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Kidney Exchange in Practice

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The Health Economics Day, 1 February 2019



Outline of the talk

- Kidney shortage and kidney exchange:
 - Scandinavia
 - Europe
- The idea behind kidney exchange
- Scandiatransplant Kidney Exchange Program (STEP)
- European Network for Collaboration on Kidney Exchange Programmes (ENCKEP)
- Conclusions

Scientific background

- Kidney Exchange over the Blood Group Barrier (with J. Kratz), R&R *The Review of Economic Studies*, 2019
- Building Kindey Exchange Programmes in Europe - An Overview of Exchange Practice and Activities (with P. Biró, B. Haase-Kromwijk, et al.), *Transplantation*, forthcoming, 2019
- Kidney Practices in Europe: European Network for Collaboration on Kidney Exchange Programmes (with P. Biró, L. Burnapp, et al.), 2017.
- Modelling and Optimisation in European Kidney Exchange Programmes (with P. Biró, P. Chromy, et al.), 2019.

Great news in Finland

Snart blir det lagligt att donera sin ena njure till personer utanför de närmaste familjemedlemmarna – väntas lätta på dialyspatienternas situation

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2018 Statistics, Scandiatriansplant

	Denmark	Sweden	Norway	Finland	Iceland	Estonia	Scandiatriansplant
Population	5913146	10215309	5323933	5521533	355620	1319133	28648674
Transplant center			Oslo	Helsinki	Reykjavik	Tartu	
Actual deceased donors - DBD	100	181	104	117	10	34	546
Actual deceased donors - DCD	0	10	0	0	0	0	10
Utilized deceased donors - DBD	85	172	100	108	10	33	508
Utilized deceased donors - DCD	0	10	0	0	0	0	10
Total Utilized deceased donors	85	182	100	108	10	33	518
PMP	14,37	17,82	18,78	19,56	28,12	25,02	18,08
Deceased donor Kidney	159	304	168	206		54	891
PMP	26,89	29,76	31,56	37,31		40,94	31,10
Living donor Kidney	77	144	72	32	9	4	338
PMP	13,02	14,10	13,52	5,80	25,31	3,03	11,80
Total Kidney	236	448	240	238	9	58	1229
PMP	39,91	43,86	45,08	43,10	25,31	43,97	42,90
Deceased donor Liver	40	400	0	0	0	40	440

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Deceased donor Liver	49	169	84	66		40	375

Waiting list, January 1, 2019

	Denmark	Sweden	Norway	Finland	Estonia	Scandiatransplant
Kidney Active	405	409	341	365	31	1551
Kidney Inactive	149	257	133	131	8	678
Total	554	666	474	496	39	2229
Notifications	320	457	294	283	44	1398
Dead on WL	30	30	14	10	2	86
Permanet Withd.	44	54	35	25	7	165

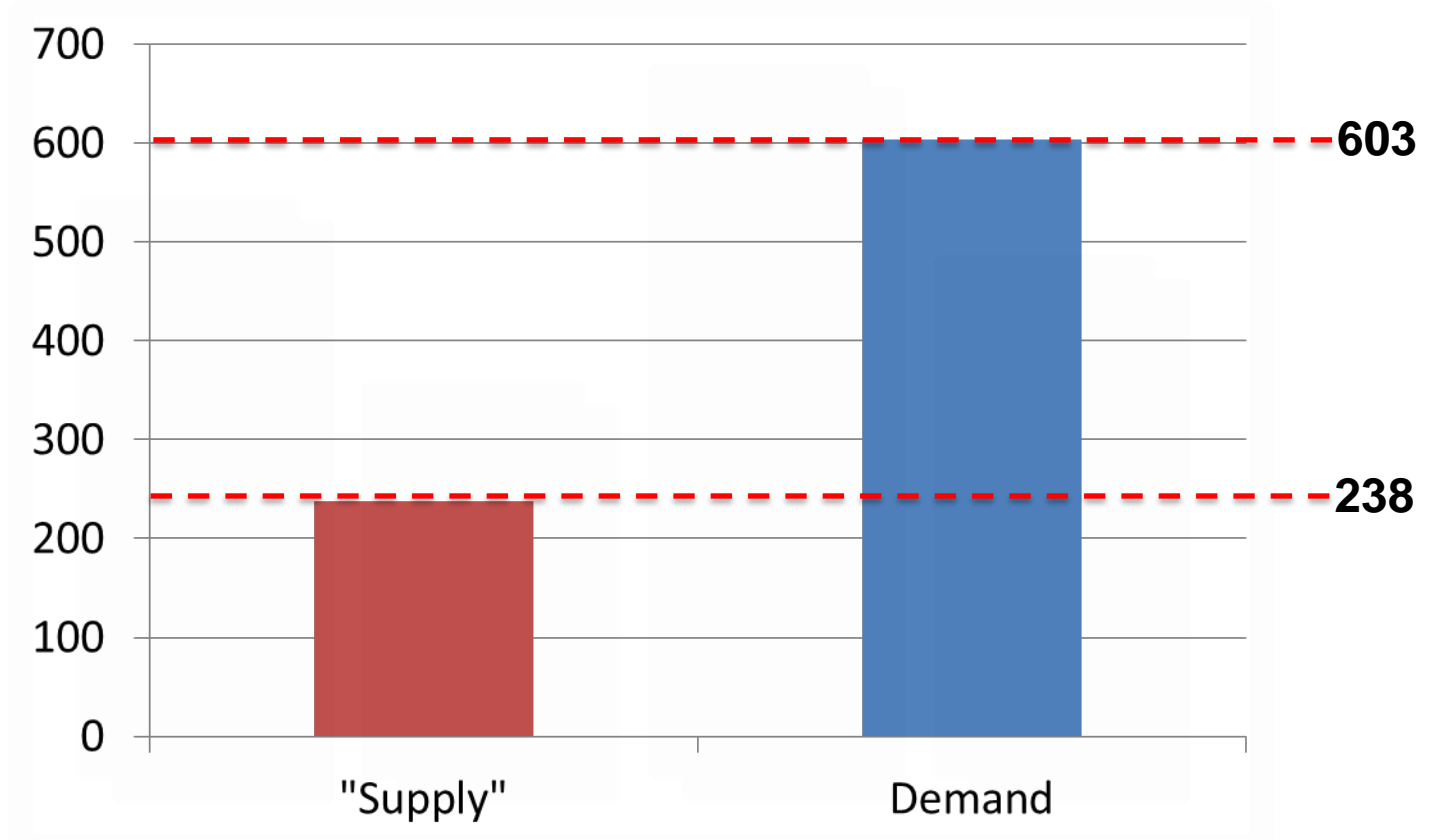
Waiting list, January 1, 2019

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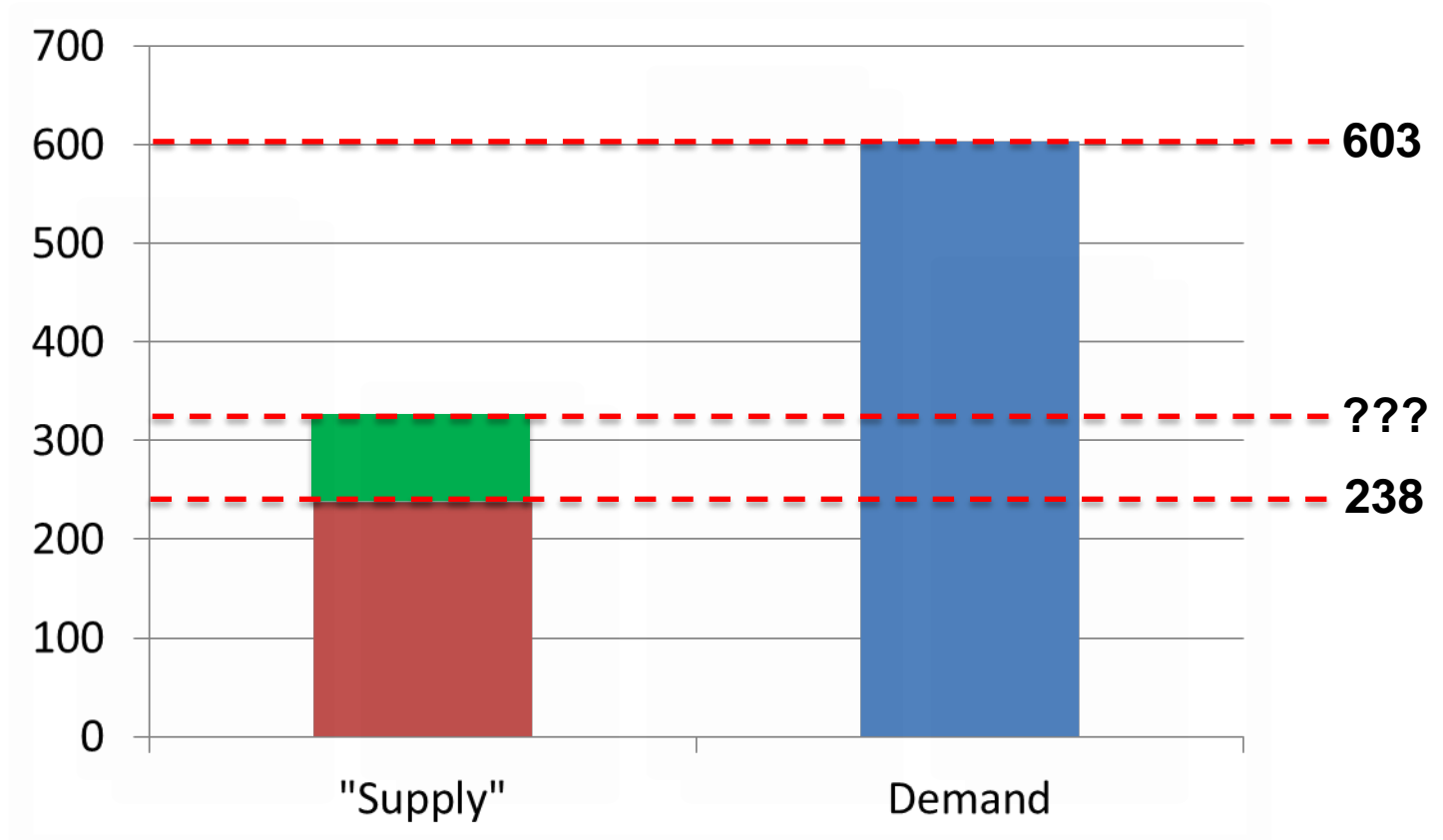
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"Supply" & Demand, Finland 2018



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Incompatibilities

- Blood group, tissue type, ...

Patient	Donor			
	O	A	B	AB
O	●			
A	●	●		
B	●		●	
AB	●	●	●	●

Increasing supply



Donor A



Patient A

Increasing supply

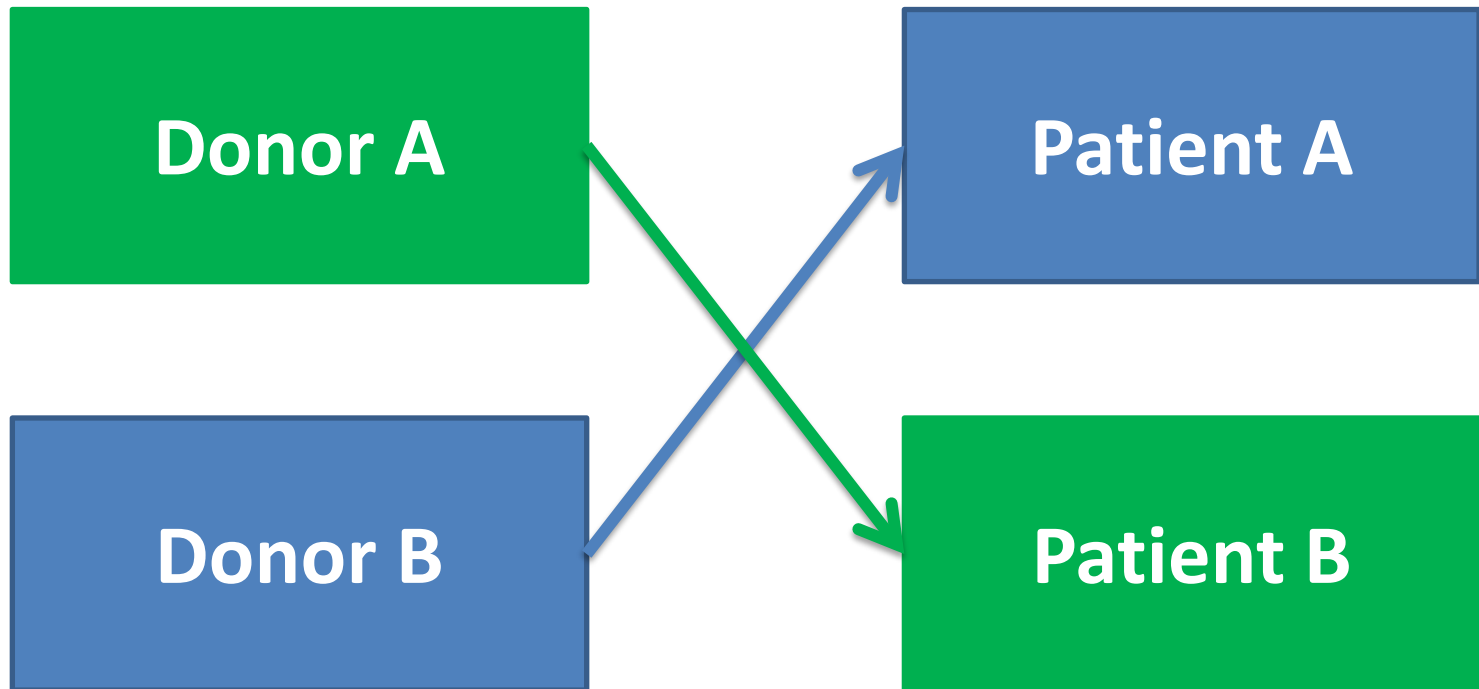
Donor A

Patient A

Donor B

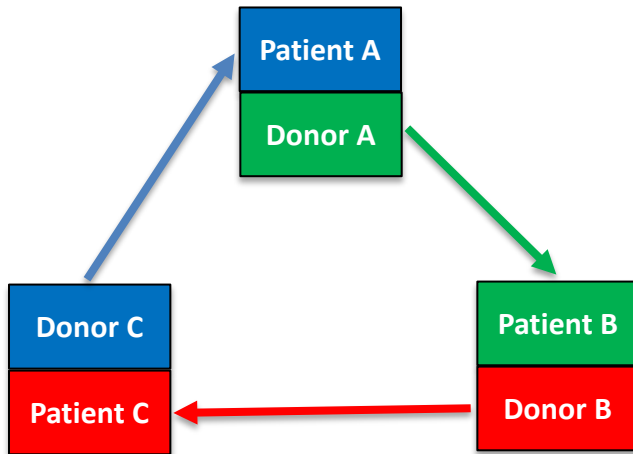
Patient B

Inreasing supply

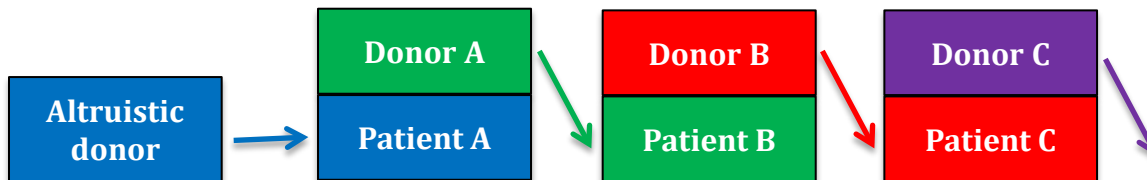


More advanced exchanges

Three-way exchange



Altruistic donor chain



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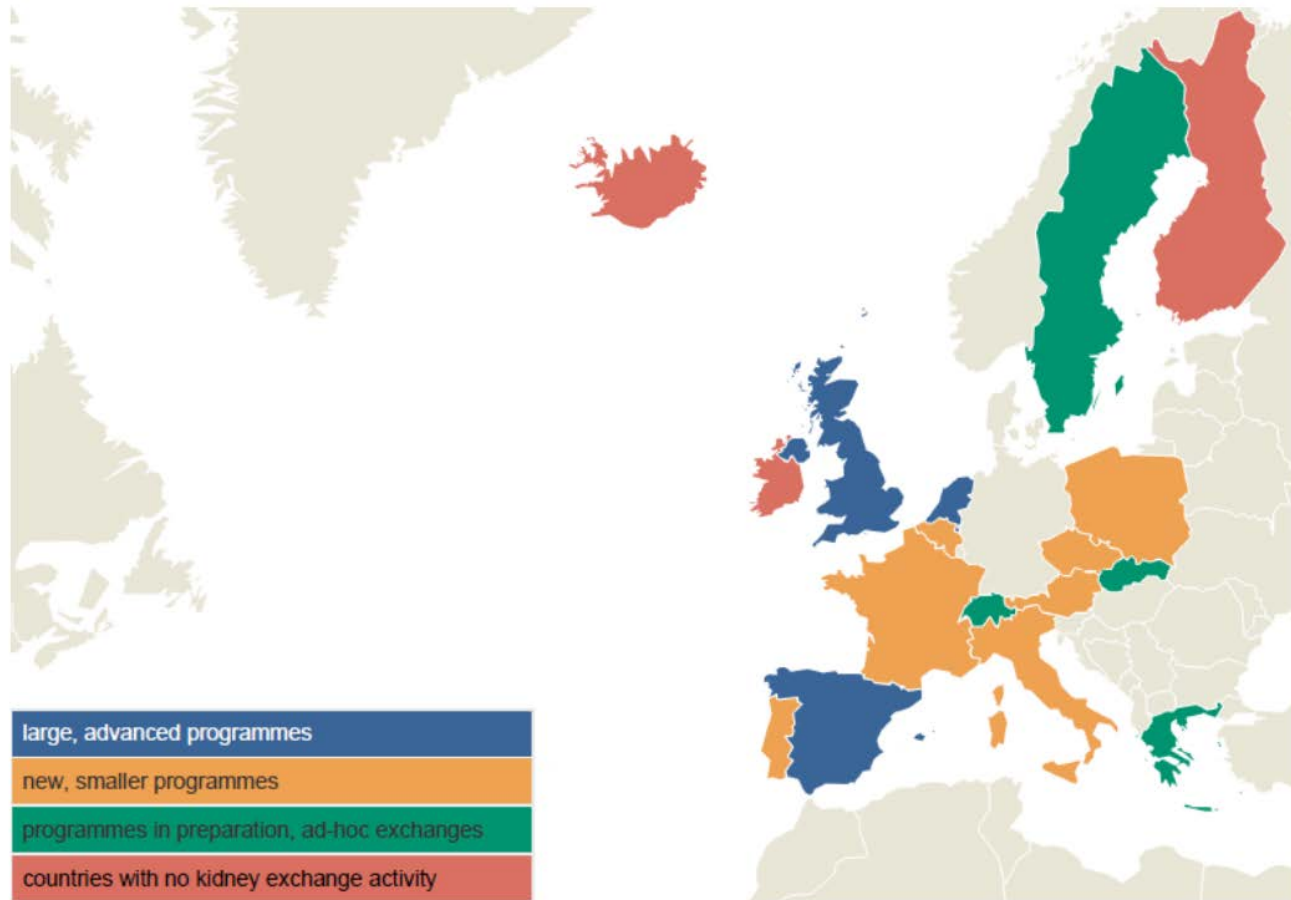
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Kidney Exchange in Europe

Figure 3: Development of KEPs by country (based on our questionnaire)



Kidney Exchange in Europe

Table 1: Summary table on system and society. The ten countries with operating KEPs at the time of writing are coloured with blue in the table.

	Austria	Belgium	Czech Republic	France	Italy	Netherlands	Poland	Portugal	Spain	UK	Greece	Slovakia	Sweden	Switzerland
Public funded health system?	✓	mix	✓	mix	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗
Incompatible transplants routine in the country?	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	ABOi Only
National KEP system?	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓	✗
First exchange in KEP: 20XX	13	14	11	14	07	04	15	13	09	07			18	
Can foreign couples be included?	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓				
Is anonymity a requirement for KEP? Legal (L) or by protocol (P)	P	P	L	L	L	P	✗	L	L	P		L	P	P
Altruistic donor chains possible?	✓	✗	✓	✗	✓	✓	✗	✓	✓	✓			✓	

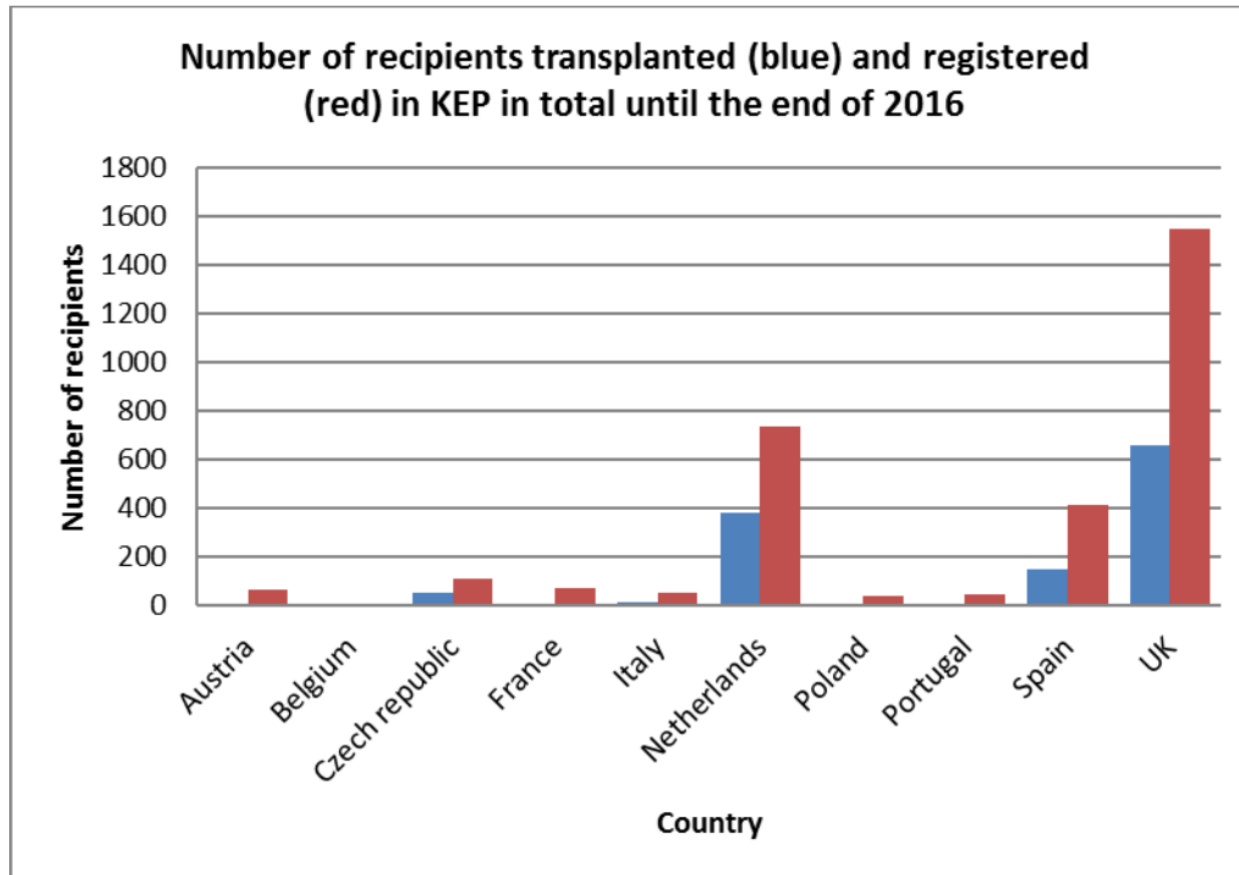
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National KEP system?	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓	✗
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Can foreign couples be included?	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓				
Is anonymity a requirement for KEP? Legal (L) or by protocol (P)	P	P	L	L	L	P	✗	L	L	P		L	P	P
Altruistic donor chains possible?	✓	✗	✓	✗	✓	✓	✗	✓	✓	✓			✓	

Kidney Exchange in Europe

Figure 5: KEP activity for all years until end of the most recent year for 10 countries



Kidney Exchange in Sweden

- The first step towards a KEP was taken in 2014 (informal conversations)
- A group containing transplant doctors, immunologists and a matching theorist was formed in 2014
- Immunological protocols, general rules and software was developed during 2015 and 2016
- STEP Sweden was launched in 2017

Practical procedure

- Data for each patient-donor pair is reported to **iSMART** (PRA, HLA, DSA, blood group, etc.)
- A *compatibility matrix* and a vector of *matching probabilities* are generated and exported to **STEPone**
- STEPone contains the matching algorithm

Compatibility matrix

- Compatibility matrix (K) where patients are stated in the rows and donors in the columns

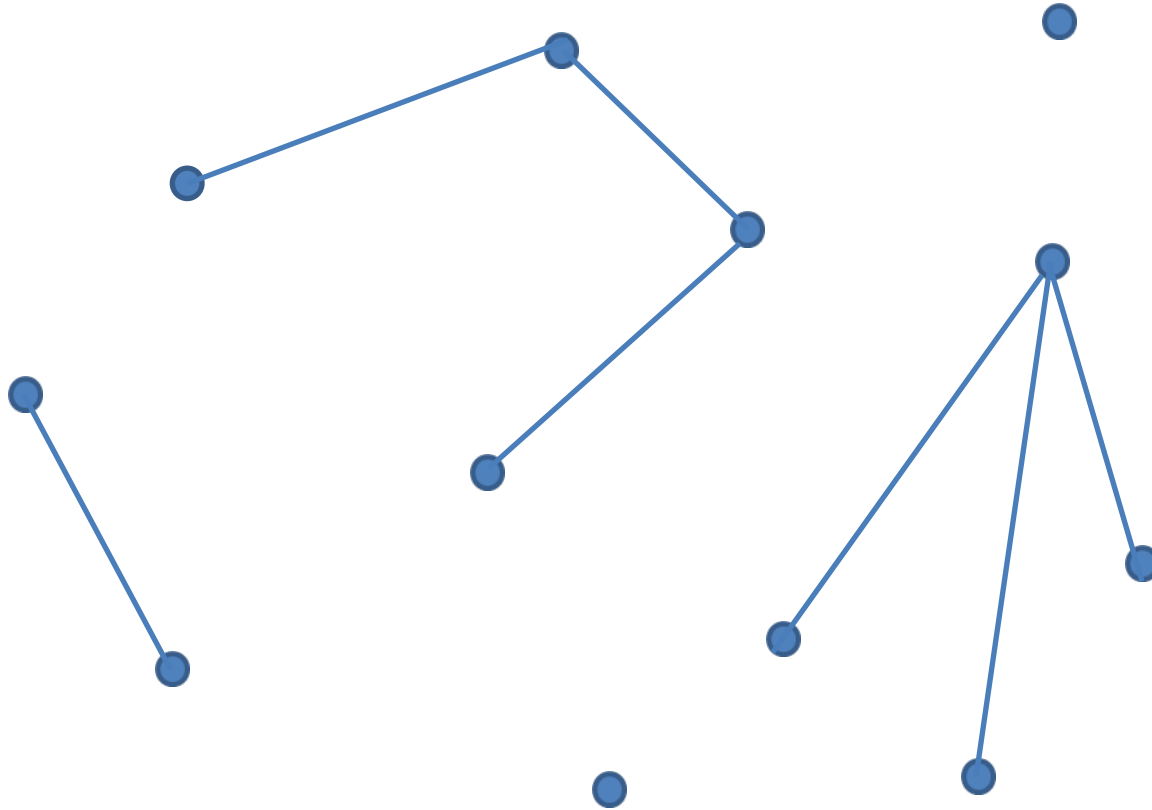
$$K = \begin{bmatrix} 0 & 1 & \dots & 1 & 0 \\ 0 & 0 & & 0 & 0 \\ & \vdots & \ddots & & \vdots \\ 1 & 0 & & 0 & 1 \\ 0 & 1 & \dots & 1 & 0 \end{bmatrix}$$

Compatibility matrix

- Compatibility matrix (K) where patients are stated in the rows and donors in the columns

$$K = \begin{bmatrix} 0 & 1 & \dots & \mathbf{1} & 0 \\ 0 & 0 & \dots & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ \mathbf{1} & 0 & \dots & 0 & \mathbf{1} \\ 0 & 1 & \dots & \mathbf{1} & 0 \end{bmatrix}$$

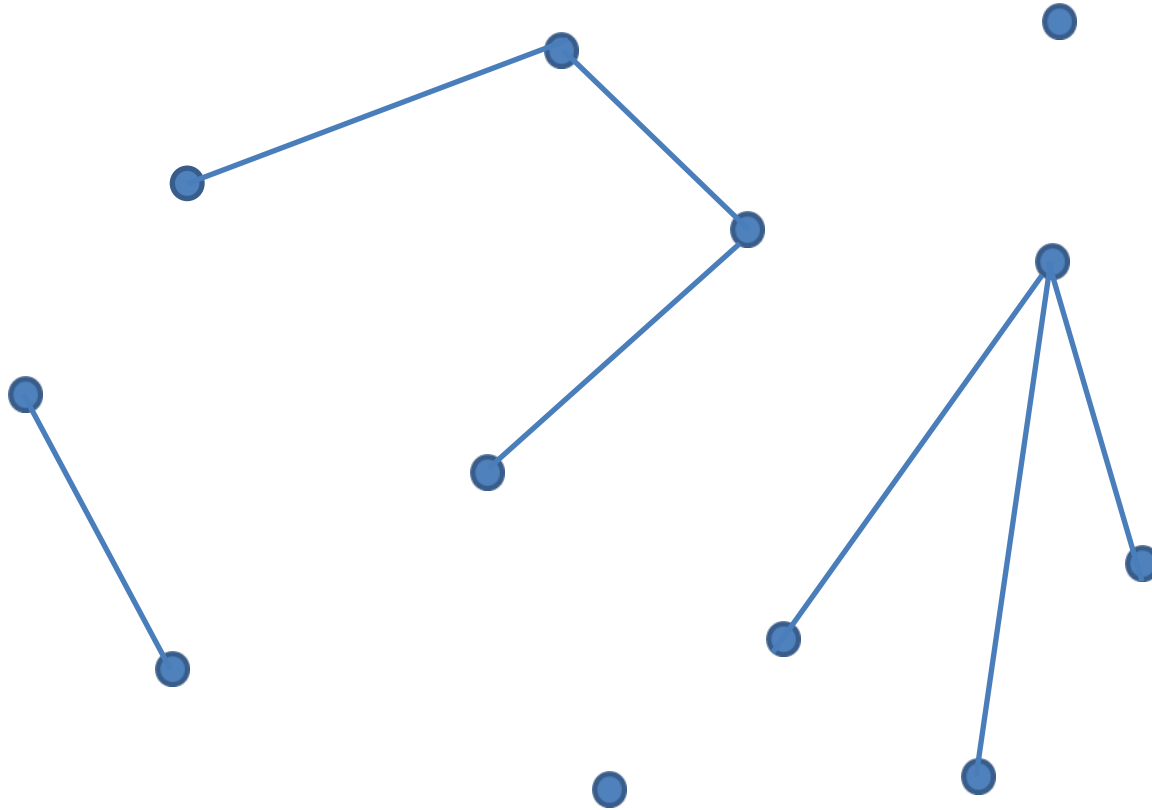
Associated graph



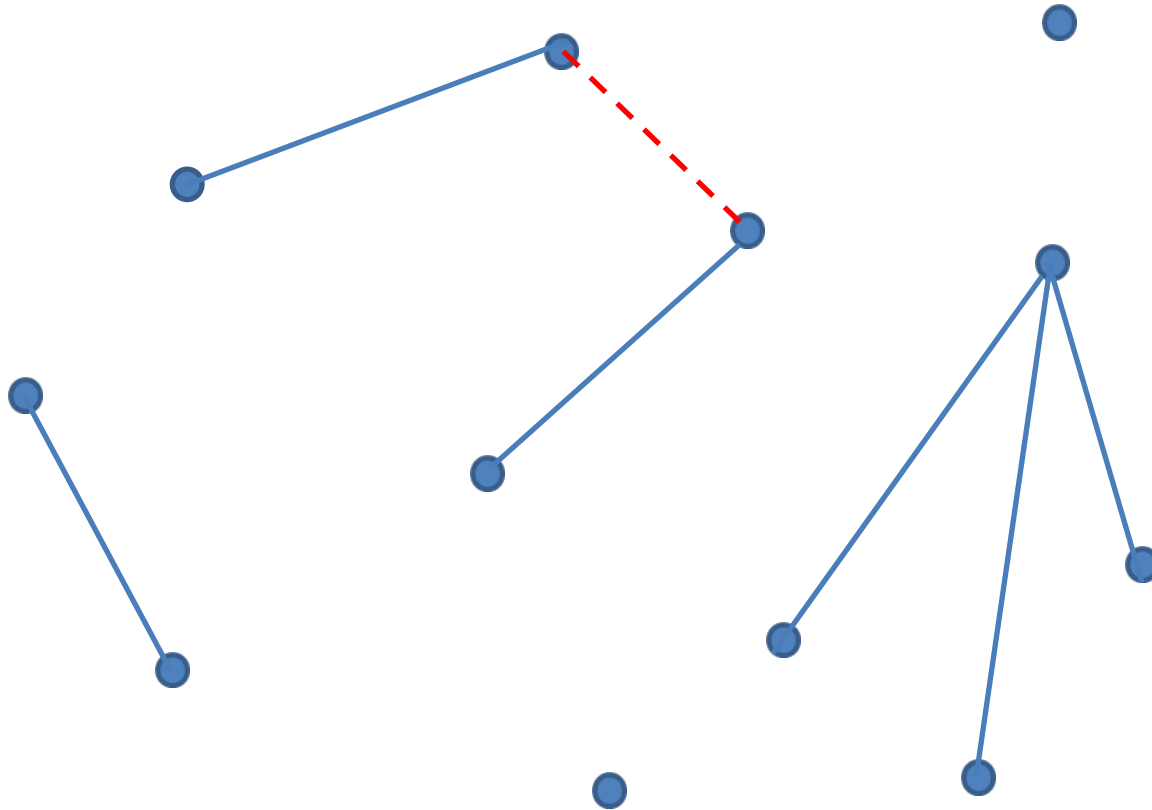
Goals of the matching algorithm

- The goals of STEP are (STEP programme 1.7):
 - The maximal number of transplanted patients
 - Low match probability
 - Compatible blood groups

Associated graph



Maximal cardinality



Matching probabilities

- Calculation of MP (Keizer et al., Transplantation Proceedings, 2005)
 - A donor pool consists of 25 donors, of which 13 donors have ABO blood group O. In this example the MP for 2 of 25 recipients are calculated.

EXAMPLE Recipient 1: ABO blood group O, HLA unacceptables: A1, DR1, and a %PRA of 57. Seven donors have either A1, DR1 or both; in theory this recipient can be matched to 6 of 13 donors.

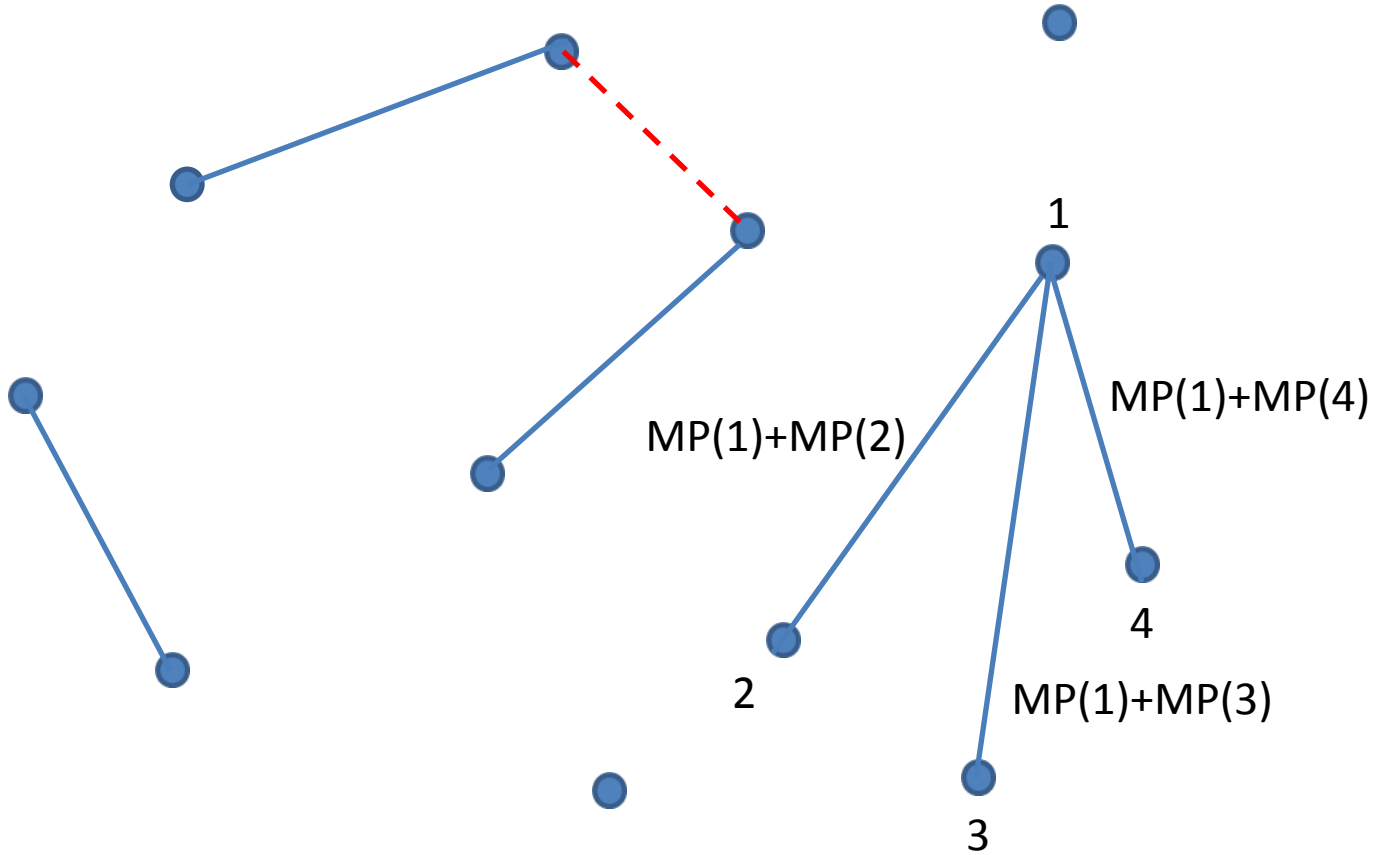
$$\begin{aligned}\text{MP recipient 1} &= (1 - \%PRA) \times (6 / 13) \\ &= (1 - 0.57) \times 0.46 \\ &= 0.2\end{aligned}$$

EXAMPLE Recipient 2: ABO blood group O, no HLA unacceptables, and a %PRA of 0.

$$\begin{aligned}\text{MP recipient 2} &= (1 - 0) \times (13 / 13) \\ &= 1.0\end{aligned}$$

- Additional “small” modification of matching probabilities are necessary to guarantee maximality of compatible blood groups

MP och priority



STEP – in Sweden

- STEP launched in 2017
- First transplant in 2018
- Problems:
 - Public awareness
 - Highly sensitised patients (85% with PRA>85%)
 - Competition from ABOi transplants (outside of KEP)
 - Backlog in registering patient-donor pairs
 - Small country

STEP – in Scandinavia

- NKG meeting in October 2016
- Decided that Norway and Denmark will join STEP
- February 2017: Andersson to ScandiTransplant HQ
- April 2017: STEP meeting in Copenhagen
- ScandiTransplant is currently working on the IT structure and the matching mechanism (in collaboration with Tommy Andersson)
- Sweden-Norway-Denmark from January 1, 2019
 - A larger pool cannot hurt the KEP
 - Iceland will likely join
 - Finland can join

ENCKEP

- European Network for Collaboration on Kidney Exchange Programmes
- Launched in late 2016
- All European KEPs are represented (mathematicians, transplant doctors, immunologists, coordinators, etc.)
- Idea: to exchange ideas, practices, experiences, software, mathematical techniques, etc.
- http://www.cost.eu/COST_Actions/ca/CA15210

Lessons from ENCKEP

- Increase public awareness
- Do not only include highly sensitised patients (include ABOi patients!)
- Before transplanting across the blood group barrier outside of the KEP, include the pair in the KEP to identify a pairwise exchange (this can mean two transplants instead of one!)
- Ask existing "problematic" pairs to be part of the KEP (this can mean two transplants instead of one)
- Include altruistic donors
- Better self confidence – believe in the KEP!

Conclusions

- Software as well as medical practices exist in Scandinavia today
- Progress in Scandinavia slow (but optimistic)
- It takes time (remember: only 5 transplants the first year in the US)
- No legal problem for Finland to join after the new legislation
- Problems:
 - Public awareness
 - Include only high PRA
 - Competition from ABOi transplants outside of KEP (solve by including ABOi patients in KEP)
 - Slow registration
 - Sweden was too small. Important that more countries join!

THANKS!

Website:

<https://sites.google.com/site/tommyanderssonlunduniversity/home>