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Opinion

On the Challenges of Blood Inventory Management

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Introduction

Managing blood is a challenging task. There are eight different blood types (i.e., A+, A-, B+, B-, AB+, AB-, O+ and O-) including some such as O+, A+, and O-, that are relatively common while others such as AB+ and AB- are relatively rare. Blood is perishable and as with any perishable product it deteriorates with age and must be discarded when its useful life expires. The need for different types of blood is highly uncertain varies by region of the country and depends on the specifics of the medical treatments or surgical procedures needed. It is also the case that because certain procedures require different levels of freshness the oldest blood in storage is not always used first. Finally, the supply of blood can be highly variable as blood donations which are voluntary, can vary depending on geographic location as well as over time.

A challenge faced by many medical centers is to match the need for blood with the availability of blood. This is done in practice via ordering policies that help determine how many units of each type to order and when to order them. Effective ordering policies provide enough units of each blood type to satisfy need without resulting in an excessive amount of waste. In other words, the effective management of blood is about simultaneously trying to reduce both shortage (having too little) and waste (having too much). Both shortages and waste lead to problems. Blood shortages may lead to the postponement of treatments, the rescheduling of surgeries, and in extreme cases to complications that may put patient's lives at risk. Reducing waste is also a high priority for most medical centers. Not only is the disposal of expired blood expensive, excessive wastage can also negatively affect the goodwill of donors.

While effective blood management is a concern in the health care sector there are no universal management guidelines and practices are not consistent across medical centers. Some medical centers rely on ad hoc management practices while others have more sophisticated methods in place. Mathematical modeling is an approach that has been quite effective in helping to develop effective ordering policies. The "fixed lifetime perishable inventory model" is one of the most widely used modeling approaches for blood ordering policies Nahmias [1], Prastacos [2] & Karaesmen et al. [3]. The objective of this model, as is the case with most perishable inventory models is to minimize total costs associated with blood management and the ability to quantify the different costs is an integral part of the process. These models work by trading off between different perishable inventory cost components such as purchase holding (all costs associated with storage) stockout (all costs associated with running out) and wastage (all costs associated with disposal) costs.

As one might expect precisely quantifying some of these costs can be quite difficult if not impossible in the blood management setting. For example, stockout costs can range from the lower end of the cost spectrum (the cost associated with expediting blood delivery) to the higher end of the cost spectrum (the costs associated with postponing surgical procedures and dealing with complications). Similarly, the holding costs can be equally opaque as it includes costs such as the staff time associated with receiving, sorting, storing, and retrieving blood, energy costs, etc. that are typically not itemized and assigned to blood on a per unit basis.

While models such as the fixed lifetime perishable inventory model can be very useful in helping to develop effective ordering policies the complex nature of blood management requires the use of mathematical models that are equally complex. In general, the more involved the problem is the more difficult it is to formulate, solve, and interpret. For example, every unit of blood in storage can have a different age which explicitly needs to be accounted for in the model. Likewise, the uncertainty associated with blood usage and the fact that there are eight different types of blood adds to the complexity of the model. As the amount of blood ordered and stored in inventory increases, the model becomes exponentially more difficult to solve. Thus, these models can be hard to understand, hard to implement and often rely on unrealistic or overly simplified assumptions that can result in them being of limited use in practice.

Another dimension of complexity is the redistribution or transfer of blood within certain healthcare networks as a mechanism to help reduce waste Puranam et al. [4] & Denesiuk et al. [5]. These transfers typically consist of older blood (i.e., blood that typically has a remaining shelf life much lower than the blood received through the standing order process) that is shipped to higher usage medical centers to increase its chance being transfused before it expires. While redistribution has the potential to reduce waste it increases supply uncertainty and introduces additional management challenges at the receiving end Puranam [4,6].

Furthermore, the transfer of blood can lead to somewhat irresponsible ordering behaviors by shifting the financial burden resulting from poor blood management Forcé [7]. Some medical centers may avoid incurring the costs associated with ordering too much by redistributing the excess blood while some medical centers may experience an increase in holding and disposal costs by receiving the redistributed blood.

On top of all of these issues cost-driven perishable inventory models do not necessarily reflect the priorities of medical professionals and outputs from the model may challenge or even contradict historical ordering practices. For example, in blood management a desired outcome is to meet all needs for blood (100% service level) while having little to no wastage. In reality these are conflicting objectives and it may not be possible to meet both objectives at the same time. For all the reasons mentioned above, there is often a disconnect between the mathematical models developed by academics and the needs of health care practitioners and an ongoing challenge is bridging this gap. Both practitioners and academics alike have stressed the need for the development of practical easy-to-implement ordering policies Civelek et al. [8], Stanger et al. [9], Nahmias [10] & Silver [11] that focus on the needs and the priorities of the medical community.

We echo that call here and encourage academics involved in healthcare management to expand their focus on the development of less complicated, easy-to-implement heuristic approaches for blood management that practitioners will adopt. Although heuristic approaches do not guarantee the best (or "optimal") solution, they can offer practical, easy-to-understand, easy-to-implement, and yet "close enough to optimal" solution approaches. Because of all the benefits that can potentially ensue it is our hope that mathematical modelers and health care professionals will work together towards continuing to improve blood inventory management.

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