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TREATMENT OF COMBINED TRAUMA COMPLICATED BY FAT EMBOLISM: EXPERIENCE OF UZBEKISTAN

Khadjibaev A. M. 1, 2,
Valiev E.Y. 1,2,
Mirjalilov F. H.1,
Makhamadaminov A. G.2
Tuxtapulatov A. T.
1 Republican Research Centre of Emergency Medicine, Tashkent, Uzbekistan;
2 Centre for Improvement of Professional Qualification of Medical Workers, Tashkent, Uzbekistan

Abstract
This article is devoted to improving the tactics of treatment of combined skeletal trauma complicated by fat embolism syndrome, which is one of the main causes of death in severe combined skeletal trauma. A single-centre study including 236 patients with combined trauma complicated by fat embolism was performed. 97 patients were in control group and received conventional therapy, 139 patients of main group undergone modern "damage control orthopedics" tactics. The authors developed and introduced into the practice of treating such patients original modern minimally invasive technologies, improved the treatment regimen for fat embolism. Modern interventions in main group significantly reduced the invasiveness and aggressiveness of interventions in patients with combined trauma and resulted in decrease of hospital stay and incidence of complications.

Keywords: Combined skeletal trauma, fat embolism, damage control orthopedics.

BACKGROUND

In connection with intensive urbanization, the development of production, urban planning, an increase in the car park, natural and man-made disasters, and

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hostilities in the last decade, the world has seen an increase in the number of casualties with severe combined skeletal trauma (CST) [Likhterman L.B., 2016; Kukharev D.I., 2018; Simmel S. et al., 2013; Gross T. et al., 2016].

In recent years, the number of CST cases has reached 17.5–28.0% of all patients in trauma hospitals. According to the World Health Organization (WHO), mortality in CST is 25-60% and ranks third in the structure of total mortality from non-communicable diseases [Firsov C.A. et al., 2016; Markosyan S.A., 2017; Butcher N. et al., 2013, Hierro-Cañas, F. J. et al., 2019].

Among the main causes of death in severe CST, along with acute blood loss, traumatic shock and complications of traumatic brain injury, an important place is occupied by fat embolism syndrome (FES), which consists in multiple occlusion of blood vessels by fat emboli (fat drops, undifferentiated lipid masses, fat cells or lipid complexes larger than 7–8 μm) with the development of multiple organ failure (MOF) [Yakovlev A.Yu. et al., 2016; Razzokov A. A., Nazarov M. K., 2017; Caricato, A. et al., 2017; Renninger, C. H. et al., 2017; Dahl, O. E. et al., 2018; Malgapo K. K. L. et al., 2018; Rozema, R. et al., 2018].

The data mentioned above demonstrates the need for further in-depth studies of the problem of prevention and treatment of FES in CST.

The aim of this study is to improve the results of treatment of severe skeletal traumas complicated by fat embolism syndrome using minimally invasive methods of surgical correction and improving methods for preventing these complications.

MATERIAL AND METHODS

The study is based on the analysis of the results of diagnosis and treatment of 236 patients with severe skeletal injuries complicated by the development of FES and observed by us in the Department of Traumatology and Intensive Care Unit of the Republican Research Centre of Emergency Medicine (RRCEM) from 2008 to 2019.

There were 192 (81.4%) men and 44 (18.6%) women, the mean age of the patients was 43.8 ± 3.6 years. Depending on the tactics of treatment and preventive

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procedures, all patients with FES were divided into 2 groups: control group and main group.

The control group included 97 (41.1%) patients who were treated with traditional treatment tactics according to the principles of "early total care" i.e., maximum performance of all medical manipulations of injuries and standard preventive procedures. In contrast, 139 (58.9%) patients of the main group underwent treatment tactics that corresponded to the modern doctrine of the correction of combined skeletal traumas "damage control orthopedics - DCO" with the widespread use of minimally invasive surgical interventions. In addition, in patients of the main group, we used an optimized scheme for the prevention of FES by including a solution of succinic acid in it. Clinical, laboratory, instrumental (X-ray, CT, MRI) studies were provided in accordance with diagnostic standards of RRCEM.

RESULTS

Patients of the control and main groups with a CST complicated by FES in accordance with the rule of the "golden hour" were delivered to the Emergency Department, where they were examined by a surgeon, anesthesiologist, a neurosurgeon and a traumatologist during the first 15 minutes. Immediate control of vital functions, complete hemostasis of external bleeding, airway management, oxygen therapy, cardiopulmonary resuscitation, central line placement, initiation of fluid resuscitation and transfusion therapy, anesthesia were performed.

Prior to surgery all necessary laboratory and instrumental examinations were caried out. In total, 216 patients - 97 patients of the control and 139 patients of main group with combined skeletal injuries complicated by FES were analyzed.

In these patients, in order to correct existing combined skeletal and cavitary injuries, we performed a total of 216 different traumatological interventions. The types of surgeries performed by are shown in Table. 1

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Table. 1. Types of surgeries performed in patients, n=216.

Type of surgery	Control group		Main group		Total	
	n	%	n	%	n	%
Closed osteosynthesis	21	9.7	75	37.2	96	46.9
- *intramedullary pinning with blocking (BIOS. ChM-Poland)*	7	3.2	52	24.1	59	27.3
- *intramedullary pin*	12	5.6	10	4.6	22	10.2
- *ANF*	2	0.9	3	1.4	5	2.3
Closed stabilization of the pelvis with the apparatus of the clinic	1	0.5	3	1.4	4	1.9
Open osteosynthesis	84	38.9	32	14.8	116	53.7
- intramedullary pin with blocking (BIOS. ChM-Poland)	6	2.7	18	8.3	24	12.0
- intramedullary nail	11	5.1	7	3.2	18	8.3
- bone osteosynthesis	67	31.0	7	3.2	74	34.2
Total	**106**	**49.1**	**110**	**50.9**	**216**	**100.0**

As can be seen from the Table. 1. All patients underwent correction of bone fractures using closed (96) and open (116) methods of osteosynthesis. At the same time, osteosynthesis was performed both by conventional methods of intramedullary osteosynthesis with pins (40) and external osteosynthesis (74), and using intramedullary osteosynthesis with blocking (BIOS. ChM-Poland) (83). In particularly difficult cases of intra-articular fractures of the bones of the lower leg and forearm (5), we used the method of external fixation. In 4 patients with fractures of the pelvic bones, closed stabilization of injuries was performed using the apparatus designed in our clinic.

It should be noted that in patients of the control group, open osteosynthesis was considered the main method of correcting skeletal injuries, which was used in the majority of such patients (38.9%). In contrast, in the patients of the main group, in the correction of existing skeletal injuries, we widely used the method of closed osteosynthesis (37.2%) using a BIOS pin, which allows simultaneous pinning and blocking of bone fractures.

Along with the above traumatological operations, we performed surgical correction of various combined abdominal injuries in 216 patients. The variety of surgeries performed in internal organs are shown in Table. 2.

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Table 2. Types of surgeries performed due to injuries of internal organs, n=216

Type of surgery	Control group		Main group		Total	
	n	%	n	%	n	%
Traditional interventions	**51**	**33,3**	**48**	**31,4**	**99**	**64,7**
Thoracotomy:	16	10,4	10	6,5	26	16,9
Suturing of lung injuries	10	6,5	7	4,6	17	11,1
Removal of clotted hemothorax with fixation of rib fractures	6	3,9	3	2,0	9	5,9
Laparotomy:	6	3,9	5	3,3	11	7,2
Suturing of liver injuries	1	0,6	1	0,6	2	1,2
Bowel resection with entero-enterostomy	2	1,3	2	1,3	4	2,6
Splenectomy	1	0,6	1	0,6	2	1,2
Conversion of laparoscopy to laparotomy	2	1,3	1	0,6	3	1,9
Craniotomy:	29	18,9	33	21,6	62	40,5
- Subdural hematoma removal	21	13,7	26	17,0	47	30,7
- Intracerebral hematoma removal	8	5.2	7	4,6	15	9,8
Minimally invasive interventions	**15**	**9,8**	**39**	**25,5**	**54**	**35,3**
Thoracoscopy	2	1,3	14	9,1	16	10,4
Intrathoracic hemostasis:	2	1,3	14	9,1	16	10,4
- Clamping	*1*	0,6	8	5,2	9	5,8
- Suturing	*1*	0,6	6	3,9	7	4,5
Laparoscopy:	1	0,6	5	3,3	6	3,9
Intra-abdominal hemostasis	1	0,6	3	2,0	4	2,6
- Cauterization	-	-	1	0,6	1	0,6
- Argon-plasm coagulation	*1*	0,6	2	1,3	3	1,9
Suturing wounds of the stomach and intestines:	-	-	2	1,3	2	1,3
- Extracorporeal sutures	-	-	1	0,6	1	0,6
-Intracorporeal sutures	-	-	1	0,6	1	0,6
Trepanation:	12	7,8	20	13,1	32	20,9
- Intracerebral hematoma removal	*8*	5,2	13	8,5	21	13,7
- Subdural hematoma removal	*4*	2,6	7	4,6	11	7,2
Total	**66**	**43,1**	**87**	**56,9**	**153**	**100,0**

As can be seen from the data presented in Table. 2., in 66 patients of the control group, the stabilization of existing combined abdominal injuries, as well as skeletal ones, was carried out by traditional methods in 33.3%. At the same time, in these patients, we maximally (up to 84.3% of patients) used the tactics of treatment according to the principles of "early total care - ETC", i.e., surgical interventions were performed by several teams of surgeons and traumatologists simultaneously and sequentially.

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Thus, traditional thoracotomy in combination with stabilization of existing fractures of the extremities was performed in 16 patients, and in 10 of them undergone lung suturing, in 6 patients the clotted hemothorax was removed with fixation of existing rib fractures, in all these patients the intervention was completed with debridement and drainage of pleural cavities.

In 6 patients of the control group, the stabilization of existing fractures of the extremities was combined with the laparotomy. Suturing of liver injury was performed in 1 patient. In 2 patients, bowel resection was performed with entero-enterostomy. In 1 case, splenectomy was performed. All surgical interventions on the abdomen were completed with debridement and drainage of the abdominal cavity.

In 41 patients of the control group, the existing fractures of extremities were combined with a traumatic brain injury, in 29 of them decompression craniotomy was carried out, subdural (21) and intracerebral (8) hematomas were removed. In 14.8% of patients of control group, the existing injuries required more than two surgical interventions due to combined abdominal and chest trauma. All patients in the control group, along with surgical methods for correcting various combined injuries, conventional methods of treatment of FES were used.

The management of fat embolism included oxygen insufflation (non-invasive ventilation or mechanical ventilation), fluid therapy, dehydration therapy (glycerol 10% - 0.5 g/kg), sedation, correction of the coagulation system (unfractionated heparin 20-30 thousand units/day), glucocorticosteroid therapy when indicated, high doses of protease inhibitors - aprotinin (300 thousand units/day), the use of lipotropic drugs and substances preventing demulsification of lipids (essential fatty acids), parenteral and enteral nutrition, antibiotic therapy.

In contrast to the control group, in patients of the main group, for the correction of combined abdominal and chest trauma in 25.5% of patients we used a staged treatment approach that corresponds to the modern doctrine for the correction of combined skeletal injuries "damage control orthopedics - DCO". As surgeries to eliminate the existing combined skeletal and abdominal injuries, we used the possibilities of modern minimally invasive technologies in patients of the main group.

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So, in 14 patients of the main group, we performed the correction of existing combined injuries of intrapleural organs with the help of thoracoscopy. At the same time, interventions in all cases included stopping intrathoracic bleeding by clipping (8), suturing (6), followed by debridement and drainage of the pleural cavity.

In 5 patients of the main group, we performed correction of the existing combined abdominal injuries using laparoscopy. At the same time, surgical interventions consisted in stopping bleeding in case of liver injury using electrocoagulation (1), argon plasma coagulation (2). In 2 patients, the gastric and intestinal injuries were sutured using laparoscopic method with extracorporeal (1) and intracorporeal (1) sutures.

Due to combined traumatic brain injury in 20 patients, trepanation with removal of subdural (13) or intracerebral (7) hematomas was carried out. For fluid therapy balanced crystalloid solutions were used. In the postoperative period various complications were observed (Table. 3).

Table 3. Postoperative complications of patients, n=55

Type of complications	Control group		Main group		Total	
	n	%	n	%	n	%
Non-specific	**28**	**50.9**	**12**	**21.8**	**40**	**72.7**
Surgical site infection	18	32.7	8	14.5	26	47.2
Pneumonia	4	7.3	2	3.6	6	10.9
Acute myocardial infarction (AMI)	2	3.6	1	1.8	3	5.4
Pulmonary embolism (PE)	2	3.6	1	1.8	3	5.4
Stroke	1	1.8	-	-	1	1.8
Acute kidney injury (AKI)	1	1.8	-	-	1	1.8
Specific	**10**	**18.2**	**5**	**9.1**	**15**	**27.3**
Intra-abdominal bleeding	2	7.3	2	3.6	6	10.9
Abdominal abscess	1	1.8	1	1.8	2	3.6
Postoperative peritonitis	4	3.6	1	1.8	3	5.4
Sepsis, septic shock	2	3.6	1	1.8	3	5.4
Adhesive intestinal obstruction	1	1.8	-	-	1	1.8
Total	**38**	**69,1**	**17**	**30.9**	**55**	**100**

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A total of 38 patients in the control group (69.1%) had various non-specific and specific postoperative complications. Nonspecific complications were observed in 28 patients which are surgical site infection and suppuration postoperative wound (18), postoperative pneumonia (4), acute myocardial infarction (2), pulmonary embolism (2), stroke (1) and acute renal failure (1). Nonspecific complications in the vast majority of cases were corrected by conservatively.

Specific postoperative surgical complications were observed in 10 patients in the control group. Among them the most frequently observed were ongoing peritonitis (2) and abdominal abscesses (1) of various localization. There were relatively less intra-abdominal bleeding (2) and mechanical ileus (1). A distinctive feature of specific postoperative complications was that the correction of the latter in almost all cases required recurrent surgery.

The average hospital stay in patients of the control group was 38.2 ± 2.7 days. A total of 12 (12.4%) patients in the control group died postoperatively. The cause of death was bowel anastomotic suture failure and peritonitis (4), multiple organ failure due to sepsis with severe intoxication or bleeding (2), pulmonary embolism (1), fat embolism (4) and myocardial infarction (1). It should be noted that patients in the control group had high rates of both the number of severe FES (32) and mortality among this group of patients (12.5%).

In total, 17 patients of the main group (30.9%) had various non-specific and specific postoperative complications. In the postoperative period patients of main group had similar nonspecific and specific complications to control group but incidences were significantly less. In this regard, attention is drawn to the decrease in the number of severe FES (17) and mortality among this group of patients (5.9%) in patients of the main group. Most likely, this was due to the expansion of indications for the use of laparoscopic and thoracoscopic technics significantly decreasing the invasiveness of surgery and improvement of the treatment regimen for FES.

The average bed-day in patients of the main group was 21.3 + 1.6. In total, 4 (2.8%) patients of the main group died in the postoperative period. The cause of death was anastomotic suture failure and peritonitis (2), FES (1) and pulmonary

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embolism (1). The number of good and satisfactory results of treatment in the main group was 1.75 times higher than those in the control group.

DISCUSSION AND CONCLUSIONS

Currently, in the general structure of peacetime injuries, there is an increase in the number of combined injuries up to 60-70% accompanied by injuries of the musculoskeletal system from 49.8% to 83.5%. At the same time, injuries of the musculoskeletal system are dominated by injuries of extremities (52.2% -86.6%), and their most typical type is fractures of long tubular bones, occurring in 56.2-86% of cases [Pankov I.O., Sirazitdinov S.D., 2015; Firmov C.A. et al., 2016; David C. et al., 2013].

One of the formidable complications in the above skeletal injuries is the fat embolism syndrome, which causes death in 1 to 15% of cases [Dats A. V. S et al., 2017; Dmitriev I.V., Dorosevich A. E., 2017; Graziani A. et al., 2018; Guerado, E. et al., 2019].

This study was devoted to a comparative analysis of the traditional and improved tactics of treating patients with combined skeletal injuries complicated by FES.

The comparative analysis of the results of treatment of the control and main groups of patients clearly demonstrated that, due to the use of improved treatment tactics in patients with combined skeletal injuries, the proportion of staged surgeries increases according to the modern doctrine of "damage control orthopedics - DCO" with the expansion of the possibilities of using laparoscopy and thoracoscopy, intracranial interventions and low-invasive orthopedic surgeries.

The latter, due to their simultaneous adequacy and minimally invasiveness, significantly reduce the invasiveness and aggressiveness of interventions in patients with combined trauma. This is expressed in a significant increase in the number of good (up to 37.4%) and satisfactory (up to 42.4%) treatment results in the main group compared with the control group. Also decrease in the number of postoperative complications, a decrease in mortality and a decrease in hospital stay shows benefits of treatment regimens which were used in main group.

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The implementation of the proposed improved tactics for the treatment of combined skeletal injuries complicated by FES in the practice of the Department of Combined Injuries of the RRCEM, its branches and sub-branches will increase the effectiveness of treatment and reduce the incidence of postoperative complications.

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