue volume” refers to the volume of all soft tissues: This includes fat, muscles, and the eye itself, as well as numerous smaller structures. “Fat volume” refers to the amount of fat contained within the confines of the bony orbit. In patients with severe enophthalmos, the anterior bony orbit is devoid of soft tissue; the size of this air-filled space is referred to as “air volume.” The total orbital area in each axial slice was bounded on each side by the medial and lateral orbital walls. Anteriorly, if the slice did not have a bony boundary because of the orbital opening, a line was drawn between the inner aspects of the orbital rim on each side. In the slices at the level of the medial canthi, the anterior line was drawn between the lateral orbital rim and the anterior lacrimal crest. Posteriorly, a straight line was drawn across the openings of the superior and inferior orbital fissures and the optic canal. By using thresholding and windowing techniques included with the ImageJ software, the total orbital volume could be divided into fat, soft tissue, and air volume. The 2-tailed Wilcoxon rank-sum test was used to assess differences between study and control patients. Right and left eyes were assessed separately so that the tendency of each individual to have symmetric orbital volumes would not inappropriately decrease the standard deviation.

Figure 1. Patient 1. External photographs with close-up view of the medial lower eyelids show loss of apposition of the lower eyelid to the globe, mucous strands, and injection due to enophthalmos.

Figure 2. Patient 1. Axial computed tomography scans show the normal position of the right globe before ventriculoperitoneal shunting (A) and severe enophthalmos ~5 years later (B) with short straight optic nerves (C).
Case Descriptions

Patient 1 is a 25-year-old man who was referred for evaluation of disconjugate gaze in September 2004. He was involved in a motor vehicle accident in November 2000 that resulted in extensive hemorrhagic brain contusions, frontotemporal epidural hematoma, and intraventricular hemorrhage. There were several skull fractures identified on CT, but none involved the orbits. In January 2001, the patient had a sudden decrease in mental status. A CT scan revealed new ventriculomegaly from presumed elevated intracranial pressure (ICP). A VPS without a valve was placed, which restored his baseline mental status. Long-term sequelae included muscular spasticity, neurogenic bowel and bladder, bradyphonia, hypophonia, and disconjugate gaze.

On ophthalmic examination, the patient’s best-corrected visual acuity was 20/70 oculus dexter (OD) and 20/50 oculus sinister (OS). He did not have an afferent pupillary defect, and visual fields were full to counting fingers. In primary gaze, he had 20-prism diopters of right exotropia and 10-prism diopters of right hypotropia. Supraduction was limited to 5% of normal OD and 50% of normal OS. Infraduction was limited to 50% of normal OD and 10% of normal OS. Horizontal ductions were intact. Despite his disconjugate gaze, the patient did not report diplopia.

His external examination (Fig 1) showed bilateral enophthalmos with exophthalmometry measurements of 9 mm oculus uterque (OU). The enophthalmos was so severe that the ocular surface had lost contact with the eyelids, especially along the medial one half of each lower lid. The gap caused accumulation of debris in the inferior fornix, inferior conjunctival injection, and recurrent keratoconjunctivitis. There was fluorescein staining of the inferior cornea. Fundus examination revealed bilateral optic nerve pallor, slightly worse on the right.

Comparison of orbital CT imaging obtained at the time of injury (Fig 2A) and slightly >4 years later (Fig 2B) documented...
acquired enophthalmos. The intracranial hypotension–related skull remodeling resulted in not only enophthalmos but also expansion of all adjacent sinuses. The optic nerves were short and straight (Fig 2C) with an intraorbital length of 18 mm bilaterally compared with a reported typical length of 25 mm.28 Magnetic resonance imaging (MRI) obtained after the development of enophthalmos, showed classic signs of intracranial hypotension. There was flattening of the pons against the clivus, reduction of the interpeduncular and pre-pontine cisterns, crowding of the optic chiasm against the pituitary gland, and thickening of the dura with gadolinium enhancement (Fig 3A, B).29 –34 The ICP was measured at 20 mm H2O (normal range 100 –200 mm H2O), confirming low cerebrospinal fluid (CSF) pressure.

To determine whether the ventriculoperitoneal shunt was still necessary, the intraventricular tube was connected directly to an external ventricular drain set to 200 mm H2O. The CSF continued to drain at a high rate, proving that the patient’s ICP would increase /H1102200 mm H2O without a VPS. To address the high ICP and avoid over-shunting, a Medtronic Delta Valve Performance Level 1.5 VPS was placed (Medtronic Inc., Minneapolis, MN). This pressure-controlled valve opens only when the ICP exceeds a certain threshold. The Performance Level 1.5 version is calibrated to maintain the ICP between 70 and 105 mm H2O (http://www.medtronic.com/neurosurgery/valves.html#delta). As demonstrated by MRI 2 months later, the radiographic signs of intracranial hypotension resolved (Fig 3C, D).

In less than 48 hours after shunt revision, some improvement of the enophthalmos was observed. Although the globes did not return to their pre-injury position, there was an increase in exophthalmometry measurements from 9 to 12 mm bilaterally. Photographs taken 2 months later showed that the ocular surface was now in contact with the lower eyelids all the way to the medial canthi (compare Figs 1 and 4A). In addition, the patient’s chronic conjunctival injection had resolved. The anterior shift of the globes was also apparent in comparison of pre-shunt revision and post-operative CT scans (Fig 4B).

Patient 2 is a 19-year-old man who presented in December 2005 with a history of a motor vehicle accident in June 2004. He had traumatic brain injury with a hemorrhage in the left frontal lobe, right internal capsule, midbrain, and fourth ventricle. Several skull fractures were observed on CT. Several ethmoid air cells were opacified bilaterally, suggesting medial wall fractures; however, no bone displacement was seen. Several weeks later, a CT scan showed new ventriculomegaly, so a right parietal ventriculoperitoneal shunt was placed. Long-term neurologic sequelae included severe spasticity and neurogenic bowel and bladder. He was wheelchair-bound with severe hypophonia, preferring to communicate by pointing at letters on a letter board.

On ophthalmologic evaluation, his best-corrected vision was difficult to assess because of his inability to communicate which letters he could see on the vision chart, but he did foveate well on targets. His pupils were minimally reactive, but his visual fields were full to confrontation. In primary gaze, he was orthotropic by corneal light reflex, and his eye movements were full except for...
poor supraduction bilaterally with some beats of convergence retraction nystagmus. He also had synchronous downbeating nystagmus in primary gaze, a combined downbeating and clockwise rotary nystagmus in left gaze, and a left-beating nystagmus in right gaze.

On external examination, he had enophthalmos with exophthalmometry measurements of 12 mm bilaterally. Loss of apposition between the globe and the eyelids was seen at the medial and lateral canthal angles. There was mild exposure with conjunctival injection, but no fluorescein staining of the corneas. Fundus examination revealed a normal optic nerve, macula, and periphery in each eye.

The only available imaging studies were a maxillofacial CT scan done at the time of the accident, a brain CT scan at 1 month showing the development of ventriculomegaly, and a brain CT at 2 months after the accident showing the VPS and reduced ventricle size. Volumetric orbital analysis could not be performed because the brain scans did not include the entire orbits. There was neither air in the superior orbit nor radiographic evidence of enophthalmos on the head CT 1 month after VPS. No orbital or brain imaging was performed after enophthalmos was detected. The patient died 2 years after his initial evaluation from positional asphyxia. Shunt revision had not been performed.

Patient 3 is a 38-year-old woman who was referred for evaluation and management of progressive bilateral exposure keratopathy in 2006. She had a ruptured left basilar artery aneurysm in 1991 and underwent VPS for ventriculomegaly. Although not certain of the exact onset, her mother reported subsequent progressive sinking in of the patient’s eyes (Fig 5A, B). She had undergone small bilateral permanent lateral tarsorrhaphies in the past but had begun to show recurrent signs of exposure. Persistent neurologic deficits included an expressive aphasia, ataxia, and a seizure disorder well controlled with carbamazepine.

On ophthalmic examination, the visual acuity was 20/50 OD and 20/200 OS. The pupils were symmetric and reactive with no afferent pupillary defect. Her visual fields were full to confrontation. She had a small exotropia in primary gaze, and her ocular motility was limited in all directions, vertically more than horizontally. Supra- and infraduction were approximately decreased to 25% of normal, and horizontal ductions were decreased to 50% of normal in both directions.

Her external examination (Fig 5B) showed severe enophthalmos with exophthalmometry measurements of 6 mm OU. The enophthalmos was so dramatic that there was no contact between the ocular surface and the lower eyelid margins across their entire length, and the upper eyelids wrapped around the superior orbital rim into the intraorbital space (Fig 6B). Severe ocular exposure had resulted in bilateral corneal scarring and vascularization, as well as significant conjunctival injection. The posterior segment examination showed a normal optic nerve, macula, and periphery in each eye.

Orbital CT scan showed extreme enophthalmos (Fig 6A) and short, straight optic nerves (Fig 6B, C) with an intraorbital length of 19 mm bilaterally. Again, the bony orbits were expanded, and the sinuses also were abnormally large. Before recognizing the association with VPS, surgical exploration with biopsies of the periorbita and orbital fat was performed to investigate possible neoplastic and inflammatory processes. Not surprisingly, in retrospect, no histologic abnormality was seen. In particular, the orbital fat cells were normal in size and morphology and had no evidence of inflammation or atrophy. The patient declined shunt revision. The exposure keratopathy resolved with larger permanent lateral tarsorrhaphies, fusing 25% of the eyelid margin.

Patient 4 is a 16-year-old male who presented in May 2010 for evaluation of progressive bilateral enophthalmos. His medical history included an in utero right hemispheric stroke resulting in a left hemiplegia. In July 2005, he underwent clipping of 2 intracranial aneurysms, complicated by intracranial hemorrhage and elevated ICP, necessitating VPS placement. Visual acuity was 20/25 and 20/20 in the right and left eyes, respectively. An incomplete left homonymous hemianopia was found on confrontation visual field testing. He had full extraocular motility and was orthophoric in all fields of gaze. He was markedly enophthalmic with loss of contact between the globes and eyelids medially (Fig 7A). Exophthalmometry measurements were 10 and 9 in the right and left eyes, respectively. Magnetic resonance imaging showed characteristic findings of intracranial hypotension (Fig 7B). The ICP ranged between negative 200 and 0 mm H2O while monitored with
a ventricular drain over the course of 3 days. The existing VPS was replaced with a pressure-controlled model. Some “filling in” of the orbits was observed within 1 day of ICP normalization. Long-term follow-up is not yet available.

Volumetric Analysis

The coronal CT scans of the enophthalmic orbits in patients 1 and 3 (Fig 8A, B) show a vaulting of the orbital roof with associated expansion of the total orbital volume. To test the hypothesis of orbital expansion, we calculated the orbital volumes of 10 control patients as described in the “Materials and Methods” for comparison with 2 enophthalmic patients. In addition, we compare the pre-shunt and post-shunt volumes of patient 1, directly showing an increase after VPS.

Table 1 summarizes the results comparing the right and left orbits of the control group and the 2 study patients (numbers 1 and 3) who had CT scans available documenting their enophthalmos. Mean right orbital volume of the control group was 24.6±3.3 cm³. Total volume of the right orbits in the study patients was 32.6 cm³ (patient 1) and 32.1 cm³ (patient 3). These volumes are ≥2 standard deviations above the mean of the control group. The difference was statistically significant by the Wilcoxon rank-sum test (P = 0.03). The mean left orbital volume of the control group was 23.9±2.7 cm³. The left orbital volumes of the patients were 35.9 cm³ (patient 1) and 32.6 cm³ (patient 3). Again, there was a statistically significant difference (P = 0.03, Wilcoxon rank-sum test).

The pre-shunt total orbital volumes of patient 1 were 28.5 cm³ (right) and 29.3 cm³ (left), which was not statistically different from the controls. The post-shunt volumes increased by 4.1 cm³ (14%) on the right and 6.6 cm³ (23%) on the left.

The other notable feature was the presence of air within the orbital boundary. The air was not post-septal, but rather, was located mostly in the expanded conjunctival fornices and partially in the deep eyelid sulci caused by the severe globe retraction (Fig 6B, C). None of the control patients had any air within their orbits, whereas the enophthalmic patients had 1 and 3.5 cm³ on the right and 4.7 and 3.4 cm³ on the left.

No significant difference was seen between fat volumes in the right orbits of the control group (7.9±3.1 cm³) compared with the study patients (7.9 and 9.8 cm³) (P = 0.75, Wilcoxon rank-sum test). Similar results were found for the left orbits (control 7.9±3.1 cm³ vs. study patients 9.2 and 10 cm³, P = 0.60 Wilcoxon rank-sum test). However, there was a trend for more total soft tissue within the orbits of the enophthalmic patients. Because the control group did not have any orbital air, the soft tissue volume is the same as the total volume (i.e., 24.6±3.3 [right] and 23.9±2.7 cm³ [left]). The enophthalmic patients had soft tissue volumes of 31.6 and 28.6 cm³ on the right (P = 0.12, Wilcoxon rank-sum test) and 31.2 and 29.2 cm³ on the left (P = 0.06, Wilcoxon rank-sum test).

The increase in total soft tissue and air volumes in the enophthalmic patients was due to the increase in the total volume of the bony orbit. The extra space was partially taken up by a volume of soft tissue (e.g., eyelids and globe), which would normally lie outside the defined anterior border of the orbit, being pulled...
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Table 1. Orbital Volumetric Analysis

<table>
<thead>
<tr>
<th></th>
<th>Total Volume (cm³)</th>
<th>Soft Tissue Volume (cm³)</th>
<th>Fat Volume (cm³)</th>
<th>Air (cm³)</th>
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<td></td>
<td>OD</td>
<td>OS</td>
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<td>Control group</td>
<td>24.6±3.3</td>
<td>23.9±2.7</td>
<td>24.6±3.3</td>
<td>23.9±2.7</td>
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<tr>
<td>Patient 1 (pre-shunt)</td>
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<td>29.3</td>
<td>28.5</td>
<td>28.1</td>
</tr>
<tr>
<td>Patient 1 (post-shunt)</td>
<td>32.6*</td>
<td>35.9*</td>
<td>31.6</td>
<td>31.2</td>
</tr>
<tr>
<td>Patient 3</td>
<td>32.1*</td>
<td>32.6*</td>
<td>28.6</td>
<td>29.2</td>
</tr>
</tbody>
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OD = oculus dexter; OS = oculus sinister.
*P < 0.05.
†Unable to change window level on scan to differentiate fat well enough from other soft tissue because the scan was available only in a hard copy.

Discussion

Shunting of CSF is a well-established surgical approach for treatment of increased ICP. Over-shunting is a known complication of this procedure. In pediatric patients when the skull is still developing, over-shunting inhibits normal expansion of the cranial vault and can lead to premature suture fusion and secondary craniosynostoses.35,36 In contrast, our data support the hypothesis that over-shunting and intracranial hypotension in adult patients can present with a different type of bony change: intracranial hypotension–related skull remodeling with expansion of the orbits, sinuses, and mastoid air cells. This is to such a dramatic degree that even aeration of the clinoid processes was seen. In previous reports, bilateral enophthalmos was associated with pediatric shunting for congenital or childhood hydrocephalus.25–27 Our cases show that CSF shunts placed during adulthood for acquired ventriculomegaly can cause remodeling of fully mature orbital bone. In patients 1 and 4, our findings strongly support the hypothesis that intracranial hypotension from over-shunting is likely the cause for this change. We propose the term sunken eyes, sagging brain syndrome to describe the enophthalmos seen with intracranial hypotension–related skull remodeling.

Previously suggested mechanisms for enophthalmos after VPS include fat atrophy25 and orbital bony expansion.26,27 Our findings are sufficient to exclude fat atrophy as a contributing factor. When the volume of orbital fat was calculated in enophthalmic patients, no significant difference was seen compared with a control group. In addition, a biopsy of the orbital fat was performed on 1 patient before the diagnosis was established. Histologically, the adipose cells were normal in size and structure, and there was no evidence of inflammation, fibrosis, or atrophy. Orbital biopsy is not necessary when the history and radiologic findings are consistent with sunken eyes, sagging brain syndrome.

Volumetric analysis of our patients supports the theory of orbital expansion. Our study is the first to compare directly the orbital volumes in an enophthalmic patient before and after VPS. Measurement of the bony orbital space confirmed that the orbital volumes in the study patients were greater than the control average by >30%. The measured mean volume of our control patients (24.3 cm³) is similar to previously published data, which range from 17.8 to 28.4 cm³37–41 supporting the accuracy of the techniques used in this study.

The orbital volume expansion stems mostly from upward vaulting of the roof of the orbit, which is apparent on CT. There may also be more subtle remodeling of the medial and inferior orbital walls. We postulate that this syndrome results from chronic intracranial hypotension, which was confirmed directly in patients 1 and 4. It represents a rare example of skull bone remodeling resulting from an altered pressure gradient across the orbital walls.

The maintenance of bone involves a dynamic process mediated by continual absorption by osteoclasts and creation of new bone by osteoblasts. The balance of bone absorption and formation is mediated in part by mechanical stress on the bone regulated by strain-sensitive cells, which are thought to be osteocytes. Although this process is more active during childhood, even mature bone has the potential for remodeling. For example, under circumstances of disuse or zero-gravity, long bones will resorb because of the lack of mechanical loading required to maintain the bone.42 In addition, previous work has shown that during prolonged bed rest, the skull will increase in mass, which is believed to result from a net bone formation from the increased ICP from a chronic caudal shift in fluid.43 We propose that the opposite process occurs in our enophthalmic patients. Essentially, with chronic intracranial hypotension, the pressure gradient across the bone of the orbital roof is altered from decreased force from the intracranial side. This effect would theoretically cause not only a net resorption of bone because of decreased stress but also an effective intracranially directed force across the roof causing orbital expansion.

Posteriorly into the orbital space as the enophthalmos develops. The remaining volume was taken up by air spaces within the orbital boundary that reside in the expanded conjunctival fornices and the deepened eyelid sulci created by the enophthalmos (Fig 6B, C). Additional volumetric analysis was performed to compare the CT scans of patient 1 before and after shunt revision. The total postoperative orbital volumes (33.5 and 36.6 cm³, right and left respectively) were similar to the preoperative measurements (32.6 and 35.9 cm³, right and left respectively). The slight difference likely represents variations in measurements.
process occurs progressively over months but, as demonstrated by patient 2, can be clinically apparent in as little as 18 months after shunt placement.

Comparison can be made with the “silent sinus syndrome.” In this entity, downward bowing of the orbital floor into an imploding maxillary sinus results in enophthalmos. Previous reports on “silent sinus syndrome” identified an altered pressure gradient across the bone of the orbital floor from a decrease in the intramaxillary sinus pressure, just as described previously for the orbital roof from a decrease in ICP in our patients. In addition, demineralization of the orbital floor consistent with bony remodeling has been identified in “silent sinus syndrome.” This is consistent with our proposed mechanism for enophthalmos resulting from intracranial hypotension–related skull remodeling.

Although intracranial hypotension–related skull remodeling seems to be the major contributor to enophthalmos, other factors also contribute as illustrated by patients 1 and 4. In patient 1, ICP was extremely low at 20 mm H2O. After correction of intracranial hypotension, a small but rapid improvement in enophthalmos was seen within 48 hours. This was also observed in patient 4, in whom negative ICP was measured, and again partial improvement was seen within days of ICP normalization. It seems improbable that a change in the orbital wall could occur this quickly. This suggests that additional factors, other than bone remodeling, are involved. First, forward movement of the globe after shunt revision may result from increased hydraulic force generated by the increased CSF pressure in the subarachnoid space of the optic nerve just as increased pressures can flatten the globe in cases of intracranial hypertension. A notable finding in the enophthalmic patients is short straight optic nerves. This was seen in our cases with imaging, and reviewed by the figures in Meyer et al.25 and Bernardini et al.27 at least 1 in each series had a short taut optic nerve. This gives the impression that the nerves might be pulling on globes, causing posterior displacement. Our findings suggest that this is occurring secondarily to the development of enophthalmos, as opposed to being causative. Perhaps the combination of chronic enophthalmos and abnormally low pressure within the subarachnoid space of the optic nerve allows this configuration to develop. Admittedly, this is speculative, and further study is needed to determine the true significance of this finding.

Several other findings are worthy of mention. First, 3 of the patients had significant ocular motility problems, in particular a marked reduction in supraduction. Potential causes could be a mechanical abnormality stemming from globe/muscle malposition versus neurologic from cranial nerve or brainstem pathology. Because each patient had a significant intracranial injury, and there is no documentation of the eye movements in the immediate period afterward, it is unclear if the abnormalities were present because of the acute event or developed later as part of this syndrome. Second, in addition to the orbits being expanded, the frontal, sphenoid, ethmoid, and maxillary sinuses also seemed enlarged, especially in patient 3, who also had pneumatized clinoid processes. (Fig 6A, B). This finding suggests that there could be expansion of all the pericranial spaces. Finally, in patient 1, bilateral optic nerve atrophy was noted, and in 1 patient in the series by Meyer et al.,35 progressive vision loss and optic atrophy to the point of no light perception in 1 eye were documented, suggesting that optic nerve and chiasm damage occur within the spectrum of findings in sunken eyes, sagging brain syndrome. This neuropathy may be the result of intracranial hypotension causing stretch injury from displacement of the chiasm.

Several management options are available. If present, correction of cerebral hypotension should be considered. This will likely halt progression, and may result in an immediate partial improvement, as seen in patients 1 and 4. Whether resolution of the intracranial hypotension will result in correction of the bony expansion remains unknown but may be revealed with longer-term follow-up. Surgical augmentation is another reasonable option. Although not performed in any of our patients, surgical augmentation has been reported in the literature. Orbital floor implants were placed in 1 of the patients included in the original series by Meyer et al.25 This procedure resulted in partial correction of the enophthalmos but also with unwanted superior displacement of the globe. However, as described by Cruz et al. and Bernardini et al. favorable results were achieved when the implant was placed in the orbital roof. Given that the abnormality lies in the roof and not the floor of the orbit, one might expect better results with augmentation of the superior orbit. Patient 3 of this series declined shunt revision and placement of an orbital implant. However, satisfactory symptomatic relief of exposure-related symptoms was achieved with simple tarsorrhaphy. Of course, some patients would consider this procedure cosmetically inferior to shunt revision and orbital volume augmentation.

This study is limited by its small size. Despite this, consistent findings in all patients and the significant measured differences from a normal control group help to substantiate our findings. Also, the control group was selected from patients aged 18 to 45 years, which overlaps but is not identical to our study subjects. Age-related changes in skull anatomy might contribute in part to differences seen between our study subjects and the control group. However, our patients were of a wide age range (16–38 years), making age-related changes unlikely to be a major contributor.

The sunken eyes, sagging brain syndrome develops primarily as the result of intracranial hypotension–related skull remodeling. The prevalence of this disorder is unknown, but with increasing recognition, the number of reports will likely increase. Other causes of low CSF pressure could also theoretically cause this syndrome, including over-shunting.
from lumboperitoneal shunting, a ruptured Tarlov’s cyst, or idiopathic spontaneous low ICP. Our data confirm that the primary mechanism underlying this syndrome is bony expansion from superior vaulting of the orbital roof likely due to an abnormal pressure gradient across the bone because of low ICP. Decreased orbital blood or CSF volume may contribute to a lesser degree. To manage a patient post-VPS with enophthalmos, consider the following options: (1) an MRI to screen for any inflammatory or neoplastic orbital pathology and to check for any radiographic signs of intracranial hypotension and large orbital cavities, (2) a procedure to confirm low CSF pressure, (3) an assessment of continued shunt dependence, and (4) either removal of the shunt if not shunt dependent or a revision with a valve-controlled shunt if still shunt dependent. Correction of the intracranial hypotension may result in partial immediate improvement and will presumably prevent further progression. Other management options include surgical augmentation of the orbital volume and tarsorrhaphy.

References

37. Chau A, Fung K, Yip L, Yap M. Orbital development in Hong


Footnotes and Financial Disclosures

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