

Chapter I

Trends in Organ Donation and Transplantation in the United States, 1999-2008

Introduction

This overview of solid organ transplantation in the United States is produced as part of the 2009 OPTN/SRTR Annual Report. The Scientific Registry of Transplant Recipients (SRTR) prepares the Annual Report in collaboration with the Organ Procurement and Transplantation Network (OPTN) under contract with the Health Resources and Services Administration (HRSA). The report was prepared by the Arbor Research Collaborative for Health, which, with the University of Michigan, is the contractor for the SRTR.

This report reviews many aspects of solid organ transplantation to provide a resource for patients, the transplant community, the public, and the federal government. It features 10 chapters showcasing specific topics in solid organ transplantation. Experts in the field of transplantation contributed to each chapter, offering a comprehensive look at the current state of transplantation and trends over the past decade.

The 2009 Annual Report reference tables may be accessed online at the SRTR and OPTN websites (www.ustransplant.org and optn.transplant.hrsa.gov), along with the 10 chapters presented here.

Summary Statistics on Organ Transplantation in the United States

At the close of 2007, 183,222 persons were recorded in available OPTN data as living with a functioning transplanted organ [*Table 1.14*]. This reflects an increase of 1.7 percent over 2006 and a 56.6 percent increase since 1999.

The total number of organs transplanted decreased from 27,586 in 2007 to 27,281 in 2008. This was an overall decrease of 305 organs transplanted (1.1 percent), including 91 (1.4 percent) fewer living donor transplants (Table I-1).

Table I-1. Change in Number of Transplanted Organs, 2007-2008

Transplanted Organs	2007	2008	Percent Change
Total	27,586	27,281	-1.1%
Deceased donor	21,279	21,065	-1.0%
Living donor	6,307	6,216	-1.4%
Kidney	16,120	16,067	-0.3%
Deceased donor	10,082	10,101	0.2%
Living donor	6,038	5,966	-1.2%
Pancreas	1,215	1,161	-4.4%
PTA	108	122	13.0%
PAK	259	214	-17.4%
Kidney-pancreas	848	825	-2.7%
Liver	5,890	5,817	-1.2%
Deceased donor	5,629	5,568	-1.1%
Living donor	261	249	-4.6%
Intestine (deceased donor)	57	69	21.1%
Heart (deceased donor)	2,143	2,085	-2.7%
Lung	1,461	1,473	0.8%
Deceased donor	1,458	1,473	1.0%
Living donor	3	-	n/a
Heart-lung	31	26	-16.1%

Source: 2009 OPTN/SRTR Annual Report, Table 1.7.

The number of deceased donor kidney transplants increased by only 0.2 percent, while living donor kidney transplants dropped by 1.2 percent. A decrease of 1.1 percent was observed in deceased donor liver transplants in 2008. There was a corresponding 1.57 percent overall decrease in the number of organs recovered for transplant during this time period (Table I-2).

Table I-2. Change in Number of Recovered Organs, 2007-2008

Recovered Organs	2007	2008	Percent Change
Total	28405	27958	-1.57%
Kidney	14381	14274	-0.74%
Pancreas-all	1,932	1,830	-5.28%
Liver	7,025	6,832	-2.75%
Intestine	205	197	-3.90%
Heart	2,287	2,226	-2.67%
Lung	2,575	2,599	0.93%

Source: 2009 OPTN/SRTR Annual Report, Table 1.2.

Table I-3, which includes patients listed at both active and inactive status, shows the 1-year change in the number of patients on the waiting list for each organ. At the end of 2008, 100,597 people were registered on organ waiting lists (67,470 active, 33,120 inactive, and 7 of unknown status). This reflects a 3.8 percent increase over the number of people waiting for an organ at the end of 2007 [Table 1.4]. There were 25,465 patients listed as inactive status on the kidney waiting list at the end of 2008. The percentage of patients who were inactive on the kidney waiting list at the end of each year has increased from 10 percent in 2003 to 33 percent in 2008 [Tables 5.1a and 5.1b]. This increase might be largely attributed to policy implemented in 2003, which allows accrual of waiting time during inactive status (http://optn.transplant.hrsa.gov/PoliciesandBylaws2/policies/pdfs/policy_7.pdf. See policy 3.5.11.1) (1).

Table I-3. Patients on Waiting Lists at End of Year, 2007-2008

Organs	End of Year				% Change in Total (2007-2008)
	Total 2007	% Inactive	Total 2008	% Inactive	
All organs	96,874	33%	100,597	33%	3.8%
Kidney	71,601	32%	76,089	33%	6.3%
PTA	581	59%	581	64%	0.0%
PAK	919	75%	856	74%	-6.9%
Kidney-pancreas	2,235	40%	2,234	45%	0.0%
Liver	16,365	25%	15,807	23%	-3.4%
Intestine	220	24%	212	31%	-3.6%
Heart	2,637	47%	2,711	38%	2.8%
Lung	2,211	55%	2,016	46%	-8.8%
Heart-lung	105	68%	91	64%	-13.3%

Source: 2009 OPTN/SRTR Annual Report, Table 1.3, 5.1a-b, 6.1a-b, 7.1a-b, 8.1a-b, 9.1a-b, 10.1a-b, 11.1a-b, 12.1a-b, 13.1a-b. PTA: Pancreas transplant alone. PAK: Pancreas after kidney.

The kidney waiting list grew 6.3 percent, while the liver waiting list decreased 3.4 percent, and the lung waiting list decreased 8.8 percent. The size of the waiting list is influenced by many factors, including listing practices, donation rates, death rates, and allocation policy.

Patient survival after transplant is recognized as an important metric for evaluating transplantation success. Table I-4 shows the percentage of transplant recipients still alive 1 and 5 years after transplantation, by organ. The “1-year survival” cohort consists of recipients transplanted in 2006-2007, while the “5-year survival” cohort is based on recipients transplanted in 2002-2005. These are the most recent cohorts for which adequate follow-up data are available. One-year patient survival was above 90 percent for transplants involving deceased and living donor kidney alone, kidney-heart, kidney-pancreas, pancreas after kidney (PAK), and pancreas transplants alone (PTA). One-year patient survival following kidney-liver transplant was lower

(87.4 percent). Patient survival was lowest for liver-intestine transplants (63.3 percent), plausibly due to the greater burden of disease for patients receiving the multi-organ transplant.

Table I-4. Unadjusted 1- and 5-Year Patient Survival by Organ

Organ Transplanted	1-Year Survival (Txp 2006-2007)	5-Year Survival (Txp 2002-2007)
Kidney		
Deceased donor	95.6%	81.9%
Living donor	98.5%	91.0%
Pancreas alone	97.8%	88.7%
Pancreas after kidney	97.0%	84.5%
Kidney-pancreas	95.7%	87.2%
Liver		
Deceased donor	88.4%	73.8%
Living donor	91.0%	79.0%
Intestine	89.3%	57.9%
Heart	88.3%	74.9%
Lung	83.3%	54.4%
Heart-lung	80.6%	44.9%
Kidney-liver	87.4%	71.4%
Kidney-heart	95.8%	77.6%
Liver-intestine	63.3%	58.0%

Source: 2009 OPTN/SRTR Annual Report, Table 1.13.

Table I-5 shows graft survival by organ at 1 and 5 years after transplantation. Graft survival was calculated using the same cohorts as patient survival (Table I-4). Over 90 percent of kidneys transplanted alone or in combination with other organs were functioning 1 year after transplantation, except for those used in kidney-liver and kidney-heart transplants, of which 83 percent and 88 percent were still functioning after 1 year, respectively. Some patients survived organ failure by receiving a subsequent transplant or alternative therapy such as dialysis or resumption of insulin, resulting in lower graft survival rates than corresponding patient survival rates.

Table I-5. Unadjusted 1- and 5-Year Graft Survival by Organ

Organ Transplanted	1-Year Survival (Txp 2006-2007)	5-Year Survival (Txp 2002-2007)
Kidney		
Deceased donor	91.0%	69.3%
Living donor	96.3%	81.4%
Pancreas alone		
Pancreas after kidney	75.5%	51.5%
Pancreas after kidney	80.0%	53.4%
Kidney-pancreas (kidney)	92.5%	78.6%
Kidney-pancreas (pancreas)	84.8%	73.4%
Liver		
Deceased donor	84.3%	68.4%
Living donor	86.0%	72.9%
Intestine	78.9%	39.6%
Heart	87.9%	73.7%
Lung	81.6%	51.5%
Heart-lung	80.5%	43.1%
Kidney-liver (kidney)	83.0%	64.4%
Kidney-liver (liver)	83.7%	66.0%
Kidney-heart (heart)	92.6%	76.0%
Kidney-heart (kidney)	88.2%	72.0%
Liver-intestine (intestine)	58.7%	53.0%
Liver-intestine (liver)	58.7%	53.4%

Source: 2009 OPTN/SRTR Annual Report, Table 1.13.

Table I-6 shows that posttransplant patient and graft survival outcomes have improved over the past decade for almost every organ [Tables 1.11b and 1.12b]. Unadjusted 1-year graft survival for deceased donor kidney recipients improved from 88.8 percent to 91.4 percent. Graft survival after living donor kidney transplant improved 2 percent. Unadjusted 1-year graft survival for deceased donor and living donor liver recipients improved 6 percent and 16 percent respectively. One-year graft survival after intestine (alone) transplant increased markedly from 50 percent in 1998 to 75 percent in 2007. The greatest improvement was seen in heart-lung recipients, for whom 1-year unadjusted graft survival increased from 54 percent in 1998 to 90 percent in 2007. While only PTA transplants showed lower graft survival in 2007 than in 1998, the graft survival estimates are based on small numbers of transplants and are not statistically significantly different from each other ($p = 0.83$). The statistical significance of each comparison of 1998 survival with 2007 survival is shown in Table I-6 by organ type.

Table I-6. Unadjusted 1-Year Graft and Patient Survival by Organ (1998 and 2007)

	Year of Transplant		% Change	P-Value
	1998	2007		
Graft Survival				
Kidney: deceased donor graft survival	89%	91%	3%	<0.0001
Kidney: living donor graft survival	95%	97%	2%	<0.0001
Pancreas transplant alone	78%	76%	-1%	0.8341
Pancreas after kidney	72%	82%	10%	0.0302
Kidney-pancreas: kidney	91%	93%	2%	0.1355
Kidney-pancreas: pancreas	83%	86%	4%	0.0392
Liver: deceased donor graft survival	80%	86%	6%	<0.0001
Liver: living donor graft survival	70%	87%	16%	0.0022
Intestine	50%	75%	25%	0.0004
Heart	85%	88%	3%	0.0006
Lung	75%	80%	5%	0.0115
Heart-lung	54%	90%	36%	0.0001
Patient Survival				
	Year of Transplant		% Change	P-Value
	1998	2007		
Kidney: deceased donor patient survival	95%	96%	1%	0.0055
Kidney: living donor patient survival	98%	99%	1%	0.0015
Pancreas transplant alone	98%	98%	0%	0.9320
Pancreas after kidney	94%	97%	3%	0.2472
Kidney-pancreas	94%	97%	3%	0.0093
Liver: deceased donor patient survival	86%	89%	3%	<0.0001
Liver: living donor patient survival	80%	91%	11%	0.0173
Intestine	67%	78%	11%	0.0995
Heart	86%	89%	3%	0.0006
Lung	77%	82%	6%	0.0016
Heart-lung	57%	90%	34%	0.0003

Source: 2009 OPTN/SRTR Annual Report, Table 1.11b, 1.12b.

Trends in patient survival over the past decade have mirrored those in graft survival, with notable improvements in survival for recipients of every organ type except PTA, PAK, and intestine. Trends in patient and graft survival are explored in detail in each of the organ-specific chapters in this 2009 Annual Report.

Transplantation at a Glance

The figure sets accompanying this chapter (Figures I-1 through I-8) provide overviews of the state of transplantation for eight organ groups: kidney, PTA, PAK, liver, intestine, heart, lung, and simultaneous pancreas-kidney (SPK) transplantation, which is the most common multi-organ procedure.

Because of the small numbers of other multi-organ procedures (e.g., heart-lung transplants), they are excluded from the counts presented here.

Number of Transplants and Size of Active Waiting List

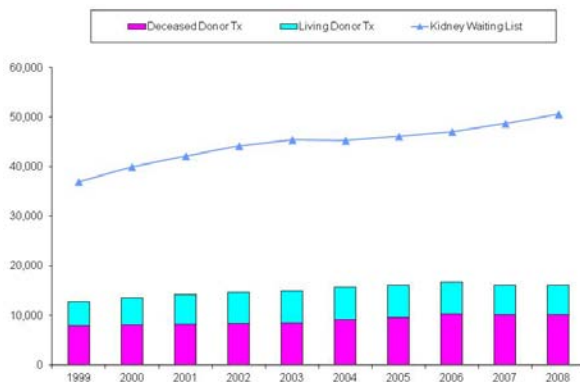
Figures I-1 through I-8 show the size of the active waiting list and the number of transplants performed for each of the past 10 years. The *size of the waiting list* is best described as a snapshot capturing the number of candidates active on the waiting list on December 31. It does not count those patients who were transplanted, listed, or removed during the preceding 12 months. The *number of transplants* includes all transplants performed over the year.

Because of these different methods of counting, for some organs (e.g., lung), the number of transplants performed during a certain year may exceed the number of people awaiting a transplant on the last day of the same year. The narrowing gap between waiting list size and number of transplants can be explained, in some cases, by changes in allocation policy and wait-listing practices.

Unadjusted Patient and Graft Survival

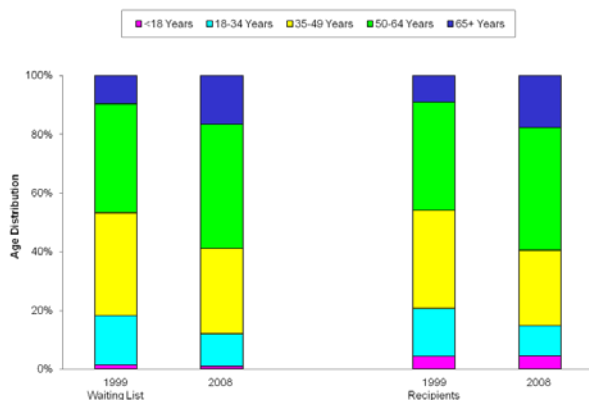
Figures I-1 through I-8 show survival of transplant recipients (patient survival) and continued function of the transplanted organ (graft survival) at 3 months, 1 year, 5 years, and 10 years following transplantation. These results are based on analysis of the most recent cohorts, with sufficient follow-up time for data collection and ascertainment of events.

Figure I-1. Kidney Transplantation at a Glance



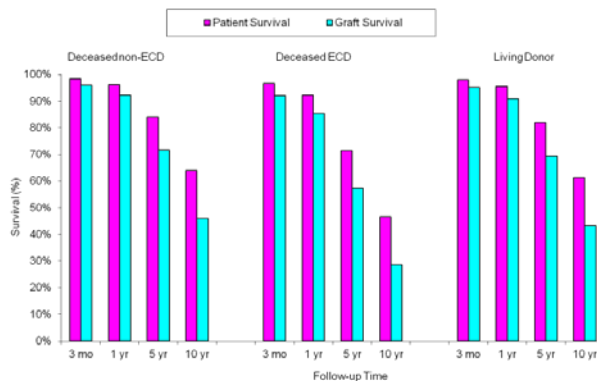
Number of Transplants and Size of Active Waiting List.

There was a very large gap between the number of patients waiting for a transplant and the number receiving a transplant. This gap widened over the decade, meaning that the waiting times from listing to transplant continued to increase. The number of living donor transplants grew until 2004, while the number of deceased donor transplants continued to rise gradually until 2006. Source: 2009 OPTN/SRTR Annual Report, Tables 1.7, 5.1a.



Age Distribution of Recipients and Active Waiting List.

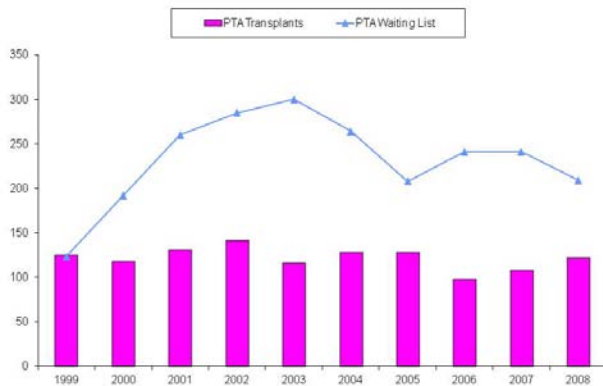
In 2008, older candidates (age >50 years) made up a much larger fraction of patients actively awaiting an organ than a decade earlier. The same pattern was observed for transplant recipients. Source: 2009 OPTN/SRTR Annual Report, Tables 5.1a, 5.4a, 5.4b, 5.4c.



Unadjusted Patient and Graft Survival.

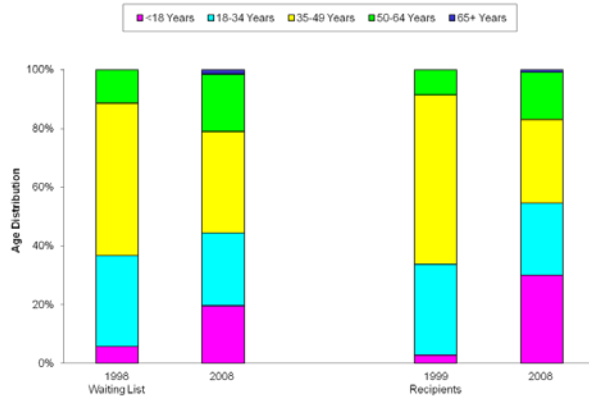
Five-year patient survival percentages (based on transplants during 2002-2007) and 10-year patient survival (based on transplants during 1997-2007) were clearly higher for recipients of living donor organs than for those of deceased donor organs. Similarly, living donor organs had the highest 5- and 10-year graft survival. Source: 2009 OPTN/SRTR Annual Report, Tables 5.10a, 5.10b, 5.10d, 5.14a, 5.14b, 5.14d.

Figure I-2. Pancreas Transplantation Alone (PTA) at a Glance



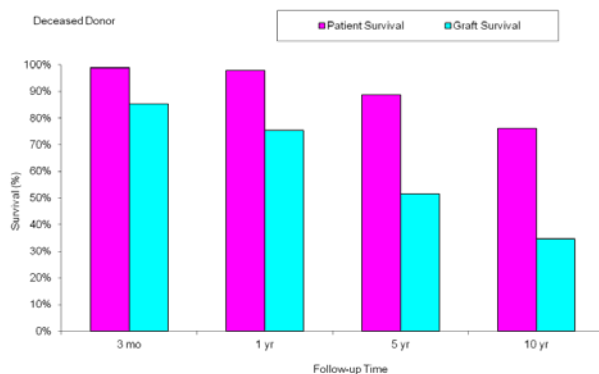
Number of Transplants and Size of Active Waiting List.

The number of patients on the waiting list for a pancreas transplant alone decreased after 2003 and has remained at pre-2001 levels. The number of PTA transplants per year was relatively stable. Source: 2009 OPTN/SRTR Annual Report, Tables 1.7, 6.1a.



Age Distribution of Recipients and Active Waiting List.

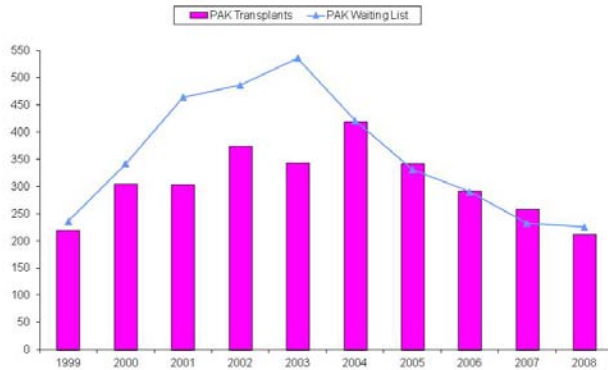
For PTA, more pediatric candidates were wait-listed and more received a transplant in 2008 than in 1999, although the absolute numbers are small. At the same time, the fraction of recipients over age 50 years grew. Pediatric diabetic patients rarely have kidney failure before age 18 years, but they are candidates for PTA. Source: 2009 OPTN/SRTR Annual Report, Tables 6.1a, 6.4.



Unadjusted Patient and Graft Survival.

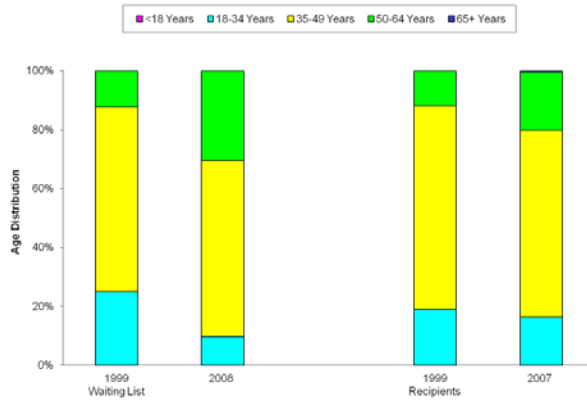
The 5-year patient survival rate for PTA transplants was 89%. Graft survival was considerably lower, especially at 5 and 10 years posttransplant. Source: 2009 OPTN/SRTR Annual Report, Tables 6.10, 6.14.

Figure I-3. Pancreas After Kidney (PAK) Transplantation at a Glance



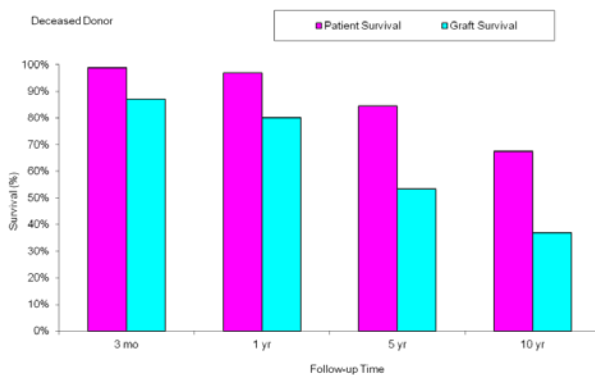
Number of Transplants and Size of Active Waiting List.

The number of patients on the waiting list for a PAK transplant has decreased since 2003. The number who received a transplant has matched the number of candidates each year since 2004. The number of PAK transplants has decreased from its highest level of the decade in 2004. Source: 2009 OPTN/SRTR Annual Report, Tables 1.7, 7.1a.



Age Distribution of Recipients and Active Waiting List.

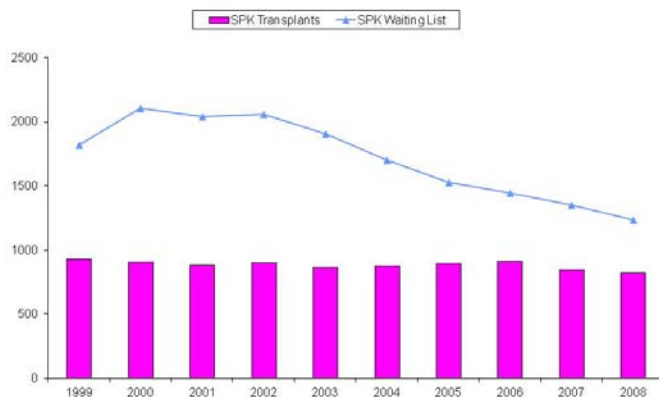
For PAK, a higher proportion of wait-listed and transplanted patients were over 50 years old in 2008 than in 1999. At the same time, a smaller proportion of candidates and recipients were in the 18-34 year age group. (Since recipients were mostly type 1 diabetics, the ages below 18 and above 65 years were virtually unrepresented.) Source: 2009 OPTN/SRTR Annual Report, Tables 7.1a, 7.4.



Unadjusted Patient and Graft Survival.

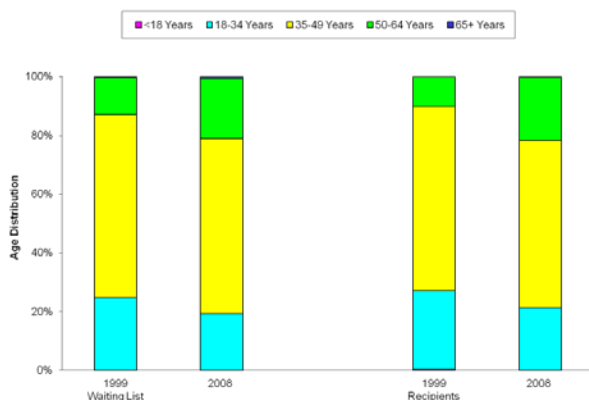
For PAK transplants, patient survival was similar to that seen for simultaneous kidney-pancreas transplant recipients. Five-year patient survival was 85%. Pancreas graft survival after PAK was considerably lower. Source: 2009 OPTN/SRTR Annual Report, Tables 7.10, 7.14.

Figure I-4. Simultaneous Pancreas-Kidney (SPK) Transplantation at a Glance



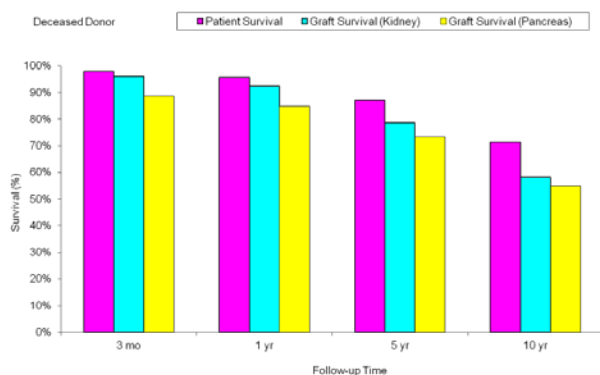
Number of Transplants and Size of Active Waiting List.

SPK accounts for the majority of all pancreas transplants. Numbers of this procedure were stable over the decade. The gap between the number of patients waiting for a transplant and the number receiving a transplant has dropped substantially since 2000. Source: 2009 OPTN/SRTR Annual Report, Tables 1.7, 8.1a.



Age Distribution of Recipients and Active Waiting List.

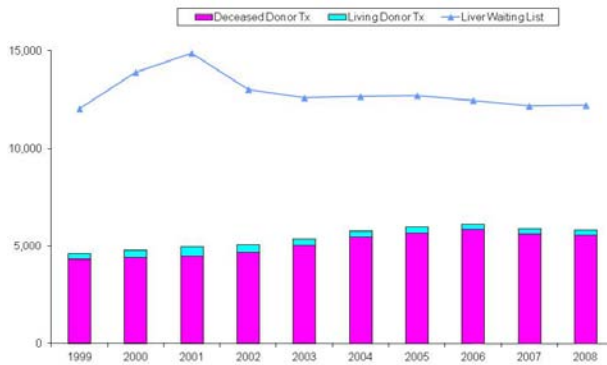
For SPK transplantation, patients over age 50 years made up greater fractions of both candidates and recipients in 2007 than in 1998. At the same time, smaller proportions of candidates and recipients were in the 18-34 year age group. (Since recipients were mostly type 1 diabetics, the ages below 18 and above 65 years were virtually unrepresented.) Source: 2009 OPTN/SRTR Annual Report, Tables 8.1a, 8.4.



Unadjusted Patient and Graft Survival.

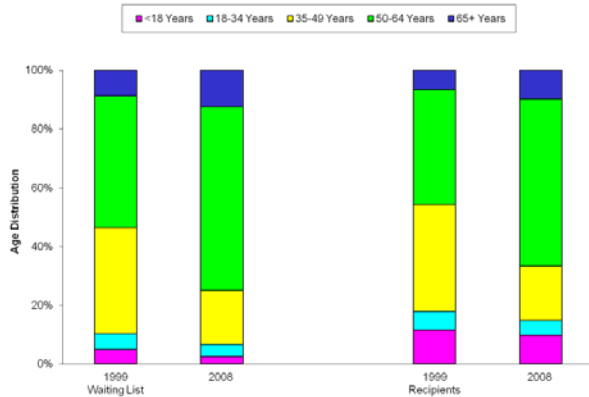
Patient survival has improved for SPK recipients in recent years. Five- and 10-year patient survival was 87% and 71%, respectively. Graft survival is shown separately for the pancreas graft and the kidney graft of each SPK transplant. Source: 2009 OPTN/SRTR Annual Report, Tables 8.10, 8.14.

Figure I-5. Liver Transplantation at a Glance



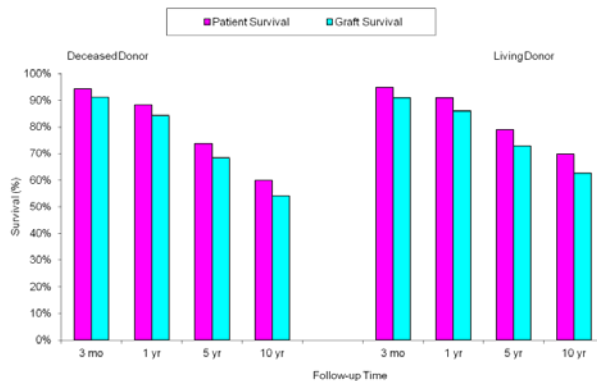
Number of Transplants and Size of Active Waiting List.

The number of patients awaiting a liver transplant at year-end peaked in 2001; this is clearly related to the introduction of the MELD/PELD allocation system in 2002. The number who received a deceased donor liver transplant has gradually increased, reaching a peak in 2006. The gap between the numbers of candidates and recipients has been slowly shrinking since 2002. Source: 2009 OPTN/SRTR Annual Report, Tables 1.7, 9.1a, 9.1b.



Age Distribution of Recipients and Active Waiting List.

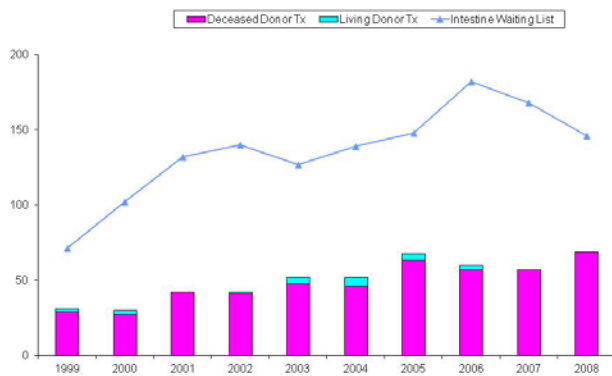
The numbers of candidates and recipients age 35-49 years remained fairly constant over the decade, but the age group's proportion by both measures declined. Recipients included transplants from both living and deceased donors. Source: 2009 OPTN/SRTR Annual Report, Tables 9.1a, 9.4a, 9.4b.



Unadjusted Patient and Graft Survival.

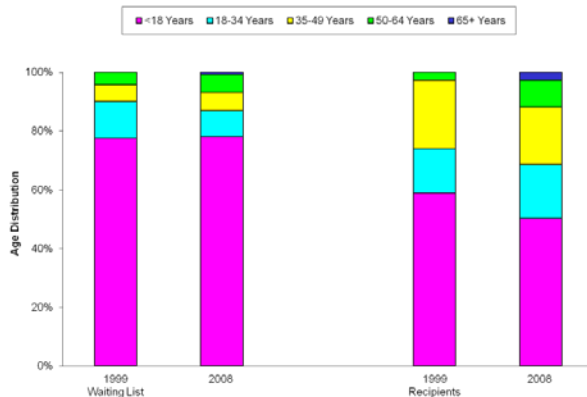
Patient survival in recent years has been improving for both deceased donors and living donors, with 74% and 79% of patients, respectively, alive 5 years following transplantation. Patient survival was higher than graft survival because of the opportunity for repeat liver transplantation in the event of graft failure. Source: 2009 OPTN/SRTR Annual Report, Tables 9.10a, 9.10b, 9.14a, and 9.14b.

Figure I-6. Intestine Transplantation at a Glance



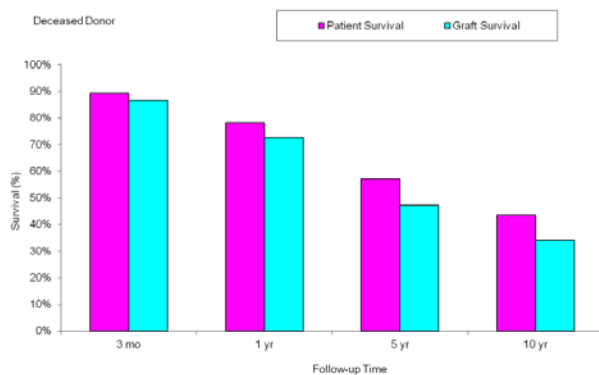
Number of Transplants and Size of Active Waiting List.

The numbers of patients on the intestine waiting list and the number receiving a transplant both more than doubled between 1999 and 2008 despite the fact that the number of patients on the waiting list has declined since 2006. Source: 2009 OPTN/SRTR Annual Report, Tables 1.7, 10.1a.



Age Distribution of Recipients and Active Waiting List.

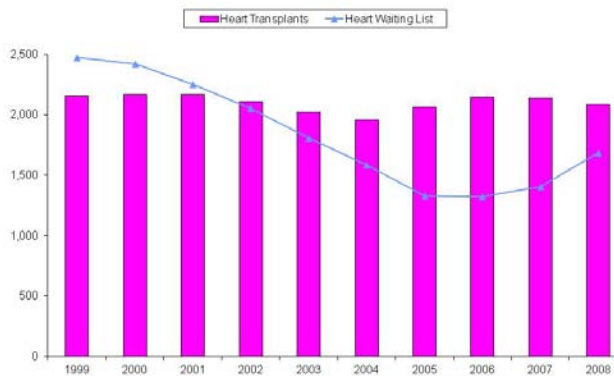
About 77% of intestine candidates were in the pediatric age group in 1999 compared with 78% in 2008. Adults made up a greater portion of recipients than candidates. Source: 2009 OPTN/SRTR Annual Report, Tables 10.1a, 10.4.



Unadjusted Patient and Graft Survival.

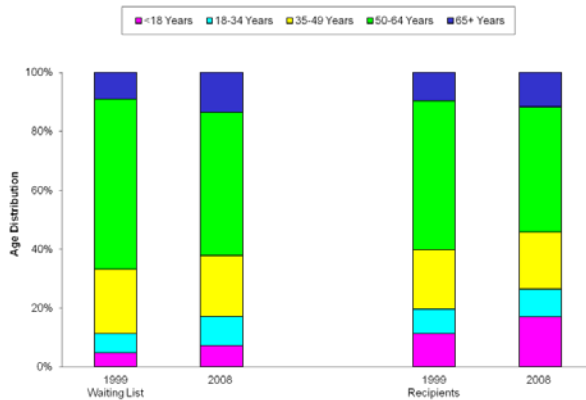
One-year patient survival was 78% in 2008. Survival at 5 years was 57%. Graft survival was lower, since recipients may receive parenteral alimentation or retransplantation after graft failure. Source: 2009 OPTN/SRTR Annual Report, Tables 10.10, 10.14.

Figure I-7. Heart Transplantation at a Glance



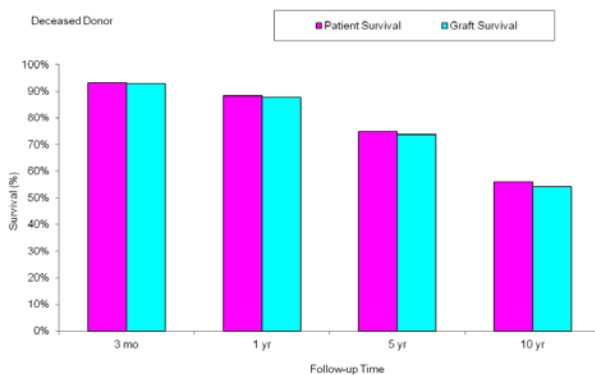
Number of Transplants and Size of Active Waiting List.

The number of heart transplants has remained stable over the past decade. The number of patients awaiting a heart decreased steeply from 2000 to 2005, likely reflecting improvements in medical and surgical therapy for end-stage heart failure. Source: 2009 OPTN/SRTR Annual Report, Tables 1.7, 11.1a.



Age Distribution of Recipients and Active Waiting List.

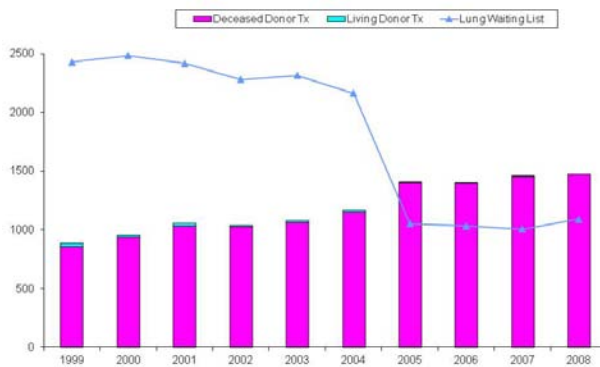
Trends in the age distribution of wait-listed candidates show that the proportions (and absolute numbers) of patients younger than 35 and older than 64 years increased, while the age group 35-64 years has decreased. The trend in transplant recipient age showed a similar pattern, although the ages below 35 years had greater representation than on the waiting list. Source: 2009 OPTN/SRTR Annual Report, Tables 11.1a, 11.4.



Unadjusted Patient and Graft Survival.

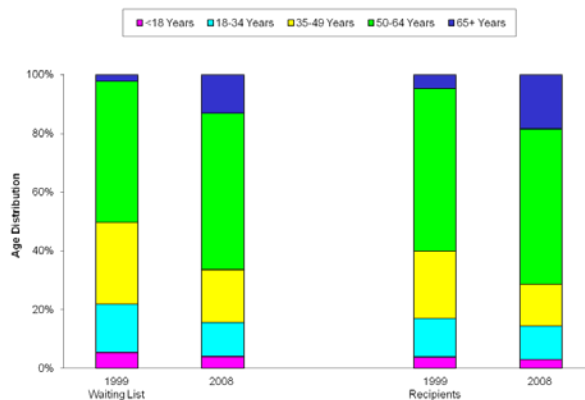
Patient survival improved in recent years for heart recipients. At 1, 5, and 10 years following heart transplantation, 88%, 75%, and 56% of patients, respectively, were alive. Graft survival was very similar to patient survival because very few patients receive a second heart transplant. Source: 2009 OPTN/SRTR Annual Report, Tables 11.10, 11.14.

Figure I-8. Lung Transplantation at a Glance



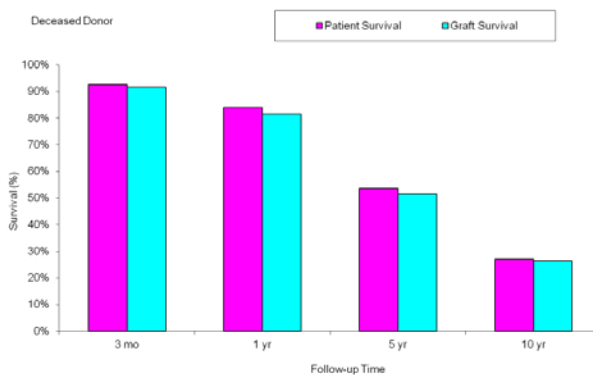
Number of Transplants and Size of Active Waiting List.

The number of lung transplants has increased in the last 2 years. The number of patients awaiting a transplant dropped steeply in 2005 after a stable pattern during the prior 6 years. This sharp reduction is largely attributable to a major change in allocation policy, which is now based on medical urgency and calculated transplant benefit rather than waiting time. Source: 2009 OPTN/SRTR Annual Report, Tables 1.7, 12.1a.



Age Distribution of Recipients and Active Waiting List.

The lung waiting list showed a mixed trend in age distribution, with increasing percentages of candidates older than 50 years and decreasing percentages younger than 18 years. Candidates 18-49 years old showed a corresponding reduction in the percentage of the waiting list. The pattern for transplant recipients showed a similar increase for ages 50 years and above, and a decrease in percentages for younger ages, including children. Source: 2009 OPTN/SRTR Annual Report, Tables 12.1a, 12.4a, 12.4b.



Unadjusted Patient and Graft Survival.

Patient survival has been improving in recent years. At 1 year following deceased donor lung transplantation, 84% of patients were alive. Graft survival was very similar to patient survival because very few lung retransplants are performed. Source: 2009 OPTN/SRTR Annual Report, Tables 12.10a, 12.10b, 12.14a, 12.14b.

The Chapters in the 2009 OPTN/SRTR Annual Report

This report first presents “Organ Donation and Utilization in the United States, 1999-2008” (2). Five organ-specific chapters then follow: “Kidney and Pancreas Transplantation in the United States, 1999-2008: The Changing Face of Living Donation” (3), “Liver Transplantation in the United States, 1999-2008” (4), “Intestine and Multi-Visceral Transplantation in the United States, 1999-2008” (5), “Heart Transplantation in the United States, 1999-2008” (6), and “Lung Transplantation in the United States, 1999-2008” (7). Each chapter provides detailed updates regarding donation, waiting time, allocation, posttransplant outcomes, and the demographics of candidates and recipients. These chapters are intended to supplement the reporting of 10-year trends, with coverage of recent changes in allocation policy, clinical practice, and other areas relevant to the transplantation of different organ types.

This year’s report concludes with three special-focus chapters that closely examine issues of recent interest to the transplant community. “Geographic Variation in End-Stage Renal Disease Incidence and Access to Kidney Transplantation” (8) investigates differences in organ donation rates and how the density of end-stage renal disease (ESRD) in the general population affects access to the kidney transplant waiting list and successful kidney transplantation. “DonorNet and the Effects on Organ Donation” (9) discusses the impact of DonorNet on organ utilization, focusing on ischemia time of transplanted organs and graft outcomes. “Transplant Outcomes Among Minorities Between 1999 and 2008: Determinants of Kidney Allograft Survival” (10) assesses trends in minority access to care and outcomes for kidney and heart transplantation by race/ethnicity category, and examines specific determinants of kidney transplant outcomes. Each chapter includes special analyses conducted by the SRTR, addressing topics that are both timely and pertinent because of their implications for policy and clinical practice.

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