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# Shaken to the core - understanding the impact of infant trauma

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Summary.
Shaken Baby Syndrome (SBS) is a severe form of abusive head trauma (AHT) in infants, caused by violent shaking. This leads to brain injuries, bleeding, swelling, and can result in lifelong disability or death. Misconceptions about the harmlessness of shaking contribute to its underdiagnosis. Infants' large heads, weak neck muscles, and fragile brain tissues make them highly susceptible to injuries from shaking, leading to ruptured veins and diffuse axonal injury. AHT affects 20-40 per 100,000 children under one year old, with triggers including excessive crying and caregiver frustration, often in cases of infantile colic. Both victims and

perpetrators are usually male, with disabled children at higher risk. Diagnosing SBS is difficult due to subtle symptoms like irritability, lethargy, poor feeding, and vomiting. The classic triad includes subdural hematoma, cerebral edema, and retinal hemorrhage. Caregiver history is crucial, as explanations often conflict with the injury. Diagnosis involves clinical assessments, X-rays, CT scans, MRIs, ophthalmological evaluations, and blood tests to identify injuries and rule out other conditions. SBS has a high mortality rate (20-30%) and causes severe long-term damage in over 90% of survivors, including cerebral palsy, brain atrophy, and blindness. Raising awareness among medical professionals and caregivers is vital for prevention. Education programs show mixed results, but continuous guidance and monitoring after an episode of shaking are essential.

Keywords: Shaken Baby Syndrome (SBS); Abusive Head Trauma; (AHT), Brain injuries; abuse; violent shaking

Highlights.

- Shaken Baby Syndrome (SBS) is a severe form of abusive head trauma (AHT) in infants caused by violent shaking, leading to brain injuries, bleeding, swelling, and possible lifelong disability or death.
- Infants are vulnerable due to their large heads, weak neck muscles, and fragile brain tissues, making them susceptible to ruptured veins and diffuse axonal injury from shaking.
- AHT affects 20-40 per 100,000 children under one year old.
- Common triggers include excessive crying and caregiver frustration, often due to infantile colic.
- Diagnosing SBS is challenging with symptoms like irritability, lethargy, poor feeding, and vomiting.
- Key diagnostic tools include clinical assessments, X-rays, CT scans, MRIs, and ophthalmological evaluations.
- Raising awareness among medical professionals and caregivers is crucial.
- Education programs and continuous guidance and monitoring after shaking incidents are essential.

Abstract.

Introduction: Shaken Baby Syndrome (SBS), a severe form of abusive head trauma (AHT), primarily affects infants due to their vulnerable anatomy and physiology. SBS results from violent shaking, causing the brain to collide with the skull, leading to critical injuries including brain damage and long-term disabilities. Despite its severity, SBS is often misperceived as non-harmful, leading to delays in diagnosis and intervention.

Materials and Methods: The study involves a comprehensive review of SBS and AHT related literature from the last 10 years available in English, focusing on the mechanisms, epidemiology, clinical presentation, and diagnostic challenges associated with the syndrome.

Aim of the Study: The primary aim is to elucidate the diagnostic difficulties and underrecognized nature of SBS. The study seeks to raise awareness among healthcare providers and caregivers about the critical need for early detection and intervention. It also aims to emphasize the importance of educational programs to prevent SBS and improve outcomes for affected children.

Discussion: SBS remains a significant yet often overlooked issue in pediatric healthcare. Its symptoms can be subtle, and the perpetrators are frequently close caregivers who may not recognize the severity of their actions. Early recognition is complicated by the non-specific presentation of symptoms and the lack of established diagnostic criteria. Effective prevention requires increased awareness and education for both medical professionals and parents. Current educational programs show mixed success, highlighting the need for continuous improvement and monitoring.

Conclusion: SBS is a severe and frequently underrecognized form of child abuse with potentially devastating consequences. Effective prevention and intervention hinge on improved awareness and education. Raising consciousness among healthcare providers and the general public, along with implementing robust educational initiatives, is crucial to reduce the incidence and impact of SBS. Early diagnosis and intervention, supported by targeted education, are essential to protecting vulnerable children and mitigating long-term harm.

Background.

Shaken baby syndrome (SBS), a subtype of abusive head trauma (AHT), is a serious brain injury occurring in young children. Whereas AHT is an umbrella term covering various types of violence against the head, SBS typically results from forceful shaking or a combination of

shaking and blunt trauma. When an infant or toddler is violently shaken, their brain can bounce back and forth against the skull causing a whiplash injury, leading to bleeding, bruising, and swelling. This forceful shaking can cause head, neck, and central nervous system injuries. The consequences of SBS can be severe, including brain damage and lifelong disability 1, [2] . Shaking is often perceived as a non- harmful behavior and therefore is not diagnosed correctly nor quickly enough. It should be noted that brain injuries caused either by impingement or violet shaking are a leading cause of fatal head injury in children under 2y.o 3,[4].

Mechanism.

SBS takes place when perpetrators violently shake very young children with or without intentional impact and cause injuries to victim's skulls and intracranial contents. Babies' brains are exceptionally susceptible to maintain such injury due to their anatomy and natural physiology. Their head size and weight are massive compared to the rest of the body, whereas their neck muscles are extremely weak and incapable of stabilizing the head. Moreover, before a child turns 2 years old, their myelinization process is still incomplete and neuronal axons are of shorth length, what makes them prone to rupture. Additionally, thein brain tissue is more watery than in adults. All of these lead to babies being very sensitive to acceleration/ deceleration and whiplash mechanism injuries, which often end up in bridging veins rupture and diffuse axonal injury[5–7].

Epidemiology.

Abusive head trauma is estimated to take occur in about 20-40/ 100 000 young children below 1 year old [8] · However, it should be noted that strict diagnostic criteria for AHT are not established [9] . The main trigger for shaking behavior is extensive crying and the carer's inability to soothe the baby. Such frustration often arises when the victims suffers from infantile colic [7,10]. The incidents usually occur in infants below 6 months of age. This can be related to the fact, that usually in such age the baby has outgrown the prolonged crying sessions phase. Both victim and the perpetrator are usually male. There are several theories as to why boys suffer from AHT more often than girls. It can be happening due to social norms attributed to men, as crying is more pardonable in girls. Boys are also considered to be prone to accidental injuries and as a result early signs of abuse may be often overlooked. Perhaps acoustic characteristics of male cries are more triggering than of female ones. Another aspect which should be taken into account is boys natural predisposition to benign external hydrocephalus, which oftentimes appears as a consequence of an assault [11–14] . One more

group at risk of suffering abuse consists of children with disabilities prior to AHT. Disabled children are at 3.4 times bigger risk of abuse compared to healthy ones [15].

Immediate trigger factors for AHT related death are listed in tab. 1 [14].

| **Triggers leading to death as a result of abusive head trauma in children** |
|---|
| Crying- 20% |
| Disobedience- 6% |
| Domestic arguments- 5% |
| Toilet training- 4% |
| Feeding problems- 3% |

Tab.1

The perpetrators are usually young caregivers of poor socioeconomic background. They generally stay in a close relationship to the victim, as they are typically parents or parent's partners. Occasionally it turns out to be a paid caregiver [5,16]

According to available literature death as a direct result of AHT occurs in around 25% of cases [14,17.]

Clinical picture.

Recognizing a baby suffering from AHT or SBS poses a challenge. There are however some clinical findings which may indicate such diagnosis. Upon admission the child can present with symptoms such as:

Extreme Irritability: The child becomes unusually fussy or irritable.

Lethargy: The baby exhibits extreme tiredness, lack of movement, and an inability to stay awake.

Poor Feeding: Feeding problems or poor appetite may occur.

Breathing Difficulties: The child may have trouble breathing or have episodes of breath holding due to acquired brain damage.

Vomiting: Frequent vomiting can be a sign.

Pale or Bluish Skin: Skin color changes due to insufficient oxygen.

Convulsions: Seizures may occur.

Bulging fontanel**:** Indicates increased intracranial pressure.

All of the complaints mentioned above can also be accompanied by signs of earlier trauma and prolonged abuse. One should look for old fractures and skin lesions [6,7,14,18,19].

Classical triad of shaken baby syndrome are subdural hematoma (SDH), usually bilateral, cerebral edema and retinal hemorrhage. The triad can lead to all disruptions mentioned above. At autopsy SDH in said case mostly turns out to consist of a thin layer of subdural blood over cerebral convexities and compressed cerebral sulci with displaced corticodural veins. The amount of blood can be less than 10mL. SDH may be accompanied by a subarachnoid hemorrhage (SAH)[20–22].

Proper history taking is crucial in case of SBS. The victim is unable to provide their version of events. Hospital staff must rely exclusively on the perpetrator's testimony. Paying close attention to carers behavior and the story they are telling will sometimes suggest a diagnosis. The first thing which should raise suspicion is a delay in seeking medical help. The aggressor often denies any kind of violence took place, but later admits to a moment of frustration and an episode of innocent shaking. Elsewhen their explanation of child's trauma is highly doubtful. The trauma is either inconsistent with the mechanism in which it was acquired according to the carers or even with physical activity of the victim to cause such an injury by themself. Babies up to 4 months old are incapable of injuring themselves in this way by any movement since they simply cannot perform them. [18,20,21,23,24]

Diagnosis.

Diagnosing acute head trauma involves a combination of clinical assessment and diagnostic tests. It is based on three diagnostic evaluations in search for the classic triad: clinical, radiological and ophthalmological.

Clinical Assessment.

Most symptoms presented on admission are a direct result of brain trauma. Typical finding in AHT is subdural hematoma (SDH) usually occurring bilaterally. SDH may be accompanied by injuries of brain parenchyma or/ and diffuse axonal damage. Brain edema follows. Subarachnoid hemorrhage (SAH) can also develop. SDH can be present both in the head and in the spine. Retinal bleeding is observed very specifically in AHT. It is considered pathognomonic for AHT, as it develops in 78% cases of intentional head trauma, whereas in accidental ones occurs only in 5%. Retinal hemorrhage (RH) is the most reliable component of the triad and has a high predictive value in child abuse. In forensics RH along with subdural effusions are investigated as signs of inflicted injury. RH correlates with worse

outcome, as the incidence of RH in death cases of AHT victims is 10 times higher than in non- maltreated survivors. [20,25–28].

AN often-overlooked group of injuries spinal manifestation of SBS. Up to this day, there has only been a few studies researching the subject. Spinal SDH is a very frequent finding, along with a ligamentous injury. It usually appears in thoracolumbar or cervical spine. Due to the fact that in SBS suspected cases imaging is typically performed only up to the upper thoracic level of the spine, even though SDH is more commonly situated way lower, spinal SDHs are vastly underrecognised[6,21].

Diagnostic Tests.

X-Ray: skeletal survey is a gold standard in cases of suspected child abuse. A whole-body X-ray (Baby- gram) should be performed in search old and accompanying fractures, especially of skull and ribs, as they may be present due to compression of thorax during violent shaking of a tightly held child. If there are other children younger than 2 years old at victim's household their X-ray exam ought to be performed as well. [15,26,28,29]

Computed Tomography (CT) Scan: Identifies the scope of injury, such as subdural or epidural hematoma, and rules out fractures. Baby below 1 year old suspected of being a victim should undergo a brain CT scan without contrast [29] . The medics should look for signs of vasular injury i.e. intracranial hemorrhage, parenchymal lesions and spine injuries.[24]

Magnetic Resonance Imaging (MRI): Provides a detailed picture of brain tissue changes. DWI sequence is most sensitive in identifying parenchymal cytotoxic edema at a very early stage, multiple hours before it can be spotted in a T2 FLAIR sequence and whole days before it shows on a CT scan[20].

Opthalmological evaluation: includes indirect opthalmology, slit lamp examination, optical coherence tomography (OCT) and digital wide fundus photography.[5]

Arterial Blood Gas (ABG): Determines oxygen-carrying capacity.

Laboratory Tests:

Complete Blood Count (CBC)-Identifies hemodynamic stability and infection

Liver enzymes, blood coagulation- to exclude coagulation disorders

Urine sediments- to monitor any signs of a latent abdominal injury [30]

Long term outcomes.

AHT is a very deadly phenomenon, resulting in death in about 20-30% of cases and causing long- term damage in more than 90% of the victims.[12,14,26] Most significant cause of morbidity

and mortality is parenchymal brain injury. Diffuse brain swelling accompanied by vascular congestion lead to neuronal death and irreversible encephalopathy. All of this causes victims to suffer from very serious conditions like cerebral palsy, brain atrophy, mental retardation, epilepsy or hydrocephalus for the rest of their lives. Opthalmological disrutpions also oftentimes leave a mark on child's wellbeing leading to blindness. Long term outcomes of AHT are presented in Tab.2 [8,14,27].

| **Long term outcomes of AHT** |
|---|
| Death |
| Spastic hemipegia or quadriplegia |
| Intreatable epilepsy |
| Microcephaly with cortico- subcortical atrophy |
| Visual impairment |
| Language disorder |
| Cognitive, behavioral and sleep disorders |

Tab. 2.

Awareness and education.

As mentioned before, diagnosing SBS poses a challenge. Often, there are minimal or no external signs of injury. The child may not present any clear externals signs of abuse and the carer may not even be aware that the abuse took place, as shaking is not usually considered dangerous. Only severe cases show up at hospital door, while mild cases generally go unnoticed. More than 40% of victims show signs of prior brain injury. At this point it should be noted, that repeated events of abuse correlate with higher mortality. In around 30% of cases it takes more than a week to make the right disgnosis and requires a mean of 2,8 doctor's appointments.[15,16,25,30].

Many factors stand behind the fact that SBS is such a silent killer. Diagnostic difficulties and insufficient awareness in society are main causes. The awareness needs to be raised on both sides of the barricade- both medical professionals and parents/ carers do not realize the danger. A research on this subject has been performed among German and Polish pediatricians. In the German group 4% of responders were not aware infantile colic is a risk factor for SBS. Among Polish doctors this unawareness occured in 46% of responders[10,22].

Creating awareness about SBS is crucial for prevention. However, studies have shown that awareness and knowledge about SBS can be poor among parents.In a cross-sectional study conducted in Riyadh, Saudi Arabia, researchers investigated parental awareness, knowledge, and attitudes regarding SBS. The study aimed to identify factors related to SBS awareness. While the results did not specify all factors, it highlights the importance of disseminating information during pregnancy, as 38.7% of parents wanted to receive SBS information at that time[31].

The way to prevent SBS is through education, raising awareness and impulse control learning. Targeted, hospital based educstion programs are suggested to be the way of doing so and there is some data on them being succesful, but overall the results are mixed [15,32] . In one experiment researching maternal shaking behaviors it turned out mothers who performed an act of shaking once are prone to do so again. Guidance and monitoring shall be implemented even after one episode of violent shaking[22].

Conclusions.

Shaken Baby Syndrome (SBS) is a critical and often underrecognized form of abusive head trauma that can lead to severe and lifelong consequences for infants. The unique vulnerabilities of infants, combined with the frequent misperception of shaking as harmless, contribute to the difficulty in diagnosing and preventing this condition. Raising awareness among caregivers and medical professionals through targeted education programs is essential. Early diagnosis and intervention, alongside continuous support and monitoring, are crucial to mitigating the devastating effects of SBS and protecting the well-being of vulnerable children.

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