# Organ Allocation and Transplantation*

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## 1 Introduction

Since at least the turn of the century there has been considerable interest by economists in organ transplants. This is due both to their importance in modern medicine and to the fact that organ transplantation deals directly with some of the most basic questions of economics, namely how to efficiently allocate scarce resources, and how to make them less scarce.

The first successful organ transplant, in 1954, was a living-donor transplant of a kidney (Murray et al., 1958). The donor was the identical twin of the recipient, and so the kidney and recipient were immunologically compatible.[1] There was still a long road before immunosuppressive drugs made transplants from even unrelated donors safe enough to become the standard of care for organ failure. Today, life saving transplants of organs include kidneys, livers, hearts, lungs, pancreases and intestines.[2] Most organs can only come from deceased donors. Kidneys are special, since healthy people have two kidneys and can remain healthy with one. (Living donors can also donate part of a liver, and also of a pancreas or a lung, but these latter two kinds of transplants don't regularly occur in the U.S.) Dr. Joseph Murray shared the 1990 Nobel Prize for his multiple contributions to transplantation.[3]

*We thank Kurt Sweat for helpful suggestions.

[1] This success, in which the recipient was returned to healthy life, was preceded by various temporarily successful attempts (see e.g. Dash et al. (2023), Tantisattamo et al. (2022)).

[2] Other transplantable organs include corneas and uteruses. Uteruses can come from either deceased or living donors.

[3] https://www.nobelprize.org/prizes/medicine/1990/murray/facts. The basic tools of vascular surgery needed to connect the blood vessels of the organ and recipient had already been recognized by the 1912 Nobel Prize to Dr. Alexis Carrel - https://www.nobelprize.org/prizes/medicine/1912/carrel/facts/.

## 1.1 International overview

In the U.S. and much of the world kidney failure is one of the top ten causes of death[4], and kidneys are the most frequently transplanted organ. Table 1 reports international statistics on kidney transplants. The table orders countries by a measure of their efficiency, namely the number of transplants they perform per million population, with an indication of the proportion of those transplants from living donors (the rest are from deceased donors).[5] The first eleven countries on the list, from the US to Sweden, perform a majority of their transplants from deceased donors. But starting with the next country, Israel, we see that living donor transplants can be more common than those from deceased donors in quite a few countries, even though deceased donors mostly donate two kidneys while living donors donate only one. Table 1 shows the percentages, which go from single digits of living donors up to 100 percent.

If we instead order countries by the total number of kidney transplants they perform, the first four countries are the US, China, India and Brazil. Except for the US, those countries don't yet have a relatively high rate of transplants per million population, but they have large populations. China and Brazil presently do mostly deceased donor transplants, while India does mostly living donor transplants.

The position at the top of both orderings might make it look as if transplantation in the US must be dealing well with kidney failure. But that isn't the case. One of the striking things about transplantation is persistent scarcity: most people who could potentially profit from a transplant will die without receiving one. In low and middle income countries a critical factor limiting transplant is the cost, in wealthy countries this scarcity is due to a shortage of transplantable organs.

In the United States, over 500,000 people are on dialysis, and there are over 130,000 new cases of kidney failure per year. But in all of 2025 there were (only) 27,574 kidney transplants. There are over 50,000 annual deaths from liver failure in the U.S., but in 2025 there were only 12,344 liver transplants. While many Americans have registered to be deceased organ donors if possible, only about 1 percent of deaths allow organs to be recovered for transplantation.[6]

The high incidence of kidney disease is only one reason kidneys are the most frequently transplanted organ. Dialysis allows many people to survive for years with kidney disease, so

[4]Center for Disease Control, https://wonder.cdc.gov/controller/saved/D176/D438F906, and World Health Organization https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death the world .

[5]Note that transplants per capita are only a noisy measure of transplant efficiency, since countries also differ in the incidence of kidney failure in their populations and in the number of deaths that could potentially lead to deceased donation, both of which are related to the age distribution of the population, among other things.

[6]Only about half that many actually become deceased donors: e.g. from somewhat more than 3,000,000 annual US deaths, there are fewer than 20,000 deceased donors.

| Country | PMP | % LD | Total | Country | PMP | % LD | Total | Country | PMP | % LD | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **United States** | **82.8** | **22.3** | **27731** | Cyprus | 37.9 | 48.6 | 52 | Colombia | 18.5 | 23.2 | 945 |
| Spain | 77.7 | 11.8 | 3 687 | Belarus | 37.7 | 0.8 | 347 | Tajikistan | 18.2 | 100 | 189 |
| Finland | 58.4 | 14.0 | 326 | Ireland | 37.1 | 15.9 | 189 | Syria | 15.0 | 100 | 354 |
| Netherlands | 58.0 | 49.5 | 1 031 | Austria | 36.3 | 22.3 | 331 | Singapore | 14.7 | 55.7 | 87 |
| France | 54.4 | 15.8 | 3 580 | Croatia | 35.2 | 7.8 | 142 | Japan | 14.5 | 86.2 | 1 809 |
| Portugal | 53.7 | 13.0 | 553 | New Zealand | 33.6 | 42.2 | 175 | Thailand | 13.7 | 19.7 | 984 |
| Canada | 53.6 | 24.6 | 2 130 | Kuwait | 32.6 | 57.1 | 158 | Costa Rica | 13.1 | 52.7 | 68 |
| Belgium | 52.0 | 13.1 | 604 | Uae | 28.9 | 47.7 | 303 | Luxembourg | 12.9 | 0.0 | 0 |
| Denmark | 50.5 | 29.9 | 299 | **Brazil** | **28.4** | **14.0** | **6241** | Sri Lanka | 12.2 | 74.3 | 270 |
| United Kingdom | 49.8 | 27.7 | 3 361 | Qatar | 27.4 | 64.9 | 73 | Mongolia | 11.8 | 90.0 | 41 |
| Sweden | 49.3 | 19.1 | 518 | Iran | 27.4 | 43.7 | 2 479 | Romania | 11.0 | 26.5 | 209 |
| Israel | 49.0 | 65.9 | 478 | Poland | 26.3 | 7.9 | 1 001 | Afghanistan | 10.9 | 100 | 451 |
| Czech Republic | 46.5 | 7.4 | 488 | Hungary | 26.1 | 16.9 | 251 | Ukraine | 10.8 | 38.1 | 394 |
| Switzerland | 45.5 | 27.3 | 400 | Latvia | 25.6 | 6.5 | 49 | **China** | **10.4** | **22.7** | **14728** |
| Norway | 43.1 | 18.1 | 237 | Germany | 25.5 | 28.6 | 2 148 | Malta | 10.0 | 60.0 | 5 |
| Australia | 41.1 | 23.6 | 1 096 | Slovenia | 25.2 | 1.9 | 53 | Ecuador | 10.0 | 8.0 | 182 |
| Uruguay | 40.6 | 11.6 | 138 | Mexico | 24.0 | 70.2 | 3 164 | **India** | **9.4** | **87.9** | **13503** |
| Argentina | 40.6 | 14.7 | 1 866 | Greece | 23.4 | 42.7 | 251 | Armenia | 9.3 | 100 | 28 |
| Turkey | 40.2 | 91.3 | 3 433 | Iraq | 22.9 | 100 | 1 033 | Albania | 9.3 | 100 | 26 |
| South Korea | 39.9 | 60.6 | 2 064 | Slovak Republic | 22.4 | 12.3 | 121 | Kazakhstan | 9.2 | 95.5 | 187 |
| Estonia | 39.2 | 9.8 | 52 | Iceland | 20.2 | 0.0 | 0 | Vietnam | 9.0 | 96.8 | 903 |
| Saudi Arabia | 38.9 | 87.7 | 1 294 | Jordan | 19.7 | 100 | 226 | Georgia | 8.4 | 100 | 31 |
| Lithuania | 38.2 | 5.8 | 107 | Chile | 19.3 | 22.3 | 382 | Panama | 7.7 | 57.1 | 35 |
| Italy | 38.1 | 15.4 | 2 259 | Taiwan | 18.8 | 45.1 | 449 | Macedonia | 7.6 | 100 | 16 |

Table 1: Kidney transplants by country in 2023: Per million population (PMP), share from living donors (%LD), and total transplants (total). From Global Observatory on Donation and Transplantation.

it is possible to wait for a kidney transplant far longer than for a liver or heart transplant, where waiting is accompanied by high mortality. Also as noted, kidneys for transplant can come from living as well as deceased donors. But the shortage of transplantable kidneys is severe compared to the incidence and prevalence of kidney failure. In the U.S., Medicare, which provides near-universal coverage, spent $141 billion for treating chronic kidney disease (CKD) in 2023.[7]

A striking thing about this shortage (at least to economists) is the near-universal legal ban on using monetary incentives to increase organ donation. Furthermore, there has been a mandate that countries should be self-sufficient in their own organ supply, with at most minor exceptions (Krawiec and Roth, 2025). These restrictions are motivated in part by a concern that poor and vulnerable people should not be subject to exploitation in a market for organ donors, and in part by confusion about the relationship between black markets and legal markets.

As economists would expect, these restrictions make it hard to relieve shortages of supply. But there has not been much study by economists about why these restrictions (which are absent in almost all other situations of scarcity) should have achieved such importance in transplantation.[8] Paying donors for their kidneys is illegal everywhere except the Islamic Republic of Iran, although there are black markets, some of them operating outside of conventionally qualified medical institutions (Elias et al., 2024).

The present survey will pay particular attention to deceased donors and how their organs (particularly kidneys) are obtained and allocated, and to the U.S., but with pointers to related issues involving living donors, other organs, and transplantation around the world.

Table 2 provides the annual number of U.S. transplants by organ and by donor type.[9] Kidneys followed by livers top the list for both deceased and living donors. The number of transplants has grown over the last decade, but not as fast as the need.

## 2 Deceased Donation

The two critical events in a deceased donor transplant are the death of a donor whose organs can be recovered and transplanted, and the identification of an eligible recipient who will receive one of those organs. A lot of organization and design is involved in making each of those things happen, before an actual transplant takes place.

[7]Taken from the USRDS 2025 Annual Data Report `https://usrds-adr.niddk.nih.gov/`

[8]Very similar arguments have been made about donation of other substances of human origin such as blood and blood plasma, but with different outcomes (Elias et al., 2024).

[9]The data are taken from `https://hrsa.unos.org/data/view-data-reports/`. The deceased donor type, donation after brain death or donation after circulatory death (DCD) was not reported for a few transplants.

| Organ / Year | 2025 | 2024 | 2023 | 2022 | 2021 | 2020 | 2019 | 2018 | 2017 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Deceased Donor** | | | | | | | | | | |
| Kidney | 21 052 | 21 341 | 21 042 | 19 636 | 18 699 | 17 583 | 16 534 | 14 725 | 14 038 | 13 431 |
| Liver | 11 635 | 10 854 | 10 001 | 8 925 | 8 667 | 8 415 | 8 372 | 7 849 | 7 715 | 7 496 |
| Heart | 4 587 | 4 572 | 4 545 | 4 111 | 3 818 | 3 658 | 3 552 | 3 408 | 3 242 | 3 190 |
| Lung | 3 490 | 3 340 | 3 026 | 2 692 | 2 524 | 2 539 | 2 714 | 2 530 | 2 449 | 2 327 |
| Liver-Kidney | 864 | 785 | 824 | 789 | 771 | 776 | 728 | 677 | 739 | 730 |
| Kidney / Pancreas | 804 | 733 | 812 | 810 | 820 | 827 | 872 | 835 | 789 | 798 |
| Intestine | 88 | 97 | 95 | 82 | 96 | 91 | 81 | 104 | 108 | 147 |
| Liver / Heart | 92 | 73 | 73 | 79 | 51 | 44 | 45 | 39 | 29 | 18 |
| **Kidney: Deceased Donor Type** | | | | | | | | | | |
| Brain Death | 11 297 | 12 694 | 13 736 | 13 526 | 13 005 | 12 891 | 12 428 | 11 446 | 11 211 | 10 891 |
| DCD | 9 752 | 8 647 | 7 306 | 6 110 | 5 694 | 4 692 | 4 106 | 3 279 | 2 827 | 2 540 |
| **Liver: Deceased Donor Type** | | | | | | | | | | |
| Brain Death | 7 059 | 7 796 | 8 306 | 7 911 | 7 752 | 7 585 | 7 659 | 7 314 | 7 201 | 2 049 |
| DCD | 4 575 | 3 058 | 1 695 | 1 014 | 915 | 830 | 713 | 535 | 514 | 447 |
| **Living Donor** | | | | | | | | | | |
| Kidney | 6 512 | 6 419 | 6 290 | 5 864 | 5 971 | 5 234 | 6 867 | 6 442 | 5 811 | 5 629 |
| Liver | 709 | 604 | 658 | 603 | 569 | 491 | 524 | 401 | 367 | 345 |

Table 2: U.S. transplants by organ and donor type, 2016–2025.

## 2.1 Registration as a willing deceased donor

In the US, the supply chain for deceased donor organs often begins at a state Department of Motor Vehicles (DMV). Driver's license applicants are asked if they would like to be included in the state's registry of those who wish to donate organs after death. Today, deceased-donor registries can also be accessed online. The U.S. employs an "opt-in" registration system– there is no presumption that a person wishes to donate organs after their death unless they actively affirm that they do, i.e. unless they opt in to the donor registry. The opt-in system is sometimes referred to as an "informed consent" system, in contrast to an "opt-out"(also called "presumed consent") system used in some other countries, in which a person is presumed to be a willing donor unless they take an action to indicate otherwise.

The legal framework governing deceased donation in the U.S. is the Uniform Anatomical Gift Act. People registered as deceased donors may change their minds at any time before the gift is made. Before donor registries were available online, it wasn't easy for people on the registry to remove their names, so it couldn't be assumed that a deceased person on the donor registry had maintained a wish to donate. Consequently, deceased organ donation almost always required consent by the next of kin. Now that online registries allow individuals to remove their names, legal opinions increasingly support allowing donors' presence on the donor registry to be a sufficient indication of their intent to make the gift (Iltis and Denny (2025)). However, in practice at American hospitals, consent from next of kin is still often required.

If the deceased is not on the donor registry, the next of kin may themselves authorize deceased donation. It appears that consent for donation in the US is given in the overwhelming majority of cases in which the deceased is on the donor registry, and substantially less frequently otherwise.

Recent attention has been paid to how the opt-in question is implemented at the DMV. Traditionally, a person could answer "Yes" to the registry question or choose not to answer, and only those who answered affirmatively were registered. A highly cited paper in *Science*, Johnson and Goldstein (2003), reported an experiment in which some participants were asked hypothetically how they would respond if the question were asked that way, and others were asked how they would respond if they were asked to answer "Yes" or "No". The surprising result of that paper was that the hypothetical registration rate rose from 42 percent when subjects were simply asked if they wished to opt in, to 79 percent "Yes" in the Yes/No framing of the same question.[10] Several states' DMVs subsequently changed to a Yes/No format. However these large predicted results did not materialize when people made actual organ donation decisions, either online or at their state's DMV.

Kessler and Roth (2014a) and Kessler and Roth (2025) reported an experiment in which participants signed on to the Massachusetts Donor Registry through a front-end that allowed their actual organ donor registration decisions to be observed, in response to the question being asked in one of those two ways.[11] Across three waves of data collection in this field-in-the-lab experiment, a yes/no frame did *not* increase organ donor registration rates over an opt-in frame. Registration rates were in fact directionally (but not significantly) lower when individuals were asked to provide a yes or no answer rather than just being given a chance to opt in. Kessler and Roth (2025) replicated this finding using a panel dataset on organ donor registration rates across US states. Changes in registration question frame in California (in 2011), New York (2013), and Hawaii (2014) yield an overall null effect on registration rates.

To participate in the Kessler-Roth experiment, participants were pre-screened to have a Massachusetts driver's license (to be able to access and change their status in the Massachusetts deceased donor registry).[12] So each participant had already been asked, at the time they got their license, whether they wished to register as a deceased donor. The percentage of participants in waves 1 and 2 who had already registered as prospective donors prior

[10]A total of 161 participants were asked to respond in one of three treatment conditions; in the third condition participants were asked to respond to the question in an "opt-out" frame, which produced a hypothetical 82 percent registration rate. See also Johnson and Goldstein (2003). This received wide publicity eg. in "Opting in versus Opting out" (Thaler, 2009). and the first edition of Thaler and Sunstein's book Nudge (although the second edition of that book substantially modified that).

[11]See also Kessler and Roth (2014b)

[12]Participants in the laboratory sessions (waves 1 and 2) did not know before arriving that the experiment involved organ donation. 514 subjects participated in waves 1 and 2, and 430 in wave 3 which was conducted online.

to the experiment was 46 percent, about the state average.[13] But the experiment allowed participants to change their status, whatever it was. Overall, 27 percent of participants who were previously unregistered chose to join the registry, while fewer than 1 percent of those who were previously registered chose to remove themselves. That is, participants were more than 30 times more likely to add themselves as to remove themselves from the donor registry. Since those entering the study unregistered had previously declined to register, this result suggests that an initial decision not to register in the DMV is changeable, and that registrations might be increased by giving people more opportunities to easily revisit that decision.

Aside from observing actual registration decisions, Kessler and Roth (2014a) and Kessler and Roth (2025) also reported a hypothetical "next of kin" experiment. Participants were asked to report what next of kin should do when deciding whether to donate the organs of a deceased relative who had been asked to register under one of the two frames. For the opt-in frame participants were told the deceased either selected or did not select "I want to register as an organ and tissue donor." For the yes/no frame, participants were told the deceased either selected "I want to register as an organ and tissue donor" or "I do not want to register as an organ and tissue donor." In each scenario the participant was then asked whether the next of kin should donate the organs of the deceased. The results were that when the deceased had joined the registry, about 94 percent of participants recommended consent to donation, with no significant difference between how the deceased had been recruited to the registry. But when the deceased had explicitly declined to register, the recommended consent dropped to 27 percent, significantly below the 38 percent of next of kin consents recommended when the deceased had simply failed to register. So these results suggest that an answer of "No" may substantially decrease *transplants*, even though requiring a Yes/No answer only insignificantly decreased *registrations*.

The distinction between registrations and transplants is also important for the ongoing work of untangling different effects of opt-in versus opt-out registration policies. Opt-out policies make deceased donation the default. Casual empiricism has suggested to many that, since defaults are often left in place, an opt-out policy would increase transplants (and not just enlarge the registry of potential donors). Some of the motivation for this hypothesis comes from the fact that Spain, which regularly has the highest rate of deceased donation per million population, has an opt-out policy. However Spanish transplant professionals reject the attribution of their success to Spain's opt-out policy (see Matesanz and Domínguez-Gil (2019), and Matesanz (2001)) pointing out that the policy was already in effect for ten years before the creation of a group of professionals whose only job was organ recovery led to a

[13] Participants in the online wave 3 had a higher percentage of registered donors, reflecting some selection after they learned what the experiment was about.

steady increase in deceased donor donations.

Current evidence suggests that the relative success of opt-in and opt-out policies depends on how they interact with other elements of deceased-donor donation and transplantation. Of particular importance is whether family consent is needed for a transplant to take place even when the deceased is on the donor registry.[14] Being on the registry by explicit choice or by default may send different signals to the next of kin about the deceased's intentions, much as actively or passively declining to be in the donor registry changed recommended next-of-kin decisions in the Kessler and Roth (2025) experiment.

In Chile, Domínguez and Rojas (2013) report that in the decade following the 2010 switch from opt-in (called "informed consent") to opt-out (called "presumed consent"), transplant rates dropped as family refusals rose to 50 percent. In contrast, Michielsen (1996) notes that in Belgium, where the presumed consent (opt-out) law does not require family consent, the policy has worked well for many years (even preceding the enactment of the law in 1986, when it was already customary for teaching hospitals to take kidneys for transplant without informing families.)

Chan et al. (2025) observe that how consent policy translates into transplants appears to depend both on the subsequent role of family consent to transplant, and the general degree of social acceptance of deceased-donor organ donation. They analyze the transplant rates for the years before and after a switch from informed consent to presumed consent for Austria (which changed to presumed consent in 1982), Luxembourg (1982), Finland (1985), Belgium (1986), Sweden (1996), Italy (1999), Chile (2010) and Uruguay (2013). Their results suggest that presumed consent only led to higher transplant rates where organ donation base rates were high and families had little opportunity to subsequently alter the decision, as in Austria and Belgium in the 1980s.[15] Their paper includes a model and an experiment that consider the information conveyed as a signal of the deceased's intent, when signals are costly (so defaults are often left in place) under each system.

Another aspect of the transplantation environment that can influence donor behavior is how deceased donor organs are allocated to recipients. In Singapore, which employs an opt-out system for registering donors, priority for *receiving* a transplant is given to recipients who did not opt out of consenting to be deceased donors themselves. In Israel, which has an opt-in system that also requires family consent, some priority for receiving a transplant

[14]Family consent takes different forms in different countries. Albertsen (2026) reports on the Danish adoption in 2025 of a "soft" opt-out system that (also) requires affirmative family consent to proceed to deceased donation, while e.g. in the Netherlands and England's opt out system a registered donation can proceed in the absence of an active objection by the family

[15]Gevers et al. (2004) in a survey of European consent laws observes that by 2004 "It appears that relatives are involved in all countries, irrespective of the law in force." Arshad et al. (2019) find no significant differences in deceased donation rates between opt-out and opt-in systems, in a comparison of 35 OECD countries. See also Molina-Pérez et al. (2022)

is given not only to individuals who have registered as potential deceased donors, but also to families that have consented to donation by a deceased next of kin.[16]

It is worth noting that changing how deceased organ donors are recruited often proves controversial, so that variations of the kinds discussed here are often debated but not adopted by legislators.

## 2.2 Brain Death and Circulatory Death

Organ recovery for deceased donation is preceded by a death. For the deceased to be a potential organ donor, the organs have to remain viable, which almost always means the death occurred in a hospital with a ventilator immediately available. Ventilator technology has led to recognition that death (and the declaration of death) is in some respects a decision, with consequences for organ donation and transplantation.

Defining death was once easy: it was the irreversible cessation of heartbeat and respiration. That changed with modern technology. The fact that death is not binary is precisely what makes transplantation possible: deceased donors may be dead, while some of their organs may be kept alive long enough to be transplanted into another person. This raises the question of what it means to be dead.

Before the widespread availability of ventilators, circulatory death ('cardiopulmonary death') and brain death ('neurological death') were essentially the same thing, because one almost immediately caused the other. But now that circulation can be maintained after the brain has gone irreversibly or permanently silent, we can make distinctions. And some of those distinctions depend on the distinction between "irreversibly" and "permanently."[17]

Loosely speaking, brain death occurs when there is no organized neural activity in the brain, including the brain stem. So a brain-dead person can no longer maintain heartbeat and respiration without a ventilator. (Most brain dead donors die while already on a ventilator, which temporarily keeps their organs alive.) And if we are who we think we are, brain death matters most: loss of heartbeat and respiration kills our brains, our selves.

But sometimes a patient is judged to have no chance of returning to life, but still has some neural activity in the brain stem. In this case, doctors may advise and families may agree to disconnect the ventilator, in the expectation that this will shortly result in cessation of heartbeat and breathing. If this doesn't happen quickly, the patient will likely no longer be a potential organ donor, as lengthy dying damages organs. But if circulatory death (and

[16]See Kessler and Roth (2012) and Kessler and Roth (2014c) for experiments prior to implementation of this priority system, and Stoler et al. (2016), Stoler et al. (2017), Ashkenazi et al. (2022) and Mor et al. (2024) for ex post analysis of field data.

[17]For a discussion of brain death see e.g. DeCamp et al. (2023), Truog (2023), Spears et al. (2022), and Greer et al. (2020).

consequently also brain death) follows before organs are damaged, the patient may still be eligible to make a donation after circulatory death (DCD). But DCD patients mostly have to be reconnected to a ventilator to keep their organs oxygenated. This will cause heartbeat and breathing to resume. So, are DCD patients "irreversibly" dead, or have they been returned to life after being reconnected to the ventilator? The concern to be punctilious on this matter has led to proposals to recognize that it's sufficient that death can be "permanent" (rather than irreversible) as when there are do-not-resuscitate orders in place.[18] Controversies about when a deceased donor is in fact dead can influence not only organ recovery in particular cases, but may also influence public support for deceased organ donation.[19] The controversy about donation after circulatory death takes on increased importance in view of the increase in the number of DCD transplants, both in the US (Table 2), and elsewhere (Martin et al. (2026)).

## 3 Allocation of deceased donor organs in practice

Deceased donor allocation in the US is regulated by federal law and the allocation process is designed and administered by the Organ Procurement and Transplantation Network (OPTN). The OPTN coordinates patient registration, organ recovery, and the allocation process.[20]

**Organ procurement.** The recovery of organs from deceased donors is handled by Organ Procurement Organizations (OPOs) and typically such organs are allocated to a national waiting list. OPOs are non-profit agencies responsible for recovering organs in their Donor Service Area (DSA) following the allocation rules given by the OPTN. In the US, there are currently 55 OPOs.[21] Starting prior to organ recovery, the OPO collects detailed information about the donor and the organ and enters it into a national database.[22]

[18] Because of the concern that brain death be permanent even if not technically irreversible at the cellular level, when the deceased donor is reconnected to the ventilator the arteries to the brain are sometimes clamped to prevent random neurons being reactivated in the brain. Alternative techniques for DCD heart transplants, involving reviving the heart outside of the body, are being explored (Kucera et al. (2025)).

[19] The NYT has reported several cases in which organ donation coordinators are said to have prematurely urged hospitals to declare the death of a potential donor. See `https://www.nytimes.com/2025/07/20/us/organ-transplants-donors-alive.html`. There have been some subsequent reports of a reduction in the number of people registered to be deceased donors.

[20] The OPTN was established by the National Organ Transplantation Act (NOTA) of 1984.

[21] There were 58 OPOs prior to 2020, and three OPO mergers took place in the beginning of 2021, 2023, and 2024. In September 2025, the U.S. Department of Health and Human Services announced a plan to decertify an OPO in Miami.

[22] Allocation procedures vary by country. In Chile, if procurement occurs in a transplant center, one kidney remains in the center and the other kidney is allocated through the national waiting list. While this approach was adopted to increase supply, Cohens et al. (2024) reports little change and that private transplant centers

**Transplant candidates on the waiting list.** A patient in need of a transplant can be registered on the deceased donor waiting list. For each deceased donor organ that becomes available, the system generates a priority order over patients who are compatible with the donor, and in principle patients will be offered the organ in priority order. Information entered upon registration includes health conditions, relevant biological data, and other information required for assigning priorities. Patients, doctors and transplant centers can preemptively reject some offers by setting filters specifying that they don't wish to receive offers of organs that fail to meet certain criteria.[23]

Compatibility between the patient and the donor depends on the organ type. For lungs, livers and hearts, compatibility depends mainly on blood type[24] and size. For kidneys, compatibility requires both blood-type compatibility and tissue-type compatibility, which means that the patient cannot have an antibody to one of the donor's human leukocyte antigens (HLA). Every person inherits antigens from their parents, and for each location on the relevant chromosome a patient has 1 or 2 antigens[25] Patient sensitivity is based on her antibodies; a common measure for the patient sensitivity is the Calculated Panel Reactive Antibody (CPRA), which measures the likelihood of a patient to be tissue-type incompatible to a random donor from a given population.

Priorities to be offered an organ are different across organs, but common to most organs (at least as a tie-breaker) is the amount of time the patient has waited since becoming eligible for a deceased donor transplant.

*Details.* In the US, waiting time of a patient with kidney failure is measured from the earliest of the date of beginning dialysis and the first date after registration in which her kidney function drops below 20% measured by eGFR – the estimated glomerular filtration rate (eGFR).[26] Prior to 2014, waiting time was counted since registration on the waiting

benefited from it without contributing much to procurement. The same approach was used in the UK until 2006 (Watson et al., 2020); early on a few centers which specialized in DCD transplants also benefited from getting both kidneys from a DCD donor. But the increasing success of DCD transplants also played a role in the shift to a national system.

[23]There is room for improvement in how such criteria are specified, as many organs that meet all the specified criteria are nevertheless rejected. Presently, there are three ways to exclude offers. Criteria can be specified by setting thresholds: a surgeon may not be willing to accept an organ for a given patient from a donor who is too old, too overweight, or has blood pressure that is too high. Such thresholds can also be set to exclude offers irrespective of the patient. Since 2022, surgeons can also define filters that exclude offers of organs that simultaneously satisfy multiple criteria while allowing exceptions for certain patient types. For example, the surgeon may exclude offers from donors above a certain age and with high creatinine as long as the patient is older or has a high CPRA. This is an area in which computational decision aids may become useful.

[24]The donor cannot have a blood-type antigen A or B that the patient does not have.

[25]One if the same antigen is inherited from both parents, in which case the person is said to be homozygous for that antigen.

[26]The GFR is a blood test that measures how well the kidney filters waste using its glomeruli filters.

list, ignoring how long the patient was on dialysis. This was changed after observing large heterogeneity across ESRD patients in access to the deceased donor waiting list. For example there is association between whether and when for-profit and non-profit dialysis centers refer patients to the waiting list (Amaral et al., 2022; Gander et al., 2019; Eliason et al., 2020).[27]

The eGFR is measured based on creatinine[28], sex, age, and body weight, but until 2023 the eGFR formula also included an indicator for Black people, who were thought to have higher average percentages of muscle mass and hence creatinine. This led to disparities in which Black patients were regarded as having better kidney function than other patients with similar blood tests. The indicator was removed in 2023 following lack of evidence for its efficacy, and Black patients already on the list were assigned extra waiting time (i.e. higher priority for a transplant) to correct for their prior eGFR readings.[29]

Deceased-donor liver allocation is prioritized by urgency. In the US, the Model for End-Stage Liver Disease (MELD) score estimates the urgency of a patient waiting for a liver transplant(Kamath et al., 2001). (Before MELD, urgency for liver patients was manipulable (Kamath et al., 2001; Ruf et al., 2022; Muñoz-Rodriguez, 2021)).[30]

**Priority rules.** For each organ the system generates a priority order over patients who are compatible with the donor and did not exclude the donor organ based on filters. The priority order is generated based on the donor's and patients' characteristics.

Several principles guide the design of priority rules, such as urgency, proximity, efficiency (or expected outcomes) and equity. Priority rules differ across organs. For example, the allocation of kidneys as opposed to other solid organs typically doesn't depend on a high priority for urgency (in part because ESRD patients can mostly remain alive and non-urgent on dialysis).[31]

[27]Eliason et al. (2020) find such an effect following an acquisition of a dialysis facility by a for-profit company. See also Agarwal and Somaini (2022) for research about patients' search and admissions to dialysis centers.

[28]Creatinine is a waste in the blood generated from muscle.

[29]See the OPTN decision regarding waiting time adjustment and the recommendations of an ad hoc committee of the National Academies of Sciences, Engineering, and Medicine for a "Fairer and More Equitable, Cost-Effective, and Transparent System of Donor Organ Procurement, Allocation, and Distribution. One of us (IA) served on this committee).

[30]Prior to the introduction of MELD scores, hospitals could give patients priority by claiming that they were in intensive care. Some pre-Meld drama involved the US attorney in Chicago suing three Chicago area transplant centers for claiming that patients were in intensive care who were not: "U.S. Alleges Liver-Transplant Fraud/ Suit Says Three Facilities Broke Rules to Receive Organs Quickly," By Thomas M. Burton and Amy MerrickStaff Reporters of The Wall Street Journal, July 29, 2003 https://www.wsj.com/articles/SB105943125893020700

[31]For organ allocation policies in the US see https://optn.transplant.hrsa.gov/media/eavh5bf3/optn_policies.pdf, in the Eurotransplant area see https://www.eurotransplant.org/allocation/eurotransplant-manual/, and in the UK see https://www.nhsbt.nhs.uk/organ-transplantation/heart/receiving-a-heart/how-does-the-offering-system-work/.

A common goal (seemingly aligned with efficiency) is "making the best use of organs". This goal already raises natural trade-offs (discussed further in the next section). This includes prioritizing for long expected graft survival[32], recipient survival, and reducing the likelihood of a recipient dying with a well functioning graft. This is typically aligned with assigning high quality organs to younger patients.[33] Another goal is attaining high utilization of recovered organs.

*Details.* Priority rules differ across countries. For example, in kidney allocation, countries differ in how they prioritize efficiency (or longevity matching): Eurotransplant assigns old donors (above 65) to old patients, in the US young patients are prioritized for high quality (typically young) donors, and in the UK, patients are prioritized based on patient- and donor-risk buckets (which can be thought of as matching age groups).

We describe briefly the current priorities for allocating deceased-donor kidneys in the US. First, patients with high Estimated Post Transplant Survival (EPTS),[34] typically younger and healthier, are prioritized for high quality donors. So each donor is assigned a quality index, called the Kidney Donor Risk Index (KDRI) based on information available prior to organ recovery.[35] The KDRI is converted into the Kidney Donor Percentile Index (KDPI), which is interpreted as the percentage of recovered organs that had a lower (less risky) KDRI in the previous calendar year.[36] Donors are split into groups based on KDPI: 0-20%, 21-34%, 35-85% and 86-100%, and are prioritized differently within each group.[37] Patients with the highest 20% EPTS scores[38] are assigned priority for kidneys with the top 20% (lowest KDPI) organ quality.

Second, the match quality with the donor also plays a role. The degree to which the patient and donor have similar HLA antigens has an impact on graft survival (Opelz and Döhler, 2007; Manski et al., 2019). Patients who have no antigen mismatches with the donor[39] are assigned the highest priority. The patient also receives extra priority points

[32] This also eases congestion from returning to the waiting list.

[33] In kidney allocation, longevity of a match can be also improved by minimizing antigen mismatch.

[34] This estimate depends on age, diabetic status, on dialysis status, and previous transplant history `https://optn.transplant.hrsa.gov/media/1511/guide_to_calculating_interpreting_epts.pdf`

[35] This information includes age, weight, height, hypertension and diabetes history, cause of death, serum creatinine, and whether donation was after circulatory death. Until 2024 KDRI also depended on Hepatitis C virus (HCV) and Black donor race due to historical association with increased risk of graft failure. See `https://optn.transplant.hrsa.gov/media/0zamk0dr/mac_kdpi_board-briefing-paper.pdf`. HCV was removed due to direct-acting antiviral treatment for HCV. Guan et al. (2024) find that surgeons had already adjusted acceptance decisions before the removal of HCV to account forthe inaccuracy of the KDRI estimate, and race has been shown to be a poor indicator for kidney quality (Miller et al., 2023).

[36] See a KDRI guide for details about KDRI and KDPI calculation .

[37] Patients must consent to receive offers of organs with KDPI 86-100%.

[38] EPTS scores are based on previous year candidates.

[39] Specifically, no mismatches in antigen loci A, B, and DR.

based on the number (0 or 1) of DR antigen mismatches.[40,41] More mismatches increase the likelihood that the recipient, upon graft failure, will develop antibodies to the donor and return more highly sensitized to the waiting list (Isaacson et al., 2022).

Third, distance plays an important role. Patients in the "local" region are prioritized over other patients.[42] Since March 2021, local means being within 250 nautical miles (NM) of the organ, together with a linear boost per mile.[43] Prior to this, the local region was a geographical zone (called the Donor Service Area) and equal priority was assigned to patients in the same proximity category.[44]

Fourth, patients are assigned scores based on their sensitization[45] and extreme priority is given to different levels of very sensitized patients (such as CPRA 98%, 99% and 100%).[46]

Patients also receive additional points for previously donating an organ (currently the equivalent of four years of waiting time).

Finally, patients are assigned a score based on their waiting time. So the priorities of patients for a given organ are lexicographically ordered based on different categories, and within each category, patients are ordered based on adding up their scores (waiting times, sensitivity, distance, etc.)[47]

Recently the OPTN has been exploring redesigning the scoring rules to be more "continuous" with respect to additional patients or match characteristics (age, size, expected survival time, etc.) for equity reasons. Such a system has been adopted recently for lung allocation (Papalexopoulos et al., 2024).[48]

**The allocation process.** Once a priority ranking is generated, the OPO begins the offering process by making offers to patients according to their priority score. The offering process typically begins before organ recovery (once the information required for the priority order is ready),[49] and further information about organ quality, such as biopsy results, pump values,

[40] See Connolly et al. (1996) for the importance of DR mismatches on graft survival.

[41] In the UK, priority scores are given by the total number of HLA antigen mismatches.

[42] Except for absolute priorities, as for no antigen mismatches or for the highest CPRA values.

[43] E.g., 125NM are equivalent to one year of waiting time.

[44] The change involved lawsuits and court orders to cease and desist from the donor service area system, on the grounds that patients were being discriminated against based on their zip codes, rather than on medical reasons. See e.g. Callahan, et al. v. Azar, No. 1:19-cv-1783

[45] Prior to 2014, there was a single priority boost for patients with CPRA above 80 CPRA.

[46] Patients with blood type B are also prioritized for O donors, due to imbalances in the blood type population.

[47] In Eurotransplant, recipients with an early graft failure are given "back" some of their waiting time: https://www.eurotransplant.org/wp-content/uploads/2025/03/H4-Kidney-2025.2-March-2025.pdf.

[48] https://optn.transplant.hrsa.gov/policies-bylaws/a-closer-look/continuous-distribution/continuous-distribution-lung.

[49] For 93% of deceased donors kidneys in 2025, the first offer notification occurred before recovery (clamp) time.

imaging, as well as refusals by centers, arrives during the allocation process.

*Details.* In the US the offering process begins with initial (provisional) offers to centers for specific patients. These offers are typically made to multiple patients simultaneously and centers have an hour to respond. Provisional acceptance indicates interest in the organ, often pending further information. Among accepted provisional offers, the OPO follows with (primary) offers to individual patients in their priority order and acceptance and rejection decisions at this stage are final.

**Congestion and expedited placement.** Rejected offers take time, which plays an important role in the offering process. The number of offers required to place an organ strongly depends on organ quality.[50] The time between organ recovery and transplantation, cold ischemia time (CIT), has a negative impact on graft survival (Quiroga et al., 2006; Peters-Sengers et al., 2019; Debout et al., 2015). This creates a challenge especially in placing marginal quality organs, which may be rejected on behalf of thousands of patients before finally being accepted or discarded. There is growing research on the reasons associated with discards (Husain et al., 2019; Guan et al., 2025). Guan et al. (2025) study the dynamic offering process, to show how refusal reasons can assist with the decision to expedite placement of organs that look hard to match. Guan et al. (2025) observe that centers often refuse an offer on behalf of multiple patients at the same time, and find that just a few multi-patient refusals by centers even before recovery time indicates a substantial increase in the risk of the organ not being utilized. (They document that approximately 38 million offers of organs to patients were refused in 2022-2023, via approximately 881,000 refusals made by transplant centers (when considering centers' refusal timestamps to account for virtually simultaneous decisions for multiple patients).)[51] There are starting to be substantial improvements for preserving the viability of livers recovered from deceased donors (Nguyen et al., 2025), which may reduce the congestion of the offering process by allowing it to continue longer.[52]

*Details.* Different approaches are used for offering organs at risk of being discarded. The UK adopted a fast-track system since 2012 for placing organs at risk of being discarded. The fast-track process is triggered after an organ accrues some cold ischemic time[53] or after 5 transplant centers have declined the organ. Transplant centers in the UK (there are 12 of them), can choose to opt-in for the fast-track option and are given 45 minutes to

[50]For example, the median number of offers per donor whose recovered kidneys were transplanted in 2024 was 6, 9, 19, 74 and 181 for KDPI groups 0-20, 20-35, 35-60, 60-85, and 85-100, respectively. The means over these groups were 82, 175, 305, 452, and 500.

[51]Multi-patient refusals are correlated with stated refusal reasons related to the organ, while single-patient refusals are correlated with patient-related reasons.

[52]One day we may even be able to preserve other organs by freezing and thawing them Giwa et al. (2017). These advancements will open up new and less time-dependent allocation protocols.

[53]12 hours for kidneys and 6 hours for other organs.

respond, after which the highest priority patient accepting the organ receives it.[54] In the US, following a large increase in discard rate, OPOs have been given discretionary power to offer some organs out-of-sequence. Out-of-sequence offering has been practiced by OPOs through making open offers to transplant centers; this has been done via telephone calls (that aren't recorded in the OPTN data), and centers could accept such an offer for any of their patients (Liyanage et al., 2025). Concerns about equity[55] have resulted in the Health Resources and Services Administration calling to standardize the process including assuring that offers are not made to centers, but to patients (even if done in batches).[56] One advantage of making simultaneously open offers to multiple centers as in the UK fast-track system (rather than to a single center) is that it creates competition that results in a higher priority patient being transplanted if the organ is accepted. Ashlagi and Roth (2026) suggest some dimensions on which policies for expediting hard to match organs could profit from careful experimentation, with the aim of crafting a transparent and equitable process that would yield reliable data for further improvement.

**Simulations for priority design.** Organ allocation agencies rely on empirical evidence and data-driven simulation tools to predict outcomes and choose between different priority rules.

*Details.* In the US, simulations are commonly used for designing priority rules, sometimes with the assistance of simulation tools developed by the Scientific Registry of Transplant Recipients (SRTR).[57] For kidney allocation reform in 2014, the committee used the Kidney-Pancreas Simulated Acceptance Module (KPSAM) developed by the SRTR to predict transplants and outcomes generated by different priority rules that can be varied in the model.[58] KPSAM simulates the arrival of organs and patients based on historical data, and acceptance behavior also trained on historical data. Similarly, the LSAM is a simulation tool for predicting outcomes under different liver allocation rules. Papalexopoulos et al. (2024) generated a novel simulation framework based on optimization and machine learning that, given social preferences, learns scoring rules that attain achievable trade-offs.

One drawback of existing simulation tools is that estimated acceptance behavior is invariant to the priority rule and therefore ignores patients' or doctors' incentives, and how new rules are likely to change acceptance behavior. Agarwal et al. (2019) provide evidence

[54] A similar informal process of simultaneous offers takes place in Israel, where a whatsapp group message is sent to all transplant centers (personal communication).

[55] https://www.nytimes.com/interactive/2025/02/26/us/organ-transplants-waiting-list-skipped-patients.html.

[56] https://optn.transplant.hrsa.gov/media/km3fskz1/hrsa-directive-to-optn-on-aoos-022125.pdf.

[57] The SRTR is a contractor under HRSA that provides statistical and analytic support to the OPTN.

[58] See https://unos.org/wp-content/uploads/Board_06-2013_Kidney_Committee_Actions1.pdf.

that such incentives play a role in patients' decisions; they document that sensitized patients who receive fewer offers than other patients are also more likely to accept an offer.

# 4 Organ Allocation: Models and Evidence

**Theoretical models of allocation mechanisms with patient choice.** Allocating deceased donor organs involves creating a queuing system which will be experienced by those in the queue as a stopping problem. Transplant candidates are ordered in the queue to receive offers, and they and their doctors have to decide whether to accept an organ when offered, or wait in the hope of being offered a better one.

Several papers study the optimal stopping problem facing a single patient (whose health may deteriorate), assuming organ offers arrive according to an exogenous arrival process (David and Yechiali, 1985b; Howard, 2002; Alagoz et al., 2009).[59]

To evaluate a queuing system with choice, observe that patients' decisions depend on each other and on the allocation mechanism.[60] A growing literature is concerned with trade-offs that arise in such queuing systems.[61]

The fact that surgeons and patients decline organ offers (which takes time, during which organs deteriorate) can result in potentially transplantable organs being discarded. For example under a First-Come-First-Serve policy, patients at the head of the queue may have the incentive to wait for a high quality organ and decline offers of lower quality organs (Su and Zenios, 2004; Bloch and Cantala, 2017). This happens because patients don't internalize their externalities on other patients. Su and Zenios (2004) observe that Last-Come-First-Serve eliminates waste and is socially optimal when patients have identical preferences, as patients fully internalize their externalities.[62] Bloch and Cantala (2017) compare a random lottery to FCFS under private or common values, and show that a lottery mechanism results in fewer discards compared to FCFS, but FCFS is preferred by patients in the queue as they

[59]See also Volk et al. (2015); Bertsimas et al. (2017); Wey et al. (2018) for data-driven decisions tools.

[60]A line of research that studies priority-based systems without choice (or assuming behavior that is invariant to the allocation rule) explores the tension between efficiency and equity (Zenios, 1999; Zenios et al., 2000; Bertsimas et al., 2013; Nikzad and Strack, 2024), efficiency and urgency in the context of liver allocation (Akan et al., 2012), as well as how to improve efficiency through region design (Kong et al., 2010). Earlier basic research on (sequential) stochastic assignment problems (Derman et al. (1972); Albright (1974); Righter (1987, 1989); David and Yechiali (1985a)) has observed that assortative assignment is essentially optimal when the match value is the product of the organ quality and the patient type.

[61]See also Baccara and Yariv (2021), Doval (2025) and Che (2026) for excellent surveys on dynamic matching.

[62]See also Naor (1969); Hassin (1985) for analogous findings in classic queuing systems, in which homogeneous agents only decide whether or not to join the queue.

can freely reject an offer while keeping their priority.[63]

Shi and Yin (2022) show that when patients' preferences are private, any queuing system that prioritizes patients based on waiting times will exhibit organ discards. Patients in their model die at an exogenous rate and may die while waiting for a desirable organ despite having declined offers of acceptable organs.[64] They suggest that offering overdemanded organs to newly arriving patients using lotteries will reduce discards.

Several papers limit choice to increase efficiency. Su and Zenios (2006) consider partitioning organs based on their qualities and offering them in separate queues. The optimal partition to maximize the sum of discounted utilities groups organs of adjacent qualities (e.g., by KDPI ranges) and patients can only choose which queue to join, but not decline offers within a queue.[65] The optimal partition depends on the tail of the value distribution, and is intended to reduce excessive waiting costs.[66] Wang et al. (2024) show that easing congestion can be done through priority rules that offer patients absolute priority for certain types of organs conditioning on not queuing for some set of higher quality organs.[67] Ata et al. (2021) restore patient choice and show that allocations on the Pareto-frontier of a large class of practical policies can be implemented using type specific priority scores that are linear with waiting time.

One source of congestion in queuing systems is the number of offers that need to be processed before one is accepted (Castro et al., 2021; Ashlagi et al., 2025). The limit on the number of offers that can be made for a given organ (due to organ expiry) can have a substantial impact on utilization and efficiency.[68] It can be further amplified when acceptance decisions are made by surgeons rather than patients (as is often the case), and congestion can be generated when thickening the market by making more transplant centers eligible to receive offers from each OPO (Ashlagi et al., 2025). One way to overcome this is by offering lower quality organs to patients with longer expected waiting times (Castro et al., 2021).

Researchers have generated valuable insights for queuing systems with choice in other applications such as the allocation of public housing.[69] Leshno (2022) is concerned with inefficiencies due to mismatches. Agents in an overloaded queue can decline an offer and join a buffer queue for a housing choice they prefer. Offering this choice by lottery to agents

[63] See also Schummer (2021); Doval and Szentes (2025); Baccara et al. (2020).

[64] In contrast, without death and quasi-linear preferences, waiting times (which act as prices) generate allocative-efficient outcomes.

[65] See also Ashlagi et al. (2025) who establish this structure in a general class of mechanisms.

[66] See also (Condorelli, 2012; Hoppe et al., 2009; Hartline and Roughgarden, 2008) for the design of money-burning mechanisms.

[67] This approach is motivated by the Eurotransplant Senior Program (ESP).

[68] Castro et al. (2021) study how this friction generates excessive waiting in ride-sharing; drivers at the head of the airport queue decline unattractive requests, resulting in impatient passengers switching platforms.

[69] See also Kaplan (1984, 1987, 1988) for the role of priorities in public housing assignments without choice.

in the queue will incentivize more people to wait for it and therefore reduce mismatches compared to FCFS. Arnosti and Shi (2020) study lottery mechanisms for allocating public housing for agents with heterogeneous outside options. They show that preserving priority in a waiting list when declining an offer results in higher match quality over losing the priority upon declining an offer (the latter is equivalent to using independent lotteries to allocate each item). However, achieving high match quality can result in low targeting of agents with need. Waldinger (2021) finds empirically that reducing choice can improve targeting applicants in need of housing but this will substantially harm tenant welfare.

**Empirical research.** A growing empirical literature seeks to evaluate outcomes under existing waitlist designs as well as counterfactual designs.

Agarwal et al. (2021) develop an empirical framework for the allocation of kidneys that accounts for patients' incentives. They find large match-specific heterogeneity, small differences between pre- and post-2014 kidney allocation rules[70] and that both leave room for large efficiency gains.[71]

Several papers are concerned with inefficiencies arising from observational learning as a result of the sequential offering process (Zhang, 2010; De Mel et al., 2021; Doval et al., 2024). While an offer refusal can result in lowering the organ quality perceived by subsequent patients, Zhang (2010) finds that sharing reasons for refusals can improve acceptance decisions and even utilization.[72] Doval et al. (2024) show that hiding from patients their position on the list can increase utilization but harm welfare. And that prioritizing patients based on the chance of accepting the offer can increase herding and organ discards.

Bae (2023) studies the effect of the 2021 kidney allocation reform in the US, which modified which patients are eligible for local priority (shifting from fixed geographical boundaries to being within 250 nautical miles from the organ location). She finds that the reform reduced both organ discards and pre-transplant mortality.

Sweat (2023) studies the effects of a 2018 reform in heart allocation, which increased the priority for adult patients who receive treatments that are associated with higher pre-transplant mortality. He finds that doctors have been very responsive to this change, including "treating the waiting list" by adjusting treatments to give patients higher priority. He develops a structural model for this endogeneity, and finds the policy resulted in small

[70]In the pre-2014 rules, sensitized patients (with CPRA above 80) were assigned additional priority irrespective of how sensitized the patient is. The post-2014 policy modified this priority to increase with the sensitivity of the patient. Some intuition for why post-2014 did not result in major differences is that highly sensitized patients naturally accumulate priority due to excessively long waiting times; so once an organ that is likely to be compatible with a sensitized patient becomes available, it is also likely that there are numerous sensitized patients with excessively long waiting times.

[71]See also Ata et al. (2020) for a closely related structural framework with similar predictions.

[72]See also (Guan et al., 2024) who document different patterns following refusal for reasons related either to the organ or to the patient.

survival benefit.[73] See also Muñoz-Rodriguez (2021) for a theoretical treatment for the allocation of organs with asymmetric information due to doctors having more information about their patients' health and Munoz-Rodriguez and Schummer (2025) for a theory on inefficiencies that arise when hospitals strategically select treatments on behalf of all their patients.

Organ allocation rules influence longevity, such as life years from transplant (LYFT). As existing designs typically do not account for endogenous behavior, Agarwal et al. (2025) study the role selection has on LYFT in existing mechanisms and counterfactuals. Their framework utilizes historical choice data to evaluate LYFT while accounting for selection on unobserved heterogeneity.

Callison et al. (2025) find that the availability of direct-acting antivirals for hepatitis C (HCV), saved many HCV positive patients the need for a transplant, and in turn benefiting many HCV negative patients on the deceased donor waiting list.

Several papers explore changes in supply. Dickert-Conlin et al. (2019) find that the repeal of motorcycle helmet laws results in additional deceased-donor transplants. Dickert-Conlin et al. (2024) document the increase in deceased-donor transplants due to opioid overdose deaths.

## 4.1 Regulation of Transplant Centers and OPOs

While the metrics used to measure both OPOs and transplant centers are in flux, the most important metric by which US transplant centers are measured is the one-year graft (and patient) survival of the transplants they perform. As a result, kidney transplantation is a very safe operation in the US, with virtually all centers having a success rate well over 90 percent by this measure.[74] Many transplant centers accomplish such a high success rate of the transplants they choose to perform by being quite risk averse, which means often declining to transplant risky organs (e.g. from older donors), and risky patients (see, e.g., Mildebrath et al. (2024) who observe that larger centers are likely to accept more risky organs, since a failed transplant doesn't move their percentages so much). Chan and Roth (2024) consider how this interacts with the incentives that OPOs have to recover organs, and with the health outcomes for patients on the waitlist who are not transplanted. They propose that a more unified incentive system, which measured transplant centers and OPOs in part by the health outcomes of all patients in their region (and not just those who were

[73] Power et al. (2024) study the effects of changes in the pediatric heart transplant waiting list. They demonstrate that the priority system is too coarse to account well for medical urgency.

[74] See https://srtr.transplant.hrsa.gov/ADR/2023/2023_ADR_Full_Report.pdf and https://www.srtr.org/transplant-centers/.

transplanted), would result in more transplants and better overall health outcomes.[75]

To increase efficiency and transparency, Centers for Medicare and Medicaid Services began public monitoring OPOs performance since September 2021: OPOs are ranked using a tiered system based on donor age–adjusted transplant rates. Bae et al. (2025) find that while low-performing OPOs have increased their organ recovery rates, transplant rates depend on the responsiveness of transplant centers to accept lower-quality organs, such as kidneys with a high KDRI.

The OPTN also publishes the pre-transplant mortality rate and organ acceptance rate of each transplant center as well as predicted waiting times.[76] Variability in waiting times and acceptance decisions across centers can be substantial even within small regions (King et al., 2020). Green et al. (2025) further identify large variability in acceptance decisions even across clinicians within the same center.[77]

Several studies also document variability across transplant centers in screening and registering candidates to the waiting list (Mandelbrot et al., 2017; Wall et al., 2019; Whelan et al., 2022).[78]

## 5 Living donation

In 2025 in the U.S. there were 6,522 kidney transplants from living donors. These were mostly directed donations, from a family member or friend to a particular recipient. One reason there are not more living-donor kidney transplants is that an intended donor's kidney is often incompatible with the intended recipient. Kidney exchange, which allows patients to receive a compatible kidney from another patient's intended donor, eases this constraint (Rapaport (1986), Roth et al. (2004)). Many kidney exchange transplants are facilitated by the formation of chains that begin with a non-directed donor, i.e. a donor who doesn't have a particular recipient in mind. Non-directed donor chains can be long because not all included transplants need to be conducted simultaneously (Roth et al. (2006)), and they are more likely to be able to include highly sensitized patients who couldn't engage in an exchange among a small number of patient-donor pairs. The first nonsimultaneous chain, Rees et al. (2009), was organized by Dr. Michael Rees, the surgeon who founded the Alliance for Paired

[75] For example, Aubert et al. (2019) report that, in France, more kidneys from donors over 80 years old are recovered and transplanted (to old recipients) than in the U.S. In the U.S., Adam et al. (2026) infer that OPOs are missing opportunities to ask next of kin to authorize deceased donation.

[76] See `https://optn.transplant.hrsa.gov/media/l30bi2uw/phase-3_tx-prgm-performance-monitoring_jan2024-draft.pdf` and `https://www.srtr.org/`.

[77] They measure within-center variability by merging on-call data from 15 centers with UNOS data.

[78] These contribute to barriers and inequities in access to deceased donor transplants (Schold et al., 2011; Lemont, 2024).

Kidney Donation, one of the earliest multi-hospital kidney exchange networks.[79]

In 2025 the OPTN database records 1,428 kidney transplants as coming from exchange among patient-donor pairs, and 545 nondirected donation transplants (anonymously to anonymous recipients).[80] For overviews of kidney exchange from different points of view see e.g. Barkel et al. (2025), Ashlagi and Roth (2021), Biró et al. (2019), Biró et al. (2019), and Sönmez and Ünver (2013).

Because almost all deceased donors are non-directed, attention has turned to starting kidney exchange chains with a deceased donor (Melcher et al. (2016), and Robinson et al. (2025), Furian et al. (2020), Furian et al. (2019), Rees et al. (2017), Roth et al. (2004)). In such a chain, the patient in a patient-donor pair waiting for kidney exchange accepts a suitable deceased donor kidney (before they would have been eligible to receive one on the deceased donor waiting list), while their living intended donor donates to another exchange pair, and so forth until the last donor in the chain donates a living-donor kidney to a person on the deceased donor waiting list who doesn't have an intended living donor to continue the chain. These chains now are in widespread use in Italy, where there have been very few living non-directed donors.

Deceased donor initiated chains may be useful in allowing highly sensitized, hard-to-match patients from small countries (or countries with at most small kidney transplant programs) to receive a transplant by starting such a chain in a country with a large deceased donor pool (which gives the highly sensitized patient a better chance of finding a compatible kidney) and a kidney exchange pool (in which to continue the chain).

More generally, it seems very desirable to foster international cooperation in kidney exchange and perhaps in other aspects of transplantation, since transplantation is so scarce relative to the need especially in low and middle income countries (LMICs), where chronic disease ending in organ failure is a rising problem.[81]

Conducting kidney exchange at an efficient scale often requires a larger pool of patient-donor pairs than are available in small countries, even wealthy ones (particularly if exchange is conducted at less than national scale (Agarwal et al. (2019)). The issue is that kidney

[79] See also Anderson et al. (2015), Ashlagi et al. (2011a), Ashlagi et al. (2011b), Agarwal et al. (2018).

[80] Not in the OPTN database is the fact that about two dozen non-directed donors donated a liver lobe after having previously donated a kidney.

[81] For many years it was the policy of the World Health Organization that countries be self-sufficient in organ transplantation. However a 2024 WHO document suggests that they may realize this works against the interest of many patients around the world, see `https://apps.who.int/gb/ebwha/pdf_files/WHA77/A77_R4-en.pdf` . So it is possible that some progress on allowing international cooperation can be made. In November 2025, an international transplant conference in Egypt was convened to consider ethical issues concerning transplantation (`https://2025.dle-eg.org/ethical-consensus/`) One of us (AER) co-chaired a working group on Ethical Frameworks for Regulated International Collaboration, which reached consensus recommendations for international kidney exchange on a global scale. (As we write this in early 2026, widely disseminating those recommendation is still work in progress.)

exchange programs need to achieve scale in terms of the rate at which new pairs enter the pool, particularly to be able to find exchanges for hard to match pairs (Ashlagi et al. (2018)).

International kidney exchange at scale has proved elusive. While kidney exchange itself is becoming widespread in Europe[82], only a small amount of international exchange occurs among EU countries. Klimentova et al. (2025) report four cross-border kidney exchange programs, whose experience teaches an important lesson. In particular, one of the programs is run by Spain, Italy and Portugal, whose total population of approximately 118 million people is far larger than the combined population of the other three, but manages to do less than 5 percent of the total cross-border exchanges. What keeps it so small is that the countries first match as many domestic pairs as possible to one another, and then nominate only their remaining, hard to match pairs for cross-border exchange. But it is often impossible to find matches for hard to match pairs if the only opportunities are to match with other hard to match pairs.[83]

Of course there are also financial barriers to organ transplantation. But Rees et al. (2017) propose that global kidney exchange is possible, because enough costs are avoided by healthcare systems when a patient is transplanted and hence taken off dialysis, so that in many situations these barriers can be overcome (Rees et al. (2024)). While this proposal has raised controversy among those who maintain that countries should be self-sufficient in transplantation, it is also receiving growing support.[84]

Not all barriers to international exchange are political or financial: we should never underestimate simple logistical and bureaucratic obstacles to organizing kidney exchange and transplantation generally. That has been part of the experience even in the US (Roth (2026a)), and there are still countries in which kidney exchange remains illegal (although this is changing in Brazil and Germany)[85]. In India, kidney exchange within single hospitals has overcome many bureaucratic impediments (see e.g. Kute et al. (2021)), and there is now an effort underway to organize it at a national level.

Note that liver exchange, although not nearly as well established as kidney exchange, is also growing around the world (see Hwang et al. (2010)). Liver donors may be incompatible with their intended recipients either because of blood type or size (but antibodies, which are

[82]See Biro et al. (2017), Biró et al. (2019)

[83]For example, Francisco et al. (2024) report that only three Portuguese patients received transplants through the international exchange program among Portugal, Spain and Italy begun in 2017. The Nordic countries have had some more success by including easier to match pairs along with hard to match pairs for international exchange, as have Czechia, Austria and Israel: see Weinreich et al. (2023) and Böhmig et al. (2024). And recognition is growing that significant international exchange is needed, see e.g., Böhmig et al. (2024), Al-Thnaibat et al. (2024), and Prasad et al. (2022).

[84]See e.g. Ambagtsheer et al. (2020), Minerva et al. (2019), Singer et al. (2020) and also, related, Roth et al. (2020), Bozek et al. (2018), Rees et al. (2017).

[85]See Ashlagi et al. (2024).

so important for kidney compatibility, don't play an important role). As in kidney exchange, the organization of liver exchange involves cycles and chains begun by non-directed donors. But in the US in 2025, while there were 11,635 deceased donor liver transplants and 709 living donor transplants (recall Table 2), there were only 29 liver exchange transplants (although there were 105 non-directed liver donations). So there is ample potential for growth of liver exchange[86].

Living donors are healthy people generously prepared to offer one of their organs to save a life, and their care and well-being are essential for the successful operation and continued growth of living donation. This includes not only their careful screening, and medical care as they become patients, but also how their needs are incorporated into donation and exchange procedures. (Gershun and Lantos (2021) give a donor view of how donors could be treated more considerately in one particular large transplant center.)

Overall, organ exchange is medically simple (in that compatible organs are transplanted) but logistically complex. Coordination between hospitals even in the same country required big efforts, as will international cooperation (Roth, 2026a). But there is ample room to increase the availability of living donor transplants.

# 6 Non-compensation of donors

Transplantation is unusual in that the the organs that save a person's life come from another person.[87] Living donation means that transplantation must be concerned not just with treating patients in need, but also with taking appropriate care of healthy donors.

That and other concerns connected to notions of human dignity have contributed to a reluctance to allow payment to donors, and a preference for relying entirely on purely altruistic unpaid donation, which often falls short of the need (Satel, 2008)[88] The Council

[86]To compare these numbers with kidney transplants, note that in the US there are about twice as many deceased donor kidney transplants, 10 times as many living donor kidney transplants, and 50 times as many kidney exchange transplants as for livers, but that there are only 5 times as many non-directed kidney donors as non-directed liver donors. See also Kute et al. (2025), Yilmaz et al. (2024), Yilmaz et al. (2023), Agrawal et al. (2023), Agrawal et al. (2022), and Salman et al. (2023). And Torres et al. (2019) report an exchange of a liver for a kidney .

[87]Transplantation shares this situation with transfusion medicine, which involves blood, blood plasma and other blood products (e.g. immunoglobulins and clotting factors) that also save lives and come from living donors. Many countries ban payments to plasma donors, but these bans are not as universal as are the bans on compensating kidney donors. Most countries that ban payments are unable to meet their domestic demand for plasma-derived pharmaceuticals, but they are able to purchase what the need, largely from the U.S, which does pay plasma donors and which exports tens of billions of dollars of plasma products each year (Elias et al. (2024), Krawiec and Roth (2025), Roth (2026b)).

[88]Roth (2007) and Roth (2026b) discuss a number of transactions that are sometimes regarded as repugnant when payments are introduced. In other medical contexts (experiments, clinical trials, surrogacy) see also Ambuehl et al. (2015), Lynch et al. (2021), Roth and Wang (2020).

of Europe (2002) states[89]: "*The human body and its parts shall not, as such, give rise to financial gain.*" And the most relevant U.S. law is the 1984 National Organ Transplant Act (NOTA),which says in part "*it shall be unlawful for any person to knowingly acquire, receive or otherwise transfer any human organ for valuable consideration for use in human transplantation*".

A much more detailed ban on payments to donors is contained in the influential Declaration of Istanbul (Abboud et al. (2008)) It seeks to prevent exploitation and coercion of donors,and bans what it calls transplant commercialism, saying "Transplant commercialism is a policy or practice in which an organ is treated as a commodity, including by being bought or sold or used for material gain." However not everyone interprets the DoI the same way: some interpret it as forbidding payments to donors only when they are coercive or exploitative. For example a joint statement by the American Society of Transplantation and the American Society of Transplant Surgeons (Salomon et al. (2015)) calls for creating an "arc of change" from removing disincentives to testing incentives."

And indeed, economists and others have long noted that paying for kidneys could relieve the shortage (Becker and Elias (2007)), and that it could pay for itself because transplantation is much cheaper than dialysis (Held et al. (2016), McCormick et al. (2018), McCormick et al. (2022)), while philosophers and others have noted that it is unusual to think that it is unethical to pay for something that it is ethical to give away (Cherry (2005), Taylor (2005), Brennan and Jaworski (2022) ). Surveys of the public indicate that there is a good deal of support for paying kidney donors as a means of reducing deaths due to kidney failure (see e.g. Leider and Roth (2010), Peters et al. (2016), Elías et al. (2019)).

As we write this in 2026, the 1984 NOTA has not been amended to allow any compensation of donors, despite several attempts, one of which is currently under consideration.[90] However, progress has been made in allowing donors to be reimbursed for the expenses they incur in donating a kidney or part of a liver.[91]

There are black markets for living-donor kidney transplants. Some of them involve paid donors who are falsely claimed to be (unpaid) relatives or friends, but in which the nephrectomies and transplants are carried out in qualified hospitals (see e.g. Ambagtsheer (2021)). There are also black markets in which transplants are conducted outside of qualified hospitals, and these can have quite bad outcomes for both donors and recipients (see e.g. Columb

[89] Council of Europe (2002) Additional Protocol to the Convention on Human Rights and Biomedicine, on Transplantation of Organs and Tissues of Human Origin

[90] The End Kidney Deaths Act would make nondirected kidney donors eligible to receive modest compensation by means of a refundable tax credit, `https://acrobat.adobe.com/link/track?uri=urn:aaid:scds:US:94cf575e-d035-3a44-99a9-92428228cb4a`. Chan and Sweat (2025) propose amending the NOTA to allow for payments to cover funeral expenses of deceased donors.

[91] Kidney exchange networks can also issue "vouchers" to donors, that are intended to be redeemable by someone else for priority in kidney exchange. See e.g. Veale et al. (2021), Akbarpour et al. (2024)

(2017)). There is some reason to believe that the Declaration of Istanbul, through its success limiting the presence of paid donors in qualified hospitals, shifted the black market to this more dangerous direction (see e.g. Ambagtsheer et al. (2020)).

Iran is presently the only country in the world that explicitly legalizes payments to living kidney donors in excess of their expenses (Akbarpour et al. (2020)). This is controversial. However Roth et al. (2022) point out that in Iran the paid donor transplants are conducted in well qualified hospitals, with appropriate care for both donors and recipients.[92]

# 7 Guide to the Data

Data on organ allocation in the US[93] is available from the OPTN (and similar data are available at the SRTR). These data are submitted by members of the OPTN. One dataset includes detailed characteristics on patients, donors (living and deceased), and all transplants.[94] Patient data include biological, medical, demographic, transplant center, active or inactive status on the list (inactive patients do not receive offers), relevant dates, transplant outcomes, metrics used for priorities (metrics may be given for a specific date, but can recalculated for any date based on raw data), and acceptance thresholds for donor characteristics. Donor data are similar and include also cause of death, the donor hospital, and the recovering OPO. Further donor lab results, such as perfusion, are also available. These data further provide waitlist history updates, which include changes to any patient-relevant data, including status, preferences, biological, etc.

Another large OPTN dataset includes all organ offers (in their priority order) and acceptance decisions,[95] the OPO that managed the offers (an organ that is accepted but ends up not being transplanted may trigger a new offering process by the local OPO), acceptance decisions, refusal reasons, notification and acceptance timestamps.[96] The OPTN website further provides descriptions of the allocation policies.

A large variability in organ recovery and transplant rates across OPO organizations has triggered CMS to monitor OPO performance metrics.[97] A challenge is shortage of data

[92] Kelishomi and Sgroi (2024) find that prospective Iranian donors who register for the paid-donor program and ultimately do donate a kidney are more risk averse than potential donors who register but don't complete the process. Their conclusion is that the alternative to donating a kidney for financially stressed people, such as dealing with a loan shark or selling a major asset, are more risky than donating a kidney.

[93] We faced some challenges in obtaining data in several countries.

[94] These data are given in Standard Transplant Analysis and Research (STAR) files.

[95] This is the Potential Transplant Recipient (PTR) data.

[96] Currently timestamps for primary offer notifications as well as expedited offers that have been declined are missing from the data. Expedited offers have usually done through phone calls. See Guan et al. (2025) for details.

[97] https://www.cms.gov/files/document/opo-annual-public-performance-report-2023.pdf.

about potential donors in each area and OPOs operations.[98,99]

Variability across centers' metrics can be found on the SRTR website[100]. We have created a dashboard that allows patients to compare transplant centers across different metrics.[101]

# 8 Open Questions and Research Directions

This section highlights research opportunities, some of which have been raised earlier.

**1. Can we design allocation rules free of justified envy that place hard to match organs quickly enough so that they remain transplantable?** A large number of recovered organs that might be transplanted are discarded. How can we increase utilization of marginal quality organs and get them accepted after fewer offers and less cold-ischemic time? How can we do this in a transparent and equitable way? How can we use information about organ quality that arrives during the offering process?[102] How can we use offer refusals in real time? How should we design allocation rules in the presence of social learning and potential information cascades (Zhang, 2010; Doval et al., 2024)? How should variability of centers' willingness to accept marginal organs be accounted for?

**2. How to design priorities to balance efficiency and equity?** How can priorities be designed to account for both longevity and urgency (Lazenby et al., 2025; Zhang et al., 2024)? How can priorities depend on patients' treatments, taking into account that treatment decisions may in turn depend on priorities (Sweat, 2023)? Countries use different priority rules and there is need to compare these to better understand trade-offs between these rules. The OPTN is seeking to implement continuous distribution allocation policies for hearts and kidneys, which will assign priority points smoothly across patient and match features. There are not yet studies that offer guidance to the resulting (in)efficiencies.[103]

**3. How should organ quality be measured and reported?** The percentile index of the kidney (KDPI) is currently used for both acceptance decisions by surgeons as well as in prioritization in the allocation system. As supply changes over time, percentiles correspond to different qualities. For example, a KDPI of 85% (which is the threshold for requiring patient consent to receive an offer) in 2018 corresponded to (i.e. has the same underlying

[98] Mortality Multiple Cause files can be attained from the National Center for Health Statistics (NCHS).

[99] A handful and selected group of OPOs have joint efforts to increase transparency (Adam et al., 2023).

[100] https://www.srtr.org/.

[101] https://tx.stanfordkpd.org/.

[102] Examples for approaches to expediting marginal organs include offering organs in parallel to multiple patients, and creating further categories for marginal organs that will be offered using different priorities.

[103] Can such an approach harm transparency, or increase congestion? How will it impact acceptance/rejection behavior? Will continuous priority rules reduce the manipulability present in existing tier systems?

non-normalized KDRI risk measure) as a KDPI of 75% in 2024 due to the recovery of more organs, and therefore more organs of marginal quality. Would the use of the non-normalized KDRI substantially change behavior and outcomes?

**4. How should surgeons' and patients' preferences be elicited?** The OPTN allows transplant centers to express preferences via filters that screen organ offers. Despite this, many organs are still declined hundreds and even thousands of times (Agarwal et al., 2021; Guan et al., 2025). How can we better design these filters? Can we use AI to help recommend filters or to predict organ refusals in real time? More broadly, how should waitlist mechanisms be designed given incomplete patients' and centers' preferences.

**5. How should transplant centers' performance be measured?** Should transplant centers be incentivized to accept marginal organs, e.g. for patients facing many years of dialysis? How should we regulate transplant centers? Are new incentive schemes useful in increasing utilization? For example, how will the acceptance rate and pre-transplant mortality rate metrics impact centers' behavior? CMS has also launched the Increasing Organ Transplant Access (IOTA) model, using a long term field experiment, that offers monetary incentives based on the number of transplants performed, graft survival, and percentage of accepted offers (Chan and Roth (2026).) How should we incorporate the huge role that transplant centers play in acceptance/rejection decisions when studying organ allocation mechanisms (Ashlagi et al., 2025; Chan and Roth, 2024)? There is need for research on designing centers' performance measures including outcomes for patients on the waiting list.

**6. How should OPO performance be measured?** OPOs vary in performance in terms of organ recovery and utilization, and incentive schemes remain controversial. How effective is the new tier system for monitoring OPOs based on donation and age-adjusted transplant rates? How should OPOs be incentivized to improve performance and transparency, and coordinate with transplant centers?[104]

**7. Understanding transplant centers' preferences.** Most theoretical models treat patients as the decision makers who accept or reject organ offers. In practice, however, transplant centers exercise substantial discretion over acceptance decisions, listing practices, and setting filters. How do equilibrium outcomes reflect centers' preferences? There is need for empirical and theoretical studies for better understanding how centers' characteristics and incentives shape outcomes.

**8. Need for simulation tools and structural models that account for equilibrium behavior.** Simulations and historical data have been instrumental to study and design allocation policies. Existing simulations apply myopic acceptance models that are invariant

[104]See Skowronski et al. (2025); Bae et al. (2025); Chan and Roth (2024).

to the allocation rules. There is need for simple modern simulation tools that account for incentives of patients and centers.[105] It would be interesting to generate tools that not only generate better equilibrium predictions but also short term equilibration effects.[106]

**9. What kinds of experiments should the OPTN conduct?** The OPTN conducts very few controlled experiments, despite facing ongoing allocation policy decisions. While simulation tools are useful to inform policy, another approach is through field experiments. Experiments can generate useful data to evaluate different approaches (e.g., for expediting placements). The size and heterogeneity of the United States presents opportunities to test different approaches. But it also raises questions about whether different approaches would work differently in different regions, and about how to overcome the reluctance to do experiments.

**10. How can countries with low transplant rates be helped?** Many countries have low living and/or deceased donation rates. Understanding the underlying barriers (organization structure, population preferences, etc.) would be fruitful in making progress towards increasing transplant rates.[107]

**11. What can be done to increase incentives for organ donation in ways that attract social support?** What accounts for the widespread reluctance to increase organ donation by compensating donors? How can economists better explain the value of incentives in addressing scarcity, and gather persuasive evidence and engage in productive dialog with those who fear that this will increase rather than decrease black markets, or who feel there are fundamental religious or ethical reasons why organs must be donated without monetary compensation? (For some thoughts on this see Roth (2026b)).

# 9 The day after tomorrow

Efforts to quickly make transplants less scarce include recovering more transplantable organs from deceased donors, successfully transplanting more of those recovered organs, and facilitating more living-donor organ transplants of kidneys and livers. In the longer term, efforts are underway to reduce the need for human organ transplants, by reducing the need for re-transplantation (after graft failure), and by preventing organ failure or curing it by other means.

[105] Patients' and centers' decisions will likely adapt to changes in the priority structure, since those determine the offers they will receive.

[106] For a simulation tool in this direction see Agarwal et al. (2021) for kidney allocation, and a simple single-dimensional preferences by Cerna et al. (2025).

[107] See, e.g., Okubo et al. (2025).

It's common to hear that xenotransplantation is tomorrow's cure for organ failure, and always will be. But recent developments with transplanting organs from genetically modified pigs into primates and humans suggest that the future possibilities are real, even though (as of this writing) no pig organ transplant to a human has yet survived for as much as a year (although there have now been some pig kidney and heart transplants that worked for months, Tector (2025)). Another somewhat related approach involves trying to bioengineer an artificial kidney by removing from a pig kidney the pig cells that would be attacked by the human immune system, leaving a scaffold that could be populated with human kidney cells (Lo et al. (2024)). Less developed so far is the hope of regrowing kidneys through some kind of stem cell manipulations, although some kidney cell growth in mice has been achieved (Araoka et al. (2025)).

Each of these lines of research offers the possibility of reducing or ending the need for and hence the scarcity of human organs for transplantation. That scarcity would also be reduced by medical progress in reducing the incidence and progression of kidney disease and its precursors, and of other kinds of organ failure that now require transplantation.

Yet it remains likely that almost everyone whose life could be extended by a human organ transplant today will die without one, and so our attention to the shortage of transplants is still needed.

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