

BIOMECHANICAL ASPECTS IN THE CRITICAL CERVICAL TRAUMAS.

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As in any other field of traumathology the tremendous development of traffic and industrialization lead to an increase in the gravity and frequency of the spine and its content lesions.

Spine fractures represent 0.7-1% of the total locomotive apparatus diseases, 4.5-7% of the overall traumas of the same apparatus and 43% of the rachis pathology (Arseni 2). The traffic traumathology represents an important percentage of the cases: 31% of the overall spinal fractures are due to the road accidents (Oblu 7); 14% (Slatis 14) or 20% (Sicard 19) of all the road trauma and lesions belong to the spine; 65% of the traffic accidents are politraumatisms. In 5% of these cases the dominant lesion is located on the spine (Slatis 14). The association of the vertebro-medullary with the cranio-cerebral trauma is very frequent and represent 14% of the politraumatized patients and 3% of the total number of critical trauma (Arseni 1). 40-50% of the spine fractures have a medullo-radicular component; this figure goes up to 100% in the cases of high dorsal and cervical trauma (Putti, quoted after 2).

The mortality rate is up to 5,7% of the total number of the spinal fractures and 20% of those fractures of the cervical spine have the highest mortality rate.

As an average the cervical spine is involved in about 1/3 of all cases of spinal fractures (Arseni 2, Lazorthes, Zvoncev quoted after 2, Oblu 7,8) but the full range of involvement varies between 15 and 60% (Slatis 14) of the cases. The cervical traumatic lesions represent 1/3 of the rachis trauma which reach the hospital and they have a medullary component in 42 (Stringa, quoted by 2) to 55% (Rogers, quoted by 2) of the cases.

Some of the anatomical and biomechanical particularities of the cervical spine must be remembered: The bodies of the cervical vertebrae have not the same architectural distribution as the others of the spine; at this level the transverse distribution of the arciform (arcuate) trabeculi is missing so at the midline level there is a minimal resistance area at this is where the cervical vertebra have their critical point. The articular interfaces having an important role in the cervical posture (Frickholm, quoted by 2) have a transverse section area which equals 1/2 of vertebral body surface. The ligamentary and fibrous elements of the cervical spine stand mechanical insults four times stronger than the bone elements.

The cervical spine is extremely mobile and in the same time has the smallest resistance. It must provide the head mobility regarding the rest of the body in order to allow the orientation of analyzers. The mobility is maximum at the level where the nervous centres are this part having the possibility of a multidirectional movement because of a joint that function on the principle of a cardanic spindle. The middle and inferior part of the cervical spine are the area where the flexion, extension, lateroflexion and rotation movements take place. The movement in the superior cervical segment (occipital bone - atlas - axis) is purely a diarthroidal movement as long as at this level there is not an intervertebral disc; between the atlas and occipital bone there is only a movement in a sagittal direction and between atlas and axis the sagittal movement does not exceed 11-15°, those in a lateral direction being even more reduced (Toussaint 16). The structure of the spine assures a great stability in flexion, movement in which the spinal joint act against sliding but in the same time in extension movements the retrolistesis is opposed only by ligaments. All these anatomical particularities provide the basis for a normal kinetik of the cervical spine (Wackenheim 18):

- the head rotation will take place almost exclusively between C1 and C2;
- the mobility of one vertebra regarding another depends on the condition of the intervertebral disc and that of the interapaphisaris joints (meniscus);
- the hyperextension is more ample being limited only very late by the contact of the occipital bone with the dorsal spine; so we can realize that the hyperextension movement is more important than the hyperflexion from the pathogenic point of view.

In the ethiology of the cervical spine trauma are described direct agents producing mostly open trauma (cervical spinovertebral wounds by white weapons) and indirect acting agents producing mostly closed traumatical lesions as in traffic, sports and work accidents.

Over a period of almost 7 years (1968-1974) at the Institute for Forensic Medicine in Jassy (Iasi) - Romania, we performed

100 post-mortem examinations on traumatized patients, 90 of them having a cervical lesions as the determinant cause of their death and in remaining 10 cases even if the cervical trauma had not been the main cause of the death it has had an important contribution. The determining agent in our statistics is shortly presented in the following tabel:

Tabel I.

Determining agent and the number of cases	By direct action=20		By indirect action=80	
	OCVMT=13	CCVMT=7	CCVMT=80	
	produced aggression=7		hanging=5	
	by train =8		traffic accidents=56	
	in aggression=5		falls=11	
			others=8	

OCVMT=Open Cervical Vertebral-Medullary Trauma
CCVMT=Closed Cervical Vertebral-Medullary Trauma

One can see from this tabel that in our statistics the road accidents represents 56% of the cases which surpasses the usual average found in the literature (10% after Sicard 19, 30% Oblu 7,8). In more than 2/3 of the cases the accident took place in the rural environment as an expected consequence of the excessive driving speed in the villages.

Depending on the position of the victim and that of the vehicle (Slatis 14) the partition of different percentages of trauma along the spine is clearly showed in the tabel II. We must pay attention to the fact that 1/3 of the vertebral trauma take place at the cervical spine level on which deceleration and inertia act firstly (Belenger 3).

Tabel II.

Vertebral spine	car	motor cycle	bicycle	pedestrians	total
	11%	7%	12%	14%	12%
	driver	front seat	passanger	back seat	passanger
	5,6%	7,6%		10%	

Lesions of the cervical spine mostly appeared at those persons who were not ejected from the vehicles (Got 5); the ejection very seldom causes lethal lesions, but when the lesion is single it is almost always a cranian one. Because "the cervical spine is the natural shock absorber for the bodies that strike the skull and that is why it is suffering almost always the consequences of the head trauma" (Crusem, quoted by 16), in 18-20% of

the cases the cervical lesion may pass as unobserved (Roy-Camille 10). In the other 24 cases in which determinant agent was acting indirectly, 9 were caused by a fall in vertex (7 work accidents, 2 sports accidents), two were caused by a fall of contondent bodies on the vertex (work accidents), 5 cases were caused by hanging and 8 by different other causes. From all the cases caused by hanging we analysed only 5 of them which had associated cervical lesions (fracture of the odontoid process in all 5 cases, one of cases showing an anterior medullary contusive area, lesion which we did not find described in the literature).

The agents acting directly produced open trauma (13 cases) of which 8 were caused by train accidents and 5 following aggression by white weapons and closed trauma (7 cases).

There is a strong male prevalence in the statistics (84 cases) but this figure matches with all the statistics regarding traumathology. Regarding the age we can see the low percentage of cervical trauma below the age of 20 and this is because of some anatomical and biomechanical peculiarities listed below:

In this happy tolerance take part (Roy-Camille 11)

- the great looseness of different joints;
- the width of intervertebral discs;
- the elasticity of intervertebral discs (because of their excellent hydratation). This also confirms the Roaf's hypothesis (quoted by 2) which states that the traumatic forces act upon the basic vertebral unit (made up of two adjacent vertebrae and the discal-ligamentary complex in between them). All these factors ensure to the child cervical spine an extraordinary mobility (Vigouroux 17) so as in spite of the fact that the number of trauma is very high, the fractures and luxations are only seldom seen and the lesions followed by neurological sequelae are extremely rare. So we can conclude that Blount's witticism (quoted by 11): "On peut faire des nœuds avec un enfant sans lui casser la colonne vertébrale" is true.

Tabel III.

Age	under 20 years	21-40	41-60	more than 60
	minimal age=17 years	years	years	maximum age=59 years
	16	48	36	0

In spite of the fact the weight of the head is loading this already lordotic segment of the spine, increasing its instability the lesions in this area are present only seldom. They are produced by a direct shock (usually a fall) which settles the

vertebral body. In 1/2 of the cases especially in elderly children the lesions consist of luxation-fractures of the cervical spine (Roy-Camille 11). We must mention that the cervical lesions are more frequent in children presenting congenital malformations at this level (Vigouroux 17).

The mechanism of the cervical vertebral-medullary lesions encountered in our statistics was as it follows:

Tabel IV.

Direct mechanisms=20	OCVMT	beheading by train=8
		cord section produced by white weapons associated or not with bone lesions=5
	CCVMT	striking of the cervical region by a hard body=7
Indirect mechanisms=80		- falls=7
	Hyperflexion	- other causes=1
		- falls=2
		- hangings=5
	Hyperflexion	- other causes=4
		- traffic accidents=56
		- falls=2
	Whiplash	- other causes=3

OCVMT=Open Cervical Vertebral-Medullary Trauma
CCVMT=Closed Cervical Vertebral-Medullary Trauma

In the case of direct lesions the mechanism of lesion represent an evident cause-effect relationship.

The traumatic lesions by indirect mechanisms which represent the great majority of spine fractures even today elicit an enormous discussion on their way of development. From Chedevergne's "pulling" theory (quoted by 2) to the Roaf's experiments (quoted by 2) many explanations were given which can be syntetized as follows: "the traumatic lesions are the result of action of combined forces but the most important component is the one which leaves the major impression"(Arseni 2). The combination of compressive with rotative forces may produce any kind of spinal lesion (Roaf, quoted by 2).

The biomechanical aspects must be regarded in relation with the lesional types, types which can be classified as follows(2):

- Type I - Fractures of the vertebral body - settling mechanism ^
(cuneiform or total fracture, depression of "en plateau" type)
- parcelled or comminutive fracture

Type II - Fractures of the neural arch (of the laminae, pediculi, isthmus, processes articular/transverse/spinous)

Type III- Combined lesions - luxation partial and complete
 - luxation-fracture
 - disc-ligamentary lesions

Making the correlation between the mechanism of development and the anatomical lesion (Wackenheim 18) we can reach the following classification:

Tabel V.

Mechanism	Anatomical lesion	
	Type	Bone lesion
Hyperflexion	I+II	Fracture of one or more vertebral bodies
		Fracture of odontoid process
		Fracture of articular or spinous process
Hyperextension	II	Fracture of the neural arch
		Fracture of odontoid process
Whiplash	I+II+III	Fracture of the vertebral body
		Fracture of the neural arch
		Combined lesions

The bone lesions from our statistics are presented in Tabel VI.

without fractures=8 cases	fractures of one vertebra= 21 cases
pure luxations =4 "	" " 2 vertebrae=30 "
fractures =68 "	" " 3 " =11 "
luxation-fractures=12 "	" " 4 " = 8 "
spinal crushes =8 "	

fractures involving the cervical vertebra (C)- C1=16 cases
 C2=20 cases
 C3=40 cases
 C4=32 cases
 C5=24 cases
 C6=12 cases
 C7= 8 cases

Comparing with the data found in the literature, in our statistics the percentages referring to the involvement of one or multiple vertebrae are opposite (Arseni 2 gives the involvement of one vertebra in 70-88% of the cases, involvement of two vertebrae in 10% of the cases and three or more vertebrae in 23% of cases) but this is explained by the fact that this statistics belongs to a neurosurgical clinic and our belongs to a forensio medicine institut.

In 8% of the cases we encountered cervical spinal cord lesions, leading to death without being complicated by any bone lesions. In this situation we agree with Taylor (quoted by 2) who shows that the hyperextension (which reduces the antero-posterior

diameter of the spinal canal by one third) even if it does not cause the rupture of the motor area may produce lesions of the spinal cord by folding the ligamenta flava which compress it from behind especially in the aged who already have a narrowed spinal canal and some arthrosis of the intervertebral discs (Scripcaru 12,13). Even if there is not any direct compression a simple concussion of the spinal cord may lead to a sudden death. In some cases the death may supervene lately as a consequence of the vascular process (Denischi 4).

The involvement of C1-C2 vertebrae (20-40% of all the cervical spine fractures - 2) was in our statistics of 25% being either pure luxations (one case of Malgaigne occipital-atloidian luxation and one case of anterior luxation of the atlas following an impact the occipital bone with the ground) or fractures of the atlas of Jefferson type (9 cases of falls on the vertex) and fractures of the axis (7 cases of fractures of the odontoid process, 5 of them being produced by hanging and 7 fractures of the axis body and/or of the vertebral arch).

The fractures of the C3-C7 segment which represent 59% have their maximum frequency at the C3 level and they were either pure luxations (one posterior disjunctive luxation-fracture at the C3-C4 level and a total anterior dislocation at the C4-C5 level) or simple fractures (45%) and luxation-fractures (12% of the cases). Of all simple fractures, 36% were of comminutive type being encountered mostly after the age of 40 and they were caused by a violent pressure exerted in an axial direction, pressure which determined the penetration of the intervertebral disc into the vertebral body followed by the explosion of the last one. Always it was a comminutive fracture having one of the fragments insinuated into the spinal cord. These fractures are the ones that give a high mortality rate in the clinics.

Two facts to be noticed: - the fractures produced by hyperextension are far more serious than those by hyperflexion (Bădulescu, quoted by 15); - in the case of luxation-fractures instead of the classically described mechanism, Arseni (2) suggests another, one which would act in two phases:
1. the association of axial compression with the hyperextension and 2. the violent flexion of the spine.

In 8% of our cases (in which the mechanism was the beheading by train) the extremely complex lesions did not allowed us any systematization.

The cervical spinal cord lesions involved in the death determination can be systematized as it follows:

Tabel VII.

no lesions	4 cases
spinal cord concussion	(4 cases ?)
spinal cord contusion	40 cases
spinal cord contusion+extramedullary haematoma	6 cases
haematomyelia	5 cases
partial section of the spinal cord	5 cases
total section of the spinal cord	11 cases
spinal cord laceration	29 cases

From the above tabel and from the individual study of our cases we can notice the following facts:

- the evident prevalence of contusive and laceration type lesions especially following comminutive fractures;
- the partial sections of the spinal cord were caused mostly by white weapons and the total sections mostly by train;
- in the haematomyelia group of lesions we framed also those lesions which even if they did not succeed to organize an intramedullary haematic collection they showed many areas of haemorrhagic lesions. These lesions usually known as "centro-medullary contusion", a term which we consider to be unsuitable, because the action of traumatizing agent is not a direct one but mediated by the vascular system of the cervical spine cord;
- those 4 cases without cervical spinal cord lesions are represented by hangings in which the death mechanism was firstly the asphyxia; in only one case we encountered a contusive spinal cord area corresponding to the odontoid process which presumes a combined hyperextension-hyperflexion mechanism;
- in all cases a variable degree of spinal cord oedema was associated, this being more evident in contusive lesions;
- generally speaking not always exist a correlative relation between the vertebral and the spinal cord lesions (the prototype being the centro-medullary syndrome, the ischemia of the spinal gray matter syndrome consequence of the anterior spinal artery lesion).

The mechanism of the spinal cord lesion was mostly a crush of the spinal cord produced by the displacement of the spinal canal with or without a vascular component and only seldom by vascular mechanism alone (Honnart 6, Osterholm 9). Depending on the death mechanism the period of time elapsed from the moment of the accident until the death supervened was:

Tabel VIII.

in the first hour	61 cases of which - 50 in the moment of the accident - 11 in the next few minutes after the accident
in the first day	24 cases
from the 1-st - 3-rd day	9 cases
from the 7-th -14-th day	6 cases

In 15 cases who survived more than one day the death was caused by contusion and compression of the spinal cord caused by haemathoma in 6 cases; by secondary laceration in 5 cases and by a secondary displacement of an unstable fracture in 4 cases (Nicoll, quoted by 2).

We encountered in 41 cases an association of the vertebro-medullary lesions with cranio-cerebral traumas which may be caused by the same impact or by different impacts (2). The presence of a cranio-cerebral trauma may dissimulate the existance of a serious cervical lesion which may pass unnoticed being, as a matter of fact the one responsible for the patient's death.

C o n c l u s i o n s :

1. The frequency and seriousness of the cervical vertebral medullary lesions steadily increased with industrialization, increased traffic and are proportional with the speeding up of the rythm of life.

2. Among the causative agents the traffic accidents bear the first place by lethal and unlethal cervical lesions and the most frequently encountered mechanism in the production of these lesions is a complex one, the so called "whiplash injury".

3. In spite of the fact that there is not any constant correlation between trauma- anatomical bone lesion and medullo-radicular anatomic lesion the increased force of the agent combined with a particular direction of action of the agent (especially rotation) produce most often cervical laceration-contusion lesions.

4. The prognosis of these lesions is generally preserved and the therapeutical problems are not completely solved.

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