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Outcomes of operative treatment of floating sternocostal fractures

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Introduction Severe chest injury with associated trauma to the rib cage, hemothorax, contusion of the lung, heart, ruptures of the mediastinal vessels, diaphragm is an important cause of morbidity and mortality in patients with polytrauma. **Methods** An algorithm for the examination and treatment of patients with severe chest trauma was developed, and new methods of treatment protected by 5 patents proposed. **Results** We report outcomes of 29 patients with multiple floating fractures of the rib cage which were stabilized, reduced and repaired with devices and frames developed by the authors. **Discussion** Less traumatic methods of costosternal stabilization of multiple chest injury have shown to be effective in stabilization of patients' condition, improvement of pain, respiratory function properly maintaining the reduced bone.
Keywords: floating rib fractures, sternal defect, sternocostal complex, external fixation device

INTRODUCTION

Injuries to rib cage are referred to S00-T98 class of MKB-10 classification system (block S20-S29) and include 10 positions characterizing open and closed thoracic fractures, broken ribs, spine, impaired vessels, heart, muscles and insults to the thoracic viscera. Injury to the chest from traffic collisions, home and industrial accidents is one of the most severe. Severe clinical manifestations are mainly caused by broken rib cage, hemothorax, contusion to lungs, heart, mediastinal ruptures and diaphragmatic insult [1, 2]. Rib cage fracture is one of the leading causes of morbidity and mortality in polytrauma patients [3, 4]. The force that caused the fracture occasionally causes other problems, such as pulmonary contusion and other conditions [5, 6]. Multiple injury and flail chest are one of the worst subset of the sternocostal trauma [7, 8]. The therapeutic approach to the management of flail chest is a matter of controversy [9, 10]. Less traumatic techniques of controlled osteosynthesis of rib fractures and the chest are more appropriate for patients with severe traumatic shock, combined injury to the chest, abdominal cavity, skeletal trauma using external fixation devices. Experience of thoracic, trauma and orthopaedic surgeons allows for technologies to be used at specialized trauma, surgical and thoracic departments following principles of damage control and employing a simple set of devices and instruments manufactured by national industry [11, 12].

The purpose of the study was to improve results of treatment for patients with multiple injuries, flail chest and sternocostal defects using external fixation devices and less traumatic methods of rib and chest reduction and stabilization.

MATERIAL AND METHODS

The study included findings of 29 polytrauma patients with multiple injuries, flail chest and broken ribs treated at thoracic department of Samarskaya regional hospital. The injuries resulted from motor vehicle accidents (n = 21), pedestrian accidents (n = 2) and falls from height (n = 6). Patients' age ranged from 32 to 64 years. Only 9 patients were delivered to the hospital after 11/2 to 4 hours of injury, air ambulance was arranged for 20 patients who had tertiary medical care two to three days of injury. Chest injury was associated with isolated and multiple fractures of long bones in 13 cases. Pelvic injury was diagnosed in13 cases and seven of them were unstable. Multiple fractures of long bones were detected in 9 cases with 6 associated with pelvic injury. Isolated fractures of long bones were diagnosed in two cases. Radiological assessment was produced for all patients and multislice computed tomography (MSCT) administered by indication. Radiography was performed for all patients with fractures of long bones in dynamics. Assessments were produced using certified equipment by qualified personnel. The study was approved by Ethical Board of the Kurgan Ilizarov Centre (Protocol № 1/56 dtd 19.02.2018). Written informed consent for publication was obtained from all participants.

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TECHNIQUES

Methods of treatment used for the severe group of patients were dependent upon many factors including an extent of respiratory insufficiency due to an area and location of unstable portion of the chest, degree of floatation, effect on mediastinum and pain. Floatation index of costal valve (FICV) was used as an objective measurement to identify indications to a treatment technique and develop an algorithm of treatment. FICV was calculated as a ratio of displaced floating portion of sternocostal valve (SCV) at breathing in (H1) and breathing out (H2), FICV = H1:H2 (**Fig. 1**).

FICV and other factors including localisation of the valve, extent of impaired respiratory function, blood oxygen level, were important for making a decision of bone fixation mode. Either pneumatic stabilization of the costal valve or skeletal sternal/costal traction was employed in severe general condition, expressed manifestations of traumatic shock and technical inability of bone fixation.

Moderate continuous hyperventilation of the lungs was produced for pneumatic stabilization of multiple and floating ribs and sternum. Стабилизацию ребер при множественных переломах, According to E.A. Wagner, B.A. Broonce (1998) at least 10 ribs must be stabilized in multiple fractures and bilateral cases with several lines combined with respiratory acidosis [9].

External fixation was produced with 3 major techniques we developed to address rib fractures.

1. Anchor fixation of flat bones using external fixation device of our own construction was one of the first offered. Bench and biomodel tests were performed for devices and fixation techniques developed to address sternocostal fractures (**Fig. 2**).

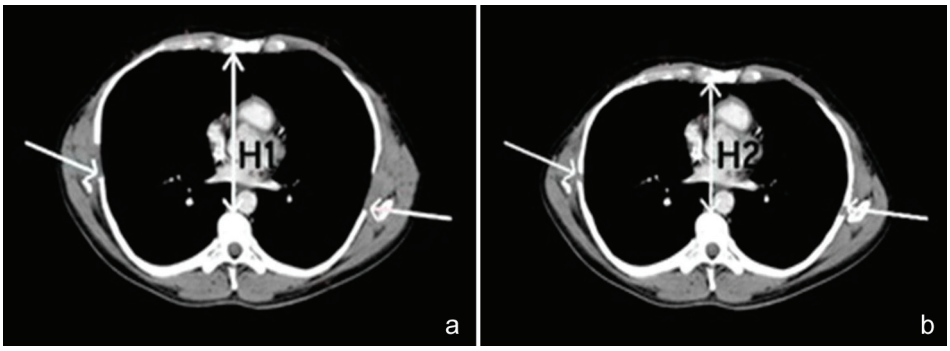

Fig. 1 MSCT scan of the rib cage (axial slide) showing floating parameters of the costal valve with (a) H1 measuring displacement of the floating portion of sternocostal valve at breathing in and (b) at breasting out. Side arrows show an extent of displaced ribs

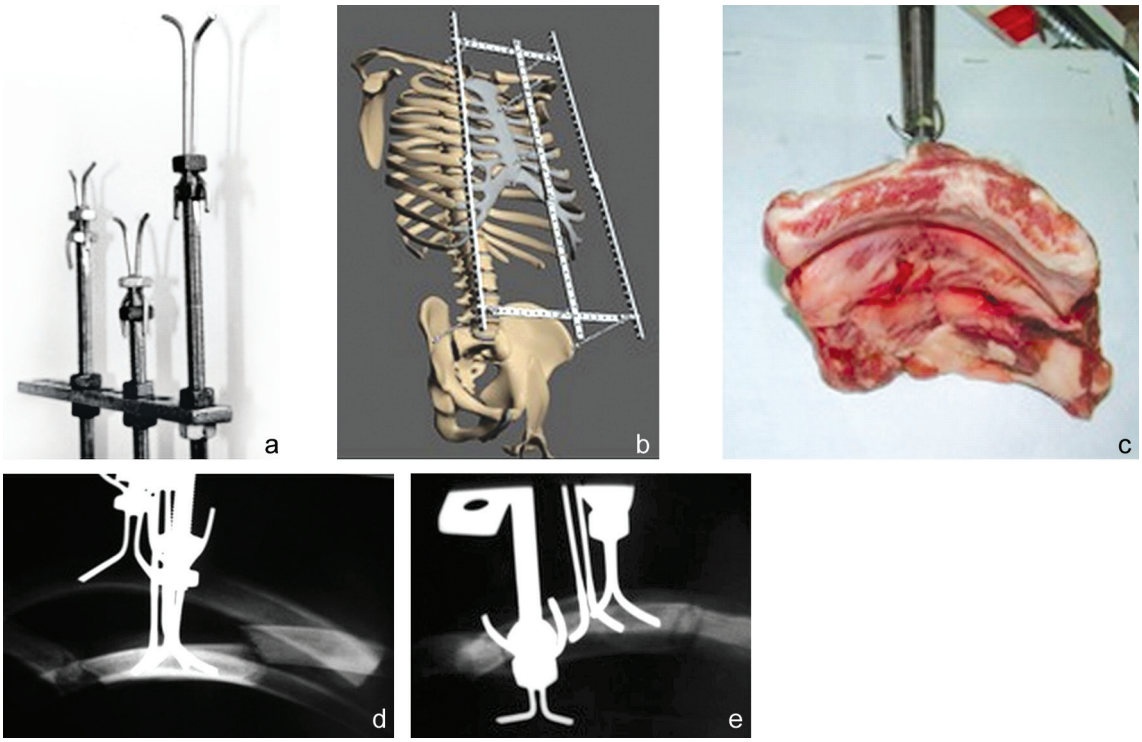

Fig. 2 Technique and device to fix and transport flat bones: (a) appearance; (b) external fixation device assembly; (c, d, e) simulated rib fracture fixed with external fixation device of our own construction

With positive biomodel test data, favorable decision for invention and patient's consent the surgery was performed for patient Sh. The patient sustained manufacturing injury falling asleep in a furrow when seed planter drove through his ribcage. The injury was complicated by hemothorax with symptomocomplex developed. He was delivered to the trauma department of Samarskaya regional hospital by an ambulance. The pleural cavity was drained after examination and anchor external fixation construct was applied to sternum with pelvic and clavicle support. Schanz screws were placed in both clavicles and anterior-superior pelvic spine and sternal fragments fixed with anchors. The technique of bone fixation was patented (utility patent № 134778 dtd 27.11.2013) (**Fig. 3**).

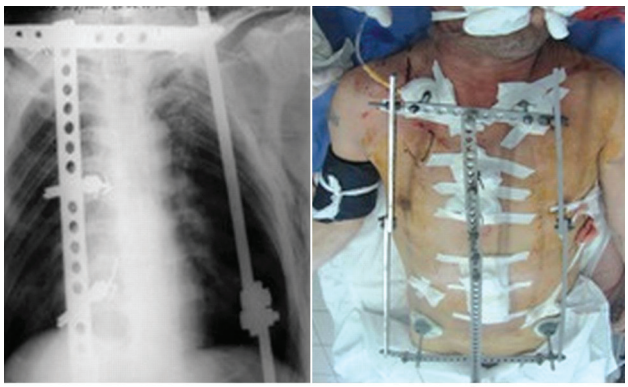

Fig. 3 (a) anteroposterior view of ribcage; (b) photograph of the patient with floating ribs and sternum fixed with external fixation device

The ribs were fixed longitudinally and transversely to improve flat bone stability using a special device of rib perforator we offered. The technique allowed for sternocostal transport anterior to posterior and longitudinal and transverse directions (Patents № 2519632 dtd 16.04.2014 and № 2539187 dtd 28.11.2014) (**Fig. 4**).

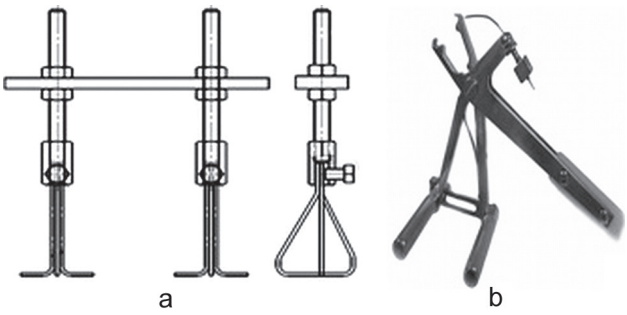

Fig. 4 (a) device for fractured bone fixation and flat bone transport; (b) costal perforator

2. Monocortical wires with stoppers were used to fix isolated fractures of 3 to 4 floating ribs. The technique and the construct were patented (№ 2497475 dtd 10.11.2013) (**Fig. 5**).

Intact ribs of either involved or intact side, or intact clavicle and pelvis were used for fixation with external fixation device. A wire had a stopper 1.5-2 cm off the tip with the costal thickness of not more than 1 cm. The stopper was used to prevent injury to costal pleura and for pneumothorax. Wires manufactured by pilot factory of the Kurgan Ilizarov Centre were used for rib fixation. The wires were placed in the ribs obliquely, arched and fixed to special clamps. The assembled construct and connection plate was employed to address floating costal valve.

3. Multiple sternocostal fractures were anteriorly repaired with external fixation device and Schanz screws with stopper located 1.5 cm off the sharp end of the screw that was practical for prevention of screw migration into pleural cavity (Patent № 2526448 dtd 20.06.2014) (**Fig. 6**).

External fixation device was assembled with screws introduced into the ribs and sternum (**Fig. 7**).

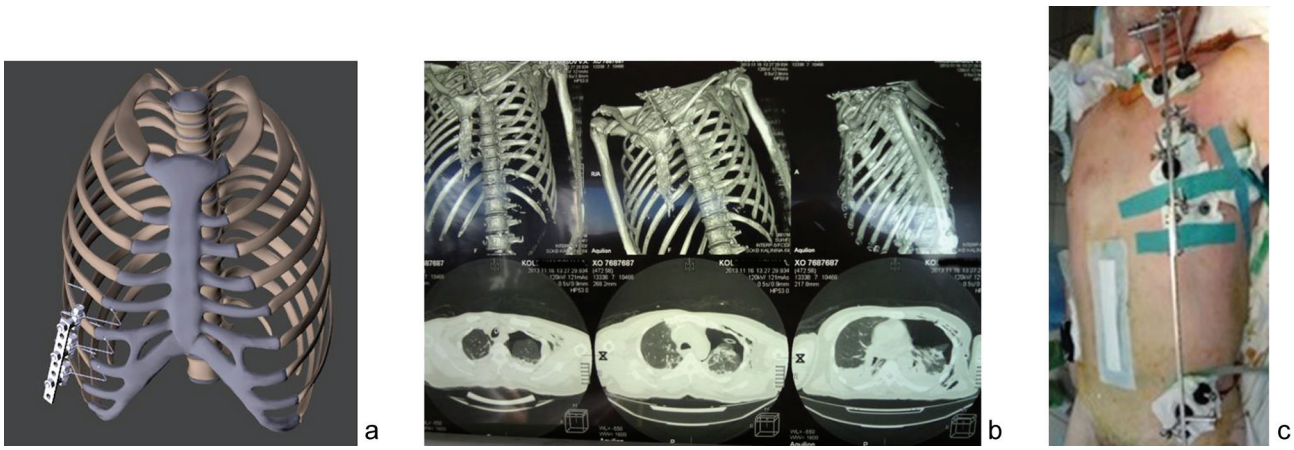

Fig. 5 (a) schematic image of the surgery; (b) preoperative CT scan of ribcage of patient K. (VRT and axial slides); (c) postoperative photo of the patient

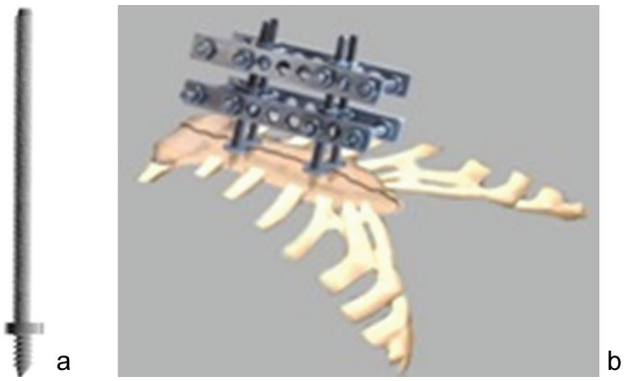

Fig. 6 Technique and the device used to stabilize sternocostal fractures with Schanz screws with stoppers: (a) screw with stopper; (b) frame assembly

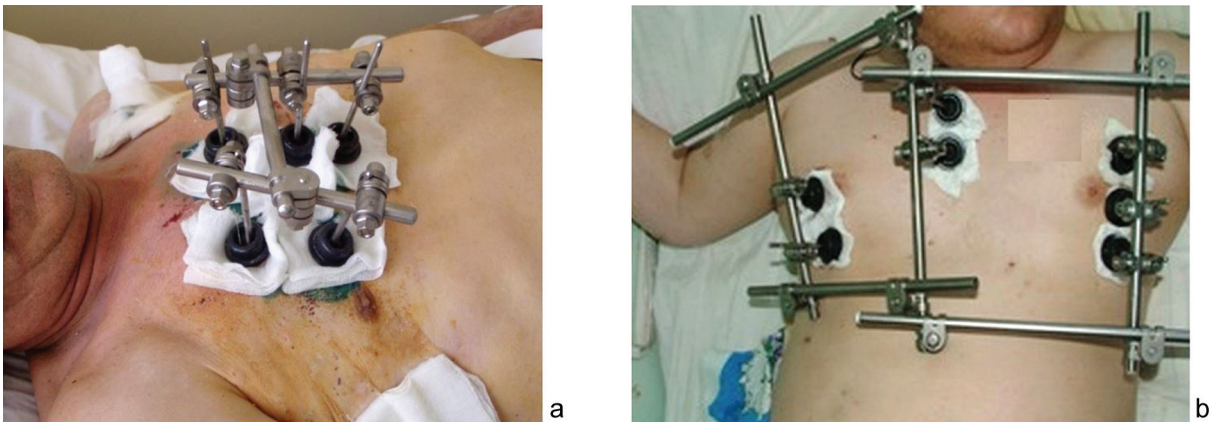

Fig. 7 Photographs of patients S. and M. with multiple sternocostal fractures stabilized with external fixation device and half-pins

RESULTS AND DISCUSSION

Intercostal anesthesia was conducted for all patients with broken ribs. Skeletal sternal traction was primarily provided for ten patients with floating ribs and broken sternum and 19 patients underwent pneumatic fracture stabilization. External fixation device with half-pins (n = 10), wires (n = 11) and a combination of both (n = 8) was applied for 29 patients after 2 to 3 days of admission. Intact ribs, clavicle and pelvis were used for fixation. Sternocostal fractures were stabilized with external fixation device and half-pins, and fractures of 7 days and older were reduced with external fixation device and wires. The techniques were practical in restoration of the shape and volume of ribcage. Matrix Rib plating system was applied 8 to 10 days following external fixation in three cases.

Plating and external fixation of sternocostal fractures resulted in considerably improved condition of the patients, pain relief, stabilized respiratory function and the patients were weaned off the pulmonary ventilation (Table 1).

Duration of pulmonary ventilation, tracheostomy, complication and mortality rates are presented in Table 2.

Table 1

Respiration and blood oxygenation at stages of treatment

Description	Period of observation		
	Pre-op	Post-op	Next day after the surgery
Respiration rate (per min.)	24.0 ± 1.9	19.0 ± 1.2	19.0 ± 1.4
Respiratory air (ml)	332.0 ± 12.2	440.0 ± 11.9	476.0 ± 2.5
Pulmonary minute volume (ml)	6400.0 ± 230.0	8100.0 ±301.0	8400.0 ± 278.0
Arterial oxygen tension (mm Hg)	70.6 ± 4.1	96.0 ± 9.1	92.0 ± 8.9

Table 2

Duration of pulmonary ventilation, tracheostomy, complication and mortality rates in patients with multiple and floating rib fractures

Results	Surgical fixation	Pneumatic stabilization
Number of ventilation days	8	15
Tracheostomy	11	33
Complications		
Intrathoracic infection	15 %	50 %
Barotrauma	–	8 %
Mortality	8 %	29 %

Fractures of long bones and pelvis in nine patients were fixed with external fixation devices (n = 6) and interlocking nails (n = 3) along with sternocostal repair. External fixation device was removed after 14 to 21 days with the patient's condition stabilized. All patients had positive results.

The results of the treatment showed that less traumatic techniques applied to address multiple ribcage fractures facilitated stabilization of the patients' condition, pain relief, recovery of the respiratory function with broken fragments reduced and retained in realignment.

CONCLUSIONS

The experience allowed us to conclude that:

1. Stabilization of sternocostal fractures at early postoperative period prevented intrapleural complications like hemo-, pneumothorax and respiratory distress syndrome.

2. Stabilization of osseous ribcage reduced respiratory ventilation time providing earlier rehabilitation.

3. External fixation devices were useful for stabilization of sternocostal fractures. External fixation devices with wires and half-pins were practical for fracture reduction in patients admitted to the hospital 7 days of injury and later.

4. The techniques facilitated restoration of the shape and volume of ribcage providing normal respiratory function.

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