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Cost-Effectiveness of Organ Donation: Evaluating Investment into Donor Action and Other Donor Initiatives

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Initiatives aimed at increasing organ donation can be considered health care interventions, and will compete with other health care interventions for limited resources. We have developed a model capable of calculating the cost-utility of organ donor initiatives and applied it to Donor Action, a successful international program designed to optimize donor practices.

The perspective of the payer in the Canadian health care system was chosen. A Markov model was developed to estimate the net present value incremental lifetime direct medical costs and quality adjusted life years (QALYs) as a consequence of increased kidney transplantation rates. Cost-saving and cost-effectiveness thresholds were calculated. The effects of changing the success rate and time frame of the intervention was examined as a sensitivity analysis.

Transplantation results in a gain of 1.99 QALYs and a cost savings of Can$104 000 over the 20-year time frame compared with waiting on dialysis. Implementation of an intervention such as Donor Action, which produced as few as three extra donors per million population, would be cost-effective at a cost of Can$ 1.0 million per million population.

The cost-effectiveness of Donor Action and other organ donor initiatives compare favorably to other health care interventions. Organ donation may be underfunded in North America.

Key words: Cost-effectiveness, organ donor, renal transplantation

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Introduction

Donor Action (DA) is an international program designed to increase organ donation through education and structured feedback of health professionals, allowing hospitals to improve donation rates through improved donation practices. In localities where it has been implemented organ donation has increased substantially, stabilizing at an average increase of 53% (1,2). The program is composed of a five-step process: 1) Consolidation of support for organ donation among senior medical personnel; 2) a two-part diagnostic review consisting of a retrospective medical record review and a survey of hospital staff attitudes towards donation. These data are then compiled into the DA database and a comprehensive profile of strengths and weaknesses produced; 3) based on gaps identified in the diagnostic review, specific programs are tailored for individual sites using modules developed for that specific issue; 4) implementation of modules; and 5) ongoing monitoring of results and improvements are undertaken.

Likewise, other organ donor initiatives with similar foci towards establishing 'best practices' in organ donation have reported improvements in donation rates. Renal transplantation has long been recognized as a cost-saving intervention when compared with its alternative, dialysis (3–6). Currently, patients in need of a kidney transplant can wait upwards of 7 years while on dialysis, as a worldwide organ shortage has severely limited the number of transplants that can be performed. It is logical to therefore think that any intervention that can substantially increase the rate of organ donation and thereby increase transplantation rates may well be cost-effective, depending upon the implementation cost of the program and the number of extra kidney transplants that occur as a result.

Successful organ donation programs, such as DA, require a substantial initial financial investment, as well as additional expenditures necessary to maintain the program's initial momentum in order to sustain improvement in donation rates. A quality assurance program like DA can be considered a health care intervention, which in combination with kidney transplantation yields quality of life and survival benefit for patients with end stage renal disease. As it competes with other health care interventions for public funding, its expected cost-effectiveness should be predicted before it is implemented at any national level.

We have constructed a Markov model capable of estimating the net present value cost savings and additional quality-adjusted life years (QALYs) that result from increasing organ donation rates. An early version of this model was published demonstrating the cost-effectiveness of DA in its pilot implementation in Germany (7). We have now adapted the model to the Canadian healthcare perspective and have also provided a mechanism for calculating the investment thresholds at which any organ donation initiative is either cost-effective (using a $50 000 value for one additional QALY) or cost saving as a function of the number of additional donors obtained through the initiative.

Methods

[For those wishing a deeper understanding of decision analysis models, we would refer you to the writings of Birkmeyer (8)]. A Markov model is a decision-analytical tool allowing for analysis of outcomes occurring in complex systems over variable time periods. Theoretical patients are assigned to different *transition states* (for example 'on dialysis') for a period of time known as a *stage* (often set at one year). Patients can move between states at the end of each stage. The inputs of a Markov model are the values of the outcomes assigned to each transition state, as well as the values of outcomes assigned for passing into or out of a state and the probabilities of those transitions. These outcomes can then be summed over the total time period of analysis producing the output of the model, and various 'what-if' scenarios examined by changing individual input values.

A Markov model was developed to compare the cost-utility of cadaveric kidney transplantation with dialysis of those patients selected for transplantation but remaining on a transplant waiting list. Three states were employed: transplanted, waiting on dialysis and death. The length of the Markov cycle was 1 year, with a 20-year time frame. Within this period treatment costs and QALYs were calculated for patients treated with the two renal replacement alternatives. Half-cycle correction was used for both costs and QALYs. A payer's perspective was used. Costs adjustments for patient time for treatment were excluded. Transition probabilities, utility values and costs were calculated based upon the published literature (Table 1). All monetary values and QALYs were discounted at a rate of 5% per year. Dollars were expressed as Canadian. The willingness to pay for a QALY gain was set at $50 000. Cost-effectiveness thresholds reflect the discounted cost-savings of the intervention plus the discounted monetary of the QALYs gained.

Table 1: Assumptions and values for base case*

	Input variables	Reference
Utilities		
Dialysis	0.57	(5)
Transplantation (1 year)	0.70	(5)
Transplantation (subsequent years)	0.70	(5)
Costs		
Maintenance cost of dialysis	$49 065	(5)
Initial transplantation cost (cadaveric)	$62 365	(5)
Organ procurement cost	$10 816	Institution**
Maintenance cost – transplantation	$15 376	(5)
Graft loss cost (incl nephrectomy)	$3450	Institution**
Maintenance cost – dialysis failed graft	$59 065	(5)
Currency	Can $1994	
Willingness to pay of society for a QALY gain	$50 000	
Probabilities/Rates		
Discount factor for costs	0.05	(22)
Discount factor for QALYs	0.05	(22)
Cadaver graft survival at 1 year	0.86	(23)
Cadaver graft loss (>1 year)	0.048	(24)
Annual patient mortality (6.3/100 patient years) in wait-listed dialysis patients (year)	0.061	(25)
Patient survival at one year post transplant	0.95	(23)
Annual patient mortality >1 year (3.8/100 patient years)	0.037	(25)
Patient mortality after graft loss (at 1 year)	0.24	(26)
Annual patient mortality after graft loss (>1 year)	0.11	(26)
Death with functioning graft	0.28	(23)
Population size (million)	31.5	(27)
Number of cadaver donors/million population	14	(23)
Procured kidneys per cadaver donor	1.64	(23)
Increase in organ donation rate with donor action	53%	(1)

*Published event rates were converted to annual probabilities (28). Annual probabilities for patient or graft loss were assumed stable after the first year over the lifetime of the patient or graft and were calculated from the observed graft or patient loss between years 1–5 assuming a constant logarithmic decline (29).

**Institution sources were used for Canadian donor organ and transplant graft nephrectomy costs as well as probabilities of graft nephrectomy in the failed transplant recipient and death on return to dialysis.

Cost-saving thresholds are also provided, which reflect only the monetary cost savings of the intervention, essentially setting the value of a QALY to 0$.

Sensitivity analysis

The cost-effectiveness threshold of any initiative aimed at increasing organ donation will vary based upon its success rate. We conducted a one-way sensitivity analysis calculating the investment thresholds that could be justified depending on the additional donors per million generated by DA varying them from 1 to 15 extra donors per million population. We also conducted a one-way sensitivity analysis on the time frame employed, realizing that many funding decisions surrounding organ donation are inherently political and therefore examining the effect of varying the time frame between 2 and 30 years.

Results

Cost savings and QALY advantage of transplantation over dialysis

In Canada, waiting on dialysis results in 4.67 QALYs and a cost of $401 810 over 20 years. Transplantation results in 6.66 QALYs and costs $297 372, an incremental gain of 1.99 QALYs and a cost savings of $14 438 per additional individual transplanted (Figure 1).

Sensitivity analysis: effect of varying success rates

As the success rate of organ donor initiatives may vary based on a number of factors, we adapted the model to calculate the thresholds for cost-effectiveness and monetary cost-savings as a function of the incremental raw numbers of donors per million generated by the intervention. Figure 2 demonstrates these relationships. All units are expressed per million population, so for example an intervention that produced three incremental donors per million population would be cost-effective at a price of 1.0 million dollars per million population.

Sensitivity analysis-varying time horizon

We also provided an adjustment to the model to examine the effect of shortening the time frame for the accumulation of QALYs and cost-savings. Figure 3 demonstrates the thresholds for cost-effectiveness and cost savings for interventions that produce either 5 or 10 incremental donors per million as a function of the time frame of the analysis. Even with limited time frames, of 8 years or less, cost-effectiveness thresholds are in millions of dollars per million population. As the time frame lengthens, the cost thresholds stabilize, reflecting the effect of continual graft loss and return to dialysis.

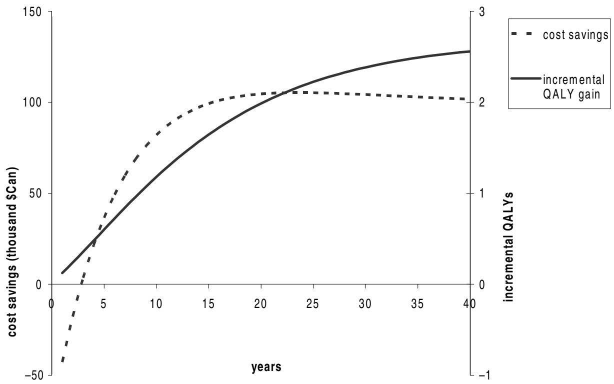

Figure 1: Incremental quality adjusted life years (QALYs) gain and cost savings of transplantation.

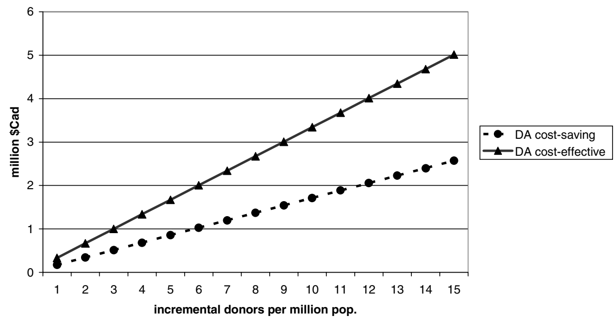

Figure 2: Investment thresholds of Donor Action in Canada per million population.

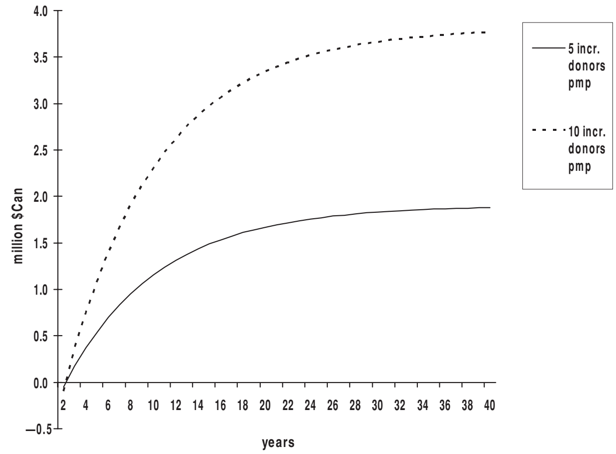

Figure 3: Effect of time frame changes on cost effectiveness thresholds.

Discussion

Our model and the accompanying sensitivity analysis clearly demonstrate that the implementation of DA would be cost reducing under most clinical scenarios. We have previously published a preliminary iteration of this model demonstrating that the implementation of DA in Germany (7), which has been extensive but is not yet country-wide, is cost-effective. Equally important, our new model provides a matrix for evaluating the cost-effectiveness of virtually any initiative to increase organ donation and simultaneously leads to the suggestion that organ donation is currently grossly under funded in North America.

There are a number of limitations to our analysis. First and foremost, this analysis ignores the effect of how transplanting other solid organs such as hearts, livers, lungs and pancreatica affect overall cost-effectiveness of organ donation initiatives. The available data on the cost-effectiveness of other forms of solid organ transplantation are limited, especially as there are few effective competing therapies for many of these transplants, but it may well be that these transplants are also cost-effective (9–12), further amplifying the effect of increasing organ donation. The actual increase in organ donation that would be likely given the implementation of DA in North America is an estimate based on the experience of the program in Europe, but it may well be that these assumptions are too large, especially in areas where donation is already at levels that were achieved only after implementation of the program in Europe.

We used cost estimates that were conservative. The cost data were generated from patients while on dialysis and up to 2 years post transplant (5). This avoids including higher dialysis costs that might accrue to untransplantable patients. However, this may underestimate the burden of dialysis costs as patients left on the wait list for long periods of time owing to the lack of donors may be removed from the wait because of complications and are likely to have more expensive care. We also assumed that patients with a failed transplant had higher mortality rates and more expensive care that continued throughout their subsequent course. Although this cost study is dated (5), the net costs of newer immunosuppressive agents are not likely to be much greater. Pharmacoeconomic studies would argue that the newer agents have been cost saving or at least cost neutral for microemulsion cyclosporinee and basiliximab and in the early post transplant period for mycophenolate mofetil (13–15).

Despite the above limitations, our sensitivity analysis indicates that considerable sums could be invested into organ donation initiatives and be cost-effective, even if only a single additional donor per million was achieved. For example, an intervention that yielded one additional donor per million across all of Canada would still be cost savings at an implementation price of 9 million dollars! We also examined the effects of limiting the time frame of the accumulation of QALYs and cost savings. Our analysis demonstrates that the cumulative savings attributable to increased organ donation diminish as time progresses and plateaus by 30 years, reflecting the fact that few grafts are left functioning that far post-transplant. We do recognize that decisions to fund health care initiatives are often political in nature and the principals involved may be limited to a much shorter time perspective. Even when we limited the monetary gains seen by increasing transplantation rates to shorter and shorter time frames, organ donation initiatives that resulted in five extra donors per million population achieved savings of greater than $300 000 pmp in as little as 5 years. Another implication of our sensitivity analysis is that our results are likely to be roughly generalizable to the U.S. Our inputs are all derived from Canadian sources, but the graft survivals and costs are similar to published data from the U.S., as one might expect, given the similarity in practices between the two countries. Generalizability is also related to implementation cost. The implementation costs of DA have varied from country to country but have consistently been less than 55 000 Canadian dollars per million population and maintenance costs have been less than 70 000 Canadian dollars per million population.

A critical question left unanswered by this analysis is just how much organ donation can be increased. An underlying assumption of our analysis was that organ donation can be increased above current levels in even the best-performing locales. A variety of data support this assumption. Polls of the general population consistently demonstrate that as much as 75% of the general population state that they would wish to be organ donors (16), yet actual consent rates for organ donation run closer to 50% (17). The number of organ donors per million population in Canada varies from nine to 19 donors per million population and remains well below some European countries such as Spain, which has reported 32 donors per million (17–20). Although the accuracy of using donors per million population as an index of organ donation performance has been rightfully called into question (21), it seems unlikely that a three-fold difference between the worst performers and the best can be explained by methodology alone. It is not clear if there is a level of organ donation after which the cost of increasing donation rates still further becomes prohibitively expensive. Experience with DA up to this point has not demonstrated such a point of diminishing return in several European countries as well as Canada (1,2,7). Our analysis makes it seem likely that substantially more resources could be put towards organ donation in even the best-performing locales and still be well spent.

Our analysis has focused solely on DA, a program designed to improve donation practices among health care professionals. The relative efficacy of other established approaches such as public education programs or putative approaches such as providing financial compensation for donors and their families is not well studied. Our analysis is not intended to make a value judgment of best-practice initiatives vs. other approaches, but our model could be used in the future to examine exactly these issues, as the transplant community continues to examine ways of increasing organ donation in forums such as the recent National Consent Conference in Organ Donation sponsored by the United Network for Organ Sharing.

There are a number of likely reasons why organ donation is underfunded. In Canada, there is no federal program to promote organ donation or oversee retrieval, rather these activities are coordinated provincially (20). Some provinces have separately funded organizations to promote donation publicly and professionally (e.g. British Colombia and Ontario) while others are hospital based (Nova Scotia) and rely, for the most part, on the transplant programs to provide promotion and education. Support organizations such as the National Kidney Foundation of Canada help promote donation and more recently the funding of research that would increase organ donation. All hospitals are chronically under funded and there are financial disincentives given the costs of maintaining donors and retrieving organs. Reimbursement costs for organ donor maintenance and retrieval are currently only provided in the province of Quebec. As most hospitals are neither transplant nor dialysis centers, there is no infrastructure support or financial incentive (remove patients off dialysis) to identify donors and procure organs. Most activity to date has been based on goodwill and has relied heavily on the enthusiasm and initiative of a relatively few individuals. An amendment to the Human Tissue Gift Act (Ontario) for required request/routine referral legislation has been enacted but not yet implemented. Some provinces and hospital bylaws have required referral policies but these are not uniformly applied throughout the provinces or country. A federal expert advisory committee has been created to investigate these deficiencies and consider a national integrated process for monitoring, data collection, professional education and training, facility licensing, accountability, standards of practice and accreditation. At present lack of professional education, absence of an integrated national network, inadequate hospital infrastructure and economics continue to be major barriers to donation.

In conclusion, initiatives to increase organ donation such as DA are likely to be cost-effective under a variety of clinical scenarios. Aggressively implementing such programs could be an important step to generating long-term savings and alleviating the worldwide organ shortage.

References

1. Roels L, Wight C. Donor Action: an international initiative to alleviate organ shortage. Prog Transplant 2001; 11: 90–97.
2. Wight C, Cohen B, Roels L, Donor Action. A quality assurance programme for intensive care units which Increases organ donation. J Intensive Care Med 2000; 15: 104–115.
3. deWit GA, Ramstein PG, deCharro FT. Economic evaluation of end-stage renal disease treatment. Health Policy 1998; 44: 213–233.
4. Eggers P. Comparison of treatment costs between dialysis and transplantation. Semin Nephrol 1992; 12: 284–289.
5. Laupacis A, Keown P, Pus N et al. A study of the quality of life and cost utility of renal transplantation. Kidney Int 1996; 50: 235–242.
6. Whiting JF, Zavala EY, Cohen DS et al. Economic cost of expanded criteria donors in cadaveric renal transplantation: Analysis of Medicare payments. Transplantation 2000; 70: 755–760.
7. Roels L, Kalo Z, Boesebeck D, Whiting JF, Wight C. Cost-benefit approach for evaluating investment into Donor Action: the German case. Transplant Int 2003; 16: 321–326.
8. Birkmeyer JD, Liu JY. Decision analysis models: opening the black box. Surgery 2003; 133: 1–4.
9. Sagmeister M, Mullhaupt B, Kadry Z, Kullak-Ublick GA, Clavien PA, Renner EL. Cost-effectiveness of cadaveric and living-donor liver transplantation. Transplantation 2002; 73: 616–622.
10. Weintraub WS, Cole J, Tooley JF. Cost and cost-effectiveness studies in heart failure research. Am Heart J 2002; 134: 565–576.
11. Anyanwu AC, McGuire A, Rogers CA, Murday AJ. An economic evaluation of lung transplantation. J Thoracic Cardio Surg 2003; 123: 411–418.
12. Ouwens JP, VanEnckevort PJ, TenVergert EM et al. The cost effectiveness of lung transplantation compared with that of heart and liver transplantation in the Netherlands. Transplant Int 2003; 16: 123–127.
13. Coukell AJ, Plosker GL. Cyclosporin microemulsion (Neoral). A pharmacoeconomic review of its use compared with standard cyclosporin in renal and hepatic transplantation. Pharmacoeconomics 1998; 14: 691–708.
14. Young M, Plosker GL. Mycophenolate mofetil: a pharmacoeconomic review of its use in solid organ transplantation. Pharmacoeconomics 2002; 20: 675–713.
15. Walters SJ, Whitfield M, Akehurst RL, Chilcott JB. Economic implications of the use of basiliximab in addition to triple immunosuppressive therapy in renal allograft recipients: a UK perspective. Pharmacoeconomics 2003; 21: 129–138.
16. The Gallup Organization I. The American Public's Attitudes Towards Organ Donation and Transplantation. Boston, MA: The Partnership for Organ Donation, 1993.
17. Baxter D. Beyond Comparison: Canada's Organ Donation Rate in an International Context. Vancouver, British Columbia: The Urban Futures Institute, 2001.
18. Canadian Organ Replacement Registry 2001 Report, Vol. 2. Organ Donation and Transplantation. Canadian Institute for Health Information. Ottawa, Ontario, 2001.
19. Bosch X. Spain leads world in organ donation and transplantation. J Am Med Assoc 1999; 282: 70 7–7–.
20. Volpe JP. Organ and Tissue Donation: a Canadian Approach. Report of the Standing Committee on Health. Ottawa, Canada: Public Works and Government Services, 1999: 1–90.
21. Stogis S, Hirth RA, Strawderman RL, Banaszak-Holl J, Smith DG. Using a standardized donor ratio to assess the performance of organ procurement organizations. Health Serv Res 2002; 37: 1329–1344.
22. Whiting JF for the Transplant Outcomes Research Group. Standards for economic and quality of life studies in transplantation. Transplantation. 2000; 70: 1115–1121.
23. Canadian Organ Replacement Registry, Vol. 1: Dialysis and Renal Transplantation. Ottawa, Ontario: Canadian Institute for Health Information, 2001.
24. Hariharan S, Johnson CP, Bresnahan BA, Taranto SE, McIntosh MJ, Stablein D. Improved graft survival after renal transplantation in the United States. N Engl J Med 2000, 1988–96; 342: 605–612.
25. Wolfe RA, Ashby VB, Milford EL et al. Comparison of mortality in all patients on dialysis, patients on dialysis awaiting transplantation, and recipients of a first cadaveric transplant. N Engl J Med 1999; 341: 1725–1730.
26. Meier-Kriesche H, Kaplan B. Death after graft loss: a novel endpoint for renal transplantation. Transplant Proc 2001; 33: 3405–3406.
27. Statistics Canada. Population Census 2002.
28. USRDS. Annual Report 2001. Bethesda, Maryland: National Institute of Health, National Institute of Diabetes and Digestive and Kidney Diseases.
29. Beck JR, Kassirer JP, Pauker SG, Gottlieb JE, Klein K. A convenient approximation of life expectancy. Am J Med 1982; 73: 883–897.