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BORDERLINE POLYTRAUMA PATIENTS MANAGEMENT PROTOCOL

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ABSTRACT

Introduction: The adoption of the use of the damage control orthopaedics (DCO) protocol in clinical practice is of particular importance for trauma centers in this country. The concept of damage control (DC) in polytrauma patient management has been developed in an attempt to answer the question, when and how to operate on a patient with a severe trauma based upon inflammatory trauma response. The purpose of DCO is to minimize the time of surgical intervention and bleeding and thus reduce to a minimum the "second wave" of postoperative complications. While patients with stable vital signs can be treated with primary definitive osteosynthesis, DCO is a safe method that can be applied when it is advisable to cut the time for surgical intervention, or when a systemic immune response is inevitable. Borderline patients are those who, while stabilized through initial resuscitation measures, are exposed to factors that place them at risk of an adverse treatment outcome or rapid deterioration of their condition. **Material and Methods:** A prospective study was conducted on, and data processed from, 93 borderline polytrauma patients over a 5-year period. The study population were of 42.23±16.07 years' average age, ranging between 17 and 81 years; of them, 60 (64.5%) were male and 33 (35.5%) female. The most numerous age group (18) among the males were the 40-49 year-olds, followed by the 20-29 year-olds (13), and the least numerous (2) were the 70-79 age group. Among the female patients, the most numerous (8) was the 30-39 age group, followed by the 60-69 year-olds (6), while the 80-89 age group numbered a single patient. Patients with polytrauma injuries treated in Bulgaria all

had Injury Severity Score (ISS) over 16. **Methods:** diagnostic (laboratory) tests; imaging diagnostics: X-ray images; CT; ultrasound diagnostics; angio CT. Therapeutic – debridement; external fixation; conversion. **Results and Discussion:** Lethal exitus: in 4 males and 1 female. The mortality rate among the 93 patients in the study was calculated at 4.65%. One patient died during surgery, two survived the first 36 hours from admission, and the remaining two survived 72 hours from admission. Average duration of stay in ICU: 5.91 days for the males and 7.61 days for the females. Disability for up to 1 ½ years occurred in 10 males and 7 females; pulmonary thromboembolism in 1 male, no females; sepsis, in 2 males and 3 females; infections, in 16 males and 8 females; bone nonunion, in 11 males and 7 females. Conversion was performed on 52 male and 29 female patients. **Conclusions:** Our clinical experience in polytrauma patient management is based on DCO. We have made no significant distinction between open and closed fracture in administering DCO. As we adhered to the DCO principles in dealing with such patients, clinical experience shows that the average stay in ICU was 6.763 days, and the average total length of stay in hospital, 28 days, with a mortality rate of 4.65%.

KEYWORDS: Polytrauma, DCO, SIRS, CARS, external fixation, conversion.

INTRODUCTION

The adoption of the use of the damage control orthopaedics (DCO) protocol in clinical practice is of particular importance for trauma centers in this country.

The concept of damage control (DC) in polytrauma patient management has been developed in an attempt to answer the question, when and how to operate on a patient with a severe trauma based upon our understanding of inflammatory trauma response.

By applying DCO, we seek to contain bleeding, suppress the pathological inflammatory response, excise non-vital tissue, prevent ischemia-reperfusion damage and reduce pain.

DCO is a concept in the treatment of bone fractures in patients with severe injuries. The fractured bones are stabilized by means of external fixators, rather that by applying definitive osteosynthesis, known as early total care (ETC). The purpose of DCO is to minimize the time of surgical intervention and bleeding and thus reduce to a minimum the “second wave” of postoperative complications. While patients with stable vital signs can be treated with primary definitive osteosynthesis, DCO is a safe method that can be applied when it is

advisable to shorten the time for surgical intervention, or when a systemic immune response is inevitable.[1,2,3,4,5,6]

The application of standardized protocols in the treatment of multiple traumas, multiple injuries as well as single traumas has enabled an improvement of traumatological treatment, resulting in a reduction of posttraumatic morbidity and mortality. Replacing the ETC algorithm with the DCO concept has assumed a leading role in polytrauma patient management.

For the purposes of of this article, we define polytrauma as 2 traumas with Abbreviated Injury Scale (AIS) $\geq$ 3, plus one or more of the following 4 physiological responses to trauma: arterial hypotonia, disturbed consciousness, acidosis, and coagulopathy. In polytrauma patients, certain trauma complexes are seen as an indication of damage control.[7]

Multiple traumas result in significant blood loss and accumulation of necrotic tissue in an ischemic-hypoxic environment; in both cases this causes coagulopathy and an inflammatory response. Such an inflammatory response as a result of multiple trauma constitutes an important element of the system reaction at molecular level. The acute posttraumatic phase of the inflammation consists of two, almost synchronized, pillars: the pro-inflammatory reaction (systemic inflammatory response syndrome, or SIRS) and the anti-inflammatory reaction (the compensatory anti-inflammatory response syndrome, or CARS). SIRS includes changes in heart rate, breathing frequency, body temperature regulation and immune cell activation. Where a posttraumatic inflammatory response occurs and proceeds naturally, the ratio between pro- and anti-inflammatory reactions is in a state of balance, maintaining biological homeostasis and triggering controlled regenerative processes, thus enabling the body to recover normally, without any major complications. It seems, however, that an excessive posttraumatic inflammatory response includes simultaneously and in an accelerated fashion the activation of congenital (through pro- and anti-inflammatory mediators), and the suppression of adaptive immunity, all of this contributing in a decisive way to the onset, in an early phase, of multiple organ failure.[8,9,10,11] Moreover, a long-lasting and unchecked immuno-inflammatory response is associated with slow recovery, accompanied by complications, especially if a delayed multiple organ failure has also occurred. Owing to improved modern reanimation methods, we often observe progress in the clinical manifestations of the syndrome of persistent inflammations, immunosuppression and catabolism, which could replace the late-occurring form of multiple organ failure (MOF), but

is still associated with the kind of undesirable outcome that manifests itself as "silent death".[12]

The initial traumatic strike ("**first strike**") triggers an inflammatory cascade that stimulates the immune system of the host. The massed initial traumatic impact (first strike) causes a severe systemic inflammatory response syndrome. In the circumstances, the enormous secretion and emission of pro-inflammatory and anti-inflammatory mediators causes multiple organ failure and a quick death. A weaker initial traumatic strike causes a more moderate SIRS-CARS condition. In such a case, the inflammatory and immune cells undergo a period of "priming". Some patients, however, develop posttraumatic complications such as sepsis, acute renal impairment, acute respiratory failure or multiple organ failure. The emergence of such complications is determined by a variety of exogenous and endogenous factors. Patients with severe injuries of the soft tissue of extremities, and with the ensuing hemorrhagic shock or acute muscle crush syndrome are at risk of developing serious remote organ damage. *Hip fractures with soft tissue injury usually lead to changes in the hemodynamic parameters such as increase in heartbeat, tachycardia, reduced systemic vascular resistance and decreased blood flow to the liver.*[13,14,15,16,17,18,19] Long bone fractures and unstable pelvic fractures are characterized by severe blood loss and associated with grave soft tissue injuries, which trigger an inflammatory response at both local and systemic level. *All of the above is evidence that, in and by itself, the initial trauma makes the patient more susceptible to posttraumatic complications.*[20,21,22]

Patients who have survived the initial damage („first strike") could still be at risk of sepsis or multiple organ failure.

Secondary ("second") strikes, that come after the initial damage, exacerbate the systemic inflammatory response by upsetting the balance between pro- and anti-inflammatory mediators, pro-coagulants and anticoagulants, pro-apoptotic and anti-apoptotic events and pro-regenerative and anti-regenerative processes. Said secondary ("second") strikes are complicated by endogenous and exogenous factors.[23]

Endogenous secondary strikes include respiratory distress, cardiovascular instability, ischemia and reperfusion traumas, as well as infections.

Exogenous secondary strikes include surgical and anesthesiological interventions and blood transfusions.[24 25 26]

Blood transfusion is a kind of therapy of paramount importance for patients with traumatic/hemorrhagic shock. Various studies show that blood transfusions are associated with infections, SIRS, ARDS, and MOF after a trauma, which in themselves constitute a "second strike" for the polytrauma patient.[27, 28, 29, 30,31,32]

MATERIALS AND METHODS

A prospective study has been conducted on, and data collected from, 93 borderline polytrauma patients over a 5-year period. The study population were of 42.23±16.07 years' average age, ranging between 17 and 81 years; of them, 60 (64.5%) were male and 33 (35.5%) female (Fig. 1).

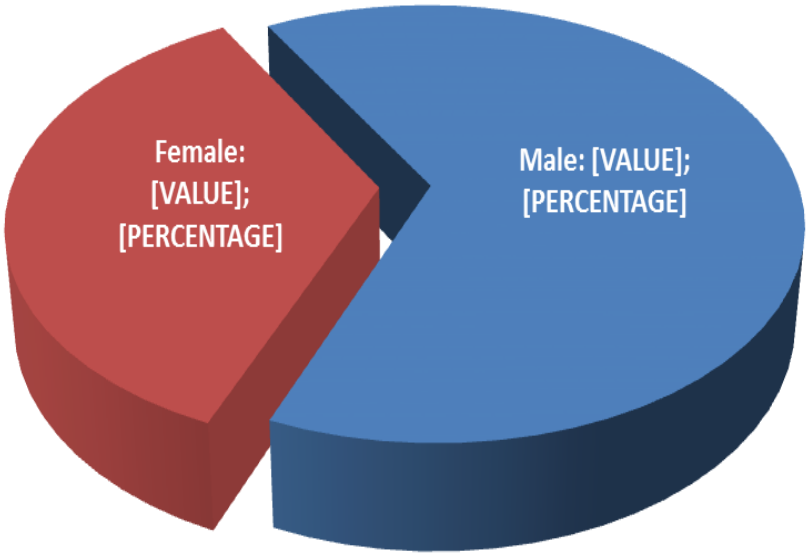

Fig 1: Distribution of the study population by gender.

The most numerous age group (18) among the males were the 40-49 year-olds, followed by the 20-29 year-olds (13), and the least numerous (2) were the 70-79 year-olds age group. Among the female patients, the most numerous (8) were the 30-39 age group, followed by the 60-69 (6), while the 80-89 age bracket numbered a single patient.

Our study of polytrauma in borderline patients included an investigation of the following **indicators.**

1. Review of the patient population by gender;
2. Review of the patient population by age group;
3. Analysis by gender and year the trauma was inflicted;
4. Investigation of the manner the trauma was inflicted;
5. Review by type of damage sustained;
6. Review by number of injuries;
7. Review by type of fracture (open or closed), for the total population and by gender;
8. Review of death cases, for the total population and by gender;
9. Analysis of the distribution of complications, for the total population and by gender;
10. Distribution of subjects by type of damage;
11. Distribution of subjects by time of day when the trauma was inflicted;
12. Distribution of subjects by season when the trauma was inflicted;
13. Distribution of subjects by day of the week when the trauma was inflicted (whether on a weekday or a weekend).
14. Distribution of subjects by time of admission to a hospital.

Pursuant to the concept, the patients are divided into 4 categories.

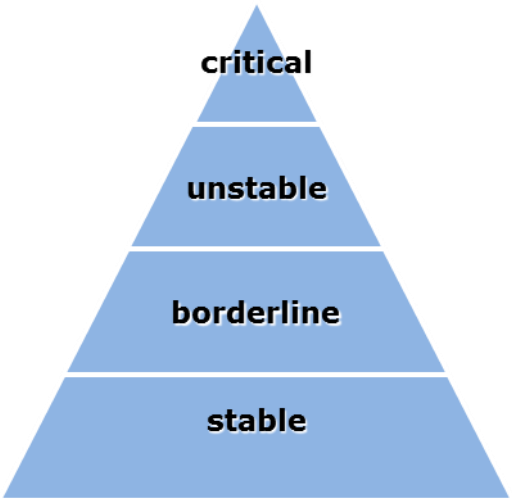

Fig. 2: Categories of patients.

The categorization of patients in terms of their belonging to one group or another was carried out on the basis of.

- the severity of the trauma;
- the existence of specific traumas;

- their hemodynamic status.

Borderline patients: patients who have been stabilized through the initial resuscitation measures, yet display factors that put them at a risk of a bad outcome of the treatment or rapid deterioration of their condition.

We based our selection of patients for DCO on physiological indicators and traumatological damage.

Most patients fell into the groups of either „stable" or „borderline", as their fractures could be definitively stabilized on an emergency basis, i.e. those were patients eligible for ETC. The unstable patients, as well as those who could not be stabilized through emergency resuscitation, were deemed unsuitable for long-term surgical treatment and had to be treated through temporary stabilization.

In polytrauma patients, certain types of damage can be seen as indication for DCO: pelvic fracture, hip fracture, multiple long-bone fractures, muscle crush injuries of extremities, cranial brain trauma, severe thoracic and abdominal trauma, as well as patients in advanced old age with limited biological reserves.

Of special interest and therapeutic challenge are the sub group of ***stable patients*** who have responded adequately to the resuscitation but the type of damage sustained makes them susceptible to a future rapid deterioration. *This is the subgroup of borderline patients.*

In our clinical practice we identify such patients on the basis of several clinical parameters, scales and trauma complexes**.**

The clinical parameters used in their identification are as follows

- Injury Severity Score >16
- Polytrauma (ISS>20), in combination with thoracic trauma (AIS>2)
- Polytrauma, in combination with severe abdominal (Moore ≤ 2) or pelvic damage (AO class B or C), with hemorrhagic shock on admission (systolic pressure < 90 mm Hg)
- Cranial brain trauma (CBT)
- Patients in advanced age with limited biological resources
- Muscle crush syndrome
- Hemoglobin 80-100 g/l

- Lactate 2,5 mmol/L
- Thrombocytes 90 -100 G/L
- Fibrinogen 1 g/dl
- Acidosis pH < 7,1
- Hypothermia (t < 36º C)

Normally at least three of the above parameters must be in evidence in order for a patient to be classified as borderline.

The proposed algorithm is based upon our clinical experience in treating borderline patients. Data from 93 polytrauma patients have been processed.

The patients with polytraumatic damages that we had been dealing with had an ISS higher than 16. They were assessed in accordance with an Abbreviated Injury Scale (AIS), whereby traumas are rated according to the affected area and the degree of severity of the trauma, as follows: Light: 1 point; Moderate: 2 pts.; Serious: 3 pts.; Severe: 4 pts.; Critical: 5 pts.; Maximum severity (incurable): 6 pts.

The anatomic injury severity score (AIS) has been analyzed in respect of 9 body areas: head; face; neck; chest; abdomen; spine; upper extremity; lower extremity; skin, a.o.

ISS is the sum total of the three highest values (for the three most severely affected areas), squared:

$ISS = A^2 + B^2 + C^2$

Patients were diagnosed using: lab. tests;; X-ray images; CT; ultrasound diagnostics; angio CT.

To determine DCO and orthopedic behavior, we used the AO classification for long bone fractures.

- Fractures of the femur are classified as type 31 A2, type 32 C3, type 33 C3.
- Fractures of the tibia are classified as type 41 A3, type 42 C3, type 43 C3.
- Pelvic ring fractures are classified as type A, B and C.

Methods of treatment

Debridement - purpose

- to remove foreign matter;
- to reduce bacterial infection;
- to get rid of non-vital tissues.

External fixation – using the following tools: **C** clamp - *Synthes*, mono- or bi-plane AO fixator - *Aesculap*.

Conversion

The period between primary stabilization using an external fixator and definitive osteosynthesis. Pape et al.[4] recommend how to determine the right period of time between the primary placement of an external fixator and the definitive stabilization. They compare between two groups of patients having similar ISS and Glasgow Coma Scale scores. In one group, definitive stabilization vas carried out between day 2 and day 4 after the trauma, whereas in the other group, between day 5 and day 8 after the trauma. In their study, early definitive stabilization results in a higher incidence of polyorganic damage (46% as compared with 15.7% in the later conversion group). The same study also tested the concentration of the pro-inflammatory cytokine interleukin-6 (IL-6), both on admission and subsequently, at equal intervals. Early conversion was found to be associated with higher concentrations of IL-6 as compared with conversion at a later stage, whereas a high IL-6 concentration on admission and early conversion correlate with the onset of polyorganic damage.

The study concludes that conversions should begin not earlier than day 4 of the trauma

Another study seeks to establish a connection between the inflammatory response after temporary osteosynthesis and after conversion, on the one hand, and the onset of polyorganic damage and other complications, on the other.

Although the patients in the DCO group in the cited study had more severe traumas, they showed a weaker, and briefer, postoperative inflammatory response, and did not develop multiple organ failure to any higher extent than the patients treated urgently with intramedullary osteosynthesis.

The authors conclude that, in order to fully utilize the benefits of the DCO approach, the conversion should be postponed until the ultimate resolution of the inflammatory response.

Our approach is informed by data that posttraumatic days 4 to 6 are a safe period for conversion. In isolated cases, due to adverse clinical indicators, we did not proceed with the conversion until after day 14.

The definitive surgical intervention in cases of conversion follows, in most cases, the principles of fracture management of the **AO group.**

Fractures of the femur

- In 5 patients, the fracture of the femur was type 31. A2. The definitive osteosynthesis was carried out using a femoral recon nail.
- In 17 patients, the fracture of the femur was type 32 C3. The definitive osteosynthesis was carried out using IN.
- In 20 patients, the fracture of the femur was type 33 C3.
- The definitive osteosynthesis was carried out using an MIPO technique.

Fractures of the lower leg

- In 8 patients the type of damage was 41 A3. In the case of one patient the definitive osteosynthesis was carried out using IN, and in the remaining 3 cases, using an MIPO technique.
- In 24 patients, the type of damage was 42 C3. In 10 patients IN was used, while in the remaining 8, an MIPO technique was applied.
- In 8 patients the type of damage was 43 C3, and the definitive osteosynthesis was carried out using an MIPO technique.

Fractures of the humeru

- In 4 patients, the type of fracture was 12 A2.
- The definitive osteosynthesis was carried out using an MIPO technique.
- In 8 patients, the type of fracture was 12 C2. The definitive osteosynthesis was carried out using IN.

OUTCOMES

Table 1: Outcomes.

Outcome	Males	Females
Mortality	4	1
Stay in ICU	5,91	7,61
Disability up to 1 ½ yr.	10	7
PTE	1	0
Sepsis	2	3
Infection	16	8
Nonunion	11	7
Conversion	52	29

Clinical case

Male, 41 yr.-old. Trauma caused by fall from a 12-meter height.

Admitted to anti-shock care at 5:30 p.m. Dec. 12, 2014, 30 min. after the incident. **ISS: 27**

Diagnosis on admission: fracture of sacrum, open fracture of right femur, fracture of right tibia.

Initial vital signs in anti-shock care: HGB: 130-105; HCT: 0,40-0,33;PLT: 224-189;AP: 108/70; Pulse: 100; T: 35,8.

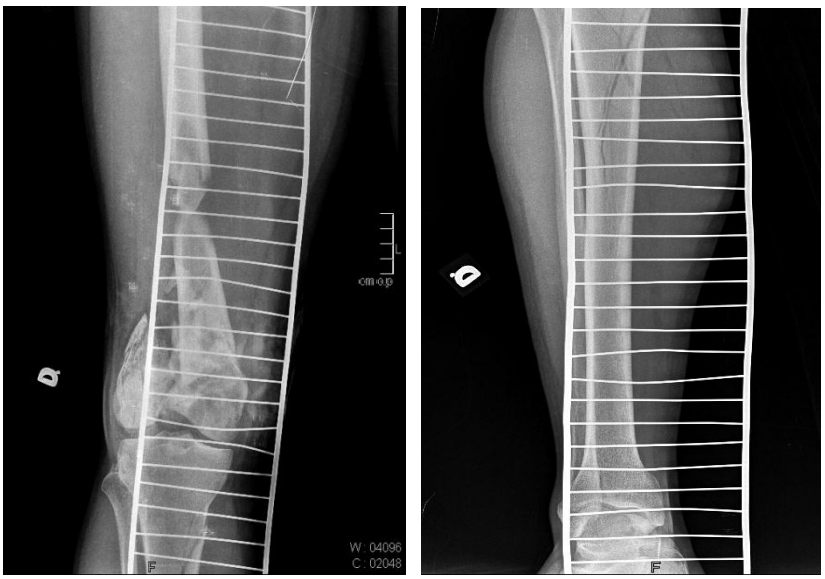

Fig. 3: Diagnostic X-ray.

Moved to surgery 30 min. following admission. External fixators placed on fractures on an emergency basis, aspiration drainages applied.

Operating time: 45 min.

Placed in ICU for 3 days.

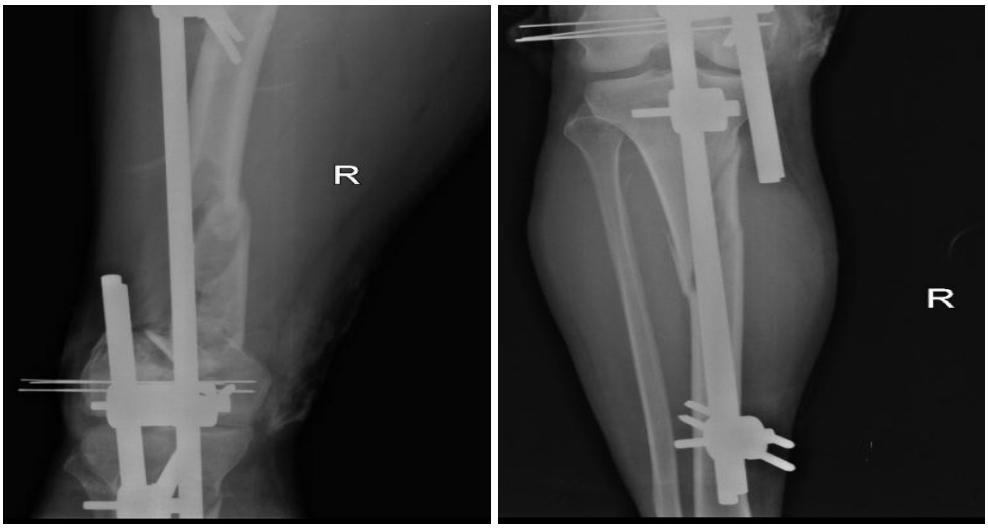

Fig. 4: External fixation.

Fig. 5: Pelvic C clamp.

Fig. 6: External stabilization of pelvis and lower extremity.

On day 6 after surgery, conversion was carried out as the patient had the following vital signs: HGB: 84; HCT: 0.29; PLT: 220; AP: 125/70; Pulse: 72.

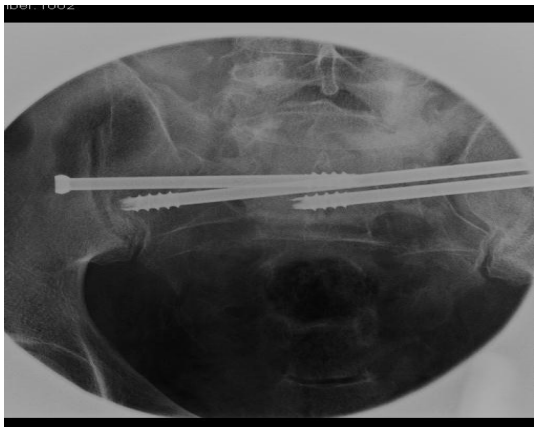

Fig. 7: Stabilization of the pelvis using IS screws.

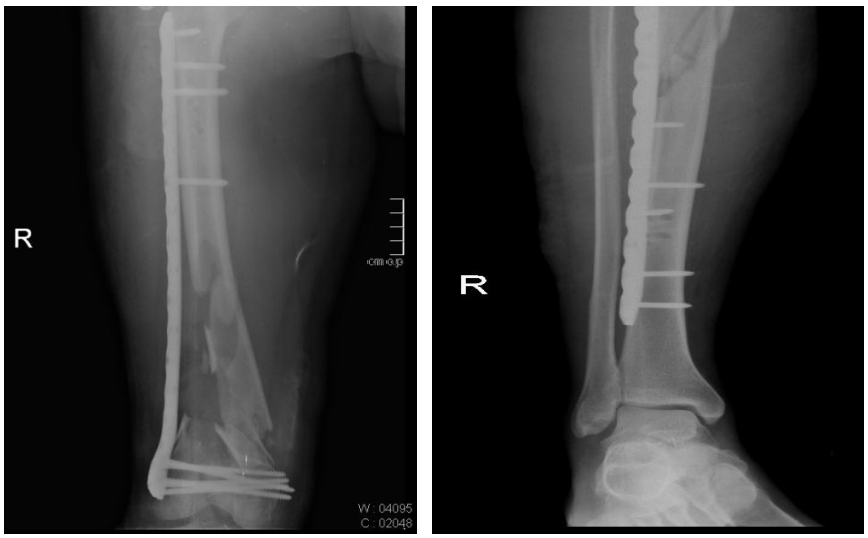

Fig. 8: Conversion of the fractures.

Feale, 31 yr.-old. Sustained road accident as a pedestrian. Admitted to anti-shock care at 5:35 a.m. Jan. 24, 2016, 30 min after the incident. **ISS: 48.**

Diagnosis on admission: fracture of pelvis, fracture of right acetabulum, open fracture of left tibia, dislocation of left knee joint.

Initial vital signs in anti-shock care: HGB: 89-82; HCT: 0,25-0,25;PLT: 283-100;AP. 100/79; Pulse. 62; T: 35.8.

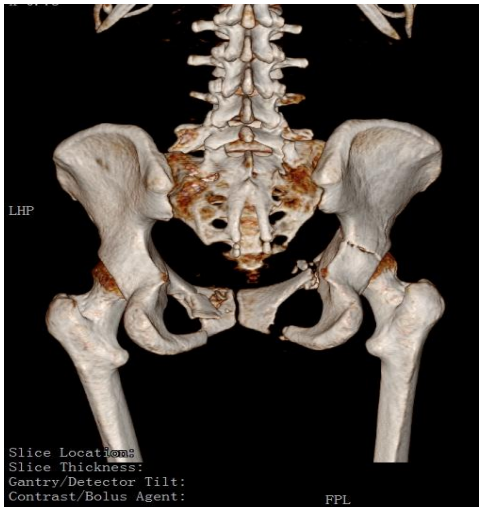

Fig. 9: CT pelvis.

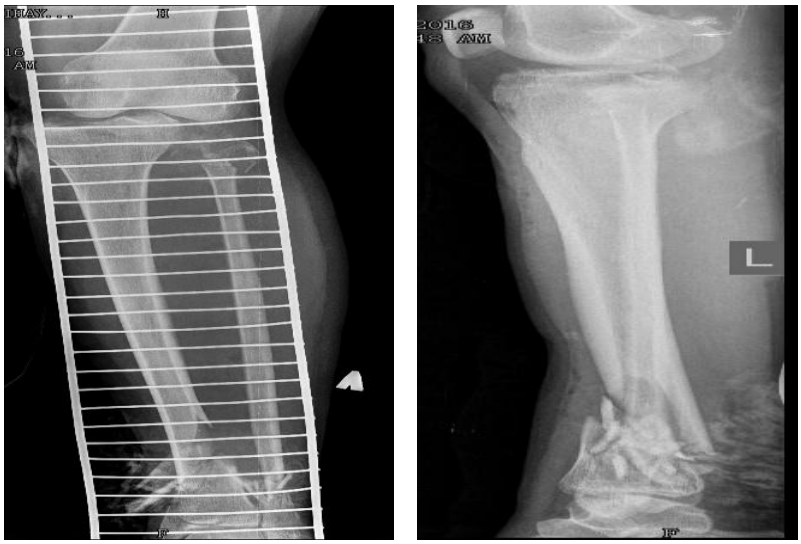

Fig. 10: Diagnostic X-ray images.

Patient moved to surgery 30 min. following admission. Surgical processing of incident-related injuries performed on an emergency basis. Left lower leg fracture stabilized with AO fixator. Repositioning of dislocated knee joint and stabilizationи with AO fixator. C clamp placed on pelvis.

Operating time: 40 min.

Placed in ICU for 4 days.

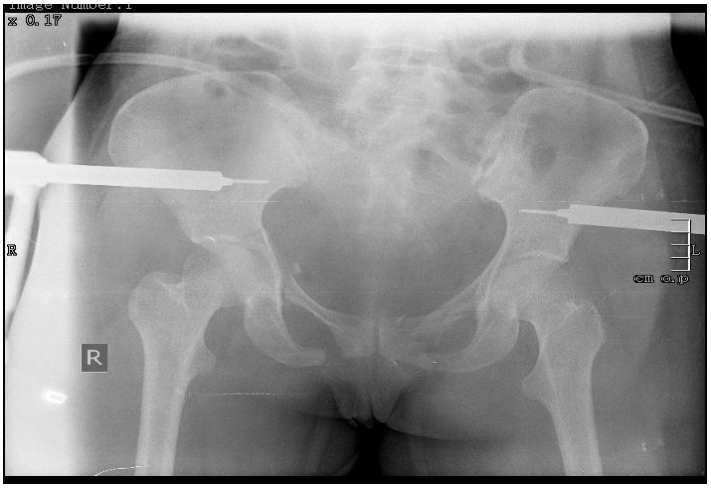

Fig. 11: C clamp.

Fig. 12: Ex. Fix.

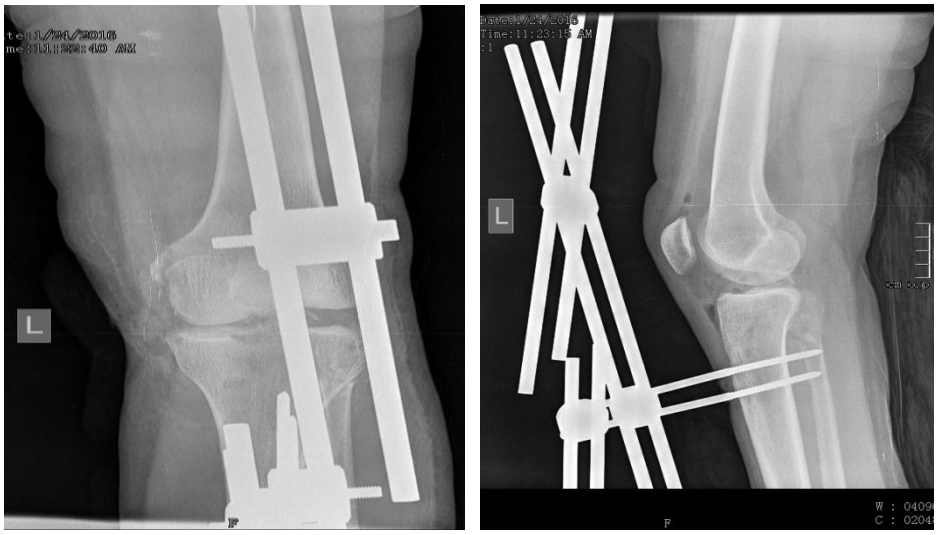

Fig. 13: X-ray image after repositioning of dislocated knee joint and external stabilization.

On day 5 after surgery, conversion was carried out as the patient had the following vital signs: HGB: 105; HCT: 0.29; PLT: 180;AP: 110/80; Pulse: 80; T: 37.8.

Fig. 14: Stabilization using IS screws.

Fig. 15: Conversion.

DISCUTION

ETC/DCO – What are the modern treatment concepts

Polytrauma phases.

- Acute phase: 1st through 3rd hour – resuscitation
- First phase: 1st through 48th hour – stabilization
- Secondary phase: day 2 through day 10 – regeneration
- Third phase: a few weeks to a few months following the polytrauma– reconstruction and rehabilitation

ETC was the preeminent doctrine in polytrauma patient management in the 1980s and early 90s. It comprises definitive stabilization of fractures of all long bones at the early treatment phase (24th through 48th hour). The ETC concept focuses on the need for stabilization of long tubular bone fractures. This marks the first step in the development of modern management in polytrauma treatment. Until recently, the prevailing opinion was that such patients were too frail to survive a surgical intervention so the treatment of their fractures was discouraged on account of possible complications involving occurrence of fat embolism. Surgical stabilization of the femur was introduced in the 1970s with the purpose of reducing pulmonary complications while achieving a speedier recovery, mobilization and discharge of the patient.

The evolution of that doctrine was possible owing to the advancement of the intraoperative techniques for osteosynthesis and resuscitation, including improved cardiorespiratory monitoring and a possibility for more continuous mechanical ventilation.

Patients who receive ETC have fewer pulmonary complications, spend less time in the ICUs and in hospital as a whole. But despite all the evidence in support of the advantages of that concept, some controversies have also emerged. ETC is not suitable for all polytrauma patients in light of the unusually high rate of pulmonary complications observed in association with it.

The shift in strategy from ETC to DCO came after a change of the views in terms of the pathophysiology and immunology of polytrauma.

By applying DCO, we seek to achieve control of bleeding, suppression of the pathological inflammatory response, excision of non-vital tissue, prevention of ischemia-reperfusion damage and analgesia.

The rationale for each type of intervention is the mitigation, as completely as possible, of the intensity of the „second strike". Such a step-by-step approach minimizes the extent of surgical shock for the patient, who is in a state of unstable balance following a severe trauma. The treatment of such patients can be divided into four steps. During the acute phase, only resuscitation and life-saving procedures are applied. After the initial resuscitation, during the period of primary stabilization, severe damages to the extremities, arterial ruptures and compartment syndromes are put under control through orthopaedic interventions aimed to restrict the damage. In the secondary phase, the patient is subjected to continuous re-evaluation, and is acted upon accordingly. No justification exists for any more significant procedures („second strike") as they involve an additional overload that would put to a severe test the immunological status of the patient who is already at risk.[33,34,35]

Later, between day 5 and day 15, there occurs the so-called „window of opportunity" during which the definitive treatment of the fractures can be undertaken.[36] It is from that moment onwards that any complex reconstructive measures should be planned. Although it makes it incumbent to consider a longer hospital stay and the costs associated with it, this approach definitely changes the perceptions and day-to-day practices of orthopaedic surgeons.

In our view, the ETC methods are only of relevance to patients with isolated traumas of the musculoskeletal system.

Our clinical experience in treating a polytrauma patient is based upon DCO. We have not made any meaningful distinction between the presence or absence of an open/closed fracture as a factor for opting for DCO. Following the DCO principles in the treatment of such patients, combined with our clinical experience, shows that the average stay in ICU is 6.763 days, the total hospital stay is 28 days, and the mortality rate is 4.65%.

Table 2: Correlation analysis between ISS, stay in ICU and total hospital stay.

Indicator	Stay in ICU	Total hospital stay
ISS	0.491***	0.475***

*** - p<0,001

Through the timely stabilization of fractures, DCO has proven instrumental for the favorable outcome of the treatment. In our group of 93 patients **the mortality rate was 4.65%**. One patient died during surgery, two survived 36 hours from admission, and the remaining two deceased patients survived the first 72 hours of their hospital stay.

Table 3: Comparative analysis ISS according to lethal exitus.

Lethal exitus						P
No			Yes			
n	$\overline{X}$	SD	n	$\overline{X}$	SD	
88	50.56	14.01	5	56.40	19.15	-

The severity of the damage in those cases was ISS 66-75, which places them in between borderline and unstable.

CONCLUSION

Recent decades have seen a significant increase in the number of high-energy, severe, multiple and combined traumas, of which anything between 15 and 50 percent end in death. One reason for that is the advancement of modern technology, which comes in conflict with the way transport is organized and the behavioral culture of motor vehicle drivers. A high percentage of the victims are in a state of traumatic shock and massive blood loss. The choice of a method of treatment by the traumatologist in such circumstances could save the patient and determine the quality of his or her life. ETC entails a prolonged stay in surgery and can inflict a serious trauma that could prove overwhelming for such a patient's depleted resources. On the other hand, withholding treatment and the use of traction or cast immobilization leads to a general deterioration of the patient's condition, a prolonged stay in ICU, and worsens the outlook for the orthopaedic functional outcome. Inter-disciplinary collaboration and the organization of emergency care are the other two fundamental factors for a successful treatment. Rehabilitation is of key importance for obtaining an optimum outcome. Its purpose is to minimize the probability of the victim becoming permanently disabled, while ensuring his or her early recovery and successful re-socialization. The algorithms for patient management and the application of early and follow-up rehabilitation are an unavoidable element in severe trauma therapy.[37,38,39] In the majority of cases the

problems arising as a result of damages to the body are interdisciplinary, so individual rehabilitation plans are an effective factor for the successful recovery of a patient from a severe physical or mental affliction. The newly introduced definition of a „borderline patient" has reasoned a change in the behavior of the orthopaedic surgeon. In the past two decades DCO has brought a sea change in behavior, resp. the prognosis for such patients towards reduced ICU and hospital stay, lower mortality and a more predictable orthopedic outcome. The adoption of this concept and its practical implementation will not resolve all problems in the treatment of such life-threatening damages. DCO, however, is a reliable tool that will help us help our patients.

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