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Optimal ordering decisions for red blood cells at hospitals under blood-type substitutions

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Abstract: Hospitals face numerous challenges when determining the ordering quantities of red blood cells (RBC) from a central blood bank. Due to limited shelf-life of RBCs, hospitals need to ensure that they have enough inventories to meet the needs of their patients, but also avoid over-ordering to prevent wastage. Besides uncertainty in demand, supply is also uncertain. Blood in the blood bank is replenished by donations, which results in a stochastic and limited supply. In practice, order quantities at hospitals are typically determined through ad-hoc methods which can leads to inefficiencies in the blood supply chain. Further, in most transfusion cases, hospitals may need to substitute one type of blood product for another due to patient's specific medical condition, or a shortage of supply, or for preventing wastages of the close-to-expiry units (Hirani et al. 2017). However, blood-type substitution decisions at hospitals have some unique characteristics due to the blood compatibility matrix. Therefore, hospitals must ensure that they have an effective blood inventory management and ordering policy for RBCs in place that also takes into account the effective blood-type substitution decisions.

Hospitals use regular with same-day delivery from central blood bank. However, insufficient inventory leads to costlier emergency orders and could delay a required transfusion, while holding high inventory levels could lead to wastage. Therefore, this decision on ordering quantities is a trade-off between wastage and shortage over time. Research on hospitals' blood inventory systems includes investigations into optimal ordering policies (e.g. Ayer et al. 2023) and effective heuristics approaches (e.g. Zhang et al. 2020). However, the research on inventory management of perishable products has mainly focused on a single product under the age substitution (e.g. Deniz et al. 2020, Karaesmen et al. 2011).

This research aims to develop efficient inventory management at hospitals to address the critical issues of ordering decisions under blood-type substitutions. We use a distributionally robust optimization (DRO) framework to formulate this optimisation problem. DRO is a data-driven decision-making approach that estimates the true distribution by minimizing the worst-case expected cost over all distributions (Ben-Tal et al. 2009). Using numerical analysis, we compare the results of this model with an empirical guideline. The results demonstrate that DRO is an effective method for reducing the imbalance between the supply and demand while reducing the costs associated with wastage and shortages.

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