QATAR UNIVERSITY

COLLEGE OF HEALTH SCIENCE

ASSESSING THE CURRENT STANDING OF HAMAD MEDICAL CORPORATION BLOOD DONOR CENTER IN QATAR AND DEVELOPING A FORECAST MODEL FOR THE BLOOD STOCK NEEDS DURING THE 2022 WORLD CUP EVENT

BY

ABEER SULEIMAN QUSH

A project Submitted to

the Faculty of the College of Health Sciences

in Partial Fulfillment of the Requirements for the Degree of

Masters of Science in Biomedical Sciences

June 2019

COMMITTEE PAGE

The members of the Committee approve the Project of Abeer Suleiman Qush defended on 25/04/2019.

_____

Layla Kamareddine
Thesis/Dissertation Supervisor

_____

Manar Elsheikh Elhassan
Committee Member

_____

Nader.Al-Dewik
Committee Member

_____

Mashael Nedham A J Alshafai
Committee Member

ABSTRACT

QUSH, ABEER, SULEIMAN, Masters of Science : June : 2019, Biomedical Sciences

Title: Forecasting The Blood Stock Required During World Cup Events Qatar 2022 , Prepositions, and Articles

Supervisor of Project: Dr. Layla, Yehya, Kamareddine.

Background: In four years from now, Qatar will host the 2022 World Cup competition which requires high level of preparedness and readiness in different sectors including health care. Among different sub-sections of health, the blood bank and the Blood Donor Center will have a major role in this event especially in case of unforeseen incidences. Accordingly, a proper assessment of the current blood resource availability and a prediction of future blood needs helps in overcoming any obstacle that could be faced during the event. **Objectives:** (1) Highlight the process of the blood supply chain, with a detailed delineation of the needed amount of blood components for both routine and emergency situations services, and outline the proper measures taken to deliver the safest and most appropriate blood units and reduce wastage of blood component. (2) Assess the current standing of the Blood Donor Center and corresponding units in Qatar. (3) Develop a forecast model that predicts the number of blood donors in the next four years as a method to evaluate the readiness of the Blood Donor facility to host the world cup event. (4) Explore the potential challenges that could be faced when meeting the benchmark of donation and established an action plan to overcome these anticipated challenges. **Materials and Methods:** Both qualitative (interviews) and a quantitative (data collection and analysis) approaches have been implemented in our study. We also established a time

series forecast model using Autoregressive Integrated Moving Average (ARIMA). **Results:** The number of donors in the next four years, which is predicted to increase by 26%, will not be able to get accommodated in the current Blood Donor Center facility. Therefore, the established blood stock benchmark will not be met despite that the Center and its corresponding units are fully equipped with high standard equipment and follow international guidelines in the process of blood withdrawal. **Conclusion:** Infrastructure improvements and logistics support for Hamad Medical Corporation Blood Donor Center are required to support the continuously increasing numbers of blood donors for daily demand and during mega events.

Key words: Forecasting, demand, 2022 World Cup, Blood Donor Center, Donor Marker Testing Unit, Component Processing Unit, Blood Bank, Infrastructure, Logistics, Challenges and Awareness.

DEDICATION

I would like to dedicate this work to my parents who supported me in the march of my life.

ACKNOWLEDGMENTS

Praise be to God, first and foremost, for his great blessing, which made us students of knowledge. This project would not have seen light without the kind support and help of many individuals; therefore, I would like to extend my sincere acknowledgment to each of those individuals.

I would like to express my deep gratitude to Dr. Layla Kamareddine, my capstone project supervisor for her patient guidance, useful critiques, enthusiastic encouragement and keeping my progress on schedule throughout the project. A big thank you goes to my committee members especially Dr. Manar Elhassan for her valuable time and consultation and for Dr. Nader.Al-Dewik his kind assistance.

I would like to further extend my gratitude to Dr. Ajayeb Al Nabet the Chairperson of Department of Laboratory Medicine and Pathology-DLMP and to Ms. Tahani Alkuwari the Assistant Executive Director in DLMP for providing the required help and support to accomplish this project. My special thanks also go to Dr. Zeyd Merenkov, the Head of Transfusion Medicine and Blood Banks in Hamad Medical Corporation, and to Dr. Saloua Hmissi and Mrs. Sadika Al-Mahoud the Medical Manager of Blood Transfusion Services in Blood Donor Center for allocating their time and knowledge for the success of this project.

I would also like to thank all the professors and everyone who gave us knowledge and help at the University of Qatar.

I am deeply grateful to my parents for their unbelievable insistence that education pays off. A big thank you for my amazing sister Narjes, brothers Amin and Khalid, and best friends

Lina Hassna, Eiman Alkhayat, Dina Walid, Einas Abed-Rappo, Hana Ramadan, Rana Aljurf and Aisha Khan for all their moral support and encouragement throughout my study. Special thanks to my mother in law for her continuous prayers and for my great leader Mrs. Samira Saleh, who is always by my side and helps me whenever I need the help. Thank you for my son Jaguar who shared with me all nice and hard moment in this journey. I thank everyone that prayed for me and stood beside me to overcome all the challenges during the study period.

“Education is the passport to the future, for tomorrow belongs to those who prepare for its today”; as Malcon X and as Walt Disney said, "All our dreams can come true if we have the courage to pursue them."

TABLE OF CONTENT

DEDICATION v
ACKNOWLEDGMENTS vi
TABLE OF CONTENT viii
LIST OF TABLES xi
LIST OF FIGURES xii
LIST OF ABBREVIATION xiii
CHAPTER 1: INTRODUCTION 1
1.1. Research questions 1
1.2. Research objectives 1
CHAPTER 2: LITERATURE REVIEW 3
2.1. Blood collection 6
2.1.1 Donor selection 7
2.1.2 Donor reception and registration 7
2.1.3 Medical interview 8
2.1.4 Physical Examination 9
2.1.5 Donor Phlebotomy 10
2.2 Blood processing and screening 11
2.2.1. Immunohematological testing 11
2.2.2. Blood components production 12
2.2.3. Blood screening 13
2.2.4. Pathogen inactivation 15
2.2.5. Blood Storage 16
2.3 Blood distribution to hospitals and health care institutions 17
2.4 Blood disposal 18
CHAPTER 3: MATERIALS AND METHODS 22
3.1. Ethical compliance 22
3.2. Data collection 22
3.2.1. Qualitative approach 22
3.2.2. Quantitative approach 23
3.2.2.1. Data collection from interview and site visits 23
3.2.2.2. Data retrieved from Hematos IIG, Medinfo System database 24

3.3. Forecast Model 24
CHAPTER 4: RESULTS 29
4.1. Current standing of the HMC-BDC and its infrastructure 29
4.1.1 Available assets 29
4.1.2 Personnel 30
4.1.3 Mobile services provided by the HMC-BDC 30
4.2. Blood collection process 33
4.2.1 Donor reception and registration 33
4.2.2 Medical interview 34
4.2.3 Physical examination 34
4.2.4 Donor phlebotomy 35
4.3. Blood processing and screening 37
4.3.1. Component Processing Unit 38
4.3.2. Immunohematological testing and process of blood components production 39
4.4. Donor marker testing unit 42
4.4.1 Blood screening and Pathogen inactivation 43
4.5. Blood quarantine 44
4.6. Blood storage 45
4.7. Blood distribution to hospitals and health care institutions 45
4.8. Blood disposal 46
4.9. Descriptive analysis 47
4.10. Forecasting 54
CHAPTER 5: DISCUSSION 56
5.1. Challenges 60
5.1.1. Challenges related to donors 60
5.1.2. Challenges related to infrastructure and logistics 61
5.1.3. Challenges related to awareness 63
CHAPTER 6: CONCLUSIONS 65
6.1. Summary of major findings 65
6.2. Research limitations 65
6.3. Recommendations 66

REFERENCES 70

LIST OF TABLES

Table 1: Dickey Fuller Test Results *26*

Table 2: ARIMA Model (1,0,1). *28*

Table 3: Available Assets at the HMC-BDC *29*

Table 4: Staff Number and Duty Schedule at the HMC-BDC *30*

Table 5: Mobile Services Provided by the HMC-BDC *31*

Table 6:Physical Examination Acceptance Criteria *35*

Table 7: Available Equipment at the Component Processing Unit *39*

Table 8: Differences Between Reveos and Cryo Blood Bags. *41*

Table 9: Assessing the Availability of Equipment at the Donor Marker Testing Unit *43*

Table 10: Blood Components Storage Shelf Life *45*

LIST OF FIGURES

Figure 1: ACF plot for ARIMA in STATA..... 27

Figure 2: Partial Correlogram for ARIMA in STATA..... 27

Figure 3: The ongoing blood supply chain processes in the HMC-BDC and its corresponding units..... 32

Figure 4: Summarizes the allocated time for each step of the blood donation process..... 33

Figure 5: Process of blood collection and donor capacity on daily basis..... 37

Figure 6: Percentage of registered Qatari versus Non-Qatari donors. 48

Figure 7: Percentage of male donors versus female donors registered in the HMC-BDC over a six years period ranging from 2013 to 2018...... 49

Figure 8: Donors demand pattern over a six years period ranging from 2013 to 2018.. ..... *50*

Figure 9: Percentage of deferred donors versus eligible donors in blood donation process...... 51

Figure 10: Percentage of part taking donors donating either at HMC-BDC or through off-sight campaigns over a six years period ranging from 2013 to 2018.. 52

Figure 11: Percentage of donors participating in different service provided by the HMC-BDC over a six years period ranging from 2013 to 2018...... 53

Figure 12: Average percentage average of blood disposal in HMC-BDC and other facilities over a five years period ranging from 2014 to 2018. 54

Figure 13: Predicted number of blood donors in Qatar from 2013 to 2022. 55

LIST OF ABBREVIATION

American Association of Blood Banks (AABB)

Autocorrelation function plot (ACF plot)

Blood Donor Center (BDC)

Box-Jenkins (BJ)

Cryoprecipitate Antihemophilic Factor (AHF)

Council of Europe (CE)

Donor History Questionnaires (DHQ)

Food and Drug Administration (FDA)

Fresh Frozen Plasma (FFP)

Hamad Medical Corporation (HMC)

Internal Quality Control (IQC)

Medical Research Center (MRC)

Nucleic Acid Amplification Technology (NAT)

Packed Red Blood Cells (PRBC)

Plasma Frozen within 24 Hours after phlebotomy (FP24)

Platelet Additive Solution (PAS)

Saline Adenine Glucose Mannitol solution (SAGM)

Short Messages (SMS)

Transfusion Transmitted Infection (TTI)

Red Blood Cells Leukocytes Reduced (PRBCs)

National Center for Cancer Care & Research (NCCCR)

Qatar Identification card (QID)

CHAPTER 1: INTRODUCTION

Qatar is expecting around 1.3 million football fans during the World Cup competition. This event requires proper preparedness and readiness in different sectors including the health care. Among different sub-sections of health, the blood bank and Blood Donor Center (BDC) will have a major role in case of unforeseen incidences that might happen during this event. Therefore, the blood bank should have adequate blood stocks and should stay alerted to any risk that could occur in case of any emergency. A proper assessment of current blood resource availability, stock management, and a prediction of future blood is needed to provide quality services in this sector and help in overcoming any obstacle that could be faced during the event.

1.1.Research questions

(i) What is the expected percentage increase in the number of blood donors in four years from now?

(ii) Is the Blood Donor Center at Hamad Medical Corporation prepared to accommodate a huge number of donors?

(iii) What are the possible challenges that could be faced by the Blood Center as a result of the anticipated increase in the number of donors?

1.2.Research objectives

This study encloses four main objectives: First, to outline the detailed processes of blood collection, processing, screening and storage at the Hamad Medical Corporation Blood Donor Center (HMC-BDC), delineate the needed amount of blood components for both routine and emergency situations services, determine the implicated measures to deliver the safest and most appropriate blood unit, and identify the followed practices to reduce

wastage of blood and blood components. Second, to assess the current standing of blood stocks in the blood bank and questions self-sufficiency and ability to meet blood stock demands during the 2022 event. Third, to develop a forecast model that predicts the number of donors in the next 4 years as a method to evaluate the readiness of the HMC-BDC facility to host the world cup 2022 event. Finally, to explore the potential challenges and obstacles that could be faced to meet the benchmark of donation and provide recommendations and an action plan to overcome anticipated emerging challenges.

CHAPTER 2: LITERATURE REVIEW

Since 1930 until nowadays, the Fédération Internationale de Football Association (FIFA) World Cup competition is considered the biggest sport event in the world. This event encloses 208 members of FIFA associations competing together to win the World Cup every four years [1]. In such mega events usually, the hosting country has to meet certain preparation standards in different aspects including infrastructure (stadiums, hotels, transport, and communication services) [2]. When Russia hosted the 2018 World Cup event, national and urban improvement was its primary target [3, 4]. Eleven cities across Russia welcomed more than a million international spectators [5]. Around ninety per cent of the initial investment was planned to develop the infrastructure of cities and communities. Lots of effort also extended beyond the sport stadia and where mainly directed towards improving the cities around Russia, as such mega-events are not only organized for entertainment purposes but also contribute to advancement of many national programs, mainly those based on economical foundations [6]. Such events develop nations and promote investment, therefore creating better life style for millions of people [4]. Several reports issued by different consulting companies outlined such advantages of hosting mega-events [7-9]. Organizing the World Cup event in South Africa in 2010 for example reduced poverty and encouraged public health awareness. [10]. Likewise, the 2014 World Cup event and the 2016 summer games organized in Brazil aimed to develop urban transport and advancement of nearby neighborhood in Rio de Janeiro [11]. It is worth mentioning here that global media helps the sports industry a lot and influences decision-making. The economy of countries hosting mega event vastly increases usually from tourism and advertisement based revenues [12]. The revenues generated from the 1994

World Cup in the United States, for instance, exceeded four billion dollars, flourishing tourism in the States at the time [13].

In December 2010, and on that cold Zurich night, the FIFA organizers surprised the world by granting the small Persian Gulf State of Qatar the opportunity to host the 2022 World Cup event [14]. Although Qatar is a small country, populated by around 300,000 citizens only, it is considered one of the richest per capita states globally. Qatar, the sovereign Arab State, has gained the majority of the FIFA executive committee votes, turning the dream of hosting the 'royal football league' into reality. Accordingly, Qatar became the first Middle Eastern Islamic country that merited the privilege of hosting this global sport event. The outcomes of this event, which are aligned with Qatar's 2030 vision, will place Qatar in universal recognition, cultural exposure, and at the center of business activities around the world [15]. Today, Qatar's road map is heading towards an international center for sport excellences, that creates a long lasting legacy for Qatar in the Middle East, Asia and the world [14]. For the past several years, Qatar has paid particular attention to sports at the national, regional and international levels, as it believes in the ability of sports to bridge among nations worldwide. World cup is not the first experience for Qatar to host a sport event. Qatar has previously hosted the 2006 Asian Olympic Games and the 2015 World Handball Cup events successfully [16]. Qatar continues its path towards organizing successful sporting event and establishing a state-of-art infrastructure by governmental, quasi-governmental and private companies [15].

Qatar is expecting around 1.3 million visitors including fans, spectators and media representatives to attend the World Cup event [17]. To be able to successfully host that

number of visitors, Qatar should be at a high level of preparedness in all sectors. As part of its preparations, Qatar plans to invest more than $200 billion on constructions and infrastructures. The plan includes building a new airport, public transportation routes such as a metro system, high-speed rail network, and 40,000 more hotel rooms and residential buildings in addition to the currently available ones[18,19]. Moreover, Qatar is also constructing air-conditioned stadiums with breathtaking designs, and many entertainment venues to meet the FIFA requirements. Besides that, Qatar and through its public health institution, is working on providing an advanced health care system that offers high quality services based on national health policies that integrate specific standards of economical, social, financial, administrative and technical aspects [20]. The 2022 Local Organizing Committee (LOC) is currently working on meeting the international standards for health and medical services with particular focus on health care facilities, emergency medicine provisions and specific medical systems, including staffing, infrastructure and anti-doping services [2].

Among different health care services, blood donation is of a primary concern to the LOC members because blood serves as a major lifesaving element in cases of any medical emergencies or complication. In the blood donation center, several blood supply chain activities routinely occur including (1) blood collection from donors (2) blood processing (3) distribution of blood components to all hospitals and healthcare institutions and (4) blood disposal. Appropriate planning and controlling of these activities is required to avoid any stock-out or outdate of blood components [21].

The management team at the Blood Center encourages people to participate in

humanitarian practices in cases of emergency or when blood stocks are decreases. The team members reach out to regular donors and other members of the population in several ways including campaigns, phone calls, sending emails, text messages, media (TV or radio) and through social networks (Facebook, Twitter, etc.). The collection process can be carried out either in public or in private areas of public and private institutions, companies and hospitals [21, 22]. This encouraging role of the management team members is very important because in some countries, voluntary donation is not considered a regular ritual. Blood services vary between countries and are usually either centralized or decentralized. The choice between either services is related to many factors including building, infrastructure, transportation facilities, and the availability of skillful and trained staff. Many developed countries have implemented the centralized model, which aligns better with their national management structure and policies [23].

Each country has its own National blood policy that describes the principles and strategies of the blood supply chain from donor recruitment, to donor selection and deferral, to transfusion transmitted infection (TTI) blood screening, to reactive screening test results confirmation, to donor notification of positive TTI test results, to readings post-donation support that include counselling and referral [24]. The general blood collection process is summarized below.

2.1. Blood collection

Whole blood is generally collected from donors with a minimum interval between one donation and the other of 12 weeks for males and 16 weeks for females. Platelets and plasma collections happens more frequently however and within shorten intervals [25].

2.1.1 Donor selection

Donor selection is an important building block of the blood collection process. Many considerations are taken into account during the donor selection process including: (1) protecting the donors from any adverse post donation effects (2) protecting the recipients and reducing the risk of TTIs (3) avoiding resources wastage that arises from donors that don't comply with donation guidelines [26]. Recent reports from the World Health Organization Global Blood Safety Database on Blood Safety show that 92 million blood donations from 164 countries are collected yearly, 1.6 million units of which are wasted due to positive detection of the infectious markers of TTI, HIV, hepatitis B, hepatitis C and syphilis, with at least 13 million deferral donors because of anemia [27]. Collectively, these aforementioned considerations necessitates an effective blood donor selection process [26].

The health status of the donors is another crucial factor that is considered during the selection process. The donor should be in a good health on the day of the donation to avoid any health related complications during the collection process [26]. Donors should eat a light meal before donating blood to avoid fainting, and a heavy meal should be avoided prior to donation to avoid the detection of lipid plasma, a condition that necessitates discarding the collected plasma [28].

2.1.2 Donor reception and registration

All potential blood donors that meet the general acceptance criteria of age and health conditions should be registered in the Blood Donation Center System apart from whether they are subsequently admitted to donate blood or not. During the registration

process, donors provide basic identification information including their full name, demographic location and contact details. After registration, each donor be given a unique identifier (donor card) and a donation number that will be attached to the questionnaire, to the primary and secondary blood bags and to the sample tubes. In any donation process, education documentation and a questionnaire should be given for regular and new donors and should be completed during the registration process [26].

2.1.3 Medical interview

All donors will be subjected to a medical interview to determine their eligibility to continue the process of donation. Such questionnaires, which are in the form of a one-on-one interview, generally assess the health condition, travel history, medical record and risk of having TTI infection [26]. Privacy and confidentiality are highly considered during these interviews, to assure that the donor is comfortable to answer personal questions. Overcoming the language barrier is also considered while conducting this interview, so that the donor can understand the questions clearly and answer properly. Along this interview process, a written consent is obtained from the donor, approving blood testing for TTI, use of blood transfusion, quality assurance or research purposes, and confirming the validity of the information provided [26].

Qualified staff like nurses/transfusion medicine physician perform the evaluation of the medical questionnaire only. The eligibility criteria for whole blood donation varies among countries. Many countries implement the American Association of Blood Banks (AABB) and the Council of Europe (CE) guidelines for the regulatory requirements of blood banks, transfusion services, and other immunohematologic practices. This variation in the eligibility policies and in the criteria of assessment explains the discrepancy in the deferral

rates between blood institutions. In 2010 for example, percentage of the deferral among European countries, USA and Canada ranged between 1.4% and 25% [29]. In general, differences in eligibility and assessment criteria can be related to different factors including; severe need of blood, the financial standing of the Center, the demographics of the country, the spread of endemic diseases in certain areas, drug use, sexual history, residential history and others. Some countries decide on blood donations eligibility based on epidemiological criteria only while others request additional serological tests [30]. In Canada for instance, although 60% of Canadians are eligible to donate blood, [31, 32] the percentage of donation is less than 4% every year due to critical deferral criteria followed the country [32].

2.1.4 Physical Examination

After the medical interview and before donating blood, the donor also undergoes a physical examination that checks for remarkable signs and symptoms of illness or conditions that will result in their discontinuation of blood donation. In most countries, the eligibility of blood donation is 18 years and above. Some countries, however, allow 16-17 year-old participants if they pass the medical examination tests and fill out the consent form. The volume of whole blood donated should not exceed 13% of total blood volume; the weight of the donor should be at least 50 kilograms to donate 450 ml ± (10%) of blood. Similarly, the total volume of donated plasma, platelets and red cells collected should not exceed 13% of total blood volume and the maximum extracorporeal blood volume should not exceed 15% of the donor's total blood volume for apheresis procedures. Gross obesity could be a reason for deferral due to difficulties in reaching the veins of the donor. The international and national blood donation guidelines also indicate the hemoglobin levels

should be at least 12.5 g/dl in females and 13.5 g/dl in males. Other indicators of good health status include a regular pulse rate (60–100 per minute), oral temperature (less than or equal to 37.5^0C), systolic pressure (120–129 mmHg), and diastolic pressure (80–89 mmHg) [26].

A recent study showed a significant variation in the physical examination criteria implemented by different countries. In the United States, where the majority of Americans are obese, the 50-kg weight requirement can be easily met in the Indian population, with a 45 kg weight is considered acceptable [30]. Donors that don't pass the physical examination test, and therefore do not meet the eligibility criteria for donation, or are deferred due to any other reason, are usually prohibited from donation for either a temporary or a permanent period after a proper given clarification and advice for medical follow up [26].

2.1.5 Donor Phlebotomy

In blood donation, safety is a major concern for both the donor and the recipient. Reducing the likelihood of contamination of donated blood unit by skin flora from the donor's arm is a major consideration when collecting blood. Pathogens can multiply during storage, leading to fatal complications [33, 34] . Accordingly, effective antiseptics are used prior to withdrawing blood. Applying a combination of 2% chlorhexidine gluconate and 70% isopropyl alcohol for 30 seconds on the donor's arm, followed by 30 seconds drying time, is a frequently adopted sterilization practice in blood donation [35, 36].

Blood is usually collected for either whole blood usage or for apheresis. Plasmapheresis consume at least 45 minutes, and more than three hours for plateletpheresis compared to the 15 minutes time need for whole blood donation [37]. In apheresis, a fixed quantity of

blood is collected in an extracorporeal volume (ECV) bolus and the needed components (e.g. Platelets) are separated and collected in the collection bag, while other components (e.g. red blood cells, leucocytes and plasma) are returned back to the donor [38].

Post blood withdrawal, the donor should relax for a few minutes on the bed before leaving the donation room, and should receive some refreshments to re-set his normal balance before leaving the Blood Donation Center [39].

As for the collected blood, whole blood should be held in an environment that allows it to gradually cool down to 20 ^{0}C to 24 ^{0}C before beginning with processing. Blood bags will be further sent to the laboratory for processing and serological testing. Universal safety precautions should be always followed when handling blood specimens as all reagents and patient samples are considered potentially infectious [40].

2.2 Blood processing and screening

Collected blood samples are sent to the Blood Center, to undergo serological testing. In parallel, the rest of the blood bags are sent to the Component Processing Units for blood separation into components through a complex process [39], [41-43]. Any discrepancy between the blood bag and the collected specimen will be further investigated and resolved prior to testing and processing of units.

2.2.1. Immunohematological testing

Currently, the International Society of Blood Transfusion includes a list of 33 blood group systems representing over 300 antigens. The most important system in transfusion and transplantation is the ABO system and the Rhesus-system, which contain only five important defined blood group antigens out of 50, in addition to the Kell blood group

system that is classified as the third most potent immunogenic antigen after ABO and Rh system. Common Rhesus and Kell antigens are also frequently tested for in blood donors because of their clinical relevance.

Thus, common immunohematological testing includes determining the ABO group, Rh Type and any unexpected antibodies against red blood cell antigens of the donor [44, 45].

2.2.2. Blood components production

From each donor, one blood unit of 450 ml of blood is collected and processed to obtain the needed blood constituent such as red blood cells (RBCs), platelets, plasma and other products. Thirty different products can be obtained from blood processing. Thus, several patients can benefit from one donation [46, 47]. Most common blood components are packed red blood cells (PRBC), washed PRBC, leukoreduced PRBC and pooled or aphaeresis platelets; while plasma products such as Fresh frozen plasma (FFP) or cryoprecipitate antihemophilic factor (AHF), are less common [48]. Each of these products have a different shelf life [46, 47].

Blood components are generally used for different medical purposes. Red cells, FFP, platelets are used for example for patients undergoing surgery or in case of major blood loss due to accidents [49]. Packed red cells (leukocyte free) are, in turn, used for premature infants. FFP are also used for treating patients with burns and bleeding injuries, particularly those having deficiencies in multiple coagulation factor due to liver disorders or disseminated intravascular coagulation [50]. In order to be used for correction of inherited and acquired coagulopathies the Cryoprecipitate AHF is usually produced by slow thawing of FFP. Cryoprecipitate, which is rich in factor VIII, fibrinogen, fibronectin, von Willebrand's factor (vWF) and factor XIII can be also used for correction. Beside the chief

role of platelets in reducing bleeding, it is commonly used for cancer patients as well [47]. Since 1960 blood components were prepared by separated blood products from one unit of whole blood through a refrigerated centrifuge [51]. Red Blood Cells Leukocytes Reduced (PRBCs) are either be prepared automatically or manually by centrifugation and filtration of whole blood unit. Saline Adenine Glucose Mannitol solution (SAGM) is further added to extend the shelf life of RBC for 42 days, with increased functional capability and increased level of ATP in red blood cells [38]. After the RBCs bag are mixed with SAGM, they will be ready for the next step which is filtration and storage.

FFP is, in turn, is prepared from whole blood by a single‑step heavy spin centrifugation [51]. Liquid Plasma and Plasma Frozen within 24 Hours after phlebotomy (FP24) are also prepared from a whole blood. Also, cryopreciptated AHF is prepared by separating the cold insoluble portions from FFP one-hour post preparation [40, 52]. Platelets can be obtained by two methods, either harvesting them from whole blood unit or from single donor "platelet apheresis". In the first method, four to six interim platelet units are pooled and filtered with a platelet pooling set to create a final pooled platelets product. In the second method, a special machine that separates the blood cells during the collection process is used. Platelets are then collected in bags while other blood components (e.g. red blood cells, leucocytes and plasma) are returned to the donor. Agitation is required during the platelet units storage process to prevent clumping of cells [48].

2.2.3. Blood screening

Over the past three decades, different types of screening tests have been designed to detect antibodies, antigens or the nucleic acid of the infectious agent in blood. Many of

these tests have limited usages. Deciding on which test to implement is usually based on several factors like sensitivity, specificity, cost and ease of application.

In the blood bank, two main types of tests are generally used for blood screening: (1) Immunoassays which include [Enzyme immunoassays, Chemiluminescent immunoassays, Haemagglutination /particle agglutination assays and Rapid/simple single-use assays (rapid tests)] and (2) Nucleic acid amplification technology (NAT) assays. In today's practices, whole blood and apheresis are generally screened for HIV-1 and HIV-2 antigen/antibody, hepatitis B surface antigen (HBsAg), hepatitis B core antibody(anti-HBc), hepatitis C antibodies (anti-HCV) antibodies and specific treponemal antibodies infectious markers. Screening for malaria antibodies or Chagas disease might also apply depending on local epidemiological evidence [53]. Serological screening of blood products for hepatitis B virus (HBV), HBsAg , anti-HBc, hepatitis C virus (HCV), human immunodeficiency virus (HIV1/2), cytomegalovirus (CMV) and syphilis started in period ranging from 1970 to 1990s [44]. In 1995, the World Health Organization (WHO) and the National Institutes of Health (NIH) recommended to screen every donor for different infectious test such as HIV, hepatitis B and C, malaria, and syphilis [54]. In 2004, and due to increased awareness of clinical complications of TTI, AABB, and in corporation with the Food and Drug Administration (FDA), issued standards serological tests to detect risk of TTI in the donor's blood [55].

Although introducing hepatitis B surface antigen (HbsAg) as a routine screening test decreased the risk of TTI of HBV in the early 1970s, the test had still some limitation in detecting the presence of HBV during the 'window period' [56]. Therefore, the combination both serological testing and NAT has considerably reduced the risk of viral transmission by blood transfusion [57-59]

NAT testing is a new trending screening test technology used to detect HIV and HCV. Its advantage over other screening methods lies in its sensitivity and specificity of detecting

viral nucleic acids, especially in early stage of infection. Therefore, this technology contributes to narrowing the pre-seroconversion window period and can detect false positive reactive tests [60]. A major disadvantage of NAT, however, is that it is unable to detect low level viremia [61].

In Late 1990 and early 2000, the NAT approach was introduced in developed countries (primary Germany). Today, about 33 countries in the world rely on NAT for HIV detection, and approximately 27 countries rely on it for HBV identification [62]. Applying NAT in the UK for blood screening, for example, reduced the risk of HCV infection by 95% and HIV infection by 10% [63].

2.2.4. Pathogen inactivation

The risk of pathogen transmission has been recently reduced by the implementation of several pathogen inactivation strategies such as filters and the Mirasol Pathogen Reduction Technology (PRT) System which includes Riboflavin (vitamin B2) with UV light. Such system work on stopping the replication and/or transcription of nucleic acids, thus inactivating the microorganism. However, this system is not effective with cells that lack nucleic acid such as platelets and red blood cells [64-66]. Likewise, donor leukocytes should be also inactivated. These strategies enclose “nanofilters” that eliminate viruses having a protein membrane, while those with a lipid envelope virus cannot be eliminated. Also, aseptic membrane filtration (0.22 nm) can be used to eliminate micro‑organisms before filling the blood in containers [67, 68].

Collectively, all these practices including deferral criteria, donor screening, serologic and nucleic acid testing (pathogen inactivation) aid in providing safer blood for transfusion.

Unfortunately, poor financial support in many health service organizations, especially in developing countries, remains a major obstacle in implementing these screening approaches and reducing the risk of pathogen transmission.

2.2.5. Blood Storage

Because blood components are perishable, a synchronized processing of blood starting with immunohematological testing, blood screening, blood components segregation and reaching storage is essential [69].

According to the FDA standards, a novel implementation in blood storage technology has been introduced in the United States where RBCs are now being stored up to 42 days [70]. Due to the novel usage of additive solutions and validation criteria, the shelf life of RBCs has been also extended in Europe and is now considered to be 49 days [71-73].

The storage of each blood components follows specific guidelines:

(1) PRBCs is generally stored at 1-6 ^{0}C for 42 days with SAGM additive solution, up to 21 days with citrate phosphate dextrose (CPD) anticoagulant preservative; or for 35 days with citrate phosphate dextrose adenine (CPDA1).

(2) Liquid Plasma is stored at 2-6 ^{0}C for 26 days.

(3) FP24 is stored at -18^{0}C or colder for one year starting on the first day of collection.

(4) FFP and Cryoprecipitated AHF are stored at -18^{0}C or colder for one year from the day of collection.

(5) Interim Platelet Unit is stored at 20-24^{0}C for 24 hours after separation from whole blood.

(6) Pooled platelets leukocytes reduced and apheresis platelets are stored at 20-24^{0}C for 5 days with constant agitation, and 7 days if platelet additive solution (PAS) is used [40, 52].

Separating and marking screened reactive units from the quarantined ones, and securely storing quarantined stocks for their disposal or later usage for quality assurance or research purposes is also a critical element in the storage process [53].

Blood bank employees must continuously check the quality of blood components such as Red Blood Cells Leukocytes Reduced, Cryoprecipitated AHF, FFP and platelet concentrates to assure effective, and safe blood product with the lowest risk possible. Blood quality assessments are generally based on the AABB criteria that requires specific monitoring for each type of blood [74].

2.3 Blood distribution to hospitals and health care institutions

In many countries, Community Blood Centers are responsible for blood collection, blood processing into components, and finally blood distribution to blood banks and other hospitals and laboratories [21, 75]. Many countries have centralized agencies like the Canadian Blood Services in Canada and the American Association of Blood Banks in US. These agencies control the process of blood supply with other regional Blood Centers. Regional Blood Centers are usually responsible for collecting, processing and dispatching blood to different facilities in their regions. In the event of low blood inventories as in emergency situations, the blood bank will reduce dispatching blood units to hospitals and will only allocate the available blood for urgent requests. Such reductional practice usually relies on the policy of the blood bank inventory [73].

Validated shipping containers are used only for the purpose of transporting blood

components between different storage locations [76]. These containers are used to maintain the proper transport temperature that is appropriate for the blood component. RBCs and Plasma Frozen products including PF24, FFP, Cryoprecipitated AHF, and Plasma Cryoprecipitated must be transported at 1 to 10 ^{0}C, while platelets should be transported at 20 to 24 ^{0}C. The maximum number of blood component units that should be transported and packaged in one transport box and the number of ice packs needed in for transportation generally follows the manufacture's recommendations [40, 52].

Several factors should be evaluated during the shipments process including the shipping transit time, mode of transport, climatic conditions to which the container may have been exposed, presence of residual wet or dry ice upon receipt, and the gross appearance of the blood components received. Any deviation from routine shipping or component conditions should be documented and reported to the shipping facility. Similar evaluation of blood components transported between Blood Centers and hospitals should be performed by the receiving facility. Once the blood component arrives to the blood bank, and after crossmatching them for further blood type assurance, some units will be reserved as an assigned inventory. These assigned inventory units will remain until they are requested for transfusion or will be returned back as unassigned inventory for future utilizations [77]. All expired and spoiled units will be considered as wastage and eventually disposed [75].

2.4 Blood disposal

Disposal of blood products occur either during the processing of blood components and screening of blood samples or after blood distribution. This indicates that wastage can happen in any stage across the supply chain process [78]. A study conducted by Stanger *et al.* showed that the wastage in hospitals is notably higher the wastage in Donor Centers in

the United Kingdom and Germany [79]. Wastage of blood products can be due to several factors including expired blood units, clotted blood, broken bag, broken seals, returned unused RBCs bags for the blood bank after 30 min or failure of the blood unit after Internal Quality Control (IQC) assessment. Blood components that require disposal from the hospital or any medical service will be sent to the Blood Center by incineration [21, 40, 80]. A study conducted in all hospitals in Qazvin Iran, including teaching, social welfare, private, charity, and military hospitals illustrated three major causes of blood and blood component wastage including outdated units, patient hospital shortage of using these products and unused blood product [80, 81].

As for the "30-minute rule" and related guidelines for blood transfusion, many countries, like UK for example, advise to dispose RBC units that are not monitored for temperature storage for more than 30 min, because once RBC units warms up, the risk of bacterial proliferation increase over time [82].

It is worth mentioning here that because of the high demand of blood and blood components which is often unpredictable, blood and blood components are rarely out of date. However, outdating and wastage of blood and blood products can still significantly decrease if there is no proper adherence to guidelines [69, 79, 83, 84]. Undoubtedly, the consumption of blood units before they expire in treatment will avoid paying dispensable costs. The balance between consumption and wastage requires improving blood inventory management practices because having unnecessary stocks leads to unnecessary costs and wasting blood units also means wasting the donor's time and effort. Good inventory management practices require sufficient stock to cover the demand and at the same time reduce the expiry period [78, 85, 86].

Blood, blood products or contaminated materials should be disposed in a safe manner following specific policies of the donation center. There are several ways to dispose blood, including onsite treatment by heat sterilization, incineration and chemical treatment, or collecting the discarded materials in secure areas or off-sites disposed through specialized contractors [23].

Effective performance of Blood Center starts with accurate forecasting of future needs of blood and blood constituents. Information provided about the past use of blood and blood components by hospitals and the number of available donors on weekly or monthly basis, is usually important to help the Blood Center in decision making. These decisions can be strategic to improve the proper use of existing resources, to promote an increase in the number of donors, to implement any needed expanding in the infrastructure, and to consequently guarantee that all demands will be met in disastrous or situations mega-events [21]. Having that said, the blood bank should be on a high level of preparation on daily basis, in cases of natural or man-made disasters, or where hosting mega events, which require stockpile of blood. For the World Cup event for example, the hosting country should be readily alert to respond to any risk that could occur, especially among the crowds, in addition to its regular readiness, to meet the patient demands every day. So, it is particularly useful for the blood bank to use guidelines that has been previously established by blood management committees for successful emergency operations procedures. These guidelines can help in building mock scenarios that are not encountered in everyday workplace. Retrospective review of previous disaster experience greatly helps as well. Developing a disaster plan is also needed to provide further knowledge on the quantity of blood required, availability of blood components, routes of communication and mobilized

hospital staff [87].

Several challenges usually arise in planning and controlling such events. Some of which falls in the context of deciding on how to handle the process of blood donation and stock management [88]. Notably, cost is considered a focal point and a driving force of all such operation management activities.

Most countries face challenges in achieving self-sufficiency in blood components and blood types and struggle to meet current and future population needs and to balance between increased production and optimized utilization. Maintaining a high quality and safe blood products is one of the faced obstacles. Other obstacles also fall in the category of the risk of transfusion-transmitted pathogens, low percentage of blood donors, increasing demands, poor blood supply systems. This will eventually results in blood shortages, unsafe blood products and questionable blood service practices [89] .

Like all countries, Qatar is also concerned with these obstacles and is currently working on overcoming them before 2022. A proper understanding of the current available and the future needed blood resources is a must.

CHAPTER 3: MATERIALS AND METHODS

3.1. Ethical compliance

The proposal of this study has been submitted to Hamad Medical Corporation through the ABHATH –MRC's online research system. The presented study documents have been assessed initially by assigned reviewers and was then passed down to the scientific review committee by Medical Research Center (MRC). The submitted proposal has been categorized as a quality improvement study and therefore the study got exempted from IRB review by MRC. The only needed ethical compliance was an approval from the Department of Laboratory Medicine and Pathology (DLMP). Accordingly, this approval has been obtained from the Transfusion Medicine Department- DLMP and is attached at the ended of this capstone exhibition in the Appendix section.

3.2. Data collection

Our study has been conducted in the BDC-Department of Transfusion Medicine at Hamad General hospital which is located on Hamad Medical Corporation campus. In this study, both qualitative and quantitative approaches have been implemented.

3.2.1. Qualitative approach

For the qualitative part of our study, semi-structured interviews have been conducted. The interviewed Head Nurse of the HMC-BDC has provided adequate information about registration requirement, medical interview, physical examination acceptance criteria, staffing schedules and other services provided at the Center. Information about the kind of blood bags and types of donors was also provided by the Head Nurse in the Center. The Head of Transfusion Medicine and Blood Banks provided information related to the blood wastage, misuse practices and pathogen inactivation

techniques. The conducted interview with the Medical Manager, in turn, provided information related to the working system in the Center, the arrangement of campaigns among the year, the announcement methods used in cases of emergency, the challenges and obstacles faced during the blood donation process, and the limitations encountered by the blood bank to meet the donation benchmark.

3.2.2. Quantitative approach

3.2.2.1.Data collection from interview and site visits

For the quantitative part of the study, one data set have been collected from semi-structured interviews and from direct site visit observations. Within this set, data has been categorized into:

(i) Number of workers (nurses, clerks and drivers) in the BDC and number of technologists in the Component Processing Units and in the Donor Marker Testing Unit.

(ii) Assets available in the BDC (equipment, beds and cars); assets available in Component Processing Units and in the Donor Marker Testing Unit (instrumentation, Centrifuges, Mirsol-pathogen reduction system, extractors among others).

(iii) Time frame (working hours, number of shifts, allocated time for each step in the process).

(iv) Number of campaigns organized every day.

(v) Blood inventory management (number of blood bags collected from each participant, shelf life of each component, percentage of discarded blood bags, reasons for discarding).

(vi) Infrastructure data (number of BDC sites in the country, capacity per parking lot and waiting areas, number of medical examination rooms, number of physical assessment rooms, number of recovery rooms and number of rest rooms).

3.2.2.2.Data retrieved from Hematos IIG, Medinfo System database

Another quantitative data set was obtained from a retrospective analysis carried out at HMC-BDC data during the 2013-2018 period using the Hematos IIG, Medinfo System database. Authorized staff belonging to the Laboratory Information Technologist (LIS) team of DLMP provided us with the raw data. This data was in turn classified into:

(i) Number of volunteer donors in HMC-BDC versus the number of volunteer donors in campaigns per month and year.

(ii) Number of units collected per year.

(iii) Nationality of the donors.

(iv) Gender of the donors per year.

(v) Percentage of services provided by the HMC-BDC per year (platelet apheresis, Therapeutic plasma exchange and RBC exchange).

(vi) Percentage of deferral due to self-deferral, medical interview and physical examination

(vii) Percentage of blood wastage.

These raw were further analyzed to assess the current and future blood donation demands.

3.3. Forecast Model

Since our collected data falls under the category of "Time series", we choose to implement the Autoregressive Integrated Moving Average (ARIMA), widely known as

Box-Jenkins (BJ) method to develop a forecast model. This automatic BJ procedure is mathematically structured as being a useful tool for analyzing probabilistic or stochastic characteristics of single time series. In order to project blood donors demand in the coming four years, two datasets were required; (i) total number of volunteer donors per month and year (dependent variables) and (ii) number of populations per year (independent variables). The donor's data was retrieved from January 2013 to December 2018 from the Hematos IIG, Medinfo System database, whereas population number were collected from Ministry of Development Planning and Statistics' official web site.

The historical data of donors and the corresponding annual population were plotted in the STATA software to check for an increase or a decrease in the blood demand over the observed period. In order to implement the time series ARIMA forecasting model, statistical stationarity between variables (mean, variance, autocorrelation, etc) over a period is should be achieved. As such we assumed statistical stationarity and we tested our assumption using Dickey Fuller test. The result revealed a p-value <0.05, indicating statistical stationarity (Table 1) Also, stationarity was further confirmed by a lag value ranging between (0 and 9) for one stretch of the data sets. Accordingly, stationarity was further confirmed.

Table 1: Dickey Fuller Test Results

```
. dfuller prop, trend regress

Dickey-Fuller test for unit root                    Number of obs   =        71

                                 ---------- Interpolated Dickey-Fuller ----------
                 Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value            Value
------------------------------------------------------------------------------
 Z(t)            -6.888            -4.104            -3.479           -3.167
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000

------------------------------------------------------------------------------
D.prop          |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
----------------+-------------------------------------------------------------
        prop    |
         L1.    |  -.8273585    .120118    -6.89   0.000    -1.06705   -.5876668
     _trend     |  -1.443054   .5832641    -2.47   0.016    -2.606939   -.2791688
      _cons     |   807.9413   122.1414     6.61   0.000     564.2119    1051.671
------------------------------------------------------------------------------
```

To fit the donor's data into the model, the ARIMA features (AR): "variables regressed on own lagged or prior values", (MA):"past error multiplied by a coefficient" and (I): "data values have been replaced with the difference between their values and the previous values (and this differencing process may have been performed more than once)" were then calculated using Bartlett's formula. In brief, The Moving Averages (MA) value was calculated using Correlogram/Autocorrelation function plot (ACF plot) with a calculated autocorrelation and correlation ranging from -0.01 to 0.4 (Figure 1). Partial autocorrelation in the selected time series was extracted, Partial Correlogram/ pacf plot was used, and partial autocorrelation was detected (Figure 2). The AR(p) value of ARIMA model was further calculated in a similar way. From the aforementioned interpretations, I was concluded to be 0; therefore, the fitted model used for forecasting was ARIMA (1,0,1) for count and population (Table2).

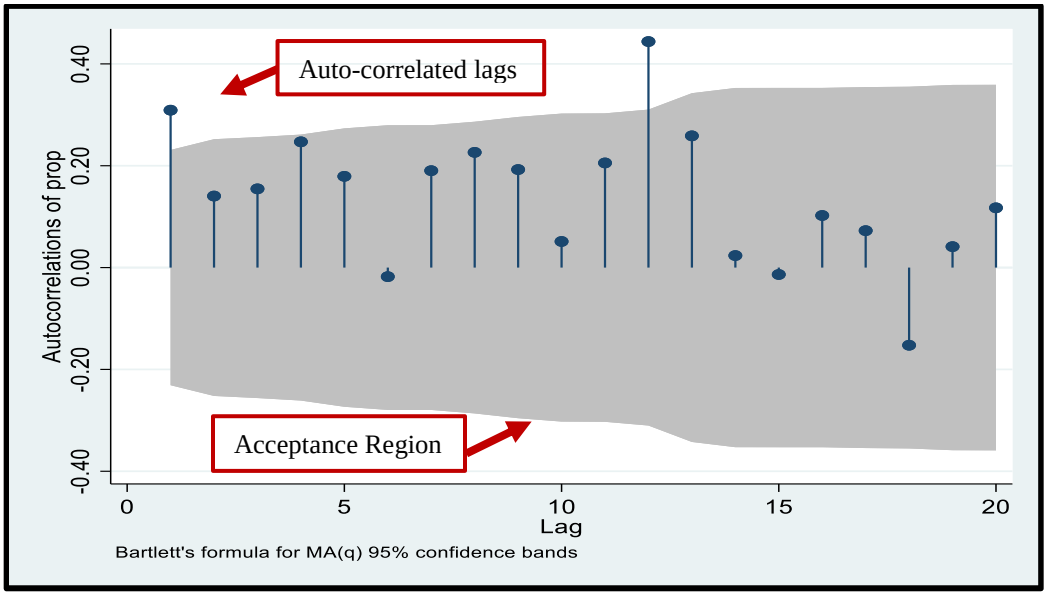

Figure 1: ACF plot for ARIMA in STATA.

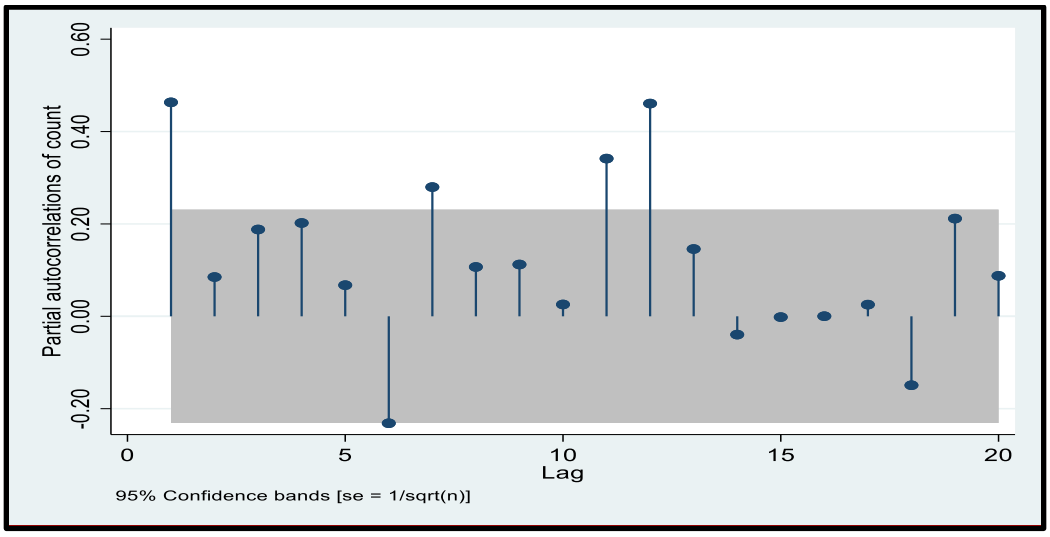

Figure 2: Partial Correlogram for ARIMA in STATA

Table 2: ARIMA Model (1,0,1).

```
. arima count pop, arima(1,0,1)

(setting optimization to BHHH)
Iteration 0:   log likelihood =  -488.4719
Iteration 1:   log likelihood = -487.81067
Iteration 2:   log likelihood = -487.45007
Iteration 3:   log likelihood = -487.44238
Iteration 4:   log likelihood = -487.43673
(switching optimization to BFGS)
Iteration 5:   log likelihood = -487.43614
Iteration 6:   log likelihood = -487.43608
Iteration 7:   log likelihood = -487.43608

ARIMA regression

Sample:  2013m1 - 2018m12                       Number of obs     =         72
                                                Wald chi2(3)      =      60.70
Log likelihood = -487.4361                      Prob > chi2       =     0.0000

------------------------------------------------------------------------------
             |                 OPG
       count |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
count        |
         pop |   499.9582   103.0571     4.85   0.000       297.97    701.9465
       _cons |   1016.579   262.4644     3.87   0.000     502.1584        1531
-------------+----------------------------------------------------------------
ARMA         |
          ar |
          L1.|  -.6899838   .3113068    -2.22   0.027    -1.300134   -.0798337
             |
          ma |
          L1.|   .8474895   .2183135     3.88   0.000       .419603    1.275376
-------------+----------------------------------------------------------------
       /sigma|   210.5899   19.72885    10.67   0.000       171.922    249.2577
------------------------------------------------------------------------------
Note: The test of the variance against zero is one sided, and the two-sided
      confidence interval is truncated at zero.
```

3. Statistical analysis

Data analysis was done using Excel 2016 and categorical data were presented as percentages. The time series analysis and graphs of forecasting (ARIMA) model were created in STATA/SE version 15. Differences between compared groups were considered statistically significant, when the calculated P-value was ≤ 0.05.

CHAPTER 4: RESULTS

4.1.Current standing of the HMC-BDC and its infrastructure

The available assets, personnel and campaign logistics of the BDC were evaluated and are summarized in tables (3,4 and 5).

4.1.1 Available assets

Table 3: Available Assets at the HMC-BDC

Infrastructure		Capacity	Logistics	
Registration area	1 area	4 donors at the same time	**Chairs in male waiting area**	27 chairs
Waiting area	1 area for males 1 area for females	27 male donors 11 female donors	**Chairs in female waiting area**	11 chairs
Medical interview room	1 room shared by males & females	1 donor only	**Beds in phlebotomy room**	6 beds in male section 2 beds in female section
Physical examination room	1 room shared between male & female	1 donor only	**T-rack**	25 (6 in male section, 2 in female section, 6 for folded beds, 11 for mobile cars)
Phlebotomy room	1 room for males 1 room for females	6 male donors 2 female donors	**Trima machine**	4 (3 in the BDC and 1 backup)
Recovery room	1 room for males No room for females	12 donors	**Optima machine**	8 (2 available in National Center for Cancer Care & Research (NCCCR) and 4 available in Hamad hospital)
Restroom	1 WC for males 1 WC for females	2 males 1 female	**Campaign cars**	3
Parking lot	1 area	8 cars	**Folded beds**	6

4.1.2 Personnel

The working days of the HMC-BDC are from Saturday to Thursday. During those days, the Center opens for 16 working hours, with two shifts (7:00 am-3:00 pm) and (3:00 pm -10:00 pm). All staff members working at the BDC are assigned different responsibilities. In general, staff in specific locations vary according to the needs and availability of personnel table (3 and 4).

Table 4: Staff Number and Duty Schedule at the HMC-BDC

Drivers	Clerks	Nurses
3	8 5 (clerks are assigned in BDC) 3 (clerks are assigned for campaigns and other responsibilities)	25
schedule (1 shift)	Morning shift: 3 clerks Afternoon shift: 2 clerks Weekend: 1 or 2 clerks (overtime)	Morning shift/ Afternoon shift: 1 nurse conducts Medical interview 1 nurse performs Physical assessment 5-6 responsible for blood collection Rest of nurses are assigned for other duties outside the Center; either in campaigns or taking care of patients in Hamad hospital sites and NCCCR

4.1.3 Mobile services provided by the HMC-BDC

In addition to the fixed services provided by the HMC-BDC, the Center is equipped to provide mobile service in various areas in the country; mainly through mobile cars. The

Center has two car models with difference in their capacities and the number of beds that they could accommodate. Usually folded beds, which are easier to carry when campaigns are held into tall building and towers are used. The number of nurses vary according to the size of the campaign (Table 5). In general, off-site one shift (8 hours) campaigns can increase the stock numbers by 96 units, while two campaigns per day will enrich the stock by 192 units.

Table 5: Mobile Services Provided by the HMC-BDC

Number of mobile cars	Number of nurses/car	Number of campaign/day	Number of beds/car	Number of clerks	Folded chair
3	Flexible according to the size of the campaign 4-5 nurses (2-3 nurses to withdraw blood for donor, 1 nurse for medical interviewing, 1 nurse for physical assessment)	Average of one campaign/ day	1 car contains 6 beds 2 cars contain 4 beds	1/car	6 beds

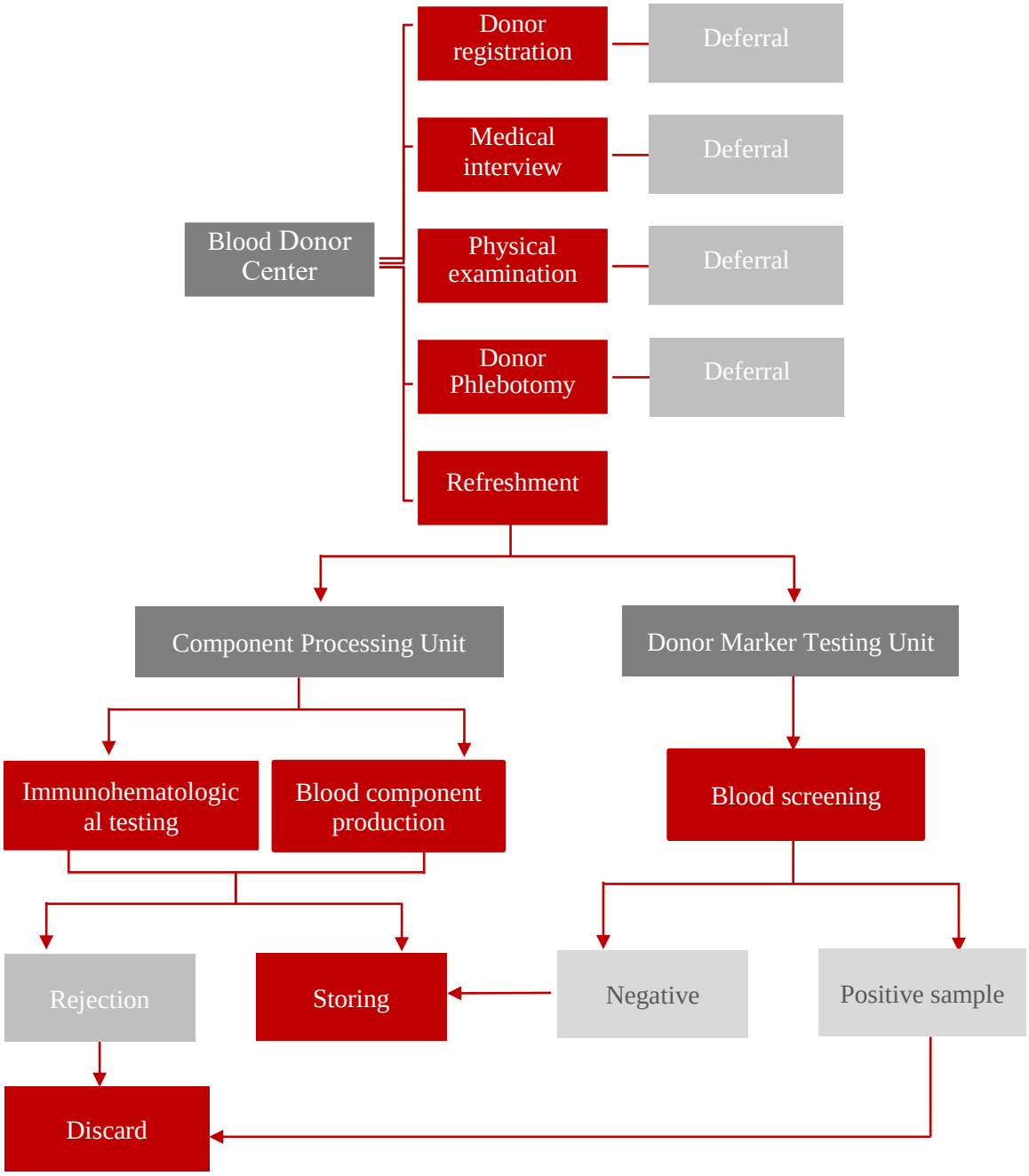

Figure 3: The ongoing blood supply chain processes in the HMC-BDC and its corresponding units. ■ Indicates the different sites as the BDC, the Component Processing Units and the Donor Marker Testing Units, while ■ indicates major processes in each unit, ■ demonstrates the actions taken (deferring donors or rejecting sample), and ■ indicates the blood screening results.

4.2.Blood collection process

The blood donation process encloses four main steps, each of which follows specific guidelines (Figure 4).

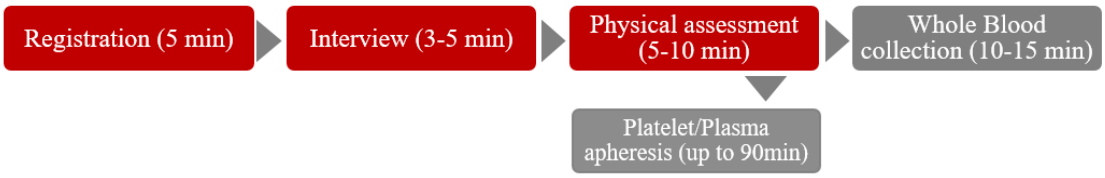

Figure 4: Summarizes the allocated time for each step of the blood donation process. ■ *Represents the main steps prior to blood collection with their allocated times* ■ *Represents the time needed for collecting whole blood or for platelet/ plasma apheresis.*

4.2.1 Donor reception and registration

The blood donation process at HMC-BDC, and like all other international set processes, starts by obtaining the needed information from the donor during the registration phase for identification purposes. In the BDC, registration is done through the "Medinfo Hematos_IIG" system. Regular donors are usually asked to present their donor's identification cards or any other identification form (Qatar Identification card (QID), Qatar driving licenses, Health card), while new donors are asked to show their QID, Qatar driving license or Health Card. During registration, regular donors are checked for any previous deferrals or abnormal screening tests result. If there is no deferral record, donor will be sent for medical interview. Figure (5) illustrates the allocated time for registration and evaluates the accommodation capacity of donors on daily basis.

4.2.2 Medical interview

During the medical interview, donors will be asked about their health, medication history and past travels using a Blood Donor History Questionnaires (DHQ) that encloses 50 to 60 questions. The questionnaire template used at the HMC-BDC and the types of questions asked are profoundly based on the criteria of the AABB with minor modifications. Few years ago, Qatar had very strict blood donation criteria; however, HMC-BDC reconsidered some of those criteria because of a 62% recorded decrease in the number of donors, due to malaria related deferrals. All answers in the questionnaire are confidential. The interview room is separated where only the donor and the assigned staff are allowed exclusively inside. After the completion of the medical interview, the donor signs consent form and proceeds to the physical examination test to check for any remarkable signs and symptoms of illness or any conditions that results in blood donation deferral.

A medical interview usually takes between 3-5 minutes depending on the case. We based our calculations on the longest time an interview might take (5 minutes) as some donors might stay for more than 3 minutes in the interview room especially if addition questions are asked. In such a scenario, the medical interview represents a bottle neck where more than half of registered donors remain un-interviewed at the end of the day. This problem could be simply resolved, and long waiting queues could be therefore avoided by providing additional interview rooms (Figure5).

4.2.3 Physical examination

The conducted physical examination results are documented in the donor's file in Medinfo, Hematos IIG system. Table (6) summarizes the physical examination criteria

needed for donors to become eligible for whole blood and platelets apheresis donation at HMC-BDC.

Table 6:Physical Examination Acceptance Criteria

	Description	Accepted values		Deferral duration	
		Minimum	Maximum	Less than minimum value	Greater than maximum value
Whole blood donation	**Body Weight (kg)**	50	-	365 Days	365 Days
	Hemoglobin (g/dl)	13.0 (Male) 12.5 (Female)	18	30 Days	90 Days
	Blood Pressure (mmhg)	100 (systolic) 60 (diastolic)	180 (systolic) 100 (diastolic)	15 Days	15 Days
	Pulse Rate (cpm)	60	100	15 Days	15 Days
	Temperature (ºC)	36.1	37.5	7 Days	7 Days
Platelet apheresis	**Platelet Counts ($x10^{-3}$/ul)**	150	500	2 Days	2 Days

4.2.4 Donor phlebotomy

After underdoing the physical examination test, eligible donors are sent to the

phlebotomy room or collection room to undergo blood collection procedure. In HMC-BDC, about 450 ml of whole blood is collected. If blood withdrawn takes places between 7:00 am to 11:00 am, then blood will be collected in Cryo bag. If blood withdrawal taken places after 11:00 am, then blood will be collected in Reveos three components blood bag sets. During the collection process, the blood bags are placed on racks for gently mixing of blood with the additive solution, improving the consistency of whole blood and avoiding clotting. The HMC-BDC follow specific guidelines to ensure that the acceptable criteria for whole blood collection are met: (1) the collection time of any blood unit should not exceed 15 minutes and (2) the acceptable volume/weight of whole blood unit should be 405 ml-495 ml (427 grams- 521 grams).

The volume of blood collected from donors is usually based on several factors including the proportionate amount of anti-coagulant to blood volume in the blood bag and to the weight of the donor. Generally, short drawn or over drawn units are not suitable for transfusion because the volume in the container may not be proportionate with the amount of anticoagulant in the blood bag. Usually, the whole blood collection process should not exceed 15 min. The variation of time from one donor to another depends on the size of donor's vein. The problem lies however in the fact that not all available 6 beds in the male section are always used for whole blood donation; because they happen to be used sometimes for other purposes as well like therapeutic or platelets apharesis. Therefore, only 3 beds are usually used for whole blood collection in the male section. Accordingly, we calculated the capability of accommodating whole blood donors based on 5 beds (3 beds in male and 2 beds in female section) (Figure 5).

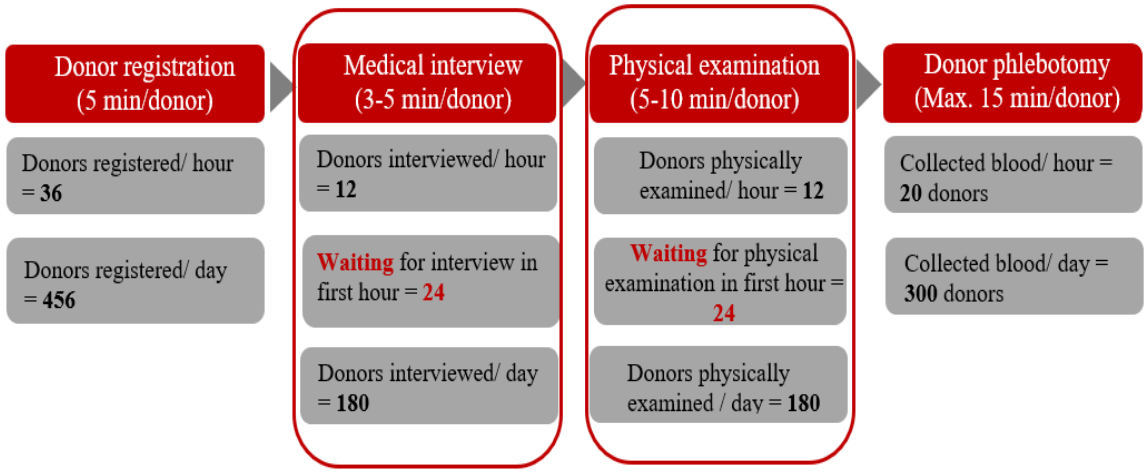

Figure 5: Process of blood collection and donor capacity on daily basis. ■ Indicates the main stages prior to the blood collection process with allocated time for each stage. ■ Demonstrates the number of donors that can be registered, medically interviewed, physically examined and processed for blood collection during the first hour and per working day. ◘ Indicates the bottle neck step which need to be resolved to avoid losing donors.

4.3.Blood processing and screening

After blood withdrawal, collected blood samples are sent to the Donor Marker Testing Unit, for infectious markers testing. The rest of the blood samples and their corresponding blood bag are delivered to the Component Processing Units for immunohematological testing and blood separation into major blood components. Both the Donor Marker Testing Unit and the Component Processing Units are located on the upper floor of the BDC. Whole Blood released in Cryo bags should cool down and get transported at 1 to 10ºC temperature to the Blood Component Processing Units. On the other hand, whole blood collected in Reveos bags and apheresis platelets should be transported at 20-24ºC. Throughout our site visits to the Center and its corresponding units, we have noticed that both units are fully equipped with highest standard instrumentation and up to date

reagents and material are used to detect pathogens, and therefore reduce risk of disease transmission.

4.3.1. Component Processing Unit

The Component Processing Unit operate from Saturday to Thursday between 6:00 am to 5:00 pm. This unit contains only 5 technical staff that are distributed over three shifts. The first shift starts at 6:00 am and ends at 2:00 pm, the second starts at 7:00 am and ends at 3:00 pm, and the third shift starts at 9:00 am and ends at 5:00 pm. In this unit, the laboratory instruments are backed-up by havening two instruments of the same kind to ensures non-stop laboratory operations and guarantee continuous service in case of equipment breakdown. Table (7) provides a list of the available equipment at the Component Processing Unit. It is worth mentioning here that this richness in equipment is limited by the available space, which restricts the ability of the staff to work freely.

Table 7: Available Equipment at the Component Processing Unit

Equipment	Quantity available	Equipment	Quantity available
Serology centrifuge	2	Weight scale	2
Reveos centrifuge	4	Tube sealer	2
Cryo refrigerated centrifuge	2	Cryoprecipitate bath (1-6°C)	2
Plasma extractor	8	Mirsol system	3
Ortho Innova analyzer	2	Holder	4
Refrigerator (1-6°C)	5 (2 fridges shared with Blood Marker Testing Unit)	Freezer maintained at -18 °C or lower	4 (4 freezers shared with Blood Marker Testing Unit)
Platelet incubator/agitator (20-24°C)	2		

In the receiving area of the Component Processing Unit, blood bags are checked once received for (i) integrity of the bag and its open sealing (ii) integrity of the label (iii) volume collected (450 ±10%) (iv) visual screen (lipimic, icteric, hemolysis, clot, unusual color of blood) and (v) lot number and expiration of blood bag used.

4.3.2. Immunohematological testing and process of blood components production

After the aforementioned steps, the staff proceed to perform Immunohematological testing and blood component preparation in parallel. Immunohematological testing include: (i) determination of ABO group and Rh types for all collections (ii) detection of unexpected antibodies to red cell antigens for donors and (iii) routine (non-mandatory) testing for Rh and Kell phenotyping for all donors. Many of the procedures performed at the component

processing unit including filtration, plasma extraction, platelets pooling, Riboflavin (B12) addition, FFP thawing for Cryoprecipitated AHF preparation and IQC assessment are performed manually. Therefore, this process requires a lot of effort and is considered time consuming. From our observations, we concluded that around 70 blood bags are prepared on average, every 8 working hours. In brief, the first staff is responsible for receiving samples and for performing the manual ABD confirmation test, the second staff is assigned for ABO/ Rh CED typing, antibody screening and Rh/Kell phenotyping using Ortho Innova analyzer, the third staff is responsible for pooling platelets and plasma preparation, and the fourth staff is in charge of Cryo and Reveos blood bag separation. Apart from these observations, we were not able to determine the exact time allocated for these tasks because of several factor related to quantity and types of blood bags, receiving time, other duties which are handled by laboratory staff such as inventory checking, in addition to the differences in the skills of the staff performing these jobs.

Different blood components can be obtained from one unit of 450 ml of whole blood and can be used later for different medical purposes. In general, blood collected in Cryo bags should be processing on the same day (2-8 hours post collection), in order to obtain PRBCs and FFP, for further production of Cryporeciptated AHF. On the other hand, blood collected in Reveos blood can be left for the second day or processed 2 hours post collection to produce PRBCs, platelets, plasma and Residual of leukocyte (buffy coat). We have noted significant dissimilarities in the handling, preparing, and storage of whole blood according to the type of bag used and the need components (Table 8).

Table 8: Differences Between Reveos and Cryo Blood Bags.

Action	Reveos bags	Cryo bags
Storage environment post collection	18-28ºC (room temperature)	1-6ºC
Shelf life post collection	24 hours (overnight)	2-8 hours
Whole blood units processing in the machine	A minimum of 2 to 24 hours (including filtration time)	A minimum of 2 to 8 hours (including centrifugation time)
Centrifuge	Reveos automated blood processing system	Cryo refrigerated centrifuge
Capacity of blood bags	4 sets of bags	6 sets of bags
Centrifugation period	30 min	10 min
Extraction of blood components	Automated	Manual

After plasma separation from both bags, it gets treated with Mirsol to inactivate the pathogens. The interim platelet unit is generally ready at this stage for further processing, (resting with agitating, pooling with 4-6 other interim platelet units and filtration with a Platelet Pooling Set) to create a final pooled platelet. All platelet from a female donor are discarded before the pooling process to avoid any complication post transfusion like Transfusion-Related Acute Lung Injury (TRALI), due to antibodies in blood of pregnant women [90]. Agitation is essential to prevent platelet clotting. Pooled platelets are also treated with Riboflavin and Mirsol PRT. When pooled platelets leukocytes reduced are prepared, the pH and leukocytes count is usually taken into consideration. Apharesis

Platelets are in turn treated with Riboflavin and Mirsol PRT.

Residual of leukocyte (buffy coat), which contain a large number of leukocytes with few erythrocytes and granulocytes get discarded in specific waste container. Sometimes, the Component Processing laboratory provides leukocyte bags (source of PRBCs) for other laboratories to be used in research or for quality control purposes.

4.4. Donor marker testing unit

The Donor Marker Testing Unit operates from Saturday to Thursday between 6:00 am and 2:00 pm and have four technical working staff. In the receiving area of the Donor Marker Testing Unit, blood samples are checked for labelling, integrity, hemolysis and volume. Once checking is completed, blood samples will be centrifuged before applying the screening test of interest. The unit contains a number of different instruments that are found in duplicates (Table 9).

Table 9: *Assessing the Availability of Equipment at the Donor Marker Testing Unit*

Equipment	Quantity available	Capacity
Serology centrifuge	2	-
Dynex DS2® 2-Plate ELISA processing system	2	(100 samples/run) requires 5 hours
ARCHITECT machine	2	Maximum capacity 65 samples/batch (Batch systems)
Auto-LIA- 48 processing system	2	48 sample require 4-5 hours
Procleix systems	2	100 samples require 5 hours (Batch systems)
Refrigerator (1-6^{o}C)	5 (two of them are shared with the Component Processing Units)	
Freezer maintained at -18 ^{o}C or lower	4 (shared with the Component Processing Units)	

4.4.1 Blood screening and Pathogen inactivation

The Donor Marker Testing Unit performs a number of tests to assure the safety of blood delivered to patients. This unit has updated facilities and instruments, some of which are considered cutting-edge instruments in terms of technology and price. The different tests performed in the unit include: Malaria tests, Human immunodeficiency virus (HIV) antibody test, Treponema pallidum (Syphilis) antibody tests, Hepatitis tests (HBsAg, anti-HBc and HCV antibody), Human T cell leukemia virus (HTLV) antibody tests and Nucleic Acid Testing (NAT).

Dynex DS2® 2-Plate ELISA processing system, is only used for malaria antibodies detection in blood sample of donors coming from endemic region. Malaria Ag test (rapid

test) is carried out to identify the type of *Plasmodium* species (*Plasmodium falciparum, P.vivax, P.ovale* and *P. malariae*). If the results of samples are positive for malaria Ab and malaria Ag, the unit should be discarded. Also, HIV Ag/Ab assays, Syphilis antibody detection, HTLV antibody detection, HBsAg, HBcAb and anti-HCV detection are performed in the unit using the ARCHITECT machine which is based on the Chemiluminescent Microparticle Immunoassay principle. Any positive result of these tests will be followed by INNO-LIA tests on Auto-LIA- 48 Processing System for further confirmation.

Despite the expensive cost of NAT, which is based on the Transcription-Mediated Amplification technique, it is considered a mandatory test for HBV, HCV and HIV detection due to its sensitivity and specificity for viral nucleic acids. This reduces the risk of missing the identification of virus infection during the window period. NAT is performed on Procleix systems. According to NAT results, the blood unit will be either dispatched for clinical use or discarded.

4.5. Blood quarantine

All unscreened donated blood and its components are placed in the quarantine until the screening for infection markers is completed and the suitability of donated blood for therapeutic use is determined. Screened and unscreened units are generally stored in separate fridges. Reactive or positive blood bags are labelled “Not for transfusion” and removed from quarantined stock to separate and secure stores to be discarded or to be used for other purposes as quality assurance or research purposes.

4.6. Blood storage

All blood components are stored in controlled temperature and conditions to maintain the recommended shelf life (Table 10).

Table 10: Blood Components Storage Shelf Life

Component	Storage	Shelf life	Additive solution
PRBCs	1-6 ^{0}C	42 days	SAGM
FP24			
FFP	-18^{0}C	1 year	-
Cryoprecipitated AHF			
Pooled platelets leukocytes reduced Apheresis platelets	20-24^{0}C	7 days	PAS

During the storage period, IQC is implemented to check the quality of blood components and therefore guarantee using effective, safe products with lowest risks.

4.7. Blood distribution to hospitals and health care institutions

In HMC, the dispatching of blood components starts from the Component Processing Unit to the blood bank laboratories and finally to other facilities and medical centers to meet their transfusion requirements and complete their inventory unites. The HMC Receiving Facilities includes Hamad General Hospitals (HGH), Heart Hospital

(HH), Al Wakra Hospital (AW), Al Khor Hospital, Dukhan/Cuban Hospitl (DH), Qatar Rehabilitation Institute (QRI) and other private hospitals.

Proper shipping containers are used to maintain a proper transport temperature that is appropriate for the components. For instance: RBCs and Plasma Frozen products including PF24, FFP, Cryoprecipitated AHF, and Plasma Cryoprecipitated Reduced are transported at a temperature of ranging from 1 to 10 ^{0}C, while platelets must be transported at temperature between 20 to 24 ^{0}C. Moreover, blood and blood components are transported using double insulated, proof security sealed containers to ensure that optimal temperature ranges are maintained during transportation.

4.8.Blood disposal

Blood and blood products are generally discarded if they do not meet certain specified criteria. Scenarios that usually result in discarding blood and blood components include (1) units that are positive for infectious markers (2) unsuitable products such as under/over weight blood bag or those that have not been maintained at proper temperatures (3) outdated units (4) leaks detected in the units (5) blood component that do not meet the inspection criteria (6) failure of the blood unit to meet the set quality standards after IQC assessment or (7) insufficient storage space. Unfortunately, a high percentage of collected blood units is ending being discarded either in the pre-analytical or post analytical phase of the blood supply chain process. In the pre-analytical phase, 5-10% blood is discarded due to various technical issues, while this percentage is slightly higher in the post-analytical phase (more than 20%) due to the screening test results.

Due to confidentiality considerations, we were unable to assess blood wastage in the BDC. We were also unable to assess the number of current available stock for each component

and blood group, the number of requested units and blood transfusion units. Also, information obtained about departmental and blood requests, needs and misuses were not provided. The only piece of information we obtained from the Head of Transfusion Medicine of Blood Banks in that regard was that there is a high percentage of blood and blood product wastes due to improper clinical practices. The Emergency Department usually consumes blood units the most because of urgent blood transfusion for life saving and for compensating for the sever blood loss as in case of accidents, accidents or blood vessel rupture. Many clinicians in the Emergency Department prefer to order O positive blood type for urgent and non-urgent cases to avoid the possibility of any complications that may affect the patient's life. This practice leads to shortage in O positive blood stock and generally affects the scheduled operations resulting in delays. Interestingly, historical data shows that 39% of blood wastage is mainly due to the expiration of the units, storage insufficiency and unaccepted temperature.

4.9. Descriptive analysis

In Qatar, blood service practices are based on voluntary unpaid donations. The BDC at HMC is the only available center that offers blood services across the country. Over the past six years, more than 180,000 people from over 100 different nationalities have been registered as donors. On average, 13% (21231) of those registered donors are Qataris, while the remaining 87% (140554) are non-Qataris. Figure (6) represents the distribution of Qatari vs non-Qatari donors over a six period (2013-2018).

Among different non-Qatar nations, Indians donate blood mostly especially the Lutheranisms. The Lutheran Church: encouraged its members to donate blood because it is "an expression of sacrificial love for a neighbor in need" [91]. Usually, the ethnic groups

cluster and arrange with the administrator personnel at the BDC to donate blood during the weekends. Likewise, Indian Sikh Nation (Sikh Quom) group together and organize campaigns to donate blood as attribute to the events of 1984, where civilians Sikh were targeted by aggression and attack. The Philippinoes also participate in blood donation during certain religious occasions. Some blood donation campaigns take place in the BDC on Fridays.

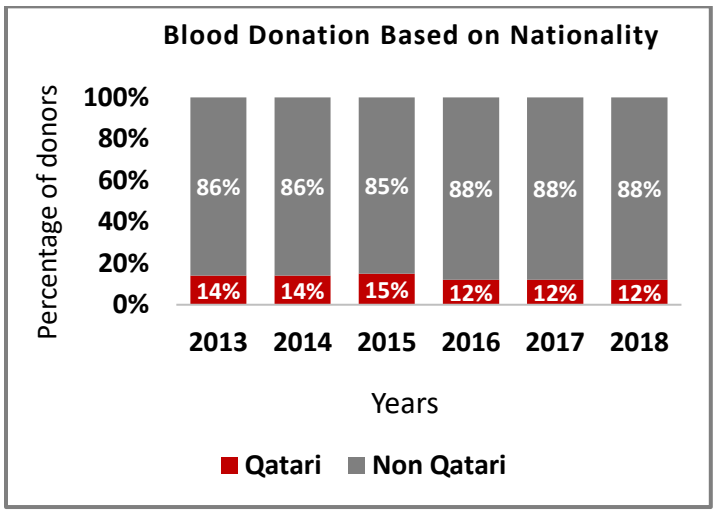

Figure 6: Percentage of registered Qatari versus Non-Qatari donors. The figure shows the distribution of blood donation based on nationality in the HMC-BDC over a six years period ranging from 2013 to 2018. ■ Represents Qatari donors and ■ represents non-Qatari donors

In case of emergency or low blood stock (shortage in specific blood group or platelets), HMC-BDC sends announcement in different languages broadcasts via radios, on Qatar TV channels, by short messages (SMS), through twitter or through any other mean of social media. From a statistical stand point, the number of male donor's dominant female

ones. The average percentage of male donors for the past six years was (97%; 36687) as compared to (3% ;1088) female donors (Figures 7). This could be due to several reasons including low hemoglobin levels and pregnancy conditions, or lack of privacy in the Center.

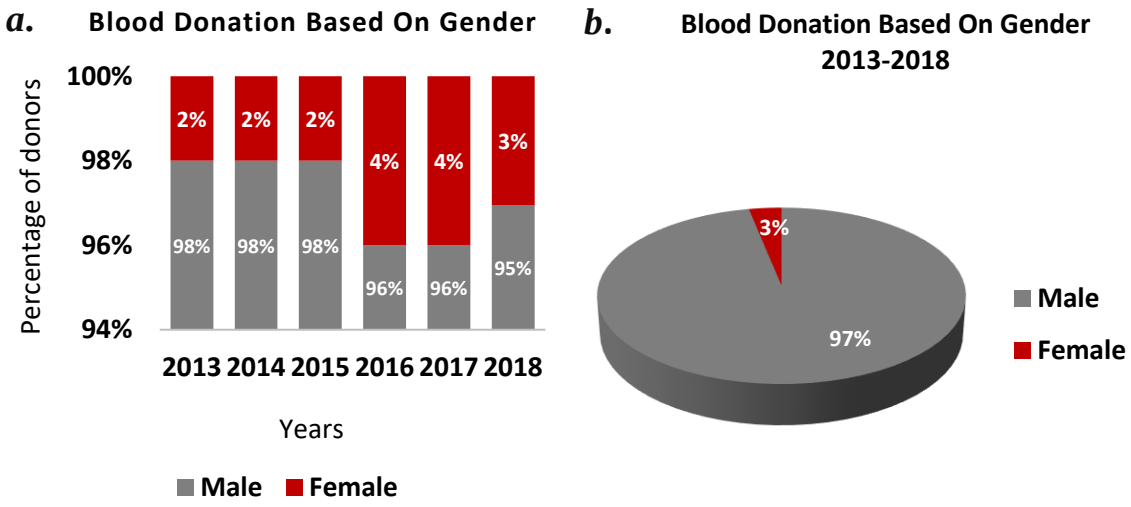

Figure 7: Percentage of male donors versus female donors registered in the HMC-BDC over a six years period ranging from 2013 to 2018. (a-b) ■ Represents the average percentage of male donors and ■ represents the average percentage of female donors

The graph shows an average increase of whole blood donation over the past six years by 5%. For instance, a continuous upward trending (8.4%) between 2017 and 2018 reaching (30209) donors (Figure 8).

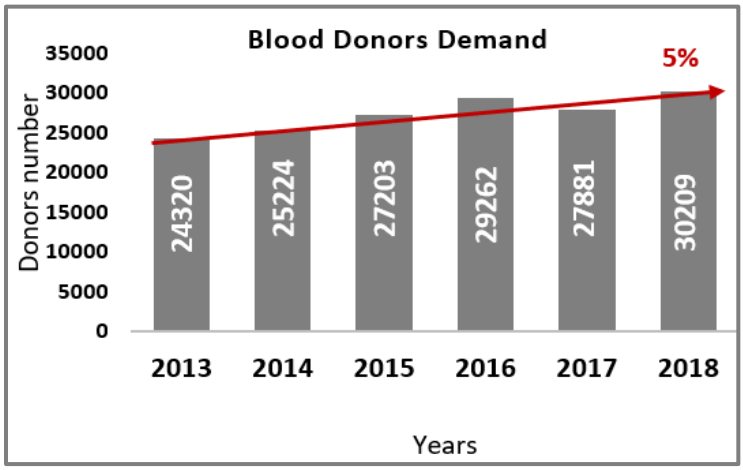

Figure 8: Donors demand pattern over a six years period ranging from 2013 to 2018. Represents an increase in the whole blood donation demand except in 2017. Represents total number of donors.

In each step of the blood donation process, a number of registered donors ends-up being deferred due to eligibility standards. The highest average percentage of donor deferral for the past five years was at the medical interview stage (26%; 10492) compared to physical assessment deferral (9%;27480) or self-deferral after registration (5%;2195). Interestingly, 62% of the 26% deferred at the medical interview stage were deferred due to malaria criteria (Figure 9).

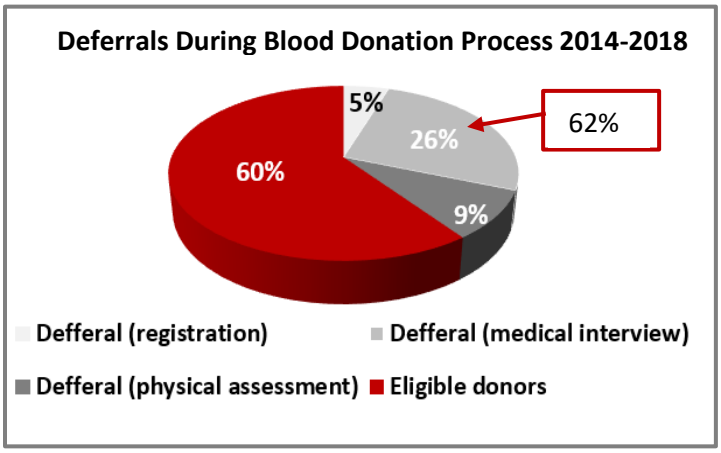

Figure 9: Percentage of deferred donors versus eligible donors in blood donation process. ■ Indicates the eligible donors (60%) ■ indicates defferal due to physical assessment ■ indicates defferal due to medical interview (26%) and ■ indicates defferal due to the registration step (5%). ▢ indicates defferal due to malaria criteria.

Usually, these donors either visit the BDC at HMC campus or participate through off-site campaigns organized by the state. The percentage of blood collected in the BDC was relatively higher than blood collected through campaigns. Over the past six years, the number of donors has slightly increased reaching 30209 donors in 2018; 13697 of which participated in off-site campaigns and 16512 visited the center in 2018 (Figure 10).

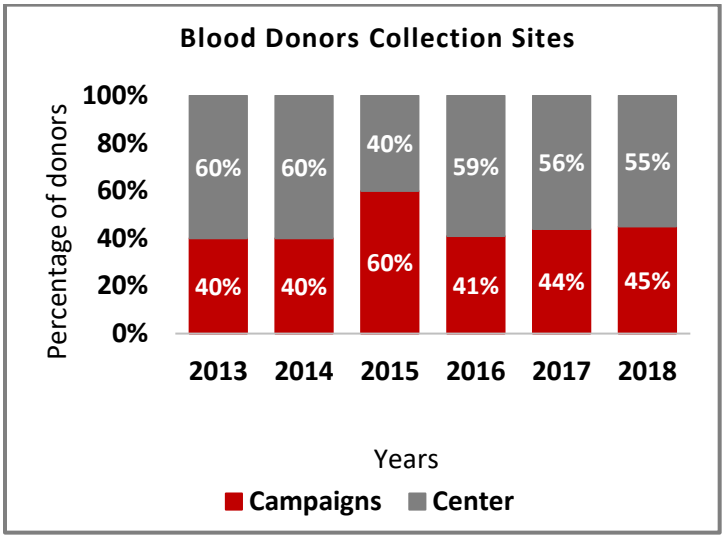

Figure 10: Percentage of part taking donors donating either at HMC-BDC or through off-sight campaigns over a six years period ranging from 2013 to 2018. ■ Denotes the percentage of donors participating through-off-sight campaigns and ■ denotes the percentage of donors donating at BDC.

Different ministries, governmental institutions, petrol companies, embassies and schools participate in a series of blood donation events in shopping centers and other prominent places in Qatar. Annual campaigns schedule begins with the Ministry of Defense and Qatar Armed Forces that usually succeed in involving large numbers of participants in these campaigns. The Medical Manager at HMC-BDC is usually engaged in arranging such needed campaigns along the year. Additionally, the BDC, receives frequent requests from schools or companies to provide cars when such activities are organized. These requests are generally accepted when the number of volunteers is greater than or equal to thirty.

Whether through campaigns or visits to the BDC, blood is usually donated for different purposes including whole blood or single component (platelet apheresis) usage or for therapeutic purpose (Therapeutic phlebotomy, Therapeutic plasma exchange or RBC

exchange). On average, from (27933) donors over the past six years, 97% (26964) were used for whole blood collected procedures, 2% (690) for platelet apheresis procedures, 0.8% (297) for Therapeutic plasma exchange and 0.2% (42) for RBC exchange (Figure 11).

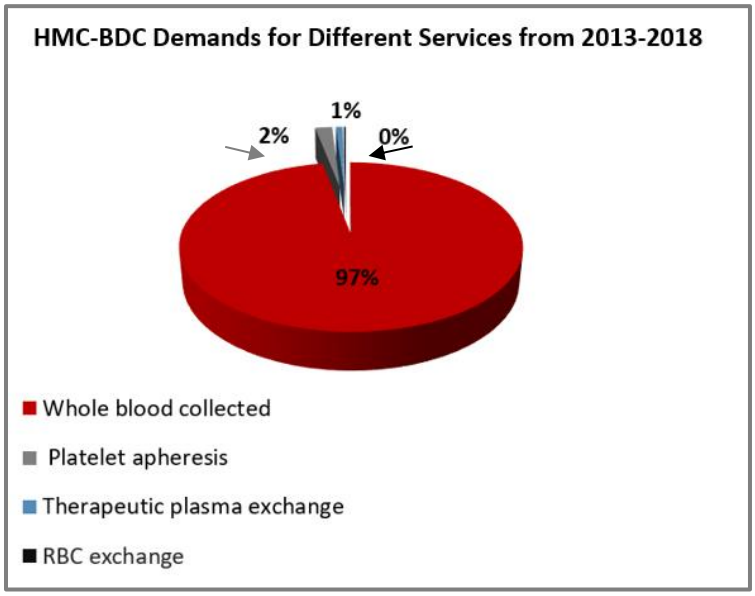

Figure 11: Percentage of donors participating in different service provided by the HMC-BDC over a six years period ranging from 2013 to 2018. ■ Indicates whole blood collection, ■ platelet apheresis, ■ Therapeutic plasma exchange, and ■ RBCs exchange.

Over the past five years, the average percentage of whole blood disposal of the BDC and its corresponding units reached (61%), while blood wastage in other facilities was (39%). This percentage can be justified due to technical issues, positive infectious markers testing, outdated units and other reasons (Figure 12).

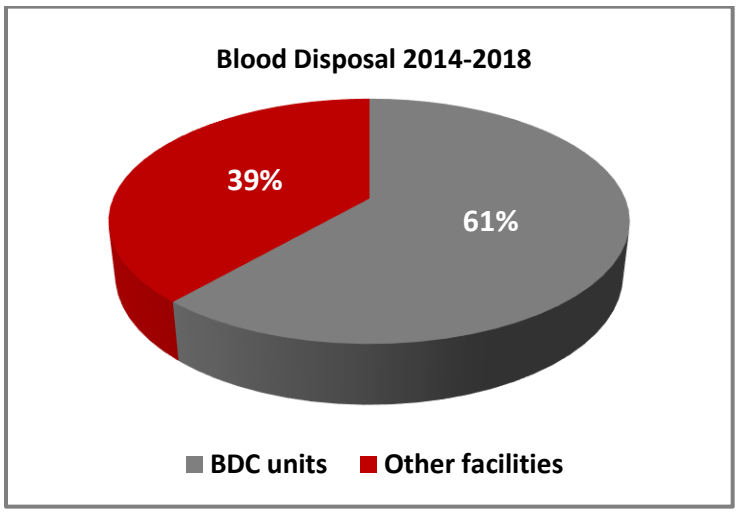

Figure 12: Average percentage average of blood disposal in HMC-BDC and other facilities over a five years period ranging from 2014 to 2018. ■ Indicated the blood wastage in the BDC and ■ indicated the blood wastage in other facilities.

4.10. Forecasting

In this study, we predicted the demand of whole blood donation for the four coming years using two main variables: the number of blood donors on monthly basis versus the population of Qatar. Our established forecast model shows a significant increase (26%) in the expected number of donors who will visit HMC-BDC or participate through off-sight campaigns in 2022 (Figure 13).

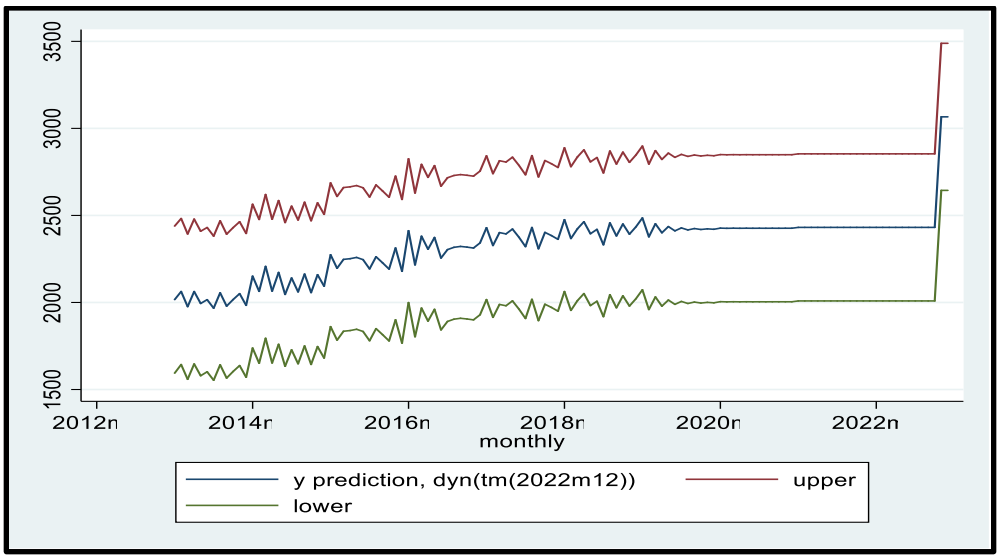

Figure 13: Predicted number of blood donors in Qatar from 2013 to 2022. Represents the predicted demand of whole blood donation in Qatar for the next four years. Both upper and lower lines indicate confidence intervals for the predicted period.

CHAPTER 5: DISCUSSION

In 2022, Qatar will witness a historical event by hosting the World Cup. According to the current statistics, Qatar is expecting around 1.3 million football fans to visit Doha in 2022. Such a mega event requires proper preparation and readiness in both the infrastructure and health care sectors. Previous FIFA World Cup events data illustrates unexpected and remarkable increase in demand for health care facilities because of an increase in the number of patients during and after each event [92]. Many International standards for health and medical services should be met in this event particularly those related to health care facilities, emergency medicine provisions, and specific national provisions for medical services, including (staffing, infrastructure and anti-doping services).

The readiness of the BDC for accommodating the required number of donors is on top of the to-do list. The BDC is of particular importance to all medical practitioners because blood serves as a lifesaving element especially when medical complications occur. As such, a proper assessment of blood resource availability, stock management, and a forecasting model that predicts future needs can guarantee quality service and therefore help in overcoming any obstacle that could be faced in this event. In this study, we have assessed the current standing of HMC-BDC infrastructure and blood donation related activities including blood collection from donors, blood processing, screening, storage and distribution of blood components to all hospitals and healthcare institutions. This assessment revealed our current standing in term of readiness to host the World Cup event. The HMC-BDC is the sole center that provides blood services in the country. Based on our

collected data, 55% of volunteered donors were received on the premises of the Hamad Medical corporation campus at the BDC and 45% participated through different off-site campaigns across the country in 2018 (Figure10). The role of BDC is not limited to blood donation, but also provides therapeutic services such as Therapeutic plasma exchange, RBC exchange, reductive leukoheresis, reductive thrombapheresis, stem cell collection and photopheresis, which are performed in Hamad hospital facility and in the NCCCR. These kinds of services are supported by the Transfusion Medicine Department staff and by the available equipment. By evaluating the origin of donation purposes from 2013 to 2018, and based on our statistical data, the majority of donors (97%; 26964) came for whole blood donation compared to (2%; 690) for platelets apheresis (Figure11).

Collectively, the BDC and its corresponding units such as the Donor Marker Testing Unit and the Component Processing Unit are fully equipped with high standard instruments and practice blood withdrawal and processing as per the guidelines and regulations of the AABB and the CE (Table 6).

First, A powerful software system "Medinfo Hematos_ IIG" is used to provide high security for the sensitive information where no third party other than authorized staff can access the database (1). The system is linked to the Ministry of Interior which provides information on the donor's identification in Arabic, thus preventing any conflict as language related in accuracy. Second, a very stringent of DHQ is used for the medical interview to ensure detailed and straight forward answers to determine the donor's eligibility. This leads to the loss of a big number of donors, especially those with long deferral periods. Accordingly, in January 2019 the transfusion medicine physician revaluated some medical questions enclosed in DHQ especially those with related to

malaria and reduced the deferral period from six months to four months based on the Australian system. Third, irrespective of the high cost of materials and equipment used in the Center and in branching laboratories, the HMC-BDC is designed to be one of the leading centers in the world in providing the safest blood with the longest shelf life and the fastest collection and processing procedures (Table 7 and 9). In order to approach the safest blood, all samples are initially screened for the following infectious markers prior to being released for transfusion (HIV Ag/Ab, HTLV-I/II Ab, Syphilis TP Ab, HBsAg, HBcAb, anti-HCV, Malaria Ag/Ab and NAT for HBV, HCV and HIV). In addition, HMC uses additional protections methods for platelets and plasma such as the pathogen inactivation technology that uses riboflavin (vitamin B2) and the Terumo BCT Mirasol system. Blood bags (Reveos and Cryo bags) as well contain (nanofilters) which eliminate leukocytes and viruses that contain protein membranes. Furthermore, the quality of the platelets is improved through the use of additive solution (PAS) which minimize adverse reactions associated with plasma transfusion by reducing the Leukocytes and extend the shelf life from 5 days to 7 days. Also, the use of SAGM extend the shelf life of RBCs from 35 days to 42 days (Table 10). The Donor Center offers fast service for platelets or plasma donors by using Trima machine, which consume around 90 minutes for whole the process of collection instead of 3 hours or more. Likewise, using an automated blood processing system (Reveos) helps in separating more than 200 bags/8 hours into four main components which are PRBCs, plasma, platelets and buffy coat (Table 8). Overall the availability of back up instruments insures the continuity of all services and the ability to accommodate high workload. It is worth noting here that the availability of instrumentation alone is not enough, especially with heavy workloads like in a World Cup scenario or in any other

scenarios associated with unexpected increase in demands. Therefore, other factors such as the employment availability and storage depots could be a barrier in accommodating the required quantities. These obstacles will be discussed in the below action plan section of this study.

By comparing the data of over the past six years (2013-2018), we concluded that the average blood donation in Qatar has increased by 5%, and the total number of whole blood donors was the highest in 2018 (30209) (Figure 8). As a general trend, blood demands are in an increasing pace. Despite this slight increase in the total number of donors, the BDC is still facing a major problem in meeting the daily benchmark of some blood types specifically O positive. Although the blood type distribution may vary according to ethnic groups, O positive is considered one of the most common blood types in most of the countries including Qatar whose population is distributed into 11.6% Qatari and 88.4% Non-Qatari [93]. On average, the Qatari donors represent 13 percent of the total number of donors which is considered a relatively acceptable percentage as compared to the percentage of Qatari versus non-Qatari population (Figure 6). Yet, if we dissect this 13% in depth, we question this percentage in accordance with the of eligibility of the Qatari population to donate blood. The causes behind this reluctance should be seriously considered to improve the percentage of donation in the coming years.

In case of emergency or low blood stock, HMC broadcasts the need of blood donors through various media tools. The overall data recorded for the past six years shows, 97% (36687) male donors as compared to 3% (1088) female donors (Figure 7). This percentage of female donors is considered very low compared to the percentage of females in the Qatari population (24.6%; 659036 females in 2018) [94]. This low percentage of female

donation can be justified due to several clinical reasons for instance low hemoglobin levels, pregnancy especially in young women, in addition to lack of privacy in the Center. A study conducted by Bani and Giussani shows that female donors represent only 30% of the Italian population, which is opposing to the scenario in many other European countries where donor distribution is gender similar. Several published data have indicated that this discrepancy in gender could be due to deferrals reasons where women deferrals rates are usually higher than men deferral rates. This could be due to low levels of hemoglobin, which are the most frequent cause of deferral in women, increased possibility of adverse reactions in women due to low body weight as compared to men, or difficulties in venous access [95, 96].

5.1.Challenges

In this study, we categorized the challenges faced by HMC-BDC to meet the benchmark of donation into three parts; challenge related to donors, challenge related to infrastructure (logistic/personnel/campaigns) and challenges related to awareness.

5.1.1. Challenges related to donors

By comparing the percentage of the eligible donors to ineligible ones, we found that 40% of the donors were deferred, with the highest percentage of deferral (26%) happening at the medical interview stage. It is worth noting here that around 62% of this 26% deferral is due to the malaria criteria (Figure 9). The stringent criteria of the questionnaire is also another challenge that lead to a significant loss in the number of donors. For instance, donors who visited malaria endemic area in the past 6 months got deferred for 6 months. Qatar receives many donors from malaria endemic areas especially those currently recruited to participate in construction plans for the World Cup event. The

percentage deferral for this reason was high and the deferral period was long. In addition to loosing donors, sometimes although blood is collected, it ends up being disposed mostly in BDC unites or other facilities such as HGH, HH, NH and AW (Figure 12). More than 20 % of the blood bags were discarded during the post-analytical phase due to positive infectious disease markers testing. In general, the percentage of discarded blood may increase due to the nationality of donors. High percentages are usually detected with donors coming from some South Asian countries, due to high prevalence of syphilis and other infectious diseases. A recent study conducted by Silverman *et al*. showed the proportion of syphilis and HIV co-infection is relatively high (accounts for 31.0%) in Nepalian people [97]. Likewise, high percentage of discarded blood from Egyptian donors is detected due to high prevalence of HCV in their originating countries [98]. From the 88.4% of Non-Qatari residents, Indians account for 24% of the population, followed by 16% Nepalis, 11% Filipinos, 5% Bangladesh, and 5% Sri Lankan [99].

5.1.2. Challenges related to infrastructure and logistics

As previously described, the HMC-BDC is very small and can't accommodate more than 180 donors/day, although it is the sole blood donation Center in Qatar. People living in North or West parts of Doha find it difficult to come to the Center and donate blood regularly. Furthermore, the BDC has limited number of chairs in both males and females in the waiting area which affects the ability of the donors to read and understand the education procedures slowly and carefully. Currently, the calculated daily benchmark is 542 donors for all blood groups, with 227 donors for O positive, owing to the fact that O positive blood group is commonly requested in cases of emergency. In our study, we have detected that failure to meet this benchmark starts at the medical interview stage

where only a maximum of 180 donors can be interviewed per day. This problem occurs due to presence of only one room, which also lacks complete privacy. As such, this stage is considered a bottle neck, and therefore, requires further planning to rectify the arising problem. Another constrain is having only one physical assessment room where only a maximum of 180 donors can be physically assessed daily (Figure 5). This also leads to an increase in the waiting time for each donor, and results in long queue of donors waiting for their turn because the available chairs to sit are not enough. This will eventually delay the process of blood donation and negatively impact the health of the donor especially in the summer season where many donors stand outside the Center, get exposed to the sun, ending up being exhausted, dizzy or start vomiting. This decreases the donation process and results in wastage of material used (bags) and waste in the effort and time of the staff. Additionally, there is a limited number of beds in the phlebotomy room, and the available beds are used for different purposes including whole blood donation, therapeutic procedures or platelet apheresis. Usually the whole process of whole blood donation takes around 30 minutes. Maximum 15 minutes is required to donate blood, while donating plasma or platelets using the apheresis machine takes up to 90 minutes (Figure 4). This means that it is very difficult to accommodate 542 donors per day if the capacity of the center can't even reach half of that number.

Some basic facilities are not even available in the BDC. For example, the Center lacks female recovery area, adequate rest rooms and a praying room. The Center also lacks enough parking lot; a space that can only accommodate 8 cars is available. Donors are sometimes subjected to fines due to parking their cars in unauthorized locations or in

prohibited parking areas close to the Center. This requires the Medical Manager of the BDC to contact the traffic department to waive these violations or to coordinate with the traffic department ahead of time to avoid receive these violations. This problem always occurs during working days, weekends and on formal holidays. The overall conditions of the BDC as not appealing and are discouraging for many people that have an inner will to participate.

In addition to the space constrain, inadequate number of personnel working at the HMC-BDC is another reason for not meeting the daily benchmark (Table 4). Nurses are responsible for various tasks such as medical interview, physical assessment and patient phlebotomy. Also, nurses are scheduled during the weekdays to cover the therapeutic procedures in HGH or in NCCCR, as well as handling other campaigns duties. Such a staff schedule impacts the number of organized campaigns per day. In addition, four laboratory staff in the Donor Marker Testing Unit and five technical staff in Component Processing Unit cannot handle all the work, which requires a lot of efforts. Therefore, the shortage in staff is eventually affecting the overall workflow. Mobile services are another factor behind not meeting the daily benchmark. Off-site campaigns are scheduled once every day and in very rare events two campaigns per day take place (Table 5).

Moreover, insufficient storage area in the Donor Marker Testing Unit and in the Component Processing Unit is a serious obstacle that is obstructing storage of blood products for long time, leading to wastage.

5.1.3. Challenges related to awareness

Lack of awareness and motivation programs among different age groups to

encourage more people to participate in humanitarian action, explains the low number of donors relative to the population size.

Another problem related to awareness is wastage of blood due to misuse from improper clinical practices especially for O positive blood type. Such misuse of blood usually occurs because physician lack proper awareness of what to order and how blood or blood components should be ordered. The Emergency Department is considered the most consuming of blood units. There are many causes of blood loss that require urgent blood transfusion like blood needs for life saving purposes after accidents, or blood vessel rupture. In HGH-Emergency Department many clinicians prefer to order O positive for urgent and non-urgent cases to avoid possible blood transfusion complications. This practice negatively affects the blood stock leading to shortage in O positive stock, and therefore delays all scheduled operations.

Predicting the number of donors in the next 4 years is one aspect of a needed rectification plan for a better percentage of blood donation over the coming years. Our short-term prediction forecasting model showed a significant projection of number of donors. In 2022, Qatar's population will increase by 52% reaching 4.1 million people. This increase in the population number is positively correlated with a 26% increase in the expected number of blood donors during that period. This assumption drew our attention to the challenges and obstacles that the HMC-BDC will seriously face in accommodating more donors to enrich the blood stock in the coming few years. Therefore, proactive strategies by decision makers are needed to prevent blood shortage in the coming years, improve donor retention, and reduce the loss in the number of blood donors that could occur as a consequence of availability of poor infrastructure.

CHAPTER 6: CONCLUSIONS

6.1. Summary of major findings

Despite of the advantage of an expected 26% increase in the number of donors between 2019 and 2022, the HMC-BDC will not be unable to accommodate this increase in the number of donors with the current available facilities and infrastructure. The findings of this study show that, although the center and its corresponding units are fully equipped with high standard equipment and follow an international guidelines and regulations that provide safe blood transfusion, a lot of challenges and obstacles related to donors, infrastructure (logistics, personnel, mobile services), and awareness still occur. Here, we provide an action plan to able to meet the increasing blood needs in the coming future. Accordingly, we suggest to review the strict donor deferral criteria that leads to the loss of high percentage of donors, provide alternative solutions to meet the required benchmark, develop a better infrastructure that reflect the financial shading of Qatar, and put more efforts towards increasing awareness on the importance of participation in humanitarian action.

6.2. Research limitations

Several limitations have been encountered while conducting this study. First, the high confidentiality and restrictions in exploring the healthcare preparation plan for the 2022 World Cup event was one of the major limitations we faced. Furthermore, the confidentiality of blood bank data, which are related to the current standing of blood stock and stock management in term of departmental and blood requests, needs and misuse was another limitation. In this study we were unable to uncover the exact facilities that misuse blood and blood component disposal in all blood supply chains. Moreover, the difficulty

in validating the qualitative questionnaire mainly due to lack of literatures related to the preparation plan, further complicated some reads in this study. Finally, the major limitation was in approaching expert Biotechnicians that could make use of the raw data in implementing a time series-forecasting model with sophisticated information such as forecasting the daily benchmark for targeted blood group such as O positive.

6.3. Recommendations

By stitching all the pieces of our study together, the infrastructure at HMC-BDC cannot accommodate the large number of donors expected in 2022. Surprisingly, the HMC-BDC does not actually represent the financial shading of Qatar and its economical classification as a super-rich country. As such, certain changes at the level of practices and infrastructure should be implemented. To be able to approach the current benchmark, we recommend increasing the off-sight campaigns to at least two campaigns per day. During the 2022 World Cup event, three off-sight campaign will be even better. From a practical perspective, attracting a large number of donors for enough blood supply before the World Cup events can be achieved by purchasing new mobile blood collection vehicles that can reach people easily in different locations. These vehicles will not be a waste of money because they can stand as a backup car when any damage or maintenance problem arise to avoid any stop in BDC services that could affect the blood bank daily inventory. Some companies provide a customization option to design the vehicle according to specific need as installing critical amenities like collection equipment, donor beds, private history rooms, canteen areas and short-term storage solutions.

Many BDCs worldwide have only one centralized blood bank and multiple donor sites

(hybrid model) have been shown helpful in collecting more donors. Also, other countries have multiple donor sites accompanied with processing units in different area of the country where the donation blood will be eventually transported to the main Center. In Qatar, we recommended to adapt similar systems. We also, encourage to build a small Donor Center close to hospitals outside Doha, such as in Cuban hospital-Dukhan, Alkhor hospital that can be easily reached by the people living in the North part of Qatar and by employees working in Ras Lafan, Hazm Mebaireek hospital which is located in the heart of the industrial Area and Al Wakra Hospital. Although this idea may require a huge budget and might take lots of time to get established, it is considered very practical and safe, especially in case of disaster.

Besides that, we also recommend constructing a new donation center or renovating the currently available one. The HMC-BDC should reflect the country's financial standards and should provide comfortable conditions for donors. This encourages donors to participate more frequently in blood donation and attracts the recruitment of newcomers to the Center. The Center should also provide a good working environment for the staff. It should contain a wide parking lot, more than 4 clerks, more than 4 interview rooms, more than 4 physical assessment rooms, special room for platelet and plasma apheresis for both males and females, a special phlebotomy room with at least 10 beds, a prayer room for males and females and a spacious waiting area for males and for females considering the privacy of females. Also, the Center should be supported with free Wi Fi access and all other comfort conditions. Any expansion or increase in the facility of BDC should be similarly considered for the Donor Marker Testing Unit and the Component Processing Unit to be able to handle this anticipated increase. The Center should also look forward to

recruit additional staff (nurses and technical staff). This allows task organization among shifts and permits handling heavy workloads comfortably.

We also, recommended that the BDC changes the regular practice of accepting donors. It is highly advisable to collaborate with the Ministry of the Interior in order to obtain the necessary information about the blood types of citizens and residents. This type of information helps in conducting comprehensive studies to solve problems related to waste of time, money and efforts. Accordingly, donors can be contacted, thus guarantying the availability of needed donors. This, collaboration with the Ministry of the Interior is particularly useful when targeting certain blood type in cases of emergency.

However, the BDC should not accept a particular blood group if they don't need it. Donors can be contacted later when there is a real need for a specific blood group, especially if storage space insufficient. Therefore, implementing mobile application will notify donors when blood is needed. The application can be supported with many features such as the next donation date, date after deferral, eligibility and donation criteria, working hours of the Center, and the location through Google map. Such an application can save a lot of money instead of sending SMS. SMS can be only used for real emergency cases. This kind of practice can make the donor feel involved in a particular human action. A mobile phone application can be also used as a learning tool for children that sees it on their parent's mobile. This will motivate them to donate blood when they reach the eligible age.

Because of the high prevalence of some infectious diseases and because of the huge number of blood that can be discarded due to ineligibility leading to waste of financial resources, especially with some nationalities that are widely known to have a high prevalence of HCV, blood sample should be collected for HCV examination before collection of whole blood.

This practice can save a lot of money which can be used to improve the blood facility itself. Today is the ideal time to educate the students about the importance of blood donations. Schools should include in their curriculum the benefits of donating blood for health and how much this little effort can save thousands of lives, and faculty should be leaders in these practices. Undoubtedly, this will positively impact the donation practice by spreading awareness among the new generation.

The BDC should put more efforts in the awareness part and advertisements through social media, websites, internet Pop-ups, direct mails, billboards, newspaper and TV. They should improve the official web site by providing more information as those proposed for the mobile application. Transfusion medicine clinicians should also conduct more education programs to direct physicians in performing correct practices when requesting blood and therefore avoid blood misuse or wastage.

Finally, we highly recommend that the Component Processing Unit implement some validation on frozen packed RBCs in order to be able to use liquid blood in case of any emergency during the World Cup event and for daily routine needs as well.

REFERENCES

1. *FIFA World Cup™*. Available from: https://www.fifa.com/aboutfifa/worldcup.
2. *2022 FIFA World Cup Bid Evaluation Report: Qatar*. 2010, Fédération Internationale de Football Association: Zurich, Switzerland.
3. Trubina, E., *Manipulating neoliberal rhetoric: Clientelism in the run-up to international summits in Russia.* European Urban and Regional Studies, 2015. **22**(2): p. 128-142.
4. Zubko, I. *Russia's successful 2018 World Cup bid built on promises*. 2010; Available from: http://www.telegraph.co.uk/sponsored/rbth/society/8229978/Russias-successful-2018-World-Cup-bid-built-on-promises.html.
5. Wolfe, S.D., *2018 FIFA World Cup: isolating Russia could harm global health.* The Lancet, 2015. **385**(9970): p. 749-750.
6. Kassens-Noor, E., *Transport Legacy of the Olympic Games, 1992–2012.* Journal of Urban Affairs, 2016. **35**(4): p. 393-416.
7. Ernst and Young, *Brasil sustentável: Impacts socioeconômicos da Copa do Mundo 2014.* São Paulo, 2011.
8. PricewaterhouseCoopers, *The games effect. Toronto: Author.* 2011.
9. Müller, M., *How mega-events capture their hosts: event seizure and the World Cup 2018 in Russia.* Urban Geography, 2015. **38**(8): p. 1113-1132.
10. Pillay, U. and O. Bass, *Mega-events as a Response to Poverty Reduction: The 2010 FIFA World Cup and its Urban Development Implications.* Urban Forum, 2008. **19**(3): p. 329-346.
11. Gaffney, C., *Mega-events and socio-spatial dynamics in Rio de Janeiro.* Journal of Latin American Geography, 2010. **9**(1): p. 7–29.

12. Bohlmann, H.R. and J.H.v. Heerden, *Predicting the economic impact of the 2010 FIFA World Cup on South Africa.* Int. J. Sport Management and Marketing, 2008. **3**.

13. Baade, R.A. and V.A. Matheson, *The Quest for the Cup: Assessing the Economic Impact of the World Cup.* Regional Studies, 2004. **38**(4): p. 343-354.

14. Brannagan, P.M. and R. Giulianotti, *Qatar, Global Sport and the 2022 FIFA World Cup and other ligacies*, in *Leveraging Legacies from Sports Mega-Events: Concepts and Cases* 2014, Palgrave Pivot, : London.

15. Al Refai, H. and M.A. Eissa, *The impact of FIFA's official announcements on the stock market of Qatar: The case of the 2022 World Cup.* Research in International Business and Finance, 2017. **41**: p. 347-353.

16. Ministry of Foreign Affairs. *Sports*. 2019 January 3, 2019]; Available from: https://mofa.gov.qa/en/qatar/history-of-qatar/youth-and-sports.

17. Mathew, D. and I. Hubloue, *The Readiness of Primary Healthcare Facilities In Qatar To Deal With Potential Mass Casualty Incidents During The Fifa World Cup 2022.* Arch Med, 2018. **10**(1).

18. Ganji, S.K., *Leveraging the World Cup Mega Sporting Event.* Journal of Migration and Security, 2016. **4**: p. 221-259.

19. Senouci, A., I. Al-Abbadi, and N. Eldin, *Safety Improvement on Building Construction Sites in Qatar.* Procedia Engineering, 2015. **123**: p. 504-509.

20. *Qatar National vision 2030_Arabic version*. 2008, Ministry of Development Planning and Statistics.

21. Filho, O.S.S., et al., *Demand Forecasting for Blood Components Distribution of a Blood Supply Chain.* IFAC Proceedings Volumes, 2013. **46**(24): p. 565-571.

22. Oliveira, C.D., et al., *Temporal distribution of blood donations in three Brazilian blood centers and its repercussion on the blood supply.* Rev Bras Hematol Hemoter, 2013. **35**(4): p. 246-51.

23. World Health Organization, *Design Guidelines for Blood Centres*. 2010 a: Geneva , Switzerland

24. Aide-Mémoire, *Developing a national blood system*, B.T. Safety, Editor. 2011, World Health Organization: Geneva.

25. World Health Organization, *Blood Donor Counselling: Implementation Guidelines*, W.H. Organization, Editor. 2014: Geneva 27, Switzerland.

26. World Health Organization, *Blood Donor Selection Guidelines on Assessing Donor Suitability for Blood Donation*. 2012.

27. World Health Organization, *Global Database on Blood Safety. Summary report 2011, Geneva*. 2011.

28. *Management of National blood donor program*, W.H.O. 2010, Editor. 2010, WHO Press: Switzerland, Geveva. p. 1-167.

29. De Kort, W., et al., *Blood donor selection in European Union directives: room for improvement.* Blood Transfus, 2016. **14**(2): p. 101-8.

30. Karp, J.K. and K.E. King, *International variation in volunteer whole blood donor eligibility criteria.* Transfusion, 2010. **50**(2): p. 507-13.

31. Custer, B., et al., *The consequences of temporary deferral on future whole blood donation.* Transfusion, 2007. **47**: p. 1514-23.

32. Drackley, A., et al., *Forecasting Ontario's blood supply and demand.* Transfusion, 2012. **52**(2): p. 366-74.

33. Hutin Y, e.a., *Best infection control practices for intradermal, subcutaneous and intramuscular needle injections.* Bulletin of the World Health Organization, 2003. **81**(7): p. 491–500.

34. Organization, W.H., *WHO guidelines on hand hygiene in healthcare*. 2009 a, World Health Organization: Geneva.

35. Pratt, R., et al., *epic2: National evidence-based guidelines for preventing healthcare-associated infections in NHS hospitals in England.* Journal of Hospital Infection, 2007. **65**: p. S1–S59.

36. McDonald, C., *Bacterial risk reduction by improved donor arm disinfection, diversion and bacterial screening.* Transfusion Medicine, 2006. **16**(6): p. 381–396.

37. Charbonneau, J., M.S. Cloutier, and B. Fainstein, *How do people become plasma and platelet donors in a VNR context?* J Clin Apher, 2018. **33**(3): p. 236-248.

38. Basu, D. and R. Kulkarni, *Overview of blood components and their preparation.* Indian J Anaesth, 2014. **58**(5): p. 529-37.

39. World Health Organization, *WHO Guidelines on Drawing Blood: Best Practices in Phlebotomy* 2010 b, World Health Organization Geneva, Switzerland.

40. Fung , M.K., et al., *Technical Manual, 18th edition (Technical Manual of the American Assoc of Blood Banks) 18th Edition*. 2014: American Association of Blood Banks (AABB); 18th edition (July 15, 2014).

41. Van Dijk, N., et al., *Blood platelet production: a novel approach for practical optimization.* Transfusion, 2009. **49**(3): p. 411-420.

42. Hillyer CD, et al., *Bacterial contamination of blood components : risks, strategies and regulation.* American Society of Hematology Education Program, 2003: p. 575–589.

43. Blajchman, M., *Incidence and significance of the bacterial contamination of blood components. Developmental Biology.* Developmental Biology, 2002. **108**: p. 59–67.

44. Seifried, E. and M.M. Mueller, *The present and future of Transfusion Medicine.* Blood Transfus 2011. **9**(4): p. 371–376.

45. Mitra, R., N. Mishra, and G.P. Rath, *Blood groups systems.* Indian J Anaesth, 2014. **58**(5): p. 524-8.

46. Katsaliaki, K. and S.C. Brailsford, *Using simulation to improve the blood supply chain.* Journal of the Operational Research Society, 2017. **58**(2): p. 219-227.

47. Jyrki, S.R. and M.S. Karen, *Using simulation to increase efficiency in blood supply chains.* Management Research News, 2006. **29**(12): p. 801-819.

48. Arya, R.C., Wander, G., & Gupta, P., *Blood component therapy: Which, when and how much.* Journal of anaesthesiology, clinical pharmacology, 2011. **27**(2): p. 278–284.

49. Wallace EL, S.D., Hao HS, An J, Chapman RH, Churchill WH, *Collection and transfusion of blood and blood components in the United States, 1989.* Transfusion, 1993. **33**(2): p. 139-44.

50. Helme, H.J., et al., *Management of bleeding disorders in traumatic-haemorrhagic shock states with deep frozen fresh plasma.* European journal of intensive care medicine, 1976. **2**(4): p. 157-161.

51. Moog, R., *A new technology in blood collection: Multicomponent apheresis.* Nova Science Publishers, 2006: p. 141-6.

52. American Association of Blood Banks, *Standard for Blood Banks and Transfusion Services, 28th Edition, Bethesda, MD: American Association of Blood Bank.*, t. Edition, Editor.

53. World Health Organization, *Screening donated blood for transfusion-transmissible infections: recommendations.* World Health Organization, 2009, 2009 b.

54. NIH, et al., *Infectious Disease Testing for Blood Transfusions: NIH Consensus Development Panel on Infectious Disease Testing for Blood Transfusions.* JAMA, 1995. **274**(17): p. 1374-1379.

55. American Association of Blood Banks, *American Association of Blood Banks: Guidance on implementation of new bacteria reduction and detection standards. AABB Bulletin ,04(07)*. 2004.

56. Bihl, F., et al., *Transfusion-transmitted infections.* J Transl Med, 2007. **5**: p. 25.

57. Allain, J., et al., *Protecting the blood supply from emerging pathogens: the role of pathogen inactivation.* Transfus Med Rev, 2005. **19**(2): p. 110-126.

58. Kleinman, S., P. Chan, and P. Robillard, *Risks associated with transfusion of cellular blood components in Canada.* Transfus Med Rev, 2003. **17**(2): p. 120-162.

59. Dodd, R., E. Notari, and S. Stramer, *Current prevalence and incidence of infectious disease markers and estimated windowperiod risk in the American Red Cross blood donor population.* Transfusion, 2002. **42**(8): p. 975-97.

60. Hans, R. and N. Marwaha, *Nucleic acid testing-benefits and constraints.* Asian J Transfus Sci, 2014. **8**(1): p. 2-3.

61. Schuttler, C., et al., *Hepatitis C virus transmission by a blood donation negative in nucleic acid amplification tests for viral RNA.* Lancet, 2000. **355**(9197): p. 41-42.

62. Roth, W., et al., *International survey on NAT testing of blood donations: expanding implementation and yield from 1999 to 2009.* Vox Sang 2012. **102**(1): p. 82-90.

63. Soldan, K., K. Davison, and B. Dow, *Estimates of the frequency of HBV,HCV, and HIV infectious donations entering the blood supply in the United Kingdom, 1996 to 2003.* Euro Surveill 2005. **10**: p. 17-9.

64. Keil, S.D., et al., *Treatment of Platelet Products with Riboflavin and UV Light: Effectiveness Against High Titer Bacterial Contamination.* J Vis Exp, 2015(102): p. e52820.

65. Mundt, J.M., et al., *Chemical and Biological Mechanisms of Pathogen Reduction Technologies.* Photochemistry and Photobiology, 2014. **90**(5): p. 957-64.

66. Marschner, S. and R. Goodrich, *Pathogen Reduction Technology Treatment of Platelets, Plasma and Whole Blood Using Riboflavin and UV Light.* Transfus Med Hemother, 2011. **38**(1): p. 8-18.

67. Hardwick, J., *Blood processing: Introduction to blood transfusion technology.* ISBT Sci Ser, 2008. **3**(2): p. 148-176.

68. O'Shaughnessy, D., et al., *Guidelines for the use of fresh-frozen plasma, cryoprecipitate and cryosupernatant.* Br J Haematol 2004. **126**: p. 11-28.

69. Baesler, F., et al., *Analysis of inventory strategies for blood components in a regional blood center using process simulation.* Transfusion, 2014. **54**(2): p. 323-30.

70. *United States General Accounting Office: Public health: blood supply generally adequate despite new donor restrictions*. 2002.

71. *European Directorate for the Quality of Medicines & Healthcare: Guide to the Preparation, Use and Quality Assurance of Blood Components, 18th edn. Strasbourg, France, Council of Europe,* . 2015.

72. Roback, J.D., *Perspectives on the impact of storage duration on blood quality and transfusion outcomes.* Vox Sang, 2016. **111**(4): p. 357-364.

73. Kopach, R., B. Balcıoğlu, and M. Carter, *Tutorial on constructing a red blood cell inventory management system with two demand rates.* European Journal of Operational Research, 2008. **185**(3): p. 1051-1059.

74. Sultan S, et al., *Internal quality control of blood products: An experience from a tertiary care hospital blood bank from Southern Pakistan.* J Lab Physicians, 2018 **10**(1): p. 64-67.

75. Kazemi, S.M., et al., *Blood inventory-routing problem under uncertainty.* Journal of Intelligent & Fuzzy Systems, 2017. **32**(1): p. 467-481.

76. Hardwick, J., *Blood storage and transportation* ISBT Sci Ser 2008. **3**(2): p. 177-96.

77. Pierskalla, W.P., *Supply Chain Management of Blood Banks.* Operations Research and Health Care 2005. **70**: p. 103–145.

78. Cobain, T., *Fresh blood product manufacture, issue, and use: A chain of diminishing returns?* . Transfus Med Rev 2004. **18**: p. 279-92.

79. Stanger, S.H., et al., *Blood inventory management: hospital best practice.* Transfus Med Rev, 2012. **26**(2): p. 153-63.

80. Kurup, R., et al., *A study on blood product usage and wastage at the public hospital, Guyana.* BMC Res Notes, 2016. **9**: p. 307.

81. Far, R.M., et al., *Determination of rate and causes of wastage of blood and blood products in Iranian hospitals.* Turk J Haematol, 2014. **31**(2): p. 161-7.

82. British Committee for Standards in Haematology, *Guideline on the administration of blood components*. 2009.

83. Heddle NM, et al., *Factors affecting the frequency of red blood cell outdates: an approach to establish benchmarking targets.* Transfusion, 2009. **49**(2): p. 219–226.

84. Zoric L, et al., *Blood wastage reduction: a 10-year observational evaluation in a large teaching institution in France.* Eur J Anaesthesiol 2013. **30**: p. 250–255.

85. Rock, G., et al., *The supply of blood products in 10 different systems or countries.* Transfus Sci, 2000. **22**: p. 171-82.

86. Prastacos, G., *Blood inventory management: An overview of theory and practice.* Manage Sci, 1984. **30**: p. 777-800.

87. Gschwender, A.N. and L. Gillaed, *Disaster Preparedness in the Blood Bank.* CLINICAL LABORATORY SCIENCE, 2017. **30**: p. 250-57.

88. Karaesmen, I.Z., Scheller–Wolf, A. and Deniz B. , *Planning Production and Inventories in the Extended Enterprise*. Vol. 1. 2011: International Series in Operations Research & Management Science.

89. Dhingra, N., *Expert Consensus Statement on achieving self-sufficiency in safe blood and blood products, based on voluntary non-remunerated blood donation.* World Health Organization, 2012: p. 1-10.

90. Eder, A., et al., *Effective reduction of transfusion-related acute lung injury risk with male-predominant plasma strategy in the American Red Cross (2006-2008).* Transfusion, 2010(50): p. 1732–1742.

91. *What Christianity & Islam say about blood transfusion*. 2017, October 19; Available from: https://www.pulse.ng/communities/religion/religion-vs-science-what-christianity-and-islam-say-about-blood-transfusion/zj9r2zd.

92. Morimura, N., et al., *Analysis of patient load data from the 2002 FIFA World Cup Korea/Japan.* Prehosp Disaster Med, 2004. **19**(3): p. 278-84.

93. Index mundi. *Qatar Demographics Profile 2018*. Available from: https://www.indexmundi.com/qatar/demographics_profile.html.

94. *Ministry of Development Planning and Statistics*. Available from: https://www.mdps.gov.qa/en/statistics1/StatisticsSite/pages/population.aspx.

95. Bani, M. and B. Giussani, *Gender differences in giving blood: a review of the literature.* Blood Transfus, 2010. **8**(4): p. 278-87.

96. Prados Madrona, D., et al., *Women as whole blood donors: offers, donations and deferrals in the province of Huelva, south-western Spain.* Blood Transfus, 2014. **12 Suppl 1**: p. s11-20.

97. Silverman, J., et al., *Syphilis and hepatitis B Co-infection among HIV-infected, sex-trafficked women and girls, Nepal.* Emerg Infect Dis. , 2008. **6**(14): p. 932-4.

98. Gomaa, A., et al., *Hepatitis C infection in Egypt: prevalence, impact and management strategies.* Hepat Med, 2017. **9**: p. 17-25.

99. *Qatar Population*. (2019, February 2018); Available from: http://worldpopulationreview.com/countries/qatar-population/.