

ACUTE SUBDURAL HEMATOMA AND DIFFUSE AXONAL INJURY IN FATAL ROAD TRAFFIC ACCIDENT VICTIMS

A clinico-pathological study of 15 patients

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ABSTRACT - Objective: Although acute subdural hematoma (ASDH) and diffuse axonal injury (DAI) are commonly associated in victims of head injury due to road traffic accidents, there are only two clinico-pathological studies of this association. We report a clinical and pathological study of 15 patients with ASDH associated with DAI. **Method:** The patients were victims of road traffic accidents and were randomly chosen. The state of consciousness on hospital admission was evaluated by the Glasgow coma scale. For the identification of axons the histological sections of the brain were stained with anti-neurofilament proteins. **Results:** Twelve of the 15 patients were admitted to hospital in a state of coma; in three patients, the level of consciousness was not evaluated, as they died before hospital admission. **Conclusion:** The poorer prognosis in patients with ASDH who lapse into coma immediately after sustaining a head injury, as described by several authors, can be explained by the almost constant association between ASDH and DAI in victims of fatal road traffic accidents.

KEY WORDS: acute subdural hematoma, diffuse axonal injury, head injury, road traffic accident.

Hematoma subdural agudo e lesão axonal difusa em vítimas fatais de acidente de trânsito: estudo clínico-patológico de 15 pacientes

RESUMO - Objetivo: Embora o hematoma subdural agudo (HSDA) e a lesão axonal difusa (LAD) estejam frequentemente associados em vítimas de trauma crânio-encefálico causado por acidentes de trânsito, há somente dois estudos clínico-patológicos sobre esta associação. Relatamos o estudo clínico-patológico de 15 pacientes com HSDA associado com LAD. **Método:** Os pacientes, vítimas de acidentes de trânsito, foram selecionados aleatoriamente. O estado de consciência à admissão hospitalar foi avaliado pela escala de coma de Glasgow. Para a identificação dos axônios, os cortes histológicos do cérebro foram corados com antisoro anti-proteínas do neurofilamento. **Resultados:** Doze dos 15 pacientes foram admitidos no hospital em estado de coma; em três pacientes, o nível de consciência não foi avaliado, pois eles faleceram antes da admissão hospitalar. **Conclusão:** O pior prognóstico em pacientes com HSDA que apresentam coma imediatamente após serem admitidos por trauma crânio-encefálico, como descrito por vários autores, pode ser explicado pela quase que constante associação entre HSDA e LAD em vítimas fatais de acidentes de trânsito.

PALAVRAS-CHAVE: acidente de trânsito, hematoma subdural agudo, lesão axonal difusa, trauma crânio-encefálico.

Acute subdural hematoma (ASDH) and diffuse axonal injury (DAI) are both produced by the same mechanism - acceleration of the head, and its frequency varies according to the biomechanical characteristics of acceleration/deceleration rates¹. For this reason, they are commonly associated in victims of head injury due to road traffic accidents, in which

inertial (acceleration) forces are the primary mechanisms. Diffuse axonal damage is responsible for immediate post-traumatic coma, whereas ASDH causes compression of the brainstem, producing secondary unconsciousness^{2,3}. When these two types of brain damage are associated, a poorer prognosis can be expected, even if treatment of the ASDH is

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started early. Although ASDH and DAI are the most frequently encountered brain lesions in head injury caused by acceleration^{1,4}, only Sahuquillo-Barris et al.^{5,6} and Kubo et al.⁷ studied the association of these lesions.

As ASDH and DAI are lesions produced by acceleration of the head, and the axon injury occurs at lower acceleration levels than those required to cause vascular rupture⁴, we rise the hypothesis that DAI should be commonly associated with ASDH in fatal road traffic accidents.

The aim of the present study is to demonstrate that DAI is almost always associated with ASDH in victims of fatal road traffic accidents.

METHOD

Sixteen random patients with ASDH, victims of road traffic accidents, who had sustained either a motor vehicle accident (four patients), or an auto-pedestrian injury (12 patients), autopsied in the period between 1989 and 1993, in Belo Horizonte, Minas Gerais, Brazil, were studied. Both the victims that had died after being admitted to the hospital and those whose death had occurred at the site of the accident or before admission were included. The autopsies were performed within 24 hours of death. Complete postmortem examinations were performed in every case. After the trunk and limbs had been examined, the external lesions on the head and neck were described, followed by removal of the brain and description of the bone and intracranial lesions found. All brains had been fixed in 10% formalin solution for a minimum period of three weeks. After the external brain surface had been described, frontal sections through the cerebral hemispheres, horizontal sections through the brainstem, sagittal sections through the left cerebellar hemisphere, and oblique sections through the right cerebellar hemisphere were made. The sections were separated by 10 mm intervals at cerebral hemispheres level and by 5 mm intervals at brainstem and cerebellum levels.

Fragments for microscopic examination were taken from the frontal, parietal, temporal and occipital lobes, corpus callosum and fornix, basal ganglia, thalamus, hypothalamus, midbrain, pons, medulla, and cerebellar hemispheres. The fragments were processed for paraffin-embedding, cut into 7 μ m sections and stained with hematoxylin-eosin. In addition, frontal sections of the brain, including parasagittal regions from both sides of the frontal lobes, basal ganglia, internal capsule, corpus callosum (at three levels), anterior commissure, and fornix, and horizontal sections of the brainstem were also processed for paraffin-embedding, cut into 7 μ m sections and stained for the identification of axons with a mouse monoclonal antibody to neurofilament proteins 70-, 160-, 210-kD (Dianova-Immunotech, Hamburg, Germany) at a dilution of 1:200. The sections were incubated for two hours at 4°C. For the visual-

ization of the reaction product, the sections were reacted in 0.05% 3,3 diaminobenzidine tetrahydrochloride (DAB, Sigma Chemical Company, St. Louis, MO) using the peroxidase-antiperoxidase method (PAP). The histological sections were counterstained with hematoxylin. For positive controls histological sections of normal brains were used. For negative controls, the phosphate buffer solution or normal mouse serum were used instead of the primary antibody.

Axonal injury was considered as evidence of DAI when axonal swellings and bulbs were diffusely distributed throughout the brain, although preferentially located in the corpus callosum, the internal capsule, the cerebral white matter, and the rostral brainstem^{8,9}. Axonal injury around focal lesions (hemorrhages, contusions, infarcts) were not considered as DAI.

DAI was graded according to the criteria proposed by Adams et al.¹⁰: grade 1 - presence of axonal swellings and bulbs; grade 2 - presence of hemorrhagic lesion in the corpus callosum (generally in its inferior part and on one or other side of the midline); grade 3 - presence of primary hemorrhagic lesion in the dorsolateral quadrant of the rostral brainstem (midbrain and rostral pons). In those patients that died at the site of the accident or before reaching hospital or that had died immediately after being admitted to the hospital, the presence of DAI was assigned by the finding of hemorrhagic lesion (macro or microscopically) in the corpus callosum and/or in the dorsolateral quadrant of the rostral brainstem. Isolated or sparse focal hemorrhages, anywhere, were not considered as DAI. Also, focal hemorrhagic lesions secondary to increased intracranial pressure (Duret's hemorrhage in the midline of the tegmentum of the midbrain and pons) were not considered as DAI.

The state of consciousness on hospital admission was evaluated by the Glasgow coma scale (GCS) established by Teasdale and Jennett¹¹.

RESULTS

In 15 of the 16 patients with ASDH there was association with DAI. Of these, nine were male and six female (Table). Their ages varied from 17 to 76 years; nine were 35 years old or younger. Seven patients survived for less than one day, and eight died within two to eleven days after the head injury. Twelve patients were admitted to hospital in a state of coma (3 to 8 points in the GCS); in three patients, the level of consciousness was not evaluated, as they died before hospital admission. Computerized tomography (CT) was performed immediately after admission in nine patients (cases 1, 2, 3, 5, 8, 9, 13, 14 and 15). Signs of subdural hematoma were found in all of these patients. In the other six patients CT was not performed either because the patients died before admission (cases 10, 11 and 12) or because they were admitted with signs of brain death (3

Table. Clinical data, grading of diffuse axonal injury (DAI) and other neuropathological changes in 15 patients with acute subdural haematoma (ASDH) and DAI.

Case	Sex	Age (years)	Survival (days)	GCS	DAI (grade)	Morphological signs of increased ICP	Other neuropathological diagnoses
1	F	21	4	5	1	+	CC, HBD
2	F	62	11	8	1	+	CC
3	M	35	2	3	2	+	EH, CC, ICH, HBD
4	M	19	0	3	1	+	CC
5	M	50	7	3	1	+	CC
6	M	43	3	3	2	+	CC, HBD
7	M	20	0	3	2	+	CC
8	F	17	8	5	1	-	HBD
9	M	23	0	5	2	+	CC
10	F	50	0	NE	2	-	CC, HBD
11	F	76	0	NE	3	+	CC
12	M	56	0	NE	3	-	-
13	M	35	10	6	1	+	EH
14	F	26	4	6	2	+	EH, CC, HBD, Leptomeningitis
15	M	31	0	3	2	+	CC

Survival 0, patients who either died at the site of the accident or immediately after being admitted to the hospital; GCS, Glasgow coma scale (score on admission); ICP, Intracranial pressure; NE, Not evaluated; +, Present; -, Absent; CC, Cerebral contusion; EH, Extradural hematoma; HBD, Hypoxic brain damage; ICH, Intracerebral hematoma.

points in the GCS and absence of brainstem reflexes), and died between one to two hours (cases 4 and 7) and three days (case 6) after admission. Five of the nine patients with evidence of subdural hematoma on CT were submitted to surgical intervention for drainage of the hematoma (cases 3, 5, 9, 14 and 15). The other four (cases 1, 2, 8 and 13) were not surgically treated, as the subdural hematoma evidenced on CT was small. DAI of grade 1 was seen in six patients, of grade 2 in seven, and of grade 3 in two. Morphological signs of increased intracranial pressure (wedge of pressure necrosis in the parahippocampal gyrus, hemorrhage in the midline of the tegmentum of the midbrain and pons, medial and basal occipital infarction) were found in 12 patients. Other intracranial lesions were found in 14 of the 15 patients with ASDH: cerebral contusion (12 patients), hypoxic brain damage (6 patients), extradural hematoma (3 patients), intracerebral hematoma and purulent leptomeningitis (one patient each).

Subdural hematomas are classified as acute, subacute and chronic^{12,13}. Although there is no uniformity in attempts to age subdural hematomas, from the neurosurgical viewpoint they are classified as acute when they are composed of clotted blood (usually within the first 48 hours after injury), subacute when there is a mixture of clotted and fluid blood (developing between 2 and 14 days after injury), and chronic when the hematoma consists of dark, turbid fluid and varying amounts of fresh blood (developing more than 14 days after injury). All cases of the present series with hematoma subdural were classified as acute because the diagnosis was established at autopsy or by CT and at surgery within the first 48 hours after the head injury. Only one patient (case 6) did not have the diagnosis of subdural hematoma established within 48 hours after the injury. This case, which could be classified as subacute, was included in the present study on account of acute and subacute subdural hematomas having a similar pathogenesis and pathophysiology¹⁴.

DISCUSSION

Since Holbourn's^{15,16}, and Pudenz and Shelden's¹⁷ works, the pathogenesis and biomechanics of ASDH has been discussed. Experimental work on head acceleration in subhuman primates has provided a better understanding of the pathogenesis of ASDH, and has shown that its frequency varies according to the nature of the trauma^{1,4,18-20}. By controlling the intensity and duration of angular acceleration, different types of impact were simulated⁴. At a certain level of intensity and duration, angular acceleration caused subdural hematoma and mild cerebral concussion (unconsciousness for less than 30 minutes). As the same level of acceleration was allowed to act over a longer period of time, subdural hematoma did not occur, but the animal became immediately unconscious and remained so for hours or days, in the absence of hematoma, contusion or increased intracranial pressure. As duration of the acceleration impulse was maintained, but its level increased, then subdural hematoma associated with prolonged coma was produced. Thus, as duration of the acceleration impulse is increased, so must its level be increased in order to cause rupture of the bridging veins. Almost all animals that developed a subdural hematoma showed immediate unconsciousness of a variable degree, depending on the acceleration level and duration.

In a clinico-pathological study of patients with mild and severe closed head injury, Blumbergs et al.⁹ suggested that the absence of vascular damage in the mild head injury patients indicates that axons are more vulnerable than blood vessels to traumatic damage. These experimental and clinico-pathological studies are in accord with our finding of DAI in 15 of the 16 cases of ASDH, and coma in 12 patients that underwent neurological evaluation. As in the experimental situation, long-duration high-level acceleration, as occurs in road traffic accidents, certainly accounts for the close association between rupture of the bridging veins, axonal injury and immediate alteration of consciousness.

Sahuquillo-Barris et al.^{5,6} studied the brains of 31 victims of severe head trauma. In 10 of these, ASDH was the predominant lesion. In six other patients, ASDH associated with DAI was identified. All of these six patients had been victims of road traffic accidents, had become immediately unconscious and had remained so until they died. Kubo et al.⁷ reported a case of traumatic subdural hematoma accompanied by DAI in a 58-year-old man who was assaulted, and

immediately lost consciousness, and remained unconscious during about 44 hours until his death.

Traumatic ASDH remains one of the most lethal of all head injuries and the extent of primary underlying brain injury is more important than the subdural hematoma itself in dictating outcome^{21,22}. Many patients with ASDH showed immediate post-traumatic coma, and mortality among them was greater when compared to those that did not have immediate coma^{4,5,23}. The poorer prognosis has been explained by the association between ASDH and DAI^{4,5,24-27}. ASDH may be no more than an epiphenomenon of a primary lesion of variable intensity: DAI. Thus, the prognosis would be primarily dependent on the severity of such lesion. Coexistence of ASDH and DAI is explained by the fact that both result from the same mechanism, that is, acceleration or deceleration of the head^{1,4}.

Finally, as the findings from the present series demonstrate, the frequent presence of other intracranial lesions associated with ASDH could also contribute to greater morbidity and mortality of ASDH in victims of fatal road traffic accidents. The high frequency of these other lesions would be explained by the complex mechanisms (impact and acceleration) of brain damage (e.g., extradural hematoma and cerebral contusion) that results from a head injury in road traffic accidents and by the appearance of complicating processes (e.g., hypoxic brain damage) which are common in this type of traumatic brain injury³.

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