The management of the multiply-injured patient has been revolutionised during the past century. Advances in prehospital care, resuscitation, implants and intensive-care medicine have all contributed to better treatment of the patient in physiological crisis after trauma, who is at risk for the multiple-organ dysfunction syndrome and is battling for survival.

The introduction of standardised surgical treatment for fractures in the early 1950s by the AO group and the implementation of advanced trauma life-support training were probably the greatest stimuli affecting the philosophy in the treatment of patients with polytrauma. However, more recent developments in molecular medicine and genetics have influenced our perception of management leading to the concept of 'damage control orthopaedics'. While the basic concept of 'save life - limit disability' has not changed, the type and timing of our interventions have been gradually modified. This review highlights the current concepts in the management of patients with multiple injuries with particular emphasis on the surgical priorities in damage control orthopaedics.

Historical perspectives

Before the 1950s the surgical stabilisation of fractures of the long bones was not routinely performed. The multiply-injured patient was not considered to be physiologically stable enough to withstand a prolonged surgical procedure. The fear among many surgeons was of the fat-embolism syndrome which was thought to be the result of the early manipulation of fractures of the long bones with the resultant release of fat and intramedullary contents into the peripheral circulation. Operation was therefore avoided.1,2

The management of femoral fractures with a Thomas splint illustrated the importance and benefits of skeletal stabilisation resulting in the improved survival of the patient. The positive effect of skeletal stabilisation became even more apparent with the implementation of standardised techniques of fracture fixation.3 However, these procedures were not universally adopted and for years the philosophy prevailed that the injured patient was ‘too sick to operate on’ and was kept instead on skeletal traction with enforced bed-rest. There were reports by some authors4,5 that healing of fractures would be quicker if the operation was not performed acutely and this led to the recommendation that the operation should be delayed until up to 14 days after the injury.

In the 1970s pioneering studies showed that the early skeletal stabilisation of femoral fractures dramatically reduced the incidence of traumatic pulmonary failure and postoperative complications.6,7 Further evidence of the beneficial effects of the early operative stabilisation of fractures within 24 hours of injury followed and it was shown that the greatest benefits were seen in those patients who had sustained the most severe injuries.8,9

However, it was not until the late 1980s that a seminal study by Bone et al10 was published which showed the beneficial effect of the early stabilisation of fractures on both morbidity and length of hospital stay. This new philosophy in the management of the patient with multiple injuries was named early total care (ETC). The previously held belief among surgeons that the patient was ‘too sick to operate on’ was now replaced with the opposite view that the patient was ‘too sick not to operate on’.

ETC became the optimum treatment in surgery for trauma and developments in intensive-care medicine supported this more aggressive approach to the injured patient. It represented a giant step forward. Patients were able to mobilise early and were discharged from hospital sooner, avoiding the complications associated with prolonged bed-rest.11-13

In the early 1990s a variety of unexpected complications related to the early stabilisation of fractures of long bones was described. It was suggested that the operative procedure used to fix the bone, in most cases a reamed intramedullary nail, could provoke rather than protect against the development of pulmonary complications. The findings of a multi-
centre study by the AO foundation reinforced this concern. An unexpectedly high rate of pulmonary complications was reported in young patients after reamed femoral intramedullary nailing who had not suffered thoracic trauma. This led to the conclusion that the method of stabilisation and the timing of surgery may have played a major role in the development of such complications.

Further reports appeared describing an adverse outcome after ETC including an increased incidence of adult respiratory distress syndrome and multiple organ dysfunction. These complications mostly developed in patients with severe chest injuries and after severe haemodynamic shock. The findings indicated that ETC was not appropriate for all multiply-injured patients and that there was a particular subgroup in whom management by this approach was detrimental. On the basis of both clinical and laboratory findings these were described as borderline, or the ‘patient at risk’ (Table I), indicating the necessity of awareness of the potential for the development of unexpected complications.

It is now clear that both the type and severity of injury, the first-hit phenomena, predispose the borderline patient to deterioration after surgery. Furthermore, the type of surgery, the second-hit phenomenon, poses a varying burden on the biological reserve of the patient, the individual biological response, and may predispose to an adverse outcome. Clearly, only the second-hit phenomenon can be modulated by medical treatment. The impact of inappropriate clinical decisions may have a detrimental effect on the well-being of the patient. This creates a dilemma for the surgeon. The patient may be ‘too sick not to operate on’ to provide skeletal stabilisation, but when should this stabilising surgery be performed and what procedure should be used? Will it do more harm? Shall we wait?

The inability to quantify not only the biological impact of the initial injury but also the additional effect of the surgical procedure was apparent. The crude clinical parameters used did not reflect the influence of the surgical load on the inflammatory system. However, recent advances in molecular medicine allowing the measurement of proinflammatory cascades during surgery, have resulted in several studies which have highlighted the importance of inflammatory mediators in the response to trauma. 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 if several impacts were added.

In response to these observations, the concept of damage control orthopaedics for the management of the polytraumatised patient was developed. This approach is based on the principle of damage limitation and is an attempt to minimise the magnitude of the second hit or the inflammatory reaction induced by the operative procedure.

The evolution of damage control surgery

The concept of damage control surgery arose because of the increasing incidence of penetrating abdominal trauma which occurred in the USA during the 1980s. This term was originally coined by the US Navy, in reference to the ‘capacity of a ship to absorb damage and maintain mission integrity’. The concept of damage control as a treatment describes the surgical manoeuvres used to control but not definitively to repair or stabilise the injuries which have arisen. It was developed to meet the challenges posed by injuries caused by the more widespread use of semiautomatic guns on the streets of the USA. Damage control surgery involved a formalised approach to the management of severe abdominal haemorrhage which utilised already practised techniques. Rotondo et al proposed a standardised protocol for the management of uncontrollable abdominal haemorrhage which consisted of three stages and named it ‘damage control surgery’. Stage 1 consisted of immediate surgery for the control of haemorrhage and contamination. Stage 2 involved resuscitation of the patient in the intensive-care unit allowing correction of hypothermia, coagulation disorders and hypovolaemia. Stage 3 comprised definitive surgery when the patient’s condition had been optimised to allow reoperation. This practice resulted in improved survival rates after penetrating abdominal injury.

Damage control orthopaedics

While the benefits of the early fixation of fractures have been well documented, in some situations such as severe chest trauma, injuries to the pelvic ring or traumatic brain injury, the patient may not be stable enough to have definitive surgery performed initially or may fall into the borderline group of patients at risk of further deterioration if prolonged surgery was undertaken. Based on the concepts of damage control surgery, the application of the same principles to the management of the multiply-injured patient with associated fractures of the long bones and pelvic fractures was named ‘damage control orthopaedics’. It also consists of three stages. The first involves early temporary stabilisation of unstable fractures and the control of haemorrhage and, if indicated, decompression of intracranial lesions. The second stage consists of resuscitation of the patient in the intensive-care unit and optimisation of his condition. In the third stage delayed definitive management
of the fracture is undertaken when the patient’s condition allows.

The favoured technique for achieving temporary stability of the fractured pelvis or a fracture of a long bone is external fixation. This is an expedient and minimally invasive method and can be used very efficiently to accomplish early stabilisation of the fracture and to control the additional biological stresses posed by prolonged surgical procedures. The delayed definitive procedure for the stabilisation of fractures of long bones, in particular fracture of the femur, is usually intramedullary nailing and this is carried out when the condition of the patient is stable and optimised.

The practice of delaying definitive surgery in damage control orthopaedics is an attempt to minimise the second hit, the additional burden of the surgical procedure, on the already traumatised patient. In applying this approach several issues have to be considered. First, is this a safe, viable method of surgical management of the multiply-injured patient? Secondly, when is the right time to perform the secondary definitive surgery? Finally, is it safe to convert external fixation to intramedullary nailing or is this associated with an unacceptably high rate of infection?

Two recent studies have described the success of this approach in the management of multiply-injured patients. Scalea et al. compared 43 patients treated initially by external fixation with 284 treated by primary intramedullary nailing of the femur. The first group was more severely injured than those treated by intramedullary nailing. They had a significantly higher injury severity score (26.8 v 16.8) and a lower Glasgow coma scale (11 v 14.2) and required significantly more fluid (11.9 v 6.2 l) and blood (1.5 v 1.0) in the initial 24 hours. In the external fixation group the median operating time was 35 minutes with an estimated blood loss of 90 ml compared with 130 minutes and 400 ml of blood loss in patients having intramedullary nailing. Four patients in the external fixation group died, three from head injuries and one from acute organ failure compared with one after intramedullary nailing. The authors concluded that external fixation was a safe, viable procedure to achieve temporary rigid stabilisation in patients with multiple injuries at risk of an adverse outcome.

In the second study Nowotarski et al. also found that an approach using damage control orthopaedics was also safe for managing fractures of the shaft of the femur in selected patients with multiple injuries.

Guidance as to the time interval between primary stabilisation with an external fixator and definitive surgery has been given in a recent study by Pape et al. The authors compared two groups of patients who had a similar injury severity score and Glasgow coma scale. In the first group early definitive surgery was carried out between two and four days after injury while in the second group late definitive surgery was undertaken between five and eight days. With early definitive surgery 46% of patients showed evidence of multiple organ dysfunction compared with 15.7% in the late group. Assessment of the biological load of trauma and surgery was measured by the release of inflammatory mediators. The levels of the proinflammatory cytokine interleukin-6 (IL-6) were measured on admission and at regular intervals throughout treatment. Early secondary surgery was associated with a significantly increased release of IL-6 when compared with late secondary surgery and an admission level of IL-6 of >500 pg/dl, and correlated positively with the development of multiple organ dysfunction. It was concluded that the definitive operation should be delayed until after the fourth day from initial surgery.

Whether external fixation can safely be converted to intramedullary nailing without increasing rates of infection has been a topic of debate for some time with conflicting results available in the literature.

Early studies were focused on tibial fractures and showed rates of infection of up to 44% Later studies gave a much lower rate of infection after conversion ranging from 4.8% to 6%, even when conversion was delayed for up to 57 days (Table II). Rates of infection after conversion of external fixation of the femur to intramedullary nailing range between 1.7% and 3%, and are similar to those for primary intramedullary nailing of the femur. These studies indicate that conversion of external fixation to intramedullary nailing can be performed safely within the first two weeks and has a very low rate of infection.

The sequence of damage control

The general aims in managing fractures include the control of haemorrhage, suppression of an exaggerated inflammatory response, removal of devitalised tissue, prevention of ischaemia-reperfusion injury, relief from pain, and facilitation of nursing care. All these can be achieved by appropriate stabilisation of the fracture with debridement and fasciotomies when indicated.

The severity of the injuries sustained and the clinical condition of the patient are the major factors governing which line of treatment should be used in patients with polytrauma. Several guides to treatment have been developed especially for the management of fractures of the long bones and pelvis. For the stable patient with an isolated fracture of the femoral shaft and polytrauma without tho-
In traumatic trauma, the ETC approach is still advisable. Definitive osteosynthesis may be safely performed within 24 hours when all points of resuscitation have been accomplished (Table III).

For the borderline patient ETC may be still used but extreme caution must be observed throughout surgery. To reduce the surgical burden an unreamed nail should be considered for the femur if possible and the surgeon should be alert to the possibility of having to convert to the damage control pathway at any time throughout the procedure if the clinical condition of the patient deteriorates.

For the patient who is unstable or in extremis the damage control approach is recommended (Fig. 1). Any surgical intervention here must be considered as life-saving and should be simple, quick and well performed. Rigid rules relating to timing and the choice of implants should be avoided to prevent unnecessary delay which may become critical for the survival of the patient.

In the presence of severe head injuries the damage control approach is also advocated. The treatment and protection of the central nervous system are priorities in patients with considerable intracranial trauma since secondary brain injury may lead to further morbidity and disability.

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Table III. Endpoints of resuscitation

Stable haemodynamics
Stable oxygen saturation
Lactate level <2 mmol/l
No coagulation disturbances
Normal temperature
Urinary output >1 ml/kg/hour
No requirement for inotropic support

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Fig. 1

Diagram showing the protocol for application of the damage control concept. In the borderline patient conversion to the damage control approach may be necessary at any point (OR, operating theatre; ICU, intensive-care unit).
practical steps of the damage control sequence are summarised in Figure 2.

Damage control orthopaedics gives a step-wise 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 haemodynamically unstable, or in extremis.

The manoeuvres used focus on the rapid resuscitation of the patient by providing temporary stabilisation and minimising the biological load of surgery, allowing the biological reserve of the patient to compensate better while struggling for survival. Damage control orthopaedics is the outcome of better utilisation of the increased knowledge acquired of the inflammatory response to trauma and its application in the operating theatre. It serves as a useful reminder to surgeons of the age-old importance of the adage ‘primam non nocere’ or ‘do no further harm’.

This is a new and evolving practice and although the preliminary results are encouraging, further work is required to assess fully its effectiveness in reducing the incidence of acute respiratory distress syndrome, multiple organ failure and mortality after multiple trauma.

References


