Disaster Preparedness

Strategies for the Blood Supply

Constantine E. Kanakis, MD, MSc, MLS(ASCP), Glenn Ramsey, MD*

KEYWORDS

• Blood banks • Disasters • Disaster planning • Emergencies
• Mass casualty incidents

KEY POINTS

- Blood banks need robust disaster procedures for preparatory training, communication and rapid provision of blood components.
- Overall blood usage in mass casualty events is driven by a small percentage of patients requiring rapid massive transfusion of blood components already in hand.
- Alternative blood components such as low-titer group O whole blood, cold-stored platelets, and dried plasma will likely become more prominent features of disaster responses.

INTRODUCTION

Blood transfusions are a critical element of patient care across many medical disciplines. Therefore, contingency measures are required to manage unscheduled severe blood supply interruptions, sometimes seen in natural disasters, or sudden increases in blood demand, or mass casualty events (MCEs) with severe injuries. This review sets out measures needed to plan for disasters affecting blood supply or demand.

DISASTER COMMUNICATION

Communication is a critical part of disaster response. Effective exchange can preserve safety, property, and response efforts.[1] Incident Command (IC) is an operational framework ensuring delivery of services modeled by the US National Incident Management System.[2] IC models are meant to be activated in response to crises in real-time. Hospital Incident Command Systems (HICS) facilitate response in the clinical setting, preserving patient outcomes, addressing balancing resource limitations or threats.

Department of Pathology, Feinberg School of Medicine, Northwestern Memorial Hospital, Northwestern University, Feinberg 7-301, 251 East Huron Street, Chicago, IL 60611, USA
* Corresponding author.
E-mail address: gramsey@nm.org

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Abbreviations	
AABB	Association for the Advancement of Blood and Biotherapies
COOP	continuity of operations planning
COVID-19	coronavirus disease 2019
CSPs	cold-stored platelets
D neg	D negative
D pos	D positive
EMRs	electronic medical records
FDA	Food and Drug Administration
FWB	fresh WB
HDFN	hemolytic disease of the fetus and newborn
HICS	Hospital Incident Command Systems
IC	Incident Command
IDTF	Interorganizational Disaster Task Force
ISS	Injury Severity Score
LIS	laboratory information systems
LTOWB	low-titer group O whole blood
MCEs	mass casualty events
MHPs	massive hemorrhage protocols
MT	massive transfusion
RBC	red blood cell
RITN	Radiation Injury Treatment Network
UPA	units per admission
WB	whole blood
WBB	walking blood bank
WCA	women of childbearing age

HICS is an integral part of hospital crisis management and requires training and exercises.[3] The use of a forward-command model (using a strategic leading department) establishes formal structure.[4] **Fig. 1** demonstrates this organized hierarchy of leadership and communication. Unified leadership provides continuous, clear communication reducing dangerous misinformation. HICS collects information on disaster type, patients' needs, logistics, resource limitations, and other operational planning. Data reported back to IC leadership addresses all these needs in real-time: available staff, open beds, and equipment. They may also include blood/blood product inventory considerations depending on the type and scope of disaster. Exercises can strengthen this dynamic communication model and identify gaps in logistics before disasters occur.[5]

Transfusion services are uniquely time-sensitive, especially when managing acutely bleeding patients during MCEs. Blood and blood products are only as available as inventory and supplier deliveries allow. Research cites timing as a significant challenge blood suppliers and hospitals may face in connecting life-saving resources to hospitals during disasters.[6] Modern transfusion emergency preparedness strategies were born out of military experiences, further informed by business continuity concepts.[7] Analyses of recent MCEs, such as the 2017 Las Vegas shooting, demonstrates supply can meet appropriate surge demand, and that blood suppliers should engage the public in calls for donations when appropriate.[8]

Within hospitals, responses should be tailored to the type of disasters and service interruptions. Disasters may include MCEs, staffing shortages, blood supply interruptions/shortages, or other emergencies affecting operations. With the activated HICS, transfusion department staff should communicate how the event has affected delivery of services. The blood bank must effectively disseminate information to its clinical partners and staff while protecting its personnel (ie, keeping staff in place if necessary)

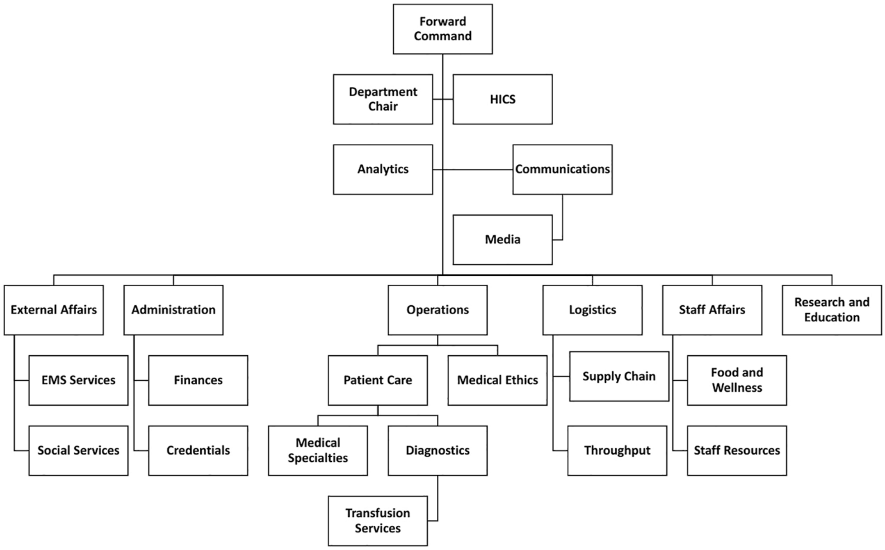

Fig. 1. A forward-command approach utilized organizational hierarchy frameworks to lead and manage communication, resources, and response, here shown to extend considerations for clinical transfusion services.[4] (Farcas A, Ko J, Chan J, Malik S, Nono L, Chiampas G. Use of Incident Command System for Disaster Preparedness: A Model for an Emergency Department COVID-19 Response. Disaster Medicine and Public Health Preparedness. 2021;15(3): e31-e36. doi:10.1017/dmp.2020.210.)

and may need to call in additional support to maintain operations. Military research on disaster preparedness shows that educating personnel improves response.[9] In some settings, prehospital transfusion may offer some relief for patients requiring blood in the emergency response phase.[10]

RESPONSE PROCEDURES

As one of the most regulated aspects of medicine and laboratory services, blood banks are required to have processes and procedures for disaster preparedness.[11,12] The Association for the Advancement of Blood and Biotherapies (AABB) also outlines preparedness standards for operational continuity, disaster planning, and communication.[13]

A large-scale MCE may necessitate hospital surge policies, triage protocols, and high-volume blood product usage. Retrospective studies have trended median units needed per admission.[14] Clinical and prehospital scoring systems can provide predictive guidance for blood product needs.[15] When there are significant blood shortages, contingency planning targets the prioritization and preservation of transfusion needs. These plans include collaborative designs between blood bank, medical ethics, IC, hospital transfusion committee, a blood supplier, or other relevant stakeholders. Regularly reviewed plans reflect unique needs and are exercised through regular drills.[16] Internal hospital disasters limit routine service delivery due to utility failures, facility damages, secondary effects of natural disasters, disruptive digital cyberattacks, or other causes. Large metropolitan areas are regularly home to high occupancy events, and all-hazard template frameworks like the Hospital Surge Preparedness and Response Index may offer tailored approaches to various disaster planning needs.[17]

Blood bank preparedness protocols (ideally easily accessible) address clear roles and responsibilities applicable to various situations. Delegation of responsibility may provide structured support for inventory, test utilization, and patient care needs in real-time.

Regardless of resource limitations, access to technology, or changes to the facility, a functional transfusion service's main duty is the safe and available provision of blood products to patients. During disasters, electronic crossmatching may not be available. This may require paper forms for issuing products, tracking massive transfusion (MT)/ massive hemorrhage protocols, serologic reaction records, and ongoing inventory re-evaluation. HICS can support transfusion medicine, balancing patient needs and transfusion safety.[18] MCEs have higher risks of accidental ABO-incompatible blood transfusions. **Fig. 2** demonstrates HICS and blood bank considerations.

To minimize delays and risks, triaging the most urgent cases offers effective inventory allocation. Full patient typing and crossmatching may be limited without significant detriment to patient care, requiring quickly issued group O red blood cells (RBCs) and group AB or A plasma. Blood banks emphasize preserving Rh-negative units, or during scarcity, adopting more liberal Rh-positive transfusion protocols in practice.[19] Maintaining adequate supplies of type-specific blood products is critical; the use of secondary, satellite inventories may benefit high-use, high-risk patients in emergency departments, obstetrics units, or operating rooms. In disasters, establishing temporary group O blood storage depots may minimize delay. Studies show minimal risk to patient care and low rates of complication when validated tracking systems or intelligent remote inventory software are used.[20,21] Utilization only in emergencies, redistribution to remote areas, and monitoring expiry dates maximize utility.

BLOOD NEEDS

"Blood required for today's disaster was donated yesterday."[22] Belgian workers describing blood needs in a terrorist attack succinctly expressed the importance of maintaining adequate blood inventories. Supply is often expressed as the number of days of normal usage on hand for each blood type. US and Canadian blood centers

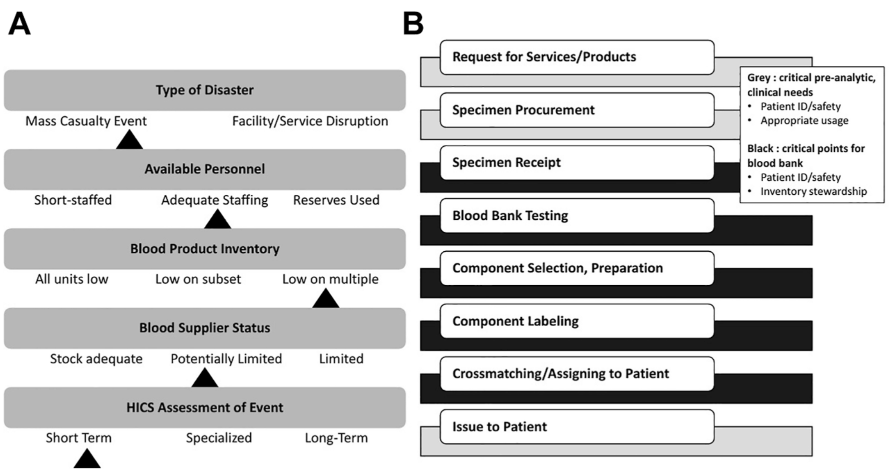

Fig. 2. When the Hospital Incident Command System is activated, critical data (*A*) are communicated that help assess the scope and effects of a disaster, while ensuring critical and supportive facets (*B*) of maintaining blood bank operations.

aim for 3 to 4 days of supply.[23–25] Transfusion services must determine their own inventory criteria, which may vary depending on factors such as surge needs or travel time from suppliers. However, a 3 day RBC supply is desired in many US hospitals.[23] The AABB Interorganizational Disaster Task Force (IDTF) recommended a 7 day supply for regional blood centers and hospitals combined, corresponding to 3 to 4 days at hospitals.[26] Internationally, 3 to 5 days was the most commonly cited inventory range for hospitals in Europe.[27]

Platelet inventories fluctuate rapidly and have short 5 to 7 day shelf lives. Donor centers in 6 US cities had average available inventories of 84 apheresis units in disaster simulation analyses.[28] In US hospitals, 49% with less than 100 beds did not stock any platelets.[29] The average US Level 1 trauma center inventory in the disaster simulation analysis was 30 units, compared to 3 in all other hospitals.[28] Large urban hospitals with frequent blood supplier deliveries may not stock much more than their normal daily needs.

Transfusion Supply and Projected Demand in Simulated Mass Casualty Events

A series of US studies compared projected MCE blood needs to actual blood inventories available in surveys of trauma centers and donor centers.[28,30,31] Bombing injuries were modeled in several cities, with all severely injured patients (Injury Severity Score [ISS] greater than 15) receiving large balanced 1:1:1 or 2:1:1 ratios of RBCs, plasma, and platelets. Under these assumptions, 83% of simulations depleted trauma center platelets and 44% and 67% were at risk for insufficient RBCs or plasma, respectively.[28]

Published Transfusion Needs in Mass Casualty Events

Only 4% of all MCE publications include transfusion information.[32] Blood component units per admission (UPA) is a frequent metric for transfusion needs.[26,33] The AABB IDTF recommended planning for 3 group O RBCs per admission in a disaster (**Table 1**).[26] A literature analysis examined 32 MCEs from 1980 to 2020 with greater than 5 admissions and needing greater than 50 RBC units.[14] In event-wide analyses, the 75th percentiles of transfusion needs were 4 RBCs, 1 plasma, and 0.25 platelet-dose (apheresis or pool) UPA. For reports from trauma centers, the 75th-percentile

Table 1
Recommendations for transfusion planning in mass casualty events or trauma

Setting	Recommendation	Source
Disaster	3 group O RBC units per admission	AABB IDTF Handbook[26]
Mass casualty events:		
Trauma center	6 RBC, 4 plasma, 0.5 platelet doses per admission	75th percentile of published MCE data[14]
Blood center (event-wide data)	3 RBC, 1 plasma, 0.25 platelet doses per admission	
Combat	20% of combat casualties need transfusion; 8 whole-blood equivalent units[a] per transfused patient	US Department of Defense[40]

Abbreviations: AABB IDTF, Association for the Advancement of Blood and Biotherapies Interorganizational Disaster Task Force; MCE, mass casualty events.

[a] Whole blood unit or 1 RBC: 1 plasma: 1 whole-blood-derived platelet-unit equivalent.

values were 6 RBCs, 4 plasmas, and 0.5 platelet-dose UPA. These values were used to guide recommendations for MCE planning (see Table 1). More recent events with balanced MTs used more plasma per RBC unit. Recent mass shooting events needed 25 to 45 platelet doses in day 1.

Emergency Needs for Severe Injuries and Massive Transfusions

A transfusion analysis of the 2015 Paris attack included blood use in severely injured patients (ISS >15).[34] The analyses discussed earlier for projected MCE transfusions assumed balanced MTs in all such patients. However, among all Paris patients with ISS greater than 15, their overall usage was 4.4 RBCs, 3.6 plasmas, and 0.45 platelet-dose UPA (ratio of 1:0.81:0.51), and only 59% were transfused.[35] The median percentage of blood components given in the first day compared to total transfusions needed for the MCE cohort (1 week median follow-up) was 67% for RBCs, 78% for plasma, and 86% for platelets.[14] Within the first day, most blood components are given in the first 8 to 10 hours.[34]

In the literature review, patients with MTs drove overall MCE usage. MT patients comprised a median of 5% of MCE admissions and received a median of 66% of all RBCs.[14] In the Paris attack, the 6% of patients needing MT used 67% of all RBCs, 77% of all plasma, and 79% of all platelets given.[34]

Alternative Blood Components

Whole blood (WB) has been employed in MCEs and will likely play a larger role in the future. WB units are usually collected from group O donors screened to have low anti-A and anti-B titers, so emergency patients of unknown ABO type may safely receive them with low risk of plasma-mediated hemolysis. WB is approved by the Food and Drug Administration (FDA) for life-threatening hemorrhage, with storage up to 21 days.[36] WB has become widely used in trauma, both on hospital arrival and in prehospital resuscitation. A Texas blood center has greater than 4000 active group O WB donors.[37] Their WB has been employed in MCEs involving a large-scale motor vehicle accident[38] and a school shooting.[39]

The US military plans for 20% of combat casualties to need transfusion, and for each transfused patient to receive 8 WB or WB equivalents (see Table 1).[40] When stored RBCs or WB are unavailable or depleted, the US Armed Services Blood Program has emergency procedures to collect fresh WB (FWB) from low-titer group O donors[37,41] comprising a “walking blood bank (WBB).” Eligible donors are preidentified for blood type, low ABO antibody titers and negative infectious disease testing. FWB has been collected for MCEs in combat[42] and on a hospital ship receiving helicopter crash casualties.[43]

For civilians, Holcomb and colleagues[44] promulgated a protocol for establishing WBBs. WBB donations are not approved by the FDA, but the Texas center is developing a civilian program, including the scenario to obtain emergency FDA approval.[45]

Cold-stored platelets (CSP) with a 14 day shelf-life are not yet approved in the United States, but the FDA has issued guidance on regulatory exception to make and use CSPs when conventional platelets are not available or not practical.[46] In randomized clinical trials in trauma, CSP generally show noninferiority in outcomes and adverse events to regular platelets.[47,48] CSPs could help meet the rapid surge capacity needed for MCEs.

Dried plasma is available in Europe and was used during the 2015 Paris attack.[49] The US military has emergency authorization for dried plasma in austere environments.[50] Various dried platelet preparations are in development.[50] Dried plasma or platelets could be useful in prehospital treatment and/or in stockpiles prepared for MCEs.

STAFF PREPARATION

Transfusion personnel may include physicians, medical laboratory scientists, nurses, ancillary service workers, and operational administrators all with varied training exposure to emergency preparedness. The AABB, The Joint Commission, the American Society for Clinical Pathology, and the College of American Pathologists all provide continuing education, which includes disaster planning[51] with focuses on being disaster-ready, ensuring personnel safety, protecting inventory, and supporting recovery efforts.[52]

TRAINING AND PRACTICE

Employee competency, required by accrediting agencies, requires participation in laboratory continuity of operations planning (COOP) in collaboration with HCIS.[53] The AABB's *Disaster Operations Handbook* outlined recommendations, roles, checklists, and expectations.[26] Standard operating procedures should outline preparedness efforts and be easily accessible. Beyond laboratory COOP, special consideration should be made for massive transfusion protocols (MTP) or massive hemorrhage protocols (MHPs). Transfusion services should have plans in place to adequately and safely manage simultaneous cases during potential MCEs.

Drills focused on MTP/MHP knowledge through discussion, physical engagement, or mock-ups can improve efficiency in delivery of care with collaborations between surgery, trauma, and transfusion medicine.[54,55] These exercises strengthen communication between relevant parties, identify critical process gaps, and highlight where more representation is warranted.[16]

MATERIALS NEEDED

Electronic medical records (EMR) and laboratory information systems (LIS) are baseline needs for clinical services. At minimum, transfusion services require (1) a safe space to receive specimens and perform compatibility testing, (2) working monitored refrigerators, freezers, thawers, rotators, and other equipment to store or modify blood products, (3) adequate staff, (4) a medical director, (5) means through which to communicate with internal and external partners (including HICS), and (6) access to the policies and reference procedures. In the event of disruption of services, back-up resources become critical. **Fig. 3** demonstrates the relationship between these evolving resource limitations and minimum materials needed (highlighted in gray).

DIGITAL PREPAREDNESS

Patient histories are vital for compatibility safety. If the EMR/LIS was unavailable during an event, compatibility testing may require a retrievable backup database. Paper copies are a safe option, but storage and retrieval pose significant challenges. Offline digital backups take up valuable server space and access may be limited. Antibody history reports may be available on local EMR or LIS networks for a defined period, with limited retrievability. Cloud-based, local network, or remote databases also require storage and maintenance and may offer multiple interface options with retrievable histories in times of crisis.[56]

Two large blood centers in the US Southeast and in New York each had 10 day disruptions from cyberattacks in 2024 to 2025.[57,58] Interruptions of collection and processing forced importation of blood components from other facilities to maintain transfusion care. A US Midwest pediatric hospital had to function manually

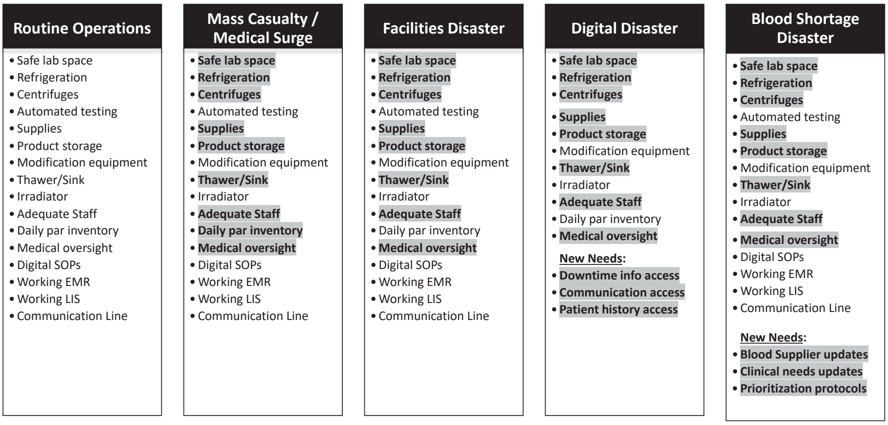

Fig. 3. Routine blood bank operations require equipment, space, and other considerations to ensure delivery of services. During disasters like MCEs, facility failures, digital downtime, and severe blood shortages, these aspects may become reduced to minimum operational levels (highlighted in *gray*) while new needs may emerge, depending on the type of situation.

for a month, including the transfusion service.[59] Downtime procedures are frequently activated for brief periods, but additional planning is needed for extended outages.

BLOOD SHORTAGES

Blood banks routinely deal with episodic shortages often managed on the blood supplier side through increased donor engagement, inventory reallocation, and reserve inventory. Volunteer blood donors have steadily dropped, particularly in younger demographics.[60] There have been over 201 billion-dollar natural disaster events, and nearly 5000 mass shootings in the United States over the last 10 years.[61,62] Shortages during the coronavirus disease 2019 (COVID-19) pandemic led to AABB publishing guidance tips for hospitals trying to maintain continuity of operations despite challenges.[63] Simultaneous communication with the blood supplier and the HICS are important to ensure effective blood requests and inventory management.

To adequately prepare for supply-side challenges, a blood bank may have more than one official blood supplier and reference laboratory—this is often useful for challenging cases, rare components, and antigen-negative needs. In the setting of blood shortages or high-usage MCEs, multiple sources of blood can protect clinical outcomes. In a shortage, a hospital with a significant number of MTP/MHP patients with trauma may heavily increase the use of group O units from a single blood supplier, decreasing the relative amount available for less urgent procedures in the same hospital, or for smaller centers in the region. Relative shortages can be overcome in the short term, but over an extended period they can ultimately cause absolute shortage crises. Incorporating other blood suppliers provides access to alternative means of inventory replenishment and may indirectly save lives. This suggested redundancy can offer transfusion services resiliency and improve patient survival.[64]

Severe shortage strategies may include austerity measures, daily limits, transfusion thresholds, or effective practice algorithm re-evaluation. Due to the nature of these clinical decisions, a transfusion service should collaborate with champions of medical ethics, patient blood management, relevant medical subspecialties, and their blood suppliers. Transfusion medical directors may engage in discussions of nonbeneficial interventions, saving blood products for more appropriate patients. The AABB provided a series of helpful resources for hospitals establishing their own contingency planning. These models highlight communication, clear transfusion thresholds, prioritization tables, roles, and responsibilities.[65] Internal calculation of routine inventory and minimum volume to maintain operations is key.[14,66]

Triaging available blood supply involves strong stewardship. In one model, a tool for allocating blood products during shortages incorporated ethics and clinical scores into a framework of stewardship triaging both the available blood supply and monitoring patients who would most benefit.[67] **Fig. 4** explores the basic premise of this tool in action.

SPECIAL CONCERNS

ABO and RhD for Red Blood Cells

For first-time or unknown patients, compatibility testing protocols usually require a second specimen for blood type confirmation to issue non-O type specific RBCs. The risks of specimen misidentification might be higher when multiple severely injured patients present simultaneously. In the Boston Marathon bombing, transfusion services maintained the 2 sample requirement for this reason, even though more group O RBCs were needed until the second specimens were typed.[68]

When D-positive (D pos) RBCs are given to D-negative (D neg) patients, the rate of anti-D alloimmunization is 20% to 35%.[69] The use of low-titer group O whole blood (LTOWB) in trauma is increasing, and inventories are predominantly or wholly D positive (D pos). Ideally, D neg RBCs should be conserved for women of childbearing age (WCA) or younger. Having a wristband identification system for unknown patients, which indicates female versus male has been recommended,[68] and this could be further extended to WCA. Regarding the use of D pos RBCs or LTOWB in WCA, life should be saved first, and proponents calculate that the odds of future severe hemolytic disease of the fetus and newborn (HDFN) are low.[70] Others caution that HDFN, should it occur, has a high morbidity rate.[71]

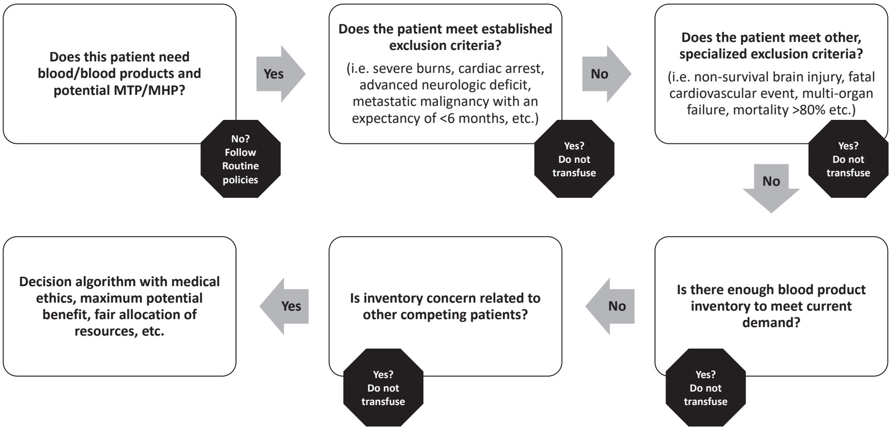

Fig. 4. Triage tools like these may provide critical exclusion criteria in times of significant blood product shortages to maintain stewardship of available inventory and maximize patient outcomes when considering potentially nonbeneficial transfusions. (*Adapted from* Doughty et al.[67])

Large-Scale Disasters

The most frequent large-scale US disasters are hurricanes. Health care facilities and blood centers may be affected by storm damage, power and communication outages, and disruption of transportation for staff, donors, and donor specimen testing. Although nonurgent patient care is postponed, blood centers may need outside assistance to maintain essential blood supplies. Storms usually present a blood supply problem rather than a blood demand problem.

Severe earthquakes cause both widespread injuries and damage to health care facilities. In Asian and New Zealand earthquakes, direct blood needs per injured patient were like other MCEs.[14] One of the periodic US national-level disaster exercises was an earthquake scenario in Seattle, Washington. MT needs were projected for care at functioning hospitals in the damage zone or for patients transported to unaffected areas.[72]

The US maintains the Radiation Injury Treatment Network (RITN) for radiation accidents and attacks. The RITN enlisted several dozen US hospitals skilled in hematopoietic stem cell transplants to treat patients with radiation injury. Disaster planners attempted to project blood needs after a nuclear explosion. In one model, 76,000 to 223,000 RBCs would potentially be needed if all injuries were treated, but actual use would be limited by hospital capacity.[73,74]

Internal Emergencies

Hospital transfusion services should be prepared with periodic practice to relocate quickly in case of an area emergency. This requires keycard access, blood component transfer to monitored inventory space, plasma thawing provisions, telephones, computers, printers, manual testing equipment, and dissemination of the new location and contacts to hospital staff and blood suppliers.

BLOOD CENTERS

Advance disaster preparation by blood centers includes setting up coordination channels with local public safety authorities and emergency management agencies.[54] Local American Red Cross offices are also involved through their humanitarian assistance role. Blood centers should participate in community disaster drills and planning for upcoming high-profile events. As a critical public health service, they should seek high-priority status for repairs from local utilities in case service is interrupted.[26]

Blood centers provide backup communication channels with hospitals and may have alternate delivery services. Hospitals may need to provide blood courier identification information to their security services if alternate vehicles or credentials are presented. Likewise, hospitals should provide alternate delivery route information if needed due to hospital security.

After an MCE, blood donation is a frequent altruistic impulse. Hundreds or thousands of units have been donated in response to high-profile events such as mass shootings.[8,75,76] As discussed previously, most of the blood for MCE victims comes from units already in hand, although there is some ongoing RBC use. Blood centers should work with public authorities and news media to provide appropriate messaging about their needs and try to space out future donations if appropriate.

When regional blood providers in the US encounter emergencies in supply or demand beyond their capability, they contact the AABB Interorganizational Task Force for Domestic Disasters and Acts of Terrorism—less formally, the AABB IDTF.[77] The ITDF was founded after the 2001 9/11 terrorist attack and is a cooperative forum for blood banking organizations and key health care organizations in liaison with the US

Department of Health and Human Services, the FDA, and the Centers for Disease Control and Prevention.[78] The AABB is the designated coordinating entity. The IDTF's liaison role with HHS is part of the National Response Framework, the federal disaster plan.[79] Threats to the blood supply from hurricanes, epidemics (Zika virus, COVID-19), cyberattacks on blood centers, and an earthquake in Haiti have all required IDTF assistance. During an emergency, the IDTF helps craft public messaging with HHS about blood donation and arranges for shipments of blood components and critical material (eg, generator fuel) to the affected region if needed.

The Blood Emergency Readiness Corps is a consortium of nearly 40 US blood centers.[80] Each week on a rotating basis, one-third of the centers collect and set aside 10 O pos and 4 O neg RBCs for 1 week.[81] In case of an emergency need, the units are sent to the affected blood center. This could total over 120 O pos and 48 O neg units. Participating blood centers contribute to an emergency response and educate donors on the need for blood to be on hand before a crisis.

SUMMARY

The complex process of providing blood components for vital patient care requires complex planning to mitigate disasters threatening the blood supply or blood operations or requiring a surge in blood needs. Operating procedures, training, communication, mass casualty projections, and partnerships between transfusion services and their blood suppliers are all needed. US blood organizations and federal agencies have developed frameworks for managing regional and national blood supply problems.

CLINICS CARE POINTS

- Blood banks must prepare for severe imbalances of blood supply and demand with procedures for communication, rapid provision of large quantities of blood to multiple patients, and training.
- Patients requiring MTs account for most of the blood needed in MCEs.
- WB, CSPs, and dried plasma have emerging roles in the transfusion management of disasters.
- In large-scale events such as hurricanes, a US national task force of private blood and health care organizations and federal agencies coordinates blood shipments and donor recruitment messages.

DISCLOSURE

The authors have no disclosures relevant to this study. No external funding was received for this study.

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