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The Role of Supportive Computer Program in Diagnosis, Management, Prevention and Prognosis of Fat Embolism Syndrome Following Skeletal Trauma

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Abstract The article discusses the current state of the problem of fat embolism. The role of supportive computer program in the diagnosis, prevention and prognosis of fat embolism syndrome is discussed, as well as the effectiveness of various types of osteosynthesis at the stages of treatment of patients with fractures of tubular bones. A case study is given as an example.

Keywords Fat embolism syndrome, Fat globulemia, Combined trauma

15 to 35% of severe combined trauma patients die due to severe complications of trauma. One of the life threatening complications of trauma is fat embolism syndrome (FES) [4,11,12,17].

Fat embolism syndrome (FES) is defined as a clinical condition characterized by dysfunction of the lungs and central nervous system due to microvascular obstruction with large globules of fat, occurring mainly after fractures of tubular bones or pelvis [6,8,9,18,19].

Despite the progress achieved in the treatment of multiple and combined injuries, the problem of early diagnosis of this syndrome remains unsolved, especially at the stage of preclinical manifestations. A wide range of studies has been proposed for the diagnosis of FES. However, none of them has 100% specificity. The existing laboratory and instrumental methods of diagnosing FES are not satisfactory and changes are mainly detected when clinical picture is expanded and usually they only confirm the clinical diagnosis [3,5,7,15].

Diagnosis of FES remains a difficult and not fully resolved problem, because of absence of clear clinical picture and pathognomonic symptoms. Specific and highly informative laboratory tests are yet to be developed. At the same time, the clinical manifestations of FES in severe combined trauma can be blinded by a picture of traumatic shock, severe traumatic brain injury (TBI) and post-traumatic respiratory failure of different etiology. There is no single rational scheme for the prevention and treatment of FES [1,13,14,16].

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We aimed to optimize methods of diagnosing, predicting, preventing and treating of FES in patients with fractures of long bones and pelvis by creating a pathophysiology based scoring system with objective criteria.

1. Material and Methods

We studied the patterns of occurrence of FES in patients with skeletal trauma. Retrospective analysis of medical records of 181 patients with diagnosis of fat embolism syndrome treated in the Trauma Department of the Republican Research Centre of Emergency Medicine of Uzbekistan in the period of 2010 to 2017 was performed. 124 (68.5%) of patients were males. The largest number of patients 65.2% were young, most of working age. According to the mechanism of injury 158 (87.2%) cases were results of motor vehicle accidents. 131 (72.3%) patients were diagnosed with traumatic shock upon admission, 43 (23.7%) patients were in a state of alcohol intoxication. The scope of diagnosis and care is strictly regulated by the diagnostic and treatment standards developed in the clinic.

In addition, 155 patients (85%) had TBI, 16 patients (8.8%) had combined abdominal trauma, 66 patients (36.4%) had chest trauma, 32 patients (17.6%) had facial trauma, 9 patients (4.9%) hadinjuries of main arteries of lower extremities.

Mostly, the clinical picture of the FES developed after the "light gap" from 12 to 72 hours. 23 patients (12.8%) developed an acute form of FES, in 44 patients (23.8%) and in 112 patients (63.4%) subacute and subclinical forms of fat embolism were observed respectively. The mixed clinical form prevailed in 94 patients (52%), pulmonaryformin 67 (37%) and cerebral form occurred in 20 (11%) patients.

2. Results and Discussion

For the diagnosis of FES we used a set of large and small diagnostic criteria published by Gurd [2]. Major signs include: respiratory failure; cerebral involvement; petechial rash. Minor signs are hyperthermia; tachycardia; retinal changes; jaundice; renal signs and laboratory confirmation of the diagnosis: fat globulemia; anemia; thrombocytopenia; red blood cell segmentation. At least two positive major criteria plus one minor criterion or four positive minor criteria with the obligatory identification of globulemia are suggestive of FES diagnosis.

In accordance with the above diagnostic scheme, we analyzed the frequency of major andminor criteria and laboratory signs. The following data was obtained:

- respiratory failure (tachypnea, dyspnea and with or without cyanosis, a decrease in PaO_2 and an increase in $PaCO_2$) - occurred in 85.1% of patients with FES;
- braindysfunction not associated with TBI (disorientation, drowsiness, lethargy, convulsions, coma) - observed in 86% of cases;
- petechial rash on mucous membranes and skin of the chest and neck, was noted in 76.6% of patients.

In our study 33.8% of patients developed major signs within 24 hours and 66.2% within 48 hours.

Table 1. Diagnostic scale of fat embolism syndrome

Clinical, instrumental or laboratory signs	**Score**
Petechial rash	
No	0
Yes	4
Fever	
Subfebrile - up to 38°C	0,5
High (pyretic) - up to 41°C	2
Excessively high (hyperpyretic) - above 41°C	3
Heart rate	
Normal	0
90 - 110	1
< 110	2
Respiratory rate	
Normal	0
Above 20	1
Altered mental status	
Conscious	0
Stupor	1
Coma 1st degree	2
Coma 2nd degree	3
Coma 3rd degree	4
Immobilization for transportation	
Adequate	0
Inadequate	1
Injured segments number	
One	1
Two	1,5
Three	2
Four	3
Five	4
Six	5
Rib fracture	
Non complicated	0,5
Complicated	1
Pelvic fracture	
Stable fracture (type A)	0,5
Non stable fractures (types B, C)	1

continuation

SpO_2	
above 90	1
90- 80	1,5
below 80	2
"Snowstorm" infiltration in chest X-ray	
No	0
Yes	4
Presence of fat globules in plasma	
1st degree	1
2nd degree	2
3rd degree	*3*
4th degree	4
Presence of fat globules in CSF	
No	0
Yes	4
Fat globules in bronchial lavage	
No	*0*
Yes	*2*
Fat globules in urine	
No	*0*
Yes	*1*
Hematocrit	
above 30	1
25-30	1,5
below 25	2
Traumatic shock	
1st degree	1
2nd degree	1,5
3rd degree	2
4th degree	3
Blood loss	
Up to 750 ml	1
750- 1500 ml	1,5
1500- 2000 ml	2
above 2000 ml	3
Total	**0 - 44**

Also, studying the frequency of occurrence of minor signs, the following results were obtained: fever in 74.3% of cases, tachycardia in 97.2%, retinal changes in 67.9%, jaundice in 31.5% and symptoms of kidney injuryin 46.1% cases.

Laboratory data (day 1): anemia was observed in 76.9% of patients, thrombocytopenia in 57.8% of cases, an increase in erythrocyte sedimentation rate (ESR) of 45.1%, and fat globulemia in 96.3% of cases.

According to the results of the analysis, we developed a quantitative assessment of symptoms significance with the calculation of fat embolism score index, where petechial rash and diffuse alveolar infiltration rated with highest scores, and hypoxemia, confusion, hyperthermia, tachycardia and tachypnea with gradually decreasing significance. All the most frequently detected symptoms of FES were systematized, taking into account their specificity which was given a point value. In addition, to data such as number of damaged musculoskeletal system segments, the adequacy of their immobilization at the prehospital stage, the severity of shock, severity of blood loss etc. were included (Table 1).

The diagnosis of FES required ten or more scores. When total score is 8 to 14 points the course of fat embolism is mild; 14 – 20 - the course is severe, but with a favorable prognosis; more than 20 points - the course is extremely severe and prognosis is poor. Up to 14 points was in subclinical course of a fat embolism, when score is between 14 and 21 subacute course was observed, 21–30 and more than 30 scores demonstrated acute and fulminant course respectively.

In order to optimize the diagnosis and determine the further tactics of treatment for this group of patients, we have developed an auxiliary computer program. For the computer program "The program for the diagnosis, prediction and tactics of treatment in patients with skeletal injury complicated by fat embolism" a patent was obtained.

The computer program used by us in the clinic has been used for the last two years in patients with combined and multiple injuries and with shock-related injuries of the musculoskeletal system. It allows us:

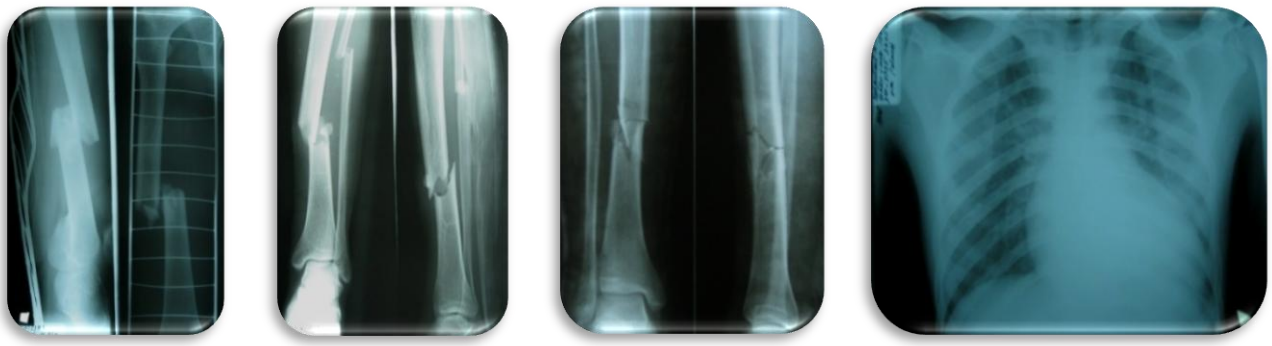
1. Perform electronic registration of scores obtained as a result of a clinical, laboratory and instrumental examination based on approved medical standards, with the possibility of recording information as soon as it is received.
2. On the basis of special criteria (specific and nonspecific), the degree of fat hyperglobulemy, the program allows automatic calculation.
3. The program allows us to work out with the electronic provision of recommendations on the implementation of diagnostic procedures, assessment of the status and determination of further tactics. According to a point scale and by the result of the obtained data, the program allows to formulate a diagnosis, work out a treatment strategy and determine the prognosis.
4. The program is the basis for the choice of tactics for further management of patients with skeletal injury, complicated by fat embolism depending on the volume of fat globules in biological fluids.

3. Clinical Case

25 y/o male admitted to Emergency department (ED) after motor vehicle accident. He was a pedestrian, delivered 45 minutes after injury. The whole diagnostic measures was carried out in ED according to the standard (Fig. 1). Examination of traumatologist, neurosurgeon, surgeon, urologist, thoracic surgeon. X-ray, ultrasound of the pleural and abdominal cavity, CT scan, laboratory diagnostics were performed. At the same time, shock management was carried out.

Diagnosis: Combined trauma. Open comminuted fracture of the middle third of the right femur with bone fragments displacement. Closed comminuted fractures of the middle third of tibia and fibula with bone fragments displacement. Blunt chest trauma. Bruise of the left lung. TBI, concussion. Sutured wounds of the right thigh and right heel region. Traumatic shock 3rd degree.

Initial management: Intensive management of shock, skeletal traction system for both lower limbs and wound surgery, transported to surgical ICU (intensive care unit).

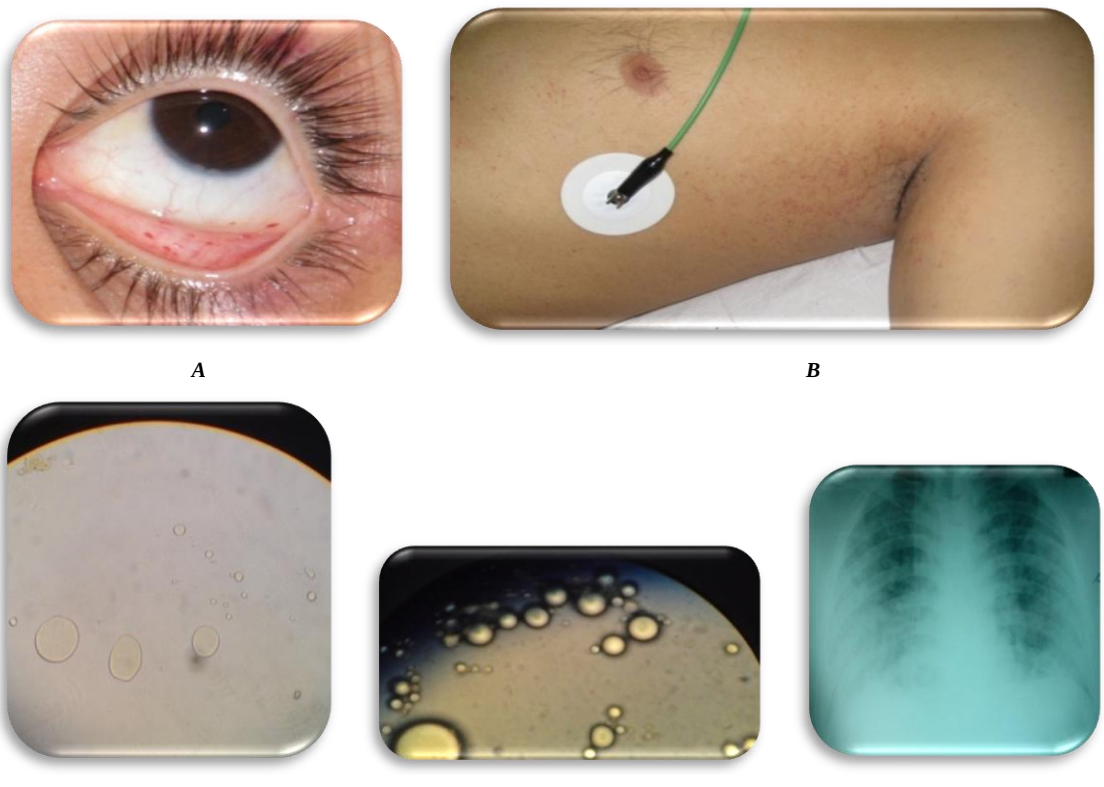


A *B* *C* *D*

Figure 1. Chest and extremities X-ray: A- Fracture of the middle third of the right femur with a displacementof bone fragments. *Type B*; B and C-comminuted fractures of the middle third of tibia and fibula with the displacementof bone fragments. *Type B*; D - Plain X-ray of chest *without bone-traumatic changes*

Next day after admission: The patient has developed an impaired consciousness (stunning); respiratory failure (SpO_2 - 85 - 90); tachycardia (above 110 per min.); petechial rash on the skin of the chest and conjunctiva (Fig. 3.A,B.); hyperthermia - up to 38.5℃; chest X-ray - "snowstorm" (Figure 3.E); hemoglobin –6,8 g/dl; fat in urine (++); fat in venous blood (++) (Figure 3.C,D.). All clinical and laboratory data were entered into a computer program, a total of 19.5 points was obtained, according to which a complication was exposed: Fat embolism syndrome 2rd degree; acute course, mixed form. Taking into account the data with a computer program for the patient, an early osteosynthesis of all the damaged segments was performed on the 3rd day (Fig. 5.6). Surgery was performed under general anesthesia combined with ultrasound guided regional nerve blocks and multimodal postoperative analgesia was used. The postoperative period was uneventful. On the 8th day the patient was transferred from ICU to the ward (Fig. 7.) and on 14th day discharged for outpatient treatment. The patient was followed up and after 11 months, a complete anatomical and functional recovery was noted (Fig. 8 and 9). The patient underwent surgery to remove metal fixators (Fig. 10.)

Figure 2. The patient at 1st day in ICU



A ***B*** ***C*** ***D*** ***E***

Figure 3. Initial manifestation of fat globules

A *B*

C *D*

Figure 4. Surgery performed 3 days after trauma: A - Patient on the operating table. B - Closed intramedullary osteosynthesis of the right tibia with a pin without drilling the medullary canal. C - Closed intramedullary osteosynthesis of the left b/tibia with a pin without drilling the medullary canal. D - Closed intramedullary osteosynthesis of the right femur with a pin without drilling the medullary canal.

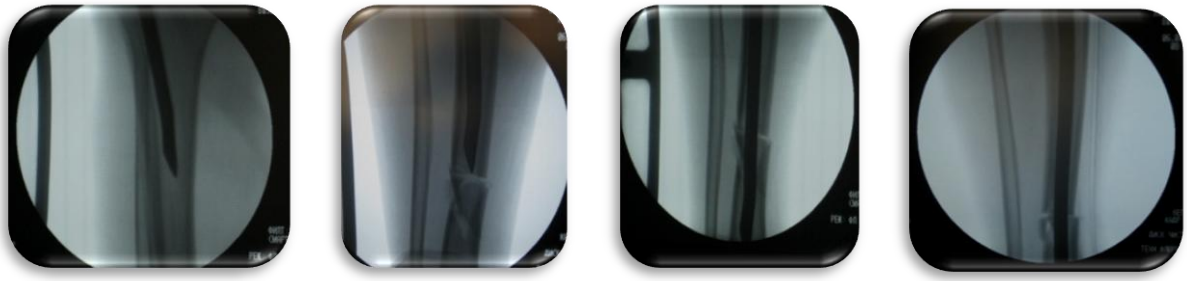


Figure 5. Intraoperative X-rays of intramedullary osteosynthesis of the left and right lower leg bones under the image intensifier

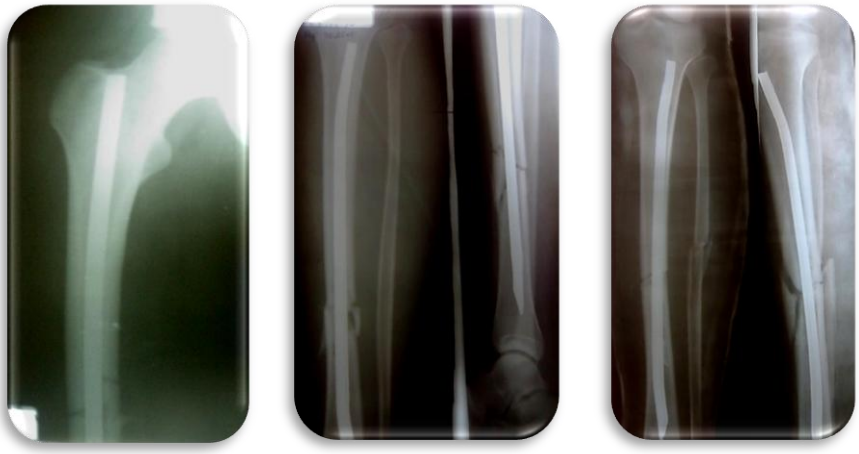


Figure 6. Immediate postoperative X-rays the right thigh and both tibia after intramedullary osteosynthesis (standing of bone fragments is satisfactory)

Figure 7. Patient 8 days after surgery

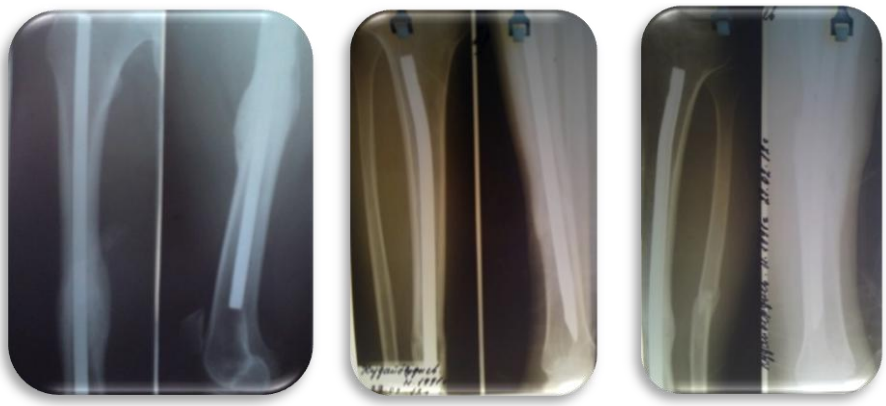
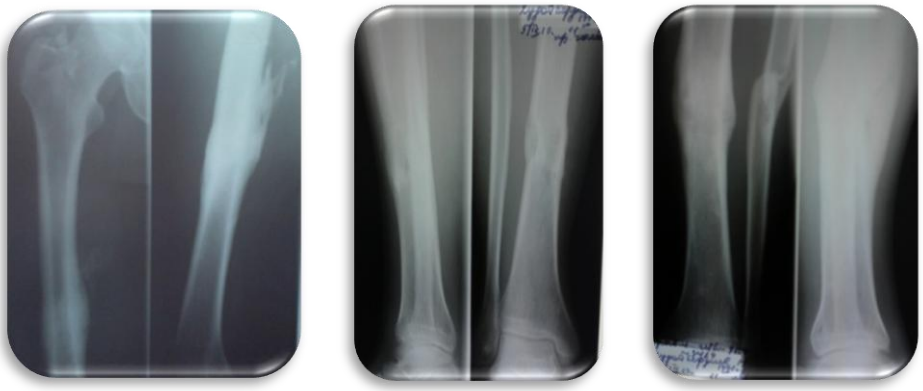


Figure 8. X-ray 11 months after surgery: complete consolidation of the right and both tibia

Figrue 9. The patient 11 months after surgery



Figrue 10. X-ray after metal fixators removal (*Radiographs of the right thigh and both tibia after metal removal (16 months after surgery)*)

Thus, on the basis of the data obtained by the method of binary logistic regression, significant predictors for predicting fat embolism syndrome were identified. This method allows us to identify risk groups and carry out a differentiated approach to the prevention and treatment of FES. The developed algorithm for predicting the development of FES is clinically tested in the Trauma department of the Republican Research Centre of Emergency Medicine of Uzbekistan. The experience obtained allowed us to reduce mortality from FES to 9.4% and to increase positive results of treatment to 88.3% of patients.

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