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Damage Control Orthopedics or Early Total Care: What you Need to Know

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Abstract

Patients with multi-system injuries are defined as polytrauma patients and may need multiple surgical procedures from more than one specialty. The importance of evaluating and understanding the resuscitation status of a polytrauma patient is critical. Orthopedic strategies when caring for these patients include temporary stabilization or definitive early fixation of fractures while preventing further insult to other organ systems. This article will define polytrauma, and discuss specific markers used in assessing patients' hemodynamic and resuscitation status. The decision to use damage control orthopedics (DCO) or early total care (ETC) for treatment of the patient are based on these factors and an algorithm is presented to guide treatment. We will also discuss principles of external fixation and the management of pelvic trauma in a polytrauma patient.

Key words: polytrauma, damage control, lactate, resuscitation

Defining Polytrauma

Any discussion regarding damage control orthopedics vs. early total care must first define the polytrauma patient. The term polytrauma was first described by Tschernee et al. in 1966 as a patient who presents with at least two severe injuries of the head, chest, or abdomen or one injury to the above along with an extremity injury[1]. Definitions and scoring systems have since evolved over the years. Interestingly, although broadly used for the assessment of injury severity and determination of outcomes, the Injury Severity Score (ISS) does not currently play a role in the definition of the polytrauma patient[2]. The most up-to-date definition of the polytrauma patient was developed via a consensus of experts from multiple international trauma societies and is known as the Berlin definition of polytrauma. This definition considers multiple affected body systems and laboratory abnormalities, leading to an increased mortality risk [2,3]. The definition is established with an abbreviated injury score (AIS) ≥3 for two or more different body regions and one or more of the following physiologic parameters: hypotension (systolic < 90 mmHg), altered mental status (Glasgow coma scale ≤ 8), acidosis (base excess ≤ 6) coagulopathy (partial thromboplastin time ≥ 40 s or international normalized ratio ≥ 1.4) and age (≥70). The Berlin Criteria should be applied in the hospital within the first 24 hours of care[3]. The additional physiologic parameters effectively characterize the “lethal triad” that occurs in severely injured patients presenting in hemorrhagic shock or extensive soft tissue injury: coagulopathy, hypothermia, and acidosis, which may ultimately lead to end-organ dysfunction and an exaggerated immunologic response. These factors thereby guide clinical care strategies[4].

Evolution of Fracture Surgery Timing

The timing of fracture fixation in polytrauma patients has evolved over the past several decades. Recommendations moved from one extreme to the other before a better understanding of patient physiology allowed surgeons to use better markers of resuscitation status to guide decision-making. Historically, fracture treatment was delayed in the polytrauma patient, sometimes for weeks. Then came the era of Early Total Care (ETC), where management was defined by urgent definitive fracture stabilization. Prevailing evidence at the time recognized the increased risk of complications when femoral intramedullary nailing was delayed longer than 48 hours, including longer ICU stays and a higher incidence of ARDS and pneumonia [5]. The general presiding principle was that the patient was "too sick **not** to have femur surgery.". However, this aggressive push for urgent, definitive surgery led to increased complications in under-resuscitated patients, thus leading to the era of damage control orthopedics (DCO). In DCO, temporizing measures, like external fixation or skeletal traction, are utilized to acutely and provisionally stabilize long bone fractures to allow for ongoing patient resuscitation before definitive surgery. At its inception, DCO was indicated for patients with a massive head injury, hypotension (SBP <90 mmHg), acidosis (lactate >2.5 mmol/L or base deficit >6 mmol/L), coagulopathy (platelets <70,000, INR >1.5) or hypothermia (core Temp < 33º C)[6]. The more limited procedures in DCO prevented the "second hit" phenomenon, whereby the stress of prolonged/invasive surgery leads to further injury due to escalation of the inflammatory cascade.

The concept of Early Appropriate Care (EAC) then recognized that most patients are responsive to early resuscitation measures, thus allowing for safe definitive care in the first 24-36 hours after injury. In the EAC model, patients are monitored on an ongoing basis for acidosis (base deficit and lactate). When labs reach an appropriate level and patients no longer require vasopressor support, one may proceed with definitive care [8]. The EAC model delineates four groups of patients: stable, borderline, unstable, and in extremis based on laboratory evaluation of resuscitation (table 1). Stable patients can safely proceed with definitive surgery. Patients in extremis should be treated with DCO. Borderline patients who are being appropriately resuscitated and trending in the right direction can safely proceed with ETC in most cases without increased complications. Unstable patients should be actively resuscitated for the first 24-36 hours, and orthopedic care can then be driven by their response to resuscitation (figure 1).

Utilizing factors from the EAC approach, the Safe Definitive Surgery (SDS) methodology recognizes that early definitive surgery, when the patient is appropriately resuscitated, leads to less time in the ICU and a lower incidence of ARDS.[9]. Determining stability necessitates a multifactorial approach that considers other body systems' injuries, as well as real-time monitoring of the patient's resuscitation status through labs and vital signs [4,6].

Assessing Patient's Resuscitation Status: Labs, Biomarkers and Future Directions

For a polytrauma patient, it is critical to define the resuscitation status of the patient to ascertain the appropriate care pathway (figure 1). Various markers have been studied, and ongoing research in the field is leading to newer ways to identify those likely to have a higher risk of complications.

Lactate

Lactate is one of the key variables monitored in the polytrauma setting and is a marker of acidosis. Hypoxia of muscle tissue leads to a buildup and release of lactic acid, which is an early marker of ongoing resuscitation status as it typically clears rapidly, allowing for an active measure of tissue perfusion. A lactate level below < 2.5 mmol/L is a marker of patient stability for safe definitive management of fractures, barring significant abnormalities in other body systems. Lactate levels between 2.5-4 mmol/L are called “borderline”. In accordance with research from the development of the early appropriate care protocol, definitive fixation can safely proceed as long as the markers are trending in the appropriate direction and the patient is not on vasopressors[5]. If the lactate is > 4 mmol/L, patients should be further resuscitated before definitive fixation, and DCO should be considered if the lactate remains significantly elevated for over 24 hours.

Base Deficit

Base deficit is also useful for assessing acidosis and can serve as an ancillary marker to lactate for determining patient resuscitation status. The base deficit is described as the amount of base needed to neutralize the blood to a pH of 7.4. Stable patients have a base deficit <2.0 mmol/L. Utilizing the EAC model, a base deficit < 5.5 mmol/L indicates adequate resuscitation for proceeding with early definitive surgery[5,10].

pH

Lactate and base deficit are more frequently reported markers of metabolic acidosis in trauma patients; however, an arterial blood gas pH level ≥ 7.25 is appropriate for early definitive care[5,6,10].

Urine output

Urine output of 1 cc/kg/hour is a marker of fluid resuscitation and can be utilized with other factors as a reassuring sign of adequate resuscitation status. Patients with adequate urine output can still have elevated lactate due to preferential perfusion of vital organs such as the kidneys, which indicates a condition called "compensated shock."

Traumatic Brain Injury

Managing patients with traumatic brain injury (TBI) and concomitant orthopedic injuries is challenging due to the concern for the "second hit" phenomenon. In patients with TBI, surgery can be deleterious due to anesthetic/surgery-driven hypotension, elevation in intracranial pressure, and hypoxia, which may exacerbate cerebral hypoperfusion and worsen brain injury. In these patients, increased surgical time and/or intra-operative blood loss may result in morbidity, particularly in under-resuscitated patients[18]. There is little quality evidence regarding the effects of orthopedic surgery on intracranial pressure and brain injury. A decision to proceed with DCO vs. ETC necessitates ongoing conversation between trauma surgeons, intensivists, the treating neurosurgeon, and the orthopedic surgeon based on the necessary surgical procedure and the patient's particular brain injury If DCO measures are initiated, studies suggest that definitive care can likely proceed once GCS > 12 or if the intracranial pressure remains below 20 mmHg for more than 48 hours[6,19].

Inflammatory Cytokines/ Immunologic response

Recent research has determined that levels of several cytokines have been implicated in complications following trauma. including IL-6, IL-4, TGF-beta, IL-10 and others[4,11–14]. Elevated IL-6 levels on admission and hospital day one have shown a direct correlation with the systemic inflammatory response syndrome (SIRS) and are associated with higher complication rates in polytrauma patients[15]. More recent evidence has suggested that monitoring a broader selection of cytokines and their distribution over time may create a more accurate picture of abnormal inflammatory cascade effects in the face of trauma[11–13,16]. A delayed pro-inflammatory response may be indicative of poor tolerance to the shock state and provide insight into patients at high risk of developing complications, including ARDS.[12]. Better characterization of these cytokine pathways will improve our ability to recognize patients at risk for complications, and ultimately, these pathways may prove useful for targeted therapeutic interventions.

Neutrophil changes in polytrauma patients

Neutrophils are mediators of the body's natural response to infection but are also found in great numbers following traumatic injury. Defining neutrophil phenotypes in the acute traumatic period may provide insight into the patient's physiologic state and the risk of adverse events. For example, the presence of bone marrow precursor cells and greater than 8% CD16 low neutrophils are ominous signs for the patient[17]. This research is in its early stages, as delineating neutrophil types is currently specialized and time-intensive. Further research is required to operationalize efficient neutrophil phenotyping and study clinical relevance.

Planning Staged Management: Principles of External Fixation

External fixation is the mainstay of damage control orthopedics (figure 2). Typically, external fixators are used for DCO in polytrauma patients who are under-resuscitated or as a life-saving measure for unstable pelvic ring injuries and long bone fractures.

In a damage control situation, the goal of the external fixator is to align the fracture fragments expeditiously for resuscitation purposes. This is critical in the pelvis and the femur, where significant blood loss can occur due to fracture displacement. External fixation is typically performed in the operating room. Still, depending on the acuity of the scenario, certain external fixators can be placed in the ICU or in the trauma bay with /or without fluoroscopy.

Skeletal traction can also be utilized for vertically unstable pelvic and femur fractures and can often be applied more rapidly. Authors have found no difference in complications between skeletal traction and external fixation of femur fractures with an average application length of up to 4-5 days. However, others have reported higher rates of respiratory complications with skeletal traction.[38,39] The benefit of skeletal traction is the ability to apply it quickly and safely without fluoroscopy in the ICU, trauma bay, or emergency room setting. However, it is more difficult to position patients in skeletal traction than in external fixators, leading to potential pulmonary complications or decubitus ulcers, as well as transporting patients for imaging studies. If the patient has an expected prolonged resuscitation period, consideration should be given to applying an external fixator.

When placing an external fixator, several principles should always be maintained. The pins should be placed outside of the immediate zone of injury as much as possible, and they should be bicortical. The greater the number of pins and bars, the more stable the construct. In a damage control situation, where the key is to rapidly stabilize the extremity, this may not be as pertinent but should remain a consideration. When placing a pelvic external fixator, the bars should be placed facing the ceiling or slightly toward the abdomen to allow the patient to sit up without the external fixator hitting the patient’s thighs. This is critical for avoiding pulmonary complications. The bars should also not be placed too close to the abdomen to allow for abdominal distension and access to any surgical incisions.

Once placed, external fixators can safely stabilize the limb/pelvis in anticipation of future surgery or, in certain circumstances, be used for definitive management. If the external fixator is on for an extended period, the pin sites should be carefully monitored to ensure there are no signs of complication, like infection or skin breakdown.

Management of the Pelvic Ring in the Polytrauma Patient

Pelvic ring injuries account for 3-5% of all fractures and are often associated with polytrauma. Given the surrounding vasculature and the large bleeding bony bed, pelvis fractures are associated with significant blood loss and morbidity, as well as mortality approaching 18%[20,21]. Historically, delayed treatment was often performed on pelvic injury due to the complexity and invasive nature of the intervention. Complications, including pneumonia, decubitus ulcers, and anemia, were common. Newer percutaneous surgical techniques and a better understanding of the benefits of early appropriate care have revolutionized the treatment of pelvis fractures in polytrauma patients, allowing for earlier and safer interventions.

It is well established that patients with pelvic ring disruption and hemorrhagic shock should receive urgent pelvic stabilization via external mechanical compression (EMC)[18,25–28]. Pelvis fracture patterns most commonly associated with hemorrhage are the anteroposterior compression (APC) and vertical shear (VS) categories of the Young Burgess classification. Certain anatomic fracture locations, including fractures about the sciatic notch, anterior column fractures, and sacroiliac joint diastasis, may have an increased risk of bleeding [22–24]. EMC can be effectively applied utilizing a sheet or a commercially available pelvic binder[27–29]. Either device should be applied over the greater trochanters. The benefit of sheet utilization is the ability to cut out holes for vascular and surgical access and apply compression across a broad area. In contrast, commercially available binders may be easier and faster to apply in the field. EMC effectively closes the available space in the pelvic cavity, thereby decreasing blood loss (Figure 3). Given that the EMC provides circumferential compression, it may be better than an anteriorly based external fixator or a C-clamp in managing pelvic hemorrhage, which can only provide compression in a single plane.[29] EMC devices are being applied empirically in the prehospital environment and trauma bay successfully, reducing the number of blood transfusions necessary during resuscitation without increasing the risk of complication[30,31].

If patients remain hemodynamically unstable despite EMC application, other strategies for controlling hemorrhage should be employed early. These include angiography and embolization, extraperitoneal pelvic packing [32–34], and/or application of external fixation devices. Each of these adjuncts is complementary and not mutually exclusive[27,28,35]. The choice of which adjunct to use often depends on the availability of resources and personnel at a given trauma center. Still, a clear protocol should be delineated at each institution to efficiently stabilize patients.

Rates of arterial injury in pelvic trauma are reportedly between 0.01-2.3% for all fractures but reach up to 80% of unstable fracture patterns[6,36]. Angiographic embolization can either be performed selectively to a known bleeding vessel or prophylactically via nonselective embolization. There are both permanent and temporary embolization procedures available. The procedure is generally safe, but rare complications can occur, including skin and deep tissue necrosis[36]. When available, angiography and embolization can be an excellent, rapidly deployed, minimally invasive procedure for the management of hemorrhage in acutely ill patients.

Extraperitoneal pelvic packing is another adjunct available for the management of pelvic hemorrhage. Typically performed by trauma surgeons, the packing material (laparotomy pads) can be placed in the retroperitoneal space through a Pfannenstiel or a lower longitudinal infra-umbilical incision, separated from a midline laparotomy incision by a bridge of normal tissue of approximately 4-5 cm. The procedure has the benefit of controlling both venous and bony bleeding, with some control over arterial bleeding via tamponade [32,33]. It should be performed in conjunction with the application of an external fixator to close the pelvic volume for maximal effect.

While the EMC is a very effective means of reducing pelvic volume for resuscitative purposes, anterior external fixators are another useful adjunct. They may benefit patients already in the operating room, patients where EMC does not sufficiently close the pelvic volume, or patients who require prolonged recovery time before definitive fixation. This is important because prolonged EMC may lead to skin breakdown. Anterior external fixation can be applied in two locations, either the iliac crest or the supraacetabular corridor. If necessary, Iliac crest pins can be placed without fluoroscopic guidance, but their trajectory is not as mechanically optimized for closing the pelvic ring. Supraacetabular pins require fluoroscopic guidance and some technical expertise but allows for a more stable reduction of pelvic volume secondary to their advantageous biomechanical trajectory.

C-clamps have historically been used to close the posterior pelvis and are still used in some trauma centers. They should be applied cautiously in specific pelvic fracture patterns (primarily vertical shear without iliac crest fracture) and require technical expertise. They must be placed under fluoroscopic guidance to prevent over-compression and iatrogenic fracture. They may also compromise the soft tissues around future surgical beds and should be utilized sparingly.

There has been increasing literature supporting the benefits of applying the early appropriate care strategy to pelvis and acetabular fractures once the patient has been sufficiently resuscitated. It has been documented that early fixation and stabilization of the pelvis and acetabulum in appropriately selected patients reduces rates of pulmonary complications, including pneumonia and ARDS, DVT, AKI, and reduces the length of ICU stay[37]. When utilizing the same markers as long bone fractures -lactate, base deficit, and vital signs- stable patients with pelvis and acetabulum fractures can be safely taken to the operating room for definitive management within 24 hours of presentation[37]. When determining the feasibility of performing definitive pelvis and acetabulum surgery on borderline patients (lactate 2.2-2.5 mmol/L), surgeons should comprehensively evaluate the patient and the required intervention. Evaluation of patient age, functional reserve, and invasiveness of the proposed procedure should be considered- especially given the variability in invasiveness required for pelvis and acetabular surgery. Percutaneous pelvis fixation via intraosseous corridors is a relatively quick procedure with limited blood loss. In contrast, an open approach to a complex acetabulum fracture can have considerably more blood loss and increased operative time. Some authors have found equivocal or improved outcomes when treating borderline patients with DCO, and others have found improved outcomes with ETC; further evidence is required to fully elucidate[37]. If the decision is made to proceed with operative intervention, serum markers, including lactate and base deficit, can continue to be utilized to monitor patients throughout the duration of their procedure. Surgeons should be aware of the patient's status and may consider surgical staging intraoperatively if the patient deteriorates. This decision is very situationally dependent. It is recommended that the surgeon verify the patient's status at natural stop points throughout the procedure before proceeding.

Conclusions

Determining the stability of a polytrauma patient is a complex and ongoing process. Orthopedic surgeons should utilize multiple indicators to create a comprehensive, dynamic picture of patient status over time to determine the feasibility of performing DCO or ETC. On initial presentation, patients with a suspected pelvis injury should be placed in an external mechanical compression device to limit blood loss. Baseline and trending laboratory values should be obtained, including lactate, base deficit, and pH. Utilizing the early appropriate care model, stable and borderline patients- those with normalized pressures, lactate <2.5 mmol/L, and no head injury- can safely undergo early definitive surgery. Patients who are unstable but resuscitated- lactate between 2.5-4 mmol/L- can be managed with definitive surgery if they are trending in the right direction and not on vasopressors. Extremis patients, those with persistent lactate above 4 mmol/L, TBI, and pressor requirement, or those for which definitive surgery is time intensive and invasive, should be treated with damage control orthopedics, with later definitive fixation. Orthopedic damage control strategies include the application of pelvic external mechanical compression, skeletal traction, and external fixation.

Future directions in the management of polytrauma patients include a better understanding of patients with poor or prolonged activation to the stress of trauma, which likely portends increased complication rates. Newer research focusing on cytokine release and time mapping, as well as neutrophil response, may ultimately give us clinical indicators for predicting patients with poor physiologic tolerance and those at higher risk of complications, and create new opportunities for treatment.

Supplemental Digital Content

SDC 1. Author Conflict of Interest Forms

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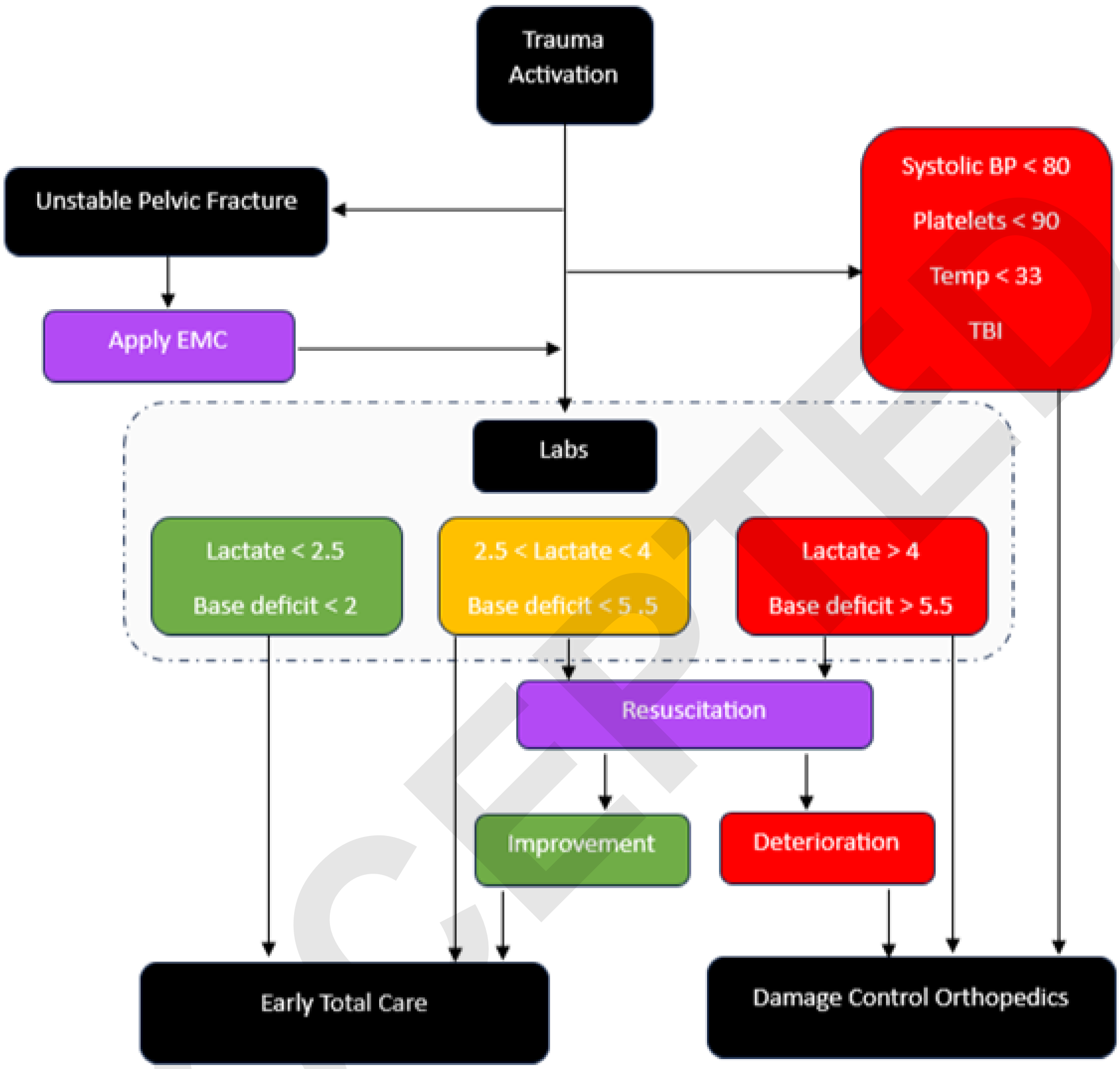
FIGURE LEGENDS

Figure 1: Algorithm for determining patient stability and initial surgical care in the poly trauma patient

Figure 2: Anteroposterior radiograph of comminuted segmental shaft fracture provisionally stabilized with external fixator. Patient is a 29M motorcycle accident presenting with traumatic brain injury (TBI), lactate 7.6 mmol/L on arrival. He was taken emergently to the operating room due to extensive abdominal injury and positive fast exam, external fixator applied in same operative setting.

Figure 3: AP pelvic radiograph of polytraumatized patient demonstrating APC type pelvis fracture including pubic symphysis diastasis, comminuted sacral fractures and left pubic root fracture before and after EMC application with significantly improved pelvic volume and alignment. Embolization coils can also be appreciated.

Figure 1



Trauma Activation
Unstable Pelvic Fracture
Systolic BP < 80
Platelets < 90
Temp < 33
TBI
Apply EMC
Labs
Lactate < 2.5
Base deficit < 2
2.5 < Lactate < 4
Base deficit < 5.5
Lactate > 4
Base deficit > 5.5
Resuscitation
Improvement
Deterioration
Early Total Care
Damage Control Orthopedics

Figure 2

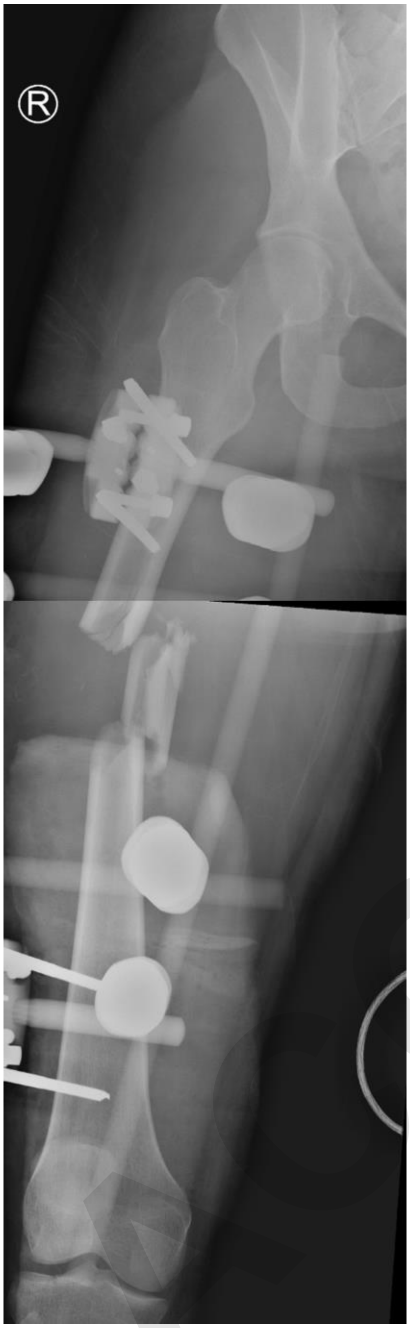


Figure 3

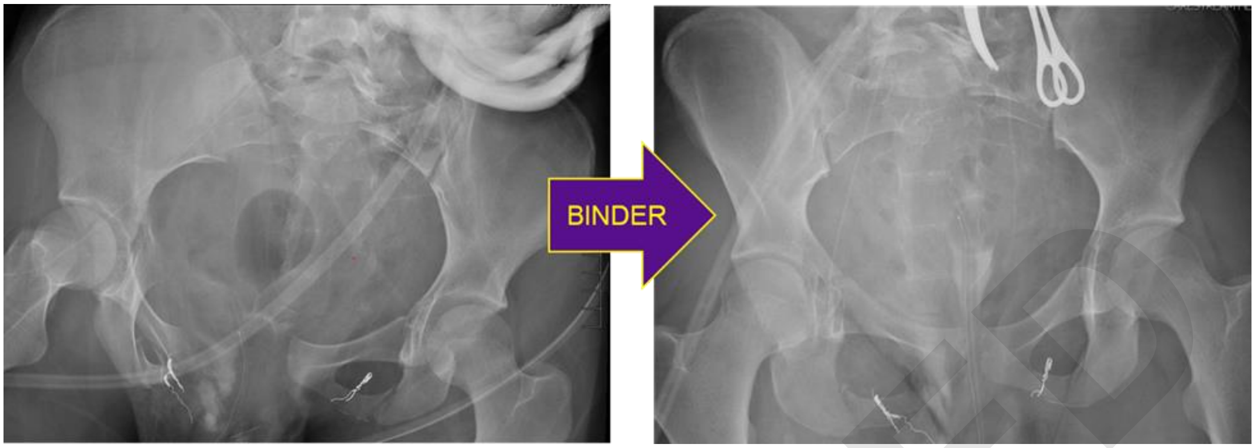


Table 1: Delineation of patient resuscitation status

Parameter	Stable	Borderline	Unstable	In Extremis
Shock				
Systolic BP (mmHg)	≥ 100	80-100	60-80	≤ 60
pRBC transfusion (within 2 hr)	≤ 2	3-8	9-15	≥ 15
Lactate (mmol/L)	≤ 2.2	2.2-2.5	2.5-4	≥ 4
Base deficit (mmol/L)	0-2	2-6	6-10	≥ 10
ATLS shock	I	II	III-IV	IV
U/O	--	--	Decreased	Significantly decreased
Coagulation				
Platelet count (10^3< μL)	≥110	90-110	70-90	≤ 70
Temperature (deg C)	≥ 34	33-34	30-33	≤ 30
Soft Tissue Injury				
Lung Function PaO2/FiO_2	≥ 350	300-350	200-300	< 200
Chest score, AIS	0-2	3	4	5
Abdominal trauma (Moore)	0-2	3	4	5
Pelvic Trauma (AO)	none	A	B	C

The Journal of
Trauma and
Acute Care Surgery

CONFLICT OF INTEREST DISCLOSURE FORM

Based on ICMJE Form

Date: 12/6/2023

Your Name: Nicole Stevens

Manuscript Title: Damage Control Orthopedics of Early Total Care: What do you need to know

Manuscript Number (if known): Click or tap here to enter text.

In the interest of transparency, we ask you to disclose all relationships/activities/interests listed below that are related or unrelated to the content of your manuscript. Disclosure represents a commitment to transparency and does not necessarily indicate a bias. If you are in doubt about whether to list a relationship/activity/interest, it is preferable that you do so.

Participants of an accredited activity must disclose all personal **financial and non-financial relationships**, over the previous 36 months with an **ineligible company** (formerly defined as a commercial interest). **Financial relationships** are those relationships in which the individual benefits by receiving a salary, royalty, consulting fee, honoraria, ownership interest (e.g., stocks, stock options or other ownership interest), or other financial benefits, and may affect activity content relevant to products or services of an **ineligible company**, defined as an entity whose primary business is producing, marketing, selling, re-selling, or distributing healthcare products used by or on patients.

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	medical writing, article processing charges, etc.) No time limit for this item.		Click the tab key to add additional rows.
Time frame: past 36 months			
2	Grants or contracts from any entity (if not indicated in item #1 above).	☒ **None**	
3	Royalties or licenses	☒ **None**	
4	Consulting fees	☒ **None**	
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6	Payment for expert testimony	☒ **None**	
7	Support for attending meetings and/or travel	☒ **None**	

		Name all entities with whom you have this relationship or indicate none (add rows as needed)	Specifications/Comments (e.g., if payments were made to you or to your institution)
8	Patents planned, issued or pending	☒ None	
9	Participation on a Data Safety Monitoring Board or Advisory Board	☒ None	
10	Leadership or fiduciary role in other board, society, committee or advocacy group, paid or unpaid	☒ None	
11	Stock or stock options	☒ None	
12	Receipt of equipment, materials, drugs, medical writing, gifts or other services	☒ None	
13	Other financial or non-financial interests	☒ None	
14	Family Disclosure. Disclose any financial associations involving a spouse, partner, or children	☒ None	

Please place an "X" next to the following statement to indicate your agreement:

☒ I certify that I have answered every question and have not altered the wording of any of the questions on this form.

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Date: 12/6/2023

Your Name: Nirmal Tejwani

Manuscript Title: Damage Control Orthopedics of Early Total Care: What do you need to know

Manuscript Number (if known): Click or tap here to enter text.

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4	Consulting fees	☐ **None**	
		Stryker	
		Acumed	
5	Payment or honoraria for lectures, presentations, speakers bureaus, manuscript writing or educational events	☒ **None**	
6	Payment for expert testimony	☒ **None**	
7	Support for attending meetings and/or travel	☒ **None**	

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		OTA	AOA
		AAOS	
		FOT	
11	Stock or stock options	☒ None	
12	Receipt of equipment, materials, drugs, medical writing, gifts or other services	☒ None	
13	Other financial or non-financial interests	☐ None	
		Stryker (research funding)	
14	Family Disclosure. Disclose any financial associations involving a spouse, partner, or children	☒ None	

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