Blood Platelet Production: a multi-type perishable inventory problem

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Abstract. Blood banks produce and store blood products in order to fulfil the uncertain demand at hospitals. Platelet pools are the most expensive and most perishable blood product having a shelf life of only four to six days. Production volumes need to be chosen carefully in order to reduce outdating while keeping the occurrence of shortages low.

We investigate the structure of the optimal production policy by solving a down sized periodic Markov Decision Problem. The optimal production volumes appear to depend on the number of pools on stock and their ages. Simulation results for the optimal MDP-policy suggest two rules: the $1D$ and $2D$ rule. Both rules perform quite well. The $2D$ rule performs nearly optimal even if one acknowledges the distinction of multiple and limited compatible blood groups and the uncertainty in the supply by donors.

1 Problem setting

Blood banks collect blood and produce blood products from it. From one whole blood donation, of 500 *ml* by a single donor, most of the red blood cells and plasma are filtered. The residual called, the *'buffy coat'*, contains a high concentration of blood platelets. The platelets of five buffy coats are distilled and pooled into a so-called platelet pool. These pools are delivered to hospitals on demand at least once a day (in the morning).

Blood banks are interested in setting (near-)optimal production volumes of platelet pools since it is the most expensive and most perishable blood product. The price of a platelet pool sold to a hospital is in the Netherlands 458 euro. The maximal lifetime of a platelet pool is set at 5 days at most blood banks, but current developments allow raising this maximum to 7 days. Since collection, production, and laboratory tests together take one day the effective shelf life of a platelet pool is 4 to 6 days. All other blood products can be kept on stock for weeks or even months.

Platelets are of live saving importance. As small particles inside the bloodstream platelets prevent bleeding by recognizing and 'repairing' damaged blood vessels. Platelets deteriorate rapidly in quality even inside the blood stream, but most people's platelets production at the bone marrow is sufficient to retain a safe level. Nevertheless after a major bleeding caused by a

trauma or a surgery, patients may temporarily have a lack of platelets. These patients need to be transfused with platelet pools of *any* age up to the maximal shelf life. This demand category is called *'any'*, since there is no strong preference with respect to the age of the pools. The *'any'* demand comprises 30% of the total demand of about 176 pools per week per Dutch blood bank.

The remaining 70% of the demand is for patients suffering from a platelet function disorder. They need to be transfused at least once a week with *'fresh'* pools that are stocked for at most 3 days. Transfusing older platelet pools is less desirable. Although part of the transfusions at the hospitals are scheduled, a considerable amount of demand is unknown to blood banks.

At the supply side enough buffy coats are available. In the Netherlands only a third to a half of the buffy coats is used for processing platelet pools depending on the occurrence of donors. So it seems reasonable to ignore the uncertainty in the supply of buffy coats.

Another complication is the distinction of eight different blood groups based on four $AB0$-categories and the Rhesus-D factor ($RhD+$ or $RhD-$). Figure 1 shows the compatibility of the different blood groups and the frequencies by which they occur in the Western population. In section 5 we deliberate on the compatibility of the blood groups and also on the stochastic supply of buffy coats.

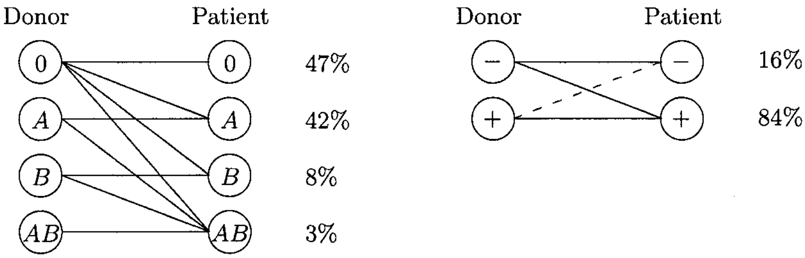

Fig. 1. Compatibility of blood groups of donor and patient following the $AB0$−system and Rhesus-D system (+/−)

We distinguish four types of linear costs:

- *shortage* costs: for demand that cannot be fulfilled from stock
- *mismatch* costs: for demand for a 'fresh' pool that is met by an older pool
- *outdating* costs: for a pool that has to be disposed because of its age
- *holding* costs: for keeping a pool on stock during a day.

Under this linear cost structure we are interested in (near-)optimal production volumes that minimize the *long-run average weekly cost*, taking into account:

- *two types* of 'periodic' demand
- the limited shelf life of the pools