Addressing Waiting Time Inconsistencies due to ABO Status in Transplantation

David A. Stanford PhD, Jung Min Lee, Natasha Chandok MD, Vivian McAlister MD

1Statistical and Actuarial Sciences, Departments of Medicine and Surgery, Western University;
4Multi-Organ Transplant Program, London Health Sciences Centre, London, Canada

Introduction

Many studies of wait times for transplantation have revealed a common pattern: recipients of blood type O wait substantially longer on average than blood type A, who in turn wait substantially longer than blood type AB. Blood type B patients wait somewhat less or more than type O, depending on circumstances.

This situation arises qualitatively in many countries for various organ types, with only quantitative differences in degree.

Several studies of wait times for transplantation have revealed a common pattern: recipients of blood type O wait substantially longer on average than blood type A, who in turn wait substantially longer than blood type AB. Blood type B patients wait somewhat less or more than type O, depending on circumstances.

Many studies of wait times for transplantation have revealed a common pattern: recipients of blood type O wait substantially longer on average than blood type A, who in turn wait substantially longer than blood type AB. Blood type B patients wait somewhat less or more than type O, depending on circumstances.

This situation arises qualitatively in many countries for various organ types, with only quantitative differences in degree.

Key wait time formula

- The classic single server model (the M/M/1 queue (see Kleinrock (1975))) assumes a customer/patient arrival rate of λ per unit time and service/treatment rate of μ per unit time.
- The average time waiting in the queue is

\[ W_q = \frac{1}{[\lambda - \mu]} = \frac{1}{[\mu(1-\rho)]} \]

where \( \rho = \lambda / \mu \) is the fraction of time the server is busy.

Canadian Blood Type:
Population and permitted transplant matches

- Blood Group O Studies:
  - Numerous other kidney studies: Danovitch & Cecka (2003), Slakey et al (2010), etc.

- Blood Group A Studies:
  - Numerous other kidney studies: Danovitch & Cecka (2003), Slakey et al (2010), etc.

- Blood Group B Studies:
  - Numerous other kidney studies: Danovitch & Cecka (2003), Slakey et al (2010), etc.

- Blood Group AB Studies:
  - Numerous other kidney studies: Danovitch & Cecka (2003), Slakey et al (2010), etc.

ABO Identical Transplantation

- An exemplar study for the blood group O problem

  - of 1,186 waitlisted patients, median wait time was 85 months for blood group O vs 59 months for non-O patients
  - increased death rate without transplantation was reported (13.6% O vs. 9.6 non-O; P-value < 0.05), as were poorer graft outcomes for O patients.

Liefeldt et al (2011) found similar disadvantage to ESRD seniors. As a result, Eurotransplant modified its kidney transplantation policy to require only ABO-identical matching.

The Crux of the Problem

Although an ABO-identical policy would decrease the wait time and improve the outcome for O blood type patients, over time, blood groups B and AB patients would experience a situation worse than O ever experienced.

The theory of queues can reliably predict that blood type B patients will wait on the order of five times longer than O patients, and blood type AB patients on the order of fifteen times longer using an ABO-identical policy.

Under such a policy, assuming the same propensity to donate for all ABO blood type AB patients, on the order of fifteen times longer using an ABO-identical policy.

An example policy would decrease the wait time and improve the outcome for O blood type patients, over time, blood groups B and AB patients would experience a situation worse than O ever experienced.

The average wait times will differ in proportion to the patient placement rate to the organ availability rate happen to be identical, the average wait times will differ in proportion to the patient placement rate to the organ availability rate happen to be identical. The ratio of the patient placement rate to the organ availability rate will be identical if the patient placement rate is identical, the average wait times will differ in proportion to the patient placement rate to the organ availability rate happen to be identical. The ratio of the patient placement rate to the organ availability rate will be identical if the patient placement rate is identical.

The idea behind the linked systems: the O and B case

- Divert a small fraction \( p_o \) of type O organs to B recipients, to reduce type B wait times.
- Equal Accessibility Goal: \( W_q = W_{qB} \)
  - \( W_{qO} = (\mu_o(1-p_o) - \lambda_o)^{-1} \)
  - \( W_{qB} = (\mu_B + p_o \mu_B - \lambda_B)^{-1} \)
  - Solving for \( p_o \) leads to \( p_o = \frac{R}{2R - 1} \)

where \( R \) equals the ratio \( \mu_o/\mu_B \).

Fraction diverted:

- Result: In the Canadian case where \( p_o \cong 0.4 \), since O organs become available at roughly five times the rate of B organs, one finds
  - \( p_o \cong 0.4(1 - \rho) \)
  - Since \( \rho \) is close to 1, it follows that \( p_o \) will be a small fraction, not likely to exceed 4%.

Implementation

- An implementation policy needs to closely monitor two factors:
  1. The observed long-run wait times to transplant of the two groups in each pair.
  2. The long-run fractions of cross-transplanted organs
- Simulation studies are needed to identify the precise balance between fractions and wait times.

References