Kidney Exchange: Past, Present, and Potential Future

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Kidney Transplants

- There are close to 96,000 patients on the waiting list for deceased donor kidneys in the U.S. as of April 2013.
- The shortage of kidney increases by about 3,500 kidneys each year in the U.S.
In 2012:

- 34,840 patients were added to waiting list while 28,437 patients were removed;
- 10,868 transplants of deceased donor kidneys performed; and
- 4,185 patients died while on the waiting list and 2,667 were removed from the list due to being too sick to receive a transplant.
- There were also 5,619 transplants of kidneys from living donors.

Often living donors are incompatible with their intended patient.
There are four blood types: A, B, AB and O.

In the absence of other complications:
- Type O kidneys can be transplanted into any patient;
- type A kidneys can be transplanted into type A or type AB patients;
- type B kidneys can be transplanted into type B or type AB patients;
- type AB kidneys can only be transplanted into type AB patients.

Type O patients are disadvantaged because of this “natural injustice.”
Medical Constraint: Tissue Type Compatibility

- Tissue type or Human Leukocyte Antigen (HLA) type: Combination of several pairs of antigens on Chromosome 6.

HLA proteins A, B, and DR are especially important.

Prior to transplantation, the potential recipient is tested for the presence of preformed antibodies against donor HLA. If there is a positive crossmatch, the transplantation cannot be carried out.
Institutional Constraint: No Money

- The 1984 National Organ Transplant Act (NOTA) makes paying for an organ for transplantation a felony:
  
  “it shall be unlawful for any person to knowingly acquire, receive or otherwise transfer any human organ for valuable consideration for use in human transplantation.”
Allocation of Deceased Donor Kidneys in the U.S.

- U.S. Congress views deceased donor kidneys offered for transplantation as a national resource, and the 1984 NOTA established the Organ Procurement and Transplantation Network (OPTN).

- United Network for Organ Sharing (UNOS), as the OPTN contractor, overseas the allocation of deceased donor kidneys.
A patient identifies a willing donor and, if the transplant is feasible, it is carried out.

Otherwise, the patient remains on the deceased donor queue, while the donor returns home.

In the period 2000-2004, additional possibilities have been utilized in a few cases through exchanges between two incompatible pairs.
Paired Kidney Exchange

- First proposed by Rapaport (1986).
- The first kidney exchanges were carried out in South Korea in early 1990s.
- Renewed interest in the U.S. with Ross et al. (1997) on “Ethics of Kidney Exchange.”
Paired Kidney Exchange

- In 2000 the transplantation community issued a consensus statement declaring it as “ethically acceptable.”
- The consensus statement urged all four operations to be carried out simultaneously!
- The first kidney exchange in the U.S. was carried out in Rhode Island in 2000.
Kidney Exchange as a Market Design Problem

- The emerging field of Market Design applies insights and tools from economic theory to solve real-life resource allocation problems.
- In early 2000s, market designers observed that the two main types of kidney exchanges conducted in the U.S. correspond to the most basic forms of exchanges in house allocation models in matching literature.
- Building on the existing practices in kidney transplantation, Roth, Sönmez, & Ünver (2004, 2005, 2007) analyzed how an efficient and incentive-compatible system of exchanges might be organized, and what its welfare implications might be.
- The methodology and techniques advocated in this research program provided the backbone of several kidney exchange programs in the U.S. and the rest of the world.
Organized Exchange & Optimization is Important

Pair 1  Pair 3
Pair 2  Pair 4

- Even in the absence of more elaborate exchanges, merely organizing the paired-exchanges may result in increased efficiency.
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Gains from Larger Exchanges are Considerable

- Additional live-donor transplants may be possible through three-way, four-way, . . . , exchanges.
- Three-way exchange is especially important!
Simultaneity is not critical when a kidney-chain starts with a donation from an altruistic donor. Hence large kidney-chains can be utilized!
Inclusion of Compatible Pairs is Important

- Typically a blood-type compatible pair participates in kidney exchange only when the donor is tissue-type incompatible with the intended recipient (a.k.a. positive crossmatch).
- This is a relatively rare event: Zenios, Woodle & Ross (2001) reports the positive crossmatch frequency as
  - 33.3 % between female patients and their husbands, and
  - 11.1 % between other types of pairs.
- In contrast, a blood-type incompatible pair is automatically referred to a kidney exchange program.
- Hence there are many more blood-type incompatible pairs in kidney exchange programs than blood-type compatible pairs!
  \[ \Rightarrow \quad \# \text{O Patients} \gg \# \text{O Donors} \]
- This disparity can be minimized if compatible pairs can also be included in kidney exchange.
There are “Economies of Scale” in Kidney Exchange

- Larger kidney exchange programs (such as national programs) provide a more efficient system than several smaller ones.
- Larger programs are especially beneficial for hard to match patients such as those who have positive crossmatch with a large fraction of donor population (a.k.a. high PRA or highly sensitized patients).
A handful of kidney exchanges in the U.S. prior to 2004, increased to 93 in 2006 and to 553 in 2010.

Currently kidney exchanges in the U.S. account for about 10% of all live donor kidney transplants.
The Progress of Kidney Exchange in the Last Decade

1. Organization & Optimization of Kidney Exchange
2. Utilizing Gains from Larger Exchanges
3. Integration of Altruistic Donors via Kidney Chains
4. Inclusion of Compatible Pairs for Increased Efficiency
5. Higher Efficiency via Larger Kidney Exchange Programs
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To what extent these insights have been utilized so far?
Welcome

A Life-Saving Option

The New England Program for Kidney Exchange offers new life-saving options to those seeking a kidney transplant, but whose potential living donor is not a good biological “match” due to either blood type incompatibility or cross-match incompatibility. This option is known as kidney exchange, kidney paired donation, or kidney swap.

The New England Program for Kidney Exchange uses a computer program to find cases where the donor in an incompatible pair can be matched to a recipient in another pair. By exchanging donors, a compatible match for both recipients may be found. You can learn more about the program HERE and read our newsletter HERE.

NEPKE can also find potential kidney recipients for those generous people who seek to become non-directed living donors (otherwise known as Good Samaritan Donors or Altruistic Donors). Information about that process is available HERE.

NEWS:

Transplant centers are being provided with brochures to provide information about this program to their kidney patients.

NEPKE Transplants to Date

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Notes:

There are many good websites on the Internet that help kidney patients learn more about transplant options.

Links

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The Program

FAQ

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http://www.nepke.org/ (1 of 2) [4/10/2011 3:58:29 PM]

Alliance for Paired Donation – Saving Lives through Kidney Paired Donation

More than 84,000 people in America are waiting for a kidney transplant; sadly, about 12 of these patients die every day because there aren’t enough donors. Many kidney patients have someone who is willing to donate, but because of immune system or blood type incompatibilities, they are not able to give a kidney to their loved one.

The Alliance for Paired Donation can help. Kidney paired donation matches one incompatible donor/recipient pair to another pair in the same situation, so that the donor of the first pair gives to the recipient of the second, and vice versa. In other words, the two pairs swap kidneys. APD has also pioneered a new way of using altruistic, or good Samaritan, donors, so that the transplants no longer have to be performed simultaneously. Non-simultaneous Extended Altruistic Donor Chains (NEAD Chains) allow donors to “pay it forward” after their loved one receives a transplant.

Paying it Forward:

Saving Lives Through Paired Kidney Exchange

Watch the Video

Thank you for caring enough to get involved.

If you find our efforts worth supporting, would you consider making a tax-deductible donation to support the work of the Alliance for Paired Donation?

Alliance for Paired Donation

3661 Briarfield Boulevard, Suite 105, Maumee, Ohio 43537

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Want to learn more about NEAD chains? Click here to view Video

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I NEED A KIDNEY TRANSPLANT

I WOULD LIKE TO DONATE A KIDNEY

I WANT TO DONATE FINANCIALLY
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Incredible 3-way kidney swap

Mike and Susan Williams of Banton

Massive transplant effort pairs 13 kidneys to 13 patients

By Val Willingham, CNN
December 14, 2009 8:40 a.m. EST

Washington (CNN) -- Renee Patterson's most precious present this Christmas won't be under her tree, and it didn't come from a store. This holiday, she said, she got her life back.

The Upper Marlboro, Maryland, resident learned nine years ago she had kidney disease. One of her kidneys began to deteriorate, and she had to begin regular dialysis. Because she couldn't find a family match, her former colleague and friend, Michael Williams, offered to donate one of his kidneys. Problem was, Patterson and Williams didn't match either. But Patterson's doctor suggested they look into the paired kidney donation program at Washington Hospital Center in Washington, D.C.

She became part of a massive mix-and-match transplant effort in the U.S., involving more than a dozen kidneys.

DENVER AND THE WEST

Selflessness, to the third power

3 kidney transplants to occur simultaneously across country

By Brian Malnes
The Denver Post

With clocks synchronized, three kidney transplants will happen simultaneously at three hospitals in three time zones around the country this morning.

At 7:30 a.m. Denver time, the three-state kidney exchange will begin with patients in North Carolina, in Alabama and at the University of Colorado Hospital in Aurora.

"It's the first time in U.S. history that three transplants will be happening at the same time," said Vonnie Bagwell, the living donor coordinator at CU Denver Health Center.

World's Largest Kidney Exchange Gives 14 People New Chance at Life

By LISA STARK (@LisaStark) and BRADLEY BLACKBURN
June 19, 2010

In the nation's capital, a circle of strangers is now connected for life.

Beginning last month, 14 donors gave their kidneys to 14 people who desperately needed them in the largest kidney exchange in history.

Washington kidney exchange is largest ever

By Melanie D.G. Kaplan | December 1, 2009, 4:00 AM PST

The largest-ever single-city kidney exchange took place this summer in Washington. The seven-way exchange, which involved 14 patients, occurred at Georgetown University Hospital and Washington Hospital Center over four days in July. It was the brainchild of Dr. Keith Melancon, director of Georgetown's Kidney and Pancreas Transplant Surgery, who used a procedure called plasmapheresis to address not only donor compatibility but racial disparity.
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60 Lives, 30 Kidneys, All Linked

FROM START TO FINISH A donation by a Good Samaritan, Rick Ruzzamenti, upper left, set in motion a 60-person chain of transplants that ended with a kidney for Donald C. Terry Jr., bottom right.
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Inclusion of Compatible Pairs

- Very limited implementation of this idea.
- Limited or no incentives for compatible pairs to participate in kidney exchange.
The first market design paper on kidney exchange, Roth, Sönmez, & Ünver (2004), presented considerably larger potential efficiency gains from kidney exchange than we observe in practice today.

Part of the difference is due to larger exchanges along with more elaborate list exchanges allowed in RSÜ (2004).

However, by far the biggest factor in this difference is the prominent presence of compatible pairs in RSÜ (2004).

Patients are assumed to have strict preferences over compatible kidneys in RSÜ (2004).

As such, patients have valid reasons to participate in kidney exchange even if they have a compatible donor.

Hence, the disparity between numbers of O patients and O donors is minimal in RSÜ (2004) as an implication of its modeling choice.
As a “prerequisite” of collaboration with members of New England transplantation community, we were asked to develop a model that is limited to two-way exchanges where patients are indifferent between compatible kidneys (i.e. dichotomous preferences).

Doctors were worried that the strict preference assumption might lead to patients or hospitals competing over “better” kidneys, potentially hurting the system.

This request resulted in RSÜ (2005) which became the starting point of a series of fruitful interactions between market designers and members of the transplantation community.

However, this alternative modeling choice also removed the primary reason of compatible pairs to participate in kidney exchange!

The practice of kidney exchange mostly adopted this approach based on dichotomous patient preferences, even though this assumption is in part reflection of some “transplantation politics.”
The Progress of Kidney Exchange in the Last Decade

- Organization & Optimization of Kidney Exchange ✓
- Utilizing Gains from Larger Exchanges ✓
- Integration of Altruistic Donors via Kidney Chains ✓
- Inclusion of Compatible Pairs for Increased Efficiency 😞
- Higher Efficiency via Larger Kidney Exchange Programs
Establishing Larger Kidney Exchange Programs

When we initially helped found New England Program for Kidney Exchange (NEPKE), it was unclear whether kidney exchange is in violation of NOTA.

In particular, it was unclear whether kidney exchange was considered to involve transfer of a human organ for valuable consideration.

In Dec 2007, an amendment of NOTA has passed in the Senate, clarifying that kidney exchange is legal and removing the barrier from establishment of national kidney exchange.
Establishing Larger Kidney Exchange Programs

U.S. National Kidney Paired Donation Pilot Program

- In 2010, a pilot national kidney exchange program in U.S. (UNOS-KPD) is launched.

As of December 2011, NEPKE became part of UNOS-KPD.

- However, in part because of its late establishment, activity in the UNOS-KPD is relatively modest compared to major programs.
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Towards a More Efficient Kidney Exchange System

Incentivizing Compatible Pairs

- On the one hand countless blood-type O patients with non-O donors are waiting for a potential exchange, on the other hand many O blood-type donors directly donate to their non-O recipients.

- How can we incentivize participation of these compatible pairs to kidney exchange?

Some potential paths:

- Cash incentives: Currently a taboo in much of the world...
- Giving up the dichotomous preference paradigm as in RSÜ (2004) and Nicoló & Rodríguez-Álvarez (2012): More promising than cash incentives but so far restricted to a few small programs.

- In Sönmez & Ünver (2013) we propose an alternative policy that might potentially be more compatible with the current paradigm.
A New Proposal

- **Policy Proposal** (Sönmez & Ünver 2013): If an O donor with a compatible non-O patient (or if an AB patient with a compatible non-AB donor) participates in exchange, even though they do not need to, the patient is given priority in the deceased donor wait list in case he needs another kidney in the future due to a second failure.
  - Altruism is incentivized with an "insurance" for a potential future failure.
  - About 15% of kidney transplants are repeat transplants.
  - Such priority is already given to living donors!

- If adopted, this incentive scheme will give a major advantage to UNOS-KPD, since UNOS is in charge of the deceased donor wait list.
Hitting Two Birds with One Stone

Given a fixed patient-donor pool, patients of all groups benefit from the above-described incentive scheme.

**Theorem** (Sönmez & Ünver 2013): Weakly more transplants are made within each patient group under a policy that incentivizes participation of ABO compatible pairs via increased priority in future kidney failures.
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  **Theorem** (Sönmez & Ünver 2013): Weakly more transplants are made within each patient group under a policy that incentivizes participation of ABO compatible pairs via increased priority in future kidney failures.

- Moreover, having an edge over other programs, only the national kidney exchange program survives under our incentive scheme.

  **Theorem** (Sönmez & Ünver 2013): Consider the game where patient-donor pairs choose among multiple kidney exchange programs based on the expected patient “utility.” All pairs list themselves at the national exchange program that has adopted the above described incentive scheme, and thus no pair list themselves in any other program under the unique Nash equilibrium.
Potential Future of Kidney Exchange

1. Organization & Optimization of Kidney Exchange ✓
2. Utilizing Gains from Larger Exchanges ✓
3. Integration of Altruistic Donors via Kidney Chains ✓
4. Inclusion of Compatible Pairs for Increased Efficiency 😊
5. Higher Efficiency via Larger Kidney Exchange Programs 😊
In the absence of compatible pairs, the only blood-type O donors in kidney exchange pools are those with positive crossmatch with their intended patients.

In other words, we would not see any O donors in kidney exchange pools in the absence of tissue type incompatibility!

Thus, the only viable exchange would be between
- blood-type A patients with B donors, and
- blood-type B patients with A donors.

Ironically, the presence of tissue type incompatibility considerably increases the scope of kidney exchange in the absence of compatible pairs.
ABO and HLA Desensitization Protocols

- For some patients with “moderate” antibody levels for ABO (blood-type) or HLA (tissue-type) antigens, it may be possible to reduce their level of antibodies with medication below levels that preclude transplantation.

  This process is known as desensitization in transplantation.

- While this medical modality is expensive and inferior to donation from compatible donors, in some cases it may be the only option for some “hard to match” patient-donor groups.

- In the absence of kidney exchange, both ABO-desensitization and HLA-desensitization increases the number of patients who can receive transplants.

  After all, that is the intention of the desensitization protocols!
However, contrary to its intended purpose, HLA-desensitization is a source of negative externality to the general patient population in the presence of kidney exchange.
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**Theorem** (Sönmez & Ünver in preparation): While ABO-desensitization increases the number of patients who receive transplants from live donors (either directly or via exchange), HLA-desensitization decreases the number of patients who receive transplants from live donors in the presence of kidney exchange.
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Just as tissue-type incompatibility increases the scope of kidney exchange by increasing the supply of much needed O donors in the pool, HLA-desensitization reduces it via the opposite effect!
Conclusion

- The share of transplants from kidney exchanges have increased dramatically over the last decade with the introduction of organized kidney exchange programs that embraced optimization techniques and certain innovations by market designers.

- However a number of factors including
  - the presence of too many small programs,
  - the disparity between blood-type distributions of donors and patients due to lack of participation of compatible pairs

limit the real life benefits from kidney exchange considerably below its potential.

- While current kidney exchange programs are fairly successful in optimizing transplants within static kidney exchange pools, there are still considerable gains in adopting policies that will result in more favorable patient-donors pools.
Conclusion

- Insight from several branches of economic theory, including
  - Incentives,
  - Adverse Selection,
  - Externalities

provide guidance on achieving such favorable patient-donor pools.