Challenges in Managing the Blood Supply Chain, from Donor to Patient together with the Hospital

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Abstract. This paper aims at identifying challenges in blood supply chain management and mentioning management strategies in improving the blood supply services (BSS), starting with blood donations and ending with transfusion of needed blood components to patients. Management strategies like optimal scheduling, a web based information system and a short-term forecasting mechanism for inventory check are required to focus on tackling blood donors with. In the present study, We used past literature in identifying the research questions and challenges in blood supply chain from donors to patients. In general focusing on blood supply, a general management framework is prepared to efficiently manage the blood supply chain.

Keywords: Blood Supply Chain, Donor, Recipient

1. INTRODUCTION

At its simplest, a supply chain is a system of suppliers, manufacturers, distributors, retailers and customers where material typically flows downstream from suppliers to customers (except for reverse logistics) and information flow in both directions. Supply Chain Management (SCM) involves managing a connected series of activities which is concerned with planning, coordinating, and controlling movement of material, parts, and finished goods from supplier to customer. It is a set of approaches to efficiently integrate suppliers, manufacturers, distributors, warehouses and retail stores so that merchandise is produced and distributed in the right quantities, to the right locations, at the right time to minimize costs and maintaining service level requirements of the customer (simchi-Levi *et. al.*, 2003).

The past several years supply chains have seen many dynamic changes and become more complex in reality than ever before (see Bowersox and Closs (1996), Surana *et. al.* (2005)). Driven by continual cost pressures and other operational constraints, the supply chain in healthcare sector represents one of the largest opportunities and the challenge is to develop a strategy that allows us to succeed creating a perfect environment in delivery of care with a focus on cost containment and cost-benefit analysis (Sime, 2005). However, despite significant research contributions supply chains and healthcare sectors in Inventory management,

forecasting and operational research modeling techniques (Datta *et. al.* (2007)), cost and risk minimization (Nagurney *et. al.*, 2012), demand and supply variability (Chen and Samroengraja (2004)), the research in supply chain management (SCM) lacks addressing many practical, real world challenges in healthcare supply chain systems.

It is challenging enough to design and efficiently operating healthcare supply chains specifically for time-sensitive perishable products having a fixed life time. A p*erishable product* can usually be divided into two categories, Category 1 include items that have unlimited or random lifetime with an amount of decrease over time due to deterioration, such as petrol, alcohol and radioactive elements (see, for e.g., Datta and Pal (1990), Pal *et. al.* (1993), Su *et. al.* (1996) and Sarker *et. al.* (1997) . Category II includes those items that have a fixed life time. For example, lysis of red blood cells renders blood unacceptable for transfusion 21 days after it is drawn. Fresh produce, meats, and other foodstuffs become unusable after a certain time has elapsed. The fixed life assumption is that units may be retained in stock to satisfy demand for some specified fixed time after which they must be discarded (Nahmias (1982), Hwang and Hahn (2000), Blackburn and Scudder (2008), and Zhou and Yang (2003)). Notably, in some cases that of medicines and vaccines in the second category of perishable products may result in a matter of "life or death" for its consumers.

With the ageing populations and advances in medical treatments that require blood transfusions, the demand for a life saving product-human blood and blood products continues to increase and there is a need to develop plans to ensure the adequacy of the blood supply. The acquisition and distribution of blood and related products is a service vital to society; blood is sometimes referred to as the "elixir of life" due to its necessity to sustain humanity (Starr, 2000).

Blood is a living tissue of unique medical value to the human body. It is the vehicle that carries oxygen, nutrients and chemicals to all parts of the body, and carries away all waste products. In modern medical treatments, patients may receive a pint of whole blood or just specific components of the blood needed to treat their particular condition. This approach to treatment allows several patients to benefit from one pint of donated whole blood. The main transfusable blood components include red cells, or *erythrocytes* that carry oxygen from the lungs to body's tissue and take carbon dioxide back to your lungs to be exhaled, Platelets, or *thrombocytes,* are small, colorless cell fragments in the blood whose main function is to interact

with clotting proteins to stop or prevent bleeding, Plasma which is a fluid, composed of about 92% water, 7% vital proteins such as albumin gamma globulin, anti-hemophilic factor, and other clotting factors, and 1% mineral salts, sugars, fats, hormones and vitamins. All of these components except plasma are perishable, with their lifetimes varying from 5 days (platelets) to 42 days (red cells), while the whole blood can be used ranging 21 to 35 days. The shelf life of whole blood and red cells varies based on the type anticoagulant used.

The only source of blood is the health human being who donates one unit (approximately one pint) of blood a maximum of five times per year at a time. Blood donors are ordinary people – college going students, factory and office workers, business executives, parents and grandparents, and people from every walk of life. But they share one thing – a generous spirit, a desire to give back to their community and help others. Blood donors play an integral role in the delivery of modern healthcare. Many life-saving medical treatments and procedures involve blood transfusions and would not be possible without a safe and reliable blood supply. Each year, the volunteers and employees of American Red Cross Blood Services collect approximately 6.5 million units of blood, from roughly 4 million generous volunteer blood donors. From these donations, the Red Cross is able to distribute around 9.5 million blood products each year, including 6 million units of red blood cells, to patients at approximately 3,000 hospitals and transfusion centers across the country (redcross.org).

'Blood Supply chains' are a key supply chain operations of the healthcare systems all over the world starting with patients' needs and ending with transfusion of needed blood components (BCs) to patients. This blood supply chain comprises two main sectors: the hospitals-where transfusion is ordered by clinicians and administered to patients; and the suppliers, acting from donor management to blood component distribution, usually Blood Establishments (BE) like American Red Cross (ARC) which is U.S. largest blood collection organization supplying more than 40 percent of the blood and the blood products and rest supplied by independent members of the American Association of Blood Banks (AABB), members of the Council of Community Blood Banks (CCBB), and by commercial blood banks (Prastacos, 1984).

All blood establishments, including the ARC, charge hospitals a fee for processing blood, which is intended to cover the costs of personnel, equipment, and supplies involved in the

collection, laboratory testing, storage and distribution of blood. Most members of the AABB generally add a "replacement" or "recruitment" fee (generally in the range of $70-$1340 depending upon the blood products) that is passed on to the patient unless he, his family or his friends "replace" the blood transfused. The official philosophy of the ARC and most members of the CCBB is that the blood supply is a "community" responsibility, and the patient should be able to receive blood without having to pay a replacement fee (Johnson 1977).

Blood is collected in units of one pint per donor at collection sites such as a Regional Blood Center, a Hospital Blood Bank, or a mobile unit. When collected it undergoes a series of typing and screening tests, and may be separated into components. It is then shipped to a Hospital Blood Bank where it is available to satisfy demands for transfusions to patients. Donor inclusion and exclusion criteria and testing procedures have to be balanced to provide optimal safety for both donors and recipients while ensuring an adequate supply of blood products at the same time (Seifried *et. al.*, 2011).

Cooperation between hospitals and BEs for transfusion related matters is vital to ensure that the end user is satisfied with the products and services provided. Although optimizing blood utilization greatly impacts both patient safety and blood supply security, the blood supply management (BSM) itself is the top priority exerted both by BEs, supply blood components, and hospitals, storing, delivering, prescribing and transfusing blood components to patients, to make safe blood supply available for patients (Follea, 2013). Several other authors have tried identifying relationship between the donors and the transfusion services, technological advances in the preservation and utilization of human blood (see Mole (1975), Pegels (1978), and Kendall (1980)). Jonna, Richard and Sue in 2009 discussed the vital flow of blood supply chain and tried balancing supply and demand with three major challenges stakeholders' collaboration, time and wastage, falling donor base. In the present work we aim to outline the issues facing blood supplies discussing the challenges and the possible solutions.

2. Challenges in Blood Supply Services

When considering the blood supply we must consider the actual and the potential magnitude of the blood donor base and also the entire blood supply chain in order to get accurate estimates of blood supply potential. This chain begins with donor motivation, donor access, and eligibility and proceeds to collections, testing, storage, distribution and finally transfusion into a

patient. Innovation and change are also hugely important, including how we work with hospitals to manage blood stock levels and plan our blood collections to meet the needs of hospitals. It's important that blood services like ours collect the right blood mix to supply hospitals and patients with the blood that they need, when they need it.

The management issues of blood offers unique challenges as the supply of donors is fairly irregular and the demand is being stochastic in nature and highly variable during times of crisis and emergencies (Belien and force, 2012). Donors too during the year, especially summer and mid-winter donors are time periods prefer not to donate and because of the short lifespan, blood shortages occur. These blood shortages disrupt the operations of usually scarce healthcare facilities in the form of postponed surgery, patients being forced to do with less blood than would otherwise be available for replacement (as in surgery) or for therapeutic purposes (as in hemophilia) (Frankfurter *et. al.* 1974). American ABC news dated September 19, 2012 claimed a critical shortage of blood has forced the cancellation of elective surgeries in Los Angeles, Philadelphia and Atlanta. Seifried *et. al.* (2011) summarized different factors affecting the consumption and supply of blood components (See table 1).

Table 1: Factors affecting the demand/consumption of blood components and supply of blood products

Factors affecting the consumption of blood components	
Increasing consumption	*Decreasing consumption*
Ageing of patient population with more invasive procedures in older patients	Optimal use of blood components
Untreated preoperative anaemia	Implementation of perioperative blood-saving methods including recovery of shed blood
Changes in treatment, e.g. cord blood as source for hematopoietic stem cell transplantations	Novel treatment options (e.g. CML treatment)
	Recombinant coagulation factors replacing plasma-derived products
Blood donation and blood component supply trends	
Increasing supply	*Decreasing supply*
Re-activation of deferred or inactive blood donors	Ageing of the (donor) population
Mobilization of health population currently not donating blood	Loss of current reliable donor population (baby boomer generation) in the future.

Source: Seifried *et.al.* (2010)

Several other authors used simulation in studies of blood supply chain ordering policies with the objective of reducing wastage and shortages by increasing service levels (See Katsaliaki and Brailsford, 2007; Katsaliaki,2008). Kopach *et. al.* (2003) refocused the models using multiple demand rates, cost, and shortage and service levels. He emphasized on differentiating the non urgent and urgent of blood demand and thus restricting the orders of non urgent demand in order to meet the urgent requirements. Stanger *et. al.* (2012) define the managing perishable inventories as a trade-off of shortages and lost sales against wastage. Their paper aims to identify drivers of good management of perishables within the supply chain using the example of blood inventory management in hospitals.

Li and Liao (2011) in their study designed a robust blood supply chain system considering the total cost and the safety of patients with data from Taichung Blood Center of the Taiwan Blood Services Foundation and its contracting hospitals. Nagurney, Mousmi and Yu (2012) developed a multicriteria system-optimization framework for the supply chain network design of a sustainable blood banking system. The framework allows for the simultaneous determination of optimal link capacities through investments, and the flows on various links, which correspond to such application based supply chain network activities as: blood collection, the shipment of collected blood, its testing and processing, its storage, its shipment to distribution centers, and, finally, to the points of demand.

Based on the above references to the literature, more concern towards the most required life saving product- the human blood have been on inventory practices, optimizations, donors and transfusion services at the blood banking centers instead of considering the blood supply issues in the supply chain. Most of the authors with few exceptions considered it as a traditional inventory management as practiced in industry but ignored on strategy for managing blood supply services alongwith matching the donor base to recipients. Our understanding of the complexity and fragility of the supply chain that connects blood donors to patients is a step forward in identifying the future solutions in taping the potential for blood donations and blood supply to adapt under these kinds of challenges.

3. Management of the blood supply services

A blood supply chain begins donor motivation, donor access and eligibility and proceeds to collection, testing, storage, distribution between the organizations and finally to the

institutions that use them for transfusion into a patient. Despite rapid advances in SCM and logistics, inefficiencies still persists. The inefficiency begins with the collecting blood at the blood establishment centers. The collection at the center may face the time lag in the scheduled visits of the donors, uncertainty in the walk-in donors at the center's donor facilities and unknown responses to the emergency calls for blood. Even the number of actual donors is usually less than the number of people who originally signed up for blood donation. This can reduce the ability of the center to collect the appropriate amount of blood that is needed at the time of collection.

To manage the blood supply, we may require a scheduling algorithm, an efficient information system and more importantly developing a short-term computerized blood inventory level forecast system. Forecasting tools may provide the blood supply management (BSM) maintaining efficiently the short-term inventory level of blood supplies so that they can take corrective action to either reduce or increase blood collection. The information received from the forecast system may help in increase blood collection efforts during the lead time if low inventory levels are projected and decreases blood collection efforts if high inventory levels are projected. As a result, the short-term blood inventory level forecast system enables management to eliminate blood shortages and excessive expirations which result from excessive high blood inventory levels. However, this approach can be more effective if electronic linkage exists between hospital patient information system and the transfusion laboratory computer, so that information on patient diagnoses and blood usage can be linked.

A forecasting model which provides estimates of future blood inventory conditions has the potential of producing a high benefit-cost ratio. The benefits of knowing future blood inventory levels consist of the ability to modify the inventory levels which produce the attendant savings in reductions of expirations and eliminations of deferred surgical operations. Deferred surgical operations are quite common in regions affected by blood shortages (See Frankfurter *et. al.* , 1974).

Information and computer technology popularizes in blood supply chain management for its potentials in working efficiency as well as service quality. A good information system with an extensive database and an effective data base management system can keep track of potential donors and of the units in the region, and that will be helpful in meeting special needs, and

balancing out short-term fluctuations. As use of the Internet and the Web increases in sophistication, blood establishment centers can deploy web-based supply chain applications to enhance operations and improve mutual knowledge, including instant sharing of demand, inventory at the centers.

The problem of scheduling collections with donors' no-show, that is, donors not showing up for scheduled appointments needs to be addressed. Facing the no-show rates, one commonly adopted strategy is to overbook, i.e. to schedule multiple donors in one lot to hedge against the risk that some of them do not show up. The other common problem is the attendance behavior of the donors based on appointment delays that is the time between the day when a patient makes the appointment request and the actual appointment date given to her (See Chan and Green, 2013 and Gupta and Denton, 2008). In general, it can be observed in a variety of practice settings, the longer the appointment delay, the higher the chance that a person will not attend her appointment. Thus, we can adopt a strategy to shorten appointment delays; by doing so the blood establishment centers expects lower no-show rates.

However, despite the wide use of these strategy of overbook the donors, limiting the number of days of appointment scheduling window so that blood donors cannot make appointments beyond certain days can affect the management operational efficiency. An overly restrictive scheduling window may leave too many donors unable to schedule their appointments. Liu (2013) optimization models can suggest a strategy in determining the optimal size of appointment windows for practices operating with donor no-shows.

4. Conclusions

Given its major impact on patients' safety, developing an effective management of the blood supply chain appears to be the most important challenge for the future of blood establishment centers. Ageing of our populations and its impact on blood donor populations, the higher mobility of people, the changing social networks and families have also an impact on the overall altruistic behavior of blood donors and volunteer helpers at donation campaigns. To meet challenges there is a need for constant evaluation of inactive and deferred blood donors and their behavior. Further, the donor eligibility criteria and testing procedures have to be balanced to provide safety for both donors and patients while ensuring the adequate supply of blood.

For these purposes, a collection planning system has to include the forecasting models to predict the quantity of supply from different sources, a scheduling optimization models to schedule visits to organizations so as to achieve the desired targets; and an web based information system with an extensive data base and an effective data base management system that will keep track of potential donors and of the units in the region, and that will be helpful in meeting special needs, and balancing out short-term fluctuations.

Finally to build on the service continuum, the relationship between the blood supplier and the transfusion provider needs to be put in context of the world that is cost containment. It is essential that the blood supplier and transfusion provider think collectively toward improving vertical efficiencies and cost-saving down the chain of supply and the distribution. There is also a need to look for practical modalities to improve collaboration between hospitals and BEs, as a key factor for continuous improvement of BSS.

5. References

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