

## INVITED REVIEW

# Whole blood in disaster and major incident planning

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Transfusion emergency preparedness is increasingly becoming an integrated part of major incident planning. The spectrum of planning extends from the sophisticated healthcare system dealing with multiple casualties, to the isolated healthcare facility resuscitating the critically ill patient with massive haemorrhage. Transfusion preparedness should follow risk assessment and be nested within the wider emergency planning system. The response should be designed to deliver both safety and sufficiency of transfusion support and includes diagnostics, donation and distribution. The biggest transfusion risks in emergency situations are those of red cell ABO incompatibility and delayed provision. Sufficiency and supply may be compromised when communities are isolated and cannot access mutual support. Planning may need to consider local collection and testing of blood as a further resilience measure. Considerations include demand planning; inventory management and transfusion triage; a whole blood preparedness model; resilience and resupply and the human factor. We suggest a whole blood programme can simplify the whole vein-to-vein process for production, laboratory and clinical staff and can be integrated into a range of healthcare systems.

**Key words:** blood component production, massive transfusion, transfusion medicine (in general)

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## Introduction

Transfusion support is a small but essential element of emergency healthcare planning especially in the context of traumatic haemorrhage [1]. Major haemorrhage is a relatively common medical emergency seen not just in trauma but also in obstetrics, gastrointestinal disease and major surgery [2,3]. Haemorrhage control together with blood-based resuscitation are essential to optimize the chance of survival in haemorrhagic shock. Modern healthcare therefore demands a safe, sufficient and timely supply of blood both in routine practice and major incidents. Preparedness must be based on context and scale. A single critically ill patient with haemorrhage may rapidly drain the resources of a local blood bank if blood

is not replaced. Industrial and transport incidents may generate multiple casualties with traumatic haemorrhage necessitating management of both transfusion demand and supply. However, it is the increased frequency of terror attacks in Europe that has most re-energized an interest in transfusion preparedness.

Recent publications in the UK have included clinical guidelines for major incidents and mass casualty events [4] together with national guidance for hospital transfusion teams [5]. These guidelines have been informed by military-style planning [6]. However, the number of patients requiring blood and the mean blood use per patient admitted in recent civilian Mass Casualty Events (MCEs) differs from that seen in the recent military experience [6]. Military practice has been characterized by the increasing use of 'massive' transfusion [7,8]. In contrast, mean civilian blood use in MCEs has consistently been 2–3 units per casualty with only a small number of hospitalized patients requiring transfusion [9,10]. The total usage figures appear modest however the challenges are preparing for an unexpected surge in demand and to ensure timely distribution.

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However, planning should be proportionate to the risk, economical and effective. Holding high stock levels of blood 'Just in case' risks outdated due to the limited shelf-life of cellular components. An alternative is to have a responsive resupply system providing a 'Just in Time' solution based on whole blood (WB). We suggest that a whole blood (WB) programme [11,12] simplifies the whole vein-to-vein process for production, laboratory and clinical staff. The purpose of this article is to explore some of the considerations when reintroducing WB as part of disaster and major incident planning

## Methodology

The methodology for this short paper includes reference to the literature on transfusion planning in mass casualty events and recent policy. The paper is informed by the professional practice of the authors who are both actively involved in transfusion emergency preparedness in their own countries. The term whole blood (WB) covers both fresh and stored WB. The term 'fresh' whole blood (FWB) is used to denote WB stored for less than 48 h, and 'cold-stored' whole blood (CSWB) to denote WB stored refrigerated for longer periods of up to several weeks [13].

## Disasters and definitions

A disaster has been described as a sudden, calamitous event that seriously disrupts the functioning of a community or society and causes human, material and economic or environmental losses that exceed the community's or society's ability to cope using its own resources [14]. Disasters are commonly divided into 'natural and man-made' but Redmond claims these distinctions are generally artificial as all disasters are fundamentally human made, a function of where and how people choose to live [15]. It is the combination of hazards, vulnerability and the inability to reduce the potential negative consequences of risk that results in disaster. The relationship can be expressed in the following equation.

$$\text{Disaster} = \text{Vulnerability} + \text{Hazard} / \text{Capacity} + \text{Capability}$$

Many developed countries now use the term Major Incident rather than disaster. This definition recognizes that with planning and preparation the impact of the event can be mitigated or avoided. Such emergency healthcare planning should consider both capability and capacity. For instance, a major incident may be the care of a single critically ill patient in a remote healthcare facility such as an island healthcare facility, on board ship, offshore installations and communities isolated by

geography or weather. Alternatively, multiple casualties may exceed the resources of a mainland major trauma centre. Further terms attempt to convey the magnitude of the event and the impact on health care. A Mass Casualty Event (MCE) may be defined as a 'single or simultaneous event(s) or other circumstances where the normal major incident response of one or several health organisations must be augmented by extraordinary measures to maintain an efficient, suitable and sustainable response'. Glasgow argues that MCE is a more appropriate term than Major Incident or disaster in the context of transfusion planning because it is healthcare-specific and addresses healthcare load [16].

The overarching framework for disaster planning, including transfusion, is well established by humanitarian organisations. Players such as the International Federation of the Red Cross and Red Crescent Movement (IFRC) and the World Health Organization (WHO) provide regional guidance for healthcare laboratories and blood donation [17]. National transfusion bodies have also produced valuable contingency guidance [18,19]. The key functions of transfusion services in disasters include diagnostics, donation and distribution. We suggest transfusion support also extends to direct patient care. Diagnostics are key to both blood testing and guiding patient care. Careful management of donors is essential as many will present to donate following disasters. The sudden influx of donors may overwhelm local collection and handling capacity. The surge requires co-ordination and control advised by demand planning. Finally, disruption of communication and distribution can undermine the best of plans. The detailed review of transfusion services following the Bam earthquake in Iran illustrates the national lessons learnt following a natural disaster and the need for excellent communications and logistics [20].

The Bam paper highlights that transfusion plans should be nested within wider emergency and healthcare planning, including business continuity, and not considered in isolation. Although the response to disasters is centred on the blood collector in the affected area, the situation should be rapidly communicated to either supra-regional or national planners to raise awareness and support co-ordination. Doughty *et al.* have previously highlighted the need for preparedness across the continuum of healthcare agencies, from the pre-hospital community to the blood providers [21]. In transfusion, the balance between demand and supply often straddles organisational boundaries and therefore partnership within the whole health care and their volunteer system is essential when planning. All partners must understand the need to work within the appropriate regulatory framework. Planning must therefore include regular staff training, a well-rehearsed response together with a post-event recovery plan to be effective.

## Demand planning in mass casualty events

### Assumptions

Demand planning is an important element of both preparation and response. The number of casualties requiring blood is based on those hospitalized with haemorrhage, that is priority 1 and 2. Planning assumes that only the more severely injured need haemostatic support. Traditionally, the planning is based on the number of red cell units in the first 24 h. However, such planning can be adjusted to accommodate alternative approaches. An example might be where a plasma first [22] or WB resuscitation policy [23] is being used. Planning should be adjusted to accommodate both component content and volume; examples include WB with a volume of approximately 500 ml; versus plasma (200–340 ml); and red cells in optimal additive solution (approx. 300 ml).

Estimating the amount of blood required to meet a potential surge in demand is traditionally based on the number of red cell units rather than components. The estimated demand starts with a gap analysis of existing stock and future demand. Red cell demand for the first 24 h is a product of the casualty load, mean blood use and a variable demand factor [21] each of which is discussed in turn. The same principles can be applied to whole blood.

$$\text{Red cell demand} = \text{Casualty load} \times \text{Demand per patient} \\ \times \text{Demand factor}$$

### Casualty load

Traditional NATO planning for MCE is an injury severity distribution of 25% P1, 25% P2 and 50% P3 [24]. Only the first two groups would be expected to need blood and then only if their injuries resulted in haemorrhage. The biggest contribution to the modern civilian planning figures is from Israel. A review of 1645 attacks involving 7497 casualties, suggested 13% death at scene with 8% (P1) severely and 12% moderately injured (P2) casualties, that is a total of 20% who may need blood [25] rather than 50%. However, more recent reviews of mass shootings suggest similar blood use per patient but higher mortality at scene [26,27]. The casualty load appears to differ dependent on mechanism of injury and speed and sufficiency of healthcare response. Survival is enhanced by early haemorrhage control and resuscitation which may be delayed where the security situation prevents access for healthcare responders. Survival in turn impacts on the demand for blood.

### Demand per patient

Two key reviews have informed recent MCE blood demand planning. In 2012, Glasgow *et al.* calculated demand at 2–3 red cell units for each patient hospitalized. He observed that most blood is used within the first 6 h and that transfusion practice was changing; following military experience [9]. The 2016 paper by Ramsey included an estimate for haemostatic components [10]. The paper builds on the 2008 AABB guidance in which planning is based on 3 units of red cells per patients [18]. Most MCE reviewed were associated with improvised explosive devices (IEDs). However, these estimates appear to hold for mass shootings [28]; mass disaster and trauma situations [29]. Although these demand figures appear modest, a small number of critically injured with multi-trauma may require early massive transfusion and ongoing transfusion support. The revised UK planning guidance advises hospitals to plan for 7–8 red cell units used within the framework of a massive haemorrhage protocols for the more severely injured [5]. The challenges for the medical teams are the timely triage and identification of that critically ill patient and whether transfusion should be started in the pre-hospital environment.

### Demand factor

Clinical capability, context, location and logistics are keen considerations in transfusion demand planning. Long evacuation times and prolonged holds may necessitate pre-hospital transfusion. The distance between blood suppliers and their hospitals and delays in distribution impact on demand and stock holdings. Centralized blood providers may use a locally defined demand: use ratio to accommodate the agreed pattern of ordering. Experience from Israel [30] and the UK [31] has reported an overall demand: use ratios for red cells of 2–3:1, that is hospitals order three times as much blood than actually used. These planning principles would have worked well for the Manchester Arena bombing in 2017 where 20% of those admitted were transfused with a median use of 3 units [32]. The demand:use ratio was 3.5:1 for all red cells, which is similar to past attacks. However, the demand: use factor for group O D negative blood was 5.25. The explanation may be the large number of young women injured in this event. The example highlights the need to triage transfusion to balance clinical demand with supply.

### Inventory management and transfusion triage

The inventory management and issue of the modern transfusion portfolio are based on components. Component therapy offers targeted transfusion support and

optimizes shelf-life together and the use of each donation. However, inventory management based on multiple components of different blood groups requires careful stock management to minimize wastage. Smaller facilities tend to hold small amounts of mainly universal components and do not hold platelets. For example, twenty of the fifty hospitals in Norway with emergency departments do not routinely hold stock platelets and rely on emergency delivery. In this situation, group O low-titre CSWB may be the best resuscitation transfusion treatment to hold in stock. It is the best treatment for the patient [33] and speeds the clinical process when using massive haemorrhage protocols. Sufficiency can be addressed through the appropriate use of O neg WB units and regular supply of both D pos and D neg donations. CSWB is a licensed blood product in many jurisdictions and could be provided by most blood providers. Ongoing refinements balance leukodepletion against platelet content, determining shelf-life and establishing standards for haemolysin titres. The biggest challenge is streamlining WB production within systems optimized for large scale component production. Despite this, early adopters have demonstrated the feasibility of reintroducing WB back into a conventional portfolio [23,34].

The concept of clinical triage is well established in the context of multiple casualties. The purpose is to prioritize incoming patients for care. Over-categorization uses scarce resources and limits availability for others. We suggest the concept of transfusion triage may also be applied throughout the transfusion pathway including patient care; sample handling; laboratory; and donor organisation [1]. Experience following four major incidents in London during 2017 demonstrated the value of the transfusion team in the clinical space [35]. The initiative had been designed to support patient safety through accurate sample labelling. It developed further to support optimal blood use and inventory management. Consequently, UK policy has changed [5]. Although before, hospital laboratories were advised to re-call issued but non-essential units from remote fridges to centralize stock, the advice now includes pre-positioning blood components and transfusion staff in the Emergency Department and theatres. The frontline transfusion staff provide a vital link between the clinical and laboratory teams and help inform resupply.

Each healthcare facility or system will need its own mechanisms to manage both the demand resulting from an MCE, resupply and the replenishment of stock following the incident. A variety of approaches may be used to resupply following disasters including:

- (1) Stock movements
- (2) Support from other blood services.
- (3) Adjustments within testing and processing

- (4) Increase in subsequent collection targets
- (5) Use of emergency or high-readiness donors

In most mature healthcare systems, the immediate demand for blood should be met by existing stocks although this may require stock movement. Most services aim to hold enough stock of blood components in the right location to meet the surge in demand rather than to accept emergency donations. However, platelets stocks are normally low and localized. Rapid replacement may be required, however, emergency resupply times for remote facilities may be many hours. Although many countries have blood bank inventories based only on component therapy, a WB programme could be considered where blood and platelets need to be generated locally in an emergency.

### Transfusion emergency preparedness in Norway

Planning in Norway has been influenced by the increased frequency of terror attacks in Europe including their own tragedy of MCE [26]. The twin terrorist attacks together with the collaboration between the military and civilian transfusion services, including the Blood Far Forward programme [36], have stimulated the development of civilian WB programmes. Such programmes offer simple local emergency preparedness within the framework of a wider plan. Many established centralized services assume that all immediate demands will be met from existing hospital and blood service stocks. However, these assumptions may not hold for isolated communities or communities at risk of being isolated due to distance, deteriorating weather, communication breakdown and/or loss of transport. High-readiness donor panels may need to be considered as part of the resilience plan. Haukeland University Hospital, Bergen, Norway, is a blood collection facility that has worked closely with the local blood donor community to develop a transfusion contingency plan [37].

The emergency blood collection programme is based on an agile WB programme using a high-readiness donor panel integrated within their routine donor service. An outline of the process is shown in Fig. 1. Donor selection and testing fulfil national acceptance criteria. However, they are preselected male and female blood group O low-titre donors who have agreed to be readily contactable in emergencies. There are approximately 3000 donors, many of which live or work locally and have timely access to the hospital blood collection facility. Whole blood is collected using the Terumo Imuflex<sup>®</sup> collection kit with an integrated platelet sparing leukodepletion filter. Testing for mandatory grouping and viral markers is undertaken as normal. The total time from collection to release is approximately 3 h. In contrast, release of blood

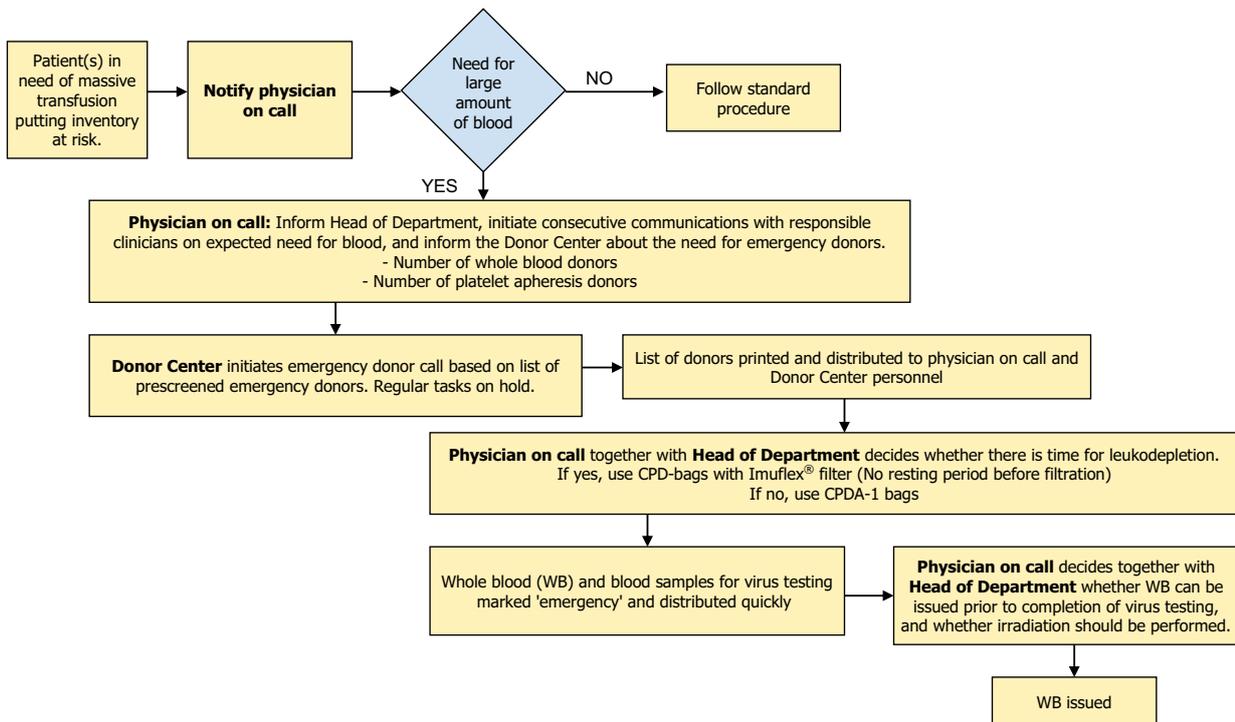


Fig. 1 Algorithm for use of the emergency walking blood bank.

components in some countries with centralized production facilities may be delayed 2–3 days.

The system in Bergen was recently tested in July 2018 during the care of a critically injured individual [36]. The patient received massive transfusion of about 200 units of blood products over a short period of time (<24 h). Early resuscitation exhausted the pre-existing stock of 10 leukodepleted group O low-titre WB. Resuscitation continued with component therapy used in a 1:1:1 ratio. Subsequently, the platelet inventory ran low. The collection of fresh WB from established Group O low-titre donors was considered the fastest way to make a platelet-containing blood product available for immediate use. The total number of WB units transfused to this single patient was 35, including 25 freshly drawn units.

Several practical lessons were learnt from this clinical event. The activation needs to include a consultant or senior clinician to oversee the process and provide experienced clinical advice. Additional steps to reduce the time from collection to transfusion were identified including:

- (1) the use of non-leukoreduced WB.
- (2) direct administration from the primary collection bag
- (3) access to appropriate rapid diagnostic tests

The use of point-of-care tests when rapid release of units is required is based on the clinical risk-benefit

analysis for the emergency. The donors are pre-tested and the rates of sero-conversion in known donors in Norway are very low. In contrast, patients arriving in the emergency room hypotensive and in need of immediate laparotomy have a mortality of approximately 50%.

Ongoing communication is required between the clinical team treating the patient(s) and the donor area especially when additional donors are required. The donor response should be phased with the immediate response focussed on the collection of type O red-blood-cells. However, the response should be proportionate as the overuse of group O neg donors in the initial response risks depleting the universal donor pool. The immediate phase is then followed by the production of red cells of all ABO/Rh types together with platelets. Rebuilding the stocks is essential not only for an ongoing demand related to the incident but also to support ongoing activities unrelated to the incident including regional provision. Mutual support is an important principle of business continuity. In late 2018, the resuscitation of a single patient exhausted platelet stocks and compromised red cells stocks in another University Hospital. However, resupply from Bergen was hampered by adverse weather conditions. We suggest that local preparedness is required for both well-developed urban centres as well as isolated communities when timely mutual support cannot be assured.

## Resilience and resupply in isolated communities

Small island communities illustrate the risk of isolation, the need to prepare but also the need for proportionate planning. Islands are subject to both natural and man-made disasters and need to be able to provide life-saving intervention. However, they do not have full blood collection and laboratory support. In 2017, a shark attack on Ascension Island led to emergency collection of WB from islanders and expatriate contractor staff, highlighting the need for transfusion preparedness [38]. The patient was fully resuscitated and supported until evacuation to a surgical unit several days later. Since this event, a new temperature-controlled transfusion storage and supply system was introduced using modest regular blood supply from the Falkland Islands. However, the arrangement for a fully managed Emergency Donor Panel (EDP) was also reinstated. An EDP is a managed pre-tested group of blood donors called when blood is urgently required and is not available [39].

The resupply plan for red cells (in optimal additive solution) is normally determined by the shelf-life which is 35–42 days depending on the regulatory framework. For island communities this normally means delivery by air, land bridge or sea. Other resupply options include maritime parachute-based airdrop validated by a UK group delivering red cells, lyophilised plasma and essential EDP equipment [40]. Other groups have established air drop on to land [41] and others have developed drone-delivered blood [42]. However, timely resupply may not always be available. An alternative for resilience includes a frozen red cell programme [43]. Advantages include the long-term storage of fully screened red cells. However, these cells require a washing preparation process before being ready for clinical use. Additional disadvantages include the investment in infrastructure and training and the need to supplement the red cells with haemostatic components in the context of massive haemorrhage. An alternative is emergency local collection from an EDP.

The starting point for safe blood is donor selection. The risk of infection is dependent on disease prevalence and should be mitigated in part by pre-testing the panel together with rapid diagnostic testing and sampling at the time of collection. Donors must be well at the time of donation and should fulfil national acceptance criteria. In addition, donors should be contactable and have timely access to a pre-arranged blood collection area. However, donors should only be bled as and when required to minimize wastage of blood. We have previously commented on the practical aspects for the non-specialist faced with the emergency collection of fresh WB [39]. Healthcare

providers in this situation should be taught the principles and practice of donor selection and care, to optimize both donor and patient safety. However, the biggest transfusion challenges in this situation are appropriate call-up of donors and avoiding ABO incompatible transfusion due to human error.

## Patient safety and the human factor

The 2008 AABB Disasters Operations Handbook [18] highlights the importance of supportive human resource management during disasters. Staff should be clear about their roles and responsibilities and the communication plan. The 2019 UK guidance [5] notes that the roles and responsibilities of staff within transfusion are changing as they deliver more proactive transfusion support. Mention has already been made of the use of the wider transfusion team within the clinical area [33]. The introduction of a local WB collection programme would extend this further. Both the clinical area and the laboratory staff are at risk of emotional stress and exhaustion and must be supported physically and psychologically. An important mechanism for this is early debriefing of all staff. Further consultation is advised to document lessons identified, plan service improvement and prepare for recovery. Timely psychological and physical support is recommended to sustain staff and reduce the risk of error.

The 2016 SHOT UK haemovigilance report continues to show that human error remains the biggest risk for ABO incompatible transfusions [44]. The risk is conventionally associated with failures throughout the transfusion process but especially at the bedside. Emergency situations will challenge even the most experienced staff as errors are increased in unfamiliar situations. Staff must be familiar with the agreed identification system. Conventional wisdom is to use pre-agreed systems for the emergency identification of the unknown patient and their sample labelling. Emergency identification should be based on a unique identifier using non-sequential numbering [45]. In addition, baseline patient blood samples should be taken before transfusion to establish the ABO and RhD group. However, in the setting of WB for emergency resuscitation purposes, the selection of blood group O donors who have low-titre anti-A and anti-B antibodies is advocated to reduce the risk of ABO incompatible blood. Disaster review data sets should include haemovigilance data together with demand and usage details to inform future transfusion policy and practice [1].

As transfusion is increasingly accepted as a part of emergency healthcare planning, the requirement for staff training will change. The administration of blood is a core clinical skill for many hospital staff. However, increasingly the move to pre-hospital transfusion has led

to some allied healthcare professionals administering blood, but often subject to remote 'authorisation' or prescription by doctors. We suggest the introduction of 'non-medical authorisation' to enable a wider range of healthcare providers such as paramedics to initiate the use of blood. The concept has been introduced in the UK for nurses and has been successfully been extended to paramedics in Wales. The practice is already established in Norway. In contrast to blood administration, blood collection is not a core clinical skill in many countries. In many parts of the world, the task is likely to be delegated to laboratory staff. The professional background should not matter; validated competence of donor selection, care and blood collection can be achieved with appropriate educational support. Extending the scope of practice requires a revised governance framework but affords healthcare planners much greater emergency resilience [46].

### Future areas for research

The body of published literature for transfusion in major incident planning remains limited. Current planning guidance is based on pragmatism together with intelligent application of current evidence. Demand planning figures are based on MCE involving bullets, home-made bombs, stabbings and the blunt trauma seen from the use of vehicles as weapons. These figures may need to be adjusted as methods of attack change. Therefore, quantitative and qualitative research should be embedded into routine clinical and emergency planning practice. Data collection should consider the spectrum of transfusion support including the use of WB together with haemovigilance data. It might be that the benefits of WB over component therapy may be of greater significance in the emergency situation than in routine hospital practice [6].

Further component development research is required. Whole blood is the original blood preparation and used globally. Despite these facts, there is need for future research especially around shelf-life. Most civilian centres who have re-implemented a WB programme do not store CSWB beyond 14 days, despite storage to 21 days or beyond being permitted by regulatory authorities. The optimal shelf-life of WB needs to be redefined since its current shelf-life is based on red cell viability and does not consider the platelet and plasma elements of WB and their deterioration during cold storage. Although there is increasing interest in the effective use of cold platelets in haemorrhage, a more detailed appreciation of the interactions of the different components is required to determine the optimal storage conditions and duration for future WB preparations.

In addition, WB is initially collected into a citrate-based anticoagulant at a volume ratio of 1:7 anticoagulant to WB. In this sense, WB is already a diluted blood product from the outset and may not address any established coagulopathy. Replacement therapy may need to be supra-physiological resuscitation using additional transfusion support and adjuncts. Novel hybrid products offer the future promise of volume replacement together with oxygen and haemostasis support. However, the key to preventing coagulopathy is early shock reversal. Time is of the essence. We propose that at present, professionally produced WB delivers speed and sufficiency and has a valuable role within disaster and major incident planning.

### Conclusions

Transfusion emergency preparedness is increasingly becoming an integrated part of healthcare emergency preparedness. Transfusion triage is recommended to balance demand and supply. The biggest risk is ABO incompatibility due to human error and delays related to the complexity of a component-based transfusion process. Group O WB offers a simple safe transfusion support solution that can be integrated into a range of healthcare facilities from sophisticated healthcare systems to remote civilian or widely dispersed communities. Further optimisation of transfusion support in disasters requires systematic quality data collection following incidents and continued academic underpinning coupled with translation into practice.

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### Conflicts of interest

The authors declare that they have no conflicts of interest. The opinions expressed are their own rather than the formal position of their institutions.

### References

- 1 Doughty H, Rackham R: Transfusion emergency preparedness for mass casualty events. *ISBT Sci Ser* 2019; 14:77–83
- 2 Halmin M, Chiesa F, Vasan SK, *et al.*: Epidemiology of massive transfusion: A binational study from Sweden and Denmark. *Crit Care Med* 2016; 44:468–477

- 3 Green L, Tan J, Grist C, *et al.*: Aetiology and outcome of massive transfusion in two large London teaching hospitals over a 3-year period (2012-2014). *Transfus Med* 2017; 27 (Suppl 5):342-347
- 4 NHS England: Clinical guidelines for major incidents and mass casualty events. <https://www.england.nhs.uk/publication/clinical-Guidel-Major-Incid-Mass-Casualty-Events>. 2018.
- 5 National Blood Transfusion Committee Emergency Preparedness Group: Emergency Preparedness, Resilience and Response guidance for Hospital Transfusion Teams. NBTC Website <https://www.transfusionguidelines.org.uk-Transfus-Committeesnational-Blood-Transfus-Committeeworking-GroupsEmergency>. 2019;
- 6 Doughty HA: Recent developments in military transfusion practice and their impact on civilian healthcare. Doctoral Thesis. Univ Bergen <http://borauibno.handle195617811>. 2018.
- 7 Jansen JO, Morrison JJ, Midwinter MJ, *et al.*: Changes in blood transfusion practices in the UK role 3 medical treatment facility in Afghanistan, 2008-2011. *Transfus Med* 2014; 24:154-161
- 8 Godfrey BW, Martin A, Chestovich PJ, *et al.*: Patients with multiple traumatic amputations: an analysis of operation enduring freedom joint theatre trauma registry data. *Injury* 2017; 48:75-79
- 9 Glasgow S, Davenport R, Perkins Z, *et al.*: A comprehensive review of blood product use in civilian mass casualty events. *J Trauma Acute Care Surg* 2013; 75:468-474
- 10 Ramsey G: Blood component transfusions in mass casualty events. *Vox Sang* 2017; 112:648-659
- 11 Yazer MH, Cap AP, Spinella PC, *et al.*: How do I implement a whole blood program for massively bleeding patients? *Transfusion (Paris)* 2018; 58:622-628
- 12 Cap AP, Beckett A, Benov A, *et al.*: Whole Blood Transfusion. *Mil Med* 2018; 2:44-51
- 13 Jenkins DH, Rappold JF, Badloe JF, *et al.*: Trauma hemostasis and oxygenation research position paper on remote damage control resuscitation: definitions, current practice, and knowledge gaps. *Shock* 2014; 41(Suppl 1):3-12
- 14 Mohamed A: Disaster, types of disaster, mitigation. Stamford Univ Bangladesh <https://www.researchgate.net/publication/330684577disastertypesofdisastermitigation>. 2019.
- 15 Redmond AD: ABC of Conflict and Disaster. Natural Disasters. *Br Med J* 2005; 330:1259-1261
- 16 Glasgow SM: Modelling Red Blood Cell Provision in Mass Casualty Events. PhD Thesis Queen Mary Univ Lond. 2015.
- 17 Pan American Health Organization: *The role of laboratories and blood banks in disaster situations*. Washington, DC: World Health Organisation. 2002.
- 18 AABB Interorganizational Task Force on Domestic Disasters and Acts of Terrorism (task force). Disaster Operations Handbook. Vol. Second. 2008.
- 19 National Blood Authority Australia. National Blood Supply Contingency Plan (NBSCP). Aust Health Minist Conf. 2008.
- 20 Abolghasemi H, Radfar MH, Tabatabaee M, *et al.*: Revisiting blood transfusion preparedness: experience from the Bam earthquake response. *Prehospital Disaster Med* 2008; 23:391-394
- 21 Doughty H, Glasgow S, Kristoffersen E: Mass casualty events: blood transfusion emergency preparedness across the continuum of care. *Transfusion (Paris)* 2016; 56:S208-S216
- 22 Shlaifer A, Siman-Tov M, Radomislensky I, *et al.*: Prehospital administration of freeze-dried plasma, is it the solution for trauma casualties? *J Trauma Acute Care Surg* 2017; 83:675-682
- 23 Yazer MH, Spinella PC: The use of low-titer group O whole blood for the resuscitation of civilian trauma patients in 2018. *Transfusion (Paris)* 2018; 58:2744-2746
- 24 Doughty H: Transfusion Medicine. In: Greaves I (ed). *Military Medicine in Iraq and Afghanistan A Comprehensive Review*. Boca Raton, FL: CRC Press; 2018.
- 25 Shinar E, Yahalom V, Silverman BG: Meeting blood requirements following terrorist attacks: the Israeli experience. *Curr Opin Hematol* 2006; 13:452-456
- 26 Gaarder C, Jorgensen J, Kolstadbraaten KM, *et al.*: The twin terrorist attacks in Norway on July 22, 2011: the trauma center response. *J Trauma Acute Care Surg* 2012; 73:269-275
- 27 Lozada MJ, Cai S, Li M, *et al.*: The Las Vegas Mass Shooting: an analysis of blood component administration and blood bank donations. *J Trauma Acute Care Surg* 2019; 86:128-133
- 28 DeMario VM, Sikorski RA, Efron DT, *et al.*: Blood utilization and mortality in victims of gun violence. *Transfusion (Paris)* 2018; 58:2326-2334
- 29 Altaf C, Maqsood R, Alamgir W, *et al.*: Blood transfusion support in mass disaster and trauma situations. An experience at a tertiary care center. *Pak Armed Forces Med J* 2018; 68:1481-1485
- 30 Dann EJ, Bonstein L, Arbov L, *et al.*: Blood bank protocols for large-scale civilian casualty events: experience from terrorist bombing in Israel. *Transfus Med* 2007; 17:135-139
- 31 Glasgow SM, Allard S, Doughty H, *et al.*: Blood and bombs: the demand and use of blood following the London Bombings of 7 July 2005 - a retrospective review. *Transfus Med* 2012; 22:244-250
- 32 Doughty H, Watkins E, Pendry K: Blood service support following the 2017 Manchester concert bombing. *Bloodlines Br Blood Transfus Soc* 2018; 127:28-32
- 33 Spinella P, Strandenes G, Hervig T, *et al.*: Whole blood for hemostatic resuscitation of major bleeding. *Transfusion (Paris)* 2016; 56(Suppl 2):S190-S202
- 34 Strandenes G, Berseus O, Cap AP, *et al.*: Low titer group O whole blood in emergency situations. *Shock* 2014; 41(Suppl 1):70-75
- 35 Mckeown D, Chowdhury F, Regan F: London 2017: A year to remember for all the wrong reasons!. *Vox Sang* 2018; 113 (Suppl 1):22
- 36 Strandenes G, Cap AP, Cacic D, *et al.*: Blood Far Forward—a whole blood research and training program for austere environments. *Transfusion (Paris)* 2013; 53(Suppl 1):124S-130S
- 37 Kaada SH, Apelseth TO, Hagen KG, *et al.*: How do I get an emergency civilian walking blood bank running? *Transfusion (Paris)* 2019; 59:1446-1452
- 38 Doughty H: Blood brothers: supporting the emergency donor. *S122. Transfus Med* 2017; 2:17

- 39 Doughty H, Thompson P, Cap A, *et al.*: A proposed field emergency donor panel questionnaire and triage tool. *Transfusion (Paris)* 2016; 56:S119-S127
- 40 Meli A, Hancock V, Doughty H, *et al.*: Investigation of the quality of stored red cells after simulated air drop in the maritime environment. *Transfusion (Paris)* 2017; 58:423-429
- 41 Boscarino C, Tien H, Acker J, *et al.*: Feasibility and transport of packed red blood cells into Special Forces operational conditions. *J Trauma Acute Care Surg* 2014; 76:1013-1019
- 42 Ling G, Draghic N: Aerial drones for blood delivery. *Transfusion (Paris)* 2019; 59:1608-1611
- 43 Noorman F, Badloe J: -80 o C frozen platelets - efficient logistics: available, compatible, safe and effective in the treatment of trauma patients with or without massive blood loss in military theatre. *Transfusion (Paris)* 2012; 52(Suppl s3):33A-34A
- 44 Bolton-Maggs PHB: SHOT conference report 2016: serious hazards of transfusion - human factors continue to cause most transfusion-related incidents. *Transfus Med* 2016; 26:401-405
- 45 NHS Improvement: Safer temporary identification criteria for unknown or unidentified patients (NHS/PSA/RE/2018/008). Patient Saf Alert. 2018.
- 46 Parker P, Nordmann G, Doughty H: Taking transfusion forward. *J R Army Med Corps* 2015; 161:2-4