

Analysis of ‘Code red trauma calls’ promoting the development of a novel cognitive aide for blood product resuscitation

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Abstract

Background: The management of patients involved in complex trauma follows the principles of Damage Control Resuscitation; of which haemostatic resuscitation is a key pillar to this paradigm. A Code Red Trauma (CRT) Policy enables pre-hospital clinicians and hospital trauma team leaders to deliver blood and blood products to patients at the earliest opportunity upon their arrival to hospital.

Method/ Materials: The conduct of CRT practice over a 6-month period, in a busy MTC, located in the North West of England, was retrospectively examined to assess validity of CRT activation, blood product availability and blood product wastage.

Results: Between 1 January 2017 and 30 June 2017 there were 77 Code Red activations. Approximately two-fifths of activations were attributable to penetrating trauma (32/77), with activity spread throughout a 24-hour period. Subsequent retrospective analysis concluded that only 33 cases (42.9%) actually met the criteria to be “Code Red” and warrant a declaration of a CRT with only 10 of these attributable to penetrating trauma. In total 43 units of blood products were wasted.

Conclusion: To address issues of excessive CRT activation and blood product wastage, we have increased engagement with our regional pre-hospital care services and developed cognitive aide models to assist our trauma team leader’s critical decisions for blood product resuscitation.

Introduction

Trauma has been reported to be the leading cause of death and disability world-wide for persons under the age 35 years and accounts for approximately 10% of all deaths in general [1]. Haemorrhage is one of the leading causes of death in major trauma patients [2], with 50% of lethal outcomes occurring secondary to uncontrolled exsanguinating haemorrhage within the first 48 hours [3]. Coagulopathy associated with trauma exists in 25% of severely injured patients upon presentation to hospital [4].

Lessons learnt from recent conflicts in Iraq and Afghanistan have led to the adoption of key principles for Damage Control Resuscitation (DCR) when managing complex trauma [5,6]. DCR consists of three elements; permissive hypotension, damage control surgery and haemostatic resuscitation [7] with an emphasis on avoiding the ‘lethal triad’ of acidosis, coagulopathy and hypothermia. Haemostatic resuscitation involves the administration of PRBC, FFP and Platelets in a ratio of 1:1:1 [8].

Major Haemorrhage Protocols (MHP) are also now widely adopted by Major Trauma Centres (MTC) in England. Whilst bleeding is uncontrolled blood product resuscitation is achieved by adhering to protocols that follow a set sequence of blood product administration. MHP streamlines the process of delivering DCR; haemostatic resuscitation, driving a coordinated response from all personnel involved [9]. Riskin reported a reduction in mortality from 45 to 19%

after the implementation of a massive transfusion protocol for bleeding trauma patients in a local setting [10]. MHP implementation has resulted in an improved delivery of blood components and a reduction in the waste of blood products [11].

Despite the literature demonstrating benefits of adopting a MHP, there remains variation in clinical practice regards the:

- criteria for initiation
- role of point-of-care testing
- end points for termination
- indications for therapeutic adjuncts during resuscitation, for example use of calcium

The decision to initiate a MHP and terminate remains two most contentious areas of debate. Blood product transfusion is not a benign process and is fraught with risk [12]. Nevertheless, patient mortality

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Key words: damage control surgery, haemostatic resuscitation, trauma

Received: August 13, 2018; **Accepted:** August 22, 2018; **Published:** August 27, 2018

after a massive haemorrhage significantly improves with decreased time between presentation and MHP activation, and also with decreased delays between MHP activation and the initiation of a MHP transfusion [10,13,14,15].

To date several research studies have evaluated different scoring systems to predict the need for massive transfusion in varied trauma [16]. The American Society of Anesthesiologists, the American College of Surgeons (ACS), and the European Society for Advanced Bleeding Care in Trauma (ABC-Trauma) recommend the use of validated scoring systems to predict the need for massive transfusion [17]. The Trauma-Associated Severe Hemorrhage (TASH) and Assessment of Blood Consumption (ABC) are two common scoring systems [17-19].

The TASH score is more sophisticated derived from seven independent weighted variables; Systolic Blood Pressure (SBP), Heart Rate (HR), sex, haemoglobin, focused assessment with sonography for trauma (FAST), base excess, extremity or pelvic trauma. The ABC score is simple to calculate, formed from non-laboratory and non-weighted criteria easily assessed following patient arrival in the Emergency Department (ED); SBP < 90mmHg, HR > 120bpm, penetrating mechanism and positive fluid on FAST exam.

Nunez showed the ABC score to correctly predict the retrospective need for massive transfusion in 84% of cases, with a sensitivity of 75% and specificity of 86% [20]. The scoring system was further validated using trauma patient datasets recorded at 3 large level 1 trauma centers in the United States between 2006 and 2007. The validation data concluded that the ABC score to be 75-90% sensitive and 67%-88% specific with regard to its ability to retrospectively predict MT requirements within 24 hours of trauma [19]. Sophisticated systems such as the TASH Score that include higher numbers of variables have been reported to perform superior over simple non-weighted models [21].

Transferring validity of a scoring system to other trauma networks is challenging and not without risk. The application of the ABC-Score to aide critical decisions for massive transfusion in patients presenting to our MTC may not be best placed. We have immediate access to a CT scanner, as a result, the frequency of use for focused abdominal sonography in trauma (FAST) has significantly reduced. Furthermore, the majority of our trauma population are injured via blunt mechanism.

Standardisation of MHP initiation and DCR application will support the collection of robust clinical data, improving our understanding of these practices and their true impact. Prospective validations are required to improve the use and effectiveness of scoring systems.

To ensure blood and blood products are available at the earliest opportunity following patient arrival to our MTC ED a 'Code Red Trauma (CRT) Policy' has been developed and implemented. At our institution, a "Code Red Trauma" Call can be activated by the pre-hospital team or ED Trauma Team Leader (TTL). The following criteria [22] enables the TTL to activate a CRT, this is similar to other MTCs in England [11]:

- Traumatic Cardiac Arrest.
- Systolic Blood Pressure <90mmhg.
- Suspected Active Haemorrhage
- Visible Active haemorrhage
- Poor Response to Initial Fluid Resuscitation

In other regions across the UK, pre-hospital alerts are instigated when there is the suspicion or evidence of active haemorrhage, a systolic BP <90mmHg or failure of blood pressure to respond to an intravenous fluid bolus [23]. Weaver and colleagues [24] showed the effectiveness of the above criteria with 91% of pre-hospital 'Code Red' patients receiving blood product transfusion after arrival in hospital. Furthermore, patients declared 'Code Red', received a mean of 10.4 units PRBC transfusion in the first 24 hours. The Scottish Transfusion and Laboratory Support in Trauma Group (TLSTG) also have a unified National Pre-hospital Code Red protocol. Between June 1st, 2013 and October 31st, 2015 there was 53 pre-hospital CRT activations. Subsequent analysis of this cohort concluded the above criteria to successfully predict a need for in hospital transfusion. Furthermore, it was reported CRT clinical practice did not lead to increased blood component discards [25].

At our institution, when a CRT is activated, the transfusion laboratory is contacted to provide a 'shock pack' consisting of 4 units of packed red blood cells (PRBC) and 4 units of fresh frozen plasma (FFP). To ensure blood products are available prior to patient arrival a designated 'runner' is sent immediately to collect the 4 units of PRBC, with defrosted FFP following on at the earliest opportunity. Subsequent shock packs contain platelets to enable a 1:1:1 transfusion of PRBC, FFP and platelets until control of bleeding is achieved following current evidence [26].

Once a pre-alert has been received, the trauma team (composition: Table 1) is activated (via specific criteria: Table 2), at the earliest opportunity all members of the team assemble in the resuscitation bay for an initial briefing by the trauma team leader (TTL) [27].

The initial team briefing is important as it outlines critical pre-hospital information, equipment required and to be prepared, plus an initial understanding of the TTLs mental model - what is expected to happen [28].

On arrival the trauma patient receives a primary systematic assessment with interventions completed in a horizontal fashion [29]. Survival during massive haemorrhage is critically dependent on rapid identification and control of the bleeding source(s). Every effort is taken to rule out other causes of shock, specifically addressing obstructive shock (tension pneumothorax, massive haemothorax and cardiac tamponade). Immediate access to limb tourniquets, topical haemostatic agents, compression bandages, pelvic and long bone splints, trained surgeons, chest drains and a 'thoracotomy tray' is vital.

Our institution uses the Belmont Rapid Infuser (Billerica, MA, USA), following a CRT activation the infuser is primed with crystalloid and blood products are only spiked following the instruction of the TTL after the patient arrives. The Belmont Rapid Infuser can deliver warmed PRBC and FFP at a maximum rate of 750ml/min. To prevent fluid overload, it is imperative to maintain awareness of fluid responsiveness and resuscitation state, repeated boluses of 250ml of blood product are given, this requires excellent communication skills amongst the trauma team. Speed and ease of blood product infusion places significant pressure on the hospital blood bank and wider logistic chains.

Only 7% of the UK population are blood group O Neg [30], in 2014, NHS Blood and Transplant (NHSBT, the blood service for England and North Wales) issued three 'cautionary alerts' as blood stocks of O Neg fell to 3.5 days stock. Our hospital only stores two units of A-ve platelets in the blood bank, during DCR of a trauma patient this can be consumed quickly. To protect limited resources, at the earliest opportunity, blood product resuscitation is often guided by the use

Table 1. The composition of a typical trauma team in the NHS and their roles

Team Member	Role in the Trauma Team
Trauma Team Leader (TTL) (Consultant)	Trauma Team Leader Brief the team Delegate roles and responsibilities Coordinate primary survey Maintain situation awareness.
Primary survey doctor (Emergency Medicine Specialty Trainee)	Perform the primary survey.
Anaesthetist (Specialty Trainee 5–7, Post Final FRCA)	Responsible for airway management and advanced vascular access
Operator Department Practitioner NHS Agenda for Change Band 5-6	Assist the Anaesthetist
Scribe (Trauma Nurse Coordinator) NHS Agenda for Change Band 7	Maintain a record of the events in the trauma bay
Emergency Medicine Nurse 1 (circulator) NHS Agenda for Change Band 5	Support the trauma team
Emergency Medicine Nurse 2 (rapid infuser) NHS Agenda for Change Band 5	Check blood and blood products Transfuse via the rapid infuser
Emergency Medicine Nurse 3 (rapid infuser) NHS Agenda for Change Band 5	Check blood and blood products Transfuse via the rapid infuser
Runner (Health Care Assistant) NHS Agenda for Change Band 2	Collect blood and blood products from the transfusion laboratory and other equipment as necessary.
Orthopaedic Surgeon (Specialty Trainee 4–7)	Provide orthopaedic advice to the TTL
General Surgeon (Specialty Trainee 4–7)	Provide general surgical advice to the TTL
Radiographer	Undertake chest and pelvic x-rays as required.

Table 2. Typical activation criteria for the Trauma Team in an NHS Major Trauma (taken from Kings College Hospital, Major Trauma Service: Information for Members of the Trauma Team).

Traumatic event and one of the following:	<ul style="list-style-type: none"> Oxygen saturation <90% Systolic arterial pressure <90 mm Hg Respiratory rate <9 or >29 bpm GCS <14
Penetrating injury to	Head Neck Chest Abdomen Pelvis
All gunshot wounds	
Fractures	Open or depressed skull fractures Pelvic fracture Two or more proximal long bone fractures Flail chest
Traumatic amputation	
Blast or crush injury	
Major burns	<ul style="list-style-type: none"> >10% total body surface area but lower threshold in child or elderly Combination of burns and trauma
Road traffic crash	<ul style="list-style-type: none"> High speed crash (>30 mph) or pedestrian vs vehicle at 20 mph Separation of rider and bike Intrusion into passenger compartment Ejection from vehicle Death in the same passenger compartment Bull's eyed windscreen >20 min extrication time
Falls	<ul style="list-style-type: none"> Height of >3m Paediatrics—consider the age and height of the child in relation to the height fallen
Helicopter Emergency Medical Service (HEMS) transfer	
Drowning/submersion	

of rotational thromboelastometry (RoTEM, Tem Innovations GmbH, Basel). ROTEM guidance significantly reduces the number of blood products transfused, as well as blood loss, unfortunately there is currently no evidence supporting a positive effect on mortality [31,32,33].

CRT patients are often the most complex cohort of patients presenting to UK MTCs, they require a consultant delivered service to lead a high performing team, make time critical decisions and

implement timely interventions to optimizes outcome - this is the gold standard!

The conduct of CRT practice over a 6-month period, in a busy MTC, located in the North West of England, was retrospectively examined to assess the following:

- validity of CRT activation

- blood product availability,
- blood product wastage
- grade of anaesthetic attendance amongst the trauma team.

Methods

A prospective record of all 'Code Red Trauma Calls' was compiled by the Lead Trauma Nurse Coordinator. Patient records and transfusion laboratory records were retrospectively analysed for the period of 1 January – 30 June 2017.

Results

Between 1 January 2017 and 30 June 2017 there were 77 Code Red activations. Of these, 55 were included in the Trauma Audit and Research Network return (<https://www.tarn.ac.uk>) and thus had New Injury Severity Score (NISS) and Injury Severity Score (ISS) calculations. Selected results are recorded in Table 3 and the initial destination of patients shown in Table 4. Code Red Trauma over

a 6-month period at our institution revealed nearly two-fifths of activations were attributable to penetrating trauma, with activity spread throughout a 24-hour period. A subsequent retrospective analysis of all the patient data concluded that only 33 cases (42.9%) actually met the criteria to be "Code Red" and warrant a declaration of a CRT only 10 of these were actually penetrating trauma that accounted for 32 cases in total (Table 3). The reasons for this were not specifically recorded, however possibilities are later discussed.

There was only documented evidence of blood being available prior to patient arrival in 22 cases (29%), unfortunately the clinical notes were not robust enough to confirm if blood was present prior to arrival in just under 50% of trauma calls.

Over-activation of the MHP was the finding of a previous audit conducted in 2014 by the North West Regional Transfusion Committee (NW RTC) [34]. In 44% of MHP activations a total of 2 units of PRBC or less was transfused with wastage levels reported as high for all components [34]. Unfortunately, this audit did not collect any specific details as to why wastage occurred, if this was thought to be avoidable

Table 3. Selected results

Age of Patient					
	Average 36.3 years	Median 31 years	Range 17-78 years		
Mechanism of Injury			Number of Patients		
Stabbing			32		
Shooting			13		
Pedestrian <i>versus</i> Car			7		
Fall			12		
RTC			8		
Other			5		
NISS	Average 23.6	Median 32	Range 4-66		
ISS	Average 31.9	Median 27	Range 4-75		
Time of Day			Number of Patients		
		0000-0800	33		
		0800-1800	24		
		1800-0000	20		
Blood Available Prior to Arrival of Patient					
	Yes 22	No 19	Not Documented 36		
Transfusion	0 Units	1-4 Units	5-8 Units	9-12 Units	>12 Units
O-ve PRBC	35	25	9	6	2
X-Match PRBC	68	9	2	0	0
FFP	43	25	5	3	1
Transfusion	0 Units	1 Unit	2 Units	3 Units	4 Units
Cryoprecipitate	67	7	3	0	0
Platelets	64	0	12	0	1
Blood Products Wasted			Total 43 (11 patients)		
Anaesthetic Consultant Presence			Yes 31	No 23	Not Documented 23
Emergency Intubation			Yes 35	No 42	

Table 4. Immediate destination of patient following trauma call

Destination	Number
Operating Theatre	27
Interventional Radiology	2
Critical Care	10
Major Trauma Ward	22
Other Hospital Ward	5
Home	2
Neurosciences Critical Care	4
Death	5

or unavoidable. These findings are not unusual when comparing MHP practice with another busy UK MTCs [35].

Discussion

We have highlighted a number of issues regards the management of CRT patients within our institution and the wider Trauma Network. Although it is difficult to directly compare the results of a previous regional audit conducted three years earlier, despite implementation of a CRT policy at our Trust and within the regional ambulance service, clinical practice to reduce over-activation of MHP and minimise waste of blood products, appears to be no better. 57 % of CRT activations in our study did not meet the correct criteria and clinical documentation failed to state reasons for this. We could not identify how many of the CRT activations were initiated by a pre-hospital team versus TTL.

Subsequent investigations revealed there to be no formal regional pre-hospital CRT policy. Ambulance clinicians were historically asked to "identify severe life threatening (peri-arrest) haemorrhage" via a pilot scheme without the development and support of a Clinical Standardised Operational Policy (CSOP). Without such a CSOP, pre-hospital CRT activation will have been subject to inter-operator variability dependent on wider understanding and previous clinical experience.

We fully acknowledged changing CRT practice required pre-hospital and hospital quality improvement projects! We have since increased engagement with our regional Ambulance Service and Trauma Network to develop a pre-hospital CSOP that aligns CRT practice from point of injury through to hospital ED reception, this includes the same activation criteria.

Situation awareness is defined as 'the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future' [36]. For 11 CRT activations, there was wastage of blood or blood products (43 units in total). Ideally it should be the TTL who gives decisions on whether to attach blood to the rapid infuser ('spike the blood'). The process of resuscitation is guided by both the TTL and anaesthetist, this requires good communication amongst the team, aided by good followership by all members of the trauma team [37]. During DCR it is important the TTL maintains good situation awareness particularly with reference to avoiding the waste of blood products by early decisions to return unrequired blood and blood products to the transfusion laboratory. Participation of senior clinicians in a trauma team facilitates early robust decision making [28], hence the aspiration for a consultant delivered service, this was documented in 40% of our cases.

The evidence supporting a CRT policy has been discussed, once a trauma patient arrives in ED a TTL does not need to identify the need for a massive transfusion but purely a need for blood product resuscitation? With no universally accepted method or algorithm to identify patient need for a massive transfusion, we believe the emphasis should actually be on early recognition and treatment of trauma

patients who need immediate blood product resuscitation. Doing this maximizes oxygenation delivery, minimise acidosis, hypothermia, correct coagulopathy and support other critical interventions, more importantly it saves lives [15].

Not all trauma patients present with obvious exsanguinating bleeding or a history of significant blood loss at scene, note the latter has been proven to be wildly inaccurate [38]. The initial assessment of a time critical trauma patient can often be difficult. To fully appreciate the full extent of injuries sustained diagnostic imaging and other investigations are required. Unfortunately, a patient's clinical condition often demands time critical interventions, often at times when the TTL doesn't yet have all the information to complete a thorough risk versus benefit analysis. Vital signs including heart rate, blood pressure, oxygen saturation and respiratory rate may not always support a TTL's differential diagnosis. For example, a sympathetic response to trauma can mask the true haemodynamic status of profound hypovolaemia, with blood pressure readings being normal or elevated. For such patients with poly-trauma, who also require an emergency anaesthetic, pre-induction blood product resuscitation may be commenced in context to minimize risk of post induction hypotension, this can impact morbidity and mortality in patients with traumatic brain injury [39-41].

Clinical judgement (gestalt) has been reported to be valuable tool of the Emergency Physician [41]. The use of gestalt to guide MHP initiation has been shown to be 65.6% sensitive and 63.8% specific for predicting MT requirements. These values suggest clinical reasoning alone to be insufficient to independently guide initiation of a MHP, nevertheless it remains a valuable decision-making tool.

We have developed a novel cognitive aide model to support critical decision making for when to start blood product resuscitation in trauma patients (Figure 1). This has been designed as a hybrid to include frequent criteria used in validated massive transfusion scoring systems [20], with adjusted parameters to promote earlier decisions aligned with clinical gestalt. We have also created a traffic light triggering system to promote three specific actions; immediate blood product transfusion, discussion with members of the trauma team in context to the clinical situation and a delayed state which promotes continued vigilance for evolving clinical change and a prompt to send unwanted blood products back to the transfusion laboratory early. We have developed this aide to improve human performance, however as yet we have no feedback to offer for its use. It is our intention to first test pilot the use of this cognitive aide during trauma simulation training, if well received we will aim to assess its validity and will report our findings.

TTLs need to understand metacognition ("thinking about thinking and how we make decisions"). Kahneman described two modes of thought "System 1" and "System 2". System 1 is a fast, instinctive and emotional process – "*gut instinct*", whereas "System 2" is slower, more deliberative, and logical process – "*critical thinking*" [42].

Management of the major trauma patient presents the potential of a perfect storm for medical error! Here we are often exposed to novel, time critical, complex situations. The TTL must resist from purely using system one. This system is more likely to suffer from cognitive overloaded and is prone to cognitive bias when under pressure. The key to delivering optimum DCR is effective communication [42]. During the coordination of a command huddle, delivery of a snap brief or situation report system two is more likely to be active. Shared decision-making fosters better analytical, logical and critical thinking. TTLs are encouraged to step back and avoid direct contact with the patient to




"CODE RED TRAUMA" Cognitive Aide : Traffic Light Triggering When to start Blood Product Resuscitation?		
RED FLAGS ASSOCIATED WITH MAJOR HAEMORRHAGE	NUMBER OF CONFIRMED RED FLAGS	ACTIONS
<ol style="list-style-type: none"> 1. Significant mechanism of Injury <ul style="list-style-type: none"> • Blunt high energy <i>versus</i> low energy <i>versus</i> penetrating 2. Clinical Observations <ul style="list-style-type: none"> • SBP <90mmHg or loss of radial pulse • HR > 120 (caution: beta blockade use) • Visible active haemorrhage • Poor response to initial fluid resuscitation 3. Concerned clinical acumen; suspected active haemorrhage with normal or mildly deranged BP and HR. 4. Point of Care Testing: <ol style="list-style-type: none"> 1. Lactate > 4 2. Base deficit > 4 3. ROTEM confirmed coagulopathy or confirmed anticoagulation therapy 		IMMEDIATE blood product transfusion (1:1:1) aiming for permissive hypotensive resuscitation. COMMAND HUDDLE – discussing patient journey: <ul style="list-style-type: none"> • theatre for DCS <i>versus</i> CT • candidate for IR <i>versus</i> theatre
		DISCUSS blood product transfusion in CONTEXT of anticipation of response to immediate interventions: <ul style="list-style-type: none"> <C> Control of compressible haemorrhage <ol style="list-style-type: none"> A Rapid sequence intubation & delivery of IPPV B Thoracostomy +/- insertion of intercostal drains C Application of pelvic & long bone splints D TBI + haemorrhage: targeted higher MAP
		DELAYED blood product resuscitation. Closely monitor for EVOLVING RED FLAGS AVOID WASTE – consider sending blood back to lab.

Figure 1. "CODE RED TRAUMA" Cognitive Aide: Traffic Light Triggering When to Start Blood Product Resuscitation?

maintain overall situational awareness, this also serves a purpose to provide time and space to think analytically!

In reality, during the management of a complex major trauma patients, both systems are always active and our thoughts toggle between each mode. Understanding how we think promotes analysis of critical decisions before implementation – this may prevent a medical error! We cannot switch off system one, but we can reduce cognitive load by simulation team training, developing shared decision and nurturing followership [37,43,44].

Summary

The development of a Code Red Trauma Policy allows the provision of blood and blood products in the trauma bay prior to the arrival of complex trauma patients and facilitates Damage Control Resuscitation.

Through the process of clinical audit, we have identified some key issues regards the management of CRT patients within our institution and the wider Trauma Network. Our results stimulated a number of quality improvement projects which we hope will be valuable to our institution and regional pre-hospital services. Understanding of metacognition in the context of managing major trauma was discussed. We strongly advocate simulation training to develop shared decision making and nurture followership.

Finally, we have developed a novel cognitive aide to support robust ED TTL decisions for when to start blood resuscitation. With increasing supporting evidence for the benefits of MHP, our focus was not to improve identifying patients who need a massive transfusion, but to promote early correct blood product resuscitation and preservation of limited resources by minimizing waste. We aim to validate our cognitive aide and will report our findings.

Author Contribution

Simon Morton: Identification of patients, literature search, data collection and review, revision of manuscript.

Elizabeth Perritt: Data collection and review, revision of manuscript.

Jan Gorry: Data collection and review, revision of manuscript.

Clinton PL Jones: Discussion, revision of manuscript, creation of Figure 1.

Simon J Mercer: Initial idea, first draft of manuscript and subsequent reviews.

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