Expanding the donor pool: The use of marginal organs for transplantation

Transplantation is the preferred mode of treatment for thousands of patients with organ failure. In the United States, the number of organ transplants since the year 2000 has exceeded half a million, increasing at an annual rate of 3% (OPTN 2018). On the other hand, every 10 minutes, a new candidate is added to the transplant waiting list, resulting in 15 patient deaths every day while waiting for a transplant. There are close to 115,000 candidates currently waiting for an organ transplant in the U.S.

Despite the growing need for donor organs, those harvested for transplantation are frequently rejected by patients and discarded in large volumes. In 2016, more than 14% of all organs recovered for transplantation are discarded, with highest rates for kidney (20%) and pancreas (24%). Reasons for high discard rates include inefficiencies in the organ allocation systems that expend the window of viability of organs before finding willing recipients (Massie et al. 2009) and behavioral attitudes of patients/physicians (e.g., concerns over using high risk organs) (Schold et al. 2009). In 2016, almost 40% of discarded kidneys were due to not locating any recipient after exhausting the entire waiting list (Israni et al. 2018).

Increasing pressures towards meeting the growing waiting list demand recently promoted the idea of using, instead of discarding, organs that are less than optimal for transplantation. Although there is no consensus on the definition, the lower part of the organ quality spectrum is mostly regarded as marginal organs. Marginal organs, albeit having worse outcomes than standard organs, are shown to be viable alternatives for patients dying while waiting for a transplant (Busuttil and Tanaka 2003). Massie et al. (2014) report that older patients and patients in centers with high median time to transplant benefit the most
from accepting a marginal kidney instead of waiting for a better kidney. Ojo et al. (2001) report that recipients of marginal kidneys have a substantial reduction in mortality and improvement in life expectancy compared to dialysis patients in the waiting list.

Our goal in this paper is to gain insights into the utilization of marginal organs and to investigate whether or not the expansion of the donor pool can be achieved by encouraging an increased utilization of marginal organs among self-interested patients. For this purpose, we develop a multiclass queueing model with reneging and delayed feedback. In particular, we allow heterogeneity in the types of candidates and in the quality of organs. Candidate types can be formed, for example, around age groups, geographies (e.g., candidates from the same region), medical conditions (e.g., MELD scores in liver, time on dialysis in kidney), or comorbidities (e.g., diabetic candidates). We use quality-adjusted life expectancy (QALE) to measure candidates’ utility from transplantation. We define the social welfare function as the difference between the total QALE obtained from transplantation and the social costs associated with transplantation caused by the heterogeneity in organ qualities.

We first identify the socially efficient utilization of organs that maximize social welfare. Social welfare maximizing decisions may not coincide with the decisions of self-interested individuals who optimize their own well-being while competing with other candidates; so, we next characterize their equilibrium behavior, and prove that a unique equilibrium exists. We identify that candidates set their utilization level more conservatively in equilibrium than the socially efficient level. This finding offers an explanation to the low utilization of marginal organs observed in current practice.

The gap between the socially efficient and the equilibrium decisions results from a lack of appropriate incentive mechanisms for candidates to accept lower quality organs for the common good. To help reduce this gap, we offer incentives through candidates returning to
the waiting list for re-transplantation—a significant aspect of the organ transplant systems that has not received much attention in the operations literature. A transplant recipient in practice can outlive the life of the graft she has received, in which case the patient returns back to the waiting list for a new transplant opportunity. Re-transplant candidates compose more than 11% of the current US waiting list (OPTN 2018). Increasing the use of marginal organs results in more returning candidates, and therefore, intensifies the competition for the limited set of organs, while at the same time it softens the competition by increasing the pool of available organs. We incorporate returning candidates into our queueing model, analyze the resulting tradeoff and its impact on equilibrium outcomes, and exploit the return events to offer two remedies to reduce the observed gap.

In our first remedy, we propose to compensate any returning candidate for giving up her position in the waiting list by accepting a marginal organ. In practice, this may correspond to preserving some fraction of the previous waiting times for returning candidates. We show that a unique equilibrium exists, and the utilization of marginal organs, as well as social welfare, monotonically increase with the level of compensation under this remedy.

In our second remedy, we propose to increase the access of returning candidates to higher quality organs. In practice, this may correspond to increasing priority score (e.g., MELD score in liver transplantation) of returning candidates. We show that a unique equilibrium exists, and the utilization of marginal organs monotonically increases with the level of access under this remedy. However, unlike the first remedy, social welfare increases up to a threshold access level, but than it starts to decrease, possibly dropping below the level without the remedy. This deleterious effect could emerge when the system before the remedy is efficient in allocating organs to patients that can make best use of them. Offering our second remedy in such an efficient system may hurt the system efficiency, causing a decrease in social welfare.
References


