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Role of Damage Control Orthopedics and Early Total Care in the Multiple Injured Trauma Patients

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ABSTRACT: The care of multiply injured patients with orthopedic injuries has evolved from prolonged periods in traction to early total care (ETC). ETC is advantageous in ease of nursing care and aiding patient recovery. However, concerns have been raised that this 'second hit' of surgery places these severely injured patients at risk of excessive inflammatory responses that can lead to systemic inflammatory response syndrome (SIRS). Damage control was initially used in abdominal trauma but has been adapted for use in orthopedics. The mainstay of treatment involves external fixation of long bone and pelvic fractures which acts to defer definitive fixation until physiologic stability is restored. The indications for implementing each approach are not clear and this article provides a narrative review of the topic.

KEYWORDS: polytrauma, multiply injured, damage control, early total care

Introduction

The management of multiply injured trauma patients has both changed and improved over the last 30 years. The dissemination of the advanced trauma life support principle[1] to the multidisciplinary team provides a systematic and uniform approach to the assessment of trauma patients. Furthermore, the implementation of regional trauma networks has focused the treatment of these patients at specialist centers where resources and specialist teams are available to correctly manage multiply injured patients.

Traditionally, treatment consisted of traction for a prolonged period as this group was deemed too unwell for major surgery.[2] However, these patients, particularly those with more severe injuries, are at risk of multiple complications including adult respiratory distress syndrome (ARDS), infection, pneumonia, malunion, nonunion, and death.[3] This led to the introduction of the "early total care" (ETC) which involved early operative stabilization of long bone and pelvic fractures. The aim of this aggressive management was to aid nursing care, reduce complications, and improve patient recovery. However, the risk that this additional surgical insult may contribute to a systemic inflammatory response (SIR) led to the development of the "damage control orthopedic" (DCO) approach. This involves temporarily splinting long bone and pelvic fractures with external fixation while the patient's physiology recovers from their initial trauma. However, controversy still exists on how to decide which patients would benefit from each approach and this article gives a narrative review of the topic.

Physiology of Trauma

Severe trauma with fracture of long bones results in tissue injury and the intravasation of medullary fat and marrow into the systemic circulation, which triggers excitation of the coagulation and inflammatory pathways.[4,5] Systemic inflammation

has the benefit of readying the body for action by increasing blood supply and increasing delivery of white cells. However, the body treads a fine line with overreaction leading to ARDS or multi-organ dysfunction syndrome (MODS).[6] A counter-regulatory mechanism is present but loss of control in severe trauma can lead to ARDS and MODS. Additional surgical treatment can also induce an inflammatory response but in a healthy patient with an isolated injury this has no consequences. However, in multiply injured patient the second hit of surgery can cause an excessive inflammatory reaction with subsequent development of systemic inflammatory response syndrome (SIRS), ARDS, and MODS.

The important host factors that influence inflammation are the cytokines, leukocytes, and endothelium.[7] Previous studies have shown a rise in IL-6, IL-8, C-reactive protein levels, and neutrophil elastase during the acute phase of trauma.[8,9] The level of IL-6 has also been shown to have a greater rise in patients undergoing ETC compared to DCO.[10] This supports the concern that patients undergoing ETC are subjected to a second inflammatory "hit" that may trigger ARDS, as their lungs have been primed by the initial injury to the capillary endothelium associated with shock from systemic injuries. In this scenario, the embolization of fat and marrow contents during intramedullary instrumentation stimulates further inflammation with the potential loss of control leading to SIRS.

Early Total Care

Studies from the 1980 and 1990s reported that early stabilization of femoral shaft fractures was beneficial in polytrauma patients.[11–13] Early fracture fixation has been shown to decrease the duration of ventilation, decrease the time in the intensive care unit, decrease the rates of ARDS, fat embolism syndrome, multiple organ failure, and late sepsis, decrease the overall length of hospitalization, and reduce the cost of medical care.[11–17] These patients are at risk of suffering from various respiratory complications that develop over the first few days and a window of opportunity for early stabilization may be available in the first 24 hours. One randomized trial comparing ETC and DCO in 83 patients with an injury severity score (ISS) of greater than 18 reported that the group with early stabilization had fewer pulmonary complications, shorter hospital stay and number of days spent in the intensive care unit and on a ventilator, and a substantial cost savings.[14] A meta-analysis demonstrated a large relative risk reduction (relative risk, 0.30; 95% confidence interval, 0.22–0.40) in respiratory complications in association with early operative fixation (usually within 24 hours).[4]

Damage Control Surgery

The principle of damage control surgery was first proposed in the context of general surgical trauma in 1993.[18] The principle is to address major injuries first before transfer to intensive care for stabilization when definitive surgery can be managed. DCO uses this same principle and involves the external stabilization of pelvic and long bone fractures. This approach minimizes operative time and blood loss while facilitating nursing care and earlier mobility.[14,19] DCO allows definitive treatment to be deferred until physiologic stability is restored mitigating the risk of secondary lung injury.[20] Studies have shown that DCO treatment is associated with a lower SIR than after ETC.[21] Harwood et al performed a multi-centered randomized controlled trial of 35 polytrauma patients with ISS scores over 16 and long bone fractures reporting that serum inflammatory markers were increased in those undergoing ETC.[10] Specifically regarding pelvic injuries, the rationale for early pelvic stabilization is to restrict pelvic volume and to encourage tamponade reducing blood loss. However, DCO procedures are not definitive and consideration should be given over when the patient should return for definitive treatment as well as a higher risk of infection from the pin tracts.

Chest Injuries

The safety of long bone fixation in patients with pulmonary injuries is controversial. The presence of pulmonary contusions has been shown to be a good independent predictor of the development of ARDS and pneumonia.[22,23] Therefore, the addition of a second hit from a surgical intervention in patients with these additional pulmonary injuries is thought to carry a higher risk of respiratory compromise. Pape et al performed a retrospective review of 106 patients with multiple injuries and reported that early intramedullary nail fixation in those patients with a severe chest injury was associated with an increased risk of both ARDS and death.[24] However, the findings from the literature are not consistent with a retrospective review from Charash et al of 138 patients reporting that the complication rate from delayed intervention is higher (56%) when compared to early stabilization (16%).[25] Therefore, patients with the combination of a serious chest injury and femoral fracture require a multidisciplinary decision regarding the timing and type of surgical intervention, while needing close monitoring during fracture fixation.

Head Injury

Patients with head injuries are well known to be at risk of secondary brain injury if exposed to hypotension, hypoxemia, or increased intracranial pressure. Principles of management include the maintenance of mean arterial pressure and oxygenation to ensure adequate cerebral perfusion. Surgical intervention risks periods of both hypoxia and hypotension with the subsequent secondary brain injury and this may be linked to a poorer neurologic outcome. These patients require appropriate resuscitation and careful monitoring of blood pressure, oxygenation, and intracranial pressure during surgery. In addition, discussion among traumatologists, intensivists, and neurosurgeons should decide on optimum timing in each individual case.

Many studies have retrospectively analyzed patients with the combination of head injury and long bone fractures.

Jaicks et al reviewed 33 patients and reported that after early fracture fixation, fluid requirements were greater, more suffered from hypotension and intraoperative hypoxia, and the Glasgow Coma Scale score was lower on discharge than in patients who had delayed fracture fixation. However, those with delayed fixation had more neurologic complications and stayed longer in the intensive care unit.[26] Similarly, Townsend et al retrospectively reviewed 61 patients with severe or moderate closed head injury and femoral fractures and demonstrated an eight-fold increase in the risk of intraoperative hypotension if the operation was carried out within two hours of admission to hospital and a two-fold increase if the operation was carried out within 24 hours of admission.[27] In contrast, Starr et al reported a 45-fold increase in pulmonary complications with delayed femoral fixation compared with immediate fixation. They also demonstrated that the risk of central nervous system complications and death was increased in the delayed fixation groups.[28] A review of cases series concluded that patients with brain injury who underwent long bone stabilization within 48 hours were similar to those treated with later stability in terms of mortality, length of stay in ITU, and need for mechanical ventilation.[29]

Decision Making: Early Total Care or Damage Control Orthopedics

Deciding when and how to definitively fix long bone fractures in polytrauma patients remains controversial. The evidence discussed is contradictory and the majority of evidence originates from retrospective reviews. Therefore, careful consideration should be given to each individual case and a multidisciplinary team approach to decision making should be adopted.

Table 1. Patients at risk from early total care.[33]

Multiply injured patient with ISS of >20 and thoracic trauma
Multiply injured patient with hemorrhagic shock (initial systolic blood pressure of <90 mmHg)
Bilateral pulmonary contusion
Initial mean pulmonary artery pressure of >24 mmHg

This is beneficial in both prioritizing the injuries that are life and limb threatening while ensuring intervention is performed at the optimal time.

Pape et al randomized 165 patients to receive ETC or DCO and although showed very little difference between the groups, the authors did report a five-fold increase in acute lung injury in the "patients at risk."[30] These findings suggested that a subgroup of patients may benefit from the DCO approach and further research has analyzed which parameters could be used to recognize this at risk group. Bone et al set out four factors that put ETC patients at high risk and these are shown in Table 1. Stubig et al demonstrated that patients with a high ISS (of 25–39) had a tendency toward a higher incidence of ARDS when treated with ETC compared to DCO, whereas in less severely injured patients ETC showed benefits.[31] However, the ISS is not often calculated on admission and is not a direct measurement of a patient's physiological status.

Pape et al. defined criteria that divide polytrauma patients into those that are "stable," "borderline," "unstable," and "in extremis" and these criteria are outlined in Table 2. The authors recommend that those patients who are deemed stable are able

Table 2. Criteria for categorising physiological state of polytrauma patients.[10]

	PARAMETER	STABLE	BORDERLINE	UNSTABLE	IN EXTREMIS
Shock	Blood pressure (mmHg)	100 or more	80–100	60–90	50–60
	Blood units (2 h)	0–2	2–8	5–15	>15
	Lactate levels	Normal	approx 2.5	>2.5	Severe acidosis
	Base deficit (mmol/L)	Normal	–	–	6–18
	ATLS classification	I	II–III	III–IV	IV
	Urine output (mL/h)	>150	50–150	<100	<50
Coagulation	Platelet count (mg/mL)	>110,000	90,000–110,000	70,000–90,000	<70,000
	Factor II and V (%)	90–100	70–80	50–70	<50
	Fibrinogen (g/dl)	>1	approx 1	<1	DIC
	D-Dimer	normal range	abnormal	abnormal	DIC
Temperature		>34°C	33–35°C	30–32°C	<30°C
Soft-tissue injuries	Lung function; PaO$_2$/FiO$_2$	>350	300	200–300	<200
	Chest trauma scores; AIS	AIS I or II	AIS 2 or more	AIS 2 or more	AIS 3 of more
	Thoracic trauma score; TTS	0	I–II	II–III	IV
	Abdominal trauma (Moore)	<II	<III	III	III or IV
	Pelvic trauma (AO class.)	A type	B or C	C	C (crush, rollover abd.)
	Extremities	AIS I–II	AIS II–III	AIS III–IV	Crush, rollover extrem.

to have ETC, those who are unstable or in extremis should have DCO, and if uncertainty exists over the borderline cases then they should also undergo DCO.[10] Further work has been carried out to simplify the decision making process as the criteria described are complex. Some authors suggest that stabilization has been achieved when the patient has good oxygenation and urinary output, and at this point it is safe to proceed with definitive stabilization of the long bone fractures.[2,32] O'Toole et al focused on the measurement of lactate as a tool in deciding if patients with multiple traumatic injuries were adequately resuscitated. Their approach is to perform reamed nailing after adequate resuscitation shown by normalizing lactate, plus optimized ventilatory, and hemodynamic parameters.[20] The authors do not recommend treating those with lung injury differently.

Conclusion

The ETC and DCO approaches are both routinely employed in the management of polytrauma patients with orthopedic injuries. The majority of patients are likely to benefit from ETC but a subgroup of "at risk" patients are best managed using the DCO principle. The use of ISS, lactate, ventilation, and hemodynamic parameters can aid the identification of this subgroup.

Author Contributions

Conceived the concept: RWJ. Wrote first draft of manuscript: RWJ. Contributed to writing of manuscript: RWJ, GC, MD. Agree with manuscript results and conclusions: RWJ, GC, MD. Jointly developed structure and arguments of paper: RWJ, GC, MD. Made critical revisions and approved final version: RWJ, GC, MD. All authors reviewed and approved the final manuscript.

REFERENCES

1. American College of Surgeons Committee on Trauma. *Advanced Trauma Life Support for Doctors: Student Manual*. 7th ed. Chicago: American College of Surgeons; 2004.
2. Giannoudis PV. Surgical priorities in damage control in polytrauma. *J Bone Joint Surg*. 2003;85B:478–483.
3. Baker SP, O'Neill B, Haddon W Jr, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma*. 1974;14:187–196.
4. Robinson CM. Current concepts of respiratory syndromes after fracture. *J Bone Joint Surg*. 2001;83B:781–791.
5. Robinson CM, Ludlam CA, Ray DC, Swann DG, Christie J. The coagulative and cardiorespiratory responses to reamed intramedullary nailing of isolated fractures. *J Bone Joint Surg*. 2001;83B:963–973.
6. Anderson BO, Harken AH. Multiple organ failure: inflammatory priming and activation sequences promote autologous tissue injury. *J Trauma*. 1990;30 (12 suppl):S44–S49.
7. Granger DN, Kubes P. The microcirculation and inflammation: modulation of leukocyte-endothelial cell adhesion. *J Leukoc Biol*. 1994;55:662–675.
8. Hoch RC, Rodriguez R, Manning T, et al. Effects of accidental trauma on cytokine and endotoxin production. *Crit Care Med*. 1993;21:839–845.
9. Waydhas C, Nast-Kolb D, Trupka A, et al. Posttraumatic inflammatory response, secondary operations, and late multiple organ failure. *J Trauma*. 1996;40:624–631.
10. Pape HC, van Griensven M, Sott AH, et al. Impact of intramedullary instrumentation versus damage control for femoral fractures on immunoinflammatory parameters: prospective randomised analysis by the EPOFF study group. *J Trauma*. 2003;55(1):7–12.
11. Border JR, Allgöwer M, Hansen SP, Ruedi TP, eds. *Blunt Multiple Trauma: Comprehensive Pathophysiology and Care*. New York: Marcel Dekker; 1990.
12. Meek RN, Vivoda EE, Pirani S. Comparison of mortality of patients with multiple injuries according to type of fracture treatment: a retrospective age- and injury matched series. *Injury*. 1986;17:2–4.
13. Goris RJ, Gimbrère JS, van Niekerk JL, Schoots FJ, Booy LH. Early osteosynthesis and prophylactic mechanical ventilation in the multitrauma patient. *J Trauma*. 1982;22:895–903.
14. Bone LB, Johnson KD, Weigelt J, Scheinberg R. Early versus delayed stabilization of femoral fractures: a prospective randomized study. *J Bone Joint Surg*. 1989;71A:336–340.
15. Johnson KD, Cadambi A, Seibert GB. Incidence of adult respiratory distress syndrome in patients with multiple musculoskeletal injuries: effect of early operative stabilization of fractures. *J Trauma*. 1985;25:375–384.
16. Riska EB, von Bonsdorff H, Hakkinen S, Jaroma H, Kiviluoto O, Paavilainen T. Prevention of fat embolism by early internal fixation of fractures in patients with multiple injuries. *Injury*. 1976;8:110–116.
17. Pinney SJ, Keating JF, Meek RN. Fat embolism syndrome in isolated femoral fractures: does timing of nailing influence incidence? *Injury*. 1998;29:131–133.
18. Rotondo MF, Schwab CW, McGonigal MD, et al. Damage control: an approach for improved survival in exsanguinating penetrating abdominal injury. *J Trauma*. 1993;35:375–382.
19. Behrmann SW, Fabian TC, Kudsk KA, Taylor JC. Improved outcome with femur fractures: early versus delayed fixation. *J Trauma*. 1990;30:792–797.
20. O'Toole RV, O'Brien M, Scalea TM, Habashi N, Pollak AN, Turen CH. Resuscitation before stabilization of femoral fractures limits acute respiratory distress syndrome in patients with multiple traumatic injuries despite low use of damage control orthopaedics. *J Trauma*. 2009;67(5):1013–1021.
21. Harwood PJ, Giannoudis PV, van Griensven M, Krettek C, Pape HC. Alterations in the systemic inflammatory response after early total care and damage control procedures for femoral shaft fracture in severely injured patients. *J Trauma*. 2005;58(3):446–454.
22. Antonelli M, Moro ML, Capelli O, et al. Risk factors for early onset pneumonia in trauma patients. *Chest*. 1994;105:224–228.
23. Ware LB, Matthay MA. The acute respiratory distress syndrome. *N Engl J Med*. 2000;342:1334–1349.
24. Pape HC, Auf'm'Kolk M, Paffrath T, Regel G, Sturm JA, Tscherne H. Primary intramedullary femur fixation in multiple trauma patients with associated lung contusion: a cause of posttraumatic ARDS? *J Trauma*. 1993;34:540–548.
25. Charash WE, Fabian TC, Croce MA. Delayed surgical fixation of femur fractures is a risk factor for pulmonary failure independent of thoracic trauma. *J Trauma*. 1994;37:667–672.
26. Jaicks RR, Kohn SM, Moller BA. Early fracture fixation may be deleterious after head injury. *J Trauma*. 1997;42:1–6.
27. Townsend RN, Lheureau T, Protech J, Riemer B, Simon D. Timing fracture repair in patients with severe brain injury (Glasgow Coma Scale score <9). *J Trauma*. 1998;44:977–983.
28. Starr AJ, Hunt JL, Chason DP, Reinert CM, Walker J. Treatment of femur fracture with associated head injury. *J Orthop Trauma*. 1998;12:38–45.
29. Dunham CM, Bosse MJ, Clancy TV, et al. EAST practice management guidelines work group. Practice guidelines for the optimal timing of long bone fracture stabilization in polytrauma patients: the EAST Practice Management Guidelines Work Group. *J Trauma*. 2001;50:958–967.
30. Pape HC, Rixen D, Morley J, et al. Impact of the method of initial stabilization for femoral shaft fractures in patients with multiple injuries at risk for complications (borderline patients). *Ann Surg*. 2007;246:491–501.
31. Stübig T, Mommsen P, Krettek C, et al. Comparison of early total care (ETC) and damage control orthopedics (DCO) in the treatment of multiple trauma with femoral shaft fractures: benefit and costs. *Unfallchirurg*. 2010;113:923–930.
32. Pape HC, Giannoudis PV, Krettek C, Trentz O. Timing of fixation of major fractures in blunt polytrauma: role of conventional indicators in clinical decision making. *J Orthop Trauma*. 2005;19:551–562.
33. Bone LB, Giannoudis P. Current concepts review femoral shaft fracture fixation and chest injury after polytrauma. *J Bone Joint Surg*. 2011;93A:311–317.