THE EFFICIENCY OF THE CENTRALIZED SYSTEM FOR DELIVERY OF SPECIALIZED MEDICAL CARE TO VICTIMS WITH ACUTE SPINAL CORD INJURY IN A MODERN METROPOLISE

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Objective. To perform comparative assessment and identification of determinants of efficiency of the centralized system for delivery of specialized medical care to victims with acute spinal cord injury in the modern metropolis.
Material and Methods. The results of specialized medical care delivered to 2283 victims with acute spinal cord injuries were studied. The comparison group (decentralized system: treatment in several multidisciplinary hospitals in St. Petersburg) included 306 patients, and study group (centralized system: treatment in a specialized urban center for emergency spinal surgery) — 1977. Comparative analysis of the results of surgical treatment included 44 patients from comparison group and 223 patients from the study group ($p > 0.05$). The methods of non-parametric statistics were used.
Results. The centralized treatment system is characterized by a statistically significant increase in the rate of surgical activity, a manifold increase in the proportion of emergency spinal surgery ($p < 0.01$) and the mandatory use of modern technologies for surgical stabilization of the spine, shortening the hospital stay, as well as higher values of all indicators characterizing the results of treatment ($p < 0.01$).
Conclusion. In a large city, the centralized system of treating victims with spinal cord injury is characterized by more efficient use of urban health resources and better treatment outcomes. The key to its successful creation and subsequent operation, in addition to the centralization of medical care with the reasonable formation and distribution of the incoming patient flow, adequate logistic support for the treatment process and the presence of highly qualified medical personnel, is the availability of modern surgical technologies in delivering specialized emergency care.
Key Words: spinal injuries, specialized medical care, spine surgery, trauma centers, surgical treatment in traumatology and orthopedics, treatment time, urban hospitals.
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The problem of spinal injury (SI) remains extremely relevant for any country [1–3]. Numerous studies have shown that the key to the successful treatment of victims with SI is the timely delivery of urgent surgical care, which requires the establishment of specialised medical centers [4–6].

There are two organisation models (decentralised and centralised) that can be applied for the treatment of victims with acute SI in a metropolis. In the first case, patients are usually admitted to the neurosurgery and rarely to the orthopaedic trauma department of the nearest multidisciplinary city hospital. The disadvantage of such departments is that they usually lack financial, technical, and human resources necessary for the delivery of specialised medical care to patients with acute spinal conditions in an urgent manner with taking into account all principles and using a wide range of modern technologies for surgical treatment of spinal conditions. For instance, in St. Petersburg, there had been 6 municipal medical institutions involved in the treatment of such victims until 2010: 5 large general hospitals and Dzhanelidze Research Institute of Emergency Medicine. Of them, only two hospitals were sufficiently equipped with the facility and instruments required to perform spinal surgery, while the equipment of others was poorer and varied greatly [7–9]. The centralised model assumes concentration of patients with acute spinal conditions in 2–3 multidisciplinary medical institutions. Such institutions should have modern diagnostic and therapeutic capabilities, they should be open 24/7, receive consistent central funding of acute spinal services via federal commissioning as well as mandatory health insurance high-technology care program (MHI-HTC). Such hospitals should be able to admit patients, provide work-up and early comprehensive surgical treatment, including a wide range of modern surgical interventions on the spinal column and related neural structures [7, 10–12]. In St. Petersburg, the organisation of such a system was launched in 2010, and the newly-established City

Centre for Acute Spinal Surgery (CCASS) based in Dzhanelidze Research Institute of Emergency Medicine became its hub institution. The current study builds on on this accumulated experience in the treatment of victims with SI.

The purpose of the study is a comparative assessment and identification of determinants of effectiveness of a centralised system of delivery of specialised medical care to victims with acute SI in a modern metropolis.

Material and Methods

Statistical medical and clinical parameters characterising the process of delivery of specialised medical care and the treatment outcomes of a total of 2,283 victims with acute SI of inferior cervical (C3–C7 vertebrae) and thoracolumbar localisation have been studied. The sample includes people with neurologically intact and neurologically compromised SI (both isolated and as a component of a polytrauma) who were treated in St. Petersburg health facilities in the period of 2009–2016.

All patients were divided into two groups for comparative analysis. The comparison group included 306 victims who received decentralised medical care,. These patients were treated in 6 city hospitals: City Hospital No. 26, Alexandrovskaya Hospital, City Hospital of the Holy Martyr Elizabeth, City Mariinsky Hospital, City Pokrovskaya Hospital, and Dzhanelidze Research Institute of Emergency Medicine (Table 1) in 2009. The source of information on the organisation and type of medical care received by patients in these medical institutions was the report of a specialised task force established by order of the Health Committee of St. Petersburg for assessment of the state of the system of delivery of medical care to patients with acute traumatic and non-traumatic surgical conditions of the spine. The study group included 1,977 victims receiving centralised treatment of the spine in CCASS based in Dzhanelidze Research Institute of Emergency Medicine during the period of 2010–2016.

The study included two stages. The first stage involved study and comparative analysis of parameters characterising inpatient treatment of the victims of the studied category (Table 2). At the second stage, a comparative analysis of the treatment outcomes for patients who received spinal surgery was performed. The reason for choosing such an approach was the fact that it is the outcomes of surgical treatment that most comprehensively reveal the positive and negative aspects of the particular model of medical care. However, due to the fact that this aspect was not initially included in the tasks of the above-mentioned task force, a decision was made to conduct a detailed analysis of the treatment outcomes only for patients from the comparison group who received treatment in one of the six medical institutions that were part of the decentralised system, namely Dzhanelidze Research Institute of Emergency Medicine (Table 3).

The average length of stay of a patient with SI (average LOS) was calculated using the following formula:

$$A = \frac{B}{0{,}5 \times (C + D)},$$

where A is the average LOS; B is the number of inpatient days for all patients in the hospital; C is the number of admitted patients; D is the number of discharged patients.

Evaluation of the statistical significance of the differences in these parameters between the two groups was not performed, since they were calculated based on this formula as a derivative of the total number of days spent by patients in the hospital but not as a derivative of the treatment time for each of them.

The duration of follow-up was 18 months after surgery. The adapted Russian translation of the Oswestry questionnaire (ODI) version 2.1a by Cherepanov (2009) [13] was used to assess the patients' quality of life. Neurological status was determined using the ASIA scale (American Spinal Injury Association impairment scale). Comprehensive assessment of the treatment outcome was carried out using the modified MacNab scale.

Statistical processing of the obtained data was performed using Microsoft Excel and Statistica for Windows 6.0 software packages. The median and quartiles were used for characterisation of the distributions of quantitative estimates. Comparative analysis of frequency estimates of clinical characteristics of SI as well as treatment outcomes of the victims in the study and the comparison groups (ASIA scale and modified MacNab scale) was performed using the chi-square test: Pearson 2 test, 2 test with the Yates's correction for continuity, one- and two-sided Fisher's exact test; quantitative estimates (ODI scale) were analysed using the Mann – Whitney test. The obtained differences were considered statistically significant at $p < 0.05$.

Results

The overall level of surgical activity in the comparison group was more than 2 times lower than that for the study group (Table 4). Maximum (more than 4-fold) difference was observed among the patients with isolated, neurologically intact SI. The total frequency rate of emergency surgeries (within the first 24 hours after injury for neurologically compromised SI and within 48 hours for neurologically intact SI) performed in the comparison group did not exceed 25.6 %, in almost all of these cases patients admitted to hospital had isolated, neurologically compromised injuries. All spinal surgeries in the study group were included surgical stabilisation of the spine. In the comparison group, stabilisation of the spine was performed in 91.2 % of the patients who received surgical treatment (114 persons) with the exception of 10 patients with isolated, neurologically compromised SI and 1 victim with neurologically compromised SI as a component of polytrauma: these patients underwent only decompression of the spinal canal.

Analysis of the duration of treatment of the patients in the comparison group revealed that, taking into account 5,421 inpatient days spent in the hospital, the total LOS averaged 17.7 days: 8.0 days for neurologically intact (1,176 inpa-

Table 1
Distribution of patients with spine conditions among multidisciplinary hospitals of St. Petersburg that were part of the decentralised system of delivery of specialised medical care, n

Parameters	City Hospital of the Holy Martyr Elizabeth	Alexandrovskaya Hospital	City Hospital No. 26	City Mariinsky Hospital	City Pokrovskaya Hospital	Dzhanelidze Research Institute of Emergency Medicine	Total
Neurosurgical bed count	30	60	60	30	6	60	246
Total patient count, incl.:	206	263	306	20	462	121	1378 (100 %)
Spinal injuries	76	53	59	5	44	69	306 (22.2 %)
Non-traumatic conditions	130	210	247	15	418	52	1072 (77.8 %)
Degenerative disease	119	210	235	15	418	17	1014 (73.6 %)
Other non-traumatic conditions	11	0	12	0	0	35	58 (4.2 %)

tient days, 147 patients) and 26.7 days for neurologically compromised (4,245 inpatient days, 159 patients) injuries. For CCASS, the estimates were 9.2 days (18,123 inpatient days), 6.1 days (8,503 inpatient days, 1,394 patients), and 16.5 days (9,620 inpatient days, 583 patients), respectively.

Comparative analysis of the treatment outcomes showed that the highest values were among the patients who received centralised medical care (Table 5).

Thus, the estimates of the quality of life in the study group significantly exceeded those in the comparison group ($p < 0.0001$) at each point of follow-up. This was also accompanied by more favorable estimates of the improvement of neurological status ($p = 0.0076$) and the high incidence of excellent and good outcomes ($p = 0.0001$) at the final examination using the MacNab scale.

Discussion

When considering the effectiveness of organisation of the treatment process or the treatment outcomes for patients with acute SI in a decentralised system of delivery of specialised medical care, we must admit that they were quite low in most cases regardless of the type of condition. A series of crucial and interrelated factors can be distinguished as a prerequisite for the emergence of this situation. At the same time, on the one hand, each of them allows characterisation of negative features of this organisation model, and on the other, it allows identification of trends for improving the system of treatment of victims of the studied category in large cities and industrial centres.

The most crucial factor is the specialty profile factor, first of all, of neurosurgical, and then, to a much lesser extent, of the orthopaedic trauma service of the health institution. It is the key factor that almost entirely dictates the emergence of other, secondary causes and circumstances that determine the effectiveness of delivery of medical care to such patients. In this regard, an important condition that determines the main specialty profile of the hospital, especially the one providing not just elective but also acute care services, is the number of patients with a particular condition admitted within a certain period of time (admission intensity). For example, the results of inspection of urban multidisciplinary hospitals by the St. Petersburg Health Committee task force showed that the vast majority of patients in neurosurgical departments had non-traumatic spinal conditions (Table 1). Indeed, out of 1,378 there-treated patients, only 306 persons (22.2 %) were admitted for SI, while in the remaining 1,072 patients (77.8 %) with non-traumatic spinal conditions the latter were almost entirely represented by degenerative disease (94.6% or 1,014 persons) [8, 9]. However, even among

Table 2
First stage of the study (n = 2.283)

Group	Isolated, neurologically intact SI, n (%)	Isolated, neurologically compromised SI, n (%)	SI as part of polytrauma, n (%)	Total, n (%)
Study group	1249 (63.1)	537 (27.2)	191 (9.7)	1977 (100.0)
Comparison group	208 (68.0)	81 (26.4)	17 (5.6)	306 (100.0)

SI — spinal injury.

Table 3
Second stage of the study (n = 267)

Clinical characteristic	Study group	Comparison group	p
Gender, n (%)			
female	87 (39.0)	23 (52.3)	0.1025
male	136 (61.0)	21 (47.7)	
Age, years			
minimal/maximal	18/77	19/78	0.9991
median (25th/75th percentile)	39 (31/45)	35.5 (30/56)	
Fracture localisation, n (%)			
lower cervical spine	25 (11.2)	4 (9.1)	0.534
thoracic spine	43 (19.3)	12 (27.3)	
lumbar spine	155 (69.5)	28 (63.6)	
Fracture group according to the AO classification, n (%)			
A	186 (83.4)	36 (81.8)	0.8362
B	26 (11.7)	5 (11.4)	
C	11 (4.9)	3 (6.8)	
ASIA scale, n (%)			
A	9 (4.0)	2 (4.5)	0.8506
B	31 (13.9)	5 (11.4)	
C	21 (9.4)	4 (9.1)	
D	2 (0.9)	1 (2.3)	
E	160 (71.8)	32 (72.7)	
ISS scale, n (%)			
more than 17 points	22 (9.9)	4 (9.1)	1.0
less than 17 points	201 (90.1)	40 (90.9)	
Total, n (%)	223 (100.0)	44 (100.0)	

all these patients, persons admitted to undergo elective treatment of this condition prevailed (56.1 % or 601 persons), and surgical care for patients with acute conditions was provided, firstly, based on significantly narrowed indications, and, secondly, not on the emergency basis but in a delayed manner [10]. On the other hand, the intensity of admission of victims with SI for each of the medical institutions involved in the study differed significantly and did not show any reasonable association with the number of neurosurgical beds, which resulted in a wide variation of the ratios of these parameters (from 0.2 to 7.3). It is rather reasonable that this situation resulted in a lack of a separate operating room to perform emergency surgical interventions on the spine and the corresponding staff and resources of the neurosurgical on-call service in all of the hospitals studied. Moreover, this circumstance, in its turn, entailed an unreasonable refrain from early surgical treatment in such patients. In other words, in a decentralised system, the pathway of delivery of specialised medical care to SI patients is determined not by the nature of the condition but by the features of the workflow, the financial and technical capabilities, and the human resources of the health institutions.

When discussing the choice of the optimal treatment strategy for victims with different types of SI within the particular organisation system, one should take into account the need to follow not only the general principles of modern spinal surgery regarding determination of the indications for surgery and choosing its adequate extensiveness but also the timing of providing the surgical procedure as well. To date, it is a secret to no one that one of the most important components of the successful restoration of the body functions of any SI patient is the reduction of the time interval between the injury and the respective surgical procedure. This applies not only to patients with neurologically compromised spinal trauma and polytrauma but also to isolated unstable spinal injuries in the absence of neurological deficit. This is due to the fact that a delay of surgery in such situations limits the possibility of reduction of the fragments of the damaged vertebrae and restoration of the anatomical configuration of the spinal column by ligamentotaxis using the least traumatic surgical techniques [11, 14, 15]. Moreover, in our opinion, in a large city, it is the organisation nature of the medical care system that fully determines the presence or absence of capabilities for implementation of the concept of the earliest possible surgical treatment. This conclusion can be confirmed by the obtained differences in the frequency rate of emergency surgical interventions and the treatment outcomes in victims receiving decentralised and centralised medical care.

In addition to centralisation of specialised medical care, a prerequisite for the successful implementation of the principle of the earliest surgical treatment of victims with SI is the availability of consistent funding. In our country, more than 90% of spinal surgeries are currently eligible for high-technology medical care funding in orthopaedic trauma and neurosurgery. At the same time, the scheme of funding of a medical department specialising in the treatment of patients with SI and other acute surgical conditions of the spine should ensure that high-technology surgical interventions can be performed not only and not to a great extent in an elective or delayed manner but also, first of all, in the context of delivery of emergency surgical care. In addition, it is traditionally considered that such a need for sufficient funding concerns only the provision of metal fixation devices and other implants for spinal surgery. However, in practice, it also includes the financial costs of equipment and tools, not only regarding their procurement, but also the repair, mainte-

Table 4

Distribution of statistical medical estimates characterising the process of delivery of specialised medical care to patients with spinal injuries (SI, first stage of the study)

Parameters	Isolated, neurologically intact SI	Isolated, neurologically compromised SI	SI as part of polytrauma	Total
Total number of surgeries, n / surgical activity (%)				
Study group (n = 1.977)	906 (72.5)	537 (100.0)	186 (97.4)	1629 (82.4)
Comparison group (n = 306)	34 (16.3)	78 (96.3)	13 (76.5)	125 (40.8)
p	<0.0001	0.0003	0.003	<0.0001
Emergency spinal surgery, n (% of the total number of surgeries)				
Study group (n = 1,977)	597 (65.9)	458 (85.3)	114 (61.3)	1169 (71.8)
Comparison group (n = 306)	3 (8.8)	29 (37.2)	0 (0.0)	32 (25.6)
p	<0.0001	<0.0001	<0.0001	<0.0001

Table 5

Comparative analysis of the outcomes of treatment of patients with acute spinal injuries in the context of the two organisation systems (second stage of the study)

Parameters	Centralised system, the study group (n = 223)			Decentralised system, the comparison group (n = 44)		
	6 months	12 months	18 months	6 months	12 months	18 months
Quality of life, ODI scale, points						
Median	23.2	18.5	16.3	27.8	25.4	26.6
25th percentile	20.5	15.8	13.9	25.3	23.2	23.5
75th percentile	25.5	21.3	20.1	31.5	28.8	30.1
Neurological status, ASIA scale, n (%)						
One grade or more improvement	–	–	52 (82.5)	–	–	5 (41.7)
No changes	–	–	11 (17.5)	–	–	7 (58.3)
Comprehensive evaluation of the treatment outcome according to MacNab, n (%)						
Excellent or good	–	–	185 (83.0)	–	–	25 (56.8)
Satisfactory	–	–	36 (16.1)	–	–	15 (34.1)
Unsatisfactory	–	–	2 (0.9)	–	–	4 (9.1)

nance, and upgrade. This also applies to consumables for this equipment, especially regarding its components and items of single or short-term use.

Conclusion

Centralised model of delivery of specialised medical care to victims with SI in a metropolis is characterised by more efficient use of the urban health care resources and better treatment outcomes. The key to its successful establishment and further operation, in addition to centralisation of the medical care system with the reasonable formation and distribution of the incoming patient flow, adequate financial and technical support of the treatment process, and the availability of highly-qualified medical personnel, is the availability of modern surgical technologies in the context of delivery of acute specialised care.

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