



Analysis of Results of the Surgical Treatment of the Spinal Cord Injury (Step by Step)

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Abstract: Purpose. Substantiation of the reasonable period of the surgical intervention with due account for the analysis of the surgical treatment. Methods. The research is based on the follow-up of 200 patients with spinal cord injury. In accordance with the goal of this research, all patients with spinal cord injury were allocated to four clinical groups according to the period of surgical intervention: within the first 24 hours after the injury (Group 2a), during the first 2 – 3 days (Group 2b), after 4 – 6 days (Group 2c) and over 6 days (Group 1). Results. Temporal factor is substantiated by the morphological examinations, which revealed inconvertibility of the secondary injury of spinal cord in case of its long-term compression between 7 – 8 days. Group 2a demonstrated (surgical intervention was performed within the first 24 hours after the injury) the best results in respect of neurological recovery, namely 66,7%. In Group 2b the treatment efficiency was 58,4% and in group 2c – 51,4%. The control group demonstrated the lowest percent of neurological recovery, namely 11%. All patients had the spinal cord compression due to fractures and fractures - dislocations vertebrae. In the course of the treatment we used modern methods decompression and stabilization of spinal column, as well as pharmacological treatment. Conclusions. Spinal cord injury under the action of the long-term compression of vessels of spinal cord and matter of spinal cord is followed by the progressive secondary injuries and consequently by irreversible changes in the structure of the spinal cord, which can be revealed on the 7 – 8 day after the injury. The first six days is the most effective period for the performance of the decompression and stabilization operations in the presence of the spinal cord injury.

Keywords: Spinal Cord Injury, Secondary Injury, Spinal Cord Decompression

1. Introduction

Experimental trials in the different animal models suggest that in case of spinal cord changes induced by the compression, the performance of early decompression can give rise to the reversible state of the damaged spinal cord tissues caused by the secondary injury of spinal cord [1-7].

Experimental trials in animals demonstrated the high

efficiency of the early decompression based on two aspects of pathologic physiology of the spinal cord injury, namely degree and duration of the spinal cord compression, which had an impact on the possibility of the recovery of neurological function. However, clinical trials in humans were less convincing, probably due to the complexity of medical care arrangement, absence of unified system of examination, short stay in a hospital and more medical

complications than the deferred surgery. A question as to whether the performance of surgical intervention in the early period contributes to the improvement of the condition of patients with the spinal cord injury or causes the expansion in the number of complications, generates substantial controversies and until now is under discussion. Some researchers provide evidences against the surgical treatment in the early stage of the spinal cord injury in patients with a high-level tetraplegia, combined injury or cardiopulmonary failure [8-12].

Currently there is no consensus on the period of the performance of spinal cord decompression, which confirms the urgency of this issue.

2. Methods

Primary diagnostic measures included clinical and neurological examination, general and laboratory examination, radiography of spine, computer tomography of the injured part of spinal column and spinal cord; for some patients – magnetic resonance tomography and angiographic examination of vertebrobasilar system.

All patients underwent examination of the severity of their condition, functions of the cardiovascular system, respiratory system and visceral organs. Patients were examined by the related specialists (anesthesiologist, surgeon, traumatologist) for the purpose of the exclusion of combined pathology.

The ASIA Neurological Impairment Scale proposed by the American Spinal Injury Association (ASIA) has been taken as a basis for classification of patients with spinal cord injury.

The research is based on the follow-up of 200 patients with spinal cord injury at the age from 17 to 73 years old operated after previous injury at different times in the Clinic of Nervous Diseases and Neurosurgery of the Dnipropetrovsk State Medical Academy (department of spinal neurosurgery (spinal column and spinal cord) of the Municipal Institution “Dnipropetrovsk Regional Clinical Hospital named after I.I. Mechnikov”), in the Clinic of Neurosurgery of the Odessa State Medical University (neurosurgery department of the Odessa Municipal Clinical Hospital No. 11) and neurosurgery department of the Kryvyi Rig Municipal Hospital No. 2 during the period from 2006 to 2016.

All patients had the spinal cord compression due to fractures and fractures - dislocations vertebrae. Among patients there were 170 (85%) males and 30 (15%) females. As the Table 2 shows, the most patients were at a young age (under 45 years of age), i.e. 148 (74%) patients. The average age of patients was ($M \pm m$) 36,6 \pm 1,0 years. Age category from 60 to 73 years included only 14 (7%) patients. There were no significant differences in the median age between

males and females ($p=0,317$ on the basis of M-L χ^2 test; $p=0,076$ on the basis of Student t-test) (Table 1).

Table 1. Sex and age distribution of patients (total, %).

Age*	Sex		All (n=200)
	Male (n=170)	Female (n=30)	
17 - 44	128 (75,3%)	20 (66,7%)	148 (74%)
45 - 59	32 (18,8%)	6 (20,0%)	38 (19%)
60 - 74	10 (5,9%)	4 (13,3%)	14 (7%)
Average value ($M \pm m$)	35,9 \pm 1,0	40,6 \pm 2,6	36,6 \pm 1,0

Remark* – when making all comparisons of indices between the groups of patients with different gender, $p>0,05$.

The most patients were admitted to hospital within 24 hours after the injury, namely 165 (82,5%) patients, 12 (6%) patients were admitted 2-3 days after the injury, 13 (6,5%) patients after 4-6 days, and 10 (5%) patients after 6 days.

In accordance with the goal of this research, all patients with spinal cord injury were allocated to four clinical groups according to the period of surgical intervention: within the first 24 hours after the injury (Group 2a), during the first 2 – 3 days (Group 2b), after 4 – 6 days (Group 2c) and over 6 days (Group 1).

Group 1 included 100 patients admitted to hospitals over a period from the first 24 hours to 30 days after the injury (on average after 2,21 \pm 0,44 days). Among them there were 89 (89,0%) males and 11 (11,0%) females. The median age of patients was 37,3 \pm 1,5 years. Patients were operated over a period from 7 to 47 days after the injury, on average after 14 days.

Group 2a included 39 patients admitted to hospitals and operated within the first 24 hours after the injury. Among them there were 31 (79,5%) males and 8 (20,5%) females. The median age of patients was 36,1 \pm 1,9 years.

Group 2b included 24 patients with spinal cord injury admitted to hospitals during the first 3 days after the injury (on average after 0,46 \pm 0,17 days). In this Group the surgical intervention was performed on average on the 2nd day. Among patients there were 21 (87,5%) males and 3 (12,5%) females. The median age of patients was 35,1 \pm 2,2 years.

Group 2c included 37 patients (29 – 78,4% males and 8 – 21,6% females; median age of patients was 36,1 \pm 2,1 years) admitted to hospitals during the first 3 days but operated between 4 – 6 days after the injury (on average on the 5th day).

Analysis of sex and age composition of patients in the specified groups revealed their statistical comparability in relation to each other (Table 2): in whole the significant difference between groups according to gender was $p=0,323$ on the basis of M-L χ^2 test; according to age $p=0,872$ in accordance with ANOVA analysis of variance.

Table 2. Distribution of patients from different clinical groups by sex and age (total, %).

		Group 1 (n=100)	Group 2a (n=39)	Group 2b (n=24)	Group 2c (n=37)
Sex	Male	89 (89,0%)	31 (79,5%)	21 (87,5%)	29 (78,4%)
	Female	11 (11,0%)	8 (20,5%)	3 (12,5%)	8 (21,6%)
Average value ($M \pm m$), лет		37,3 \pm 1,5	36,1 \pm 1,9	35,1 \pm 2,2	36,1 \pm 2,1

Remark. When making all comparisons of indices between different clinical groups of patients, $p>0,05$.

There were 105 (52,5%) patients with cervical injury, 46 (23,0%) patients with thoracic injury, 43 (21,5%) patients with lumbar injury, 5 (2,5%) patients with thoracic and lumbar injury and 1 (0,5%) patient with cervical and thoracic injury. Distribution of patients by the degree of spinal cord injury represented in Table 3.

Table 3. Distribution of patients from different clinical groups by the degree of spinal cord injury (total, %).

Region	All (n=200)	Group 1 (n=100)	Group 2a (n=39)	Group 2b (n=24)	Group 2c (n=37)
C	105 (52,5%)	53 (53,0%)	20 (51,3%)	16 (66,7%)	16 (43,3%)
Th	46 (23,0%)	19 (19,0%)	13 (33,3%)	3 (12,5%)	11 (29,7%)
L	43 (21,5%)	24 (24,0%)	5 (12,8%)	4 (16,7%)	10 (27,0%)
L-Th	5 (2,5%)	4 (4,0%)	1 (2,6%)	–	–
C-Th	1 (0,5%)	–	–	1 (4,1%)	–

Remark. When making all comparisons of indices between different clinical groups of patients, $p > 0,05$.

It should be noted that there were no significant differences in the structure of the spinal cord injuries between specified groups either in whole ($p = 0,166$ on the basis of M-L χ^2 test) or by pair-wise cross-group comparison ($p > 0,05$).

Degree of neurological disorders at admission of patients to the in-patient hospital was graded according to the ASIA Impairment Scale and corresponded to A-D categories.

Initially the severity of spinal cord injury corresponded to A category according to the ASIA Impairment Scale in 103 (51,5%) patients, B category in 12 (6,0%) patients, C

category in 45 (22,5%) patients and D category in 40 (20,0%) patients (Table 3). It should be noted that there was a significant difference in the distribution of patients in the clinical groups by the severity of neurological disorders ($p = 0,003$ on the basis of M-L χ^2 test).

As the Table 4 shows, Group 1 included the maximum number of patients with a complete neurologic impairment (ASIA, category A), namely 62 (62,0%) patients, and Group 2c included the minimum number of patients, namely 11 (29,7%) patients ($p_{1-2c} < 0,001$).

Table 4. Distribution of patients from different clinical groups by the degree of neurological disorders according to the ASIA Impairment Scale at admission to the in-patient hospital (total, %).

ASIA	All (n=200)	Group 1 (n=100)	Group 2a (n=39)	Group 2b (n=24)	Group 2c (n=37)
A	103 (51,5%)	62 (62,0%) $p_{1-2c} < 0,001$	19 (48,7%)	11 (45,9%)	11 (29,7%) $p_{1-2c} < 0,001$
B	12 (6,0%)	2 (2,0%) $p_{1-2a} < 0,01$	6 (15,4%) $p_{1-2a} < 0,01$	2 (8,3%)	2 (5,4%)
C	45 (22,5%)	21 (21,0%) 15 (15,0%)	8 (20,5%) 6 (15,4%)	8 (33,3%) 3 (12,5%)	8 (21,6%) 16 (43,3%)
D	40 (20,0%)	$p_{1-2c} < 0,001$	$p_{2a-2c} < 0,01$	$p_{2b-2c} < 0,05$	$p_{1-2c} < 0,001$ $p_{2a-2c} < 0,01$ $p_{2b-2c} < 0,05$

Remark. The levels of significance (p) of significant differences of indices between the relevant groups; if this is not the case, there are no significant differences, $p > 0,05$.

Distribution of patients by the severity of spinal cord injury in Group 2a and Group 2b was comparable ($p = 0,645$ on the basis of M-L χ^2 test) (Table 5).

Table 5. The level of significance of (p) between distributions of patients from different clinical groups according to the ASIA Impairment Scale prior to initiating therapy.

Groups	p	Groups	p
1-2a	0,037	2a-2b	0,645
1-2b	0,258	2a-2c	0,030
1-2c	0,002	2b-2c	0,073

Thus, all formed clinical groups of patients with spinal cord injury were statistically comparable ($p > 0,05$) by sex, age and structure of injury of the spinal cord parts prompting to compare treatment outcome in future.

In accordance with the goal of this research, all patients

with spinal cord injury were allocated to four clinical groups according to the period of surgical intervention: within the first 24 hours after the injury (Group 2a), during the first 2 – 3 days (Group 2b), after 4 – 6 days (Group 2c) and over 6 days (Group 1). Temporal factor is substantiated by the morphological examinations, which revealed inconvertibility of the secondary injury of spinal cord in case of its long-term compression between 7 – 8 days [13].

3. Results

The main group was summarized taking account of the equal number of patients in Group 1 and in the main group (2-a; 2-b; 2-c) – 100 patients. The Figure 1 illustrates the treatment outcomes prompting suggestions that the efficiency of neurological recovery is higher in the main group.

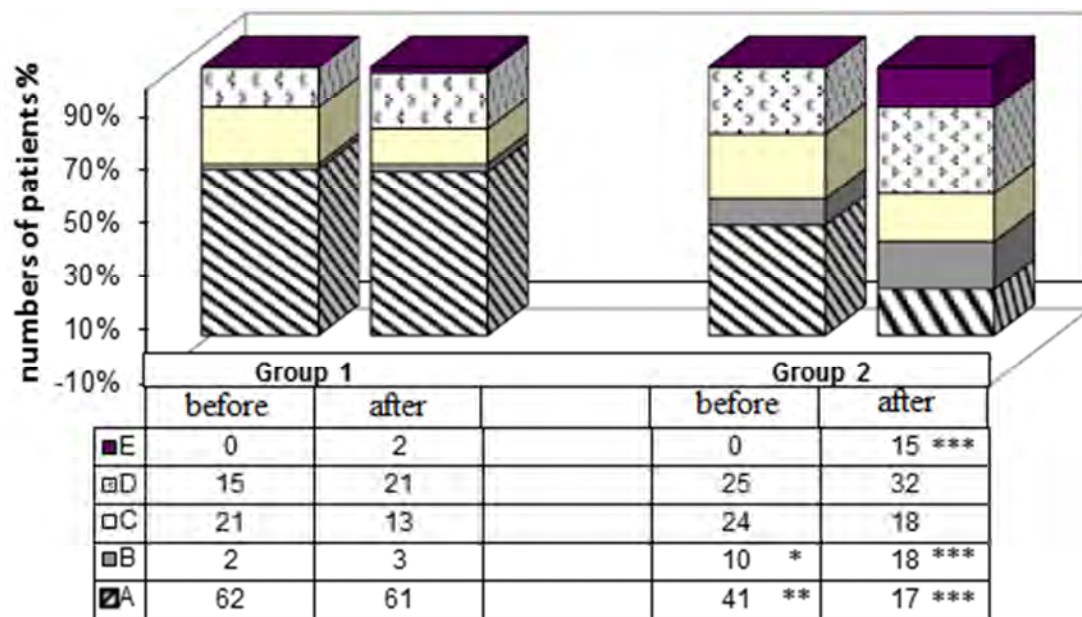


Figure 1. Distribution of patients from main group and control group by the degree of neurological disorders according to the ASIA Impairment Scale in the course of the treatment, in scores: * – $p < 0,05$; ** – $p < 0,01$; *** – $p < 0,001$ in comparison with corresponding figures in the control group.

The Figure 2 illustrates the percentage ratio of the different treatment outcomes.

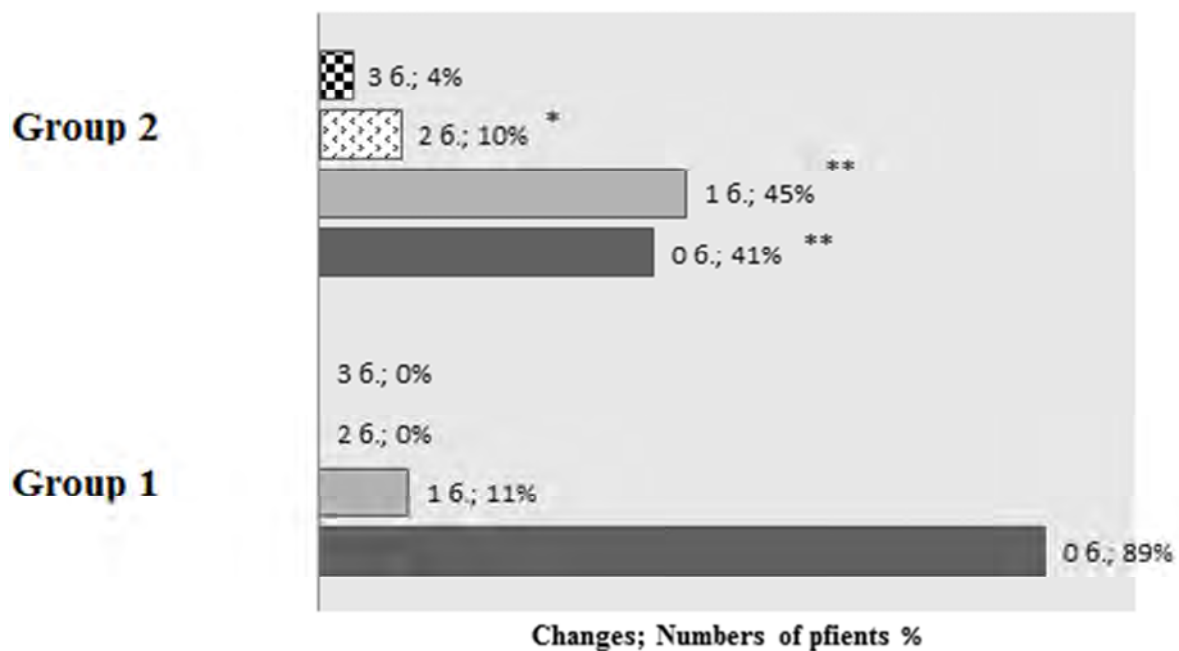


Figure 2. Change of neurological status of patients according to the ASIA Impairment Scale after treatment, in scores: * – $p < 0,01$; ** – $p < 0,001$ in comparison with corresponding figures in the control group.

The Table 6 shows the allocation of patients to clinical groups according to the ASIA Impairment Scale after performed treatment.

Table 6. Distribution of patients from different clinical groups by the degree of neurological disorders according to the ASIA Impairment Scale after treatment (total, %).

ASIA	All (n=200)	Group 1 (n=100)	Group 2a (n=39)	Group 2b (n=24)	Group 2c (n=37)
A	78 (39,0%)	61 (61,0%)	6 (15,4%)	8 (33,3%)	3 (8,1%)
		$p_{1-2a} < 0,001$	$p_{1-2a} < 0,001$	$p_{1-2b} < 0,05$	$p_{1-2c} < 0,001$
		$p_{1-2b} < 0,05$		$p_{2b-2c} < 0,05$	$p_{2b-2c} < 0,05$
		$p_{1-2c} < 0,001$			

ASIA	All (n=200)	Group 1 (n=100)	Group 2a (n=39)	Group 2b (n=24)	Group 2c (n=37)
B	21 (10,5%)	3 (3,0%) $p_{1-2a}<0,001$ $p_{1-2c}<0,001$	10 (25,6%) $p_{1-2a}<0,001$ $p_{2a-2b}<0,05$	1 (4,2%) $p_{2a-2b}<0,05$	7 (18,9%) $p_{1-2c}<0,001$
C	31 (15,5%)	13 (13,0%) $p_{1-2c}<0,01$	8 (20,5%) $p_{2a-2b}<0,05$	5 (20,8%) $p_{2a-2b}<0,05$	5 (13,5%) $p_{1-2c}<0,01$
D	53 (26,5%)	21 (21,0%) $p_{1-2c}<0,01$	8 (20,5%) $p_{2a-2b}<0,05$	7 (29,2%) $p_{2a-2b}<0,05$	17 (46,0%) $p_{1-2c}<0,01$ $p_{2a-2c}<0,05$
E	17 (8,5%)	2 (2,0%) $p_{1-2a}<0,001$ $p_{1-2b}<0,05$ $p_{1-2c}<0,01$	7 (18,0%) $p_{1-2a}<0,001$	3 (12,5%) $p_{1-2b}<0,05$	5 (13,5%) $p_{1-2c}<0,01$

Remark. The levels of significance (p) of significant differences of indices between the relevant groups; if this is not the case, there are no significant differences, $p>0,05$.

At that, the greatest differences between patient allocations were revealed between all main groups (Groups 2a, 2b and, 2c) and control group 1 (Table 7).

Table 7. The level of significance of differences (p) between distributions of patients from different clinical groups by the degree of neurological disorders according to the ASIA Impairment Scale after treatment.

Groups	p	Groups	p
1-2a	0,037	2a-2b	0,645
1-2b	0,258	2a-2c	0,030
1-2c	0,002	2b-2c	0,073

The number of patients with a severity of spinal cord injury of A grade is reduced from 51,5% (n=103) to 39,0% (n=78), and the number of patients of B and C grade reduced from 28,5% (n=57) to 26,0% (n=52). Complete functional recovery according to the ASIA Impairment Scale was observed in 17 (8,5%) patients, predominantly in patients with the early time of surgical interventions (n=15) ($p<0,05$, when making all comparisons of groups 2a, 2b and 2c with a control group).

The Figure 3 illustrates the percentage ratio of patients from all groups in the course of the treatment.

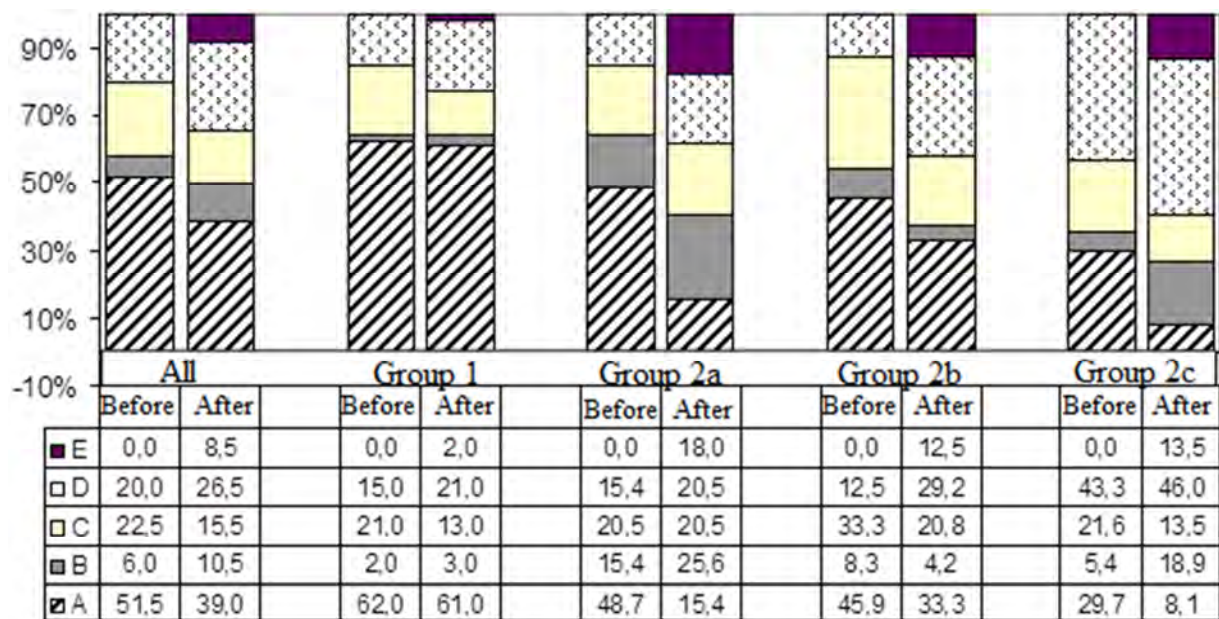


Figure 3. Distribution of patients from different clinical groups by the degree of neurological disorders according to the ASIA Impairment Scale in the course of the treatment.

Table 8 shows the changes of the neurological status of patients according to the ASIA Impairment Scale, by the scoring system. The most significant dynamics was observed in the groups with the early time of surgical interventions, in comparison with a control group ($p<0,001$, when making all comparisons of the average point assessment of groups 2a, 2b, 2c with a control group). It should be noted that the best dynamics of the neurological status of patients according to the ASIA Impairment Scale was observed in group 2a

(patients with spinal cord injury were operated within the first 24 hours): only in the third part of patients (33,3%) the neurological status remained unchanged in the course of the treatment; in 43,6% patients there was a change-over to one category; in 15,4% – change-over to two categories of the ASIA Impairment Scale; 3 patients (7,7%), with an initial status corresponding to ASIA-A, at the time of discharge from the hospital demonstrated complete recovery of sensitivity and motor function retention below the

neurological level corresponding to ASIA-D.

Table 8. Change of neurological status of patients according to the ASIA Impairment Scale after treatment, in scores (total, %).

Changes	All (n=200)	Group 1 (n=100)	Group 2a (n=39)	Group 2b (n=24)	Group 2c (n=37)
0	130 (65,0%)	89 (89,0%) p _{1-2a} <0,001 p _{1-2b} <0,001 p _{1-2c} <0,001	13 (33,3%) p _{1-2a} <0,001	10 (41,6%) p _{1-2b} <0,001	18 (48,7%) p _{1-2c} <0,001
1	56 (28,0%)	11 (11,0%) p _{1-2a} <0,001 p _{1-2b} <0,001 p _{1-2c} <0,001	17 (43,6%) p _{1-2a} <0,001	12 (50,0%) p _{1-2b} <0,001	16 (43,2%) p _{1-2c} <0,001
2	10 (5,0%)	— p _{1-2a} <0,05	6 (15,4%) p _{1-2a} <0,05	1 (4,2%)	3 (8,1%)
3	4 (2,0%)	— 0,11±0,03 p _{1-2a} <0,001 p _{1-2b} <0,001 p _{1-2c} <0,001	3 (7,7%) 0,97±0,14 p _{1-2a} <0,001 p _{2a-2c} <0,01	1 (4,2%) 0,71±0,15 p _{1-2b} <0,001	— 0,59±0,11 p _{1-2c} <0,001 p _{2a-2c} <0,01
Average (M±m)	0,44±0,05				

Remark. The levels of significance (p) of significant differences of indices between the relevant groups; if this is not the case, there are no significant differences, p>0,05.

In Group 2c (surgical intervention was performed over a period from 4 to 6 days), in spite of initially better indices according to the ASIA Impairment Scale, the average score of the neurological impairment recovery was significantly low than in Group 2a: 0,59±0,11 versus 0,97±0,14 (p<0,01 on the basis of the Duncan's test). Group 2b (surgical intervention was performed after 2-3 day after the injury) falls in between Group 2a and Group 2c by dynamics of improvement of the neurological status.

Group 2a demonstrated (surgical intervention was performed within the first 24 hours after the injury) the best results in respect of neurological recovery, namely 66,7%. In Group 2b the treatment efficiency was 58,4% and in group 2c – 51,4%. The control group demonstrated the lowest percent of neurological recovery, namely 11%.

4. Discussion

Conducted morphological examinations suggest that irreversible changes in the injured spinal cord emerge between 7 – 8 days [13]. We examined the efficiency of neurological recovery of patients operated in the period till 7 days and compared with the results in respect of patients operated in the period after 7 days.

Besides, based on the research findings, the efficiency of decompression surgery can be explained not only from a perspective of elimination of the spinal cord compression, but in the context of elimination of compression of vessels involved in the blood supply to spinal cord tissues [14, 15].

In the course of the treatment we used modern methods decompression and stabilization of spinal column, as well as pharmacological treatment [16-20].

The trauma followed by the injuries of other organs such as injury of longitudinal bones, injury of thoracic cavity and abdominal cavity, injury of pelvis and brain injury, may be restriction to the performance of urgent surgery. In case of combined pathology and impairment of vital functions that

come to the foreground, such as hemorrhagic shock, intraabdominal hemorrhage, hemothorax and hemorrhage from large vessels, the active neurosurgical actions shall be deferred to the stabilization of state.

We are of the opinion that any possibility of the performance of the urgent decompression makes sense, if it is able to prevent the secondary changes in the spinal cord.

5. Conclusions

Spinal cord injury under the action of the long-term compression of vessels of spinal cord and matter of spinal cord is followed by the progressive secondary injuries and consequently by irreversible changes in the structure of the spinal cord, which can be revealed on the 7 – 8 day after the injury. The first six days is the most effective period for the performance of the decompression and stabilization operations in the presence of the spinal cord injury.

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