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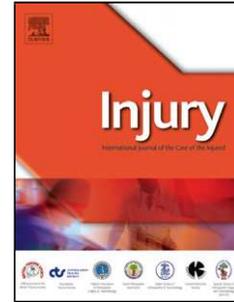


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## Accepted Manuscript

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**Time to think outside the box: 'Prompt-Individualised-Safe Management' (P.R.I.S.M.) should prevail in patients with multiple injuries**

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**Keywords:** polytrauma, management, Damage control orthopaedics, Early total care, Early appropriate care, prompt individualised safe management.

The management of polytrauma patients has undergone a revolution over the past 80 years. In its infancy in the 1940s, orthopaedic management of polytrauma patients predominately involved the use of traction, casts and splints.

The levels of morbidity and mortality which ensued following long bone fractures was problematic and there was a common consensus that “The patient was too sick to operate on” and surgeons were fearful of operating on patients.

The 1970s brought the first shift in the treatment paradigm of polytrauma patients with long bone fractures. On-going advances in osteosyntheses yielded positive results with reductions in pulmonary complications and time to mobilisation<sup>(1)</sup>. In 1985 Johnson et al. published a case series of 132 patients investigating the incidence of adult respiratory distress syndrome (ARDS). His results showed that patients with an ISS of greater than 40 who did not receive early operative fracture stabilisation within the first 24 hours had a 75% chance of developing ARDS compared to a 17% chance in those who did ( $p < 0.001$ ).<sup>(2)</sup> Subsequently, several other retrospective studies were published which confirmed Johnson’s findings<sup>(3,4)</sup>, and Bone’s publication a few years later being the first prospective randomised controlled trial built the foundations of Early Total Care (ETC).<sup>(5)</sup> His study showed reduced rates of fat embolism, ARDS and sepsis related mortality in patients who underwent definitive femoral fracture stabilisation within 24 hours. Delay in stabilisation after that time resulted in a five times greater risk of adult respiratory distress syndrome (ARDS).<sup>(5)</sup> Not surprisingly therefore, the argument became “patients are too sick not to be operated on”.

The change in treatment paradigm was successful and many patients benefit from this approach. However, in subsequent studies, it was noted that ETC itself may be detrimental to patients who were most severely injured or had associated chest<sup>(6,7)</sup> or head injuries<sup>(8,9)</sup>. These findings were particularly pertinent from the trauma centre in Hannover, Germany. This paved the way to the development of Damage Control Orthopaedics (DCO).<sup>(10)</sup>

DCO is a term originally used in naval and maritime industry implemented in emergency situations to prevent the sinking of ships through the implementation of several measures. The principles of DCO were transferred to medicine and first used in general surgery and were subsequently adapted to orthopaedics for the management of extremity injuries including pelvic fractures.

DCO includes 4 stages of management: <sup>(11,12)</sup>

1. Performance of life saving procedures as deemed necessary.
2. Control of haemorrhage, stabilisation of long bone fracture often through use of external fixators and the management of soft tissue injuries if present.
3. Vital organ monitoring and aggressive resuscitation in the intensive care setting
4. Definitive fracture fixation.

Scalea et al. first described the application of DCO in a case series of 43 patients (median ISS-27) with femoral fractures. <sup>(13)</sup> These patients underwent temporary external fixation for a median of 4 days before staged nailing occurred. Moving on, as our knowledge of the immunological system improved, the 'second hit theory' was proposed, <sup>(14)</sup> following operative interventions in patients with polytrauma. It was noted that trauma itself was the 'first hit' and the subsequent operation that was performed the 'second hit' inducing further increase in several molecular mediators (ie. IL 6, TNF $\alpha$  and IL 1  $\beta$ ), markers of immune reactivity, demonstrating a surgical stress reaction which when becoming exaggerated could lead to ARDS/MODS due to excessive systemic inflammation. <sup>(15)</sup>

The issue then became in identifying which of these polytrauma patients would be the ones who lacked the physiological capacity for further significant insult, such as the complete fixation of all fractures within 24 hours (ETC). The review published in 2005 by Pape et al. attempted to classify patients into 4 categories: Stable (grade I); Borderline (grade II), Unstable (Grade III) and in Extremis (Grade IV) physiological stage. The authors used physiological parameters to assess the four pathophysiologic cascades seen in polytrauma (shock, coagulation abnormalities, hypothermia and soft tissue injuries). <sup>(16)</sup>

For both the 'unstable' and 'in extremis' groups, consisting of patients with the highest risk of sustaining complications post surgery, DCO was recommended. Conversely, patients who are physiologically stable are eligible for ETC, which allows for the total fixation of fractures in one theatre setting. The 'Borderline' patient group, also known as group 'at risk', continues to cause debate amongst the orthopaedic community. This subset's response to surgery could be unpredictable

as their physiological parameters are not grossly abnormal and they may be susceptible to the 'second hit' phenomenon. Ultimately, this should come down to surgeons' experience and discretion in opting to follow DCO or ETC.<sup>(16)</sup>

In the Adams Cowley shock trauma centre in Maryland the authors recommend DCO in patients with the following characteristics: closed head injury; poor response to resuscitation in the first 12 hours and poor respiratory status at the time of fracture treatment.<sup>(17)</sup>

Overall, the use of DCO has its benefits for any patient not deemed to be physiologically 'stable'. Studies have also shown its successful applications in natural disasters in being able to deal with and turnover high volumes of patients.<sup>(18)</sup>

DCO also poses some negative aspects, predominately the increased risk of infection associated with both the external fixator and the subsequent second visit to theatre.<sup>(19)</sup> Furthermore, there is still no clear consensus on when the definitive fixation should be performed. Several different time points are suggested according to the long bone affected (femur 5-7 days, pelvis 5-9 days).<sup>(20)</sup> Several studies in Germany suggest a minimal delay up until day 5 where decrease hepatic and pulmonary complications were noted in a set of over 4,000 patients.<sup>(21)</sup> Of note, there has been limited Level I RCT literature published with adequate power investigating this.

Most recently, Vallier's research group have proposed the application of Early Appropriate Care (EAC) following resuscitative efforts in the polytrauma patient.<sup>(22)</sup> This approach can be applied through the evaluation of three physiological parameters: lactate, acid base excess and pH as long as initial acidosis improved to at least one of the following parameters: lactate is  $<4$ , pH is  $\geq 7.25$  or base excess is  $\geq 5.5$ . According to the authors, you can proceed to the definitive management of mechanically unstable fractures of the femur, pelvis and acetabulum and thoracolumbar spine in the form of early total care within 36 hours. However, DCO is only recommended for those who do not respond within the first eight hours to resuscitation. The authors believe that this protocol is readily and easily applicable in most trauma centres, it is affordable and can provide continued guidance to the surgeons of a patient's physiological status allowing for decisions regarding operations to be made.<sup>(23)</sup> Furthermore, in privatised healthcare systems application

of EAC can increase profitability margins and allow better allocation of trauma services.<sup>(24)</sup> In terms of patient outcomes Vallier et al. have demonstrated a reduction in patient complications and a shorter length of hospital stay since the application of this protocol. Their study investigating EAC of axial and femoral fractures in multiply injured patients yielded favourable results in using the EAC algorithm.<sup>(25)</sup> There were no differences noted in the resuscitative needs of the elderly cohort ( $\geq 60$  years old) and the 2 younger groups. Furthermore, the complication rates of the elderly cohort (16.2%) were similar to those of the younger one (15.8 %). This study was underpowered and the authors have acknowledged this so further studies with larger sample sizes are required to validate the use of EAC in patients whose physiological parameters are distorted.

Lately, Pape et al. raised concerns about EAC and its appropriateness for certain subsets of patients who suffer from multiple traumatic injuries.<sup>(26)</sup> The 3 parameters of interest suggested by Vallier et al. (lactate, PH and base excess) can be distorted in patients who are diabetic, in the elderly, and those suffering from renal failure and therefore the true physiological profile of these patients may be masked. Even the type of fluid received during the resuscitative attempts can also influence lactate levels. More over, Pape et al highlighted that the protocol does not state the type of fluids used. Furthermore, when reaching to the conclusion of using the above 3 parameters alterations were made weighting of several parameters recommended in Pape et al. publication of 2005.<sup>(16)</sup> The differing weighting statistically would increase the likelihood of producing improvements in the findings of their protocol. Finally, Pape et al raised questions concerning the data originally available in Vallier's research group. Several parameters assessing coagulopathy, clotting factors, circulatory and pulmonary functions were missing.

Pape et al went on to suggest the so called 'Safe Definitive Surgery approach'.<sup>(26)</sup> According to this strategy, the three subgroups of polytrauma patients, borderline, unstable, extremis would undergo initial assessment in the Emergency room in terms of their physiological state. Parameters for the initial physiological assessment and resuscitation requirements include 'multiple end points'. If the patient has been

declared as stable, safe definitive treatment can be applied. Alternatively, if the patient continues to be unstable or extremis, DCO surgery is recommended. After 24hrs reassessment is necessary examining coagulation, fluid balance, lung function and vasopressor need. If the patient is deemed to be 'stable' then again, the surgeon can proceed with safe definitive surgery. On the other hand, if the condition of the patient remains borderline repeated daily assessment is necessary until the patient will be declared stable and fit for definitive surgery. <sup>(26)</sup>

Overall, it is clear that a debate is ongoing amongst orthopaedic trauma surgeons as to whether one should treat a multiply injured patient with ETC? DCO? or EAC? Each strategy assumes specific indications and contraindications. However, the time has come to think outside the box and be less opinionated and leave behind us disagreements and conflicts. We should stop arguing or defending each one of these treatment modalities. Our decision making process should be based on the principles of doing no 'further harm to the patient', intervening promptly, and utilizing the concept of individualised/personalised medicine. When we manage a polytrauma patient, we should apply the dogma of 'Prompt-Individualised-Safe Management' (P.R.I.S.M.), (**Figure 1**). Our philosophy is based on the understanding that every patient responds in a different way to the same degree of injury, every patient has a different genetic constitution, and the fact that the trauma service provision and resources including man power are dissimilar from country to country. In trying to categorise polytrauma patients into specific pathways we feel that the importance of patient specific treatment may be overlooked. It doesn't matter which treatment algorithm you decide to follow as long as it is in-keeping with the specific clinical and physiological parameters the patient in front of you presents with. Ultimately we aim to do no further harm as surgeons and the clear sole aim should be to save the patient's life and to apply the differing strategies available in the patient's best interest. Therefore, we should stop discussing ETC, DCO, EAC and we should talk, implement the philosophy of P.R.I.S.M. This should become the new dogma of treating polytrauma patients. Out of this one should direct the patient to what type of treatment fits best, remain flexible to this direction in a continuous manner.

In terms of the specific criteria required to assess the physiological state of the patient, each unit should utilise whatever they have available in their armamentarium and should apply the in house protocol that they have developed. We acknowledge that not every unit can measure markers of immune reactivity such as IL-6, but they can utilise parameters that have been described over the years (lactate, acid base balance, PH, lung function, blood pressure, pulse rate, haemoglobin, etc), consider the presence of injury patterns, comorbidities and the age of the patient. All these should be taken into account to ascertain a complete picture of the state of the patient and then decide what is the safest way to proceed in an individualised/personalised manner. <sup>(27-30)</sup> Such an approach, should be established as an institutional protocol in order to simplify each individual evaluation and to standardize criteria best applied based on each unit's capabilities and the injury patterns involved.

It should not be forgotten that the initial factors which were evaluated can easily and rapidly change, related to blood loss and the quality of ongoing resuscitation. It is therefore crucial that the orthopaedic surgeon revisit the 'in house chosen' physiological assessment parameters frequently particularly during any extended surgery during ETC, coordinate with anesthesia, and be ready to revert to DCO as needed. Of interest, analysis of in house results (data not shown) failed to prove that the protocol of EAC was valid for our polytrauma patient cohort.

Safety of the patient remains our priority and direct comparisons between different health care systems in polytrauma protocols should become constructive not destructive. We therefore suggest that the dogma of 'PRISM' should be considered as a unified concept to allow surgeons to speak the same language, manage the patient promptly (no timeline cut offs ie 24 and/or 36 hours) and consider an individualised patient approach minimising the risk of unpredicted complications and mortality.

**Conflict of Interest:**

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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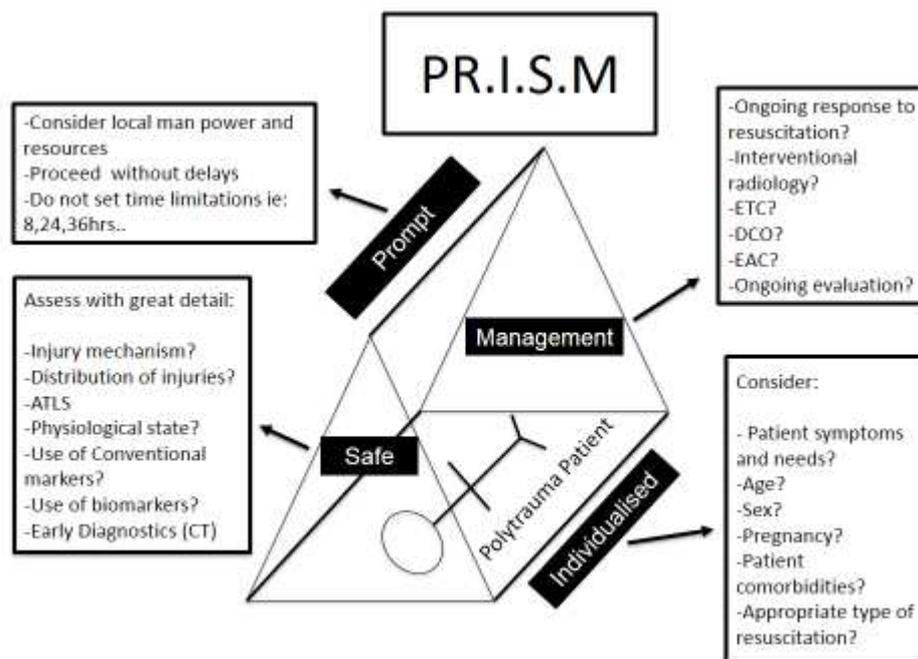
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## Legends:

Figure 1: PRISM Concept of management of polytrauma patients



PRISM= Prompt - Individualised - Safe – Management

ATLS: Advanced Trauma life support

CT: Computed tomography

ETC: Early total care

DCO: Damage control orthopaedics

EAC: Early appropriate care