A wait time study & sensitivity results for liver transplantation in Canada 2000-2004

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Liver transplantation in Canada

- Transplants performed at regional centres
- For liver transplants in Canada, there are six centres → 6 waiting lists (queues)
- West: 1 in each of Alberta & BC, they also handle some of Saskatchewan & Manitoba
- Central Canada: Ontario has 2, Quebec 1
- Atlantic Canada: 1 in Nova Scotia

Data sources and reconciliation:

- Data obtained from two sources:

CORR-CIHI and LHSC

- Study period January 1, 2000– December 31, 2004, follow-up to December 31, 2005

- Problems with data reconciliation due to missing fields, date inconsistencies, etc.

Transplant Q Statistical Analysis

- Studied waiting list Jan 1, 2000 – Dec 31, 2004; summary stats for n=1812 transplants:

Variable	Mean	Stand. Dev.
Recipient Age	47.8 years	16.0 years
Donor Age	42.0 years	18.3 years
Waiting Time	231.8 days	296.9 days

- Variability in waiting time reflects diverse patient types (failing health gets priority)

National Statistics over 1827 days

- TOTAL ARRIVALS (lambda) 3320
- Cadaveric organs available (mu) 1812
- Living related transplants 199
- Abandonment (incl. Living donors) 1104
- *Deaths prior to Transplant: 452*
- Net transfer of approx. 150 livers from female donors to male recipients

Deaths while on waiting list:

Blood Type	# on list	# deaths	# trans-plants	Average wait(days)
O	1500	245	708	309
A	1253	129	779	185
B	426	62	215	219
AB	139	16	108	88

Liver Allocation in Canada vs U.S.

- In Canada: Basically amounts to FCFS on each list; urgent patients get priority
- Patients in final stages of decline can receive an organ from another list
- In U.S.: Sickest Patient First Rule (SPFR, actually called the “MELD” system)
- Patients given a score upon entry (it gets updated); highest score gets the organ

Typical waiting time results

- Mean waiting time prior to service for M/M/1 model

$$W_q = E\{S\}\ \rho\ /\ (1- \rho)$$

where $\rho = \lambda / \mu$ for λ= arrival rate per time unit, μ = service rate per time unit

- Lots of other formulas for other quantities
- Common form for other models:

$W_q = K / (1- \rho)$ for some constant K

Priority queues

- Instead of a single class, there are priority classes 1 (highest priority), 2, 3, ..., N (lowest priority) each with their own ρ_1, ρ_2, ρ_3,..., ρ_N.
- Compute for *I* = 1,2, up to N the sums σ_i= sum of occupancies = $\rho_1 + \rho_2 + ... + \rho_i$.
- The average waiting time for the *i*th class $W_{qi} = K / (1- \sigma_{i-1}) (1- \sigma_i)$

Service & arrival processes

- Interventions mean non-Poisson arrival process. Overall increasing trend confirmed
- The “service time” is the time between organs becoming available → study process of organ availability
- Several centres passed Poisson test, not far off in the others. So exponential service times reasonable at least

Possible ways to address queue instability:

Some illustrative choices:

- Lottery systems, implemented early. “Yes” gets first access to organs
- Priority systems selected so that one or some classes see a stable system, even if others do not

Sample Sensitivity Scenario 1:

- Implement a lottery system with chance p of Yes. (High priority stream)
- “Artificial” system: one national waitlist.
- Impact of blood types ignored here.
- Organ availability rate 1 / day; times exponentially distributed.
- Poisson arrivals Rate of 1.8 / day for the purpose of this illustration. Health status not factored in. Ignores increasing trend. Presumes no physician impact on rate of placement.

Sensitivity results for Scenario 1:

- High priority stream sees a stable system if long-run rate of patient placings / day < 1.
- p = 0.5: Av. wait until transplant = 10 days. P(wait > 1 month) = 5%. At best, (1/9) of "No's" would be transplanted.
- p = 0.55: Av. wait until transplant = **100** days. P(wait > 1 month) = **74**%. Practically no "No's" would be transplanted.

Q: What could make system stable (viewed nationally)?

- A) A doubling of the donor signing rate. Renders living related unnecessary. Will not be enough if placements continue to increase.
- B) Double the living related rate, increase donor signing rate by 50-60%.
- NB both approaches assume deaths and other abandonments would vanish, due to much shorter wait times.
- **Q: Is there a hidden potential for placements to increase?**

Conclusions and next steps:

- System unstable in the queuing sense
- Need to be aware of tradeoffs between allocation criteria
- Continue standard delay calculations using appropriate Q models for various idealised variants of the regional waiting lists
- Develop priority model which allows for change in priority as a function of incurred wait