MECHANISMS OF ISOLATED SPINAL CORD INJURY IN CHILDREN

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Objective. To study the mechanisms of spinal cord injury in children of different age groups.
Material and Methods. A retrospective analysis of the results of treatment of 217 children aged 1 to 15 years with traumatic injuries of the spine and spinal cord was performed. Group A included patients with spinal cord injury without damage to the spine (n = 139), and Group B – with spinal cord injury accompanied by spinal column injury (n = 78). McAffe classification of spinal injury mechanisms was used. Neurological deficit was evaluated according to the Frankel scale. Main causes and mechanisms of these injuries were studied.
Results. Principal mechanisms of spinal cord injury in children were as follows: distractive extension and compressive flexion for isolated SCIWORA-type injuries, and compressive flexion for the spine and spinal cord injuries.
Conclusion. The most pronounced neurological deficit is observed after exposure to compression-flexion mechanism of injury. Traction mechanisms of injury cause severe neurological disorders peculiar to SCIWORA syndrome.
Key Words: injury, mechanisms, spinal cord, children, SCIWORA, SCIWONA.

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Spinal cord injury in children accounts for 1 to 10 % of all spinal injuries in children. Anatomic and physiological features of childhood period explain high (75 %) probability of specific damage, SCIWORA syndrome [2, 9, 11]. This type of injury has been described by Pang [12] and is interpreted as a traumatic myelopathy in which spinal fracture cannot be visualized during X-ray or CT studies. According to some authors [3, 12, 13], this type of injury is caused by differences in stretchability between the spine and the spinal cord. By now this phenomenon has been described in detail by many researchers [4–7, 11, 14].

The advent of MRI allowed dividing SCIWORA syndrome into two groups: in some patients MRI detects extraneural changes that are visible on X-ray and MSCT, while in others traumatic changes are observed in the spinal cord [1, 10, 15]. Two additional syndromes have been identified: SCIWORET (Spinal Cord Injury Without Radiologic Evidence of Trauma), a spinal cord injury syndrome in the absence of reliable data on injury and in the presence of degenerative or congenital spinal column abnormalities, which is characteristic of older patients [16], and SCIWONA (Spinal Cord Injury Without Neuroimaging Abnormality), a spinal cord injury syndrome without changes of the spinal cord on MRI [8, 17]. In our opinion, despite numerous studies, mechanisms of these syndromes and correlation between them and severity of an injury remain to be poorly understood.

The purpose of this research is to study the mechanisms of spinal cord injury in children of different age groups.

Material and Methods

A retrospective analysis of treatment outcomes has been conducted for 217 children aged 1 to 15 years with traumatic injuries of the spine and spinal cord, who were treated in pediatric neurosurgery, traumatology and orthopedics department of the City Children Clinical Hospital No.3 in 1994-2014. Group A included patients with spinal cord injury without damage to the spine (n = 139), and Group B – with spinal cord injury accompanied by spinal column injury (n = 78).

Inclusion criteria: age below 15 years, clinical manifestations of spinal cord injuries, which are in some cases combined with mild traumatic brain injury, absence of concomitant injuries and diseases that could affect outcome of the study.

Exclusion criteria: age above 15 years, concomitant diseases and injuries that could affect the outcome of the study, unstable injuries, isolated damage to the spinal cord roots or root damage in degenerative diseases of the spine.

McAffe classification (1986) of spinal injury mechanisms was used. Neurological deficit was evaluated according to the Frankel scale (1969). All children underwent clinical examination and X-rays of the spine. Some patients (n = 75) underwent an MRI study.

Results and Discussion

Both groups were dominated by boys, which is consistent with the literature: Group A had 81 boys and 58 girls; Group B had 56 boys and 22 girls. The most commonly encountered causes of injury were traffic accidents, sports and household injuries (Table 1). There was no statistically significant difference in their incidence.

No statistically significant difference in types of injuries has been observed between the groups.

Overall, types of injuries and their incidence differed little from the well-known data; however, we identified a number of peculiar features. There were no cases of immediate injury by a motor vehicle among victims of traffic accidents in Groups A and B, i.e. the cases when a child was hit by a car. The injury was sustained inside a vehicle. This is particularly pronounced in patients from Group A, which is dominated by so-called seat belt injury. Household injuries in children older than 7 included a high incidence of school injuries (up to 40 %). In addition, catatrauma (a fall from a height of more than 2 m) has been identified as the most severe type of injury among household injuries. Despite low incidence of sports injury, this type of injury involves characteristic damage, localized mainly in the cervical region, the so-called hyperextension mechanism. In some cases the damage occurred as a result of an exercise: jumping, somersaults, and sometimes was associated with significant damage, including a compression fracture of the thoracic vertebrae.

A detailed study of injury mechanisms allowed classification of all injuries into the following types: a fall, a direct hit, a seat belt injury (in a traffic accident), a catatrauma (falling from a height of more than 2 m), an injury sustained while diving in shallow waters, an injury during an exercise. The results of this study are presented in Table 2.

Overall, a fall from low height was the prevailing cause of injury in both groups. Notably, catatrauma was rarely associated with SCIWORA: there were 2 cases of falling from the 3rd floor (children aged 1 and 2). In both cases, the absence of spinal fracture was confirmed not only by spondylograms, but also by MRI. As can be seen from the statistical parameters presented above, the most significant factors for predicting the severity of the injury are a fall from a low height, catatrauma and diving injury.

Localization of traumatic injury is presented in Table 3. Damage to the cervical spine is the most common type of damage in Group A, which can be attributed to mobility of this portion of the spine. In group B the most commonly affected segment was the thoracic spine, which can be attributed to immature physiological curvatures of this portion. It should be noted that it was not possible to identify the affected portion of the spine in some patients of Group A, which can attributed to the peculiarities of childhood period.

The most typical biomechanical mechanisms of injuries were identified in both groups of patients. The most significant biomechanical factors were compression flexion, distractive flexion, torsion (twist) flexion, vertical compression, and distraction extension.

In most cases, an injury was a result of a combination of different mechanisms; however the analysis of clinical cases of spinal cord injury in both groups revealed the leading biomechanical factors (Table 4).

Compression flexion was the prevailing mechanism in both groups, which demonstrates that this mechanism is a typical one for childhood injuries. Distraction extension is common for spinal cord injuries without radiographic abnormalities (SCIWORA). Torsion mechanism is typical for injuries accompanied by acceleration, such as falls from a bicycle or an injury in a car. Vertical compression was reported for falls on the buttocks from one's own height and there were only 2 such observations. The study of mechanisms is of great importance in terms of statistical significance. It has demonstrated that for patients in the study most of the leading mechanisms are statistically significant and have greater prognostic value than standard observations about external causes of injury.

On admission, the patients had varying degrees of neurological deficit. Table 5 demonstrates that there is a tendency towards more severe neurological disorders in Group A patients.

We have also analyzed relationships between the degree of severity of a spinal cord injury and its mechanisms. The severity was estimated using a Frankel scale of neurological disorders and the data from the analysis of the leading biomechanical factor according to McAffe (Table 6).

The data demonstrate that compression or distraction flexion is associated with the most severe neurological deficits. The most common incidents involving these mechanisms are falls on one's back from one's own height with dam-

Table 1

Distribution of patients with stable spinal injuries by the type of injury, n

Group of patients	Household	Traffic	Sports
A	126	10	3
B	74	2	2
χ^2	1,89	1,26	0,44
p	>0,05	>0,05	>0,05
Odds ratio	0,52	2,95	0,84

Yates correction was used if the value of χ^2 was less than 5.

age to the thoracic and lumbar spine. For Group A patients there was significant damage to the nervous system in cases of such falls in the presence of hyperextension mechanism (extensions), and the cervical spine may also be affected. The most severe damage (Frankel type B) was observed for falls of a heavy object on a child (distraction flexion). It should be noted that despite the variety of mechanisms, the severity of injuries is affected by the age factor: the younger the child is, the more severe is the neurological deficit after the injury. The level of spinal injury is equally important.

According to MRI data, changes in the spinal cord were both extraneural and intraneural in nature. There were cases of reduction in the height of the vertebral bodies, and other signs of a compression fracture of the spine in Group B, which corresponded to the level of neurological disorders. In Group A, extraneural signs included swelling in the area of the cervical spine ligament (n = 1). Three patients in Group B displayed foci of the spinal cord contusion (type 2 damage according to Ahadov [1]). Spinal cord injury foci in patients from both groups were characterized by severe neurological deficit (Frankel type C), which served as an unfavorable prognostic factor for recovery.

Our research has revealed leading mechanisms of spinal cord injuries in children. Cervical spine injury is more common for an isolated spinal cord injury (injury without radiographic abnormalities, SCIWORA), and its leading mechanism is compression flexion and distraction extension. These injuries

Table 2

Distribution of patients by type of injury, n

Group of patients	Fall	Catatrauma	Direct hit	Traffic accident	Exercise	Diving injury
A	113	2	10	10	3	1
B	53	15	3	2	2	3
Total	166	17	13	12	5	4
χ^2	5,57	24,44	0,49	1,26	0,44	4,70
p	<0,05	<0,05	>0,05	>0,05	>0,05	<0,05
Odds ratio	2,15	0,06	1,94	2,95	0,84	0,18

Table 3

Distribution of patients according to localization of injury, n

Group	Section of the spine	Spinal Concussion	Spinal Cord Contusion	Total	χ^2	p
A	Cervical	42	21	63	0,15	>0,05
	Thoracic	41	15	56	1,03	>0,05
	Lumbar	5	4	9	1,50	>0,05
	Unspecified	7	4	11	0,47	>0,05
B	Cervical	2	3	5	4,61	<0,05
	Thoracic	50	16	66	3,33	>0,05
	Thoracic and lumbar	0	3	3	12,1	<0,05
	Lumbar	4	0	4	0,51	>0,05

Table 4

Distribution of patients based on the leading mechanisms of the spine and spinal cord injury, n

Group	Compression flexion	Distraction flexion	Distraction extension	Torsion flexion	Vertical compression	Unknown
A	72	6	49	10	0	2
B	59	9	3	2	2	3
χ^2	11,87	4,05	25,35	1,26	6,95	2,57
p	<0,05	<0,05	<0,05	>0,05	<0,05	>0,05

were often accompanied by more severe neurological deficits. MRI study was not conducted in all patients. Thirty Group A patients displayed complete regression of neurological deficit, whereas all patients with bleeding had persisting neurological deficit at discharge (Frankel type D). Therefore, according to our data, a ratio of incidence of SCIWORA and SCIWONA is 1 : 46.

The thoracic spine damage was the most typical for a group of patients with a combination of the spinal cord injury and the spinal column injury, and the leading mechanism was compression flexion. These injuries were accompanied by less severe neurological deficits. The outcome of injury depended on the presence of changes in the spinal cord. It should be noted that there were no cases with evidence of hemorrhage into the intrathecal space, which is possibly due to the limited resolution of the MRI machine and negative attitude of pediatric neurosurgeons towards lumbar punctures.

Conclusions

1. In most (60 %) observations the damage to the spinal cord in children is characterized by the absence of structural damage to the spinal motion segment. In 97.8 % of cases, the damage is not accompanied by changes in MRI (SCIWONA).

2. Mechanisms of isolated spinal cord injury (injury without radiographic abnormalities, SCIWORA) in children encompass a combination of divergent forces, but extension-traction mechanism of injury is very important and accounts for 35% of the cases in this group.

3. The leading mechanism for combined spinal cord-spinal column injury is compression flexion, and for spinal cord injury without radiographic abnormalities (SCIWORA) the most common mechanism is compression flexion and distraction extension.

4. The most pronounced neurological deficit is associated with compression flexion mechanism of injury. Traction mechanisms of injury cause severe neurological disorders peculiar to SCIWORA syndrome.

Table 5

Distribution of patients by type of neurological disorders, n

Group	Types of spinal cord injury by Frankel			
	B	C	D	E
A	1	13	34	91
B	–	2	19	57
χ^2	0,08	2,60	0,00	1,33
p	>0,05	>0,05	>0,05	>0,05

Table 6

Distribution of patients according to the mechanism of injury and types of neurological disorders, n

Type of neurological disorders by Frankel	Compression flexion	Distraction flexion	Distraction extension	Torsion flexion	Vertical compression	Unkown
Group A						
B	–	1	–	–	–	–
C	7	–	4	1	–	1
D	36	1	11	–	–	1
E	29	4	34	9	–	–
Group B						
C	–	2	–	–	–	–
D	15	2	–	–	1	1
E	44	5	3	2	1	2

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