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To: Ken Andreoni; Peter Stock; Timothy Pruett; Walter Graham
From: Alvin Roth, Utku Unver
CC: Darrel Thomas, Deanna Rogers, Dale Platner, Gwen Brown, Mary Ellison, Janet Smith, Karl McCleary
Re: Notes and recommendations following UNOS RFI meeting on National kidney paired donation, February 4, 2008.

A central issue raised in the first four presentations (by Roth/Unver, NEPKE, APD, Sandholm) was that UNOS policies may have a big effect on how widely and how fully patients and transplant centers participate in nationwide paired donation. This was echoed by Segev, who spoke of the importance of minimizing transportation to maximize participation by both patients and transplant centers.¹ It was also a concern of Leichtman, who spoke of his center's preference for being able to do exchanges with trusted counterparts with whom they have a long relationship.

All the presentations that use optimization (Roth/Unver with NEPKE and APD, Sandholm with APD, Segev/Gentry with Hopkins) agreed on the need to include both 2- and 3-way exchanges and NDD chains, and variations on these. Leichtman also advocated 2 and 3-way exchange, and Hil advocated NDD chains.) The flexibility called for can be accomplished without making the system complex for new users: e.g. there could be a simple set of default options, together with an "advanced features" set of choices that might initially be of interest to centers with experience in paired donation.

There are some policy questions around which disagreement remains, e.g. Rees spoke eloquently about why quality may sometimes be more important than quantity. There also appear to be unresolved policy questions on how stringent the virtual crossmatching should be, and how this interacts with the fact that some centers are prepared to do at least some desensitization. (The reliability of virtual crossmatching is likely to become increasingly important as the pool of pairs becomes larger, as will be the speed with which actual crossmatching can be accomplished following a match run.)

Many policy and IT issues can be resolved independently of the choice of optimization algorithm. The Abraham, Blum, Sandholm-CMU algorithm would be able to handle each of the issues that was raised, at national scale, which distinguishes it from the other

¹ He indicated that in his experience many patients and donors would be reluctant to participate in an exchange that required travel, and said something to the effect of 'if I know that the algorithm doesn't care if my patients remain at my center, then I won't send patients.'

flexible integer programming algorithms discussed (by Roth/Unver and Segev/Gentry, that use the commercial program CPLEX as their primary IP solver). The ABS-CMU software would also allow computational experiments to be done with even larger datasets than might be needed to run the exchanges, such as the whole pool from some number of years. The ability to run such experiments will be invaluable in evaluating, maintaining and modifying the clearinghouse in years to come.

In closing, let us emphasize three points.

1. We are persuaded that the ABS-CMU algorithm is a good one to power a national paired donation clearinghouse. While the Roth/Sonmez/Unver software that presently does the optimization for NEPKE and the APD is very adequate for current needs, (and the same is likely true of the Segev/Gentry software) it makes sense to have a purpose-built integer program solver, built and maintained by expert computer scientists.² Our colleagues at NEPKE and APD, who both have experience with systems that use CPLEX as a primary solver, concur.
2. Some of the policy issues that UNOS should consider will have an impact on participation by transplant centers. I recommend that
 - a. National paired donation should be flexible enough to allow existing paired donation programs to serve through the national clearinghouse the kinds of patients they currently serve.
 - b. Adequate time should be taken to assess these needs, and thought should be given to evaluating multiple proposals along the lines suggested by Mike Rees.
 - c. Consideration should be given to giving high priority to patient-donor pairs contributed to the pool by a single hospital that could have transplanted them internally (i.e. the clearinghouse should adopt policies that encourage hospitals to involve all their paired donation candidates in the national pool).
3. Some UNOS policy decisions, and how they can best be implemented, will require study. UNOS may therefore need to develop the capability to conduct such studies, or collaborate with those who can help it to conduct such studies. In addition, any clearinghouse needs to be monitored for performance issues so that it can be maintained and improved over time. Harvard is prepared to help in this ongoing effort, and has authorized the formation of a *Harvard Program on Paired Donation*. We already collaborate closely with NEPKE, APD, and CMU, and are eager to collaborate with UNOS and others involved in this effort.

² All three optimization systems presented (ABS-CMU, RSU, and SG) are similar in that they use cycle-weighted integer programming of the sort formulated in 2005 in

Roth, Alvin E., Tayfun Sonmez, and M. Utku Unver, "[Efficient Kidney Exchange: Coincidence of Wants in Markets with Compatibility-Based Preferences](#)," (May, 2005. NBER Paper w11402), *American Economic Review*, 97, 3, June 2007, 828-851.

But our original software relies on the commercial CPLEX integer program solver (as does SG), and the ABS solver avoids the CPLEX limitations (while still calling CPLEX for some operations). We will send a separate report with the detailed description of our software.