Aims: The aim in kidney paired-donation (KPD) is typically to maximize the utility (score) achieved via cycles among incompatible donor-candidate pairs, as well as chains originating from non-directed donors (NDD) [1]. With many possible overlapping options in a KPD pool, a preferable choice of cycles and chains realistically cannot be found by simple inspection. In practice, objective criteria are used to define near-optimal solutions. With the increasing complexity of the criteria used, solutions can be difficult to compare or visualize.

Features: Interactive visual display of the state of the KPD, including active and inactive pairs/NDDs, as well as donor & candidate characteristics. Implementation of optimization methods from previous literature [2,3] that account for probabilities of failure between selection and transplantation (which we refer here as ‘friction’), for each pair and match, as well as fallback options (sub-cycles and sub-chains) for immediate recourse in the case of such failures. Optimization is extended beyond the selection of simple cycles or chains, to more general subsets of pairs and NDDs that facilitate fallback options in case of friction.

Interface: Main screen display of a simple synthetic KPD consisting of 6 incompatible donor-candidate pairs (in red) and 1 NDD (in blue), and the matches found within.

Figure 1: Main screen display of a simple synthetic KPD consisting of 6 incompatible donor-candidate pairs (in red) and 1 NDD (in blue), and the matches found within.

Optimization Schemes (see [2]):
- Utility – Cycles/chains, highest total utility
- Expected Utility – Cycles/chains, highest total expected utility, taking account of friction
- Fallbacks – Cycles/chains, highest total expected utility, taking account of friction, as well as possible immediate fallback options
- Extended Fallbacks – Subsets of pairs/NDDs, highest total expected utility, taking account of friction and fallback options
- Note that Extended Fallbacks are the preferred option for optimization, offering increases in realized utility in simulation.

Figure 2: User options available for selection of optimal exchanges in KPD

- Shading indicates degree of sensitization, i.e. panel reactive antibody (PRA)
- KPD pools can be saved (encrypted) in their current state. Loading a saved KPD pool will restore all previously found solutions.
- Subsets of pairs can be hidden in the visualization, e.g. if they are to be left out of selection, or have no compatibilities.
- Pairs can be sorted by ID, appearances in cycles/chains or solutions, number of compatibilities, compatible donors or compatible recipients, or by PRA. Matches can be sorted by donor or candidate ID, or by appearances in cycles/chains or solutions.

Figure 3: Illustration of a Fallback solution separated from the rest of a synthetic KPD pool, consisting of two three-way exchanges ((7, 74, 48) & (27, 60, 73)) with embedded fallback options ((7, 74), (48, 74), & (60, 73)), as well as a single donation chain (66-75), highlighted in purple.

FUTURE DIRECTIONS

- **Graft Survival/Compatible Pairs:**
  - Currently, graft survival calculations are implemented as a utility option for optimization.
  - Can be used to support decision-making of compatible pairs considering participation in KPD (i.e. any match involving a candidate with an already compatible donor should yield an estimated survival benefit) [5].

- **Deceased Donors:**
  - Can be considered as NDDs for KPD [6]; involves the incorporation of the deceased donor waiting list to complete the chain.

- **Multiple Associated Incompatible Donors:**
  - Candidates entering KPD with several incompatible donors can be included as separate pairs in KPD; introduces various constraints not handled currently.
  - Extensions will incorporate these multiple donor pairings and the additional fallback options they allow.

- **Competing KPD Programs:**
  - There are many KPD programs in the US, some single and some multi-center, each seeking to optimize their own transplant decisions [7].
  - By incorporating this environmental aspect, we can compare outcomes from frequent decisions in the individual programs, to what could be achieved with larger pools.
  - Insights may improve coordination of decisions to the advantage of patients and the overall health system.

- **Technical Aspects:**
  - Improved uploading capabilities, efficient algorithms for graph searching and subset enumeration (allowing for larger fallback subsets; size is currently restricted due to computational complexity), and further customization and interactivity.