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# Kidney Exchange in Scandinavia

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Lund University

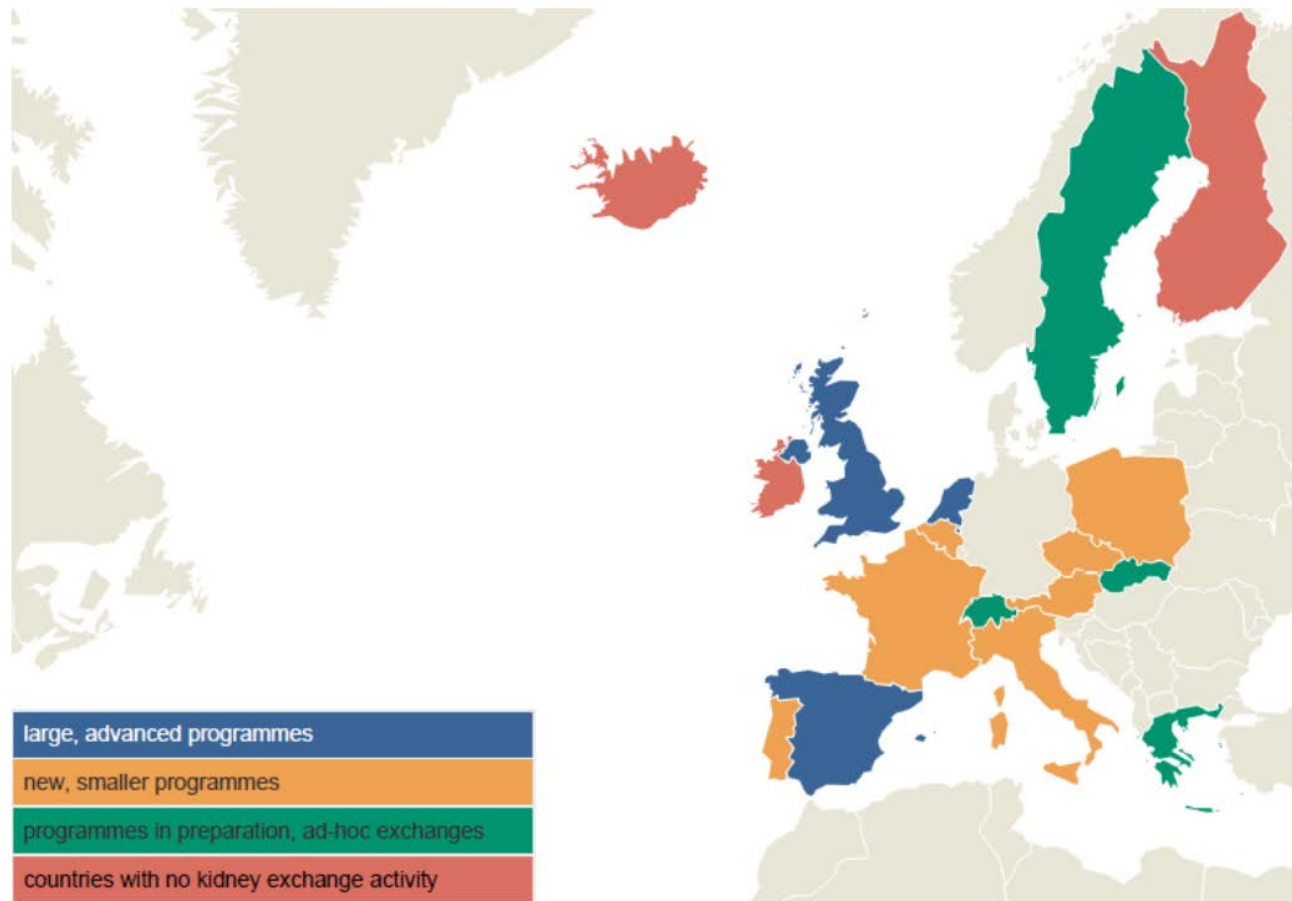


# Outline of the talk

- Kidney Exchange:
  - Europe
  - Ideas
  - Sweden
- Matching techniques and software
- STEP
  - Sweden
  - Scandinavia
- European Network for Collaboration on Kidney Exchange Programmes (ENCKEP)
- Conclusions

# 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				
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?	✓	✗	✓	✗	✓	✓	✗	✓	✓	✓				

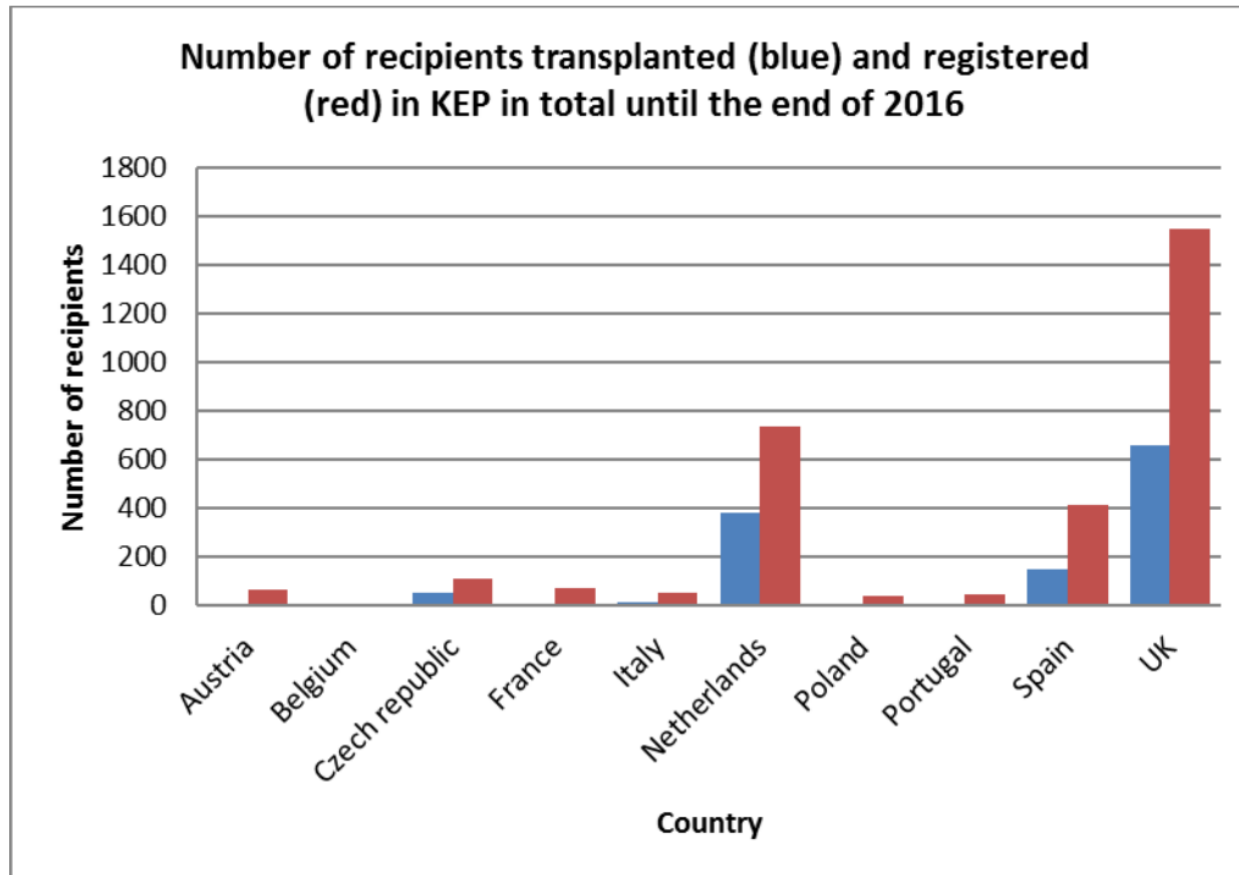
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Incompatible transplants routine in the country?	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✗	✓	ABOi Only
National KEP system?	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓	✗
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Altruistic donor chains possible?	✓	✗	✓	✗	✓	✓	✗	✓	✓	✓				

# Kidney Exchange in Europe

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



# Pairwise Exchanges



Donor A



Patient A

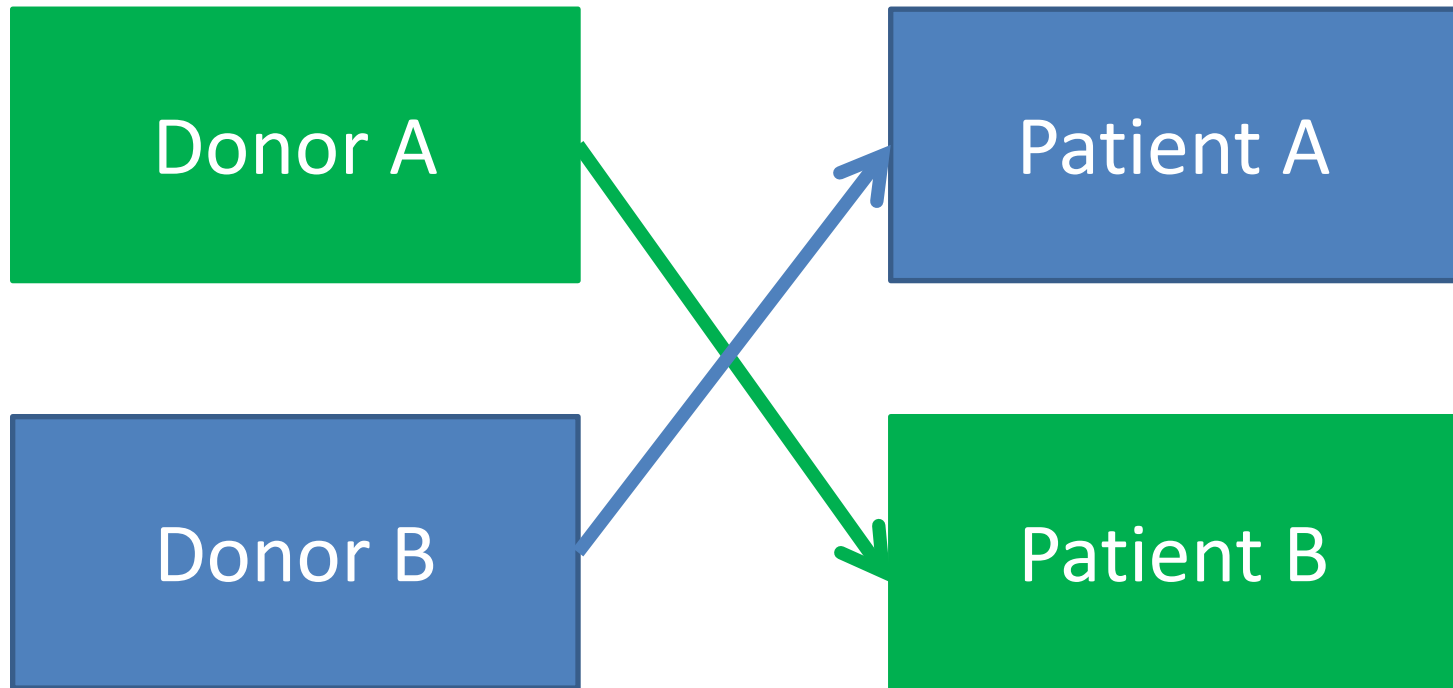


Donor B



Patient B

# Pairwise Exchanges





# More advanced exchanges

- A Kidney Exchange Program (KEP) may also include:
  - Larger cyclical trades (3-way and 4-way)
  - List exchanges with altruistic donors
  - Etc.
- Sweden: initially only pairwise exchanges (2-way)

# Kidney Exchange in Sweden

- The first step towards a KEP was taken in late 2013 (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 late 2016

# 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 (September 18)

iSMaRT

Arkiv Avliden donator Njurrecipient Levande njurdonator Administration

Information STEP körning

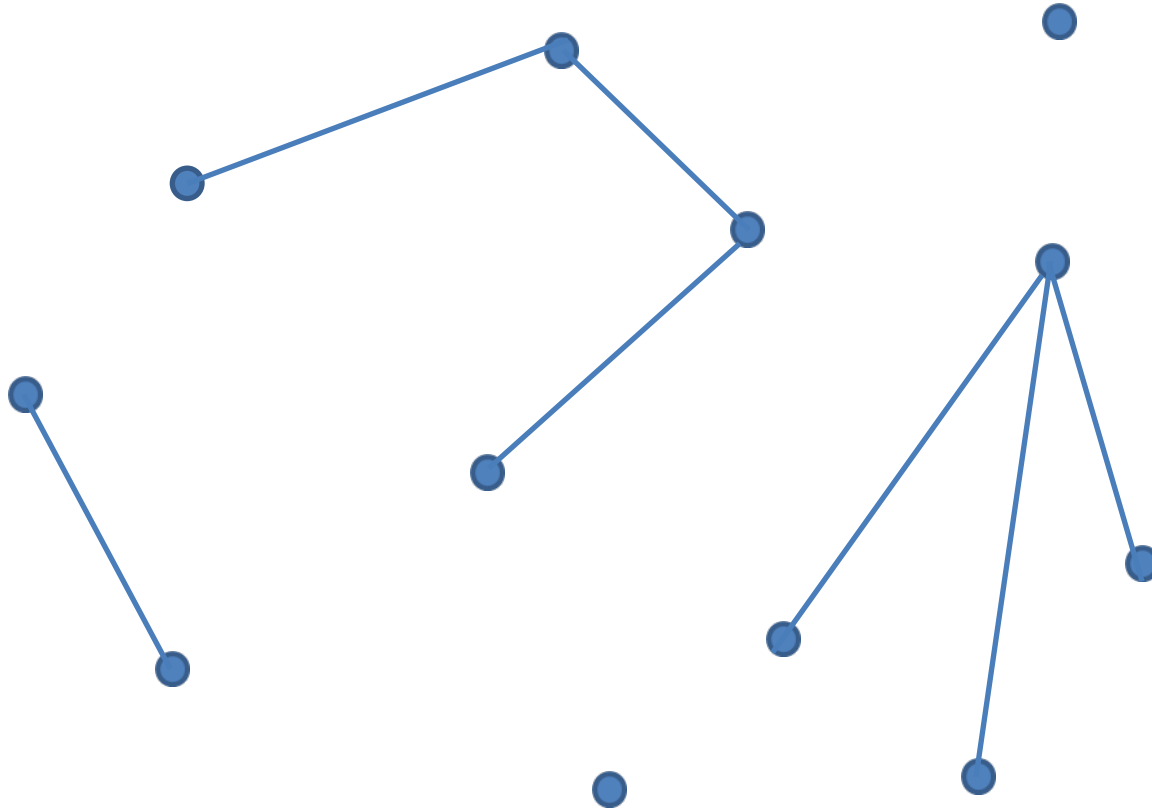
don	rec							
	MP	0.0		0.0			0.0	0.112
		6	2000	2	4	5	6	0
		2002	2000	2002	2000	2001	2002	2000
		5	2001	6	4	4	6	1
		6	2001	6	4	5	6	1
		6	2001	6	4	5	6	1
		6	2000	6	4	5	6	0
		4	2000	4	4	4	4	0
		4	2000	4	4	4	4	4

# 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

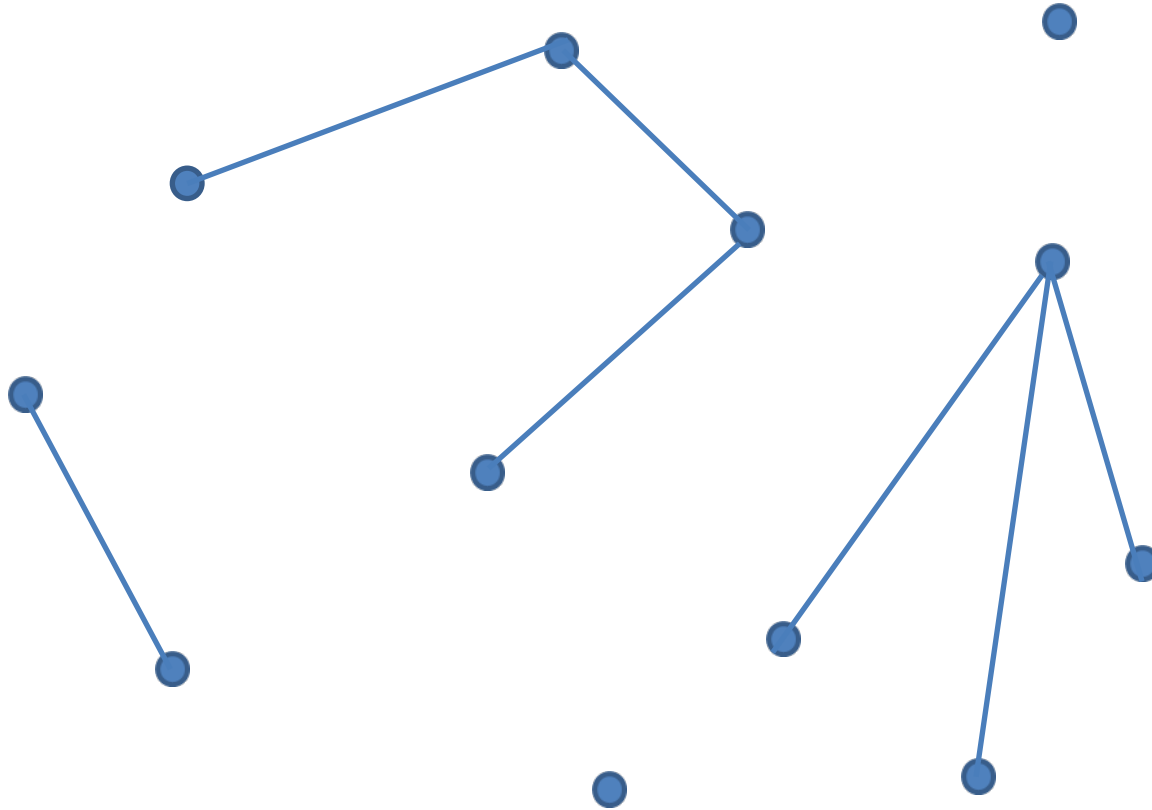


# Goals of the matching algorithm

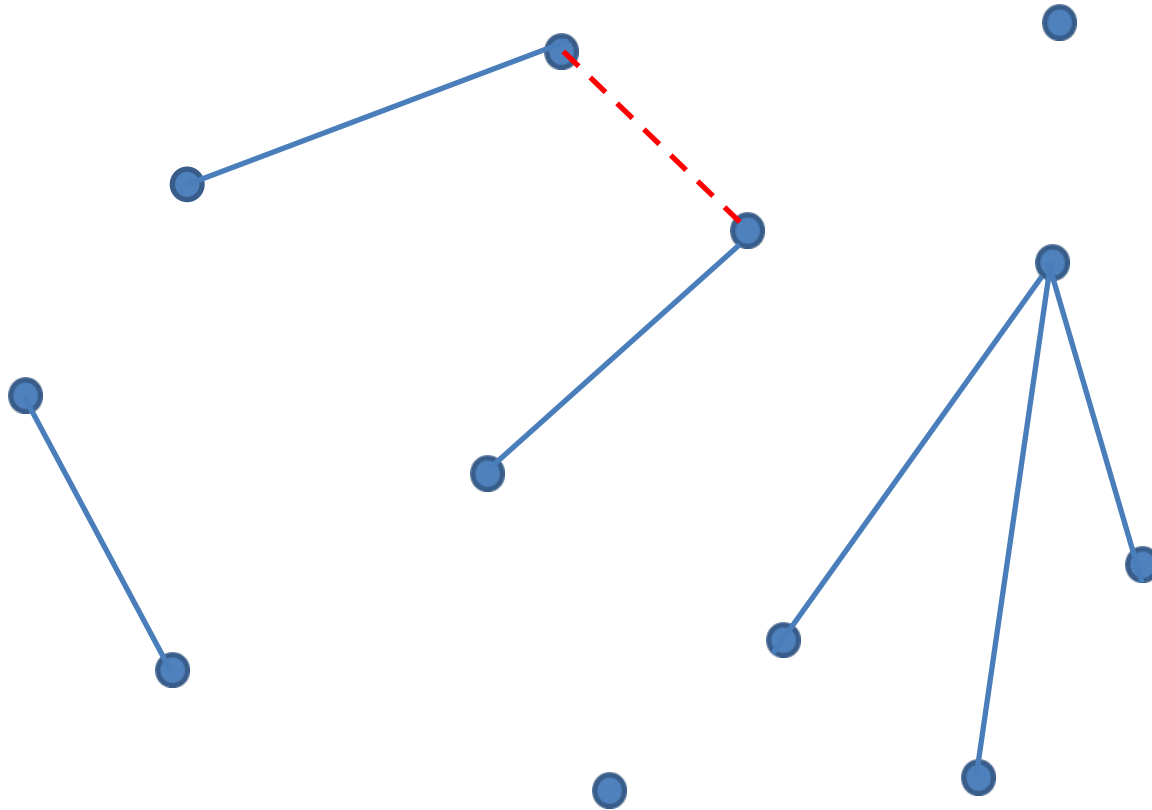
- The goals of STEP are (STEP programme 1.7):
  - The maximal number of transplanted patients
  - Low match probability
  - Compatible blood groups



# 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.

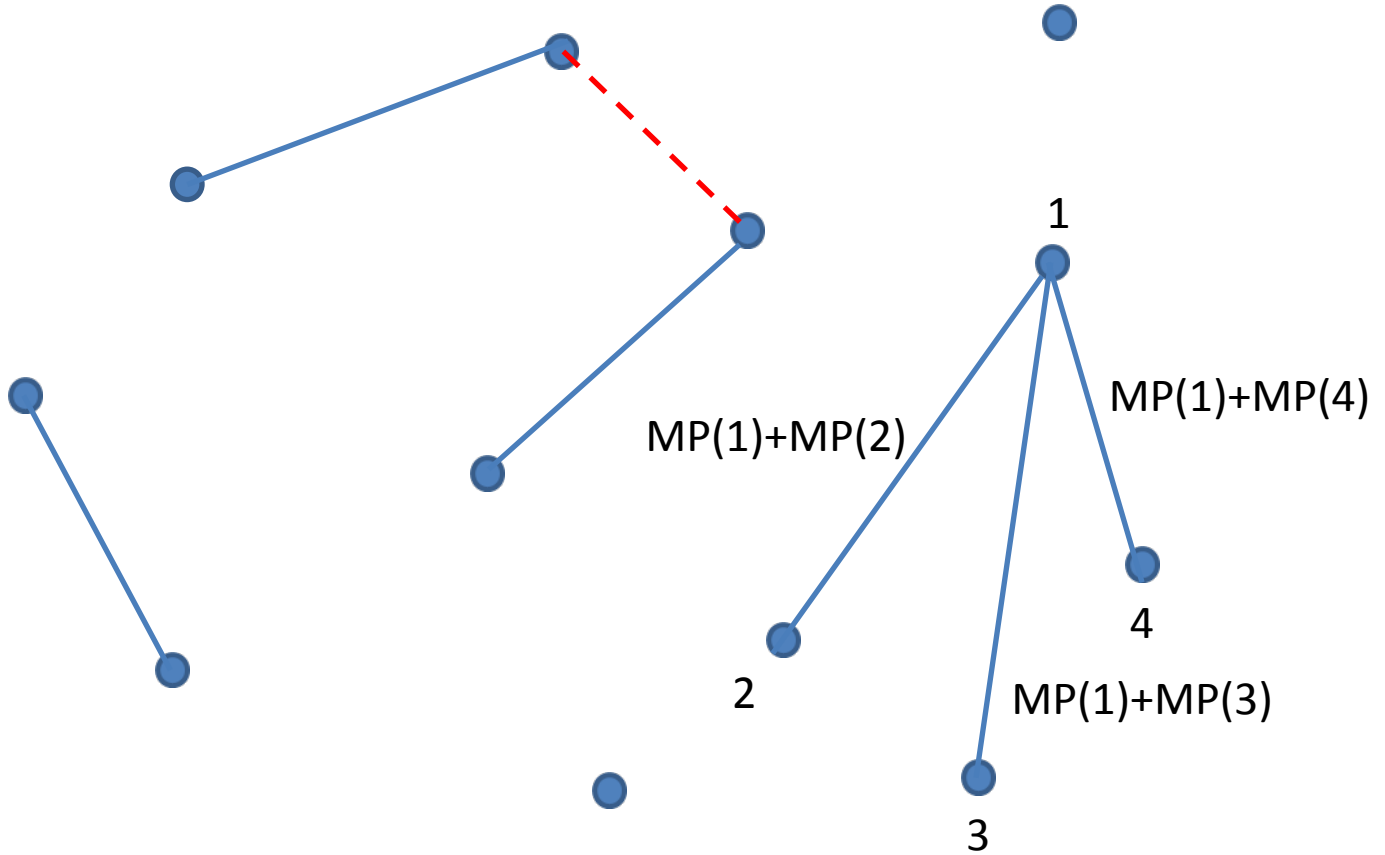
$$\begin{aligned} \text{MP recipient 1} &= (1 - \%PRA) \times (6 / 13) \\ &= (1 - 0.57) \times 0.46 \\ &= 0.2 \end{aligned}$$

**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



# iSMART

- iSMART: national software for registering pairs (medical data, medical history, etc.)
- Web interface, secure servers, etc.
- Developed by Ragnar Källen (Skånes universitetssjukhus)
- NOTE: Scandiatransplat is currently developing their own corresponding software

# iSMART

**iSMART**  
Arkiv Avliden donator Njurrecipient Levande njurdonator Administration version 2.27 036

Information 59:40

## wTx Systems

Web Start App

Java runtime version: 1.8.0 update 71 build 15

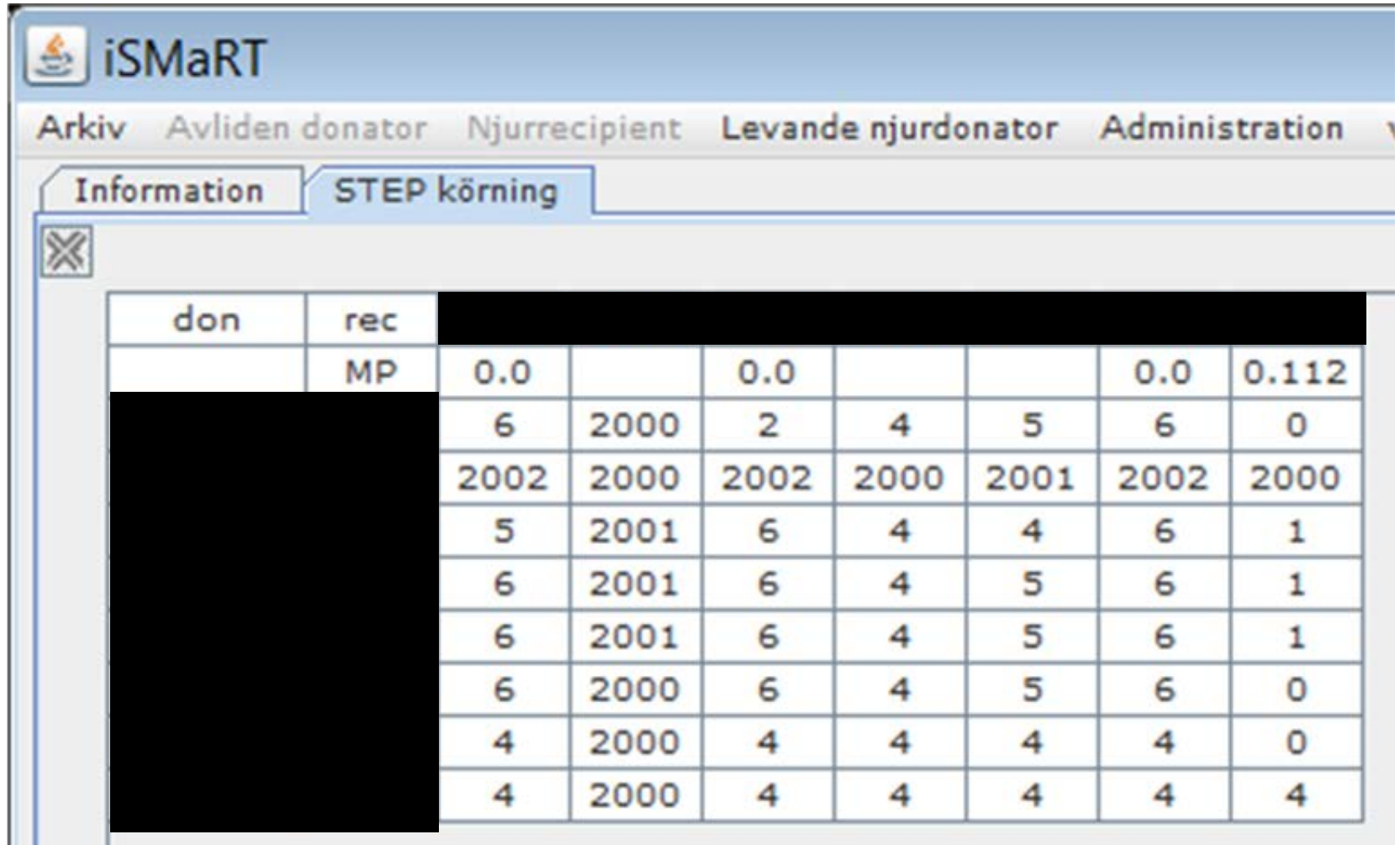
Ansluten till RC Syd | Inloggad som Tommy Andersson | wTxSystems AB Org.nr: 556935-1645

**Datornamn:** W318013  
**Domän:** VGREGION  
**IP-adress:** 10.39.12.67  
**Klassificering:** Standard | Standard  
**Operativsystem:** Windows 7  
**VGR-ID:** toman28  
**Senaste omstart:** 2017-02-06 12:58

**VGR IT Support**  
**Telefonnummer:** 010 - 47 37 100  
**Webb:** <http://intra.vgregion.se/it>

13:01  
2017-03-26

# iSMART



The screenshot shows the iSMART software interface. At the top, there is a menu bar with options: Arkiv, Avliden donator, Njurrecipient, Levande njurdonator, and Administration. Below the menu bar, there are two tabs: 'Information' and 'STEP körning', with 'STEP körning' being the active tab. A window titled 'STEP körning' is open, displaying a table with columns for donor (don) and recipient (rec) information, and a grid of numerical data. The table has 9 columns and 9 rows. The first two columns are labeled 'don' and 'rec'. The first row of data shows '0.0' in the 'don' column and 'MP' in the 'rec' column. The remaining rows contain numerical values, with some cells in the first two columns obscured by a black redaction box.

don	rec							
	MP	0.0		0.0			0.0	0.112
		6	2000	2	4	5	6	0
		2002	2000	2002	2000	2001	2002	2000
		5	2001	6	4	4	6	1
		6	2001	6	4	5	6	1
		6	2001	6	4	5	6	1
		6	2000	6	4	5	6	0
		4	2000	4	4	4	4	0
		4	2000	4	4	4	4	4

# STEPone

- Matching algorithm
- In-house implementation in MatLab by Tommy Andersson
- Scandiatransplant has received all code and documentation (February 2017)
- Scandiatransplant will migrate the code to JAVA
- The mathematics behind the algorithm can be found at: [https://ideas.repec.org/p/hhs/lunewp/2016\\_011.html](https://ideas.repec.org/p/hhs/lunewp/2016_011.html)



# STEP – in Sweden

- STEP launched in late 2016 → no transplants yet
- Currently 7 pairs enrolled in the KEP (8 donors)
- Problems:
  - Public awareness
  - Highly sensitised patients (85% with PRA>85%)
  - Competition from ABOi transplants (outside of KEP)
  - Backlog in registering in iSMART?
  - Small country

# STEP – in Scandinavia

- NKG meeting in October 2016
- Norway and Denmark will join STEP
- February 2017: Andersson to Scandiatriplant HQ
- April 2017: STEP meeting in Copenhagen
- Scandiatriplant is currently working on the IT structure (in collaboration with Tommy Andersson)
- Hopefully: Sweden-Norway-Denmark in 2017/2018
  - A larger pool cannot hurt the KEP

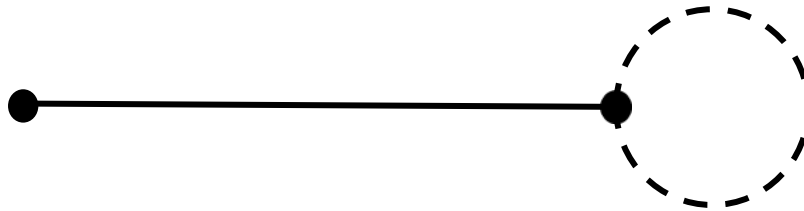
# ENCKEP

- 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](http://www.cost.eu/COST_Actions/ca/CA15210)

# Lessons from ENCKEP

- Increase public awareness
- Do not only include highly sensitised 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!
- Expand the KEP to Denmark and Norway (remember Netherlands)

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- Include altruistic donors
- Expand the KEP to Denmark and Norway (remember Netherlands)

# Conclusions

- Software as well as medical practices exist today
- Progress in Sweden slow (but still optimistic)
- Scandinavian KEP in 2017/2018
- Problems:
  - Public awareness
  - Include only high PRA
  - Competition from ABOi transplants (outside of KEP)
  - Slow registration
  - Small country

# THANKS!

Website:

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