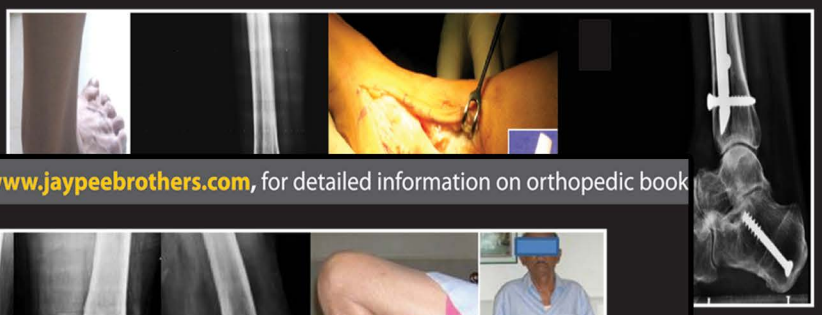
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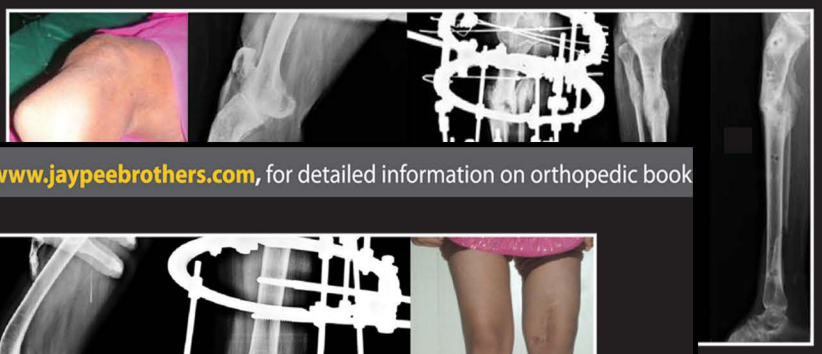
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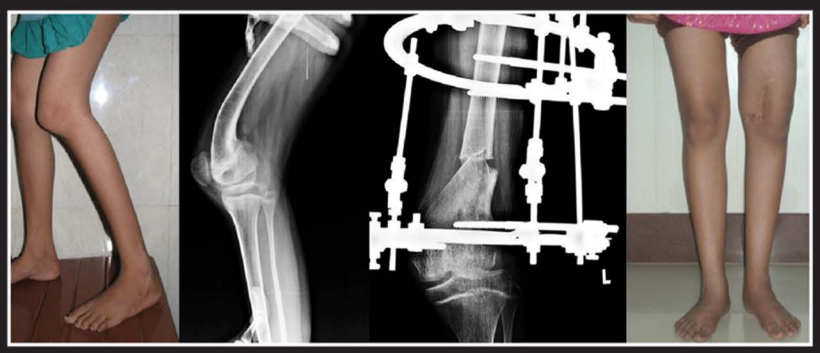
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Volume 1

Textbook of ORTHOPEDICS & TRAUMA

Under the aegis of Indian Orthopedic Association

Introduction & Clinical Examination, Basic Sciences, Diagnostic Imaging in Orthopedics, Metabolic Bone Diseases, Endocrine Disorders, Bone & Joint Infections, Tuberculosis of Skeletal System, Systemic Complications in Orthopedics, Orthopaedic Rheumatology, and Peripheral Nerve Injuries

Editors
GS Kulkarni
Sushrut Babhulkar

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2 Chapter

Damage Control Orthopedics

Anil Agarwal, Anil Arora, Sudhir Kumar

JAYPEE BROTHERS

Introduction

Polytrauma has been defined as a multisystem, multiorgan, post-traumatic insult with profound pathophysiological and metabolic changes. The management of polytrauma patients has changed considerably during the past century. Advances in fields of fracture fixation techniques and intensive care have all contributed to better treatment of a polytraumatized patient.

Prior to the 1970, early surgical fracture stabilization of long bone fractures after multiple traumas was not routinely advocated. It was believed that the multiply injured patients did not have the physiological reserve to withstand the prolonged operations. The introduction of standardized, definitive surgical protocols, led to the concept of early total care (ETC) in the 1980s. This concept was subsequently applied universally, in all patient groups, regardless of injury severity and distribution. In the following decade, it was recognized that early stabilization of skeletal injuries produced poor results in certain critically ill patients. This particularly applied for patients with significant thoracic, abdominal and head injuries and those with high injury severity scores (ISS). In response, the concept of damage control orthopedics (DCO) was developed in the 1990s. DCO methodology is characterized by primary, rapid and temporary fracture stabilization. Secondary definitive management follows, once the acute phase of systemic disbalance has passed. In the current chapter, we outline the evolution of treatment strategies for major fractures in polytrauma and the current trends towards staged management of these patients.

Historical Perspectives

There has been a consistent change in the management protocol of multiply injured patient over the last century. This has followed the advances in prehospital care, resuscitation, implants and intensive care medicine.

Before the 1950s, the surgical stabilization of fractures of the long bones was not routinely performed. The polytraumatized patient was not considered physiologically stable to undergo any surgical procedure—too sick to operate on. Many surgeons cited fat embolism following manipulation of fractures as one of the justifications for nonintervention.[1] At the same time, surgical techniques available for fracture fixation were few. Moreover, there were reports by some surgeons that fracture fixation performed late up to 14 days yielded better results,[2,3] operations were therefore delayed or avoided.

The management of femoral fractures with a Thomas splint illustrated the importance and benefits of skeletal stabilization resulting in the improved survival of the patients.[4] The routine introduction of immediate Thomas splinting of soldiers with gunshot wounds of the femur, during the First World War, reduced mortality from this injury from 80% to about 20%.[5]

In the latter half of the 1960s and early 1970s, there were several reports that early skeletal stabilization had a beneficial effect on pulmonary function and postoperative complications.[6,7] Johnson et al. demonstrated that a delay of more than 24 hours in the stabilization of a major femoral fracture was associated with a five-fold increase in the incidence of adult respiratory distress syndrome (ARDS).[8] They also noted a significant relationship between the incidence of ARDS and mortality reflecting evidence that patients with higher ISS scores tended to develop ARDS.

Bone et al. performed the first prospective randomized trial on 178 patients with an femoral shaft fracture for assessing the effect of early fracture stabilization.[9] He allotted femoral fractures into two groups—those early (within 24 hours of injury) or late stabilized (more than 48 hours after injury). The patients in the early treatment group had their fractures stabilized immediately, whereas those in the delayed treatment group were placed in traction. The study showed conclusive evidence in favor of early fracture stabilization with decreased pulmonary morbidity, ARDS,

fat embolism, pulmonary embolism and pneumonia in the early stabilized groups. The length of hospital stay was also reduced in the early osteosynthesis group of patients.

This new philosophy in the management of the patients with multiple injuries was named early total care. ETC became accepted as an important element in injured patient's care. A new view now prevailed in surgeons—too sick not to operate on. Improvements in intensive care and newer fracture fixation techniques facilitated the concept of ETC.[8]

The exact mechanism by which early stabilization contributes to decreased mortality and better pulmonary function is unknown, but reduction in the fat embolism syndrome, decreased analgesic need and an ambulatory patient participating in active rehabilitation are thought to play a part.[10] Other important benefits of ETC are pain relief, and the fact that the procedures are being performed when the patient is still in optimal nutritional state resisting any hospital acquired infection.[8] The optimal time, therefore, for any surgical intervention is in the first 24 hours post-injury.[10]

In the early 1990s, a variety of unexpected complications related to the early stabilization of fractures were described.[11,12] The term "borderline" patient was first used by Pape et al.[11] They conducted a retrospective study of a series of polytrauma patients with an ISS greater than 18, and femoral shaft fractures treated by reamed intramedullary nailing. They found that early intramedullary nailing in patients without thoracic injury was associated with lower rates of pulmonary complications. By contrast, patients with severe thoracic trauma had poor outcomes after primary intramedullary nailing, with development of ARDS. Similar findings of a multicenter study by the AO (Arbeitsgemeinschaft für Osteosynthesefragen) Foundation or the Association of the Study of Internal Fixation (ASIF) reinforced this concern.[13] This led to the conclusion that the method of fracture stabilization and timing of surgery may have contributed in the pathogenesis of such complications.

With further reports substantiating above data[14,15] and on the basis of laboratory findings, "patient at risk" or "borderline" patients were identified which have potential to do particularly badly with ETC **(Table 1)**.[16] Thus, patients with a high ISS and significant thoracic, abdominal and head injuries formed a subgroup in whom ETC approach was detrimental.

This borderline phenomenon has been explained on the basis of a two hit theory.[17] The type and severity of injury, the first hit phenomenon, may predispose the borderline patient to deteriorate after surgery. Furthermore, the type of surgery, the second hit phenomenon, poses a varying burden on the biological reserve of the patient, and may predispose to an adverse outcome. Numerous publications were able to show that surgery caused a variety of subclinical changes in the inflammatory system which could become clinically relevant with a cumulative effect of several impacts were added.[18-20] Massive amounts of transfused blood commonly used in the polytrauma patients have also been implicated as a cause of depression of immune system.[21] In response to these observations, the concept of DCO for the management of the polytraumatized patient was developed. This approach is based on the principle of damage limitation and is an attempt to minimize the magnitude of the second hit or the inflammatory reaction induced by the any major operative procedure.

TABLE 1: "Borderline" patient or "patient at risk"[16]

- Multiple injuries with injury severity score > 20 with additional thoracic trauma AIS > 2
- Multiple injuries with abdominal/pelvic trauma and initial systolic blood pressure < 90 mm Hg
- Injury severity score > 40
- Radiographic evidence of bilateral pulmonary contusion
- Initial mean pulmonary arterial pressure > 24 mm Hg
- Pulmonary artery pressure increase during intramedullary nailing > 6 mm Hg

Abbreviation: AIS, Abbreviated Injury Scale

Concept of Damage Control Surgery

The term "damage control" was originally coined by the US Navy in reference to the "capacity of a ship to absorb damage and maintain mission integrity". Rotondo et al. first applied the term "damage control surgery" to the management of patients with penetrating abdominal trauma.[22] They found that in a small subset of patients with major vascular injury and at least two visceral injuries survival was improved by an initial laparotomy to deal only with hemorrhage and contamination, followed by intraperitoneal packing and rapid closure, resuscitation to normal physiology, and subsequent definitive surgery. This practice resulted in improved survival rates after penetrating abdominal injury. Based on the concept of damage control surgery, the application of the same principles to the management of the multiply-injured patients with associated fractures of the long bones and pelvic fractures was termed "damage control orthopedics".

Damage control orthopedics consists of three stages **(Table 2)**, the first stage involves early temporary stabilization of fractures and hemorrhage control. Intracranial lesions, if indicated, can be decompressed at the same time. The second stage involves resuscitation of the patient to stable physiological state in the intensive care unit and optimization of his condition. In the third stage, delayed definitive management of fractures is undertaken and is postponed until the second stage is complete.[23]

The favored technique for temporary stabilization of fractures is usually an external fixator. This can be rapidly applied for stabilizing of fractures and avoids any additional stress on the patient. There are several criteria on which the stable physiological state of the patient is determined in the second stage. The patient is considered optimized when there is stable hemodynamics, stable oxygen saturation, the serum lactate level is less than 2 mmol/L, there are no coagulation disturbances, the patient is afebrile, and there is adequate urinary output.[24] The third stage of definite fracture fixation, usually entails intramedullary nailing (especially for fracture femur) and is carried out when the patient condition is optimized.

TABLE 2: Damage control principles algorithm

Borderline patient or patient at risk

Stage 1: Early temporary stabilization of fracture and hemorrhage control intracranial decompression, if necessary

Stage 2: Resuscitation and patient optimization

Stage 3: Definitive stabilization (after day 4) of fractures

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Several studies have supported the success of this approach in multiple injured patients. Scalea et al.[25] reviewed patients who had femoral fractures treated with either primary intramedullary nailing, or an external fixation. They found that the patients treated with external fixators tended to be more severely injured. The operative time and average blood loss was less with external fixation than with nailing. Most of the cases in the external fixation group had subsequent conversion to intramedullary nailing. They concluded that external fixation of femoral fractures in patients with multiple injuries followed by early intramedullary nailing was a viable method of treatment and afforded all the benefits of early fracture stabilization with none of the potential complications. In another study, Nowotarski et al.[26] echoed the advantageous effect of delayed definitive fixation for managing fractures of the shaft of the femur in appropriately selected cases. Taeger et al. conducted a trial in 409 patients to prospectively evaluate the concept of damage control by immediate external fracture fixation and consecutive conversion osteosynthesis with regard to time savings, effectiveness, and safety. They found that DCO appears to provide a major reduction of operation time and blood loss in the primary treatment period in severely injured patients compared with hypothetical ETC.[27]

There is some concern regarding the increased risk of infection and optimal time for conversion of external fixation to intramedullary nailing. Rates of infection after conversion of external fixation of the femur to intramedullary nailing range between 1.7% and 3%[25,26] and are comparable to those for several series for primary intramedullary nailing of the femur.[28-30] Bhandari et al.[31] after analyzing several studies examining conversion of external fixation to intramedullary nailing in the lower limb, found that the rate of infection decreased significantly when the interval between the two procedures was less than 14 days. Pape et al.[32] assessed the levels of the proinflammatory cytokine interleukin-6 (IL-6) to predict for development of multiple organ dysfunction. They showed that patients who underwent definitive surgery at 2–4 days post-injury developed a significantly increased inflammatory response compared with those who were operated on 5–8 days post-injury. They report a high association between the combination of high initial IL-6 measurements and the secondary surgery on days 2–4 and the development of multiple organ failure. It was concluded that the definitive operation should be delayed until after the 4th day from initial surgery. In a more recent prospective, randomized, multicenter intervention study, Pape et al. measured levels of proinflammatory cytokines interleukin (IL-1, IL-6, and IL-8) in patients undergoing primary femoral nailing, DCO external stabilization and during secondary osteosynthesis.[33] The study concluded that a primary (< 24 hours) intramedullary femoral instrumentation evokes a sustained inflammatory response but during DCO external fixation or the secondary conversion to an intramedullary implant, these responses were minimal. The study also reaffirmed that damage control orthopedic surgery minimized the additional surgical impact induced by acute stabilization of the femur. Harwood et al. has proposed to use systemic inflammatory response syndrome (SIRS) score as an adjuvant in clinical decision making regarding the timing of conversion to an intramedullary device since DCO patients undergoing conversion while their SIRS score was raised suffered the most pronounced subsequent inflammatory response and organ failure.[34]

These studies indicate that conversion of external fixation to intramedullary nailing can be performed safely within the first 2 weeks and has a very low rate of infection.

Algorithm of Damage Control Sequence

Most fracture surgeons now agree that there are certain severely injured patients in whom definitive early skeletal fixation is contraindicated.[35] The severity of the injuries sustained and the clinical condition of the patient dictate the major factors governing the line of treatment in polytraumatized patients. The "borderline", **(Table 1)** condition as described above is a useful guiding tool. Other parameters which predispose to adverse outcome in polytraumatized patients are hypothermia, coagulopathy, multiple fractures in long bones, fractured femur and patients presenting with lung or chest pathology,[36,37] several biochemical markers can now be used to determine patients at risk of physiological decompensation. These are serum lactate, IL-1, IL-6, IL-10 and procalcitonin and can be used to aid in the decision to carry out DCO and subsequent secondary conversion.[38]

The concept of DCO has gradually been extended to orthopedic indications other than extremities.[39-41] Stahel et al. tested a standardized "spine damage-control" (SDC) protocol for the acute management of unstable thoracic and lumbar spine fractures in 112 severely injured patients. The SDC cohort fared better in terms of a reduced mean length of operative time, length of hospital stay, and number of ventilator-dependent days and the complication rates (wound complications, urinary tract infections, pulmonary complications, and pressure sores).[39] Mooney described use of DCO in open, segmental pediatric femur fractures complicated by severe soft tissue injury and bone loss which were managed definitively by submuscular bridge plates.[42]

Damage control orthopedics gives a stepwise approach to the management of patients with multiple injuries and is designed to take account of the difficulties encountered in dealing with patients who are hemodynamically unstable. Thus, the concept of DCO entails performing initially the least morbid procedures that preserve life and prevent death whilst avoiding potentially lethal complications, such as ARDS and multiple organ failure.

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