THE IMPACT OF TRANSFUSION-TRANSMISSIBLE VIRUSES ON BLOOD PRODUCT MANAGEMENT IN THE UNITED STATES

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Submitted to the Graduate Faculty of

the Department of Infectious Diseases and Microbiology,

Graduate School of Public Health in partial fulfillment

of the requirements for the degree of

Master of Public Health

University of Pittsburgh

2013

UNIVERSITY OF PITTSBURGH

GRADUATE SCHOOL OF PUBLIC HEALTH

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April 15th, 2013

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ABSTRACT

Blood products represent valuable medical assets and also serve as critical resources in public health emergency response. In the United States, such products – which may include red blood cells, platelets, and plasma – originate almost exclusively from voluntary donors and traverse a complex regulatory pipeline before being put to therapeutic use. Despite the clinical importance of blood, however, the U.S. lacks a clear protocol for handling blood products during emergencies, particularly with respect to bloodborne viral threats. This investigation parsed scientific literature, federal and non-governmental policies, news articles, Congressional records, and publicly available surveillance data in order to elucidate the model of blood product management in the U.S. and assess its efficacy in the event of a public health emergency. This approach demonstrated that current blood product management policies in the U.S. appear to be sufficiently effective on a day-to-day basis. However, they fail to address several notable challenges associated with public health emergencies: lack of coordination between emergency management agencies, screening of donors and donations, blood distribution, healthcare worker availability and endangerment, and the financial impact of therapeutic blood use. The study

concludes with recommendations for improving the blood product management infrastructure in the U.S., thereby strengthening its overall emergency response capability.

TABLE OF CONTENTS

LIST OF TABLES

PREFACE

First and foremost, I owe an enormous debt of gratitude to my incredible family for sustaining me with infinite love and support. My parents' phone calls were especially comforting during late-night writing sessions, as were their reminders to make health and happiness my number-one priorities. Special thanks also go to my little brother, Saagar, for delivering world-class pep talks every week over the phone. My relatives graciously invited me home during breaks and took wonderful care of me despite my constant preoccupation with school. I am grateful for their hospitality and promise to be a better guest next time.

To my teachers, colleagues, and friends in Pittsburgh: you are too numerous to name individually, but you know who you are. Know that I am inspired by your commitment to service and education, and immensely fortunate to have enjoyed such excellent company. I must, however, mention the members of my essay committee, Professors Jeremy Martinson and Gerald Barron, and thank them for lending me their time and considerable expertise this year. My sincerest thanks also go to my outstanding advisor, Dr. Anthony Silvestre, for his advice in all matters school-related, his thoughtful suggestions for the execution of this project, and most of all, for his valuable lessons in mindfulness and meditation.

Finally, I must convey my deepest gratitude to the phenomenal people at the Center for Biosecurity of UPMC. My summer at the Center was an exceptionally fulfilling one, and I was

truly humbled by everyone's kindness and encouragement. I am especially grateful to Ryan Morhard for patiently helping me navigate the intricacies of policy analysis, and to Nidhi Bouri for introducing me to the issue of blood product management. It is due largely to the Center's guidance that I can present this research as the culminating endeavor of my graduate studies.

1.0 INTRODUCTION

Blood is a specialized form of connective tissue responsible for performing several functions critical to good health: transporting oxygen and nutrients, circulating hormones, removing metabolic waste, facilitating the immune response, and maintaining body temperature and pH. It is perhaps unsurprising, then, that blood and its associated components – notably, red blood cells (RBCs), platelets, plasma, and cryoprecipitate – represent important medical commodities. Unlike most commodities, however, they originate exclusively from voluntary donors and cannot be stockpiled for more than a few weeks. These limitations yield significant consequences for managing public health emergencies, defined here as "an emergency need for health care [medical] services to respond to a disaster, significant outbreak of an infectious disease, bioterrorist attack or other significant or catastrophic event." [1] As a result, American medical institutions constantly wrestle with the considerable challenges of maintaining a safe and adequate reserve of blood products, and distributing them efficiently to high-need locations.

Surpassing even the problems of blood product collection and allocation, though, is the issue of safety. Healthcare professionals must ensure that blood products are compatible with their recipients' tissues in order to prevent harmful immune complications. The process of collecting blood further highlights the difficulties associated with ensuring recipient safety, since blood and its derivatives are notoriously susceptible to contamination by a variety of bacterial, viral, parasitic, and fungal pathogens. For the same reason, intravenous drug users (IDUs),

individuals who engage in unprotected sex, and healthcare workers (HCWs) in clinical or laboratory settings are particularly susceptible to infection by blood-transmissible pathogens via needlestick injury or contact with contaminated blood. Given these risks, the U.S. government has created a complex regulatory framework to preserve the safety of blood products collected for therapeutic purposes. However, the lack of coordination among the supervising bodies within this framework may impede efforts to ensure a concerted response to pathogens in the American blood reserve; notably, viruses and other pathogens responsible for emerging infections in the U.S. Public health emergencies affecting the availability and safety of blood products further magnify this weakness.

The primary goal of this investigation is to underscore the importance of proper blood product management and shed new light on the larger issue of public health preparedness with respect to infectious pathogens. It relies, therefore, on information assembled from scientific literature, public laws, government reports, federal policies, and publically available surveillance data to accomplish several objectives. First, it provides a brief discussion of the burden associated with bloodborne infections in the U.S. Given the sheer diversity of the microbes responsible for such infections, the study pays special attention to three of the most prevalent: human immunodeficiency virus (HIV), hepatitis B virus (HBV), and hepatitis C virus (HCV). Next, the study traces the evolution of the federal and non-governmental policies that govern blood product safety, evaluates their strengths and weaknesses, and analyzes their posited efficacy in mitigating the consequences of a public health emergency. Finally, the study offers policy recommendations that aim to improve blood product management, thereby augmenting public health response capacities in the U.S.

2.0 METHODS

This study began with preliminary searches of the PubMed database, which filtered results to include only open-access articles published within the last five years and exclude those studies not involving human subjects. The searches contained the following terms:

- "blood product distribution" (256 results)
- "blood product screening" (1274 results)
- "blood products and public health emergencies" (20 results)
- "blood shortage" (292 results)
- "occupational exposure and bloodborne pathogens" (363)

  "bloodborne viruses" (101 results)

A brief analysis of the literature revealed that most recent studies on blood product research are biomedically oriented. A subsequent repeat of these searches in Google Scholar using the same criteria produced similar results. These searches revealed a dearth of publications focusing on the logistics of the blood product supply chain and blood safety policies. Therefore, this investigation, which assumes the form of a policy analysis examining blood management practices in the U.S., ultimately drew from several diverse sources. These include, but are not limited to:

- Peer-reviewed publications
- News articles
- Government reports
- Federal guidelines pertaining to blood management and emergency management
- Congressional records
- Publicly available surveillance data

Specific questions considered while parsing these sources include:

- What are the governing bodies that formulate blood product management policies?
- What measures are taken to ensure blood product safety?
- How are blood products distributed?
- Under what circumstances does the demand for blood products increase?
- Who are the stakeholders involved in ensuring emergency preparedness?
- What are the specific criteria for adequate preparedness (with respect to blood products)?

Synthesis of the information gathered from the aforementioned sources explicated the American model of blood product acquisition and delivery. The study then extrapolated the implications of this model to encompass the challenges associated with managing public health emergencies and draw conclusions about its effectiveness.

3.0 TRANSFUSION-TRANSMITTED VIRUSES

Bloodborne viruses present significant medical, social, and economic threats to populations worldwide; among these, HIV, HBV, and HCV are the most prevalent in the U.S. Despite the fact that infection by these viruses is often preventable by simple prophylactic measures such as wearing condoms, using clean needles, or – in the case of hepatitis B – getting vaccinated, many new cases continue to emerge every year. Because lengthy, asymptomatic periods of incubation often precede HIV, HBV, and HCV infections, those infected often remain unaware of their carrier status, during which time they may inadvertently transmit the virus in question to healthy individuals. In fact, the Henry J. Kaiser Family Foundation postulates that this figure is as high as 20% for HIV-positive individuals in the U.S. [2] New cases also emerge as a result of contact with infected body fluids, needlestick injury, or vertical (i.e. mother-to-child) transmission.

Even when symptoms of HIV, HBV, and HCV infections manifest, they are often nonspecific and not exclusive to the pathogens in question. Acute, early-stage HIV infections, for example, resemble mononucleosis-like syndrome during the first few weeks of infection, causing fevers, pharyngitis, and rashes; after recovering from these ailments, patients often remain asymptomatic for periods ranging from months to years. [3] Although HIV disease is primarily an affliction of the immune system, the infection permeates nearly every system in the body, precipitating a broad array of symptoms and afflictions. These may include cancer, blood cell depletion, endocrine disorders, gastrointestinal dysfunction, neuropathies, dementia, and

pulmonary complications. [2] Individuals in later stages of the disease also become dangerously susceptible to a variety of opportunistic infections, including hepatitis, malaria, tuberculosis, and pneumonia.

Acute, early-stage hepatitis B and C are characterized by mild, flu-like symptoms such as fatigue, vomiting, nausea, and fever; in addition to these, muscle aches, joint pains, and tenderness in the left upper abdominal quadrant often accompany HCV infections. [4, 5] In their chronic manifestations, however, HBV and HCV infections produce far graver sequelae: major immunosuppression, insulin resistance, renal inflammation, vitiligo, thyroiditis, and jaundice. [6] The severest consequences of hepatitis infections include cirrhosis, or the degradation of liver tissue, and hepatocellular carcinoma, a rare form of liver cancer.

3.1 DEMOGRAPHICS

Disease surveillance is a time-consuming, resource-intensive, and costly endeavor. Due to the clinical and financial burdens associated with transfusion-transmitted viral infections, federal health authorities nevertheless recommend that state and local health agencies conduct surveillance to more effectively track disease and inform health disparity reduction efforts. As dictated by the Centers for Disease Control and Prevention (CDC), new HIV infections and existing AIDS cases are reportable conditions in all fifty states, along with incident hepatitis B and C infections. [7, 8] Chronic hepatitis infections, however, present a significant surveillance challenge to public health authorities. CDC reports, "Although previously not included among nationally notifiable conditions, the public health importance of chronic viral hepatitis infections dictates that they be added. Several states and counties have established viral hepatitis infection

databases for persons testing positive for [hepatitis B antigen] or anti-HCV, but their experience indicates that managing large numbers of [hepatitis B antigen]-positive and anti-HCV positive laboratory reports has the potential to overwhelm a surveillance system and divert scarce resources into data management rather than disease prevention." [9] Therefore, current approximations of hepatitis prevalence in the U.S. are likely vast underestimates, leaving the true burden of HBV and HCV infections unknown. In light of these surveillance shortcomings, CDC, must therefore rely on data from several national surveys as parameters by which to quantify the burden of viral hepatitis: the National Health and Nutrition Examination Survey, Racial and Ethnic Approaches to Community Health, and the National HIV Behavioral Surveillance program. [10]

Based on data acquired from the above sources, the CDC approximates that there are 1,148,200 known cases of HIV infection (in individuals over the age of 13) in the U.S. as of December 2012, including an estimated 207,600 who were unaware of their status. [11] These figures are compounded by roughly 50,000 new infections every year, many of which emerge among young black men (ages 13-24). [11] Overall, white, black, and Hispanic men who have sex with men [MSMs] consistently report the highest rates of infection, followed by heterosexual black women. [11] Hepatitis B incidence, on the other hand, has steadily declined over the past decade; nevertheless, the CDC received clinical reports of 19,982 acute cases between 2006 and 2010. [12] Similar reports for hepatitis C during the same period showed a relatively constant incidence rate of (0.3%), for a total of 4,159 acute cases. [13] However, given the inconsistency of current surveillance efforts and the extended incubation periods associated with these infections, it is safe to conclude that these figures are, in fact, underestimates of the true burden of hepatitis

in the U.S. The CDC conjectures that the total number of hepatitis B and C cases emerging between 2006 and 2010 actually number 203,000 and 87,000, respectively. [14]

The distribution of hepatitis infections also varies by gender, ethnicity, and age. Men typically report higher rates of HBV and HCV acquisition, as do individuals of black, American Indian, and Asian descent; as of 2010, the U.S. Caucasian population also saw a slight increase in the number of emergent hepatitis C cases. [15, 16] The CDC also reports a shift in the age distribution of hepatitis C carriers between over the past several years: during the early 2000s, adults between ages 40 and 49 demonstrated the highest incidence of new infections, but they were eventually surpassed in 2005 by individuals in their twenties and thirties. [17] Hepatitis B, on the other hand, is now seen most frequently in the 30-39 and 40-49 demographic groups, with the number of incident cases in the 20-29 age cohort dropping dramatically since 2002. [18]

3.2 ECONOMIC IMPACT

The depletion of human capital is a major factor contributing to the economic burden associated with infectious disease. This phenomenon is especially apparent when considering bloodborne pathogens such as HIV, HBV, and HCV, since these viruses deal a disproportionately severe blow to populations of younger individuals in their prime years of economic productivity. The 40,000 new HIV infections in the U.S. in 2002, for example, are expected to accrue over $36.4 billion in lifetime expenditures, with black, white, and Hispanic Americans generating the majority of these costs. [19] These figures, which account for direct medical spending, mortality-associated productivity losses, and ethnicity-specific costs, result in an average of $910,800 spent over the lifetime of an HIV patient in the U.S. [19] However, because they did not account

for morbidity-related productivity losses, it may be inferred that these numbers are still underestimates of the true economic burden of HIV infections.

Hepatitis B and C infections incur similarly high costs, which vary depending on the stage of disease progression. In 2000, for example, outpatient treatment for symptoms of acute HBV infection in the U.S. cost $272 per incident, while hospitalization resulted in charges exceeding $8,000. [20] A 2008 cost analysis, however, demonstrated that liver complications stemming from later-stage, chronic hepatitis B can generate medical costs amounting to nearly $60,000, while the cost of a liver transplant may run as high as $163,438. [20] Meanwhile, researchers project that the economic burden associated with HCV infections will exceed $10.7 billion in direct medical costs between 2010 and 2019, while society will bear over $54 billion in economic losses due to premature mortality during the same period. [21]

4.0 THE AMERICAN BLOOD RESERVE

The American blood reserve consists predominantly of pints (units) of whole blood and its associated derivatives: RBCs, platelets, plasma, cryoprecipitate, and granulocytes. Certain blood banks and collection agencies such as the American Red Cross (ARC) and America's Blood Centers (ABC) isolate and store other blood products, including leukocytes, umbilical cord blood, stem cells, bone marrow, and mononuclear cells. [22, 23] The U.S.' Government Accountability Office (GAO) estimates that ARC and ABC operations each generate roughly 45 percent of the nation's blood supply, while the Department of Defense (DoD), hospitals, and independent blood banks collect the remaining 10 percent. [24] The Strategic National Stockpile (SNS), the U.S.' emergency repository of pharmaceuticals, antidotes, vaccines, and medical supplies, also contains cytokines and hematopoietic growth factors. [25] These are accessible under Emergency Use Authorization from the Food and Drug Administration (FDA), the agency that enforces safety guidelines for food, medical equipment, biologics, and pharmaceuticals. [25] The aforementioned blood products each serve various clinical purposes and require different storage conditions (see Table 1).

Table 1. Frequently used blood products and their associated shelf lives and clinical uses. [26]

Blood Product	Shelf Life	Clinical Use	Mode of Collection
Whole blood	35 days	• Hypovolemia correction • Exchange transfusions • Treatment of acute blood loss	Venous donation
RBCs	42 days	• Treatment of anemia • Treatment of acute blood loss	Erythrocytapheresis; fractionation
Platelets	5 days	• Treatment of thrombocytopenia • Management of bone marrow failure • Surgical prophylaxis • Treatment of acute blood loss	Plateletpheresis; fractionation
Plasma	1 year	• Correction of coagulation factor deficiencies • Correction of immunodeficiencies • Reversal of warfarin effect	Plasmapheresis; fractionation
Cryoprecipitate	1 year	• Treatment of hemophilia • Treatment of Von Willebrand disease • Source of fibrinogen	Apheresis; fractionation

The following section analyzes the contents of the American blood reserve further, discussing their origins, their availability, and the costs associated with their use in clinical and emergency settings.

4.1 BLOOD PRODUCT AVAILABILITY

Given that the American blood reserve depends predominantly upon voluntary donations, its size and availability fluctuate constantly. Despite seasonal shortages during the summer and winter months, GAO nevertheless reported in 2002 that the amount of blood in the American reserve remains "generally adequate." [24, 27] AABB, a U.S.-based standards organization in the field of transfusion medicine, corroborates these findings. Its National Blood Collection Utilization Survey (NBCUS), conducted in 2008 with sponsorship from FDA, CDC, the Department of Health and Human Services (HHS), and the National Institutes of Health (NIH), actually reported a significant surplus of blood nationwide, with the number of units available exceeding the number of units transfused by a margin of over two million. [28] In light of the challenges associated with managing surplus blood supplies – storage logistics, safety issues, and financial constraints, to name a few – GAO recommends that blood product repositories strive to maintain minimally sufficient levels of inventory at all times (i.e. a three-day supply). [24, 29]

In 2008, American blood collection agencies amassed a total of 17,286,000 units of blood (prior to testing). [28] NBCUS further reports that these agencies also acquired over 11 million units of non-RBC components (platelets, plasma, cryoprecipitate, and granulocytes). [28] Hospital-based blood banks collected an addition 17,286 units of blood, of which 127 were discarded

upon testing. [28] Of these assorted blood products, NBCUS found that transfusion patients received roughly 15 million units of RBCs and whole blood and 2 million units of platelets over the course of the year. [28] Several organizations – notably, ARC, AABB, and ABC – coordinate blood exchanges and track available inventory to facilitate the movement of blood products to high-need locations.

Thus, given the apparent abundance of blood products in the American reserve and the frameworks in place to deliver those products, it is clear that the challenge of blood product management lies not in acquiring additional products on a day-to-day basis. Rather, the problem lies in the ability of hospitals and blood centers to collect, test, and distribute blood efficiently when confronted with an event that could potentially endanger the blood reserve: infectious disease outbreaks, natural disasters, or man-made disasters.

4.2 AMERICAN BLOOD DONORS

As described above, blood products are perishable medical commodities that originate exclusively from willing donors. Although a number of synthetic blood substitutes exist – notably, artificial hemoglobin products – their safety and therapeutic efficacy remain unclear. GAO further estimates that while 60 percent of Americans are eligible to donate blood, only about 5 percent actually do so; furthermore, 80 percent of eligible, active contributors are repeat donors. [24] Thus, the sufficiency of the American blood reserve is contingent upon a small but critical sector of the population.

NBCUS indicates that a total of 10,805,000 individuals (out of 19,330,000 individuals who presented to donate) successfully gave blood. [28] Of these, roughly 30 percent were first-time

donors and 10% belonged to an ethnic minority group (i.e. African, Asian, and/or Hispanic). [28] Collection agencies and hospitals deferred 2,428,000 individuals (12.6 percent of those who presented) for various reasons: low hemoglobin levels (59.3%), high-risk behavior (2.9%), traveling to certain locations (7.9%), and other medical conditions (29.9%). [28] Collectors also discarded 127,000 units obtained from 1.2% of donors after they tested positive for certain disease markers (see section 4.3). [28]

4.3 BLOOD PRODUCT SCREENING AND PROCESSING

As delineated by the American Medical Association, the process of ensuring blood product safety consists of five tiers: donor screening, maintaining accurate donor deferral registries, blood testing, quarantining blood donations until they are cleared for therapeutic use, and monitoring adverse events during donation and transfusion. [30] FDA is predominantly responsible for enforcing these guidelines and modifying them as needed. As a result of implementing and adhering to these measures, blood banks help ensure that the American blood reserve is safer now than ever before.

Among the aforementioned tiers, blood testing, normally a two-day process, is arguably the most critical step in ensuring the safety of both the blood and the recipients of blood transfusions. FDA mandates that all collection agencies test blood for the presence of HBV, HCV, HIV, human lymphotropic virus I and II (HTLV-I/II), and syphilis. In addition to these, ARC also screens its blood products for Chagas disease, West Nile Virus (WNV), and is working to develop an effective test for dengue virus. [31, 32] AABB members, meanwhile, conduct nine different tests on their donations. [33] FDA currently holds licenses for the various diagnostic

assays these agencies use to test whole blood and its associated components. [34] HBV tests, for example, include three assays for detecting HBV surface antigens, one for HBV core antigen, and two nucleic acid tests (NATs) for HBV itself. [34] HCV tests, meanwhile, include three assays for HCV encoded antigen and three NATs for the virus itself. [34] Tests for HIV-1 and HIV-2 are the most numerous, encompassing some 29 antibody assays (including an at-home detection kit and an oral test) and 10 NATs. [34] Additional diagnostics include two antibody assays HTLV-I/II, two antibody assays for *Trypanosoma cruzi* (a parasitic protozoan responsible for Chagas disease), two RNA assays for WNV, and three multiplex assays capable of simultaneously screening blood for combinations of HIV, HBV, and HCV. [34] All of these tests feature high sensitivities, which may occasionally result in false positives (i.e. a test indicates that a unit of blood is reactive when it is, in fact, pathogen-free); therefore, donors whose blood appears to be reactive may undergo more specific confirmatory testing to verify the original results. [33] However, despite their sensitivity, these tests are not failsafe. HBV antigens, for example, are undetectable in blood until 30 to 60 days after infection; levels of HBV antibodies in the blood may even diminish over the course of several decades. [35] As a result, HBV-positive individuals who are unaware of their carrier status pose a considerable threat to blood product security, particularly during the early stages of infection. HCV and HIV pose similar challenges to blood screening efforts. [36]

Another important component of ensuring blood safety is the process of screening potential donors. Given that the aforementioned diagnostic strategies are not perfectly reliable, coupling blood tests with a behavioral questionnaire represents a more effective way of ensuring blood product safety. According to FDA, preliminary screening via questionnaire eliminates as many as 90 percent of unsuitable donors before they commence donation. [37] Blood collection

agencies must add the names of deferred donors to a registry, which other agencies cross-check to ensure they do not obtain donations from disqualified donors. [37] If the reason for deferral is a temporary health issue such as anemia, low body weight, or exposure to vaccinia virus, the donor in question may once again give blood after a specified deferral period. [38] Other criteria for deferral include exposure to another person's blood, needlestick injuries, recent tattoos or body piercings, or relations to an individual with Creutzfeld-Jakob disease (CJD). [39] Sexual contact with any of the following individuals may also serve as a basis for deferral: IDUs, MSMs, those who were born or lived in Africa, those who have had sex in exchange for money, hemophiliacs, or HIV-positive individuals. [39] Collection agencies may also reject donors who have lived in the United Kingdom or France after 1980 due to concerns about the transmission of variant CJD. [39]

4.4 THE ECONOMICS OF BLOOD BANKING

Despite the fact that the majority of American blood products originate from unpaid volunteers, there are still significant costs associated with using these valuable commodities in a therapeutic setting; transfusions alone, for instance, cost the healthcare industry between $10 and $15 billion annually. [40] Similarly, moving blood products through medical supply chains also generates significant costs. ARC's blood management infrastructure, for example, consists of several critical steps: collecting blood from a donor, shipping donations to a laboratory for testing and processing, storing viable blood products, shipping said products to designated distribution centers, and finally, distributing blood products to medical institutions in need. [41] Unsurprisingly, steep costs accompany each step in ARC's supply chain, a phenomenon also observed in the schemes of other distributors.

Hospitals receiving blood from a nonprofit blood bank such as ARC do not pay for the blood itself, but instead must cover the costs of laboratory screening and shipping. [42] NBCUS reports that the cost of most blood products in 2008 (except for whole-blood derived platelets and fresh frozen plasma) had significantly increased since 2006. [28] The cost of a single unit of RBCs in 2008, for instance, averaged $223.09, while a single unit of leukoreduced apheresis platelets cost hospitals a mean of $538.56. [28] Meanwhile, the price of fresh frozen plasma, cryoprecipitate, and whole-blood-derived platelets averaged $57.78, $65.10, and $64.98, respectively. [28] Fractionation, the process by which laboratories separate blood into its component parts, further compounds the overall cost of blood products: one study estimates that the additional costs generated by such processes run as high as $600 million in the U.S. alone. [43] Finally, the costs of new safety procedures also contribute to the escalating cost of blood products; leukoreduction, for instance, increases the cost of a single unit of blood by $30. [44]

Although the Centers for Medicare and Medicaid Services (CMS) reimburses hospitals for the purchase of select blood components – as much as 83% of the cost of RBCs and 93% of the cost of whole-blood derived platelets, on average – large hospitals making high-volume purchases of blood products nevertheless accumulate significant expenses. [28] Furthermore, in 2012, CMS slashed reimbursement rates for several products: whole blood (reimbursement reduced by 5.95%), split units of blood (44%), RBCs (3.34%), granulocytes (11.11%), and irradiated platelets (11.26%). [45] Such changes in reimbursement policies are sure to increase the economic burden associated with caring for transfusion recipients.

In addition to these benefits from CMS, the National Disaster Medical System (NDMS), a division of HHS, runs a Definitive Care Reimbursement Program for victims of public health emergencies that are "transported via Federal assets, processed through a FCC, and referred to

facilities or practitioners for Definitive Medical Care. The NDMS tracks all patients who are transported via Federal assets and thus, are eligible for coverage under this program." [46] The program thus compensates healthcare providers for approved medical services performed on eligible patients who sustain "injuries or illnesses resulting directly from a specified public health emergency; injuries, illnesses and conditions requiring essential medical services necessary to maintain a reasonable level of health temporarily not available as a result of the public health emergency; or injuries or illnesses affecting authorized emergency response and disaster relief personnel responding to the public health emergency." [46] Because CMS reimburses healthcare providers for blood products through Medicare and Medicaid, NDMS, may thus play a crucial role in mitigating the financial repercussions of public health emergencies.

5.0 BLOOD PRODUCT MANAGEMENT IN THE UNITED STATES

The practice of blood banking in the U.S. began in earnest in the 1930s and forties, following reports of successful blood transfusions on the battle lines of World War II. [47] In light of these successes and other medical advances such as the invention of the plastic blood bag and the discovery of sodium citrate as an anticoagulant, blood transfusion quickly evolved into an important therapeutic measure on the civilian medical front as well. However, following the emergence of more blood banks and a steady increase in cases of bloodborne infections, this trend soon underscored the need for more stringent blood product regulation. During the early days of the Acquired Immunodeficiency Syndrome (AIDS) epidemic in the U.S., for instance, the blood banking industry emerged as a crucial vector of bloodborne pathogens.

Today, authorities from FDA, HHS, CDC, DoD, and the Department of Homeland Security (DHS) have formulated a number of policies intended to safeguard the American blood reserve from pathogenic threats. Additional regulatory support originates from several non-governmental organizations; namely, AABB, ARC, ABC, and independent blood banking agencies across the country. The following section offers a synopsis of the major events and organizations that gave rise to today's blood management practices, and discusses the role of these groups in shaping today's blood regulation policies.

5.1 FEDERAL POLICIES

The federal policies governing blood product safety, distribution, and management span the jurisdictions of several agencies; notably, HHS, FDA, CDC, and DoD. Each of these agencies maintains standards for reducing the incidence of blood-transmissible viral infections and ensuring the safety of blood products overall. In order to more effectively guide the activities of these and other groups during times of crisis, the Federal Emergency Management Agency (FEMA), a division of DHS, formulated the National Response Framework (NRF) to replace its earlier National Response Plan. The core of NRF describes the roles and responsibilities of groups involved in emergency response and recovery activities, the organization of response personnel, and planning resources for national, state, tribal, and local entities. [48] The NRF also identifies fifteen emergency support functions (ESFs), detailed protocols that structure these activities further. ESF #8, which delineates procedures pertaining to emergency response in the realms of public health and medicine, is of particular import to blood product management. Other notable federal policies include 2006's Pandemic and All-Hazards Preparedness Act (PAHPA), which aims to improve the U.S.' medical response capabilities with respect to chemical, biological, radiological, or nuclear (CBRN) threats. [49] Under the provisions of PAHPA, federal policymakers also established the Biomedical Advanced Research and Development Authority (BARDA), which in turn coordinates stockpiling activities and countermeasure acquisition at the national level. The Public Health Service Act, another federal law passed in 1944, defines a medical countermeasure as follows:

> "…A drug (as that term is defined by section 321(g)(1) of title 21), biological product (as that term is defined by section 262(i) of this title), or device (as that term is

> defined by section 321(h) of title 21), that the Secretary determines to be a priority (consistent with sections 182(2) and 184(a) of title 6) to - (i) diagnose, mitigate, prevent, or treat harm from any biological agent (including organisms that cause an infectious disease) or toxin, chemical, radiological, or nuclear agent that may cause a public health emergency affecting national security; or (ii) diagnose, mitigate, prevent, or treat harm from a condition that may result in adverse health consequences or death and may be caused by administering a drug, biological product, or device that is used as described in this subparagraph." [50]

Arguably, blood products are lifesaving medical countermeasures as defined by these criteria. However, neither PAHPA, nor the Public Health Security and Bioterrorism Preparedness and Response Act of 2002, nor BARDA's Strategic Plan for 2011-2016 make any explicit mention of blood products, nor do they offer any guidance for blood product management during public health emergencies. Instead, the various agencies described below jointly shoulder the task of coordinating blood product distribution during such events.

5.1.1 Department of Health and Human Services

HHS is a cabinet department within the U.S. government that works closely with state and local agencies, with the goal of "protecting the health of all Americans and providing essential human services." [51] As the federal government's principal manager of healthcare operations, HHS encompasses numerous divisions responsible for facilitating healthcare delivery nationwide; notable among these are CDC, FDA, and NIH. As specified in ESF #8 and its Public Health Emergency Medical Countermeasures Enterprise (PHEMCE) Strategy, FEMA tasks HHS with assuming "operational control of Federal emergency public health and medical response assets, as necessary, in the event of a public health emergency"; in this capacity, HHS is responsible for

spearheading efforts aimed at ensuring the availability and safety of medical countermeasures against CBRN agents (including blood products). [52, 53] During public health emergencies that elevate the demand for blood products, HHS liaises with AABB to assess the situation at hand, evaluate supply chain sufficiency, and determine the optimal course of action for allocating available products. [54]

In order to fulfill its NRF-mandated obligations, HHS maintains an Advisory Committee on Blood and Tissue Safety and Availability, established in 1997. This committee reports directly to the Secretary of HHS and its activities span the domains of biovigilance, transfusion ethics, transplantation standards, and the economics of biologics acquisition, processing, and distribution. HHS has also developed the Blood Availability and Safety Information System (BASIS), an online tool that monitors blood supplies at participating medical institutions across the country. As of August 2007, there were nine blood centers and 101 hospitals sharing information with BASIS; these data include statistics on adherence to transfusion safety practices, delays in product delivery, and the effects of shortages. [54] Another critical component of HHS operations is NDMS, which consists of various emergency response teams charged with deploying civilian medical teams and supplies to areas overwhelmed by a disaster. [55]

HHS has also developed further plans in an effort to improve the safety of patients and HCWs, with respect to the threat of blood-transmissible viruses. In its 2011 strategy to reduce the burden associated with viral hepatitis, for example, it proposes to improve technologies used to perform viral screening, augment biovigilance initiatives nationwide, and tighten restrictions on blood, organ, and tissue donor eligibility. [10] The Obama administration's National HIV/AIDS Strategy (released in 2010) also designates HHS as a key participant in its plan to achieve greater coordination in the federal response to the HIV/AIDS epidemic. [56] However, the effectiveness of

these plans and their integration into the existing framework for emergency blood product allocation remain to be determined.

5.1.2 Food and Drug Administration

FDA, a subsidiary of HHS, also plays a key role in blood product management, focusing particularly on issues of safety and licensure. Of FDA's various divisions, its Vaccines, Blood and Biologics group handles issues relating to blood product safety. This group includes the Center for Biologics Evaluation and Research (CBER), which is responsible for "the collection of blood and blood components used for transfusion or for the manufacture of pharmaceuticals derived from blood and blood components, such as clotting factors, and establishes standards for the products themselves." [57] In this vein, CBER is also charged with enforcing safety regulations pertaining to donor eligibility, educating donors about the risks associated with bloodborne pathogens, and managing licenses for plasma products, infectious disease tests (including those for HBV, HCV, and HIV), and blood phenotyping reagents. [58, 59]

As the principal administrative body for biologics in the U.S., FDA maintains strict oversight over the blood banking industry, conducting biennial inspections of all blood product facilities and holding blood product manufacturers to the same quality control standards as those of pharmaceutical industrialists. [37] FDA is also closely involved in matters affecting blood product security, providing general directions for managing said products during power outages and severe weather events. However, individual blood banks reserve the authority to manage such incidents as they see fit, with FDA serving as a source of information and assistance if called upon: "Blood establishments collecting and storing blood and blood components generally have written procedures in place to address emergency circumstances. Problems or issues

affecting the blood supply should be brought to the attention of the FDA." [60] It is critical to note that the aforementioned guidelines pertaining to emergency blood product management are not compulsory, nor do they "create or confer any rights for or on any person and does not operate to bind FDA or the public"; in fact, FDA welcomes alternate strategies, provided they satisfy "applicable statutes and regulations." [35, 36]

FDA has also released a number of guidance documents over the years intended both for its staff and the blood banking industry. These documents describe advances in blood product analysis and drug manufacturing, offer recommendations for the proper implementation of new technologies, contain strategies for minimizing the risk of bloodborne infections, and include guidelines to follow when screening for select pathogens. [61] One such document, for example, provides blood banks with deferral guidelines to implement in the event that a donor presents with multiple positive HBV NAT results. Given the relative non-specificity of this test, FDA recommends that blood banks refrain from discarding the reactive donation and instead reserve it for producing plasma derivatives as opposed to performing an allogeneic transfusion. [35] FDA proposes additional, extensive parameters for screening blood donations for HCV. In the event of positive HCV NATs, for instance, FDA recommends that the blood bank look back into the donation history of the individual in question for further indicators of HCV infection; this strategy is also prescribed when a donation yielding negative NAT results still generates positive HCV antibody tests. [36]

Current FDA guidelines are especially stringent with respect to testing blood donations for HIV. During the early stages of the AIDS epidemic in the U.S., scientists and public health officials struggled to pinpoint the various routes by which people acquired HIV infections. Although they soon identified unprotected sex as a significant mode of HIV transmission, the

emergence of new cases in hemophiliacs, infants, and recipients of blood transfusions indicated that HIV was a blood-transmissible pathogen. As a result, the blood banking industry was suddenly confronted with intense scrutiny and criticism. CDC officials at the time favored implementing stricter deferral guidelines barring gay men, Haitians, and IDUs from donating blood; however, this recommendation met with considerable resistance. [62] The National Hemophilia Foundation, for example, fretted over the implications of connecting what was still considered a gay man's disease to the contamination of Factor VIII, a clotting protein isolated from blood and used to prevent hemorrhaging in hemophiliacs. [62] Gay community leaders, on the other hand, condemned the deferral guidelines as civil rights infringements. Doctors, too, worried about potential blood shortages stemming from the ban since gay men made significant contributions to the nation's blood reserve. [62] Furthermore, FDA resented CDC's apparent intrusion into their jurisdiction, believing that CDC "had taken a bunch of unrelated illnesses and lumped them into some made-up phenomenon as a brazen ruse to get publicity and funding for their threatened agency." [62] Today, however, in cognizance of the various routes of HIV transmission, FDA's donor deferral policies extend to MSMs, IDUs, those who have taken money or drugs in exchange for sex, and those who have engaged in sex with the aforementioned individuals, among others. [58]

5.1.3 Centers for Disease Control and Prevention

While HHS, FDA, DHS, and DoD focus predominantly on creating and enforcing safety policies, CDC, another subsidiary of HHS, participates directly in many of the biovigilance initiatives that ensure blood product security and keep health authorities appraised of the burdens associated with blood-transmissible pathogens. CDC's Division of Healthcare Quality

Promotion, for example, maintains an Internet-based surveillance program known as the National Healthcare Safety Network (NHSN). Like BASIS, NHSN enrolls healthcare facilities nationwide on a voluntary basis, and assists them in reporting adverse events such as hospital-acquired infections, identifying epidemiological trends, pooling public health data, and sharing best practices. [63] The Biovigilance Component of NHSN includes a Hemovigilance Module, which enables healthcare facilities to log and track errors, near misses, and adverse patient reactions during blood transfusions. [64]

In addition to compiling data on transfusion-related incidents through NHSN, CDC also directly monitors the safety of blood products themselves using two additional surveillance strategies: the Universal Data Collection (UDC) system and the Thalassemia Data and Blood Specimen Collection (TDC) project. Through UDC and TDC, CDC screens hemophiliacs and thalassemia patients for bloodborne pathogens that could potentially endanger the blood supply, such as HIV, the hepatitis viruses, and WNV. [65] Doing so enables CDC to "to detect known and emerging infections that could be transmitted through the frequent blood transfusions required by people with the severe anemia caused by thalassemia." [65] CDC also maintains a repository of sera from participants in UDC and TDC screening initiatives, which facilitates future outbreak investigations. In 2004, for instance, analysis of the serum samples in this repository helped researchers determine the route of transmission for parvovirus B19, a bloodborne virus responsible for a common childhood rash. [65]

Although CDC is not an official lawmaking body, it does collaborate with working groups in various government offices to ensure timely, effective responses to outbreaks with potential consequences for blood product safety. Among these are the Public Health Service Blood and Tissue workgroup and the Blood, Organ, and Other Tissue workgroup, in addition to

several other pathogen-specific workgroups. [65] In accordance with Presidential Decision Directive 39, CDC, with support from HHS and the Federal Bureau of Investigation, has also created the Laboratory Response Network (LRN). [66] LRN is a coalition of international, national, state, and local laboratory facilities charged with providing technical support during chemical or biological emergencies, thereby augmenting the U.S.' overall laboratory capacities. [66] CDC also maintains strong working relationships with its federal counterparts; namely, FDA, as well as its cabinet department, HHS.

5.1.4 Departments of Defense and Homeland Security

DHS and DoD operations are critical to maintaining the integrity of the American blood reserve. By and large, DHS plays a supervisory role with respect to blood product management during emergencies, focusing on the proper execution of ESF #8 and coordinating emergency mitigation activities at the federal, state, and local levels. DHS' major contributions to emergency management at the national level include developing the National Inventory Management System (NIMS) in 2004. NIMS, a framework for managing disasters of all scopes, represents a standardized approach to addressing public health emergencies, including blood product shortages or distributional challenges.

DoD, meanwhile, engages more directly in managing the flow of blood products from donors to recipients. In order to support the operations of its Military Health System, for example, DoD established an Armed Services Blood Program (ASBP) in 1952, which today collects blood donations from select blood centers across the nation, as well as from locations in Japan and Germany. [67] These donations, which are intended exclusively for military families and members of the Army, Navy, and Air Force, traverse a regulatory pipeline separate from the

blood product delivery system serving civilian communities. ASBP feeds newly acquired units of blood through its whole blood processing laboratory, after which they enter an Expeditionary Blood Transshipment System (an Air Force-staffed module responsible for distributing blood products to detachment units), which in turn forwards the blood to military hospitals, navy ships, support groups, and first responders. [68, 69] DoD employs FDA-licensed software, the Defense Blood Standard System (DBSS), to manage the logistics of processing donors, collecting blood, managing inventory, and testing blood products. [70] Like BASIS, DBSS supports "lookbacks for infectious disease reporting requirements" and may play a significant role in analyzing blood product supply chains and safety in the event of an emergency. [70] A 2001 memorandum penned by the Inspector General of DoD, however, reported that DBSS "was not adequate to meet all user and mission needs of the Armed Services Blood Program" and "could adversely affect asset accountability, increase the workload at Blood Program Organizations, increase the risk of blood inventory errors, and could possibly result in the inappropriate release of blood products." [71]

DoD has also instated several military-specific policies to ensure blood product security with respect to blood-transmissible viruses, which inflict a growing burden on servicemen and women. Given the military's vaccination policy for new recruits, the prevalence of HBV in the military blood supply is extremely low. HIV and HCV, however, pose a more substantial risk. In 1999, the American Forces Press Service reported that less than 1% of 20,000 military officers tested positive for HCV, a figure roughly one third of the national average at the time. [72] Initially, DoD attributed the low prevalence of hepatitis C to stringent military screening measures. Nevertheless, by the end of 2012, the *Marine Corps Times* reported 2,700 new cases of HCV infection among armed service members emerging between 2000 and 2010, while the Veterans Health Administration system tallied 170,000 chronic hepatitis C patients and an additional

4,800 receiving combination drug therapy for their infections. [73] DoD's stance regarding HIV infections, meanwhile, correspond with the National HIV/AIDS strategy. Specifically, its Directive 6485.1 prevents the military from recruiting HIV-positive individuals and mandates biennial screenings for all personnel. [74] Therefore, armed service members who test positive are often disqualified from future deployments since "the protection of the military blood supply is of utmost importance. War and major battles require large quantities of blood and 'battlefield transfusions' may be required." [75, 76] This directive also bars infected service members from donating blood, organs, or tissues, and also permits military and civilian blood banks to trace medical histories to discover potential cases of bloodborne viral transmission. [77]

In addition to ensuring the safety of the military blood supply, DoD plays an important role in addressing infectious disease outbreaks on a global scale. Its Armed Forces Health Surveillance Center, responding to President Clinton's Directive NSTC-7 in 1997, established a division known as the Global Emerging Infections Surveillance and Response System (GEIS). GEIS is meant to "centralize coordination of surveillance efforts conducted through DoD overseas medical research and development laboratories… Additionally, all host country partner activities are directed toward improvement of each country's diagnostic and reporting requirements in accordance with World Health Organization's International Health Regulations (2005) core capacities." [78] GEIS thus serves as a mechanism by which DoD can integrate its blood supply regulatory activities with ongoing global efforts.

5.2 NON-GOVERNMENTAL AND HUMANITARIAN ORGANIZATIONS

While the U.S. federal government is predominantly responsible for overseeing blood product management, several non-governmental organizations (NGOs) and humanitarian groups play critical roles in the actual acquisition and dissemination of blood products. Because these groups often interface directly with the recipients of medical resources – patients, medical institutions, and communities in need – they are uniquely situated to optimize blood product safety standards and distribution. The following section explores the scope and impact of blood product management policies in the private and nonprofit sectors.

5.2.1 AABB

AABB (founded in 1947 as the American Association of Blood Banks) is a professional body dedicated to upholding the technical and ethical standards associated with blood banking, transfusion medicine, and various cellular therapies in the U.S. In that capacity, it supports numerous education and training endeavors for aspiring healthcare professionals, in addition to offering technical assistance to medical institutions internationally. AABB also coordinates a number of activities aiming to augment the U.S.' biovigilance capabilities, assess the quality and availability of the American blood reserve, and provide timely assistance to disaster victims.

AABB's Interorganizational Task Force on Biovigilance monitors blood, organ, and tissue safety initiatives by collecting data through several extensive bio- and hemovigilance networks. Working in conjunction with HHS, CDC, and the U.S. Biovigilance Network, it helps run the hemovigilance module of NHSN, which allows participating healthcare facilities to evaluate their performances with respect to the safety of transfusion recipients. [79] AABB also

maintains its own module within NHSN, the Transfusion Safety Group, which provides enrollees with data analysis services and recommendations for implementing best practices. [79] Due to confidentiality statutes, however, CDC cannot inform AABB which medical institutions enroll in NHSN; instead, if a hospital wishes to make use of AABB services, it must notify AABB of its enrollment in the system. [80] The Donor Hemovigilance System, on the other hand – a separate unit representing collaboration between AABB, HHS, ASBP, ABC, ARC, and Blood Systems, Inc. – tracks blood donor safety by soliciting records of adverse events from participating institutions. [81] AABB also founded the National Blood Data Resource Center (NBDRC), which encourages further participation from and research collaboration (including NBCUS) between individuals and institutions working in the field of transfusion medicine. [82]

Furthermore, AABB is currently working to add two new components to its arsenal of biovigilance strategies: one, a system tracking complications stemming from cellular therapies such as stem cell transplants; and the other, a system monitoring adverse events resulting from tissue transplants. [83] In addition to surveying the safety of blood donors and recipients through these systems, AABB also presides over several pathogen-specific surveillance initiatives. For example, it collaborates regularly with various governmental committees to formulate policies concerning transfusion-transmitted pathogens. Viruses of interest include HIV, hepatitis A virus, HBV, HCV, cytomegalovirus, and HTLV-I/II; other diseases of interest include babesiosis, Lyme disease, malaria, and CJD. [83] AABB also features two biovigilance networks that focus exclusively on tracking WNV and *T. cruzi*. [84, 85]

Supplementing AABB's various biovigilance initiatives is its work in the realm of disaster mitigation. AABB defines a disaster as

> "any domestic disaster or act of terrorism that: suddenly requires a much larger amount of blood than usual, temporarily restricts or eliminates a blood collector's ability to collect, test, process, and distribute blood, temporarily restricts or prevents the local population from donating blood, restricts or prevents the use of the available inventory of blood products requiring immediate replacement or re-supply of the region's blood inventory from another region, or creates a sudden influx of donors requiring accelerated drawing of blood to meet an emergent need elsewhere." [86]

In response to these potentially ruinous consequences, AABB has set up a National Blood Exchange (NBE), a non-profit operation that facilitates the sharing of blood resources in the event of a shortage. Since its inception, NBE has coordinated the distribution of 185,000 units of blood annually. [87] AABB has also created the Interorganizational Task Force on Domestic Disasters and Acts of Terrorism (ITF), a professional coalition comprised of representatives from various public- and private-sector groups. Federal members of ITF include HHS, CDC, FDA, and ASBP, while non-governmental affiliates include ARC, ABC, AdvaMed, the American Hospital Association, Blood Centers of America, the College of American Pathologists, the National Marrow Donor Program, and the Plasma Protein Therapeutics Association. [88] During an emergency affecting the blood supply, AABB convenes the ITF to determine the most efficient way to distribute blood to high-need locations via NBE, based on information procured from local blood collection agencies. [88] The guidelines structuring ITF's subsequent recommendations are codified in AABB's Disaster Operations Handbook, a manual describing protocols relating to preparedness, blood product transportation, donor and volunteer management, and coordination with government agencies. The manual also includes contingency guidelines to follow in the event of specific natural or man-made disasters (including biological attacks and influenza pandemics). In support of this work, FDA has granted AABB a two-year contract entitled "Rapid

Data Collection for Response to Bioterrorism, Emerging and Pandemic Agents Threatening the Blood Supply," which charges AABB with developing "rapid data collection tools for blood centers to identify, quantify and reduce risks to the blood supply during such disasters." [80]

Although AABB maintains extensive protocols for handling blood supply-related emergencies, local blood centers nevertheless report problems responding to such events, citing difficulties in "obtaining fuel for generators to collect and maintain blood supplies, emergency vehicles to distribute blood with a limited shelf-life, or reliable access to emergency communications." [89] In light of these lingering shortcomings, AABB works with DHS and HHS to make blood product safety and distribution a higher priority for local emergency management agencies, encouraging them to forge stronger working relationships with medical institutions and blood banks, and submit disaster operation plans to FDA. [90]

5.2.2 American Red Cross

ARC is a nonprofit humanitarian organization that acquires and distributes blood products, offers health education and training to volunteers and HCWs, and provides disaster relief services to affected communities worldwide. ARC occupies a unique niche among American nonprofit agencies, operating under a Congressional charter delineating federally mandated responsibilities: "[fulfilling] the provisions of the Geneva Conventions, to which the United States is a signatory, assigned to national societies for the protection of victims of conflict, [providing] family communications and other forms of support to the U.S. military, and [maintaining] a system of domestic and international disaster relief, including mandated responsibilities under the National Response Framework coordinated by the Federal Emergency Management Agency." [91] In this capacity, ARC plays a critical role in stocking the national

reserve, collecting roughly 45% of the U.S.'s blood products and supplying some 3,000 hospitals nationwide. [24, 92] With approximately 80% of donations solicited through mobile, community-based blood drives, and another 20% originating from ARC centers, patients in need receive blood from ARC at no cost. [92] In order to ensure continuity in the blood supply pipeline and comply with FDA safety guidelines, ARC also conducts testing on all the donations it collects. Standard tests currently screen for HBV, HCV, HIV, Chagas disease, HTLV-I/II, syphilis, and WNV; meanwhile, efforts to develop an effective test for dengue virus are ongoing. [32, 93]

In addition to collecting and screening blood, ARC maintains an elaborate system for delivering blood to high-need locations. Its thirty six domestic blood service regions evaluate their inventory daily and provide hospitals with blood products as needed, and work with NIMS to locate scarce or unavailable components in other regions. [94] Once a hospital files a request for blood, and ARC staff members locate the products of interest, the products are delivered via car, van, truck, bus, air courier service, or, in the event of a pressing emergency, helicopter. [94] The U.S. Army also assists ARC in return for support of ASBP initiatives: "When it does not interfere with the military blood program, it is the general policy of the Army to cooperate with the Red Cross and to support the blood program by assisting with mobile unit visits to Army installations and encouraging Army members to voluntarily donate blood when feasible." [95]

FDA oversees ARC activities relating to blood product management, and reserves certain legal powers over such operations. In 2003, for example, officials from both organizations agreed to the terms of an Amended Consent Decree ("the Decree"), a document outlining legal parameters for handling blood products. In order to promote greater operational efficiency and ensure the safety of ARC-processed blood, the Decree compels ARC to identify and discontinue all obsolete operating procedures, assess the impact of those procedures on blood product safety,

review protocols relating to the use of equipment for collection and screening, improve record management, uphold stricter standards for tracking adverse events during the donation process, and revamp its employee training program. [96] Failure to comply with these FDA-mandated guidelines has proven to be costly to ARC since the issue of the Decree, generating nearly $46 million in fines since 2003. [97] These infringements, which span both managerial oversights and improper handling of blood products, are as follows:

> "The violations range from understaffing, inadequate staff training, and delayed logging of donations, to ineffective screening of donors, failure to add new donors with infected blood to the national list of deferred donors, failure to share information on deferred donors between facilities, and failure to quarantine and recall infected blood units. Other lapses include failing to notify health departments when donated blood was found to have been infected with HIV, Hepatitis C, or the West Nile virus, failing to promptly alert healthcare facilities when expired or infected blood had been distributed, failing to register adverse donor reactions as a result of giving blood, and incorrect labeling of blood products. In addition, the FDA cited the Red Cross for poor quality assurance, including keeping blood products out of controlled storage for more than 30 minutes, a backlog of approximately 18,000 donor management cases, and insufficient record-keeping. Regulators claim the organization allowed employees with no medical training, certification, or experience to serve as Medical Directors in charge of reviewing donor complications, and permitted staff to 'perform tasks they did not understand.' In some cases, employees failed to identify permanently deferred donors who previously gave blood under different or hyphenated names, and were later attempting to donate using just one part of the hyphenated last name." [98, 99]

ARC received its most recent citation in January 2012, resulting in yet another FDA-imposed fine. Indeed, given the scale of ARC's operations, such lapses in management could yield grave consequences for the security of both the domestic blood reserve and blood products

shipped internationally. Despite these risks, however, it is unclear whether ARC resorts to contingency screening guidelines to follow in the event of a public health emergency. Nevertheless, in 2006, the U.S. Senate, recognizing that ARC "supplies blood to approximately one-half the Nation's hospitals, operates the only blood system with the capacity to deliver blood anywhere and anytime it is needed, and is the only non-governmental organization with mandated primary agency responsibilities under the National Response Plan," solicited CDC to support ARC's Biomedical Technology Assurance Initiative. [100] This initiative, which outlines strategies for safeguarding blood supplies from cyber-security and biological threats, draws further support from CDC in the form of funding for additional biosurveillance, capacity-building, and stockpile activities. [100]

5.2.3 America's Blood Centers

Founded in 1962, ABC represents the largest network of nonprofit blood collection agencies in North America, encompassing some 600 centers in 45 U.S. states and Quebec, Canada; these centers, in turn, supply blood (including cord blood), bone marrow, and stem cells to nearly 3,500 hospitals and medical institutions. [101] Indeed, the scope of these operations qualifies ABC, alongside ARC, as one of the leading contributors to the American blood reserve. ABC is unique in that it subscribes to a community-based approach to blood banking: giving local patients in need primary access to blood products collected within their community, and only then distributing excess supplies to other high-need locations. In order to accomplish these tasks, ABC maintains working relationships with several government agencies, collaborating regularly with HHS, FDA's Blood Product Advisory Committee, the Occupational Safety and Health Administration, and the Department of Transportation to ensure that the U.S. blood reserve is

both safe and adequately supplied. [102] To ensure safety, ABC complies with FDA-mandated guidelines for screening blood, performing a total of thirteen tests on all units; of these, eleven detect infectious bloodborne pathogens such as HIV, HBV, HCV, HTLV-I/II, WNV, and syphilis. [103] ABC centers also adhere to FDA's deferral guidelines, nearly always discarding reactive donations and offering consultations to deferred donors. [103]

Like ARC and AABB, ABC's other work also extends into the related domains of medical resource distribution. In this vein, it has developed several software applications to facilitate blood product management and surveillance. One of these, an online tool called Stoplight, tracks blood supply availability at member centers both in the U.S. and Canada. The Foundation for America's Blood Centers, a nonprofit partner of ABC, is also financing the development of three additional blood management systems: HL7 Software, a standardized interface that streamlines data exchanges between blood centers and transfusion centers; Appropriate Inventory Management, a program that enables hospitals to monitor blood availability and patient outcomes; and a radio frequency identification system that tracks blood products at every step of the supply chain. [104] In keeping with its philosophy of community-based blood banking, ABC has also created the Resource Sharing Exchange for its member centers, an Internet-based inventory of available blood supplies. [102]

In addition to maintaining an extensive infrastructure dedicated to blood product distribution, ABC also contributes to numerous emergency preparedness efforts. As a member of AABB's ITF, for example, ABC collaborates with multiple public- and private-sector entities to respond to incidents that affect the nation's blood supply (see section 5.2.1 for further details) such as influenza pandemics. [105] ABC's work in the realm of influenza response also extends to membership in the International Blood Emergency Planning Group, an organization that focuses

on worldwide disaster planning. [105] Since 2001, ABC has partnered with DHS and HHS to devise new strategies for accelerating blood product delivery to high-need areas. It has, for example, developed a hub-and-spoke model consisting of a major blood center located near a commercial airport (the "hub") supported by twelve to fifteen smaller centers nearby (the "spokes"). [105] Furthermore, after supplying U.S. troops with blood during Operation Iraqi Freedom in 2003, ABC established an agreement with DoD whereby DoD may solicit blood support during military, humanitarian, or peacekeeping operations (known as "contingency operations"). [105]

5.2.4 World Health Organization

WHO is an agency of the United Nations (UN) that concentrates on issues of international public health. In that capacity, it offers technical assistance in implementing health interventions, influences research agendas, and provides evidence-based policy recommendations. More specifically, its work also extends to the realms of infectious disease surveillance, emergency preparedness, and blood product safety. As delineated in its International Health Regulations and Constitution, WHO does reserve legal authority to require UN members to report and respond to global health risks. [106] As a member state of the UN, therefore, the U.S. is an active contributor to international public health response activities.

WHO conducts extensive disease surveillance activities worldwide, overseeing a global "network of networks" that pulls data from government institutions, universities, the media, NGOs (including ARC), electronic discussion sites such as ProMed and Sentiweb, and military resources (including GEIS). [107] WHO then integrates these data into its Global Outbreak Alert & Response Network (GOARN), "a technical collaboration of existing institutions and networks who pool human and technical resources for the rapid identification, confirmation and response

to outbreaks of international importance." [108] GOARN tracks the emergence of twenty-one pathogens, including several bloodborne viruses: HBV, HCV, dengue virus, Ebola virus, Marburg virus, Lassa virus, Crimean-Congo hemorrhagic fever virus, and yellow fever virus. [109] WHO, in turn, recommends mandatory HIV, HBV, HCV, and syphilis screening for all blood products collected worldwide, as well as contingency screening guidelines to implement during public health emergencies: [110]

> "In emergency situations in which blood and blood components are needed urgently, but are not readily available from blood inventory, screening with rapid/simple single-use assays could be used to obtain results quickly and enable blood to be released for clinical use in consultation with the prescribing clinician. Wherever possible, however, the blood sample should be retested as soon as possible using an [enzyme immunoassay] or another assay used routinely for blood screening in the laboratory in order to check the validity of the test results. Any discrepant results should immediately be investigated further and corrective action taken, including communication with the clinician who has prescribed the blood. Countries should work towards systems that avoid these situations." [111]

The aforementioned surveillance initiatives are demonstrative of WHO's commitments both to hemovigilance and strengthening the blood management infrastructures of its member nations. Between May of 1975 and May of 2010, WHO released five separate resolutions pertaining to blood product acquisition, screening, and transfusion. Notable recommendations highlighted in these resolutions include: making blood safety a national public health priority, promoting non-remunerative donation practices, implementing national policies to guarantee efficient blood product allocation, improving medical training, and encouraging timely reporting of adverse transfusion events, donor deferrals, and best practices. [112] WHO, with respect to the last recommendation, has regularly solicited blood management data from its member states

since 1998 via questionnaire; the results are subsequently uploaded to the Global Database on Blood Safety (GDBS) in order to "provide information on the current status of blood transfusion services, assess country needs in improving blood safety, formulate strategic recommendations to countries, plan and implement activities and evaluate progress." [113] In order to strengthen working relationships between stakeholders in the realm of international blood product management, WHO established the Global Blood Safety Network (GBSN) (formerly the Global Collaboration for Blood Safety), a partnership between "WHO Collaborating Centres, expert panel members, NGOs in official relations and key implementing partners for blood safety." [114] The collective data gathered from GDBS, GBSN, and GOARN often inform WHO's public health response strategies, which are coordinated through the JW Lee Centre for Strategic Health Operations; specific commissions include organizing the medical response to the Indian Ocean earthquake and tsunami, an outbreak of Marburg hemorrhagic fever in Angola, and Hurricane Katrina. [115]

5.3 SUMMARY OF AMERICAN BLOOD PRODUCT MANAGEMENT POLICIES

Blood products collected in the U.S. must traverse a complex regulatory pipeline before being put to therapeutic use. Federal players in this infrastructure include HHS, DHS, CDC, FDA, and DoD. During public health emergencies, FEMA charges each of these agencies with the task of expediting blood product acquisition, screening, and distribution as dictated by ESF #8 of the NRF. Meanwhile, non-governmental contributors to the blood supply pipeline include AABB, ARC, ABC, hospitals, and independent blood banks. Though all of these agencies span both the

public and private sectors, they collaborate frequently to conduct disease surveillance, advance research in the field of transfusion medicine, enforce the guidelines ensuring that the blood reserve is free of harmful pathogens, and strengthen the policies that govern blood product management during times of peace and emergency. WHO, of which the U.S. is an active member, directs similar activities on a global scale, encouraging international partnership in matters of blood product regulation and dissemination.

Over the years, in cognizance of the public health hazards stemming from an unsafe blood reserve, the aforementioned organizations have executed innumerable activities to ensure blood security. These activities, which are diverse in scope and nature, span several categories: hemovigilance, which includes screening measures and disease surveillance; evaluation, which refers to the software systems and professional networks seeking to improve patient care with respect to transfusions; supply chain analysis, which encompasses the logistics of blood product delivery; and research, which includes those activities aiming to develop new, innovative methods of securing the blood reserve. These endeavors have proven to be fruitful despite the complexities associated with inter-agency collaboration, maintaining America's blood management infrastructure, and responding to pathogenic threats. As a result, the U.S. blood reserve is safer now than ever before. Given recent failures in blood product management during public health emergencies, however, the true effectiveness of current policies remains to be determined.

6.0 BLOOD PRODUCTS AND PUBLIC HEALTH EMERGENCIES

Public health emergencies – which may encompass events as diverse as disease outbreaks, nuclear and radiological accidents, natural catastrophes, or acts of terror – frequently raise the question of proper resource allocation. This issue is especially germane to disasters that deplete communities of human capital, medical equipment, or the infrastructure required to deliver supplies needed for recovery. Kapur and Smith, for instance, point out that during public health emergencies, "international organizations, countries, or local governments may possess the emergency supplies and personnel for a region in crisis, [but] on many occasions they are unable to deliver this assistance in a timely or coordinated manner." [116]

The emergencies described above would undoubtedly amplify the complexities of blood product management. ESF #8 charges HHS and its subsidiaries – CDC, FDA, and NDMS – with most of the responsibility for directing blood product acquisition and distribution efforts during such events. [52] Additional sources of support include AABB's ITF, which helps publicize imminent blood shortages; DoD, which may supplement existing blood products with supplies from the military reserve; and the Department of Justice, which offers security for SNS deployments and blood product supplies during transportation. [52] The nonprofit entities described previously – ARC and ABC – would also contribute to collection efforts and disaster assistance.

The following section includes an analysis of blood product use during the aftermath of past public health emergencies, and identifies and explores blood product-specific challenges

that public health officials, HCWs, and policymakers must account for when determining the optimal course of action to take during an emergency: surpluses and shortages, the logistics of processing and screening, and the impact of emergencies on blood product delivery. This section also includes a brief case study of blood product management efforts after the September 11th attacks, and extrapolates the lessons learned to encompass future emergencies.

6.1 SEPTEMBER 11TH: A CASE STUDY OF MISMANAGEMENT

The events of September 11th, 2001 are among the costliest public health emergencies on American soil in recent memory. The 9/11 attacks also presented public health authorities, emergency responders, and government officials with considerable challenges with respect to blood product management. GAO reports that "large numbers of Americans are willing to donate blood in response to disasters." [24] Smaller-scale emergencies in the years prior to 9/11 – the bombings in Oklahoma City in 1995 and the shootings at Columbine High School in 1999, for instance – certainly confirm this. Though these events resulted in temporary blood product deficits, local donors and blood collection agencies managed to meet the demand for additional products without soliciting assistance from state or federal authorities. [117] In fact, the Oklahoma Blood Institute eventually shipped some 7,000 surplus units of blood collected after the bombings to other parts of the country. [117] The aftermath of September 11th, however, left the U.S.' blood management infrastructure in near-total disarray. Immediately after the attacks, countless individuals instantly volunteered to give blood. Subsequently, HHS, ABC, and ARC issued simultaneous public requests for blood; as a result, collection agencies amassed some 572,000 units of blood in the weeks following 9/11, nearly a 40 percent increase from earlier

monthly averages. [24] Given the emergency at hand, FDA also sanctioned blood screening by volunteers instead of trained HCWs, interstate exchanges of non-licensed blood products, and transfusions of blood that had not been fully tested. [117]

Although certain public health emergencies may require additional blood products, the 9/11 attacks proved to be an exception because there were very few victims who needed transfusions; in fact, most survivors presented with burns and inhalation injuries. [117] Consequently, HCWs used only 258 of the roughly 572,000 units of blood to treat survivors of the attacks. [117] While approximately two-thirds of the donations collected entered the American blood reserve, blood banks ultimately discarded 208,000 units, a nearly 14 percent increase in the rate of blood product disposal due to expiration. [117] The massive influx of blood products also exacerbated the crisis by creating logistical challenges. Dr. Paul Schmidt reports, "Platelets ordinarily harvested from whole blood were lost to use. A processing backlog delayed the testing of the fresh platelets needed for patients with thrombocytopenia. At one hospital, where volunteers helped screen donors, 11 percent of the blood collected could not be used because of errors in the screening process." [117] Such waste ultimately generated $5 million in financial losses for blood banks. [24] The federal government, too, lost nearly $500,000 after compensating blood collection agencies for processing the surplus of donations. [117]

Although the surge in the American blood reserve after 9/11 engendered major logistical ordeals, analysis of entering blood products revealed more alarming trends. Many of the individuals who stepped forward to give blood were first-time donors, a pattern commonly observed after many disasters. [118] Dodd, et al., however, report that the incidence of HBV, HCV, HIV, and HTLV-I/II infections is 2.4 times higher among first-time donors compared to repeat donors. [119] The aftermath of 9/11 certainly mirrored this phenomenon, with blood banks

observing a nearly three-fold increase in donations testing positive for HBV, HCV, and HIV. [118] Though collection agencies discarded reactive donations, the increased pathogenic load in the blood reserve combined with relaxed screening guidelines undoubtedly elevated the risk of acquiring a blood-transmissible infection during this period.

Robert Jones, the president of New York Blood Center, noted, "People needed to be with one another, friends, neighbors and strangers. Blood donation sites gave them that opportunity along with something personal to do for the cause. As the response was disproportionate to the medical need, the social value of blood donation at once became far more important to the community than its medical value." [117] The repercussions emerging from such immense public altruism, however, ultimately proved detrimental to the blood industry and the efforts of agencies that collected blood after the attacks. ARC, for example, confronted much criticism for its blood management strategies, and subsequently underwent major administrative changes as a result. [117] The blood industry as a whole, too, faced considerable public distrust after its mismanagement of donations after 9/11.

6.2 BLOOD DEMAND, SURPLUSES, AND DEFICITS

CBER defines a biologic as medically necessary if "it is used to treat, cure, mitigate, prevent, or diagnose a serious or life-threatening disease or medical condition and there is no other available source or alternative therapy." [120] By this logic, it follows that blood products were medically unnecessary following the 9/11 attacks. However, such difficulties, while certainly burdensome to the U.S.' blood management infrastructure, are no less challenging to address than those associated with blood product shortages. NBRDC reports that the number of transfusions

performed in the U.S. increases 6 percent annually, a trend likely to persist due to an aging population, an increase in surgical procedures performed, and growing use of medical technologies such as chemotherapy and organ transplantation. [121] In light of the growing demand for blood, such shortages, which occur seasonally in the U.S., may force hospitals to begin rationing blood products or cancel surgeries until emergency management personnel can resolve the crisis at hand.

Given the short shelf lives of most blood products, maintaining an adequately stocked inventory and ensuring minimal waste presents blood banks with a considerable challenge. Furthermore, it is difficult to predict just how much or little blood a public health emergency will require. Injuries stemming from building collapses, for instance, typically do not require blood transfusions. On the other hand, a large-scale nuclear disaster that subjects a population to significant radioactive exposure will almost certainly require large quantities of blood products – specifically, platelets – to treat victims of acute radiation syndrome or traumatic injuries. Recent models of a nuclear detonation in a city such as Washington, D.C. project that as many as 30,000 individuals will require specific care for bone marrow suppression; that is, a decrease in cells needed for immunity, clotting, and oxygen carriage. [122] Because clinicians require blood products to successfully this condition, the need for blood products – specifically, platelets – will increase dramatically. The shelf life of donated platelets, however, is a mere five days. [123] The high turnover rate thus necessitates consistent donations to maintain the blood supply pipeline. Unfortunately, a detonation and comparable large-scale emergencies would likely incapacitate many healthy individuals – the source of these donations – and thus render them incapable of providing much-needed platelets, while continuing to amplify the demand for blood. On a similar note, several potential agents of bioterrorism include blood-transmissible viruses: dengue

virus, yellow fever virus, Ebola virus, and Marburg virus. Contamination of the blood reserve or widespread infection by any of these hemorrhagic fever viruses could rapidly diminish available supplies of safe blood products.

6.3 EMERGENCY BLOOD DISTRIBUTION AND SCREENING

Public health emergencies such as disease outbreaks or acts of bioterrorism would have relatively little impact on the physical infrastructure required to deliver blood products in a timely manner; namely, vehicles, roads, and storage facilities. Natural disasters, however, along with certain man-made disasters (e.g. nuclear terrorism), could quickly render these critical components of the blood product supply chain inoperative. Immediately after the 2003 earthquake in Bam, Iran, for instance, blood collection agencies amassed 108,985 units of blood, but, due to a deficient delivery scheme and poor transportation capabilities, distributed only 21,347 to hospitals across the country. [124] Kerman Province, the site of the disaster, received only 1,231 (1.3%) of all the units collected. [124] Given the challenges associated with importing blood products from outside locations, some blood banks in the U.S. elect to maintain a frozen reserve of pre-screened blood. However, thawing numerous blood units during an emergency is a time-consuming process and would likely serve as a poor strategy in the context of a mass-casualty emergency. ABC maintains an ad-hoc, hub-and-spoke model for impromptu blood deliveries (see section 5.2.3), but the efficacy of this approach during a large-scale disaster remains unclear, particularly in underserved regions lacking access to multiple blood centers. Differing management protocols between collection agencies and medical institutions could also hinder efforts to launch a concerted response to the emergency at hand.

Even more pressing than the challenge of coordinating distribution is the issue of ensuring the safety of newly collected donations. The full screening process for blood products collected in the U.S. typically takes two days. Although FDA reserves the authority to expedite blood product screening in the event of an emergency (as seen after the 9/11 attacks), this approach may actually generate significant logistical difficulties and endanger the safety of patients being treated with those products. Furthermore, the U.S. lacks rapid diagnostic tests for certain bloodborne viruses that are also prime candidates for weaponization. Even if the blood products on hand are pathogen-free, shortages in the equipment needed to administer them may create further delays. In addition to screening blood for infectious pathogens, blood management agencies must also contend with the issue of cross-matching the blood types of donors and recipients. Type O-negative blood, which HCWs may use to safely treat any individual, is also one of the rarest phenotypes of blood and thus likely to be in short supply during an emergency. Unless blood collection agencies and HCWs characterize each incoming donation, however, transfusion recipients run the risk of developing potentially dangerous autoimmune responses.

6.4 CONSIDERATIONS FOR MEDICAL INSTITUTIONS

As the primary administrators of therapeutic care during public health emergencies, HCWs and hospitals play a crucial role in addressing the medical repercussions of disasters, which includes administering available blood supplies to disaster victims. The Emergency Medical Treatment and Active Labor Act (EMTALA) charges participating hospitals – those receiving reimbursements from HHS or CMS – with screening and stabilizing any individual who requires emergency care. [125] Originally enacted to prevent hospitals from "dumping" (i.e. inappropriately

transferring) uninsured patients, this law nevertheless yields important consequences for emergency preparedness at medical institutions. During presidentially-declared national emergencies, HHS may waive EMTALA requirements, leaving hospitals free to move or treat patients in accordance with their respective disaster management protocols, or with plans developed by state or local authorities. [126] After Hurricane Katrina, for instance, HHS issued an EMTALA waiver to facilitate the medical response to the disaster, during which time affected hospitals could freely transfer hurricane victims to other institutions. [126] However, because EMTALA waivers are valid for only 72 hours following non-pandemic emergencies, Louisiana hospitals were quickly forced to once again comply with EMTALA or risk incurring hefty fines. [126] Furthermore, state and local incidents that are not presidentially-declared emergencies do not qualify for EMTALA waivers. As seen after 9/11, however, certain disasters could drastically escalate the demand for medical personnel and resources. The ability to move patients from a hospital affected by disaster to one that is better equipped with blood and other medical countermeasures is crucial to meeting this demand. Given the steep costs associated with maintaining a sufficiently stocked blood reserve (see section 4.4) and the difficulties of rationing limited blood supplies, EMTALA appears to unduly burden HCWs attempting to respond to a public health emergency.

A community in the midst of a disaster may also suffer from a shortage of available medical professionals, depending on the nature of the disaster at hand. In fact, many institutions in the U.S. already lack an adequate number of medical technologists to handle laboratory needs during emergencies. [127] Such a deficit in medical expertise will greatly undermine the medical response to a major catastrophe involving many victims or a concurrent shortage in blood products. With fewer available professionals, victims will remain untreated or possibly receive

suboptimal treatment. In a hypothetical case study of a pandemic of bloodborne influenza infections in the U.S., Zimrin and Hess further describe the effect that a disaster might have on a hospital, with respect to blood product management:

> "In the hospital transfusion services, maintaining staff for all work shifts will become increasingly difficult. Here, the loss of specific individuals, such as medical directors, supervisors, and lead technologists, will alter patterns of workflow that are written into policies and procedures and programmed into blood bank information systems. As remaining technologists are asked to assume responsibilities not usually their own, role confusion will occur. This will be especially evident in transfusion services where a certain degree of obsessiveness is a basic job requirement, and the flexibility needed to deal with many kinds of stressful situations may be constitutionally lacking." [128]

However, even if a community in crisis has enough trained professionals on hand to mitigate the effects of a disaster, HCWs still face increased health hazards simply by virtue of their work. Needlestick injuries, for instance, represent a significant mode of transmission for bloodborne viruses and pose a regular threat to HCWs safety on a regular basis. It is estimated that between 600,000 and 800,000 such injuries occur in American medical facilities each year, generating upwards of $500 million in healthcare costs. [129] Given the inevitable surge in individuals requiring blood products during a public health emergency, the likelihood of HCW injury or exposure to bloodborne pathogens is correspondingly higher.

Certain medical institutions have also created contingency plans for allocating blood products in the event of a shortage. The Yale-New Haven Hospital in New Haven, Connecticut, for example, typically carries 300 units of blood and distributes an average of 70 units daily for medical use. [130] In response to seasonal depletions in the blood supply, planners at Yale-New

Haven Hospital have developed an emergency distribution strategy that conserves units of liquid blood while maintaining a frozen reserve of 200 O-negative units. Depending on the severity of the shortage at hand, hospital personnel may cancel elective procedures, ration blood units to high-need patients, or thaw frozen units to ensure optimal blood product allocation. [130] Proper execution of such plans, however, depends heavily on a highly trained staff, the availability of electrical power, and functional medical equipment. Unfortunately, such resources may not be readily accessible during a public health emergency.

7.0 POLICY RECOMMENDATIONS

NIMS defines preparedness as "a continuous cycle of planning, organizing, training, equipping, exercising, evaluating, and taking corrective action in an effort to ensure effective coordination during incident response." [131] As such, preparedness represents a critical determinant of the public's health. Given the importance of blood and its derivatives during the wake of an emergency, it is imperative that both public- and private-sector authorities streamline the U.S.' blood management infrastructure so they are better-equipped to address the needs of local responders, HCWs, and communities in crisis. Current guidelines for blood collection, screening, and delivery appear sufficient in the absence of an emergency, as evidenced by the increasingly infrequent incidence of transfusion-transmitted viral infections in the U.S. These same guidelines, however, present significant obstacles to medical response coordinators attempting to address the needs of populations in crisis.

The following sections include policy recommendations that seek to strengthen the U.S.' response capabilities with respect to blood products and bloodborne viruses. These recommendations focus particularly on the following areas: federal provisions for blood products, HCWs and volunteers, disease surveillance, emergency diagnostics and research, and donor preparedness.

7.1 FEDERAL PROVISIONS FOR BLOOD PRODUCTS

Blood products are undoubtedly lifesaving medical countermeasures, albeit ones that cannot be stockpiled for longer than a few weeks. Given the storage limitations and safety considerations associated with these commodities, the federal government should include specific provisions for blood product management in existing policies, laws, and emergency preparedness guidelines. Relevant policies might include PAHPA, NRF, PHEMCE, the Public Health Security and Bioterrorism Preparedness and Response Act, and BARDA's Strategic Plan. CMS and NDMS could also modify their reimbursement policies to offer larger restitutions to medical institutions purchasing extra blood in response to a public health emergency. Similarly, eliminating the 72-hour EMTALA waiver limit could significantly reduce the onus of rationing limited blood supplies during hospital surges. Extending these benefits to disasters at the state and local level (instead of restricting them to presidentially-declared disasters) could further alleviate the financial and logistical burdens associated with emergency blood product dissemination.

Additionally, in light of the impromptu measures taken after 9/11 – volunteer-performed screenings, interstate exchanges of unlicensed products, and transfusions of unscreened blood – FDA and HHS should implement more stringent emergency blood management regulations in the public, private, and nonprofit sectors. In the interest of time constraints during emergencies, FDA might also consider devising contingency screening guidelines to follow after disasters involving a surge in blood product demand. Additionally, since the vast majority of the American blood reserve originates from nonprofit collectors, further federal collaboration with nonprofit entities is necessary. FEMA, HHS, and FDA, for instance, could work with ABC, ARC, and AABB to create a cohesive blood management plan to follow in the event of a public

health emergency. Such collaborations should ideally include state and local authorities, particularly those representing underserved or under-equipped regions.

7.2 HEALTHCARE WORKERS AND MEDICAL VOLUNTEERS

Successful blood product administration and hospital preparedness depends on the physicians, nurses, and medical technicians responsible for executing emergency protocols. Medical institutions, therefore, could certainly benefit from regular participation in disaster training exercises that include a blood product management component. The federal government's Hospital Preparedness Program could serve as a source of funding for such initiatives. Partnerships with local businesses, organizations, or pharmaceutical providers could also provide hospitals with access to resources in short supply during emergencies.

In order to facilitate emergency operations, hospitals should also review staffing procedures to ensure that enough transfusion specialists are on hand during an emergency; final staffing assignments should be commensurate with the size and special needs of the population at risk during a disaster. Medical institutions might also consider devising blood product conservation plans to enact during shortages, or, in order to optimize processing times, encourage donors to participate in plateletpheresis or erythrocytapheresis instead of whole blood donation. Additionally, implementing policies to reduce the number of unnecessary transfusions performed and the incidence of needlestick injuries would contribute to a safer workplace even during an emergency, thereby ensuring that hospitals do not lose staff to preventable mishaps.

7.3 DISEASE SURVEILLANCE

Surveillance represents a major component of ensuring adequate preparedness with respect to blood products. In that vein, state and local health authorities would certainly benefit from federal funds dedicated to augmenting disease surveillance efforts in their jurisdictions. Granting particular focus to previously undiagnosed or chronic HBV, HCV, and HIV infections would not only enable local health institutions to identify and meet the medical needs of their constituents, but also help ascertain the threat that viral pathogens pose to blood product security.

In addition to boosting surveillance capacities, streamlining and integrating existing software systems could ensure a more efficient and informed response to public health emergencies. Current blood management systems include BASIS, DBSS, NHSN, TDC, UDC, Donor Hemovigilance System, HL7 Software, Appropriate Inventory Management, and Stoplight. Additionally, WHO tracks blood product use on a global scale via GDBS, GEIS, and GOARN. Participation is mostly voluntary, with a limited number of medical institutions contributing information to these largely unlinked systems. Authorities might consider first consolidating these disparate surveillance modules into a central hub where all U.S. medical institutions can access real-time, relevant information: locations experiencing blood shortages, emerging pathogenic threats, or optimal transportation routes for blood product delivery, for example. Following up systemic integration with increased hospital participation is critical to ensuring the utility and success of expanded surveillance activities.

7.4 EMERGENCY DIAGNOSTICS AND FURTHER RESEARCH

Maintaining constant bio- and hemovigilance is an important component of ensuring preparedness with respect to bloodborne threats, but when such threats come to pass, rapid identification of and response to the agents responsible becomes equally important. Given the relative facility with which bloodborne pathogens move from place to place, it is imperative that the U.S. is able to safeguard the national blood supply from non-endemic infectious agents such as malaria or dengue virus. Therefore, NIH and CDC should support research initiatives aiming to develop rapid diagnostic tests for existing and emerging bloodborne pathogens, especially viruses. Other important areas of research include improving the effectiveness of existing medical countermeasures which, unlike most blood products, may be stockpiled: blood substitutes, cytokines, and hematopoietic factors.

Expanding laboratory capabilities to accommodate the challenges associated with emergency management is another potential area of improvement. Well-equipped laboratories could be of immense assistance to medical institutions in the event of a blood product surge, helping to screen donations and thus ensure the safety of available blood products. In this vein, CDC might consider incorporating more laboratories at the state and local levels into LRN, particularly those serving resource-poor or vulnerable populations.

7.5 DONOR PREPAREDNESS

Past emergencies indicate that the public is willing and able to donate blood during times of crisis. However, mass appeals for blood donations immediately after a disaster could quickly

overwhelm the U.S.' blood management infrastructure and damage the public's perception of the blood banking industry, as seen after the events of 9/11. Prior to issuing a mass appeal, therefore, blood collection agencies should first consult with each other to assess the need for blood and only then devise a strategy for communicating with the public to solicit donations. Collection agencies should also consider collaborating with local medical institutions and health departments to conduct outreach activities to educate the public about the role they play in emergency response with respect to blood products. Such initiatives would help create a well-informed population that understands when to donate blood and how to lessen the risk of experiencing an adverse event during donation, thereby reducing blood product waste during public health emergencies. Finally, local emergency management agencies can take additional steps to guarantee the well-being of their jurisdictions. Health departments or individual healthcare providers, for example, could maintain a registry of individuals with certain medical conditions, such as hemophilia, sickle-cell anemia, or thalassemia major. Awareness of these special needs would certainly help optimize efforts aimed at allocating blood products efficiently during a public health emergency.

8.0 CONCLUSION

The purpose of this investigation was to explore the policies governing blood product management in the U.S., and determine whether current policies include adequate provisions for responding to blood product needs during public health emergencies. The investigation revealed that the responsibilities of coordinating blood product acquisition, processing, and delivery span both the public and nonprofit sectors. Despite the importance of blood as a medical countermeasure, nonprofit organizations and government authorities at the federal, state, and local have yet to develop a cohesive blood management strategy in response to community needs during an emergency. One of the most important aspects of blood product management is ensuring that collected products are free of bloodborne pathogens, especially transfusion-transmitted viruses. Notable among these viruses are HIV, HBV, and HCV, which cause infections with significant socioeconomic and clinical burdens.

This investigation began with a description of the importance of blood and its derivatives before discussing the epidemiology and associated economic impacts of HIV, HBV, and HCV infections. It then examined the contents of the American blood reserve, delineated current pathogen screening policies, and analyzed the economics of the blood banking industry. Next, the study parsed the U.S.' complex regulatory framework for overseeing blood product use, identifying various agencies in the federal and nonprofit sectors that handle blood, assessing their roles with respect to viral threats and emergency response, and examining the policies governing

blood use on a day-to-day basis. This analysis revealed that despite significant investments of money, resources, and personnel, critical shortcomings in the U.S.' current approach to blood product management nevertheless remain: difficulties managing blood surpluses and deficits, a propensity towards blood product waste, a cumbersome screening process, poor communication between federal authorities and nonprofit agencies, and challenges in blood product use in medical settings. The study subsequently explored the repercussions of these shortcomings in the context of public health emergencies, considering past emergencies and discussing specific implications for blood banks, donors, HCWs, and medical institutions. Based on these findings, the investigation concluded with several recommendations addressing deficiencies in federal policies, surveillance activities, research initiatives, hospital preparedness, and donor education.

Blood product management represents a unique facet of emergency preparedness. Because blood products originate from individuals the local level, they are community assets in the truest sense. Without a resilient infrastructure in place by which health authorities can acquire and distribute such assets efficiently and conscientiously, the communities from which blood products emerge will remain vulnerable to public health disasters. It is the position of this investigation that in light of their status as community assets, successful blood product management requires significantly more cooperation and collaboration between federal, state, and local public health authorities in order to enhance emergency preparedness in the U.S.

APPENDIX

GLOSSARY OF ACRONYMS

AABB	American Association of Blood Banks (formerly)
ABC	America's Blood Centers
ACBTSA	Advisory Committee on Blood and Tissue Safety and Availability
AIDS	Acquired Immunodeficiency Syndrome
ARC	American Red Cross
ASBP	Armed Services Blood Program
BASIS	Blood Availability and Safety Information System
CBER	Center for Biologics Evaluation and Research
CBRN	Chemical, biological, radiological or nuclear
CDC	Centers for Disease Control and Prevention
CJD	Creutzfeld-Jakob disease
CMS	Centers for Medicare and Medicaid Services
DBSS	Defense Blood Standard System
DoD	Department of Defense
DHS	Department of Homeland Security

EMTALA Emergency Medical Treatment & Active Labor Act

ESF Emergency Support Function

FEMA Federal Emergency Management Agency

FDA Food and Drug Administration

GAO Government Accountability Office

GBSN Global Blood Safety Network

GDBS Global Database on Blood Safety

GEIS Global Emerging Infections Surveillance & Response System

GOARN Global Outbreak Alert & Response Network

HBV Hepatitis B virus

HCV Hepatitis C virus

HCW Healthcare worker

HHS Department of Health and Human Services

HIV Human Immunodeficiency Virus

HTLV-I/II Human lymphotropic virus I and II

IDU Intravenous drug user

ITF Interorganizational Task Force on Domestic Disasters and Acts of Terrorism

LRN Laboratory Response Network

MSM Men who have sex with men

NAT Nucleic acid test

NBCUS National Blood Collection & Utilization Survey

NBE National Blood Exchange

NBDRC National Blood Data Resource Center

NDMS	National Disaster Medical System
NGO	Non-governmental organization
NIH	National Institutes of Health
NIMS	National Inventory Management System
NHSN	National Healthcare Safety Network
NRF	National Response Framework
PAHPA	Pandemic All-Hazards Preparedness Act
PHEMCE	Public Health Emergency Medical Countermeasures Enterprise Strategy
RBC	Red blood cell
SNS	Strategic National Stockpile
TDC	Thalassemia Data and Blood Specimen Collection project
UDC	Universal Data Collection system
UN	United Nations
WHO	World Health Organization
WNV	West Nile virus

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