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Case Series

Infantile Acute Subdural Hematoma. Clinical and Neuroimaging Analyses of 15 Cases Focusing on Intracranial Structural Vulnerabilities

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Abstract

Objectives: There are annually approximately 100 cases of Infantile Acute Subdural Hematoma (IASDH) in Japan. Even after the advent of magnetic resonance imaging, few studies have examined the clinical profile and neuroimaging characteristics of IASDH. The present study aimed to elucidate the intracranial, structural vulnerabilities associated with IASDH.

Materials & Methods: Fifteen patients with IASDH comprising 14 males and one female aged less than 2 years were enrolled. Patients with a diagnosis of shaken baby syndrome or abusive head trauma were excluded.

Results: The patients' head trauma resulted from a short fall (n=13; 87%) and occipital impact (n=11; 73%). A retinal hemorrhage was noted in 12 patients (80%). Imaging studies revealed a mixed-density, unilateral, subdural hematoma in all the patients. Benign Enlargement of the Subarachnoid Space (BESS) was noted in eight patients (53%), and a Large Sylvian Fissure (LSF) coexisting with Small Temporal Lobes (STL) was present in all the patients (100 %). Surgery was performed in four patients (craniotomy: n=3; subdural drainage: n=1) while 11 patients (73%) were conservatively managed. The outcomes were good in 13 patients (87%) while two patients had severe to moderate disability.

Conclusion: IASDH consists of a mixed-density hematoma possibly caused by simultaneous tearing of the arachnoid membranes and bridging veins. The presence of LSF and BESS increases the Cranio-Cerebral Disproportion (CCD). In particular, the co-occurrence of LSF with STL may contribute to loosening the tight fixation of the temporal lobes at the middle cranial fossa and sphenoid ridge. In this situation, a mild occipital impact may sufficiently enhance the rotational force of the brain to induce IASDH.

Keywords: Abusive head trauma; Benign enlargement of subarachnoid space; Cranio-cerebral disproportion; Infantile acute subdural hematoma; Large sylvian fissure; Mixed-density subdural hematoma; Shaken baby syndrome; Small temporal lobe

Introduction

Short falls among infants from a sitting or standing position while at home is estimated to occur at least one million times a year in Japan. On the other hand, the incidence of Infantile Acute Subdural Hematoma (IASDH) is estimated at 100 per year [1]. Although the causes of IASDH have not been sufficiently investigated in this subpopulation, it is important from a medico-legal aspect to understand what makes IASDH more likely to occur in these infants. Furthermore, increasing the public's awareness about this disorder has given impetus to research into its causes. Even after the advent of MRI, however, few studies have focused on the clinical profile and neuroimaging characteristics of patients with IASDH [2]. The present study aimed to elucidate possible, intracranial, structural vulnerabilities which may conduce to IASDH.

Materials and Methods

Between 2014 and 2024, 51 patients aged < 2 years were referred to the Department of Neurosurgery at Bethlehem Garden Hospital with symptoms and signs of subdural hematoma and subdural fluid collection. All the clinical data on these patients, including their CT□and MRI findings and interview records, were analyzed. Fifteen of these patients (14 males and one female) received a diagnosis of IASDH on the basis of their clinical history and neuroimaging findings in accordance with the definition of IASHD as an acute, infantile, subdural hematoma caused by minor head trauma without loss of consciousness or any cerebral contusion [3], and were enrolled in the present study. All the patients were aged < 2 years with a median age at diagnosis of 8.1 months (range: 4 - 14 months). Patients with an underlying bleeding diathesis were excluded. IASDH was clinically graded as mild (grade I), intermediate (grade II) or fulminant (grade III) in accordance with the findings of a previous study. (Table 1) [3] All the patients in the present series were reported to a childcare center where an assessment for Shaken Baby Syndrome (SBS) or Abusive Head Trauma (AHT) was carried out.

Disease grade	Type	Clinical features	Present Series
I	Mild	Conscious, no motor disturbance but with vomiting &/or irritability	12 Cases
II	Intermediate	Drowsy, minimal or mild hemiparesis	1 Case
III	Fulminant	Stuporous to comatose, moderate to severe hemiparesis, with signs of cerebral herniation	2 Cases

Table 1: Clinical grade on arrival in patients with IASDH proposed in1984 [3].

Results

Clinical Results

Eleven patients (73%) had symptoms and signs of head injury after a short fall resulting in a strike to the occipital area, and four patients had no history of head trauma. All the patients presented with an acute onset of signs and symptoms, including generalized convulsive seizures (n=11) and repeated vomiting (n=2). Two patients had repeated vomiting followed by seizures. Grade I, II, and III IASDH was found in nine, three, and three patients, respectively. (Table 1) Various degrees of retinal hemorrhage were observed in 12 patients (80%); bilateral and unilateral lesions were noted in ten and two patients, respectively. Surgery was performed in four patients (craniotomy: n=3; subdural drainage: n=1), and 11 patients (73%) were conservatively managed in accordance with the treatment policy of each referring institution. The overall outcome was good recovery with no deficits in 13 patients (87%) while two patients had severe to moderate disability. There was no recurrence of subdural hematoma or fluid collection during the study period (range: 11 years 1 month - 1 year 6 months; mean: 7 years 4 months).

Neuroimaging Findings

In all the patients, the subdural hematoma appeared as a mixed-density, unilateral lesion on CT and/or MRI. The hematoma occurred on the right in ten (67 %) and left side in five patients, respectively. Benign Enlargement of Subarachnoid Space (BESS) was noted in seven patients (47 %). In all the patients, a Large Sylvian Fissure (LSF) was found concurrently with small temporal lobes. This phenomenon was more prominent on the left side in eight patients (53%) and on the right side in four patients and was equal on both sides in four patients. MRI, including Susceptibility-Weighted Imaging (SWI) and T2* weighted imaging, revealed no primary cerebral parenchymal injury indicating cerebral contusion or Diffuse Axonal Injury (DAI). No complex subdural hematoma was observed. Table 2 presents a summary of the clinical and neuroimaging findings in the total cohort.

Case No	Age (mos) Sex	Presenting history	Site of impact/ Surface	Presenting sign & symptom /Grade	Retinal hemorrhage	Neuroimaging findings			Management	Outcome/ Follow up
						SDH	BESS	LSF		
1	8M	Short fall	Occiput/ baby mat	Seizure I	Bilateral	Right mixed	No	Bilateral Right=Left	Observation	GR 11y1m
2	9M	Short fall	Occiput/ wooden floor	Vomiting, Seizure III	Unilateral (Left)	Left mixed	No	Left	Craniotomy	GR 10y3m
3	10M	Short fall	unknown	Vomiting, Seizure I	none	Right mixed	No	Left	Observation	GR 10y1m
4	9M	Short fall	Occiput/ wooden floor	Seizure I	Bilateral	Right mixed	No	Right	Observation	GR 9y5m
5	6M	No history	none	Vomiting, Seizure I	none	Left mixed	BESS	Right	Observation	GR 8y3m
6	10M	Short fall	Occiput	Seizure I	Bilateral	Left mixed	BESS	Right	Observation	GR 6y5m
7	7M	Short fall	Occiput	Seizure I	Bilateral	Right mixed	BESS	Bilateral Right=Left	Observation	GR 6y2m
8	8M	Short fall	Occiput/ bed for infants	Seizures III	Unilateral (Right)	Right mixed	No	Left	Craniotomy	Moderately disabled/ 6y1m
9	14M	Fall from chair	Occiput	Seizure, macrocephaly III	none	Right mixed	BESS	Left	Conservative	Severely disabled/ 6y1m
10	8M	Fall while trying to stand	Occiput/ soft carpet	Vomiting, seizure II	Bilateral	Left mixed	BESS	Right	Craniotomy	GR 5y7m
11	6M	Short fall	Occiput	Vomiting I	Bilateral	Right mixed	None	Left	Observation	GR 4y8m
12	9M	Short fall	Occiput/ baby mat	Seizures, Macrocrania I	Bilateral	Right mixed	None	Left	Observation	GR 3y5m
13	12M	Short fall	unknown	Altered conscious-ness II	Bilateral	Right mixed	None	Left	Subdural drainage	GR 3y4m
14	5M	Short fall	unknown	Altered conscious-ness I	Bilateral	Right mixed	BESS	Bilateral Left>Right	Observation	GR 2y11m
15	4F	No history	unknown	Vomiting, Seizure, Irritability II	Bilateral	Left mixed	BESS	Bilateral Right Left	Observation	GR 1y10m

SDH= subdural hematoma; BESS=benign enlargement of subarachnoid space; LSF=large sylvian fissure; GR= good recovery Grade I: mild type; Grade II: intermediate type; Grade III: fulminant type

Table 2: Summary of clinical profiles of 15 patients with infantile acute subdural hematoma.

Case Presentation

Case 1 (No 7)

The patient was a 7-month-old male with no significant medical history who fell backwards from a seated position and struck his occipital area on a carpeted floor at home. The infant began crying immediately after the fall. The accident was witnessed by his parents, and the father noted an upward deviation of both eyes, cyanosis, flaccidity, and altered consciousness as he held the patient in his arms. The patient was taken to an emergency hospital. En route in the ambulance he regained full activity and returned to his baseline. Evaluation in the emergency room found no external signs of trauma or neurological abnormalities. CT revealed a mixed-density Subdural Hematoma (SDH) on the right side together with BESS and LSF on the left side (Figure 1, left). Fundoscopy revealed bilateral retinal hemorrhages. The patient was managed conservatively. MRI performed 14 days later found that the decreased volume of the SDH, BESS and the LSF on the left side (Figure 1, right).

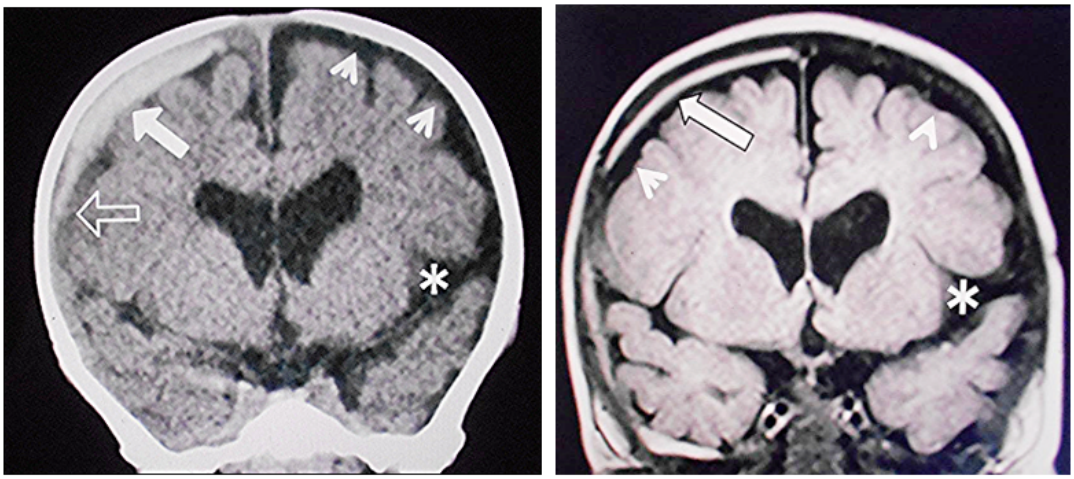

Figure 1: Case 1 (No.7) Male aged 7 months. **Left:** Coronal CT revealing a mixed-density SDH with high density in the frontal (arrow) area and low density (open arrow) in the temporal area on the right side. Note the enlarged subarachnoid spaces (arrowheads) and the LSF on the left side. (asterisk). **Right:** MRI (FLAIR, coronal view) at 14 days post-presentation at the outpatient clinic showing a decrease in the volume of the SDH around the right cerebral hemisphere. (arrow) Note the BESS (arrowheads) and the LSF on the left side. (asterisk).

Case 2 (No 8)

The patient was an 8-month-old male with no significant medical history who fell backwards from a seated position and struck his occipital area on a carpeted floor while at home. The infant began crying immediately on impact. The accident was witnessed by his parents. His father noted an upward deviation of both eyes, cyanosis, flaccidity, and altered consciousness as he held the patient in his arms. The patient was taken to an emergency room. En route in the ambulance, the patient developed repeated, generalized convulsive seizures showing status epilepticus. CT revealed a SDH on the right side, for which emergency surgery was indicated (Figure 2, left). However, the patient was transferred to another hospital due to the unavailability of an operating theater at the receiving hospital. An ophthalmological examination at the second hospital revealed bilateral, retinal hemorrhages. Evacuation of the hematoma via craniotomy was carried out six hours after symptom onset. No cerebral parenchymal abnormalities were observed intraoperatively. The patient's postoperative course was complicated by prolonged seizures requiring anticonvulsant therapy under general anesthesia. MRI performed two days later revealed a bright tree appearance indicating an infantile traumatic brain injury with a biphasic clinical course and late reduced diffusion (TBIRD) [4] (Figure 2, right), which was likely caused by delayed surgery coupled with postoperative insufficient seizure control. The patient remained severely disabled at the 6-year-1-month follow-up examination.

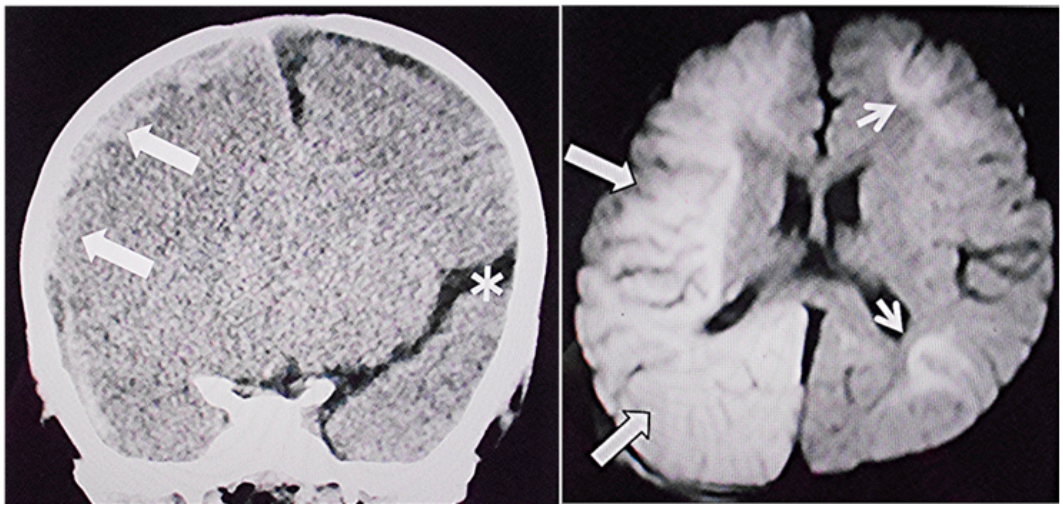

Figure 2: Case 2 (No.8), male aged 8 months. **Left:** Coronal CT at one hour after onset showing a mixed-density, acute subdural hematoma with a mass effect on the right side. (arrows) Note the large sylvian fissure on the left side. (asterisk). **Right:** Diffusion Weighted (DW) MRI on postoperative day 2 demonstrating a bright tree appearance with remarkably high intensity in the white matter in the entire right cerebral hemisphere (arrows) and part of the left cerebral hemisphere. (small arrows) This phenomenon, known as a traumatic brain injury with a biphasic clinical course and late reduced diffusion, may have been caused by delayed surgery coupled with postoperative poor seizure control. Note the resolution of the midline shift.

Case 3 (No 12)

The patient was a 9-month-old male with a large anterior fontanel, which had been noted on a regular follow-up examination at the age of 4 months. There was no other, significant medical history. When trying to stand while holding on to his mother's back, he fell backward and struck the occipital area on a baby mat. The patient began crying immediately, then began seizure-like movements and displayed signs of altered consciousness, all of which was witnessed by his mother (the scene was also recorded on video). The patient was brought to an emergency room by ambulance. On arrival, he was alert, and no abnormality was observed. CT found a SDH on the right side (Figure 3, left), prompting an ophthalmological examination, which found bilateral retinal hemorrhages. He was hospitalized for further observation and was reported to a childcare center, which ruled out AHT as the cause of his condition. MRI performed two days later revealed the SDH on the right side and a LSF on the left side (Figure 3, right) The patient had an uneventful clinical course and had achieved all his normal developmental milestones on examination at the 3-year-5-month follow-up.

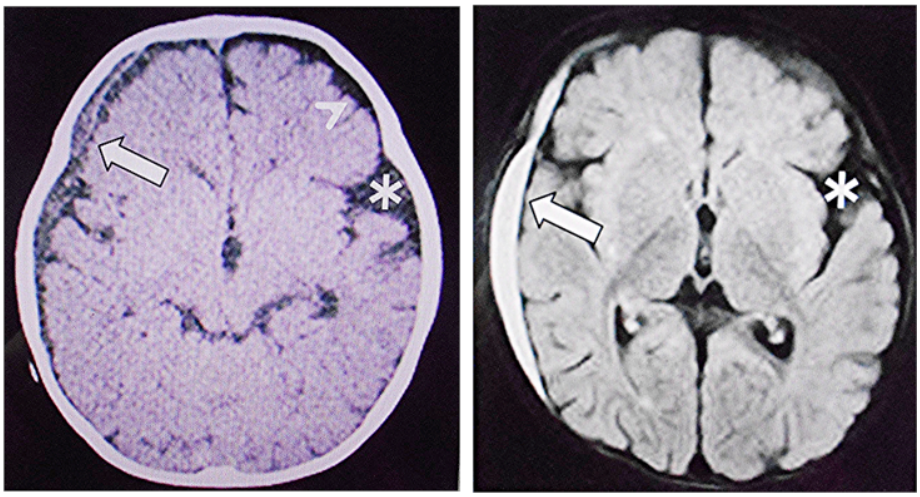

Figure 3: Case 3 (No. 12), male aged 9 months. **Left:** Axial CT on arrival showing a mixed-density subdural hematoma on the right side (arrow) with no mass effect. Note enlargement of subarachnoid space (arrowhead) and the LSF on the left side. (asterisk). **Right:** Fluid-attenuated inversion recovery MRI at day 2 after onset showing the SDH on the right side (arrow) and the LSF on the left side. (asterisk) No cerebral parenchymal abnormality was confirmed on the other MRI sequences (not shown).

Case 4 (No. 13)

The patient was a 12-month-old male who had begun to stand at the age of 11 months and experienced several, asymptomatic falls while at home. On the day of the accident, he had a respiratory syncytial virus infection. He fell backward from a standing position and struck the occipital area on a wooden floor. He began crying immediately and displayed signs of altered consciousness. The patient was brought to an emergency hospital, where CT led to a diagnosis of SDH with a mass effect on the right side (Figure 4, left). Due to persistent disturbance of consciousness, he underwent emergency subdural drainage, which revealed hemorrhagic fluid including small volume of clots. An ophthalmological examination found bilateral retinal hemorrhages. He was hospitalized for further observation and was reported to a childcare center, which ruled out AHT as the cause of his condition. MRI performed two days later found a decrease in the SDH and the absence of any cerebral parenchymal injury (Figure 4, right). Outpatient follow-up examinations at the 3-year-4-month confirmed normal development with no deficits.

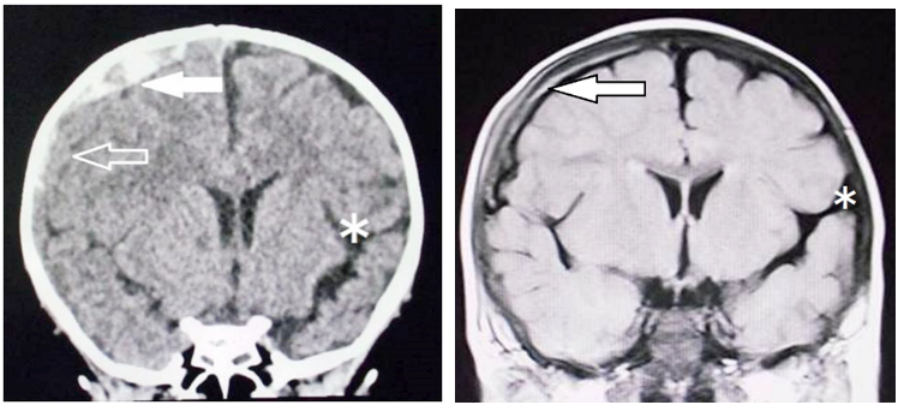

Figure 4: Case 4 (No. 13), male aged 12 months. **Left:** Coronal CT on arrival showing a mixed-density SDH , high density in the upper part (arrow) and low density in the lower part (open arrow) on the right side with a midline shift to the left side. Note the LSA on the left side. (asterisk). **Right:** Fluid-attenuated inversion recovery coronal MRI on postoperative day 1 showing a decrease in the volume of the SDH on the right side (arrow) and the LSF on the left side. (asterisk) No cerebral parenchymal abnormality was confirmed on other MRI sequences (not shown).

Discussion

Based on the biophysiological characteristics of infants, IASDH was originally defined in 1984 as an acute, infantile subdural hematoma apparently caused by minor head trauma without loss of consciousness and not associated with a primary brain injury [3]. IASDH has been reported since the 1960's in Japan [5]. However, because most cases were published in Japanese-language journals and accusations that the diagnosis was an attempt to conceal child abuse were frequently raised, the concept of IASDH has not been widely accepted in the English-speaking world. Indeed, a previous case study of 24 IASDH cases published in 1984 was critically reviewed in a Letter to the Editor as follows: "While not totally pathognomonic of shaking, the constellation of subdural hematoma and retinal hemorrhage in the context of a historically trivial injury should be regarded as whiplash shaken baby syndrome unless another etiology can be determined" [6]. However, recent Japanese reports have demonstrated that patients with IASDH can be distinguished from those with SBS/AHT through multidisciplinary assessment, including an evaluation by child abuse pediatricians and pediatric neurosurgeons [2,7-9]. Moreover, neuroimaging studies can rule out cerebral parenchymal injury, including a cerebral contusion and Diffuse Axonal Injury (DAI), when diagnosing IASDH. Table 3 lists the differing features of IASDH and SBS/AHT.

As noted earlier, the biophysiological characteristics of infants, particularly the immaturity of The Cerebrospinal Fluid (CSF) dynamics, induce age-regulated accumulation of CSF in the Subarachnoid Space (SAS). [10] This phenomenon is commonly observed in infants between the ages of 6 and 10 months and also occurs in some patients with BESS [11].

	IASDH	SBS/AHT
Applied force	minor head trauma	abuse (high energy impact)
Main etiology	disruption of bridging vein	cerebral contusional tears
Primary brain injury	none	common
Age distribution	peak in 6 ~ 10 months	widely distributed (including less than 3 months)
Gender	marked preponderance in male	no preponderance
Recurrence	rare	not rare
Prognosis	depending on volume of hematoma (mostly, benign clinical courses)	poor
Retinal hemorrhage	frequent	common

(Cited from [5] with permission by Japanese Society of Pediatric Neurosurgery)

Table 3: Comparison between infantile acute subdural hematoma (IASDH) and shaken baby syndrome (SBS) /abusive head trauma (AHT).

As the present series has shown, a SDH consisting purely of clot which is commonly observed in adult patients, is rarely seen in cases with IASDH. Neuroimaging studies have demonstrated that IASDH consists of a mixed-density SDH, possibly resulting from a simultaneous rupture of the arachnoid membranes and bridging veins. Because infants have a relatively large head in relation to the rest of their anatomy, they are more likely to fall backwards while in a sitting or standing position, thereby potentially striking the occipital area and precipitating IASDH. In Japan, about 1 million times of infantile fall occur yearly, with about 100 of these resulting in IASDH development [1]. Understanding the etiology of IASDH in these patients is important from a medico-legal standpoint. In the present study, the author has focused on intracranial, structural vulnerabilities that can give rise to IASDH. One of the more important CT and MRI findings in this respect is the presence of various degrees of LSF in all the cases reviewed.

Structurally identical to BESS, LSF contributes to the development of Craniocerebral Disproportion (CCD)7). Moreover, LSF is anatomically associated with Small Temporal Lobes (STL) (Figure 5). In infants with CCD, LSF co-occurring with STL can contribute to loosening the tight fixation of the temporal lobes in the middle cranial fossa and sphenoid ridge. In this situation, a mild occipital impact can sufficiently enhance the rotational force of the brain to cause tearing of the arachnoid tissue and rupturing of the bridging veins (Figure 5). Future, international discussions of IASDH may address the following questions and topics:

1) Is IASDH specific to Japanese infants?

2) Is IASDH really so rare that it does not exist in the English-speaking world?

3) Neuroimaging findings of subdural hematomas in infants should be compared between the English-speaking world and Japan. It is particularly important to address the presence or absence of LSF in patients with SBS/AHT in the English-speaking world.

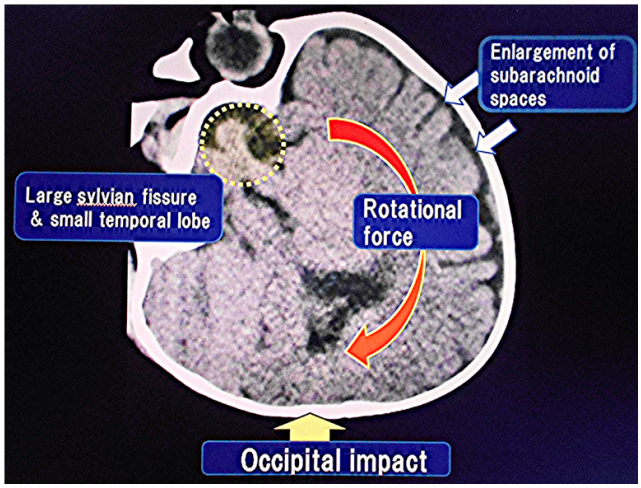

Figure 5: Schematic illustration of Case 1 (No. 7). CT sagittal view in the prone position. The LSF can be seen together with Small Temporal Lobe (STL). (dotted circle) In infants with CCD, LSF co-occurring with STL can contribute to loosening the tight fixation of the temporal lobes at the middle cranial fossa and sphenoid ridge. In this situation, a mild occipital impact can sufficiently enhance the rotational force of the brain to cause tearing of the arachnoid tissue and rupturing of the bridging veins.

Conclusion

In conclusion, the age-regulated accumulation of CSF in SAS induces CCD. LSF co-occurring with STL has the potential to contribute to loosening the tight fixation of the temporal lobes at the middle cranial fossa and the sphenoid ridge. In infants with these intracranial structural characteristics, a mild occipital impact can sufficiently enhance the rotational force of the brain to induce IASDH development.

Limitations

The present study has several limitations. The patients were all ethnically Japanese infants who were referred to the study center for a second opinion. Therefore, the findings may not be generalizable to infants of other ethnic backgrounds. Moreover, all the patients in this series were managed on an emergency basis, thus potentially introducing a selection bias.

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