

## "EXPERT ASSESSMENT OF DIFFUSE AXONAL BRAIN DAMAGE"

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**Abstract.** Diffuse axonal brain injury (DAI) is a variant of severe traumatic brain injury, the main substrate of which are diffuse breaks or tears of axons. DAI is characterized by a prolonged comatose state that has arisen since a traumatic brain injury (TBI). Its morphological manifestations are diffusely distributed axon ruptures and small focal hemorrhages in cerebral structures. DAI is mainly common among young people and children. In childhood, it is accompanied by more severe neurological disorders and a deeper coma. (1,3,4,12).

Some authors suggest the division of DAI by severity (2,5,6,8). Mild degree corresponds to a coma duration of 6-24 hours, moderate – coma longer than a day, but without gross stem manifestations. Severe diffuse axonal brain damage is characterized by a prolonged coma with symptoms of decortication and decerebration.

From a forensic point of view, DAI presents certain difficulties both in determining the severity of the injury inflicted, and, in particular, in making a forensic diagnosis in case of fatal TBI. In such cases, with all the evidence of traumatic brain injury, clinical and morphological manifestations of DAI are very scarce. To date, there are no scientifically sound recommendations for the forensic assessment of TBI in diffuse axonal lesions of the brain.

**Keywords:** diffuse axonal brain injury (DAI), axonal brain damage, mobile hemispheres, focal contusion injuries.

**The aim** of the study was to develop clinical and morphological criteria for assessing the diagnosis and severity of traumatic brain injury in diffuse axonal injuries.

### **Materials and methods of research.**

The material for this study was forensic medical reports of corpses of persons who died from TBI under various circumstances: 15 cases – in case of an accident (car injuries when victims are in the passenger compartment of cars), when falling from a height – 10 cases and 15 cases – when falling from a height of their own growth. In all these types of TBI occurred due to angular acceleration of the head in direct contact of the head with a solid object. And also 3 cases of receiving DAI in children under the age of 2 years with severe head shakes were considered. It is under such conditions of injury that angular acceleration of the head occurs. At the same time, the more mobile hemispheres of the brain are rotated, and the more fixed stem sections are twisted. In addition, mutual displacement of individual layers or parts of the brain is possible. Even a small displacement of cerebral structures can lead to partial or complete rupture of axons, as well as small vessels.

Both clinical (CT, MSCs, EEG, biochemical blood tests, etc.) and morphological (microscopic) research methods were used in the work.

### **The results of the study and their discussion.**

A distinctive feature of DAI, in comparison with the clinic of other TBI, is a prolonged moderate or deep coma that occurs immediately after injury. In our observations, the ratio of cases

of moderate to deep coma in adults was 64.5% to 35.5%, in children – 42% to 58%. The average duration of coma varies from 3 to 12 days.

Typical for DAI coma were tonic reactions of a diffuse nature provoked by various stimuli, periodic motor excitation against the background of adynamia.

Stem symptoms were characteristic: a decrease or complete loss of photoreaction and corneal reflexes, anisocoria, a different arrangement of the pupils horizontally, disorders of the respiratory rhythm and respiratory rate. In addition, variable spontaneous nystagmus, rigidity of the occipital muscles and Kernig's symptom, as well as vegetative symptoms (hyperhidrosis, hypertension, hypersalivation, etc.) were often detected in the neurological status.

Prolonged coma in most cases (67.5%) passed into a vegetative state, which lasted from 2 days to several months. With persistent vegetative states, neurotrophic disorders (including bedsores) developed.

Death in such cases developed from multiple organ failure and intercurrent infections (pneumonia, pyelonephritis, sepsis).

Particular attention was paid to the moment of coma after injury, the severity and dynamics of stem and hemispheric symptoms. At the same time, the depth of the coma was estimated according to the Glasgow scale (1974) in accordance with the accepted gradations of the state of consciousness (Table No. 1).

**Table №1.**

***Criteria for assessing the state of consciousness in TBI (no Teasdale C., Jennett B.,1974)***

Clear consciousness	15 points
Moderate stun	13-14 points
Deep stun	13-11 points
Sopor	10-8 points
Moderate coma	7-6 points
Deep coma	5-4 points
Outrageous coma	3 points

To assess the degree of focal contusion injuries, a contusion index (CI) was used, which was determined for each affected lobe by multiplying 2 coefficients characterizing the area and depth of the lesion (Adams J.H.1988).

The first coefficient depends on the number of affected convolutions and can be from 1 to 3; the second is determined by the depth of the damage and is equal to: 1 – with damage to the surface layers of the cortex, 2 – with damage to all layers of the cortex, 3 – with damage to the cortex and the adjacent white matter. In cases of damage to several lobes, their CI is summed up and the total concussion index (CI) is determined. The SKI in our observations ranged from 1 to 18, on average was equal to  $5.7 \pm 1.4$ .

When analyzing clinical and morphological data, all cases of DAI, depending on the life expectancy of victims after injury, were divided into 6 groups (Table No. 2), taking into account the periodization of TBI proposed by L.I.Smirnov (1947). At the same time, two groups were identified in the early and intermediate periods, which, in our opinion, allows us to characterize the post-traumatic process in more detail.

*Table №2.*

***Distribution of cases of DAI depending on the duration of life after injury.***

Group №	Injury prescription	Number of observations
1	From 2 to 3 days	5
2	From 4 to 6 days	15
3	From 7 to 13 days	7
4	From 14 to 28 days	8
5	From 29 to 50 days	6
6	From 51 and more	2

**The first group.** The duration of the injury is from 2 to 3 days. It includes 5 observations (the age of the victims is on average  $14.8 \pm 1.6$ ). The injury was sustained in an accident (hit-and-run (1) and an injury in the cabin (4)). The victims were immediately hospitalized. Since the injury, everyone has been in a deep coma. The rating on the Glasgow scale (SHKG) is 4-5 points. Gross stem symptoms in the form of pupillary and oculomotor disorders, changes in muscle tone and reflexes, bilateral pathological stop signs were revealed.

In one case, the coma was accompanied by symmetrical decerebration provoked by painful irritations. There were no meningeal symptoms. The ECHO-EG performed immediately after the injury and subsequently revealed no displacement of the median structures of the brain.

Examination of the corpses revealed swelling of the brain with signs of insertion of its stem section.

Histological examination of brain preparations in the area of contusion foci revealed small, sometimes merging hemorrhages, located mainly along the crests of the convolutions, mainly in the cortex.

Thus, DAI with a life expectancy of victims within 3 days is characterized by a deep coma, a normal CT picture of the brain with no focal lesions, swelling of the brain and small-point hemorrhages in the cerebral cortex.

**The second group.** The duration of the injury is from 4 to 6 days. It includes 15 observations (men 11 and 4 women, age 5-35 years). The injury was received in an accident (hit-and-run –7, injury inside the cabin - 4), when falling from a great height - 4).

From the moment of injury, all the victims have a coma, in 6 cases deep (4-5 points on the SHG), in the rest moderate (6-7 points on the SHG). In two observations, the victims were in a coma for 4 days, in the rest – the coma lasted until death.

ECHO-EG at admission to the hospital and in the dynamics of the displacement of the median structures of the brain was not determined.

The hemodynamics of all the victims remained stable from the moment of injury. Due to the violation of spontaneous breathing, all the victims underwent a ventilator.

With CT and MRI, only two observations revealed a normal picture of the brain. In other cases, CT and MRI revealed: a moderate increase in brain volume and an increase in brain tissue density (7), in 4 observations – compression of the lateral, III and IV ventricles and cisterns of the base.

During the forensic medical examination, the immediate causes of death were: pneumonia on the background of cerebral edema (8), wedging of the brain (stem structures) – 4 observations, pulmonary embolism (2), ventricular bleeding (1).

Histological examination revealed necrosis zones in the form of structureless fields devoid of cellular elements. Deformed glial cells were observed along the edges of such zones, and "single pale" melting" gangmyotic cells ("shadow cells") were observed between them. Most nerve cells underwent chromatolysis with swollen light nuclei and fragmented processes.

Beyond the necrosis zone there was a border zone of "secondary disintegration", which characterizes the accumulation of granular balls in the form of a dense cellular shaft.

Thus, DAI with a life expectancy of victims ranging from 7 to 13 days is characterized by clinically gross cerebral and focal neurological symptoms. With CT and MRI – the absence of focal lesions, a moderate increase in brain volume. Macroscopically – the presence of small focal hemorrhages in the deep structures of the brain; microscopically – multiple axonal balls in the areas of damage to the white matter.

**The third group.** The duration of the injury is from 7 to 13 days. It includes 7 observations (men – 3, women – 2 and children under 2 years old who were injured as a result of a sharp shake). Men and women received TBI as a result of falling from a height of their own height with their heads on a hard surface.

All the victims were treated after injury at the Republican Center of Neurosurgery.

In all cases, stem symptoms in the form of pupillary and oculomotor disorders, as well as pathological stop signs on both sides, pyramidal and extrapyramidal disorders were detected in the victims against the background of a comatose state. Meningial symptoms are noted in children, and in the absence of shell hemorrhages.

There was no ECHO-EG displacement of the median structures.

Hemodynamics remained stable.

CT and MRI – in one observation showed a normal picture of the brain. In other cases, CT showed a marked increase in brain volume with an increase in tissue density.

The immediate causes of death were pneumonia, cerebral edema. During macroscopic examination of the brain, small focal hemorrhages were recorded in the area of the ammonic horn, in the bridge and in the middle legs of the cerebellum.

When microscopy of the brain, both in the areas of the foci of bruises and in the area of hemorrhages, a picture of vascular neoplasms was observed, granular balls and small extravasates were detected.

Thus, DAI with a life expectancy of victims within 13 days is characterized by clinically gross stem and hemispheric neurological symptoms against the background of a comatose state; with CT and MRI – the absence of focal lesions, an increase in brain volume. Microscopically pronounced degenerative changes of axons in the area of damage to the white matter and the formation of granular balls.

**The fourth group.** The duration of the injury is from 14 to 28 days. It included 8 observations (5 men and 3 women; average age  $25.4 \pm 5.3$ ).

In all cases, the victims developed a coma from the moment of injury, which was assessed by the SHG from 4 to 6 points. All had gross hemispheric and stem symptoms. Meningial symptoms were detected in two victims in the absence of shell hematomas. ECHO-EG at admission to the hospital and in the dynamics of displacement of brain structures was not determined. Hemodynamics remained stable for all.

In CT, in three out of 8 cases, there were no changes in volume and density. In the rest, a moderate increase in brain volume and narrowing of the ventricular system were recorded.

The immediate cause of death in this group were: pneumonia (4), sepsis (3) and pulmonary heart failure (1), against the background of bronchiectatic disease.

The macroscopic picture was unchanged. Microscopy of the brain in the injury area showed gradual mixing of the necrosis focus with a glial-mesenchymal scar, profusely vascularized by newly formed vessels.

Thus, DAI with a life expectancy of victims within 28 days is characterized clinically by the transition of coma into a persistent vegetative state. The morphological picture is the organization of small focal and focal hemorrhages in the deep structures of the brain, pronounced degeneration of nervous tissue in the areas of injury and necrosis.

**The fifth and sixth groups** clinically and morphologically had no special differences, which made it possible to combine them. All the victims in these groups received treatment at the Republican Center of Neurosurgery of the Ministry of Health of the Republic of Uzbekistan.

Upon admission, in addition to coma, all the victims had severe focal neurological symptoms.

ECHO-EG during the post-traumatic period, there was no displacement of the median structures of the brain. Hemodynamics remained stable.

CT studies did not differ much from the data of previous groups of victims.

The cause of death was: pneumonia, sepsis, pulmonary embolism.

Macroscopically: in most of the observations, no special changes were detected in these groups.

In 3 observations of the 5th group and in the 2nd - sixth group of victims, small-point brown tassels occurred in the corpus callosum, the xiphoid nucleus and the roof of the midbrain during histological studies.

Thus, DAI in groups 5 and 6 of victims with a long period of survival after TBI is characterized by a clinically persistent vegetative state with the appearance of a syndrome of separation of the hemispheres, subcortical and stem parts of the brain.

Morphologically – the presence of brown cysts in the deep structures of the white matter, demyelinization of the white matter and pronounced degenerative changes in the nervous tissue.

### **Conclusions:**

The information given in the previous sections allows us to state that DAI is quite isolated, one of the most severe forms of TBI and is characterized by severe neurological symptoms with an initial traumatic coma, turning into a persistent vegetative state with a detailed picture of the syndrome of separation of the large hemispheres, subcortical structures and the brain stem.

It should be noted that the morphological picture of DAI is characterized by minimal manifestations in the deep structures of the brain and widespread traumatic changes of axons in various parts of the brain.

Because of this, and also taking into account that questions of DAI (as a form of TBI) may arise during forensic medical examination in cases of non-fatal head injury, the basis for the study of axonal trauma should be based on the clinical and morphological principle, which allows not only to substantiate the regularity of the change of some phenomena by others during traumatic illness, but it is also more accurate to set their time limits.

This allows the medical examiner to determine not only the severity of the injury, but also the time of receiving a TBI.

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