



The Ongoing Design of Kidney Exchange: Recent and Prospective Developments



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Abstract

Kidney exchange today contributes almost 15% of the living-donor kidney transplants in the U.S., and is growing in many other countries (Fig. 1). However the contemporary design of kidney exchange is different than was anticipated at the outset. The majority of kidney exchange transplants are carried out between patient-donor pairs registered at the same transplant center, while several large multi-hospital kidney exchange networks primarily organize chains of transplants that may be long and non-simultaneous, and provide transplants for hard to match pairs. The changes in design have evolved in response to changing participant behavior, and have involved close collaboration between market designers and transplant professionals. Progress has been made in eliciting the preferences of surgeons over kidneys for particular patients. Prospective future changes involve standardizing the acquisition charges for exchanged kidneys, beginning some kidney exchange chains with a deceased-donor kidney, and inviting into American kidney exchange patient-donor pairs from countries in which transplantation is financially unavailable, with the costs to be paid from the savings to the American health care system when an American patient is transplanted and hence removed from much more costly dialysis.

Introduction

Kidney exchange increases the number of transplants by allowing two or more patient-donor pairs to exchange kidneys. Many exchanges today take the form of chains initiated by a non-directed donor (see figures 2-3)

We initially anticipated that kidney exchanges would be conducted among a population that mirrored the characteristics of patients on the waiting list for deceased donation, and that exchanges between few pairs would be sufficient [1]. However, as kidney exchange became well-established, hospitals began to do internal exchanges between easy to match pairs, and multi-hospital exchanges began to host an increased proportion of hard to match pairs, many of whom are now transplanted in chains of exchange initiated by non-directed donors [2-5,7]. New computational tools have been developed for optimizing matches that include many chains [8].

One issue that contributes to transplant centers transplanting their easy to match pairs internally is that different hospitals have different costs in preparing kidney exchange donors, and hence charge different kidney acquisition fees. Pilot studies are underway to standardize such costs and hence facilitate inter-hospital exchanges [6]. Another issue is that it turns out to be difficult for surgeons to express their preferences over the combinatorial properties of particular kidneys for particular patients, and progress on this has been made by introducing a threshold language in which surgeons can prospectively express some limits (e.g. on donor age, blood pressure, BMI, kidney function, etc.) beyond which they would not presently want to accept a kidney for a given patient [9].

Present efforts to increase the number of transplants include initiating some chains with a deceased donor kidney, and including some foreign patients in American kidney exchange, as discussed next.

Fig. 1 Kidney exchange and non-directed donor transplants as a % of all U.S. living donor transplants, over time

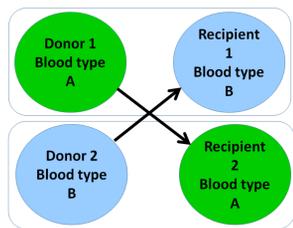
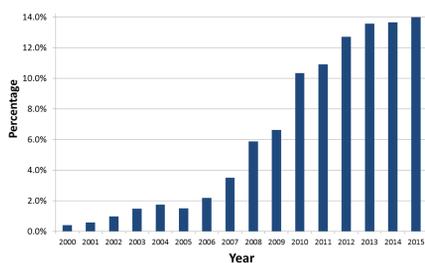


Fig.2: a simple exchange between two pairs.

Starting Chains with Deceased Donor Kidneys

Recent US experience with kidney exchange chains begun by living non-directed donors has been that these chains produce an average of almost 5 transplants. Although virtually all deceased-donor (DD) kidneys are non-directed, each DD kidney presently facilitates only a single transplant. So there is an opportunity to increase the number of transplants by using some suitable DD kidneys to initiate kidney exchange chains, with the donor from the last patient-donor pair in the chain donating a living donor kidney to a patient on the deceased donor waiting list. The average number of transplants achieved by non-directed donor chains would decrease if the number of non-directed donors were to increase in this way (or in any other way), but the average number of kidney transplants facilitated by DD chains of this sort would be greater than 1, and could be organized to help reduce the number of patient-donor pairs waiting for kidney exchange without disadvantaging patients on the deceased donor waiting list [10].

Global Kidney Exchange (GKE)

In the developed world, dialysis and transplantation are available for patients with kidney failure, and kidney exchange makes living donor transplants available even to patients with incompatible donors. But in much of the *developing* world financial barriers prevent most patients from receiving any form of renal replacement therapy, and so kidney failure is a death sentence. However there are mutual benefits to including foreign patient-donor pairs who face financial barriers in American kidney exchanges, with the costs of their care being financed by the savings to the American health care system that are realized whenever an American patient is transplanted and removed from (much more expensive) dialysis. These savings are more than enough to pay for the cost of transplantation for the foreign pair, and their subsequent post-surgical care (including many years of immunosuppressive drugs) in the home country.

The first global kidney exchange chain was conducted by the Alliance for Paired Donation in 2015, with a Filipino patient-donor pair, whose recipient was transplanted in the US with an American donor's kidney at no cost to him, as part of a chain begun by an American non-directed donor (Fig 4). Rees et al. [11] report the one-year experience of this pair, who are now safely home. Nikzad et al. [12] model how GKE would continue to work in the steady state in which waiting times for dialysis in the US, and hence dialysis costs, may have been reduced sufficiently to be comparable to transplant costs. Work remains to be done on engineering the financial flows to move the savings that accrue from removing American patients from dialysis to pay for the costs of transplantation for the foreign patients. However the initial GKE chain (and those that have followed it) demonstrate that the logistical problems of organizing the surgeries, although substantial, are surmountable.

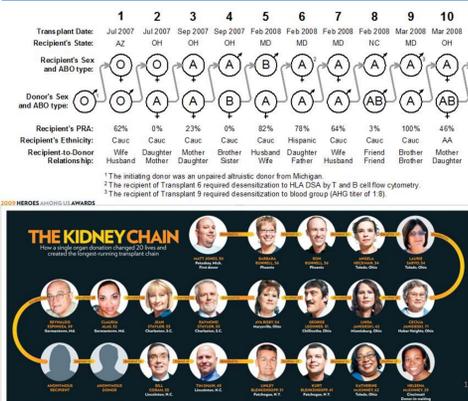


Fig. 3: The first non-simultaneous exchange chain--Rees et al. 2009

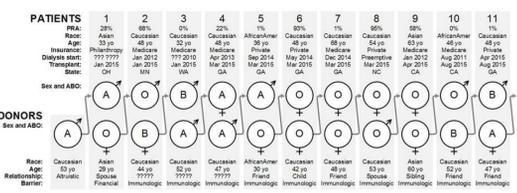


Fig. 4: The first Global Kidney Exchange chain--pair 1 is the pair from the Philippines (Rees et al. forthcoming).

Discussion

This brief report on changes in kidney exchange design concentrates on work I have been directly involved in, but is also reflected in the larger kidney exchange environment. (For some other work around the world see <http://marketdesigner.blogspot.com/search/label/kidney%20exchange>.) In particular, kidney exchange protocols operate in medical environments in which patients, surgeons and transplant centers have very large strategy spaces. As kidney exchange has become a standard mode of transplantation, the major players have adapted to it, in ways that in turn require changes in kidney exchange. In addition, as kidney exchange has become well established, possibilities to expand and extend it have opened up that did not initially seem feasible, in terms of new patient populations and further integration with deceased organ transplantation. In the evolving medical environments, much of the contemporary design discussion has taken place in medical journals.

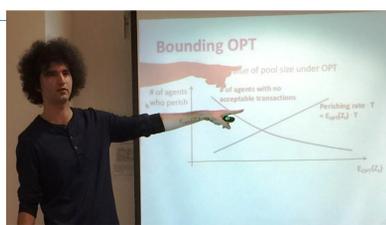
The constantly evolving design of kidney exchange is rather different than my experience with market designs involving medical labor markets, or school choice, or even the economics job market, in which design features have remained constant for years at a time.

References (in chronological order):

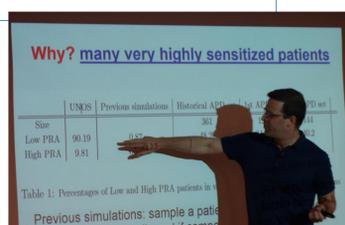
- Roth, Alvin E., Tayfun Sönmez and M. Utku Ünver, "Kidney Exchange," *Quarterly Journal of Economics*, 119, 2, May, 2004, 457-488.
- Roth, Alvin E., Tayfun Sönmez, M. Utku Ünver, Francis L. Delmonico, and Susan L. Saidman, "Utilizing List Exchange and Undirected Good Samaritan Donation through "Chain" Paired Kidney Donations," *American Journal of Transplantation*, 6, 11, November 2006, 2694-2705.
- Rees, Michael A., Jonathan E. Kopke, Ronald P. Pelletier, Dorry L. Segev, Matthew E. Rutter, Alfredo J. Fabrega, Jeffrey Rogers, Oleh G. Panekwycz, Janet Hiller, Alvin E. Roth, Tuomas Sandholm, Utku Ünver, and Robert A. Montgomery, "A Non-Simultaneous Extended Altruistic Donor Chain," *New England Journal of Medicine*, 360, 11, March 12, 2009, 1096-1101.
- Ashlagi, Itai, Duncan S. Gilchrist, Alvin E. Roth, and Michael A. Rees, "Nonsimultaneous Chains and Dominos in Kidney Paired Donation - Revisited," *American Journal of Transplantation*, 11, 5, May 2011, 984-994
- Ashlagi, Itai, Duncan S. Gilchrist, Alvin E. Roth, and Michael A. Rees, "NEAD Chains in Transplantation," *American Journal of Transplantation*, December 2011; 11: 2780-2781.
- Rees, Michael A., Mark A. Schnitzler, Edward Zavala, James A. Cutler, Alvin E. Roth, F. Dennis Irwin, Stephen W. Crawford, and Alan B. Leichtman, "Call to Develop a Standard Acquisition Charge Model for Kidney Paired Donation," *American Journal of Transplantation*, 2012, 12, 6 (June), 1392-1397. (published online 9 April 2012)
- Ashlagi, Itai, and Alvin E. Roth, "Free Riding and Participation in Large Scale, Multi-hospital Kidney Exchange," *Theoretical Economics* 9 (2014), 817-863.
- Anderson, Ross, Itai Ashlagi, David Gamarnik and Alvin E. Roth, "Finding long chains in kidney exchange using the traveling salesman problem," *Proceedings of the National Academy of Sciences of the United States of America (PNAS)*, January 20, 2015 | vol. 112 | no. 3 | 663-668
- Fumo, D.E., V. Kapoor, L.J. Reece, S.M. Stepkowski, J.E. Kopke, S.E. Rees, C. Smith, A.E. Roth, A.B. Leichtman, M.A. Rees, "Improving matching strategies in kidney paired donation: the 7-year evolution of a web based virtual matching system," *American Journal of Transplantation*, October 2015, 15(10), 2646-2654
- Melcher, Marc L., John P. Roberts, Alan B. Leichtman, Alvin E. Roth, and Michael A. Rees, "Utilization of Deceased Donor Kidneys to Initiate Living Donor Chains," *American Journal of Transplantation*, 16, 5, May 2016, 1367-1370.
- Michael A. Rees, Ty B. Dunn, Christian S. Kuhr, Christopher L. Marsh, Jeffrey Rogers, Susan E. Rees, Alejandra Cicero, Laurie J. Reece, Alvin E. Roth, Obi Ekwenna, David E. Fumo, Kimberly D. Krawiec, Jonathan E. Kopke, Samay Jain, Miguel Tan and Siegfredo R. Paloyo, "Kidney Exchange to Overcome Financial Barriers to Kidney Transplantation," *American Journal of Transplantation*, forthcoming
- Nikzad, Afshin, Mohammad Akbarpour, Michael Rees, and Alvin E. Roth, "Financing Transplant Costs of the Poor: A Dynamic Model of Global Kidney Exchange," 2016

Market design is a team sport*:

*and some contributors are camera-shy...



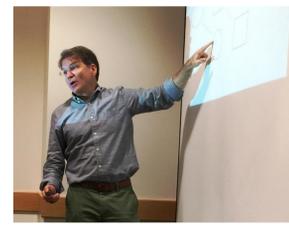
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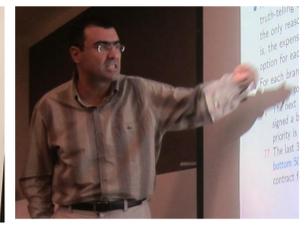
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