Unpaired Kidney Exchange: Overcoming the double coincidence of wants without a medium of exchange

M. Akbarpour (Stanford GSB), J. Combe (CREST – Ecole Polytechnique), Y. He (Rice U), V. Hiller (U Paris II), R. Shimer (U of Chicago), O. Tercieux (CNRS & PSE)

Standard technologies for Kidney Exchange:

**Pairwise exchanges**
- Donor gives while patient receives
- No renege risks of donors
- Double coincidence of wants

**Chains**
- Donor gives after patient receives
- Renege risks of donors

Proposition of this paper: Realize transplantations as soon as they are possible

**Unpaired Kidney Exchange**
- Donor gives before the patient receives
- Renege risk for donors
- Donor gives after the patient receives
- Waiting time of patients in P
- No needs of altruistic donors

Non-Directed Donor (without a patient)
Unpaired Kidney Exchange: Overcoming the double coincidence of wants without a medium of exchange
M. Akbarpour (Stanford GSB), J. Combe (CREST – Ecole Polytechnique), Y. He (Rice U), V. Hiller (U Paris II), R. Shimer (U of Chicago), O. Tercieux (CNRS & PSE)

We focus on the limit of the average waiting time at steady-state when $p_H \to 0$

$$\lim_{p_H \to 0} (\lambda W_H(Alg) + (1 - \lambda)W_E(Alg))$$

We can show that for the algorithms we study $p_H W_E(Alg) \to 0$ as $p_H \to 0$

⇒ Need to study the limit of $p_H W_H(Alg)$

H patients

$$\lim_{p_H \to 0} p_H W_H$$

We can show that for the algorithms we study $p_H W_E(Alg) \to 0$ as $p_H \to 0$

⇒ Need to study the limit of $p_H W_H(Alg)$

Our main result

$W(\text{Optimal}) \approx W(\text{Unpaired}) < W(\text{Chain}) < W(\text{Pairwise})$

Model
- Continuous time
- Pairs of patient-donor arrive at Poisson rate $\eta$
- Proportion $\lambda$ of hard to match patients
  ⇒ Prob. $p_H$ to be compatible with a donor (iid)
- Proportion $1 - \lambda$ of easy to match patients
  ⇒ Prob. $p_E = 1$ to be compatible with a donor (iid)
- Patients and donors leave the market once matched
We perform counterfactual simulations by drawing arrival dates consistent with the real participation of each pair + no exit.

<table>
<thead>
<tr>
<th></th>
<th>Pairwise</th>
<th>Chain (+ Pairwise)</th>
<th>Unpaired</th>
<th>Omniscient (best ex post)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nb. of grafts</td>
<td>22.74</td>
<td>23.14</td>
<td>44.47</td>
<td>45.23</td>
</tr>
<tr>
<td>% of grafts</td>
<td>29.2%</td>
<td>29.7%</td>
<td>57%</td>
<td>58%</td>
</tr>
<tr>
<td>Waiting time (days)</td>
<td>706.32</td>
<td>674.65</td>
<td>424.17</td>
<td>410.35</td>
</tr>
<tr>
<td>Waiting time in P (days)</td>
<td>0</td>
<td>0</td>
<td>392.19</td>
<td>598</td>
</tr>
</tbody>
</table>

Match rate of unpaired greedy similar to omniscient but...
... the waiting time in P is a real issue so far.

Data

- French KEP+DDL from Dec 2013 – Feb 2018
  ⇒ Only pairwise exchanges + centralized at national level
- Small market: 78 pairs participated
- Data on 540 pairs who did “desensitization”

- Small market issue?
  ⇒ We simulate large markets (FR, APKD, NKR)
- Can propose good kidneys from deceased donors to patients in P
  ⇒ We simulate this using data on the French Deceased Donor List (DDL)

Significantly weaken the issue
Unpaired Kidney Exchange: Overcoming the double coincidence of wants without a medium of exchange  
M. Akbarpour (Stanford GSB), J. Combe (CREST – Ecole Polytechnique), Y. He (Rice U), V. Hiller (U Paris II), R. Shimer (U of Chicago), O. Tercieux (CNRS & PSE)

### Large market simulations

<table>
<thead>
<tr>
<th></th>
<th>French KEP + Desensit pairs</th>
<th>NKR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pairwise</td>
<td>Unpaired</td>
</tr>
<tr>
<td>Size</td>
<td>586</td>
<td>586</td>
</tr>
<tr>
<td>% grafts</td>
<td>44%</td>
<td>67%</td>
</tr>
<tr>
<td>Waiting Time</td>
<td>471</td>
<td>270</td>
</tr>
<tr>
<td>Waiting time in P</td>
<td>0</td>
<td>265</td>
</tr>
</tbody>
</table>

Unpaired still close to Omniscient + waiting time in P is low (even for HS patients)

### Use of the DDL

<table>
<thead>
<tr>
<th></th>
<th>Pairwise</th>
<th>Chain (+ Pairwise)</th>
<th>Unpaired</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>78</td>
<td>78</td>
<td>78</td>
</tr>
<tr>
<td>Nb. of grafts</td>
<td>22.74</td>
<td>23.14</td>
<td>65.5 (+21)</td>
</tr>
<tr>
<td>Nb of grafts from living</td>
<td>22.74</td>
<td>22.14</td>
<td>39.94 (-5)</td>
</tr>
<tr>
<td>Waiting Time</td>
<td>706.32</td>
<td>674.65</td>
<td>171.47 (-238)</td>
</tr>
<tr>
<td>Waiting time in P</td>
<td>0</td>
<td>0</td>
<td>77.1 (-315)</td>
</tr>
</tbody>
</table>

80% of grafts + median waiting time in P at 4 days!