A model for change: predicting the impact of system-wide improvements

Collected in February 2018

What is this research about?

Platelet products are currently stored at room temperature with gentle agitation. However, if the platelet unit is contaminated with bacteria, this environment allows the bacteria to grow to potentially dangerous levels. Transfusing a contaminated platelet unit can cause sepsis, a potentially fatal transfusion reaction. To mitigate the risk of contamination, the donor's skin is disinfected with an antiseptic arm scrub and the first few millilitres of the blood collection are separated into a diversion pouch. Blood operators further reduce the risk to patients by using a short shelf life for platelet products and screening each unit for bacterial contamination.

In brief...

Computer simulation predicts that extending the platelet shelf life from five to seven days will reduce the wastage of platelet products by about 35 per cent.

As safety measures for platelet products improve, many blood services around the world have extended their platelet shelf life from five to seven days. Canadian Blood Services recently improved the bacterial testing procedures for platelet products and extended their shelf life to seven days. When making this decision, it was critical to understand how it would affect the blood supply network that Canadians rely on. How can we accurately test system-wide changes that affect thousands of blood products across the country?

That's where simulation modelling comes in. Simulation can be used to study many complex problems faced by Canadian Blood Services, such as recruiting donors and scheduling blood donations, identifying populations to target for the stem cell registry, and managing blood product inventory. Rather than generating new data through physical experiments, engineers can use existing data to develop process flow models; these can then be used to run virtual experiments to predict outcomes under different operating scenarios.

Inventory management for platelet products is particularly difficult due to the short window between their release (after the initiation of bacterial testing, including a waiting period) and expiry date. There have been studies testing the effect of platelet shelf life extension in other jurisdictions, but these have focused on the hospital or blood supplier and do not capture changes across the entire supply chain. One of our researchers, an industrial engineer, used modelling to predict the system-wide impact of extending platelet shelf life.

What did the researcher do?

The seven production sites (suppliers) and 306 hospitals (customers) in Canadian Blood Services' platelet distribution network were modelled with an algorithm simulating a complex sequence of events that repeated daily for a period of time. The daily sequence of events in this virtual experiment included collecting, manufacturing, testing, distributing and transfusing. For production sites, collected units were generated daily by sampling from distributions based on historical data for that day of the week at each production site. To determine distribution to the hospitals, the simulation compared each hospital's inventory of platelet products to a defined threshold. If the inventory for any blood type was below this threshold, the hospital ordered stock from its regional supplier. Demand from patients was then simulated based on historical data for that hospital and filled from the hospital's simulated inventory. If any demand was unable to be met, it was marked as a shortage. At the end of each simulated day, the age of all platelets in stock at production sites and hospitals was increased by one day, and any platelets with less than zero days of shelf life remaining were removed from the system.

To validate the model, the researcher populated it with information derived from the Canadian Blood Services platelet distribution network from 2015–2016, ran 10 replicates of 364 days (for equal weekday representation), and compared the simulation outputs to the operational data from that time period.

The validated model was then modified to determine the effect of the new shelf life and improved bacterial testing procedures, which increase the delay before the platelet products can be released for transfusion. The minimum time between collection and release to the supplier was conservatively estimated at two days with the implementation of improved bacterial testing. The model was also used to evaluate inventory policies at the hospitals and suppliers. The inventory targets for hospitals were set at 1.1 (as in the original model) or 2.1 days of demand; the supplier inventory targets were set at 1, 2 (as in the original model) or 3 days of demand.

What did the researcher find?

- The number of units collected, distributed, transfused and outdated in the simulation closely matched the records for that time period, supporting the accuracy of the model.
- After adjusting the parameters to reflect the new bacterial testing procedure, the average number of units outdated per day decreased by 18.1% with a six-day shelf life, by 35.7% with a seven-day shelf life, and by 45.6% with an eight-day shelf life, without increasing shortages. The results suggest a linear relationship, with wastage decreasing by approximately 16% per additional day of shelf life.
- Increasing the inventory kept at the hospital increased the number of units outdated, regardless of the shelf life used. The lowest rates of outdating were seen when the hospital inventory was set to 1.1 days' demand and the supplier inventory was 2 days' demand.
- The decreased wastage from extending the shelf life was location-dependent. Wastage decreased more rapidly at hospitals than at suppliers, and smaller supplier sites had higher outdating rates that benefited less from extending the shelf life than larger suppliers. Blood type did not affect wastage.

How can you use this research?

The computer simulation predicts that each additional day of shelf life after five days will significantly reduce wastage of platelet products. This supports Canadian Blood Services' recent decision to extend the shelf life to seven days. If future safety or efficacy evidence supports further extension of the platelet shelf life, this study predicts additional reductions in wastage. The decreased wastage of platelet products after the shelf life change could help offset some of the costs associated with implementing the additional testing procedures. This will allow Canadian Blood Services to increase the bacterial safety of our platelet products and the efficiency of our operations.

The detailed information from the simulations can help Canadian Blood Services manage donor recruitment to maintain a consistent platelet supply while accounting for the increased bacterial testing time. Data from this study can also guide hospital inventory policies. A hospital inventory of 1.1 days' demand and a blood supplier inventory of 2 days' demand were optimal to reduce wastage without increasing shortages. Hospitals that maintain a larger inventory could reduce the number of wasted platelet products by lowering their inventory size and making more frequent orders.

Computer simulations allow Canadian Blood Services and health-care providers to predict the outcomes of system-wide changes that could not be studied in other ways. Although these models are an approximation rather than an exact prediction of the future, they are still important to help the organization make evidence-based decisions.

About the research team: The author, **Dr. John Blake,** is an associate professor in the department of industrial engineering at Dalhousie University and a research engineer at Canadian Blood Services.

This ResearchUnit is derived from the following publication:

1. J.T. Blake. Determining the inventory impact of extended-shelf-life platelets with a network simulation model, Transfusion 2017; 57:3001-3008.

Acknowledgements: This research received funding support from Canadian Blood Services, funded by the federal government (Health Canada) and provincial and territorial ministries of health. The views herein do not necessarily reflect the views of the federal, provincial, or territorial governments of Canada.

Keywords: platelets, shelf life, modelling, inventory, efficiency, wastage, outdating

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