

# Recent Progress and Future Issues in the Management of Abusive Head Trauma

Hiroshi NISHIMOTO<sup>1,2</sup>

<sup>1</sup>Department of Neurosurgery, Saitama Children's Medical Center, Iwatsuki, Saitama;

<sup>2</sup>Department of Neurosurgery, Kasukabe Municipal Hospital, Kasukabe, Saitama

## Abstract

Head trauma is the leading cause of death in child abuse cases and one of the important issues in the care of abused children. Since the Child Abuse Prevention Law was enforced in 2000 in Japan, various measures have been taken to prevent child abuse over the following decade. Accordingly, medical research on abusive head trauma (AHT) has advanced, leading to significant progress in the medical diagnosis of AHT. This progress has been brought about by (1) the widespread establishment of child protection teams (CPTs) at core hospitals, (2) the progress in neuroradiological imaging and ophthalmoscopic technologies, and (3) the introduction of postmortem imaging. However, the pathological condition of patients with AHT, particularly that of the diffuse brain swelling type, still remains poorly understood. As a result, no clear treatment strategies for AHT have been developed and no treatment outcomes have been improved to date. The development of new treatment strategies for AHT and the construction of a comprehensive database that supports clinical studies are required in the future.

Key words: abusive head trauma, shaken baby syndrome, child abuse, pediatric head injury, retinal hemorrhage

## Introduction

Abusive head trauma (AHT) is the leading cause of death in child abuse cases and one of the important issues in the care of abused children.<sup>1)</sup> In addition, the pathological condition, diagnosis, and treatment of children with AHT are completely different from those of accidental head trauma in children in terms of characteristics and underlying problems, which should be well understood to develop effective treatment strategies for AHT. The recent progress and future issues in the treatment of AHT are reviewed in this article.

### I. Recent trends in child abuse and history of related policies in Japan

The number of consultations on child abuse in child guidance centers in Japan has been increasing since 1990 and reached 66,701 in 2012 (Fig. 1).<sup>2)</sup> The preliminary figures for 2013 are 73,765. The main causes of this increase seem to be the growing public awareness of child abuse and the decline in the capacity for nurturing children in the locality or at home. An examination of deaths in child abuse

cases, which was initiated by the Ministry of Health, Labour and Welfare in 2003, revealed that there are approximately 50 deaths every year, about 43% of which involved infants 1 year of age or younger. The major causes of such deaths are head trauma and asphyxia; head trauma is still a serious medical condition in abused children.<sup>1)</sup>

Tracing back the history of policies on child abuse in Japan,<sup>3)</sup> the Child Abuse Prevention Law was enforced in November 2000, and this law and the Child Welfare Law were revised in October 2004 for the purpose of extending the obligation of notification to child guidance centers and promulgating the Regional Council of Countermeasures for Children Requiring Aid (a regional network for protecting children). In April 2008, the regional network for protecting children was improved so that on-site inspection to confirm the safety of children was reinforced and information regarding high-risk children who had medical problems during the perinatal period and who were difficult to raise came to be shared throughout a certain region (Fig. 2).<sup>2)</sup>

The revised Organ Transplant Act was fully enforced in July 2010, which enabled organ donation from children and required the establishment of child protection teams (CPTs) at organ donor hospitals

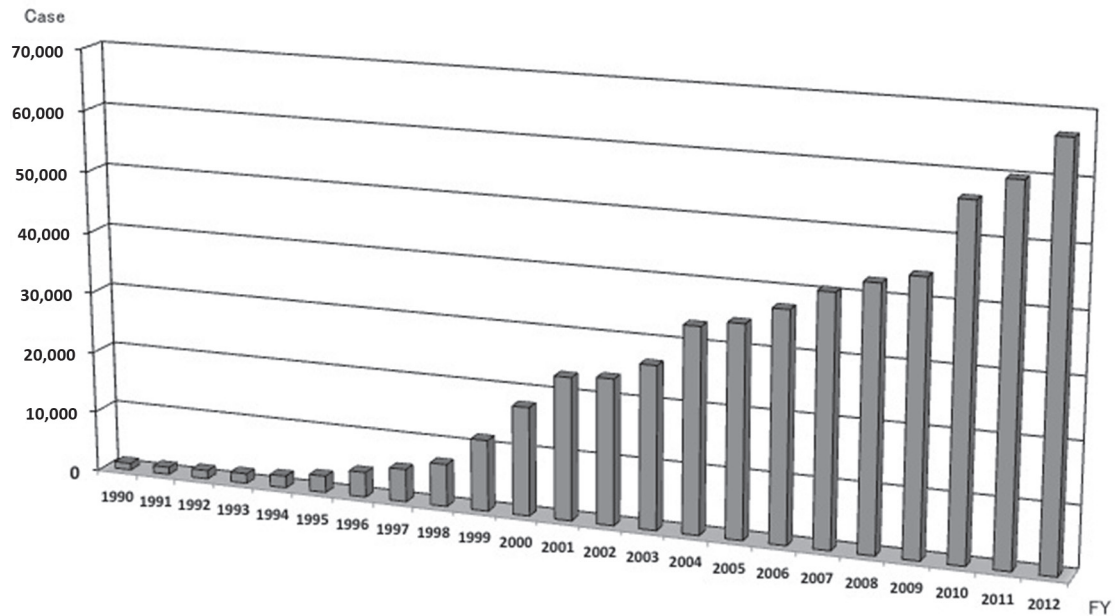


Fig. 1 Changes in the number of child abuse consultations handled at child guidance centers in Japan.

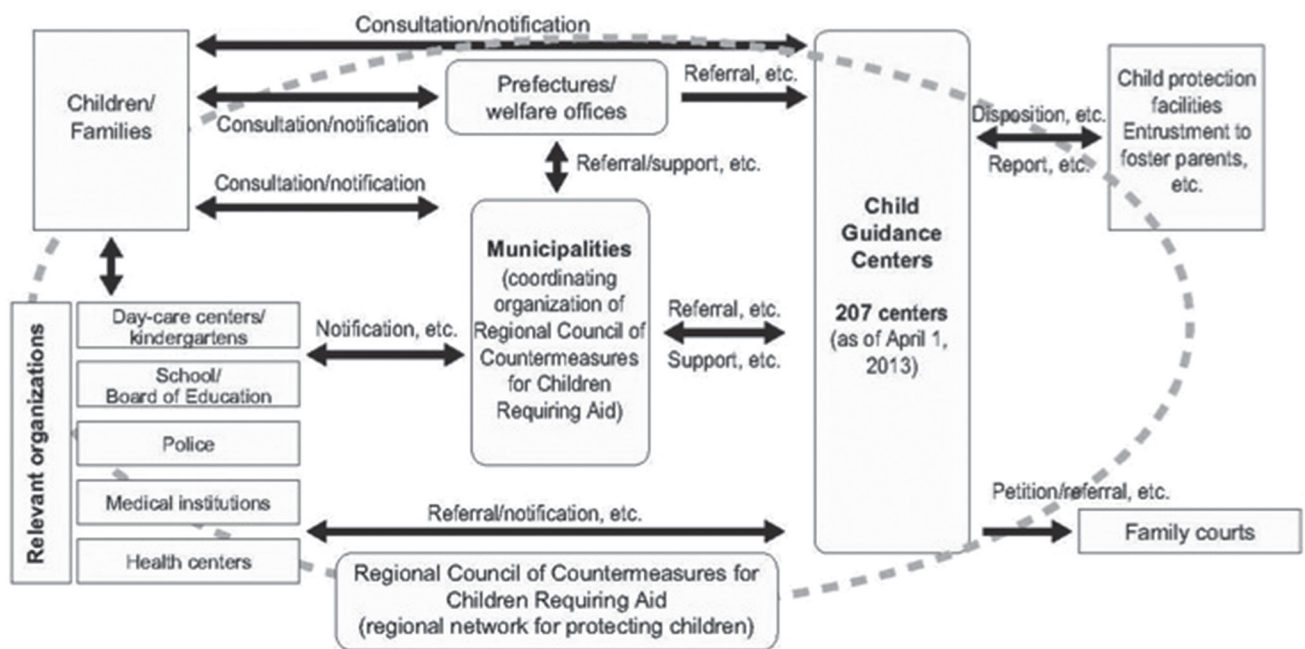


Fig. 2 Child abuse prevention system in regions of Japan (Quoted from the Annual Health, Labor, and Welfare Report 2012–2013 by the Ministry of Health, Labour and Welfare Japan,<sup>2)</sup> <http://www.mhlw.go.jp/english/wp/wp-hw7/index.html>).

across Japan.<sup>4,5)</sup> This led to the rapid establishment of CPTs at regional core hospitals across the country.

## II. Effects of establishment of CPTs at regional core hospitals

A CPT is an expert team consisting of specialists

from different fields including doctors, nurses, and social workers and dealing with child abuse cases at hospitals. The aims of the establishment of CPTs are to standardize the handling of these cases and to reduce the burden on primary doctors.<sup>4)</sup> The CPT at Saitama Children’s Medical Center (SCMC) has been

functioning as a formal organization of the hospital since the fiscal 2003. The number of reports of child maltreatment to the CPT from other departments of the hospital has rapidly increased after the start of its activities, and now there are approximately 120 cases that require attention every year. Approximately 10 such cases are notified in writing to child guidance centers as actual child abuse cases.

With the start of the activities of CPT, an awareness of child abuse among hospital staff members, who provide daily clinical care and support to the patients' families from the perspective of child abuse prevention, has been raised. The activities of CPT have also led to the establishment of guidelines in the handling of child abuse cases in the hospital, the enhancement of regional cooperation, and the promotion of expertise of team members and medical research on child abuse. Figure 3 shows recent changes in the number of child maltreatment cases examined by the CPT. Although the percentage of physical abuse has been decreasing yearly because of the initiation of support at early stages, the percentages of cases of neglect and psychological abuse are increasing. The promotion of early intervention resulted in a decrease in the percentage of child abuse that culminated in physical abuse.

Future issues facing the CPT are the provision of educational trainings to improve the expertise of CPT members, the establishment of standard criteria for identifying child abuse cases among hospitals, the establishment of a feedback system for information about notified cases from child guidance centers and the police to hospitals, and the enhancement

of information sharing among various regions.

### III. Progress in diagnosis of AHT

Recent progress in the diagnosis of AHT includes progress in neuroradiological imaging and ophthalmoscopic technologies, and the introduction of postmortem imaging (autopsy imaging).

**Progress in neuroradiological imaging:** Computed tomography (CT) was conventionally the first choice of neuroradiological imaging in child abuse cases, and magnetic resonance imaging (MRI) was mainly used in the subacute or chronic phase.<sup>6-9)</sup> Recently, however, it has been stressed that the assessment of the accompanying brain parenchymal injury is important for accurately determining the cause and prognosis.<sup>10-12)</sup> Because the use of MRI at an early stage is essential in assessing brain parenchymal injury,<sup>13,14)</sup> the guidelines for diagnostic imaging of AHT<sup>15)</sup> recommend the use of MRI 3 days to 5 days after the trauma.

The recommended MRI techniques are spin-echo ( $T_1$ -weighted and  $T_2$ -weighted) sequencing,  $T_2^*$ -weighted gradient-echo, diffusion-weighted imaging, and fluid-attenuated inversion recovery (FLAIR) sequencing.<sup>13-15)</sup> Recently, the significance of susceptibility-weighted imaging (SWI) in AHT has been drawing attention.<sup>16-18)</sup> Colbert et al. (2010)<sup>19)</sup> reported that AHT patients with microhemorrhage detected by SWI and with ischemia shown by diffusion-weighted imaging have a poor prognosis and that SWI is useful for predicting the prognosis at an early stage. Yilmaz et al. (2014)<sup>20)</sup> reported that clot formation is detected by SWI at an early

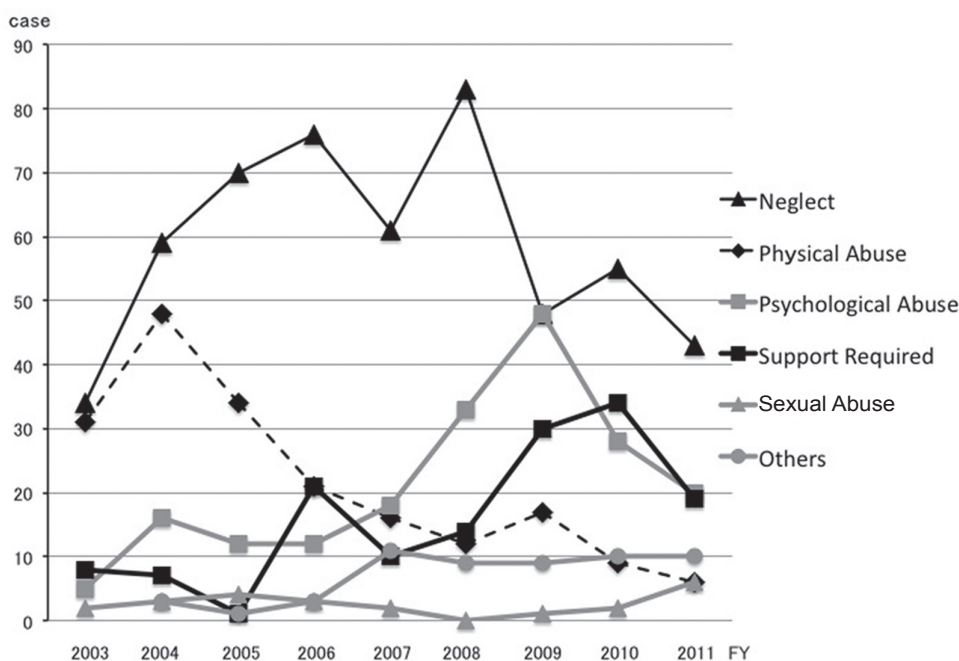


Fig. 3 Changes in the number of child maltreatment cases reported to Child Protection Team at Saitama Children's Medical Center.

stage at sites of multiple bridging vein injuries due to violent shaking, which enables the differential diagnosis between acute subdural hematoma due to AHT and that due to other causes.

The pathogenetic mechanism underlying hypoxic-ischemic injury, which occurs in association with AHT, has remained largely unclarified. Hypoxic-ischemic injury is an important factor that markedly determines the prognosis of AHT patients. Conventionally, temporary respiratory failure due to cervical injury caused by violent shaking has been considered a pathogenetic mechanism underlying hypoxic-ischemic injury. However, parenchymal injury of the cervical spinal cord is rarely identified in MRI.<sup>21,22</sup> Kadom et al. (2014)<sup>23</sup> reported that, in examining injury of the ligament of the cervical spine in 74 children with head trauma and who underwent cervical spine MRI, cervical cord ligamentous injury was observed in 81% of children with bilateral hypoxic-ischemic brain injuries. This is an interesting finding on the pathogenesis of hypoxic-ischemic brain injury in patients with ATH. Thus, the use of cervical spine MRI in the acute phase of AHT should be examined in the future.

The major findings of the neuroradiological examination of AHT are interhemispheric subdural hematoma, posterior fossa subdural hematoma, subarachnoid hemorrhage, intraventricular hemorrhage, hypoxic-ischemic parenchymal brain injury, big black brain, and contusional cleft;<sup>8–10,13</sup> however, none of these are specific to AHT. Therefore, a definite confirmation of child abuse cannot be achieved by neuroradiological imaging alone<sup>24,25</sup> but requires a complete skeletal survey and ophthalmoscopy.

A complete skeletal survey is important in the diagnosis of the metaphyseal fractures of the appendicular skeleton, posterior rib fractures, and multiple fractures in different stages of healing, which are strong indicators of child abuse. It should be performed twice; at the time of admission and 2 weeks after the first examination.<sup>26</sup> The second examination is required because the periosteal reaction due to fractures is not necessarily detected at the first examination. Three-dimensional (3D) CT can be used in addition, if necessary, in the diagnosis of rib fractures.

**Progress in ophthalmoscopy:** Retinal hemorrhage is observed in 85% of patients with AHT and in 100% of postmortem cases.<sup>27–29</sup> A theory, namely, retinal hemorrhage is caused by the traction applied to the eyeballs owing to acceleration injury, is currently favored.<sup>27–30</sup> The basis of this theory is that retinal hemorrhage is concentrated at the posterior pole and ora serrata where the attachment

between the retina and the sclera is strong but is scarcely observed in the intermediate peripheral zone.<sup>31</sup> Whether the hemorrhage is localized to the retina posterior pole or extends to the peripheral retina is a key point for identifying child abuse.<sup>32</sup>

The layers affected by retinal hemorrhage is another key point. It has been reported that hemorrhage is observed in multiple layers of the retina when traction is applied to the eyeballs.<sup>27–30,33</sup> Observation across a wide area of retina is therefore essential in ophthalmoscopy in child abuse cases, which means observation and imaging using a wide-field digital fundoscope.<sup>34</sup>

Fundoscopy examinations using the wide-field digital ophthalmic camera system (RetCam 3™; Clarity Medical Systems Inc., Pleasanton, California, USA) are performed by a pediatric ophthalmologist. The RetCam 3 camera is technically the easiest to use and offers the advantage of excellent wide-angle views (30–130 degree). Before starting the RetCam examination, it is essential that the pupils are dilated well. Pupils are dilated with 0.5% phenylephrine and 0.5% tropicamide eye drops (Mydrin-P®; Santen Pharmaceutical Co. Ltd., Osaka), half an hour before the procedure. Oxybuprocaine hydrochloride (0.4%) eye drops (Benoxil®; Santen Pharmaceutical Co. Ltd.) are used for topical anesthesia. After a pediatric lid speculum is inserted, a coupling agent like 1.5% hydroxyethyl cellulose (Scopisol®; Senju Pharmaceutical Co. Ltd., Osaka) is used so that the hand-held camera can be placed over the cornea. The operator adjusts the light intensity and changes focus to get a sharp image using foot switch controls. The setting can be changed to save still images. While recording the images, it is customary to first photograph the anterior segment, followed by the posterior pole, and then the retinal periphery.

Defoort-Dhellemmes et al.<sup>33,35</sup> distinguishes between three types of retinal hemorrhages, depending on their number and their extent:

Type 1: intraretinal hemorrhages, flame-shaped, blots or punctiform, situated at the posterior pole of the eye;

Type 2: preretinal dome-shaped hemorrhages, small (no larger than the diameter of the optic disc) and pearl-shaped, situated at the posterior pole, around the optic disk and along the vascular arcades or mid-way out towards the periphery. These hemorrhages may occur alone or in combination with type 1 retinal hemorrhage;

Type 3: profuse, multiple hemorrhages of all types (intra-, pre-, or subretinal), coating the whole retina or flecked out to its periphery, combined with unilateral or bilateral premacular hemorrhagic plaques (which are sometimes immediately

suggestive of hemorrhagic retinoschisis).

Type 3 hemorrhage, a multilayer hemorrhage extending into the peripheral retina, is highly specific to AHT, whereas types 1 and 2 hemorrhages that are localized around the posterior pole are observed in both AHT and accidental head injury. It is therefore impossible to diagnose AHT due to child abuse based on the presence of retinal hemorrhage alone. Therefore, the assessment of the severity of retinal hemorrhage is always important.

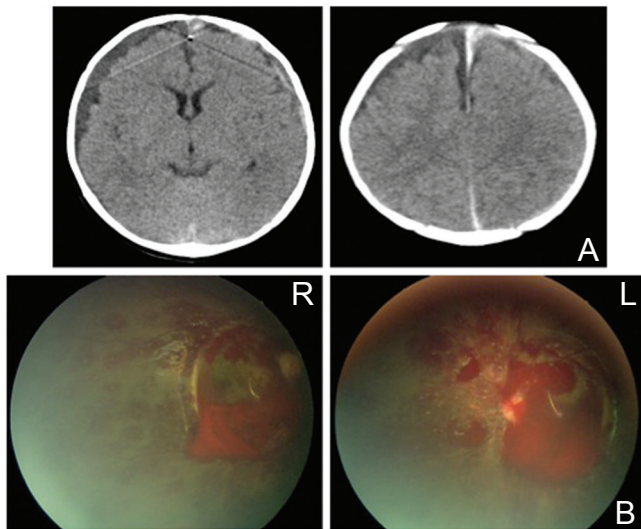
**Illustrative cases:** Case 1 was a 2-month-old girl with acute subdural hematoma due to AHT. Multilayer retinal hemorrhage was observed over a wide area in both eyes by ophthalmoscopy (Fig. 4). Her father explained that convulsion and cyanosis suddenly occurred at about 20:30 in the evening. A small skull fracture was found by a complete skeletal survey and determined to be caused by child abuse. This case was reported to a child guidance center and the girl was temporarily taken into protective custody.

Case 2 was a 9-month-old boy who, as witnessed by his mother, fell down backward on the floor while standing with hold at home. He screamed immediately after the fall, then fell into a drowsy state, and was thus taken to the hospital as an emergency patient. Very mild hemorrhage localized

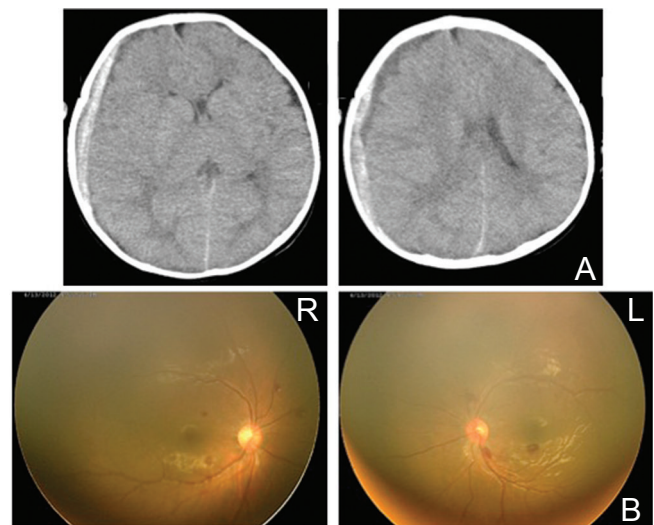
around the posterior pole of both eyes was detected by ophthalmoscopy (Fig. 5). After discussion among CPT members and consultation with a child guidance center, this case was determined as an accidental head injury. The boy left the hospital after guidance was provided to his parents on the basis of the programs for the prevention of accidents at home.

**Introduction of postmortem imaging (autopsy imaging):** Some of the children taken to the hospital as emergency patients had cardiopulmonary arrest on arrival (CPAOA) or had an unclear cause of death. These may include child abuse cases.<sup>1)</sup>

In 1989, Kleinman et al.<sup>36)</sup> conducted a complete skeletal survey of 12 postmortem cases of infants with an unclear cause of death. The cause of death was child abuse in eight cases, an accident in two cases, and sudden infant death syndrome in two cases. Their study suggested, for the first time, the significance of postmortem imaging in the determination of child abuse. In the postmortem CT (PMCT) imaging of 38 infants who unexpectedly died in Japan, acute subdural hematoma, skull fracture, and clavicular fracture were observed in three infants. These findings provide the basis for suspecting child abuse, which was not expected in clinical practice.<sup>37)</sup>



**Fig. 4** Cranial computed tomography (CT) findings and wide-field fundus photographs in Case 1. A: Plain-CTs, B: Bilateral fundus photographs. Non-contrast CT scans demonstrate mixed dense bilateral frontal and hyperdense interhemispheric subdural hematomas with loss of the normal gray-white matter differentiation. Bilateral multiple pre-, intra-, and subretinal hemorrhages extended from the posterior pole to the peripheral retina are shown. L: left, R: right.



**Fig. 5** Cranial computed tomography (CT) findings and wide-field fundus photographs in Case 2. A: Plain-CTs, B: Bilateral fundus photographs. CT scans show a right-sided mixed dense subdural hematoma with mass effect and midline shift. The cerebral hemispheres retain normal densities and a normal gray-white matter interface. Bilateral few small intraretinal hemorrhages are shown at the posterior pole of the retina. L: left, R: right.

Because CT is effective for detecting fractures, fractures of the appendicular skeleton and ribs, which are difficult to detect by autopsy, are sometimes detected by PMCT.<sup>38)</sup> Recently, in our hospital, PMCT imaging has been performed on patients with CPAOA or unclear cause of death regardless of whether an autopsy is carried out or not. The use of postmortem MRI in some cases has been reported;<sup>39)</sup> however, CT is usually used in our hospital because there are no concerns about radiation exposure in postmortem cases and MRI is not readily available at night.

#### IV. Differentiation between accidental acute subdural hematoma in infants due to trivial head trauma and that due to AHT

Acute subdural hematoma caused by an accidental fall from a low height seen by neutral witnesses has been rarely reported in other countries.<sup>40–42)</sup> Moreover, there have been no reports on the simultaneous occurrence of acute subdural hematoma and retinal hemorrhage caused by an accidental fall from a low height seen by neutral witnesses.<sup>43–45)</sup>

In Japan, however, there have been many reports of accidental acute subdural hematoma in infants due to trivial head trauma caused by something other than child abuse. In the 14 key studies of many cases of accidental acute subdural hematoma in infants during the period from 1965 to 2009,<sup>46,47)</sup> the clinical picture of the reported symptoms remained consistent for approximately 40 years (Table 1). This shows that acute subdural hematoma caused by trivial household head trauma indeed exists (Fig. 5). Although there was no case witnessed by reliable and neutral observers in these key

**Table 1 Clinical features of accidental acute subdural hematoma in infants due to trivial head trauma**

1. Age of patients: limited age distribution (peak in from 6 months to 10 months old)
2. Gender of patients: striking preponderance in male (almost 80%)
3. Cause of the accidents: caused by a trivial household head trauma such as a backward fall on the floor, a fall while standing with hold, or a fall from a low height
4. Site of head blow: occipital of the head
5. Initial symptoms: convulsion or slight disturbance of consciousness
6. Retinal hemorrhage: frequent, but less than abusive head trauma, grading of hemorrhage has not been reported
7. Neuroimaging or operative findings: absence of primary parenchymal brain injury such as cerebral contusions or contusional tears
8. Outcomes: benign clinical courses in many cases, no recurrence of hematomas

studies, the possibility of child abuse was often excluded based on these long-term follow-up studies. Nishimoto et al. (2006)<sup>48)</sup> conducted a long-term follow-up study of 25 infants with acute subdural hematoma that met the conditions listed in Table 2 and was attributed to trivial household head trauma based on the differential diagnosis that took into consideration the possibility of child abuse. Their report pointed out the enlargement of the subarachnoid space as the underlying cause of acute subdural hematoma.

Miyazaki et al. (2012)<sup>49)</sup> carried out an engineering simulation of head trauma due to a fall from a low height and backward fall on a floor while standing with hold and AHT due to violent shaking using a dummy human body model. They examined the possibility of damage to the bridging veins on the brain surface in each case and found that violent shaking more likely caused damage to the bridging veins than a fall from a low height or backward fall. In the engineering simulation, they also demonstrated that the bridging veins were unlikely damaged by head trauma caused by a backward fall on a floor while standing with hold in cases without enlargement of the subarachnoid space. On the other hand, the possibility of damage to the bridging veins was high regardless of the material of the floor against which the head hits in cases with enlargement of subarachnoid space of 9 mm in width because the bridging veins were stretched even before the occurrence of trauma. These results indicate that there are some anatomical factors in the body that are involved when accidental acute subdural hematoma in infants occurs. Some reports in other countries also support this finding.<sup>50–53)</sup>

Retinal hemorrhage is also observed in patients with accidental acute subdural hematoma although

**Table 2 Requirements for the patient selection of accidental acute subdural hematoma in infants**

1. Infantile acute subdural hematoma caused by a trivial household head trauma and a history of trivial household trauma corroborated by the caretaker.
2. Absence of any physical injuries that are consistent with child abuse.
3. Optic fundoscopic examinations were performed by a pediatric ophthalmologist. No extensive, multi-layered retinal hemorrhages were shown on the fundus photograph.
4. Absence of any fractures on complete bone survey (on admission, 2 weeks after the admission).
5. Child abuse had been denied by the long-term follow-up (more than 5 years) results.

Modified from Nishimoto et al.: *Nervous System in Children* 31: 215–223, 2006.<sup>48)</sup>

the incidence is lower than that in patients with AHT.<sup>46–48)</sup> Whether the severity of retinal hemorrhage is milder than that in AHT and whether the hemorrhage is localized to the posterior pole are unclear because there have been no studies yet that examined the range and severity of retinal hemorrhage in detail.<sup>46–48)</sup> This issue requires further study in the future.

There is a significant difference between the understanding of accidental acute subdural hematoma due to trivial head trauma in Japan and that in other countries. This difference is explained by the fact that, in other countries, the injury not witnessed by neutral observers is treated as child abuse in principle and accidental injury due to trivial household trauma is not considered.

### V. Issues in the treatment of AHT

AHT is classified into one of the following three types based on the CT findings: (1) diffuse brain swelling type (encephalopathy type), (2) acute subdural hematoma type, and (3) chronic subdural hematoma type. The incidences of types (1), (2), and (3) are reported to be 41%, 29%, and 29%, respectively.<sup>54)</sup> Hypoxic-ischemic injury may be directly or indirectly related to all types of AHT, making the treatment of AHT difficult. Other factors that make the treatment difficult are the unclear number of times AHT occurred and the time when the trauma was inflicted.

In particular, the pathogenesis and clinical state of patients with AHT of the diffuse brain swelling type are poorly understood. Although hypothermia<sup>55)</sup> and external decompression are applied as treatment strategies, currently, such strategies for AHT of the diffuse brain swelling type are still controversial. Cho et al. (1995)<sup>56)</sup> examined the effectiveness of external decompression in 32 patients with shaken baby syndrome. They compared the prognosis among (1) the group of patients with an intracranial pressure (ICP) lower than 30 mm Hg who underwent medical therapy, (2) the group with an ICP of 30 mm Hg or higher who underwent medical therapy, and (3) the group with an ICP of 30 mm Hg or higher who underwent medical therapy and external decompression. The result indicated that external decompression led to decreases in mortality rate and the incidence of sequelae in the patients with shaking baby syndrome whose ICP was 30 mm Hg or higher.

On the other hand, Oluigbo et al. (2012)<sup>57)</sup> compared the prognosis of 37 children with accidental head injury or AHT who underwent external decompression. External decompression was performed on the patients whose ICP was 20 mm Hg or higher even

after the medical therapy including the drainage of cerebrospinal fluid (CSF). As a result, the mortality rate was significantly higher in the patients with AHT than in the patients with accidental head injury, and the percentage of patients with poor prognosis was also higher in the patients with AHT. These findings did not demonstrate the effectiveness of external decompression for AHT.

As mentioned above, there have been no clear treatment strategies for AHT of the diffuse brain swelling type. This issue requires further research.

### VI. Future issues

In Japan, great progress has been made in the establishment of a system for dealing with child abuse and in AHT diagnosis. In particular, progress in research on the medical diagnosis of AHT has been remarkable. However, the development of treatment strategies for AHT and the improvement of their outcomes have been limited. Thus, there is an urgent need to develop effective treatment strategies for AHT.

A comprehensive database on the cases of AHT in Japan has not yet been constructed. Therefore, the construction of such a nationwide database is essential and urgently required to promote medical research on AHT.

### Conclusion

The author has reviewed the recent progress in the diagnosis and the treatment of AHT and also referred to future issues concerning AHT.

### Conflicts of Interest Disclosure

The author has no conflict of interest. The author who is a member of the Japan Neurological Society (JNS) has registered online Self-reported COI Disclosure Statement Forms through the website for JNS members.

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Address reprint requests to: Hiroshi Nishimoto, MD, Department of Neurosurgery, Kasukabe Municipal Hospital, 7-2-1 Chuo, Kasukabe, Saitama 344-8588, Japan.  
e-mail: hiro\_nishi1130@fd5.so-net.ne.jp