Chapter 6: Transplantation

- In this 2017 Annual Data Report (ADR) we introduce a new chapter feature with data on outcomes following wait listing for patients, as a function of their age, blood type, and percent of panel reactive antibodies (PRA; Table 6.2).
- In addition, this year we highlight any relevant trends that may have resulted from the December 2014 changes to the kidney allocation system (KAS) policy. As this chapter only includes data through the end of 2015, we cannot yet fully evaluate the impact of the policy on longer-term outcomes.
- In 2015, 18,805 kidney transplants were performed in the United States (18,021 were kidney-alone; Figure 6.5).
- One-third of kidneys transplanted in 2015 were from living-donors (Figure 6.5).
- From 2014 to 2015, the cumulative number of recipients with a functioning kidney transplant increased by 3%, to a total of 207,810 (Figure 6.6)
- On December 31, 2015, the kidney transplant waiting list had 83,978 candidates on dialysis, 52,703 (62.8%) of whom were active. Eighty-four percent of all candidates were awaiting their first transplant (Figure 6.1).
- Among 2010 candidates newly wait-listed for either a first or repeat kidney-alone transplant (living or deceased-donor), the median waiting time to transplant was 3.9 years (Figure 6.4). This waiting time varied greatly by region of the country, from a low of 1.2 years in Utah to a high of 5.2 years in Georgia (Reference Table E.2.2).
- Unadjusted rates of kidney transplantation among dialysis patients had been declining since at least 2006 for candidates for both living and deceased-donors. These appear to have stabilized as of 2013, at about 2.0 per 100 dialysis patient years for recipients from deceased-donors and about 1.2 per 100 dialysis patient years for recipients from living-donors (Figure 6.7).
- The number of deceased kidney donors, aged 1-74 years, with at least one kidney retrieved increased from 5,895 in 2001 to 8,818 in 2015.
- The rate of kidney donation from deceased Blacks/African Americans almost doubled from 2001 to 2015, from 4.0 to 7.4 donations per 1,000 deaths (Figure 6.20.b). This rate overtook that of Whites in 2009, but Asians consistently had the highest rate of deceased kidney donation during this time, at about 8 per 1,000 deaths.
- Since 1998, Whites have had the highest rate of living kidney donation, although this has been in steep decline along with all other races except Asians, who as of 2015 showed rates of living donation essentially equivalent to Whites (Figure 6.15.b).
- Seventeen percent of kidneys recovered from deceased-donors were discarded in 2015; this rate has been stable since 2010. The number of kidney paired donation transplants rose sharply in recent years, with 582 performed in 2015. This represented 10% of living-donor transplants that year, and the rate appears to have plateaued (Figure 6.17).
- Since 1998, the probabilities of graft survival and patient survival have steadily improved among recipients of both living and deceased-donor kidney transplants (Tables 6.4 and 6.5).
- In 2014, the probabilities of one-year graft survival were 93% for deceased and 97% for living-donor kidney transplant recipients (Tables 6.4 and 6.5).
- In 2014 the probabilities of patient survival within one year post-transplant were 96% and 99% of deceased- and living-donor kidney transplant recipients (Tables 6.4 and 6.5).
- The one-year graft-survival and patient-survival advantages experienced by living-donor transplant recipients persisted at five and ten years post-transplant (Tables 6.4 and 6.5).

Introduction

Kidney transplantation is the renal replacement therapy of choice for the majority of patients with end-stage renal disease (ESRD). Successful kidney transplantation is associated with improved survival, improved quality of life, and health care cost savings when compared to dialysis. This chapter reports on the trends of the kidney transplant waiting list, kidney transplants performed over the years, and the health outcomes of those who have received a transplant. To enhance further our understanding of the donor pool, we report the trends and epidemiology of deceased kidney donations among deaths of all causes and traumatic deaths. In addition, this year we add data on outcomes following wait listing for patients as a function of age, blood type, and PRA (Table 6.2).

Recently, the Organ Procurement and Transplantation Network (OPTN) conducted major revisions of the kidney allocation system (KAS). These changes took effect on December 4, 2014, with the objectives of reducing discards of potentially usable donor kidneys, decreasing access disparities, and decreasing unrealized life-years from the available organ supply. Some of the substantial KAS changes included:

(1) A move to a continuous, percentile based (lower is better) description of **donor** quality, the Kidney Donor Profile Index (KDPI; OPTN, 2016). This metric consists of ten donor factors, and replaces the previous binary categories of standard criteria or extended criteria donors that incorporated only four factors.

(2) For use in conjunction with the KDPI, the calculation of an Expected Post-Transplant Survival (EPTS) score for all adult kidney **recipient** candidates. The EPTS is based on four factors: age, time on dialysis, prior transplant of any organ, and presence of diabetes. This allows preferential allocation of donor kidneys with the best KDPI scores of 20% or less, to younger and healthier candidates with the best EPTS scores of 20% or less.

(3) Increased priority for sensitized candidates through a sliding scale point system based on their calculated panel reactive antibodies (PRA).

(4) The inclusion of pre-waiting list dialysis time in a candidate's waiting time (OPTN, 2015).

In this year's chapter, where relevant, we highlight any trend changes that may have resulted from the new policy. As this chapter only includes data through the end of 2015, we cannot yet fully evaluate the impact of the policy on longer-term outcomes, but this will be an ongoing focus in future ADRs.

Methods

The findings presented in this chapter were drawn from multiple data sources, including from the Centers for Medicare & Medicaid Services (CMS), OPTN, the Centers for Disease Control and Prevention (CDC), and the U.S. Census. Details of these are described in the *Data Sources* section of the *ESRD Analytical Methods* chapter.

See the section on Chapter 6 in the *Analytical Methods Used in the ESRD Volume* section of the *ESRD Analytical Methods* chapter for an explanation of the analytical methods used to generate the study cohorts, figures, and tables in this chapter. Downloadable Microsoft Excel and PowerPoint files containing the data and graphics for these figures and tables are available on the USRDS website.

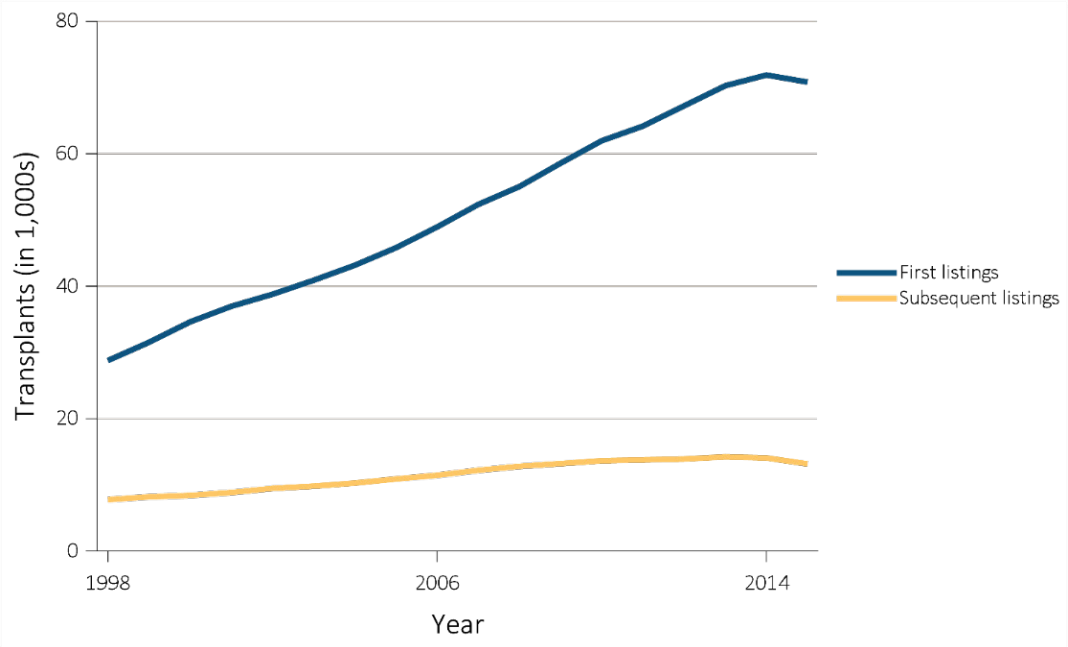
Kidney Transplant Waiting List

As of December 31, 2015, the kidney transplant waiting list decreased for the first time, by 2.3% over the previous year to 83,978 candidates (dialysis patients only), 84% of whom were awaiting their first kidney transplant (Figure 6.1). Notably, this decline was primarily driven by a reduction in the number of inactive wait-listed candidates to 31,275, a 5.6% reduction compared to the previous year (Reference Table E.3). This decrease almost certainly resulted from the new KAS policy changes. For patients already on dialysis at the time of listing, the KAS now ties the start of waiting time to date of dialysis initiation, regardless of when listing occurred. This thus reduced the incentive to list dialysis patients until they are actively ready for transplantation.

For those who meet glomerular filtration rate (GFR) criteria and are pre-dialysis, however, there is still an advantage to listing before dialysis initiation. Nevertheless, with less than 19,000 kidney transplants performed in the U.S. in 2015, the active waiting list remains nearly three times larger than the supply of donor kidneys, which presents a continuing challenge.

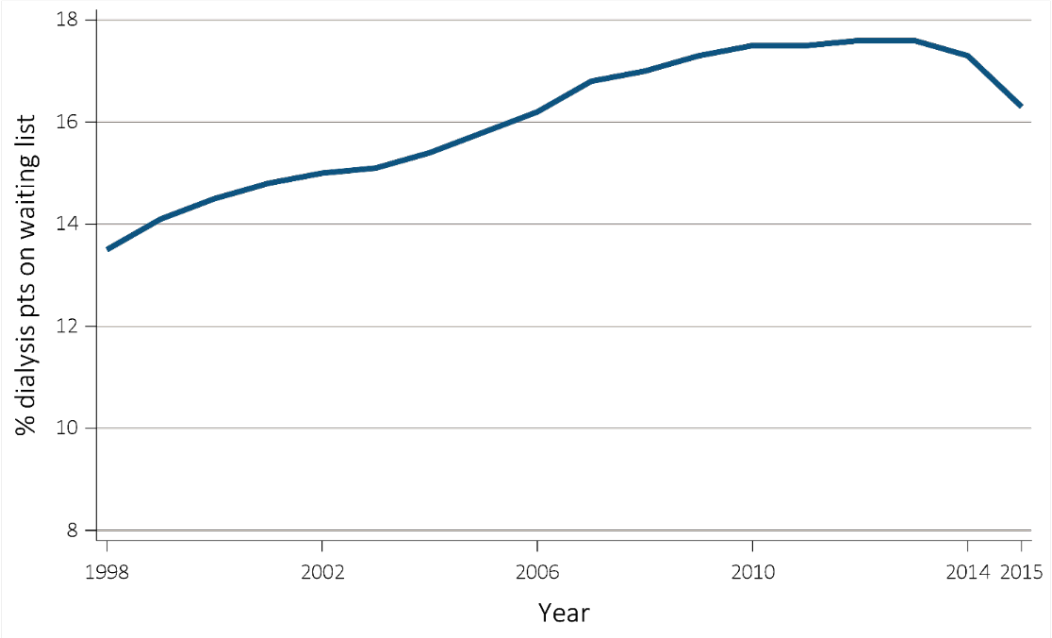
Like the above trends, the percentage of prevalent dialysis patients wait-listed for a kidney has also recently declined (Figure 6.2).

vol 2 Figure 6.1 Number of patients who were wait-listed for kidney transplant, 1998-2015



Data Source: Reference Table E.3. Number of patients wait-listed for kidney transplant. Waiting list counts include all candidates listed for a kidney transplant on December 31 of each year. Note that trends may be influenced by changes to the kidney allocation system (KAS) policy that were implemented in December 2014.

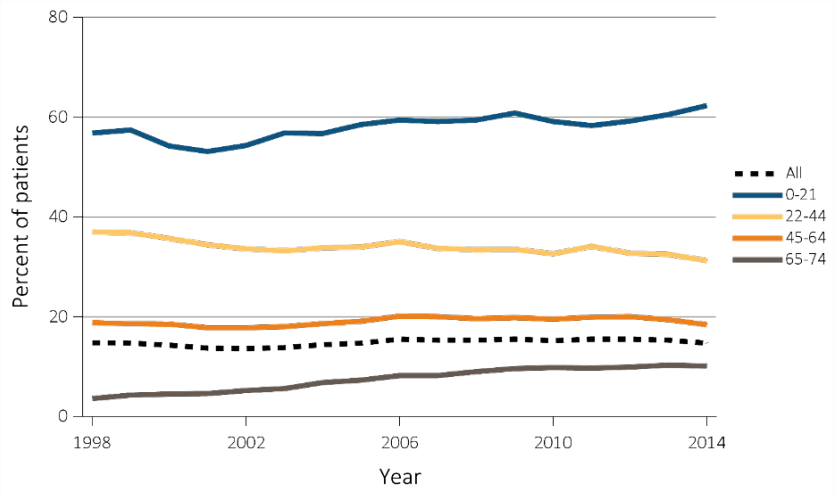
vol 2 Figure 6.2 Percentage of dialysis patients who were wait-listed, 1998-2015



Data Source: Reference Table E.4. Percentage of dialysis patients on the kidney waiting list is for all dialysis patients. Note that trends may be influenced by changes to the kidney allocation system (KAS) policy that were implemented in December 2014. Abbreviation: pts, patients.

In 2014, 14.7% of incident ESRD patients who started dialysis that year joined a waiting list, or received a deceased or living-donor transplant within one year of ESRD initiation (Figure 6.3). Since 2001, the percentage of patients wait-listed or receiving a transplant in their first ESRD-year has declined for those between the ages of 22 and 44 years, but has increased steadily among those patients aged 0-21 years. There has been a consistent increase over time in the percentage of patients aged 65-74 years being wait-listed or receiving a kidney transplant within one year of ESRD initiation, however, older patients continue to comprise the minority of this group.

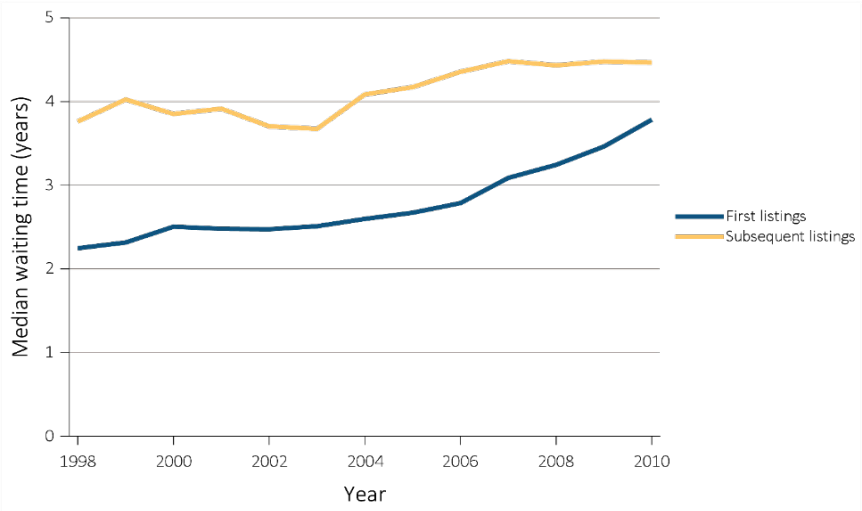
vol 2 Figure 6.3 Percentage of incident patients who were wait-listed or received a kidney transplant within one year of ESRD initiation, by age, 1998-2014



Data Source: Reference Table E.5(2). Waiting list or transplantation among incident ESRD patients by age (0-74 years). Note that trends may be influenced by changes to the kidney allocation system (KAS) policy that were implemented in December 2014. Abbreviation: ESRD, end-stage renal disease.

Median waiting time to transplantation continues to increase for those listing for the first time (Figure 6.4). Among 2010 candidates newly wait-listed for either an initial or repeat kidney-alone transplant, the median waiting time (deceased or living-donor) was 3.9 years—50% of these patients received a transplant within 3.9 years after being wait-listed for a transplant. For first-time listings, the median 2010 waiting time to transplantation (deceased or living-donor) was 3.8 years, eight months shorter than that for candidates listed for repeat transplants.

vol 2 Figure 6.4 Median waiting time for kidney transplant, 1998-2010



Data Source: Reference Tables E.2. Median waiting time to kidney transplant. Median waiting time is calculated for all candidates enrolled on the waiting list in a given year.

Table 6.1 presents median waiting times, stratified by blood type and PRA sensitization at time of listing. Patients with blood types B and O had the longest wait. As expected, patients with higher PRA percentages tended to have longer waiting times; this duration has been decreasing for those with the highest levels of sensitization (PRA of 80% or greater).

vol 2 Table 6.1 Median waiting time (in years) for kidney transplant, by blood type and PRA, 1998-2010

Blood type	PRA	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Blood type A	PRA = 0	1.5	1.5	1.7	1.7	1.7	1.7	1.8	1.7	2.0	2.2	2.3	2.5	2.9
	0 < PRA =< 20%	1.6	1.6	1.8	2.2	2.2	1.9	1.9	2.0	1.8	2.2	2.6	2.5	2.5
	20% < PRA =< 80%	2.8	3.2	3.0	3.5	3.0	3.0	3.3	2.9	2.9	3.0	2.5	2.5	2.5
	80% < PRA < 98%	5.6	4.3	4.1	4.0	4.0	5.0	4.2	6.1	4.7	4.9	3.6	4.2	3.7
	98% =< PRA =< 100%	6.5	^	8.0	7.9	8.4	9.7	5.9	9.2	7.1	7.1	^	^	^
Blood type B	PRA = 0	3.3	3.6	3.9	3.6	3.6	3.5	3.4	3.4	4.0	3.9	4.0	4.1	4.8
	0 < PRA =< 20%	3.6	3.9	4.2	4.5	4.2	3.6	3.7	4.3	4.0	3.5	3.9	4.5	4.8
	20% < PRA =< 80%	4.6	4.4	5.3	7.5	5.6	6.2	7.4	5.5	5.5	5.0	5.2	5.2	3.7
	80% < PRA < 98%	4.4	7.0	^	11.9	^	7.5	11.5	6.6	^	6.4	6.6	6.6	^
	98% =< PRA =< 100%	^	^	^	10.0	^	^	^	^	^	^	^	^	5.9
Blood type AB	PRA = 0	0.8	0.9	1.0	1.1	1.1	1.2	1.3	1.1	1.2	1.5	1.4	1.6	2.0
	0 < PRA =< 20%	1.1	1.3	1.1	1.4	0.8	1.4	1.2	1.2	1.1	1.2	1.1	1.8	1.4
	20% < PRA =< 80%	1.8	3.1	3.0	2.1	2.9	2.5	2.9	3.6	2.7	3.2	2.1	2.6	1.4
	80% < PRA < 98%	4.6	4.3	4.9	7.1	1.8	3.7	^	2.7	2.0	4.1	7.0	5.8	3.2
	98% =< PRA =< 100%	1.9	6.2	13.5	3.0	^	4.6	^	2.1	^	^	6.4	6.6	^
Blood type O	PRA = 0	2.8	3.0	3.1	3.1	3.1	3.0	3.2	3.4	3.5	3.9	3.9	4.2	4.7
	0 < PRA =< 20%	3.5	3.2	3.6	3.7	3.7	3.4	3.6	3.7	3.2	3.8	4.1	3.8	4.7
	20% < PRA =< 80%	4.8	4.5	4.6	5.2	4.2	4.1	5.0	4.4	4.3	4.5	4.1	4.1	4.3
	80% < PRA < 98%	4.8	6.7	8.0	7.1	5.9	6.6	8.8	5.4	6.1	7.5	6.3	5.6	4.8
	98% =< PRA =< 100%	5.5	^	14.6	8.0	10.8	8.5	^	10.3	9.1	^	7.4	^	^

Data Source: Special analyses, USRDS ESRD Database. Abbreviation: PRA, panel reactive antibodies. ^ Value is blank since the estimated time to transplant probability had not reached 50% (median) at the end of the follow up, so the median waiting time could not be calculated.

In addition to variations in waiting time as a function of blood type and level of sensitization, there are also large regional differences (Reference Table E2.2). Two states, South Dakota and Georgia, have waiting times greater than five years. Seven states have waiting times of less than two years, with the lowest seen in Utah (1.2 years), Vermont (1.2 years), and Nebraska (1.5 years).

Table 6.2 displays outcomes within five years of follow-up for candidates who were first listed in 2010, as a function of their blood type, PRA, and age. Overall, among those not receiving a living-donor transplant, at five years 40% had received a deceased-donor transplant, slightly over a third had died or been removed from the waiting list, and nearly a quarter remained on the waiting list. Older patients were more likely to be removed from the waiting list or to die while waiting; the outcome of death was more likely than receipt of a deceased-donor transplant for most strata of patients aged 65 years or older. As expected, blood type also affected the outcomes. Finally, PRA appears to have had a minimal effect, possibly related to allocation policy initiatives aimed at improving access for sensitized patients.

vol 2 Table 6.2 Reported outcomes within five years since first listing in 2010, by blood type, PRA, and age

Patient characteristics			Number who received a living-donor transplant	Outcomes of patients who did not receive a living-donor transplant			
				Total number of patients	Received a deceased-donor transplant (%)	Still on waiting list (%)	Removed from waiting list at death or reason other than transplant (%)
Blood type	**PRA**	**Age**					
Blood type A	**PRA<20**	0-21	122	215	83	9	7
		22-44	585	1,245	54	21	25
		45-64	879	3,566	49	16	35
		65+	202	1,311	44	8	47
	PRA>=20	0-21	*	*	*	*	.
		22-44	38	97	55	16	29
		45-64	47	213	56	13	31
		65+	11	72	43	*	51
Blood type B	**PRA<20**	0-21	36	97	81	*	*
		22-44	204	647	34	38	28
		45-64	282	1,649	31	31	38
		65+	59	503	27	18	55
	PRA>=20	0-21	*	*	*	*	.
		22-44	15	37	30	35	35
		45-64	20	130	35	31	35
		65+	*	31	*	*	65
Blood type AB	**PRA>=0§**	0-21	14	29	79	*	*
		22-44	65	197	69	14	17
		45-64	100	452	61	11	29
		65+	16	163	56	*	39
Blood type O	**PRA<20**	0-21	142	396	77	11	12
		22-44	649	2,094	34	37	29
		45-64	975	5,326	32	30	38
		65+	258	1,752	29	17	54
	PRA>=20	0-21	*	18	61	*	*
		22-44	27	177	42	26	32
		45-64	47	345	37	26	37
		65+	*	103	23	18	58
All blood types			**4,812**	**20,874**	**40**	**23**	**37**

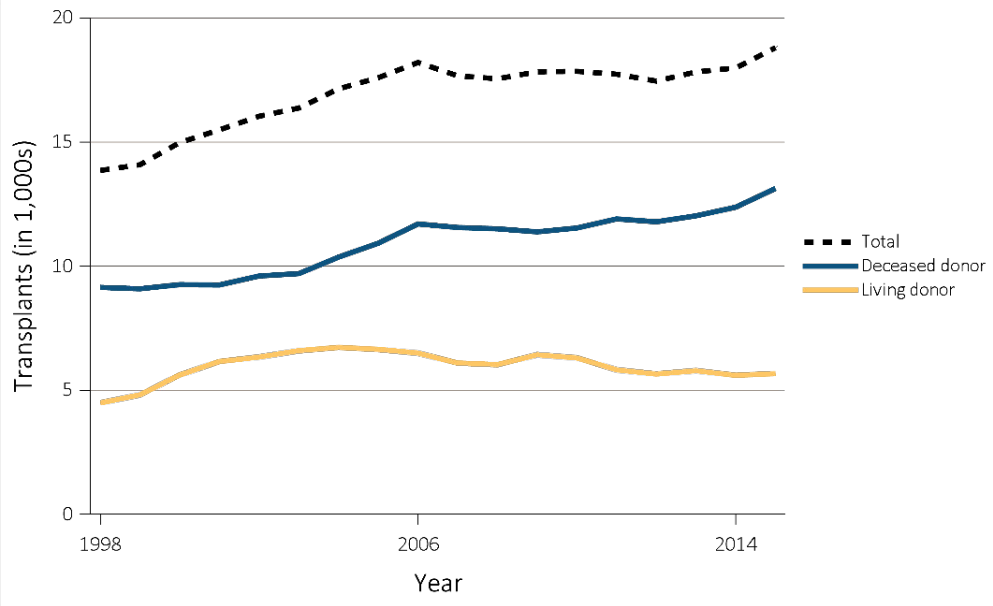
*Data Source: Special analyses, USRDS ESRD Database and the Organ Procurement and Transplantation Network (OPTN). Reported outcomes within five years since first listing in 2010, by blood type, PRA, and age. § PRA is not dichotomized due to small sample size. * Suppressed due to inadequate sample size. A dot (.) represents a zero value.*

Transplant Counts and Rates

During 2015, 18,805 kidney transplants were performed in the U.S., including 18,021 kidney-alone and 784 kidney plus at least one additional organ (Figure 6.5). Of these transplants, 5,672 were identified as originating from living-donors (30.2%) and 13,132 (69.8%) from deceased-donors. Overall, there were a record number of kidney transplants that year, with 815 (4.5%) more procedures occurring in 2015 than in 2014, and 596 (3.3%) more than during the previous peak in 2006.

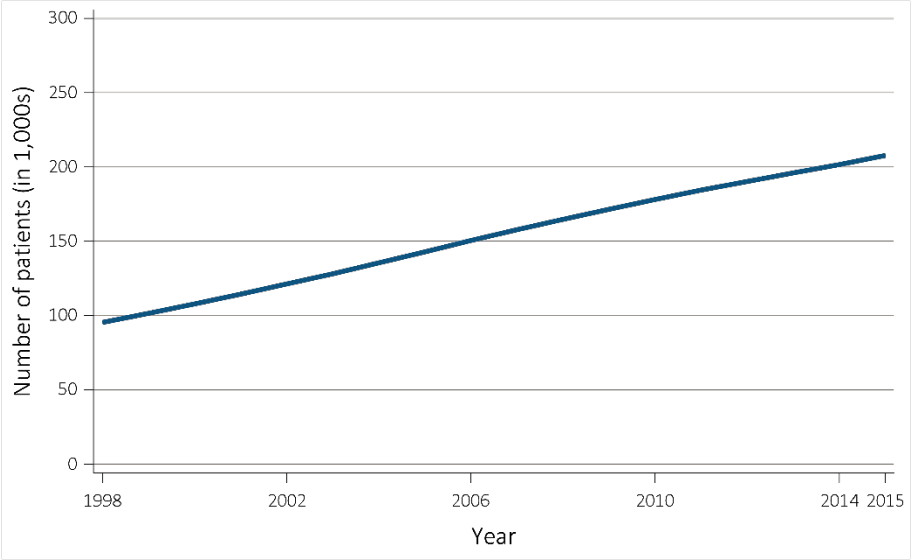
The cumulative number of recipients living with a functioning kidney transplant continues to grow, reaching 207,810 in 2015, a 3% increase over 2014 (Figure 6.6).

vol 2 Figure 6.5 Number of kidney transplants by donor type, 1998-2015



Data Source: Reference Tables E.8, E.8(2), and E.8(3). Number of kidney transplants by donor type. Note that trends may be influenced by changes to the kidney allocation system (KAS) policy that were implemented in December 2014.

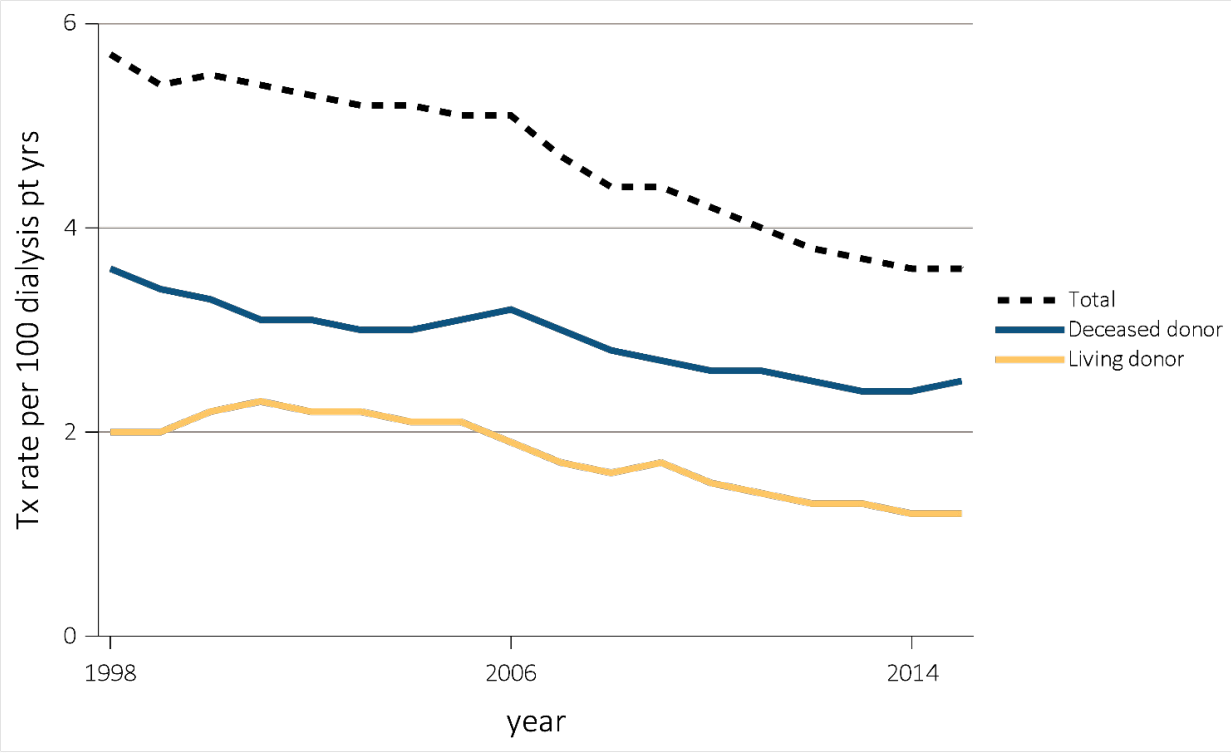
vol 2 Figure 6.6 Number of patients with a functioning kidney transplant, 1998-2015



Data Source: Reference Table D.9. Prevalent counts of patients with a functioning kidney transplant as of December 31 of each year. Note that trends may be influenced by changes to the kidney allocation system (KAS) policy that were implemented in December 2014.

As the overall dialysis population expanded, the annual unadjusted transplant rate per 100 dialysis patient years saw a continuous decline, although it plateaued in 2015 (Figure 6.7). This plateau appeared to result from a small increase in the deceased-donor transplant rate in 2015, likely influenced by a relatively large increase in the deceased-donor transplant count that year.

vol 2 Figure 6.7 Unadjusted kidney transplant rates, by donor type, 1998-2015



Data Source: Reference Table E.9. Unadjusted transplant rates are for all dialysis patients. Note that trends may be influenced by changes to the kidney allocation system (KAS) policy that were implemented in December 2014. Abbreviations: pt yrs, patient years; tx, transplant.

In 2015, there was an increase in transplant rates among patients 22-44 years old, reversing the previous decade-long trend of decline (Table 6.3). Similarly, there was also an increase in transplant rates for Blacks in 2015, reversing a decline seen since 2010. The transplant rate for patients with diabetes mellitus (DM) continued to decline. In upcoming sections, we present counts and rates of transplants separately for deceased- versus living-donor sources, as trends differed substantially for certain subgroups. This particularly resulted from KAS policy changes that primarily influence deceased-donor transplants.

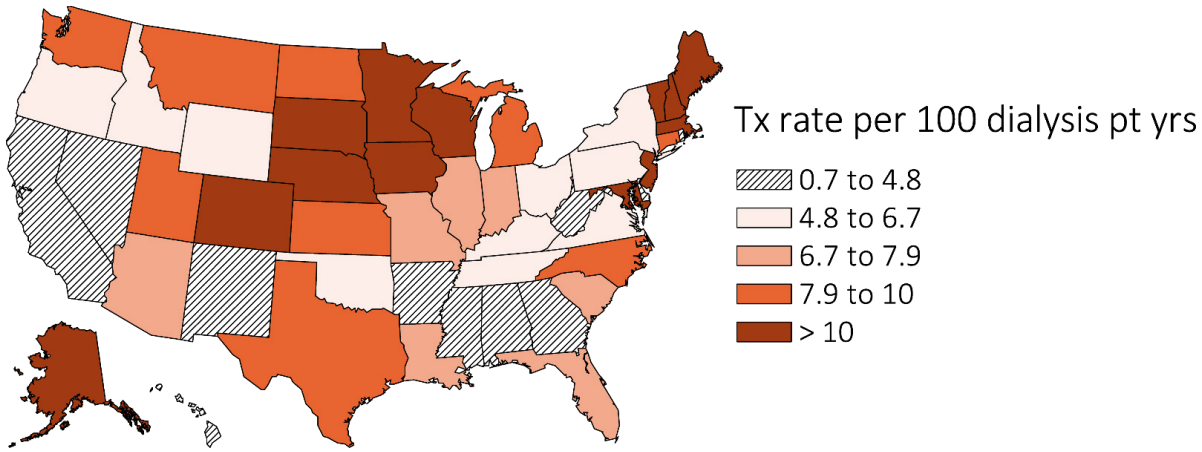
Rates of transplantation per 100 dialysis patient years are presented by geographic region in Figure 6.8, without statistical adjustment. The upper Midwest and New England demonstrated the highest transplant rates, with lower rates found in California, and areas of the Southwest and South. The wide regional variations may relate to geographic differences in organ availability and ESRD incidence (Mathur et al., 2010).

vol 2 Table 6.3 Unadjusted kidney transplant rates, all donor types, by age, sex, race, and primary cause of ESRD, per 100 dialysis patient years, 2006-2015

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Age										
0-21	38.6	32.7	33.1	35.3	33.6	32.2	32.9	32.2	33.1	34.7
22-44	10.9	10.1	9.3	9.2	8.6	8.3	8.1	7.9	7.8	9.3
45-64	5.9	5.6	5.3	5.1	4.9	4.7	4.4	4.4	4.2	4.2
65-74	2.7	2.6	2.6	2.6	2.6	2.6	2.5	2.5	2.5	2.2
75 and older	0.3	0.4	0.3	0.4	0.4	0.4	0.4	0.3	0.4	0.3
Sex										
Male	5.6	5.1	4.8	4.6	4.4	4.3	4.0	4.0	3.8	3.9
Female	4.3	4.0	3.8	3.8	3.7	3.5	3.3	3.3	3.2	3.3
Race										
White	6.0	5.5	5.2	5.0	4.7	4.5	4.3	4.3	4.1	4.0
Black/African American	3.3	3.1	2.9	3.0	3.0	2.9	2.6	2.6	2.5	2.8
American Indian/Alaska Native	3.9	2.9	3.6	3.7	2.9	3.0	2.5	2.2	2.7	3.2
Asian	5.9	5.3	5.5	5.1	5.1	4.8	4.7	4.8	4.7	5.2
Primary Cause of ESRD										
Diabetes	3.2	3.1	2.9	2.8	2.6	2.5	2.3	2.3	2.2	2.0
Hypertension	3.2	3.1	3.0	2.9	2.8	2.6	2.6	2.5	2.5	2.6
Glomerulonephritis	9.9	9.0	8.7	8.6	8.7	8.2	7.9	7.8	7.5	8.3
All	5.0	4.6	4.4	4.3	4.1	3.9	3.7	3.7	3.6	3.6

Data Source: Reference Table E.9. Note that trends may be influenced by changes to the kidney allocation system (KAS) policy that were implemented in December 2014. Abbreviation: ESRD, end-stage renal disease.

vol 2 Figure 6.8 Geographic distribution of unadjusted transplant rate by state, 2015



Data Source: Special analyses, USRDS ESRD Database. Geographic distribution of unadjusted transplant rate by state, 2015. Note that trends may be influenced by changes to the kidney allocation system (KAS) policy that were implemented in December 2014. Abbreviation: pt yrs; patient years; tx, transplant.

Counts and Rates of Deceased-Donor Transplants

As presented above in Figure 6.5, the overall number of deceased-donor transplants remained consistent between 2006 and 2011, and has increased steadily since 2012. In this section, we review detailed trends in counts and rates of deceased-donor transplants, by age, sex, race, and primary cause of ESRD (Figures 6.9-6.12).

Counts and rates of deceased-donor transplantation per 100 dialysis patient years are presented by age category in Figure 6.9, without statistical adjustment. Following a steady increase seen since before 1998, the counts were highest for recipients aged 45-64 years, reaching 6,322 in 2015 (Figure 6.9.a). In contrast, for those aged 22-44 years the number of deceased-donor transplants declined from 2006 to 2014, but increased sharply from 2,906 in 2014 to 3,915 in 2015. In 2015 there was a decline in transplant counts for those aged 65-74 years, reversing the previously rising trend.

These recent trend changes correlate temporally with the implementation of the new KAS policy in December 2014. As outlined in the Introduction, the quality assessment of deceased-donor organs was changed from a binary rating (extended criteria donor, ECD vs. standard criteria donor, SCD) to a continuous, percentile rating (lower is better) via the KDPI. In addition, the new policy gave priority for allocation of the highest quality kidneys (KDPI≤20) to younger, healthier candidates with the best EPTS, a key change. As these candidates also have equal access to other higher KDPI kidneys, they are effectively at a combined advantage in terms of overall access to deceased organs.

The patterns for deceased-donor transplant counts shown in Figure 6.9.a contrast with the rates shown in Figure 6.9.b, likely because the number of dialysis patients varies, increasing markedly with age. Due to the small denominator for children on dialysis, and the priority for allocating kidneys from deceased-donors under the age of 35 years to pediatric patients, deceased-donor transplant rates are highest in the <22 years category that includes children. The rates for this group increased in 2005-2007, then stabilized until 2013, and have since increased. There has been a slow reduction in deceased-donor kidney transplantation rates for those aged 45-64 and 65-74 years. The rate for those aged 22-44 years rose sharply in 2015, reflecting a 34.7% increase in counts that year.

vol 2 Figure 6.9 Number of deceased-donor transplants and unadjusted transplant rates among deceased-donor kidney recipients, by recipient age, 1998-2015

(a) Number of transplants by age

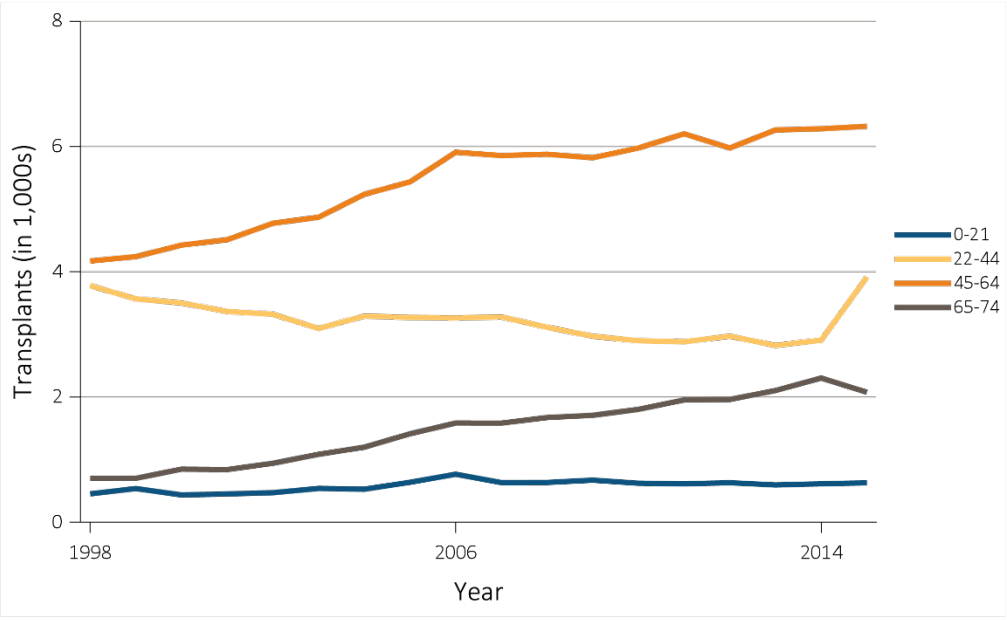
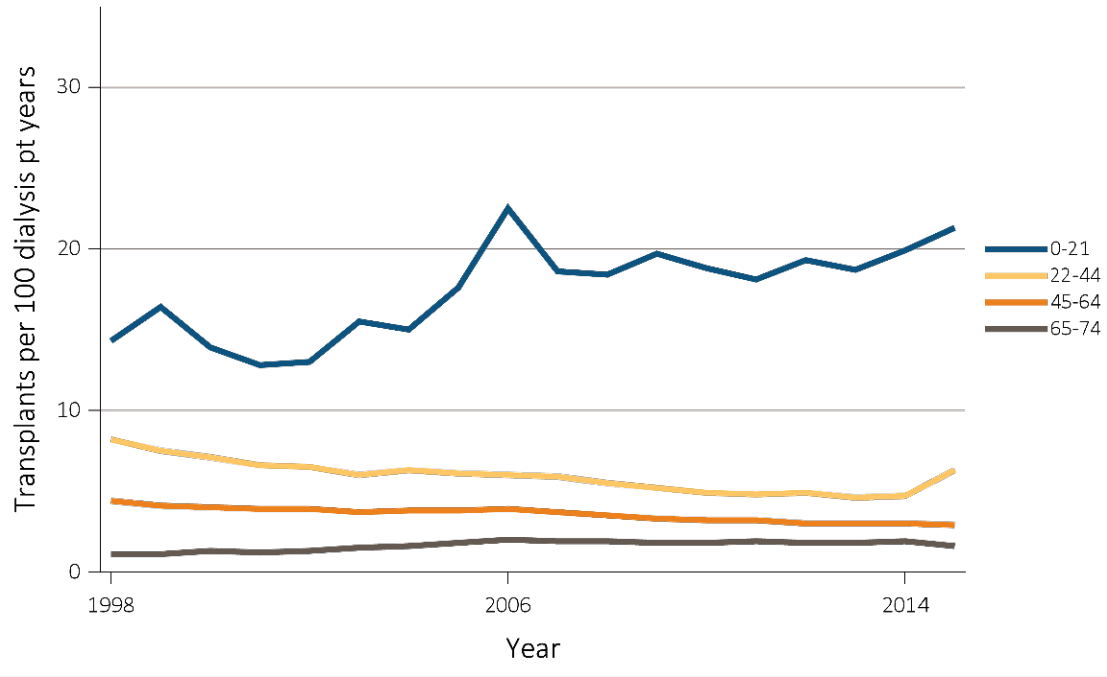


Figure 6.9 continued on next page.

vol 2 Figure 6.9 Number of deceased-donor transplants and unadjusted transplant rates among deceased-donor kidney recipients, by recipient age, 1998-2015 *(continued)*

(b) Transplant rates by age

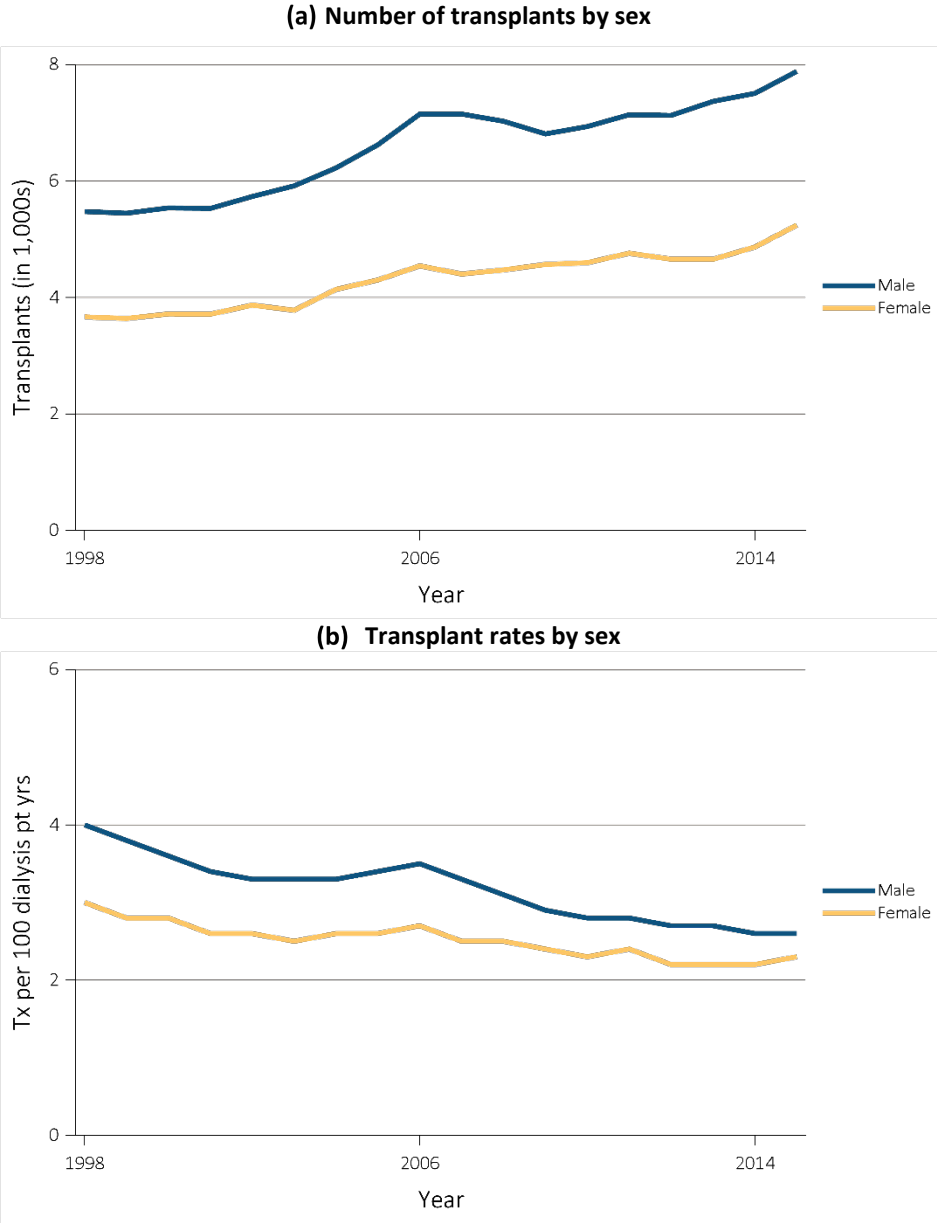


Data Source: Reference Tables E.8(2) and E.9(2). (a) Deceased donor kidney transplant counts by recipient age. (b) Unadjusted deceased-donor kidney transplant rates by recipient age. Note that trends may be influenced by changes to the kidney allocation system (KAS) policy that were implemented in December 2014. Abbreviation: pt, patient.

The trends for counts of deceased-donor transplants by year are similar for males and females—rising over the past decade, with some leveling off after 2006 and an increase seen again after 2013 (Figure 6.10.a). Males received substantially more deceased-donor transplants than did females, on average 52.9% more annually since 1998. This difference seems to be largely explained by the fact that males account for more than 60% of wait-listed candidates (Reference Table E.3).

The rates of deceased-donor kidney transplantation have generally declined since 2006 for both male and female dialysis patients (Figure 6.10.b), although they appear to have stabilized, with a slight increase among females in 2015. The latter finding may result from the additional prioritization of sensitized candidates in the new allocation policy. The difference in actual transplantation rates between males and females has been narrowing in recent years.

vol 2 Figure 6.10 Number of deceased-donor transplants and unadjusted transplant rates among deceased-donor kidney recipients, by recipient sex, 1998-2015

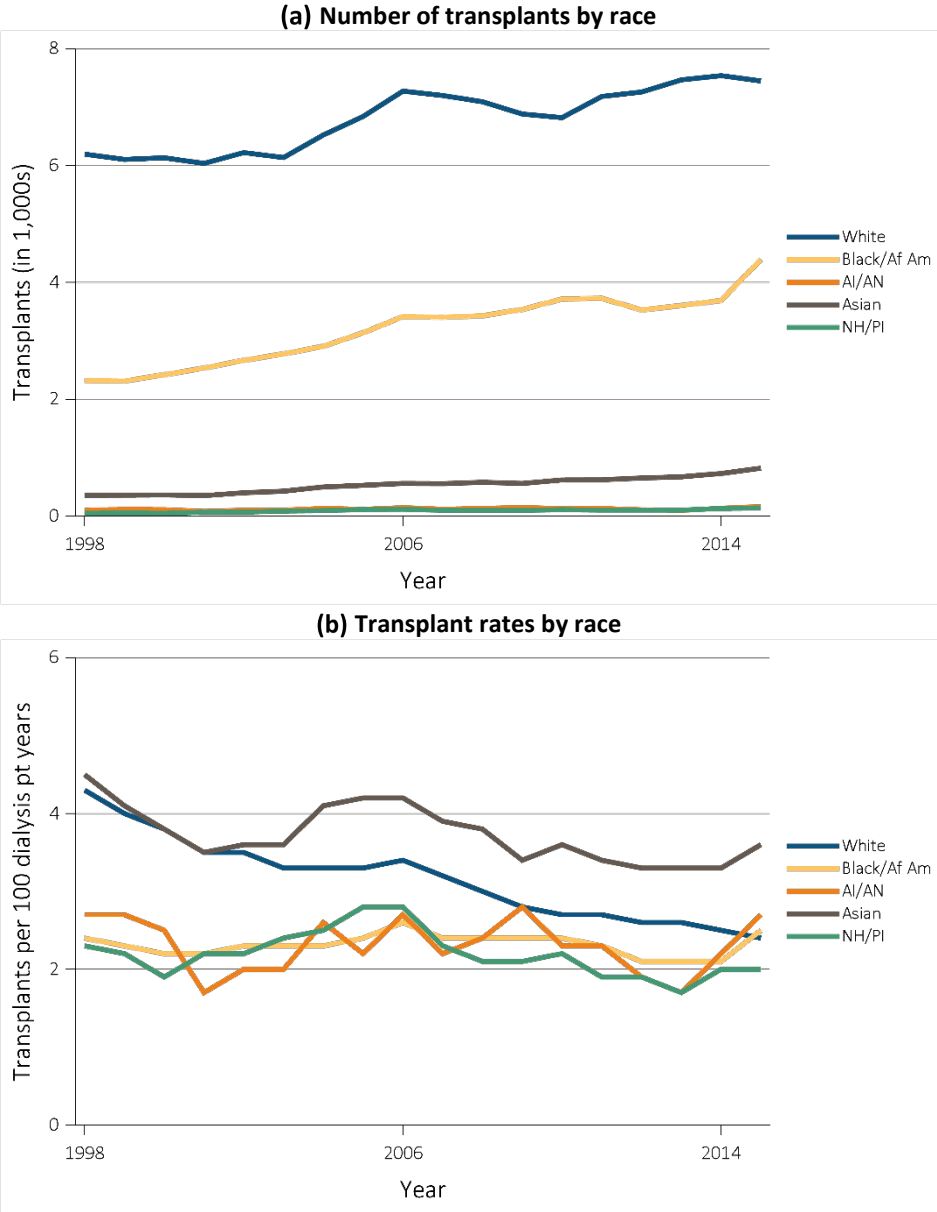


Data Source: Reference Tables E.8(2) and E.9(2). (a) Deceased donor kidney transplant counts by recipient sex. (b) Unadjusted deceased-donor kidney transplant rates by recipient sex. Note that trends may be influenced by changes to the kidney allocation system (KAS) policy that were implemented in December 2014. Abbreviation: pt yrs; patient years; tx, transplant.

For dialysis patients of White or Black race, the number of deceased-donor transplants has grown by 38.2% over the past 15 years, with a more modest increase observed for Asians (Figure 6.11.a).

Since 1998, deceased-donor transplant rates for White patients have been declining. Since 2002, deceased-donor transplant rates for Asians have been higher than for Whites (Figure 6.11.b). In 2015, the rates of deceased-donor transplants increased for Blacks, Asians, and American Indians/Alaska Natives; these are now similar to that of Whites. This recent convergence may be an impact of the new allocation policy, which dates the start of waiting list time to the initiation of dialysis, even if listing occurred after many years on dialysis. This may assist minorities and low-income persons, who often take longer to get waitlisted.

vol 2 Figure 6.11 Number of deceased-donor transplants and unadjusted transplant rates among deceased-donor kidney recipients, by recipient race, 1998-2015



Data Source: Reference Tables E.8(2) and E.9(2). (a) Deceased donor kidney transplant counts by recipient race. (b) Unadjusted deceased-donor kidney transplant rates by recipient race. Note that trends may be influenced by changes to the kidney allocation system (KAS) policy that were implemented in December 2014. Abbreviations: AI/AN, American Indian or Alaska Native; Black/Af Am, Black/African American; NH/PI, Native Hawaiian or Pacific Islander; pt, patient.

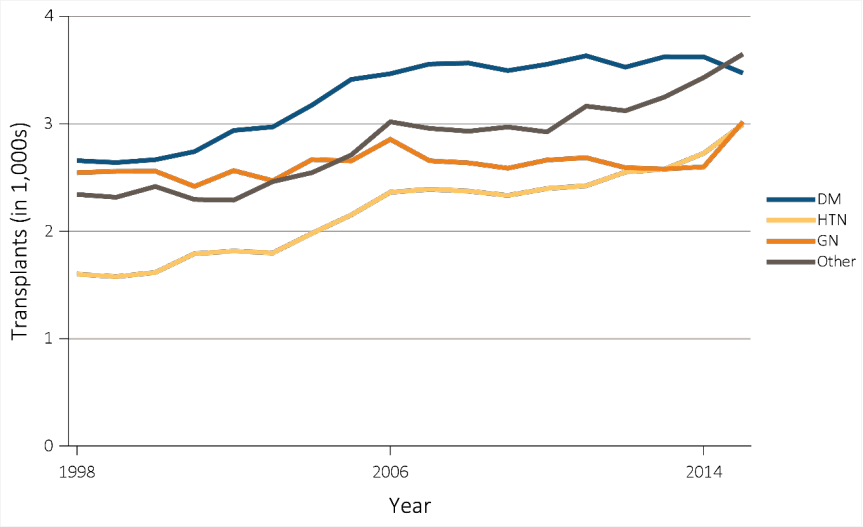
When considering transplant rates by primary cause of ESRD, the largest growth in deceased-donor transplantation numbers has been among recipients with DM or hypertension (HTN; Figure 6.12.a). This growth is not surprising, as DM has consistently been the most common disease among the major causes of ESRD.

Despite the increasing number of deceased-donor transplants over time, the rates of deceased-donor transplants for all diagnosis groups have been generally declining since 2006. In 2015, diabetics showed a sharp downturn, paired with a corresponding increase for all other causes of ESRD (Figure 6.12.b). Transplant rates among dialysis patients with glomerular disease were highest, followed by the Other causes category (including cystic disease). The lowest deceased-donor transplant rates occurred for candidates with ESRD attributed to HTN and DM; these were similar, but were lower than those observed for the glomerulonephritis and Other categories. This rank order is likely due in part to

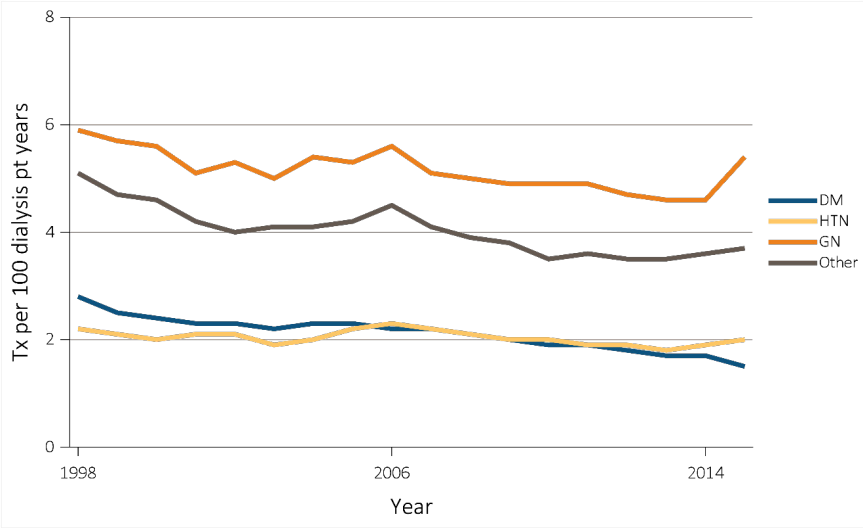
differences in the suitability for transplantation of the patients who have these diagnoses as their primary cause of ESRD. Differences in age and co-morbidities may contribute—the mean age in 2015 among those with ESRD attributed to DM was 55 years, versus 53 for HTN, 44 for glomerulonephritis and 46 for Other categories. The pattern change seen in 2015 likely reflects transplant advantages provided to healthier patients as part of the new allocation policy.

vol 2 Figure 6.12 Number of deceased-donor transplants and unadjusted transplant rates among deceased-donor kidney recipients, by recipient primary cause of ESRD, 1998-2015

(a) Number of transplants by primary cause of ESRD



(b) Transplant rates by primary cause of ESRD



Data Source: Reference Tables E.8(2) and E.9(2). (a) Deceased donor kidney transplant counts by recipient primary cause of ESRD. (b) Unadjusted deceased-donor kidney transplant rates by recipient primary cause of ESRD. Note that trends may be influenced by changes to the kidney allocation system (KAS) policy that were implemented in December 2014. Abbreviations: DM, DM mellitus; ESRD, end-stage renal disease; GN, glomerulonephritis; HTN, hypertension; pt, patient; tx, transplant.

Counts and Rates of Living-Donor Transplants

Since 2004 there has been an annual decline in living-donor kidney transplant counts, although this appears to have plateaued in recent years (Figure 6.5). In this section, we review detailed trends in annual counts and rates of living-donor kidney transplants, by age, sex, race, and primary cause of ESRD (Figures 6.13-6.16).

Counts of living-donor transplants for those aged 22-44 years decreased from 2,603 in 2003 to 1,809 in 2015. The number of living-donor transplants for the group aged 45-64 years has shown a more recent decline, falling from 2,994 in 2010 to 2,639 in 2015 (Figure 6.13.a). Transplant counts for those over 65 years have been steadily increasing.

Kidney transplantation rates from living-donors show that those in younger age groups have the highest annual rates per 100 dialysis patient years (Figure 6.13.b). However, beginning in 2003 there was a steep decline in rates for the 0-21 year-old group, likely related to the impact of the deceased-donor kidney allocation priority then given to that age group; recent trends have been more static. Among adults, the 22-44 year old group has the highest living-donor transplantation rate, although it too is declining. Only the very low rates for ages 65-74 years have remained stable over the past decade.

vol 2 Figure 6.13 Number of living-donor transplants and unadjusted transplant rates among living-donor kidney recipients, by age, 1998-2015

(a) Number of transplants by age

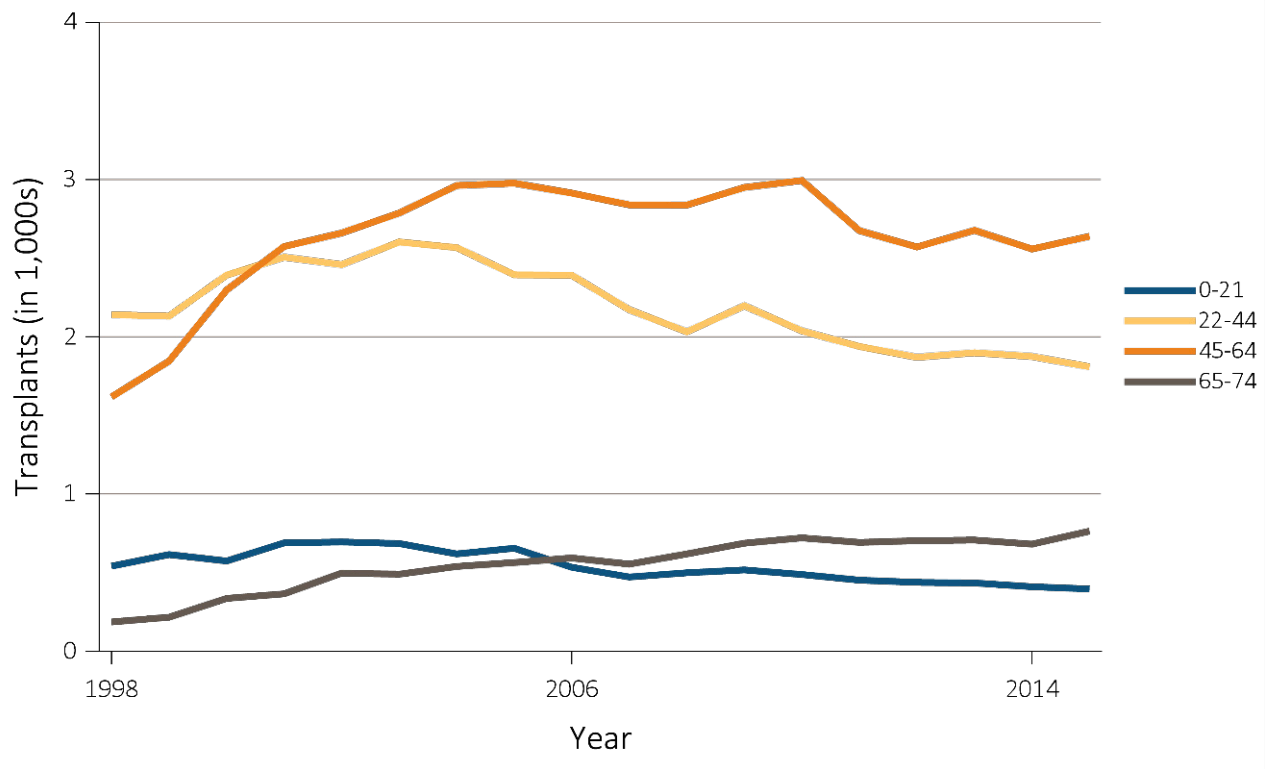
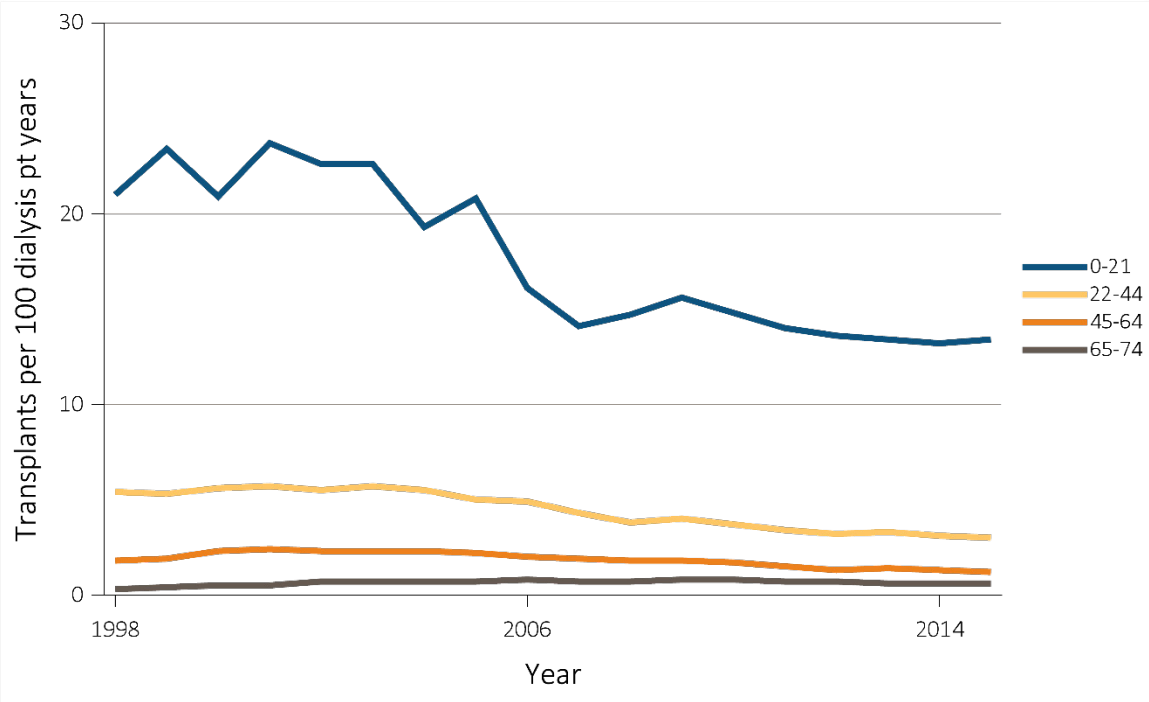


Figure 6.13 continued on next page.

vol 2 Figure 6.13 Number of living-donor transplants and unadjusted transplant rates among living-donor kidney recipients, by age, 1998-2015 *(continued)*

(b) Transplant rates by age

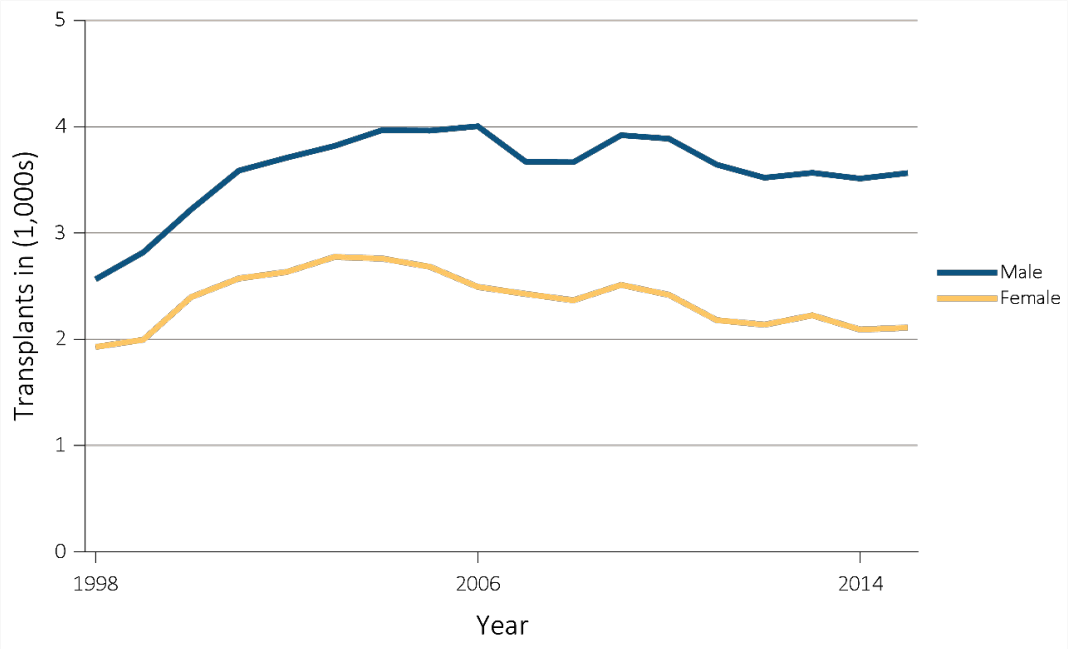


Data Source: Reference Tables E.8(3) and E.9(3). (a) Living-donor kidney transplant counts by recipient age. (b) Unadjusted living-donor kidney transplant rates by recipient age. Note that trends may be influenced by changes to the kidney allocation system (KAS) policy that were implemented in December 2014. Abbreviation: pt, patient.

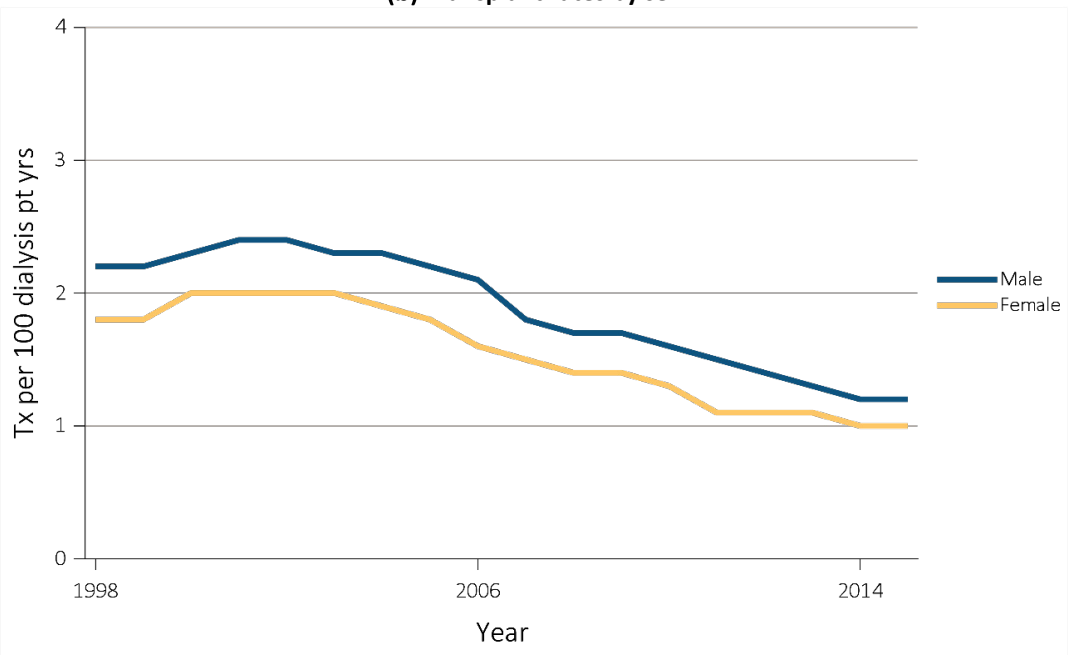
The annual counts of living-donor kidney transplantation by sex showed consistently higher numbers of male recipients (Figure 6.14.a). However, while the living-donor transplant rates continued to remain higher for males than for females, the difference was relatively small (Figure 6.14.b).

vol 2 Figure 6.14 Number of living-donor transplants and unadjusted transplant rates among living-donor kidney recipients, by recipient sex, 1998-2015

(a) Number of transplants by sex



(b) Transplant rates by sex

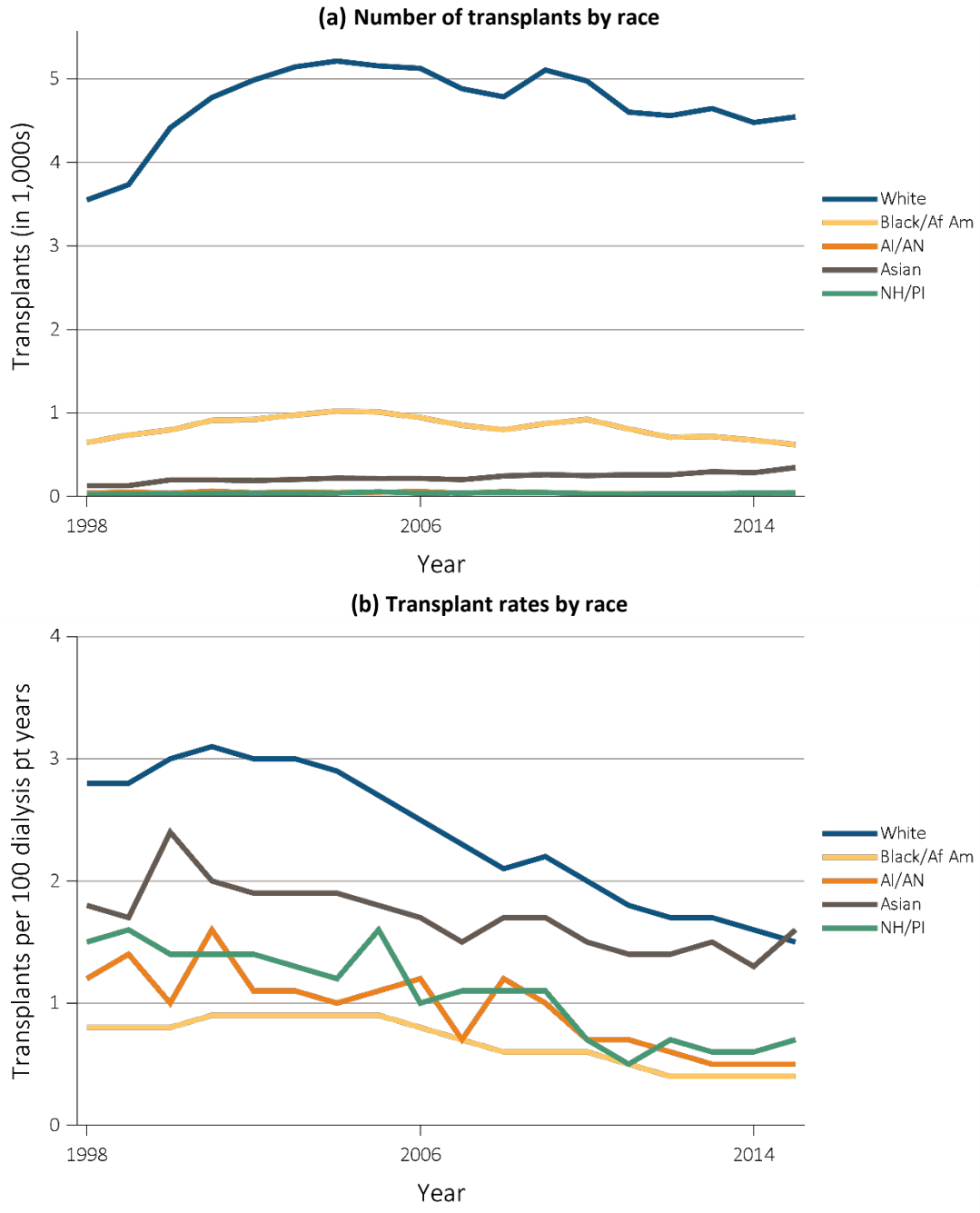


Data Source: Reference Tables E.8(3) and E.9(3). (a) Living-donor kidney transplant counts by recipient sex. (b) Unadjusted living-donor kidney transplant rates by recipient sex. Note that trends may be influenced by changes to the kidney allocation system (KAS) policy that were implemented in December 2014. Abbreviation: pt yrs, patient years; tx, transplant.

Consistent with the overall trend, living-donor kidney transplant counts steadily increased until 2004 for recipients of all races (Figure 6.15.a). Since then, the annual number of living-donor kidney transplants has decreased for Whites and Blacks, while the counts for Asians have shown a small increase.

Living-donor transplant rates for Whites and Asians are higher than for the other race groups, while rates among Blacks have consistently been lowest (Figure 6.15.b). In 2015, living-donor transplant rates increased slightly among Asians and Native Hawaiians/Pacific Islanders.

vol 2 Figure 6.15 Number of living-donor transplants and unadjusted transplant rates among living-donor kidney recipients, by recipient race, 1998-2015

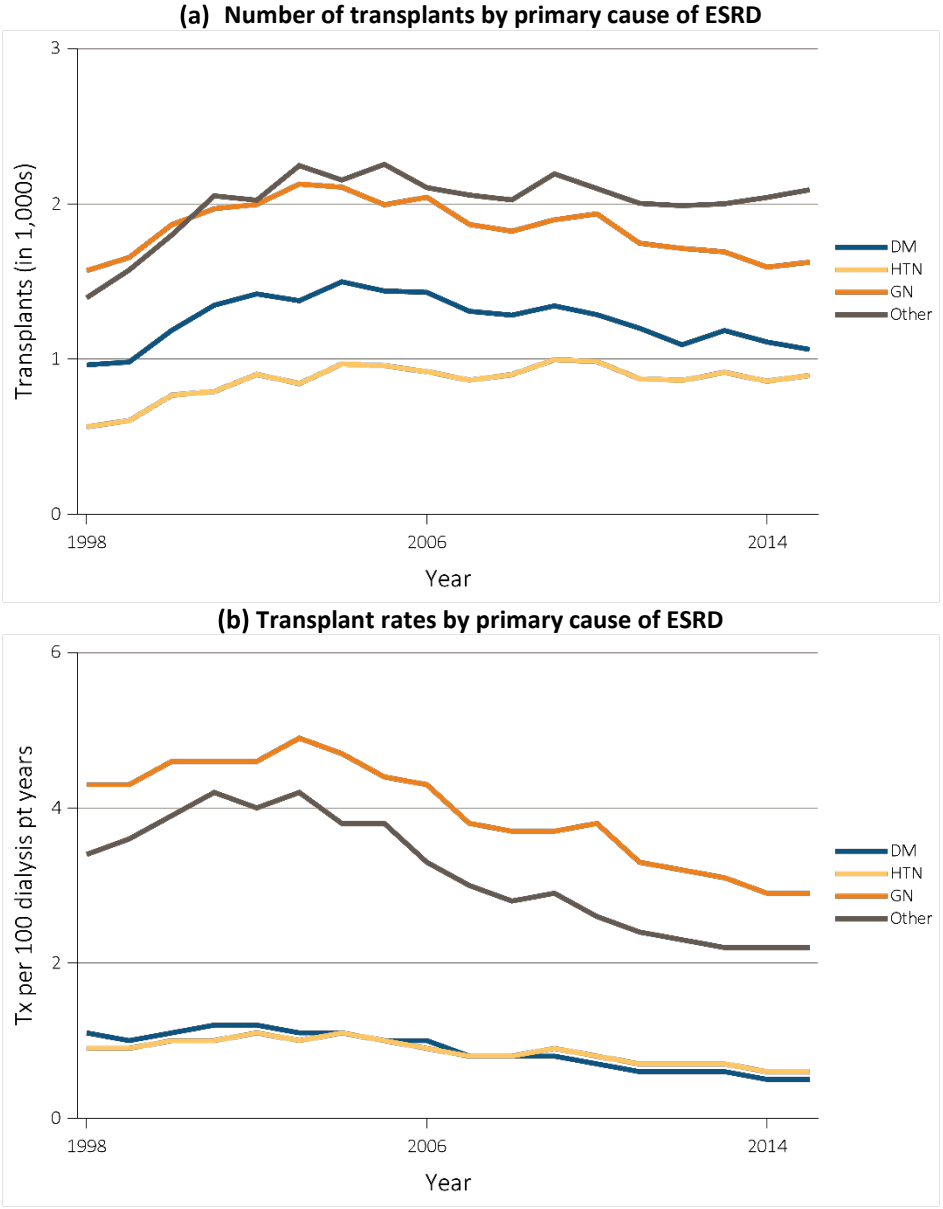


Data Source: Reference Tables E.8(3) and E.9(3). (a) Living-donor kidney transplant counts by recipient race. (b) Unadjusted living-donor kidney transplant rates by recipient race. Note that trends may be influenced by changes to the kidney allocation system (KAS) policy that were implemented in December 2014. Abbreviations: AI/AN, American Indian or Alaska Native; Black/Af Am, Black/African American; NH/PI, Native Hawaiian or Pacific Islander; pt, patient.

The ranking of living-donor kidney transplantation counts by primary cause of ESRD has remained consistent over the past decade. Rankings from highest to lowest frequency were the Other causes, glomerulonephritis, DM, and HTN (Figure 6.16.a). This trend contrasts with the pattern among deceased-donor recipients (Figure 6.12.a), where the numbers with ESRD caused by DM and HTN have grown steadily in comparison to other causes.

The rates of living-donor transplantation for all diagnosis groups have been declining over the past decade (Figure 6.16.b). Like the rates of deceased-donor transplants, those from living-donors occur most often among patients with glomerular disease. In frequency, this is followed by Other causes (including cystic disease), with rates lowest for those with HTN and DM.

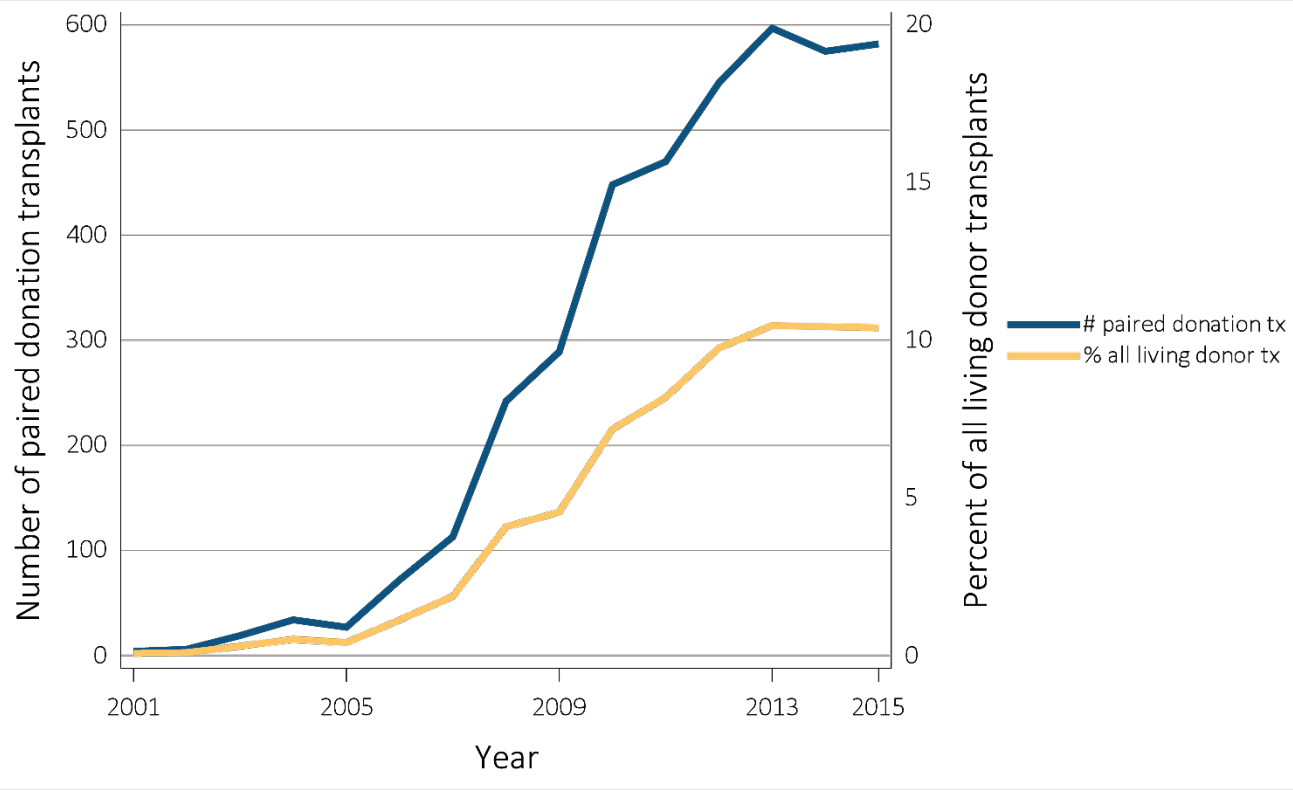
vol 2 Figure 6.16 Number of living-donor transplants and unadjusted transplant rates among living-donor kidney recipients, by recipient primary cause of ESRD, 1998-2015



Data Source: Reference Tables E.8(3) and E.9(3). (a) Living-donor kidney transplant counts by recipient primary cause of ESRD. (b) Unadjusted living-donor kidney transplant rates by recipient primary cause of ESRD. Note that trends may be influenced by changes to the kidney allocation system (KAS) policy that were implemented in December 2014. Abbreviations: DM, DM mellitus; ESRD, end-stage renal disease; GN, glomerulonephritis; HTN, hypertension; pt, patient; Tx, transplant.

A relatively recent initiative aimed at increasing the availability of living-donor transplants is the process of kidney paired donation (KPD). This typically occurs when an otherwise willing potential living-donor is incompatible with their chosen recipient. In its simplest form, two living-donors who are incompatible with their respective recipients agree to an exchange whereby their donated organs go to each other's compatible recipient. More complex chains involving exchanges among three or more recipient-donor pairs, have also occurred. Altruistic, undirected donors have also initiated complex chains. The counts of KPD transplants have risen sharply in recent years, though they appear to have plateaued since 2013 with 582 performed in 2015, representing 10% of living-donor transplants that year (Figure 6.17).

vol 2 Figure 6.17 Number of paired donation transplants and percent of all living-donor transplants, 2001-2015



Data Source: Data are obtained from the Organ Procurement and Transplantation Network (OPTN). Paired donation transplant counts and percent of all living-donor transplants. Note that trends may be influenced by changes to the kidney allocation system (KAS) policy that were implemented in December 2014. Abbreviation: tx, transplant.

Deceased Donation Counts and Rates among All-cause Deaths

The number of deceased-donors, aged 1-74 years, with at least one kidney retrieved increased from 5,895 in 2001 to 8,818 in 2015 (Figure 6.18.a). We do not report on those aged 75 years and older because of the small number of deceased organ donations from this age group. In 2015, among the 17,303 kidneys that were recovered from deceased-donors, 2,938 (17%) were discarded for various reasons. During 2011-2015, the percentage of kidneys discarded ranged from 16%-17% (OPTN, 2016).

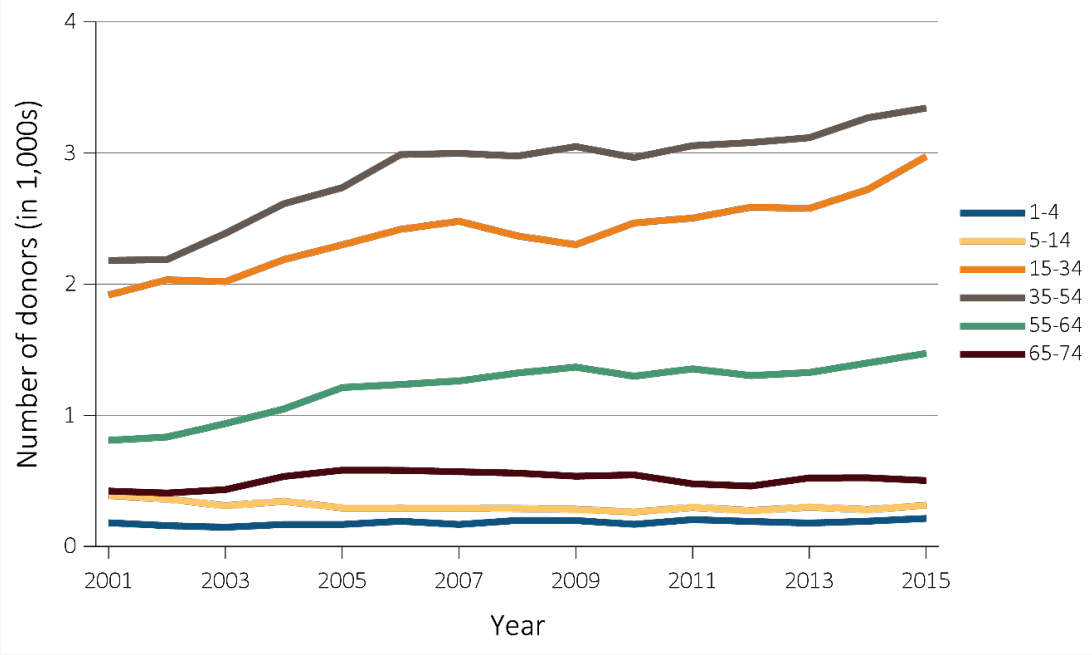
Since 2002, the number of donors among those aged 1-4, 5-14, and 65-74 years has been relatively stable, but the cohort of those aged 15-64 years has been increasing steadily, particularly over the last five years. Donors aged 35-54 years have been the leading source of kidney donations during the past 15 years, with persons aged 15-34 years being the second highest source, and those aged 55-64 years the third highest.

Annual donation rates are the number of deceased-donors with at least one retrieved kidney, per 1,000 deaths in the U.S. population (CDC, 2017). The overall

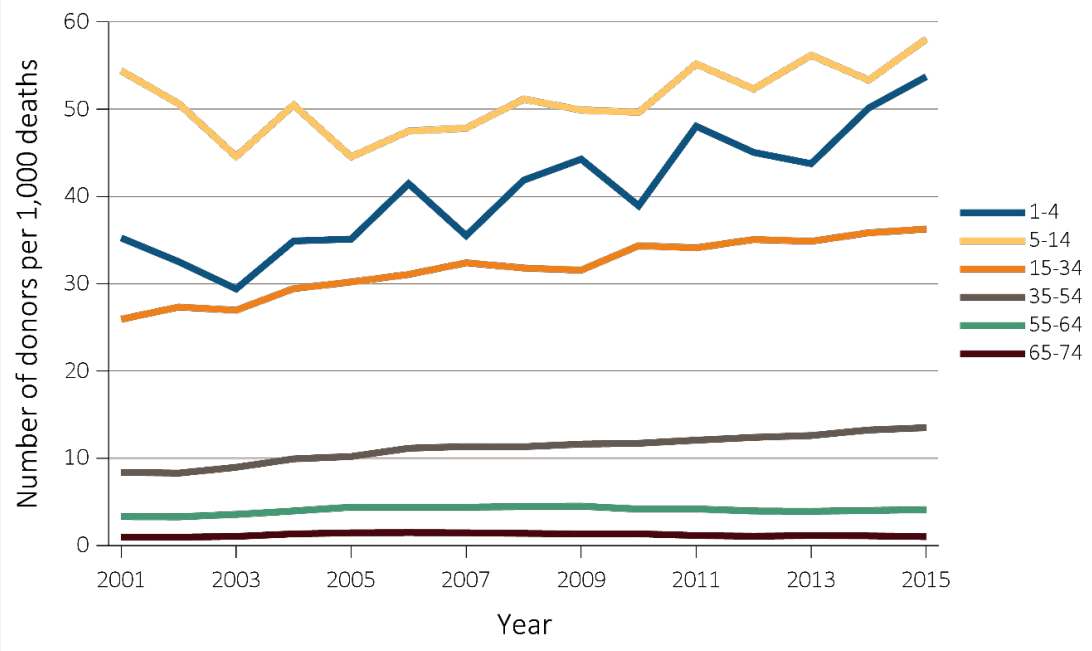
donation rates ranged from 5.6 per 1,000 deaths in 2001 to 7.3 per 1,000 in 2015 (Figure 6.18.b). The highest donation rates were among those aged 5-14, reaching 58 per 1,000 deaths in 2015, followed by those 15-34 years, from whom donations rose from 26 per 1,000 deaths in 2001 to 36 per 1,000 in 2015.

vol 2 Figure 6.18 Number of deceased kidney donors and unadjusted kidney donation rates, by donor age, 2001-2015

(a) Number of donors by age



(b) Donation rates by age

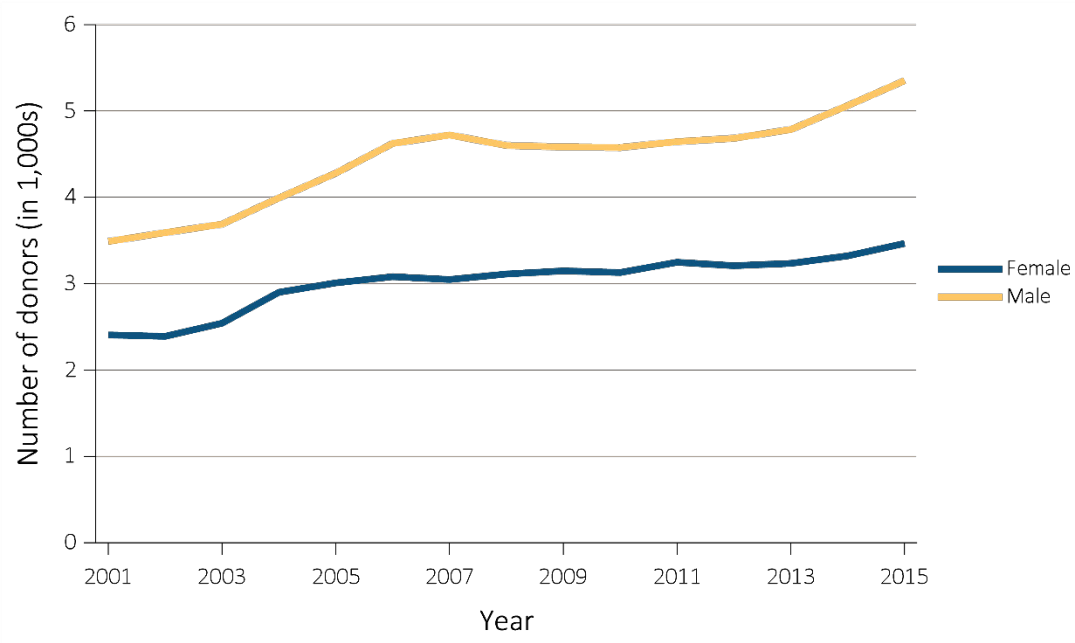


Data Source: Data on the annual number of deaths in the U.S. population are obtained from the Centers for Disease Control and Prevention; the deceased-donor data are obtained from the Organ Procurement and Transplantation Network (OPTN). Deceased-donor kidney donation counts and rates by donor age. Note that trends may be influenced by changes to the kidney allocation system (KAS) policy that were implemented in December 2014.

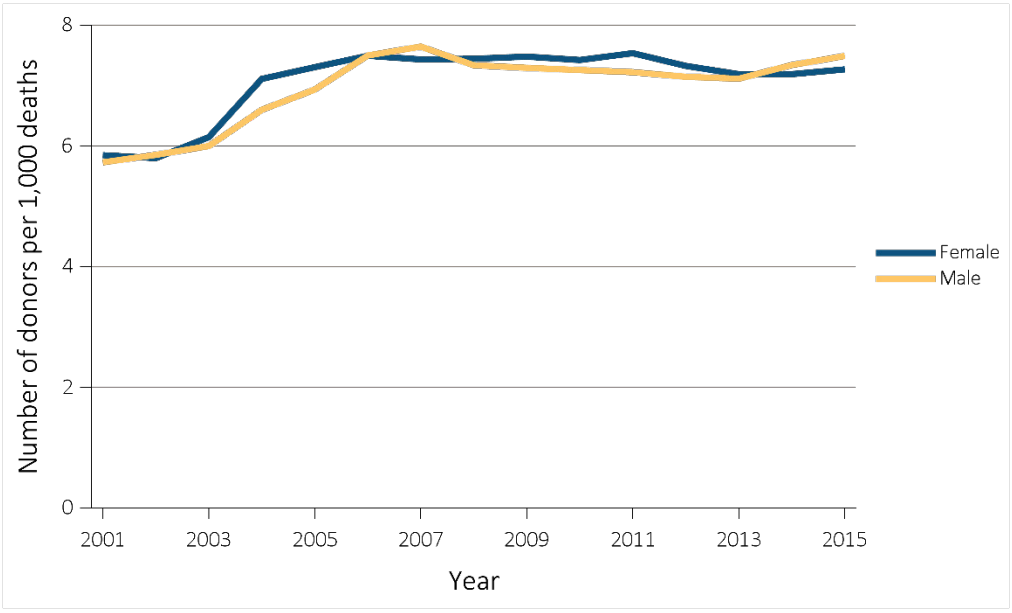
The number of deceased kidney donations by males has consistently been approximately 1.5 times greater than the number from females (Figure 6.19.a). However, the donation rates were similar between males and females (Figure 6.19.b). Both groups have demonstrated an increase in donor counts, particularly over the last two years, although rates have remained relatively stable.

vol 2 Figure 6.19 Number of deceased kidney donors and unadjusted kidney donation rates, by donor sex, 2001-2015

(a) Number of donors by sex



(b) Donation rates by sex



Data Source: Data on the annual number of deaths in the U.S. population are obtained from the Centers for Disease Control and Prevention; the deceased-donor data are obtained from the Organ Procurement and Transplantation Network (OPTN). Deceased-donor kidney donation counts and rates by donor sex. Note that trends may be influenced by changes to the kidney allocation system (KAS) policy that were implemented in December 2014.

The number and rates of deceased organ donations has also varied by race. White persons have consistently accounted for the greatest absolute number of donations each year from 2001 to 2015 (Figure 6.20.a). The rate of deceased-donors per 1,000 deaths among Blacks has almost doubled during this period (Figure 6.20.b), however, with current donation rates being similar among Blacks, Whites, and Asians or Pacific Islanders.

vol 2 Figure 6.20 Number of deceased kidney donors and unadjusted kidney donation rates, by donor race, 2001-2015

Data Source: The U.S. death population data are obtained from the Centers for Disease Control and Prevention; the deceased-donor data are obtained from the Organ Procurement and Transplantation Network (OPTN). Deceased-donor kidney donation counts and rates by donor race. Note that trends may be influenced by changes to the kidney allocation system (KAS) policy that were implemented in December 2014. Abbreviations: AI/AN, American Indian or Alaska Native; Asian/PI, Asian/Pacific Islander; Black/Af Am, Black/African American.

Deceased Donation Counts and Rates among Traumatic Deaths

In this section, we focus on donors who had a traumatic cause of death, such as a motor vehicle accident, suicide, or homicide. Such occurrences represent a common source of donation, as these individuals may be less likely to have underlying health issues that would preclude use of their organs. The number of such donors, aged 1-74 years, with at least one kidney retrieved, has been relatively steady since 2006 (Figure 6.21.a). There were 2,630 such donations in 2015, representing 20% of all deceased donations.

For this specific group, annual donation rates were calculated as the number of deceased-donors with a traumatic cause of death (motor vehicle accident, suicide, or homicide) from whom at least one kidney was retrieved, per 1,000 deaths in the U.S. population (CDC, 2017).

As expected due to the underlying cause of death, donors in the age range of 15-54 years were over-represented, with only small numbers from other age categories (Figure 6.21.a). Donation rates from traumatic deaths were highest among those aged 5-34 years (46 per 1,000 deaths, Figure 6.21.b). In 2015, overall organ donations from those with a traumatic death were 3.9 times the rate of those who died from any cause (28.6 versus 7.3 donations per 1,000 deaths).

vol 2 Figure 6.21 Number of deceased kidney donors and unadjusted kidney donation rates, for traumatic deaths, by donor age, 2001-2015

(a) Number of donors by age

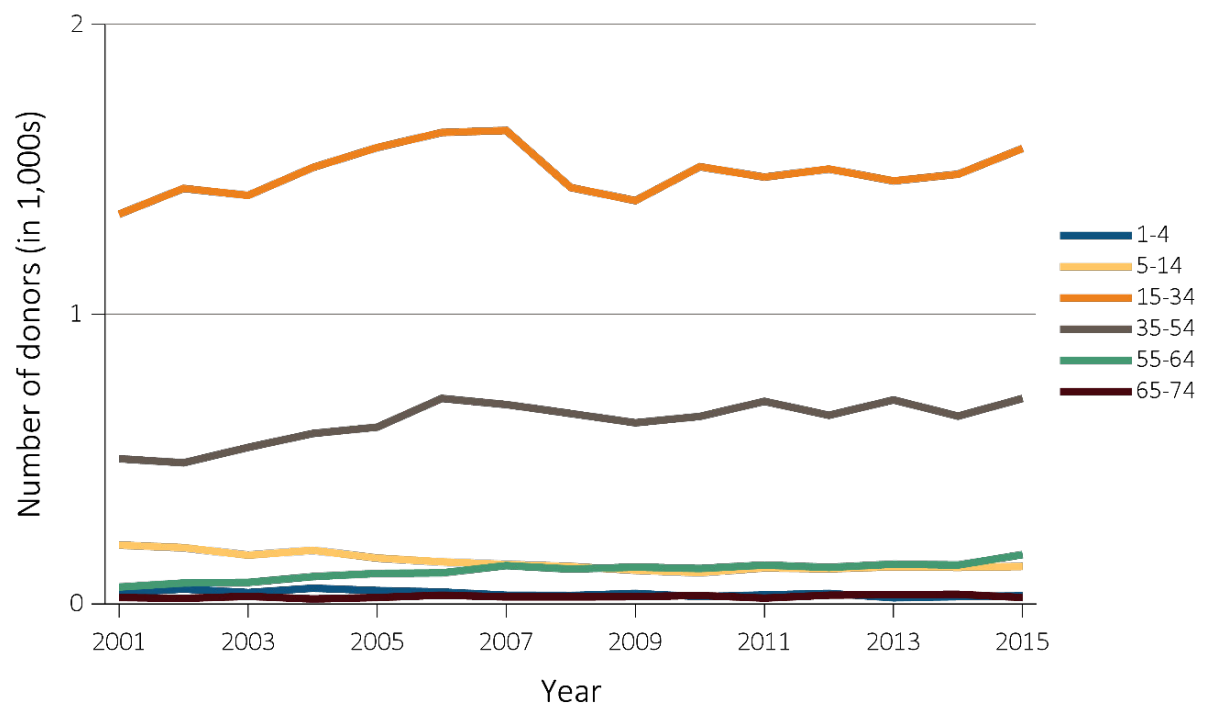
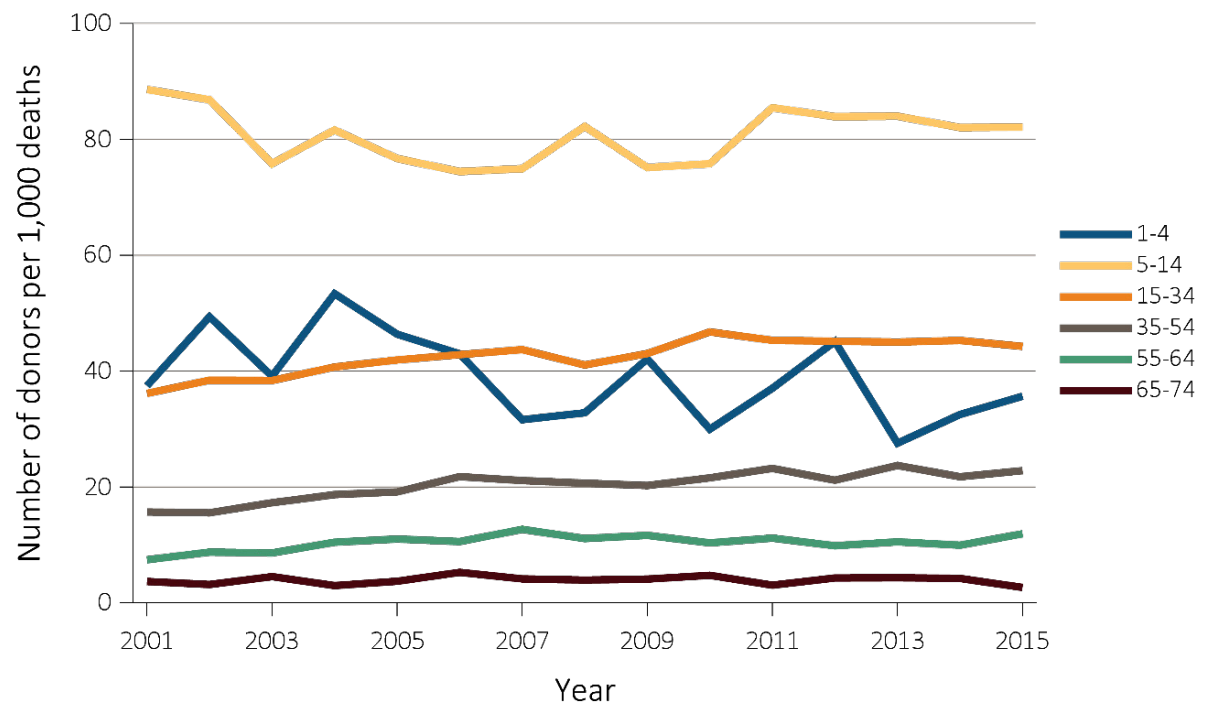


Figure 6.21 continued on next page.

vol 2 Figure 6.21 Number of deceased kidney donors and unadjusted kidney donation rates, for traumatic deaths, by donor age, 2001-2015 *(continued)*

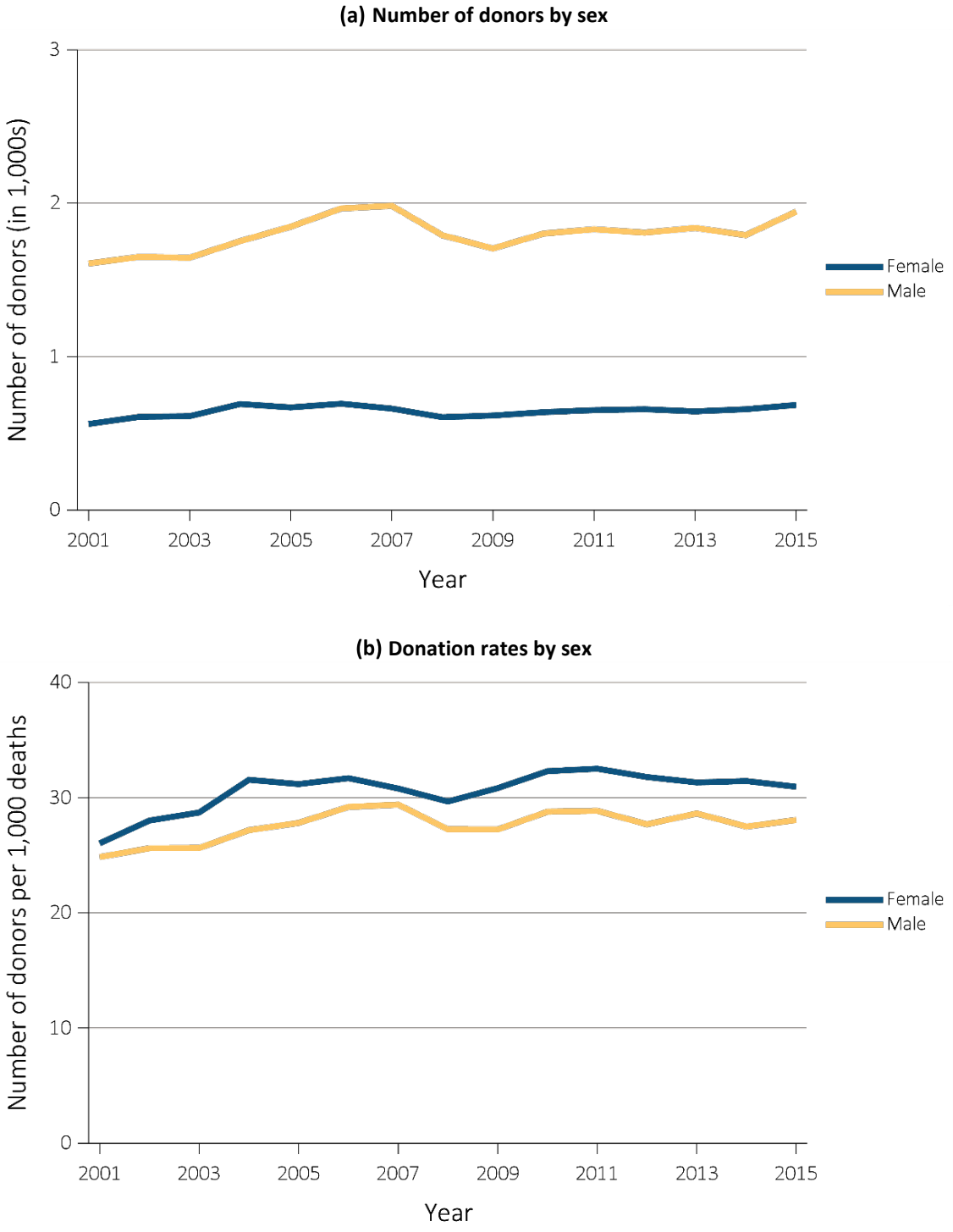
(b) Donation rates by age



Data Source: Data on the annual number of deaths in the U.S. population are obtained from the Centers for Disease Control and Prevention; the deceased-donor data are obtained from the Organ Procurement and Transplantation Network (OPTN). Deceased-donor kidney donation counts and rates by donor age. Note that trends may be influenced by changes to the kidney allocation system (KAS) policy that were implemented in December 2014.

Within this subgroup of donors, although counts for males have been consistently about double those of females (Figure 6.22.a) donation rates by sex were similar (Figure 6.22.b). Counts of donation among males with traumatic deaths increased slightly in 2015 but rates of kidney donation for both sexes in this group have been stable for the last several years.

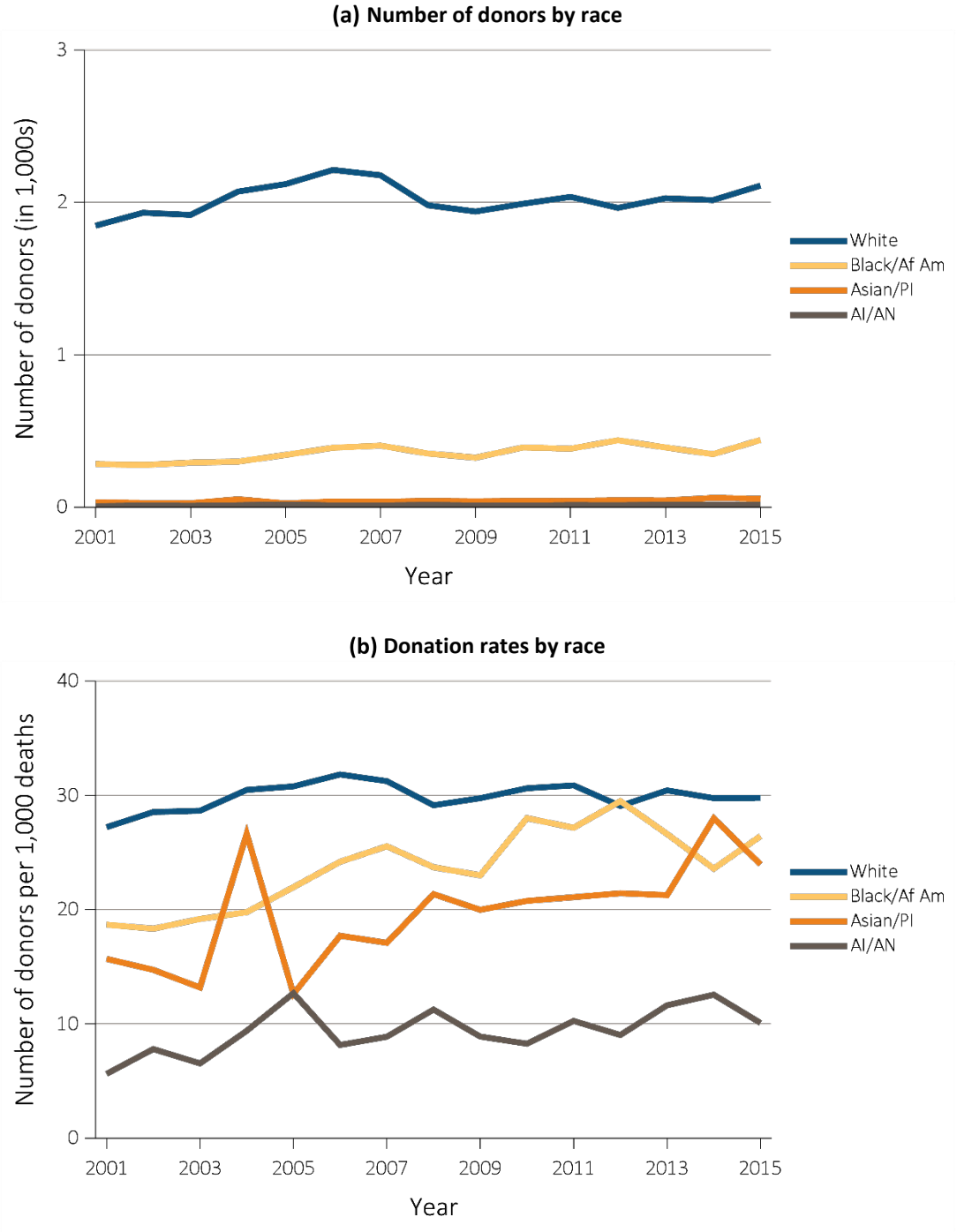
vol 2 Figure 6.22 Number of deceased kidney donors and unadjusted kidney donation rates, for traumatic deaths, by donor sex, 2001-2015



Data Source: Data on the annual number of deaths in the U.S. population are obtained from the Centers for Disease Control and Prevention; the deceased-donor data are obtained from the Organ Procurement and Transplantation Network (OPTN). Deceased-donor kidney donation counts and rates by donor sex. Note that trends may be influenced by changes to the kidney allocation system (KAS) policy that were implemented in December 2014.

Whites have contributed most to the absolute number of traumatic deceased-donors each year from 2001-2015 (Figure 6.23.a). This was consistent with patterns of all-cause deceased donations and the U.S. racial/ethnic population distribution. Actual rates of donation in the most recent years, however, have been similar for Whites, Blacks, and Asians or Pacific Islanders (Figure 6.23.b).

vol 2 Figure 6.23 Number of deceased kidney donors and unadjusted kidney donation rates, for traumatic deaths, by donor race, 2001-2015



Data Source: The U.S. death population data are obtained from the Centers for Disease Control and Prevention; the deceased-donor data are obtained from the Organ Procurement and Transplantation Network (OPTN). Deceased-donor kidney donation counts and rates by donor race. Note that trends may be influenced by changes to the kidney allocation system (KAS) policy that were implemented in December 2014. Abbreviations: AI/AN, American Indian or Alaska Native; Asian/PI, Asian/Pacific Islander; Black/Af Am, Black/African American.

Transplant Outcomes

For more than a decade, there has been a progressive improvement in the health outcomes of kidney transplant recipients. In this section, we review trends in the probability of graft failures, probability of returning to dialysis or retransplantation, and the probability of death at one, five, and ten-years post-transplant. All-cause graft failure is defined as any failure of the transplanted organ, including death with a functioning kidney. The probability of an individual's need to return to dialysis or undergo retransplantation represents a death-censored graft failure.

During 1998-2014, kidney transplant patients experienced improved health outcomes, with decreases observed in deaths and all-cause graft failures at one year post-transplantation. Among the recipients of deceased-donor kidney transplants, the 2014 probability of one-year graft survival was 93%, slightly improved from 2013. The probability of all-cause graft failure in the first year following transplant decreased from 13% in 1998 to 7% in 2014, while the chance of death decreased from 6% in 1998 to 4% in 2014 (Table 6.4). In analysis of the separate outcomes of graft failure, the probability of either returning to dialysis or undergoing repeat transplantation was 4%, equal to that of death.

vol 2 Table 6.4 Trends in 1-, 5-, & 10-year deceased-donor kidney transplant outcomes, 1998-2014

	One year post-transplant			Five years post-transplant			Ten years post-transplant		
Year	Probability of all-cause graft failure (%)	Probability of return to dialysis or repeat transplant (%)	Probability of death (%)	Probability of all-cause graft failure (%)	Probability of return to dialysis or repeat transplant (%)	Probability of death (%)	Probability of all-cause graft failure (%)	Probability of return to dialysis or repeat transplant (%)	Probability of death (%)
1998	12.6	8.9	5.5	33.8	24.1	18.2	56.7	40.6	37.9
1999	13.2	8.8	5.9	33.6	23.0	18.8	56.3	39.3	38.1
2000	12.7	8.1	6.4	33.9	22.7	19.6	56.3	38.3	38.9
2001	12.2	8.0	5.7	33.1	21.3	19.7	55.3	36.7	38.5
2002	12.3	8.3	5.6	32.8	22.1	18.8	53.5	35.9	37.0
2003	11.8	7.3	5.6	31.7	20.3	18.4	54.4	35.7	37.6
2004	11.1	7.1	5.4	31.3	20.5	18.2	53.2	35.4	36.7
2005	11.2	6.9	6.0	29.9	19.0	17.8	52.4	33.4	36.5
2006	10.4	6.6	5.1	29.3	18.6	17.1			
2007	9.5	5.9	4.6	28.2	17.7	16.8			
2008	9.4	6.0	4.5	26.8	16.1	16.3			
2009	9.3	5.5	4.9	26.9	16.4	16.2			
2010	8.8	5.4	4.4	26.6	16.0	16.5			
2011	7.4	4.4	3.9						
2012	7.8	4.7	3.8						
2013	7.7	4.7	3.5						
2014	6.9	3.8	3.7						

Data Source: Reference Tables F.2, F.14, I.26; F.5, F.17, I.29; F.6, F.18, I.30. Outcomes among recipients of a first-time deceased-donor kidney transplant, unadjusted. Note that trends may be influenced by changes to the kidney allocation system (KAS) policy that were implemented in December 2014.

Among those who received living-donor kidney transplants, the probability of one-year graft survival was even greater, at 98%. Like the deceased-donor group, the probability of all-cause graft failure in the first year following transplant decreased from 7% in 1998 to 3% in 2014, while probability of death decreased from 2% to 1% over the same period (Table 6.5). Analyzing the separate components of graft failure, the probability of either returning to dialysis or undergoing repeat transplantation was 2%, and that of death was 1%.

vol 2 Table 6.5 Trends in 1-, 5-, & 10-year living-donor kidney transplant outcomes, 1998-2014

	One year post-transplant			Five years post-transplant			Ten years post-transplant		
Year	Probability of all-cause graft failure (%)	Probability of return to dialysis or repeat transplant (%)	Probability of death (%)	Probability of all-cause graft failure (%)	Probability of return to dialysis or repeat transplant (%)	Probability of death (%)	Probability of all-cause graft failure (%)	Probability of return to dialysis or repeat transplant (%)	Probability of death (%)
1998	6.5	4.8	2.3	21.3	15.0	10.1	42.4	30.8	23.2
1999	6.3	4.6	2.1	21.0	14.9	9.4	41.0	28.9	22.4
2000	7.0	5.0	2.6	22.3	15.2	10.6	42.1	29.2	23.7
2001	6.7	4.6	2.5	21.7	14.8	10.2	41.4	28.1	23.7
2002	6.3	4.4	2.4	20.8	14.1	10.2	39.9	26.4	24.3
2003	5.5	4.0	1.8	20.1	13.8	9.4	39.3	26.0	23.0
2004	5.2	3.6	2.1	18.8	12.7	8.8	38.3	24.6	22.4
2005	5.4	3.7	2.0	18.7	12.7	8.8	38.4	25.1	22.2
2006	4.5	3.1	1.7	16.8	11.2	8.0			
2007	3.8	2.5	1.4	16.7	10.5	7.9			
2008	4.3	2.9	1.6	15.4	10.1	7.4			
2009	4.1	2.8	1.3	15.2	9.4	7.6			
2010	3.7	2.4	1.4	15.3	9.6	7.3			
2011	3.5	2.0	1.8						
2012	3.5	2.1	1.5						
2013	2.6	1.5	1.2						
2014	3.0	1.9	1.4						

Data Source: Reference Tables F.8, F.20, I.32; F.11, F.23, I.35; F.12, F.24, I.36. Outcomes among recipients of a first-time living-donor kidney transplant, unadjusted. Note that trends may be influenced by changes to the kidney allocation system (KAS) policy that were implemented in December 2014.

Improvements in patient and graft survival probabilities have persisted for most of the five- and ten-year outcomes as well. For 2010 recipients of deceased-donor transplants the probability of five-year graft survival remained unchanged from the prior year, at 73%. The probability of all-cause graft failure by the fifth year improved, dropping from 34% in 1998 to 27% in 2010. By the tenth-year post-transplant, it also decreased from 57% in 1998 to 52% in 2005 (Table 6.4). Probability of death by the fifth-year post-transplant improved by dropping from 18% in 1998 to 17% in 2010, and for tenth-year post transplant improved by decreasing from 38% in 1998 to 37% in 2005.

Similarly, for living-donor kidney transplant recipients, five-year graft survival for living-donor transplant recipients also remained unchanged at 85%. The probability of all-cause graft failure by the fifth year decreased from 21% in 1998 to 15% in 2010, while in the tenth year it decreased from 42% in 1998 to 38% in 2005 (Table 6.5). The probability of death by the fifth year post-transplant also improved, falling from 10% in 1998 to 7% in 2010; in the tenth year, it decreased from 23% in 1998 to 22% in 2005.

Overall, outcomes have been consistently more advantageous for living-donor kidney transplant recipients in comparison to deceased-donor transplant recipients. Dissemination of information on the advantages of living-donor kidney transplant is a valuable component of informed decision-making and transplant education, for both recipients and potential organ donors.

References

CDC: Centers for Disease Control and Prevention, National Center for Health Statistics. Underlying Cause of Death 2001-2015 on CDC WONDER Online Database, released 2016. Data are from the Multiple Cause of Death Files, 2001-2015, as compiled from data provided by the 57 vital statistics jurisdictions through the Vital Statistics Cooperative Program. http://wonder.cdc.gov/ucd-icd10.html. Accessed June 15, 2017.

Mathur AK, Ashby VB, Sands RL, Wolfe RA. Geographic Variation in End-Stage Renal Disease Incidence and Access to Deceased Donor Kidney Transplantation. Am J Transplant 2010; 10:1069-1080.

OPTN: Organ Procurement and Transplantation Network, Health Resources and Services Administration, U.S. Department of Health & Human Services. The New Kidney Allocation System (KAS) Frequently Asked Questions https://optn.transplant.hrsa.gov/media/1235/kas_faqs.pdf. Accessed June 15, 2017.

OPTN: Organ Procurement and Transplantation Network, Health Resources and Services Administration, U.S. Department of Health & Human Services. A Guide to Calculating and Interpreting the Kidney Donor Profile Index (KDPI). https://optn.transplant.hrsa.gov/media/1512/guide_to_calculating_interpreting_kdpi.pdf. Accessed July 19, 2016.

OPTN: Organ Procurement and Transplantation Network, Health Resources and Services Administration, U.S. Department of Health & Human Services. Kidney Donor Profile Index: A Guide for Clinicians. https://optn.transplant.hrsa.gov/resources/guidance/kidney-donor-profile-index-kdpi-guide-for-clinicians/ Accessed October 15, 2017.

Stewart DE, Kucheryavaya AY, Klassen DK, Turgeon NA, Formica RN, Aeder MI. Changes in Deceased Donor Kidney Transplantation 1 Year After KAS Implementation. *Am J Transplant* 2016; 16:1834–1847.