# Simulating the Allocation of Organs for Transplantation

**The U.S. organ allocation system**

* Patients in need of transplants are entered onto the waitlist.
* When an organ becomes available, the active candidates on the waitlist are ordered as specified by the current policy and the organ is offered to candidates in this order.
* Candidates are classified according to risk of short-term mortality on the waitlist, with priority given to those at highest risk.

*There are more patients than organs: a waiting-time based system will generally result in the allocation of organs to those patients who are healthy enough to survive until they can move to the front of the waiting queue.* 🡪 decreasing failure rate???

**Modeling methods**

Two logically separable components of the system.

1. Environment 🡪 streams of patients in the waitlist and available organs 🡪 input stream to the program 🡪 arrival records specify characteristics of candidates at the time of listing (age, transplant center, etc.) and characteristics of donors and organs (blood type, weight, etc.).
2. Allocation policies + post-transplant experience 🡪 incorporated directly into the program.

Modeling the allocation system 🡪 **Monte Carlo**: event-sequenced simulation.

This model generates sequences of pseudo-random numbers to generate realizations of random processes and advances time by sequencing discrete events in time order.

* Time-ordered input stream describes:
  + changes to each **candidate’s medical conditions** and listing statuses that would occur if the candidate received no transplant 🡪 improve or deteriorate over time, death.
  + candidates whose transplanted organs fail and who **rejoin the waitlist** 🡪 separate pools of status histories from which the simulation samples a history to assign to the relisted patient.
  + arrival time and characteristics of donated organs.
    - **Match process** 🡪 donor and candidate characteristics are compared 🡪 the waitlist is reordered every time a new organ is donated 🡪 transplanted to the first candidate to accept the offer.

🡪 vectors of donor and candidate variables

🡪 vector of coefficients of these variables for each stratum ().

* Probability of organ acceptance 🡪 logistic function of the inner product 🡪 dependence of acceptance probabilities on donor and organ characteristics.
  + The model samples a pseudo-random number and compares it to an acceptance probability.

The simulation then tracks the post-graft experience of the recipient, including the potential for graft failure and rejoining the waitlist, and mortality.

* Post-graft survival is represented by a Cox proportional risk model or a Weibull model.
* The simulation generates a survival time by sampling a pseudo-random number and inverting the survival function.
* The probability and time of relisting, stratified by post-graft survival time, are input to the model.

The simulation adds post-graft status change events, including death or removal from the waitlist, to the list of scheduled events.

**Representing policies**

The function of the policy is to specify an algorithm for ordering the waitlist, given a donated organ of specified characteristics, in terms of:

* criteria for screening out potential candidates for lack of suitability
* grouping candidates into priority classes based on common characteristics
* ranking candidates within a classification based on sequential sorts and additive point awards (e.g., waiting time or mortality risk score);
* defining subgroups of priority classes (e.g., giving pediatric candidates priority for a pediatric organ, or partitioning based on a threshold value of mortality risk).

**Data used**

The simulation runs used actual data for all patients on the waitlist in 1999, and simulated all activity in the period from 1/1/99 through 12/31/99. We input the actual entire history of status changes and death dates for all patients, except for those who received a transplant.