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Trends in Organ Donation and Transplantation in the United States, 1997–2006

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Introduction

This article provides an overview of solid organ transplantation in the United States and is produced as part of the 2007 *OPTN/SRTR Annual Report*. The *Annual Report* is prepared by the Scientific Registry of Transplant Recipients (SRTR) in collaboration with the Organ Procurement and Transplantation Network (OPTN) under contract with the Health Resources and Services Administration (HRSA). The report covers many aspects of solid organ transplantation and is a valuable resource for patients, the transplant community, the public and the Federal Government.

This report includes nine articles devoted to specific topics in solid organ transplantation. Each article was written by a group of experts in the field of transplantation and provides a comprehensive look at the current state of transplantation and trends over the past decade. The text and figures in these articles are based on recent SRTR analyses and the extensive reference tables of the 2007 *Annual Report*. This report was prepared by the Arbor Research Collaborative for Health, which with the University of Michigan has been the contractor for the SRTR since October 2000. These nine articles and extensive reference tables are available online, at the websites of the SRTR and OPTN (www.ustransplant.org and www.optn.org).

Summary Statistics on Organ Transplantation in the United States

As of the end of 2005, there were 163 631 persons living with a functioning organ transplant in the United States. This number reflects an increase of 2.1% over the prior year and a 1.6-fold increase since 1997.

The total number of organs transplanted annually increased from 27 530 in 2005 to 28 291 in 2006, an increase of 761 (2.8%). This overall increase is attributable to different levels of transplant activity by organ. There was a 7.4% increase in deceased donor kidney transplants (Table 1). Other notable changes include a 2.3% increase in liver transplants, which occurred despite a decrease in living donor liver procedures that year. Lung transplantation remained stable, while heart transplantation increased 4.1%. Percentage declines in transplantation for pancreas, intestine and heart-lung reflect relatively small changes in the numbers of transplants. The 28 291 organs transplanted in 2006 came from 14 756 organ donors, 265 more donors than there were in 2005 (2%). The year-over-year increase in the total number of donors resulted from a substantial increase in deceased donors (431, or 6%) and a slight decrease in living donors (166, or 2%). The number of living donors in 2006 was observed to be lower than any year

Table 1: Growth in number of transplanted organs, 2005–2006

Transplanted organs	2005	2006	Percent change
Total	27530	28291	2.8
Deceased donor	20633	21561	4.5
Living donor	6897	6730	−2.4
Kidney	16076	16646	3.5
Deceased donor	9508	10212	7.4
Living donor	6568	6434	−2.0
Pancreas	1368	1304	−4.7
Pancreas alone	129	98	−24.0
Pancreas after kidney	343	292	−14.9
Kidney-pancreas	896	914	2.0
Liver	6000	6136	2.3
Deceased donor	5679	5849	3.0
Living donor	321	287	−10.6
Intestine	68	60	−11.8
Deceased donor	63	57	−9.5
Living donor	5	3	−40.0
Heart	2062	2147	4.1
Deceased donor	2062	2146	4.1
Living donor	–	1	–
Lung	1403	1401	−0.1
Deceased donor	1402	1397	−0.4
Living donor	1	4	300.0
Heart-lung	34	31	−8.8

Source: *2007 OPTN/SRTR Annual Report*, Table 1.7.

Table 2: Change in number of organs recovered from deceased donors, 2005–2006

Recovered organs	2005	2006	Percent change
Total	26920	28311	5.1
Kidney	13313	14282	7.3
Pancreas-all	2045	2026	−0.9
Liver	6783	7,084	4.4
Intestine	185	184	−0.5
Heart	2220	2275	2.5
Lung	2374	2460	3.6

Source: *2007 OPTN/SRTR Annual Report*, Table 1.2.

since 2002. The overall 5.1% increase in organ recovery in 2006 was driven primarily by the 7.3% increase in recovered kidneys. Increases were also seen in liver, heart and lung procurement, while pancreas and intestine procurement remained relatively stable (Table 2).

There were approximately 94 000 people registered on organ waiting lists at the end of 2006 (64 373 actively waiting, 29 438 at 'inactive' status and 9 of unknown status), a 5.5% increase over the number of people waiting for an organ at the end of 2005. Table 3 shows the 1-year change in the number of patients on the waiting list for each organ. This table includes patients listed at both active and inactive status. The kidney waiting list grew by 8.6% while the list for kidney-pancreas shrunk by 3.7%. Other modest declines were seen on the liver and heart lists; the largest decline (8.6%) was seen on the lung waiting list. Dramatic changes for lungs in 2005 and 2006 can be largely attributed to a new deceased donor lung allocation policy that was implemented in May 2005. The allocation policy was changed from a system based on waiting time to one based on net survival benefit from transplantation and medical urgency (the latter based on mortality risk while on the waiting list) (1). Changes in the solitary pancreas (pancreas transplant alone [PTA]), pancreas after kidney (PAK), intestine and heart-lung waiting lists all reflect relatively small numbers of patients.

Table 3: Patients on waiting lists (total of active and inactive), 2005–2006

	End of year		Percent
Organs	2005	2006	change
Total	93114	98263	5.5
Kidney	65199	70778	8.6
Pancreas alone	527	609	15.6
Pancreas after kidney	983	1007	2.4
Kidney-pancreas	2510	2416	−3.7
Liver	17465	17371	−0.5
Intestine	202	238	17.8
Heart	2934	2822	−3.8
Lung	3156	2885	−8.6
Heart-lung	138	137	−0.7

Note: There were 93 811 unique patients registered at the end of 2006, but many were listed on multiple waiting lists, resulting in 98 263 total registrations.
Source: *2007 OPTN/SRTR Annual Report*, Table 1.3.

Table 4: Unadjusted 1- and 5-year patient survival by organ

Organ transplanted	1-Year survival (%)	5-Year survival (%)
Kidney		
Deceased donor	94.8	80.6
Living donor	98.0	90.3
Pancreas alone	96.7	88.1
Pancreas after kidney	96.6	83.9
Kidney-pancreas	95.0	86.1
Liver		
Deceased donor	86.9	73.6
Living donor	90.6	76.1
Intestine	81.0	53.6
Heart	87.8	74.4
Lung	84.0	52.6
Heart-lung	75.0	49.7

Source: *2007 OPTN/SRTR Annual Report*, Table 1.13.

The population of people awaiting a transplant has continued to shift toward older candidates. At the end of 2006, 59% of all candidates were 50 years old or older and 14% were 65 or older. These percentages are slightly higher than they were in 2005 (57% ≥50 years, 13% ≥65 years) and substantially higher than they were in 1997 (43% ≥50 years, 7% ≥65 years).

Patient survival is an important metric for evaluating the success of transplantation. Table 4 shows the percentage of transplant recipients still alive 1 and 5 years after transplantation, by organ. The cohort used to compute 1-year survival consists of recipients transplanted in 2004–2005, while the cohort for 5-year survival is based on recipients transplanted in 2000–2005. These are the most recent

Table 5: Unadjusted 1- and 5-year graft survival by organ

Organ transplanted	1-Year survival	5-Year survival
Kidney		
Deceased donor	90.0	67.5
Living donor	97.3	80.2
Pancreas alone	80.1	50.6
Pancreas after kidney	78.5	58.1
Kidney-pancreas (kidney)	92.9	77.9
Kidney-pancreas (pancreas)	86.2	72.5
Liver		
Deceased donor	82.3	67.6
Living donor	84.1	68.6
Intestine	73.4	36.9
Heart	87.3	73.2
Lung	82.3	49.7
Heart-lung	75.0	73.2

Source: *2007 OPTN/SRTR Annual Report*, Table 1.13.

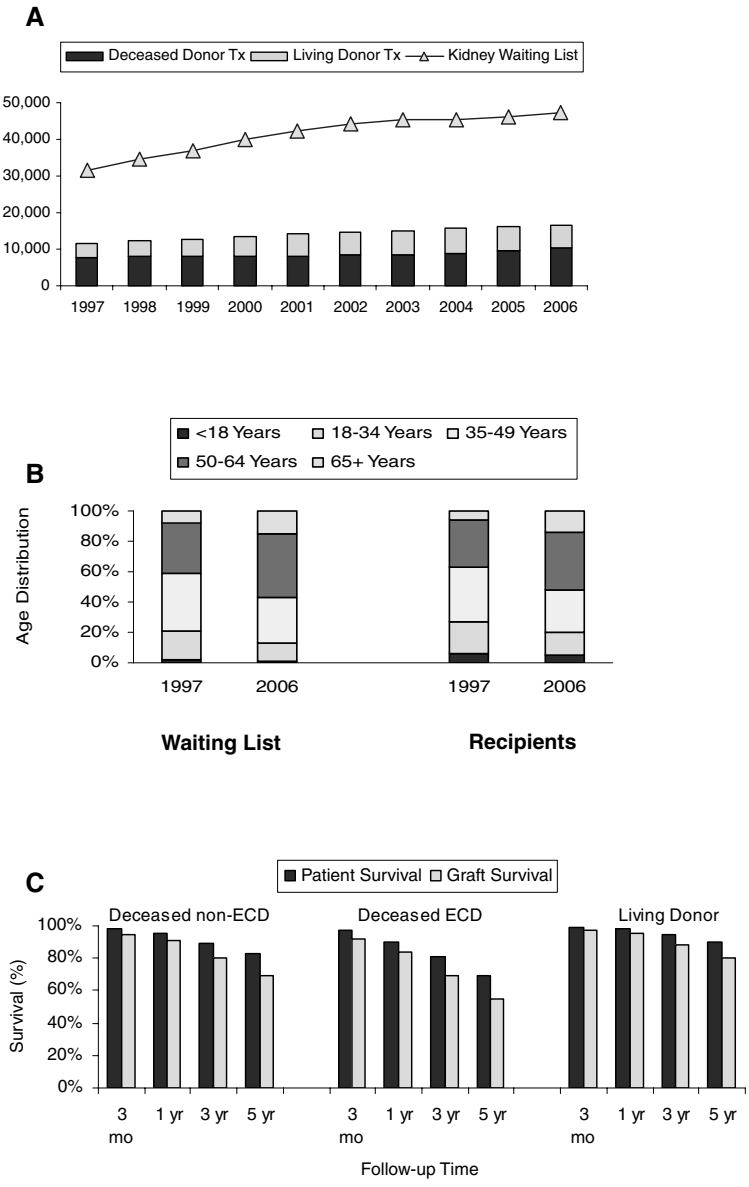

Figure 1: Kidney transplantation at a glance. (A) Number of transplants and size of active waiting list: There was a very large gap between the number of patients waiting for a transplant and the number receiving a transplant. This gap widened over the decade, meaning that the waiting times from listing to transplant continued to increase. The number of living donor transplants increased until 2004, while the number of deceased donor transplants continued to rise gradually. Source: *2007 OPTN/SRTR Annual Report*, Tables 1.7 and 5.1a. (B) Age distribution of recipients and active waiting list: In 2006, 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, except that young (age <35 years) patients showed a greater representation among recipients than on the waiting list. Source: *2007 OPTN/SRTR Annual Report*, Tables 5.1a, 5.4a, 5.4b and 5.4c.
(C) Unadjusted patient and graft survival: Patient survival in recent years has been improving. Five-year patient survival percentages based on transplants during 2000-2005 were clearly higher for recipients of living donor organs (90%) than for recipients of non-ECD organs (83%) or ECD organs (69%). Similarly, living donor organs had the highest 5-year graft survival. ECD: expanded criteria donors. Source: *2007 OPTN/SRTR Annual Report*, Tables 5.10a, 5.10b, 5.10c, 5.14a, 5.14b, 5.14c.

cohorts for which adequate follow-up data have been collected. One-year patient survival rates were highest for kidney recipients and pancreas recipients, ranging from about 95% to 98%. One-year survival for liver, intestine, lung and heart recipients was approximately 81–91%. Survival was lowest for the small number of heart-lung recipients: approximately 75% survived 1 year.

Table 5 shows the percentage of transplanted organs that were still functioning (graft survival) 1 and 5 years after transplantation, by organ. Graft survival was calculated using the same cohorts as patient survival (Table 4), the most recent cohorts for which adequate follow-up data are available. Over 90% of kidneys transplanted alone or as part of a kidney-pancreas transplant were functioning 1 year after transplantation. Graft survival rates were lower than corresponding patient survival rates because some patients survived graft failure by receiving a subsequent transplant or alternative therapy such as dialysis or insulin therapy.

Transplantation at a Glance

Figures 1–8 offer 'dashboard' views of the state of transplantation for different organs. These sets of summary graphics are included for six organs (kidney, PTA, PAK, liver, intestine, heart and lung) as well as the most common multiorgan procedure (simultaneous pancreas-kidney). Other multiorgan procedures are excluded from the counts

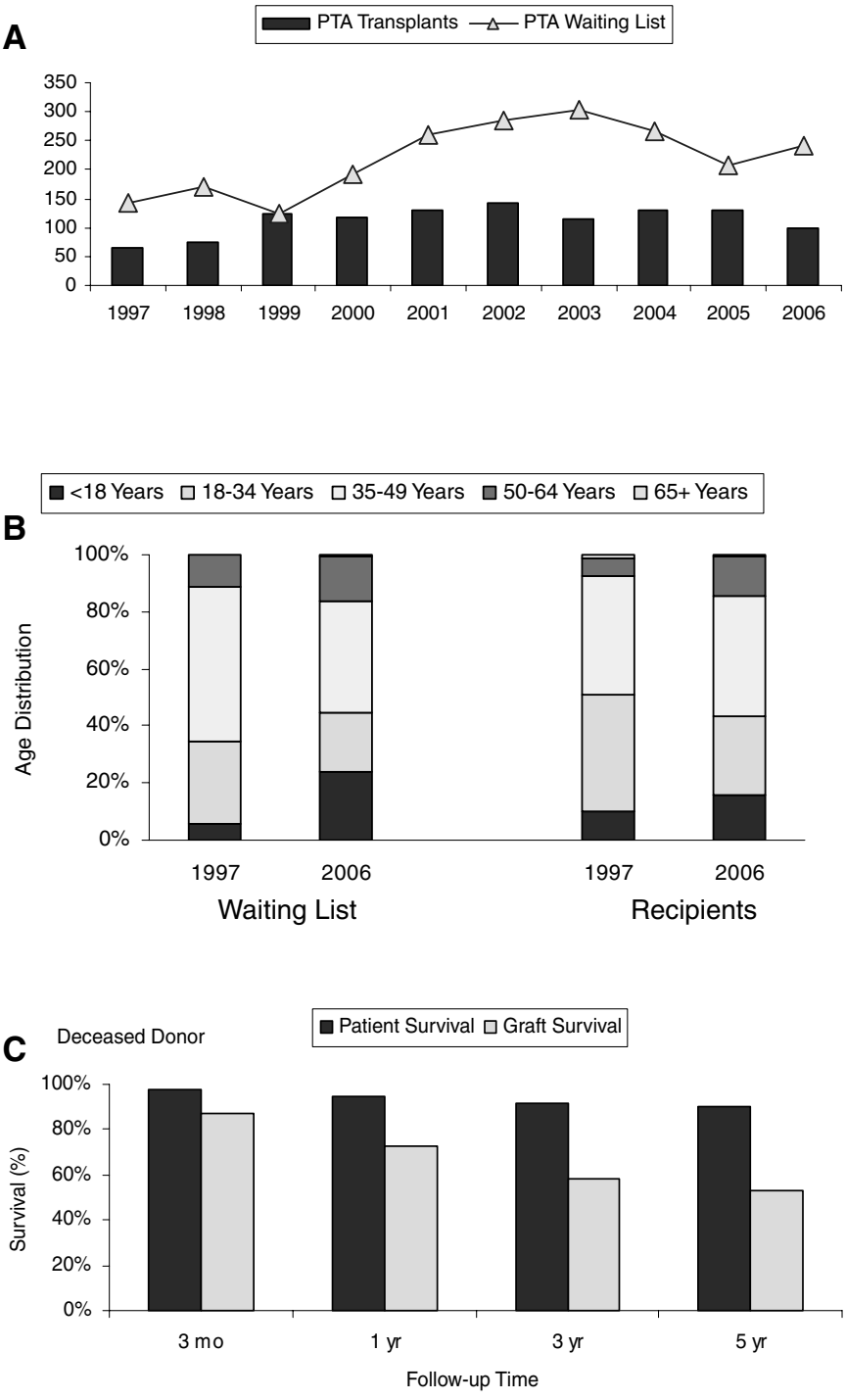

Figure 2: Pancreas transplantation alone (PTA) at a glance.
(A) Number of transplants and size of active waiting list: The number of patients on the waiting list for a pancreas transplant alone had been decreasing since 2003, but it rose slightly in 2006. The number of PTA transplants per year was relatively stable. Source: *2007 OPTN/SRTR Annual Report*, Tables 1.7 and 6.1a.
(B) Age distribution of recipients and active waiting list: For PTA, more pediatric candidates were wait-listed and more received a transplant in 2006 than in 1997. At the same time, the fraction of recipients over age 50 grew. Pediatric diabetic patients rarely have kidney failure before age 18 years, but they are candidates for PTA. Source: *2007 OPTN/SRTR Annual Report*, Tables 6.1a and 6.4.
(C) Unadjusted patient and graft survival: For PTA transplants, patient survival in recent years has been excellent; such recipients do not usually have advanced kidney failure. The 5-year patient survival rate was 90%. Graft survival was considerably lower because patient survival included time after graft failure while patients received insulin or retransplantation. Source: *2007 OPTN/SRTR Annual Report*, Tables 6.10, 6.14.

presented here. For this overview, we have omitted separate figures for heart-lung transplants, given the extremely small number of these procedures. Below we describe the three types of graph shown for each organ.

Number of transplants and size of active waiting list

These figures (A) compare, for each of the last 10 years, the size of the active waiting list and the number of transplants performed. The size of the waiting list is a snapshot

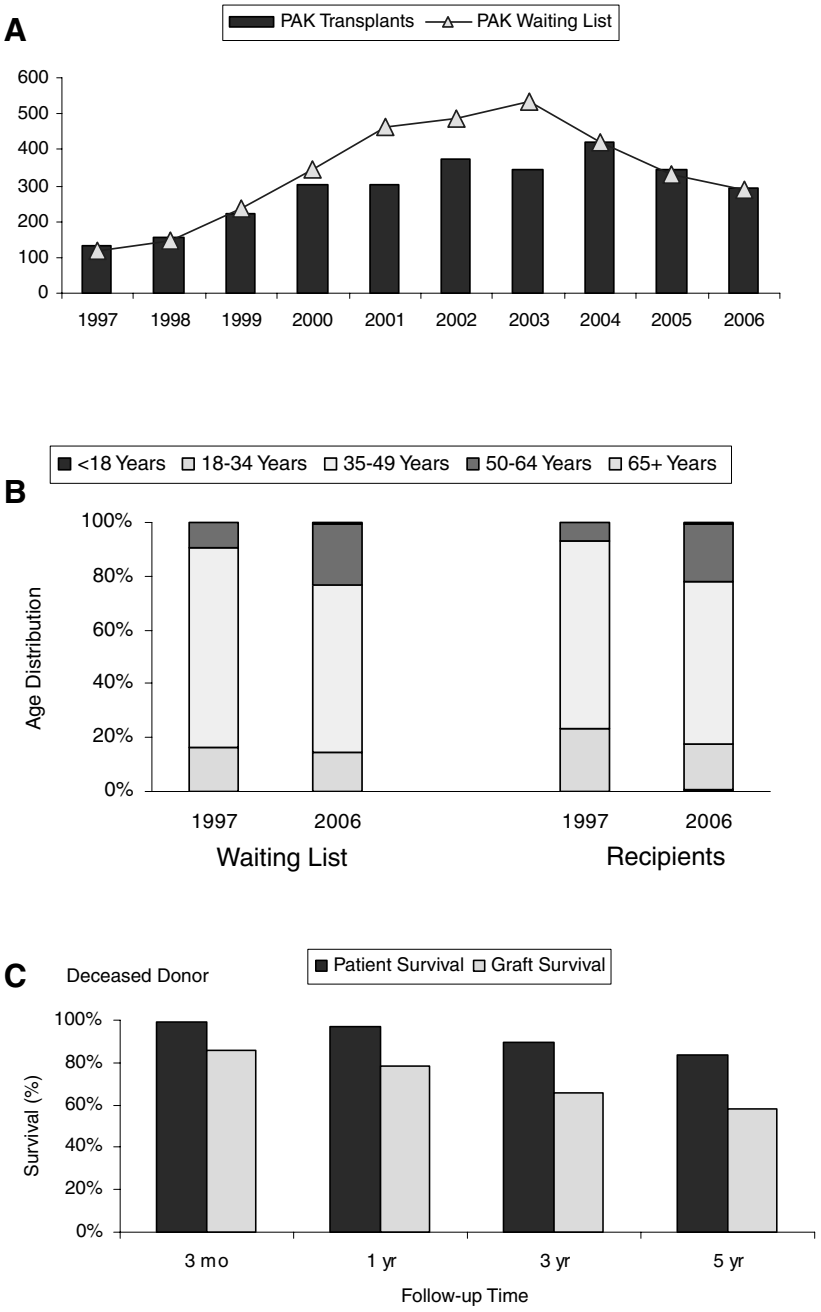

Figure 3: Pancreas after kidney (PAK) transplantation at a glance.
(A) Number of transplants and size of active waiting list: As with PTA, the number of patients on the waiting list for a PAK transplant decreased since 2003. The number receiving a transplant matched the number of candidates at the end of 2004, 2005 and 2006. The number of PAK transplants decreased further from its highest level of the decade in 2004. Source: *2007 OPTN/SRTR Annual Report*, Tables 1.7 and 7.1a.
(B) Age distribution of recipients and active waiting list: For PAK, more patients over 50 were wait-listed and received a transplant in 2006 than in 1997. At the same, time fewer candidates and recipients were in the age group of 18–34. (Since recipients were mostly type 1 diabetics, the ages below 18 years and above 65 years were virtually unrepresented.) Recipients included transplants from both living and deceased donors. Source: *2007 OPTN/SRTR Annual Report*, Tables 7.1a and 7.4.
(C) 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 84%. Graft survival was considerably lower because patient survival included time after graft failure while patients received treatment with insulin or retransplantation. Source: *2007 OPTN/SRTR Annual Report*, Tables 7.10, 7.14.

of the number of candidates active on the waiting list at the end of each year, although additional patients were listed or removed at some time during the year. The number of transplants includes all transplants performed over the year. This difference in methods of counting explains why 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. Other instances of the narrowing gap between waiting list size and number of transplants reflect changes in allocation policy and wait-listing practices.

Age distribution of recipients and active waiting list
This overview (B) groups all pediatric patients (<18 years) together, for ease of viewing. The *OPTN/SRTR Annual Report* data tables (and the accompanying chapters analyzing them) divide this group into several age subgroups: <1 year, 1–5 years, 6–10 years and 11–17 years. Here, we have included only the data for 1997 and 2006; additional

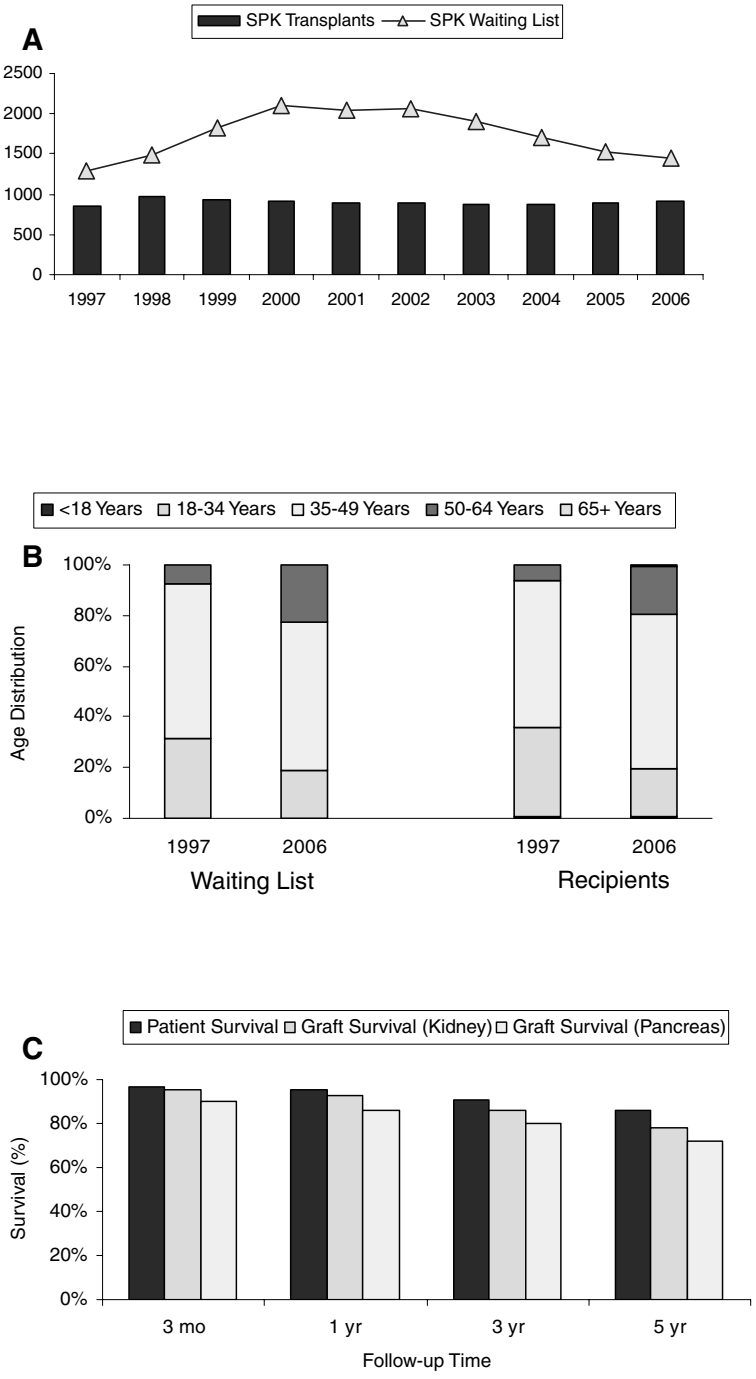

Figure 4: Simultaneous pancreas-kidney (SPK) transplantation at a glance.
(A) Number of transplants and size of active waiting list: SPK accounts for the large majority of all pancreas transplants. Numbers of this procedure were stable over the decade. The gap between the number of patients waiting for a transplant and the number receiving a transplant dropped substantially since 2000. Source: *2007 OPTN/SRTR Annual Report*, Tables 1.7 and 8.1a.
(B) Age distribution of recipients and active waiting list: For SPK transplantation, patients over age 50 made up greater fractions of both candidates and recipients in 2006 than in 1997. At the same time, fewer candidates and recipients were in the age group of 18–34 years. (Since recipients were mostly type 1 diabetics, the ages below 18 years and above 65 years were virtually unrepresented.) Recipients included transplants from both living and deceased donors. Source: *2007 OPTN/SRTR Annual Report*, Tables 8.1a and 8.4.
(C) Unadjusted patient and graft survival: Patient survival has improved for SPK recipients in recent years. All SPK transplants were from deceased donors and their 5-year patient survival was 86%. Graft survival was lower because patient survival included time after graft failure while patients received treatment with insulin or retransplantation. Source: *2007 OPTN/SRTR Annual Report*, Tables 8.10, 8.14.

detail may be found in the organ-specific articles of this report.

Unadjusted patient and graft survival

These overview figures (C) show survival of transplant recipients (patient survival) and the transplanted organ (graft survival) at 3 months, 1 year, 3 years and 5 years following transplantation. The figures are based on information about the most recent cohorts possible that allow sufficient follow-up time for data collection and ascertainment of events.

The Articles in the 2007 Report on the State of Transplantation

Figures 1–8 give a quick view of the major trends addressed and analyzed in each of the organ-specific articles

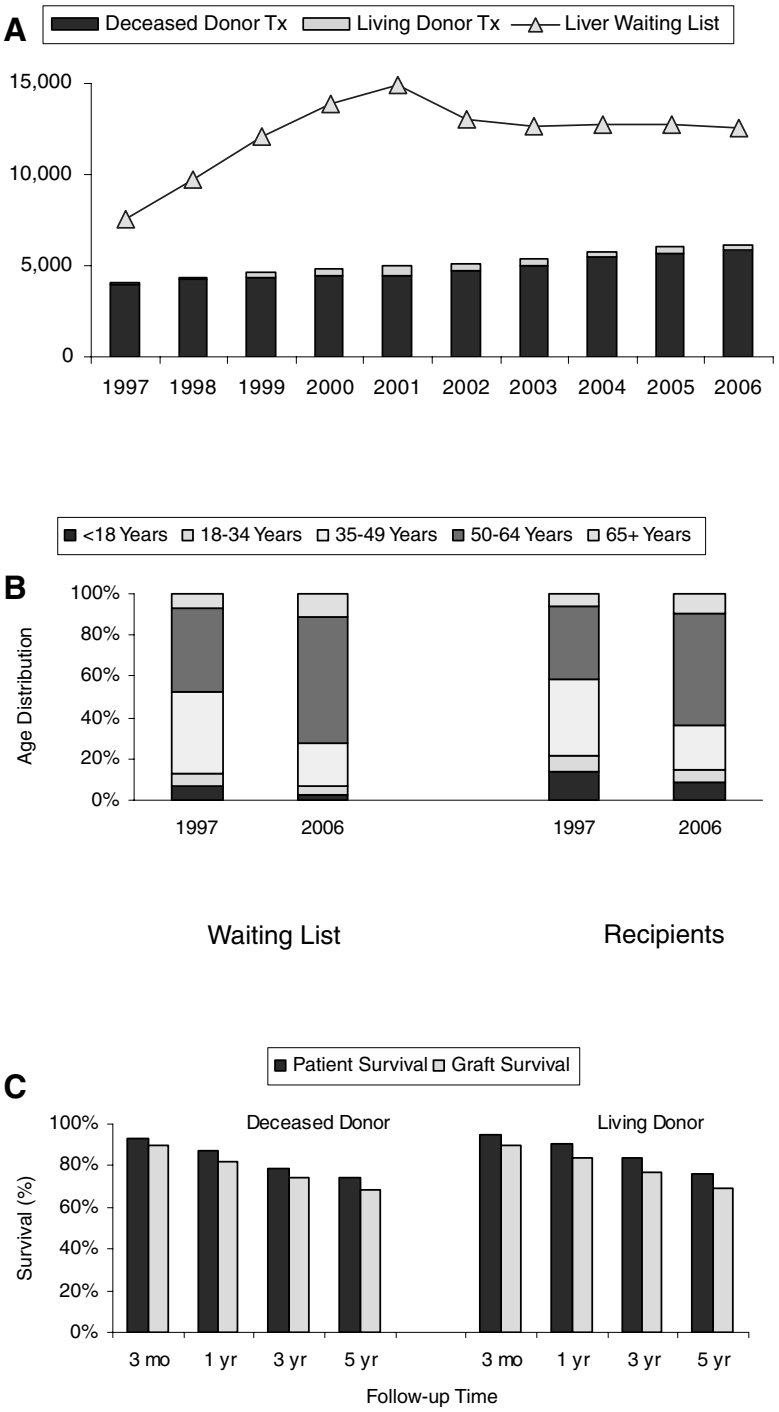

Figure 5: Liver transplantation at a glance. (A) Number of transplants and size of active waiting list: The large increase in the number of patients awaiting a liver transplant has stabilized since 2002, when the MELD/PELD system began. The number receiving a deceased donor liver transplant has gradually increased, more steeply in 2004–2006. The gap between the number of candidates and recipients has been slowly shrinking since 2002. Source: *2007 OPTN/SRTR Annual Report*, Tables 1.7, 9.1a and 9.1b.
(B) 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: *2007 OPTN/SRTR Annual Report*, Tables 9.1a, 9.4a and 9.4b.
(C) Unadjusted patient and graft survival: Patient survival in recent years has been improving for both deceased donors and living donors, with 74% and 76% of patients, respectively, alive five years following transplantation. Graft survival was lower because patient survival included time after graft failure for patients receiving repeat liver transplantation. Source: *2007 OPTN/SRTR Annual Report*, Tables 9.10a, 9.10b, 9.14a, and 9.14b.

of this report. Articles on kidney and pancreas (2), liver and intestine (3) and heart and lung (4) provide detailed trends in donation, waiting time, allocation, posttransplant outcomes and the demographics of both candidates and recipients. Additionally, these articles supplement the reporting of 10-year trends with updates on recent changes in allocation policy, immunosuppression, clinical practice and other areas relevant to the transplantation of different organ types.

In this year's report, the three organ-specific articles are preceded by a review of trends in organ donation and

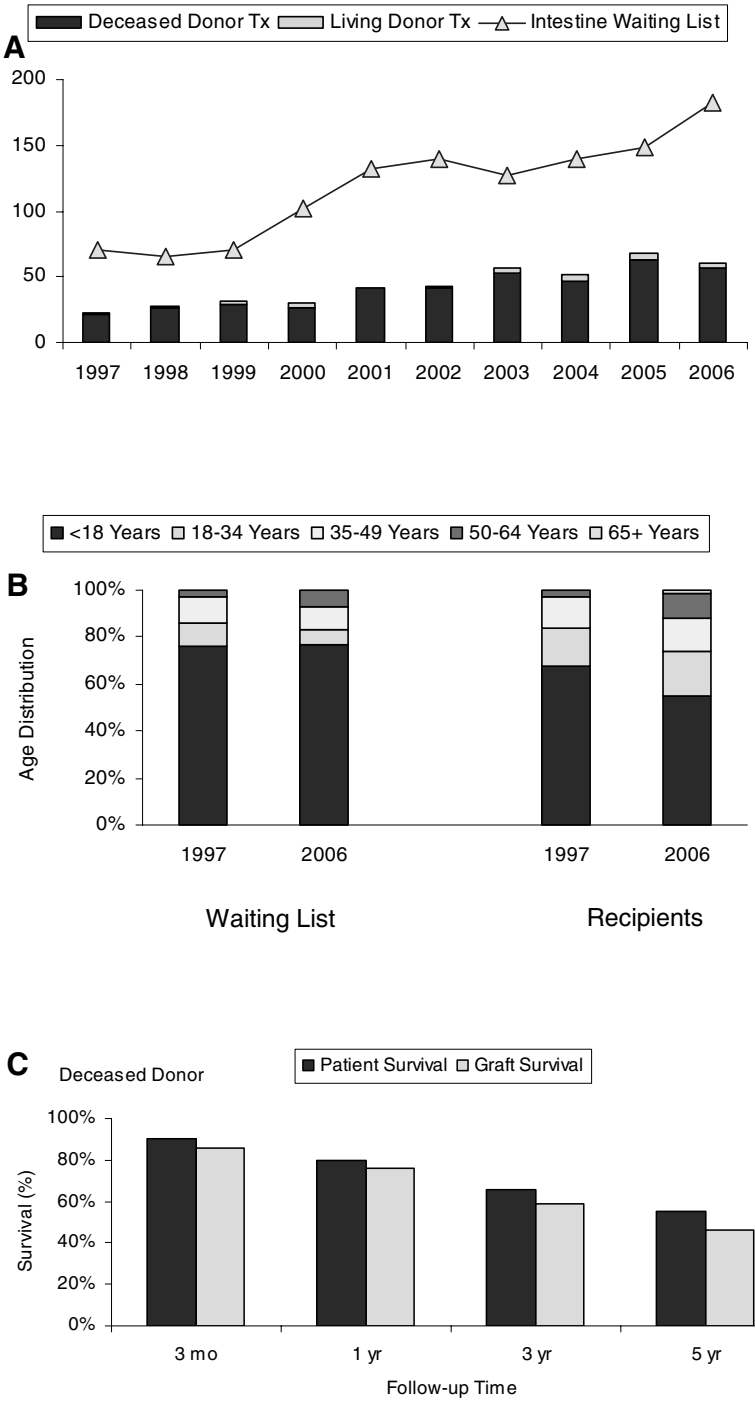

Figure 6: Intestine transplantation at a glance.
(A) Number of transplants and size of active waiting list: The number of patients on the intestine waiting list and the number receiving a transplant both more than doubled between 1997 and 2007. The difference between the number of candidates and transplant recipients increased through the second half of the decade. Source: *2007 OPTN/SRTR Annual Report*, Tables 1.7 and 10.1a.
(B) Age distribution of recipients and active waiting list: About 75% of intestine candidates were in the pediatric age group. The small group of candidates in the age group >50 years doubled during the decade. Adult recipients made up a greater portion of recipients than candidates. The age group older than 50 years showed a large increase during the decade in both categories. Source: *2007 OPTN/SRTR Annual Report*, Tables 10.1a and 10.4.
(C) Unadjusted patient and graft survival: One-year patient survival was 80% in 2006; however, longer-term survival at 5 years was 55%. Graft survival was lower, as patient survival included time after graft failure while patients received parenteral alimentation or retransplantation. Source: *2007 OPTN/SRTR Annual Report*, Tables 10.10, 10.14.

utilization (5) including recent efforts to increase the number of donors, and an article devoted to the particular outcomes and policy concerns of pediatric transplantation (6).

This year's report concludes with three 'special-focus' articles that look closely at issues of recent interest to the transplant community. An article on 'transplant tourism' (7) examines the implications of patients on US waiting lists who received transplants abroad. An article on the concept of 'life years from transplant' (8) details the methodology used in recent SRTR work done in conjunction with the OPTN Kidney Committee in establishing a kidney allocation system that incorporates a measure of expected

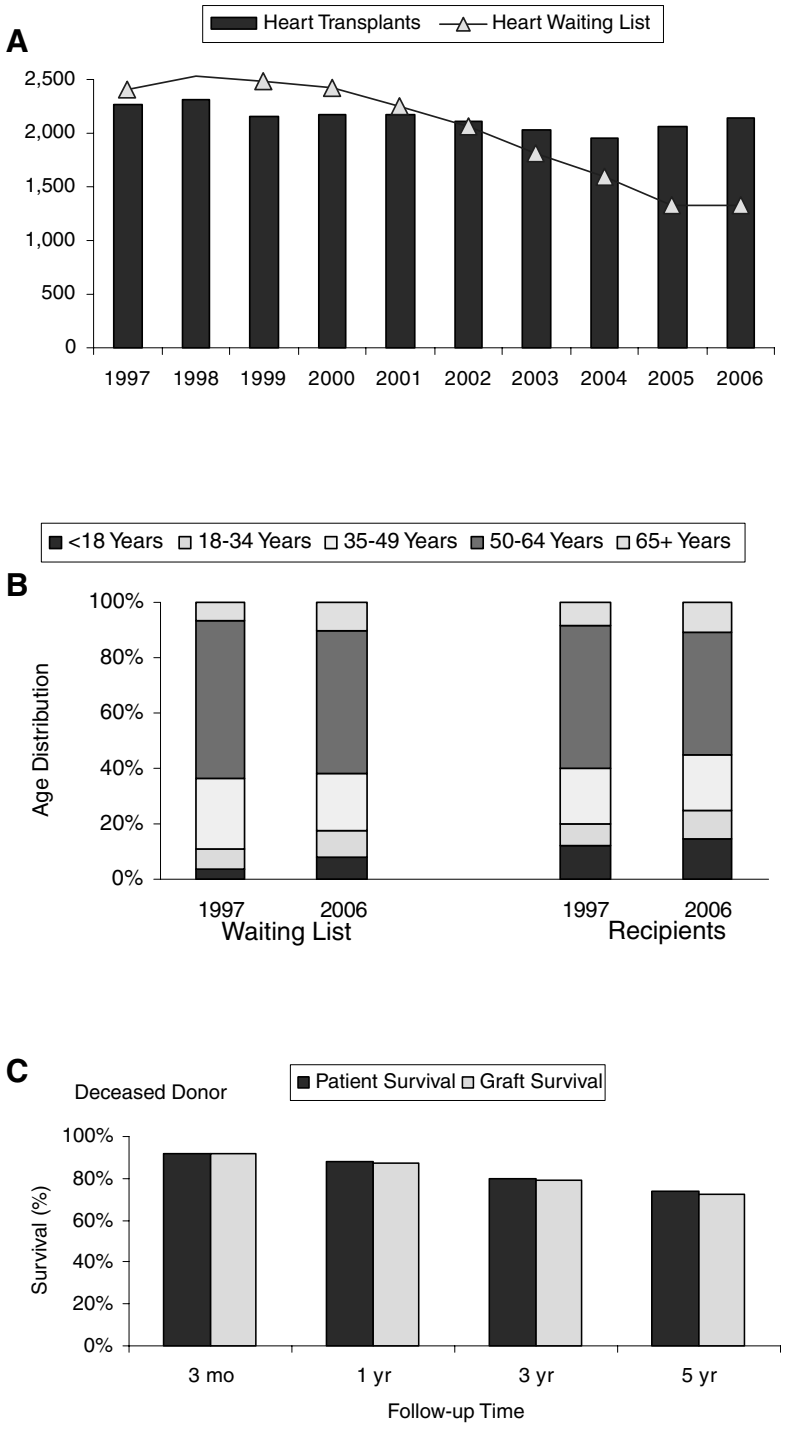

Figure 7: Heart transplantation at a glance.
(A) Number of transplants and size of active waiting list: The number of heart transplants increased in 2005 and 2006 after several years of gradual reduction. The number of patients awaiting a heart decreased steeply since 2000, likely reflecting improvements in medical therapy. Source: *2007 OPTN/SRTR Annual Report*, Tables 1.7 and 11.1a.
(B) Age distribution of recipients and active waiting list: Trends in the age distribution of wait-listed candidates show that the number of patients younger than 34 years and older than 65 years increased, while the age group 35–64 years was less represented. 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: *2007 OPTN/SRTR Annual Report*, Tables 11.1a and 11.4.
(C) Unadjusted patient and graft survival: Patient survival improved in recent years for heart recipients. At 1 and 5 years following heart transplantation, 88% and 74% of patients, respectively, were alive. Graft survival was very similar because very few patients may receive a second heart transplant after graft failure. Source: *2007 OPTN/SRTR Annual Report*, Tables 11.10, 11.14.

recipient benefit. Lastly, an article on performance measures (9) introduces readers to the SRTR's reports on transplant center and organ procurement organization outcomes. These articles all include special analyses performed by the SRTR and touch on topics that are timely and have implications for policy and clinical practice.

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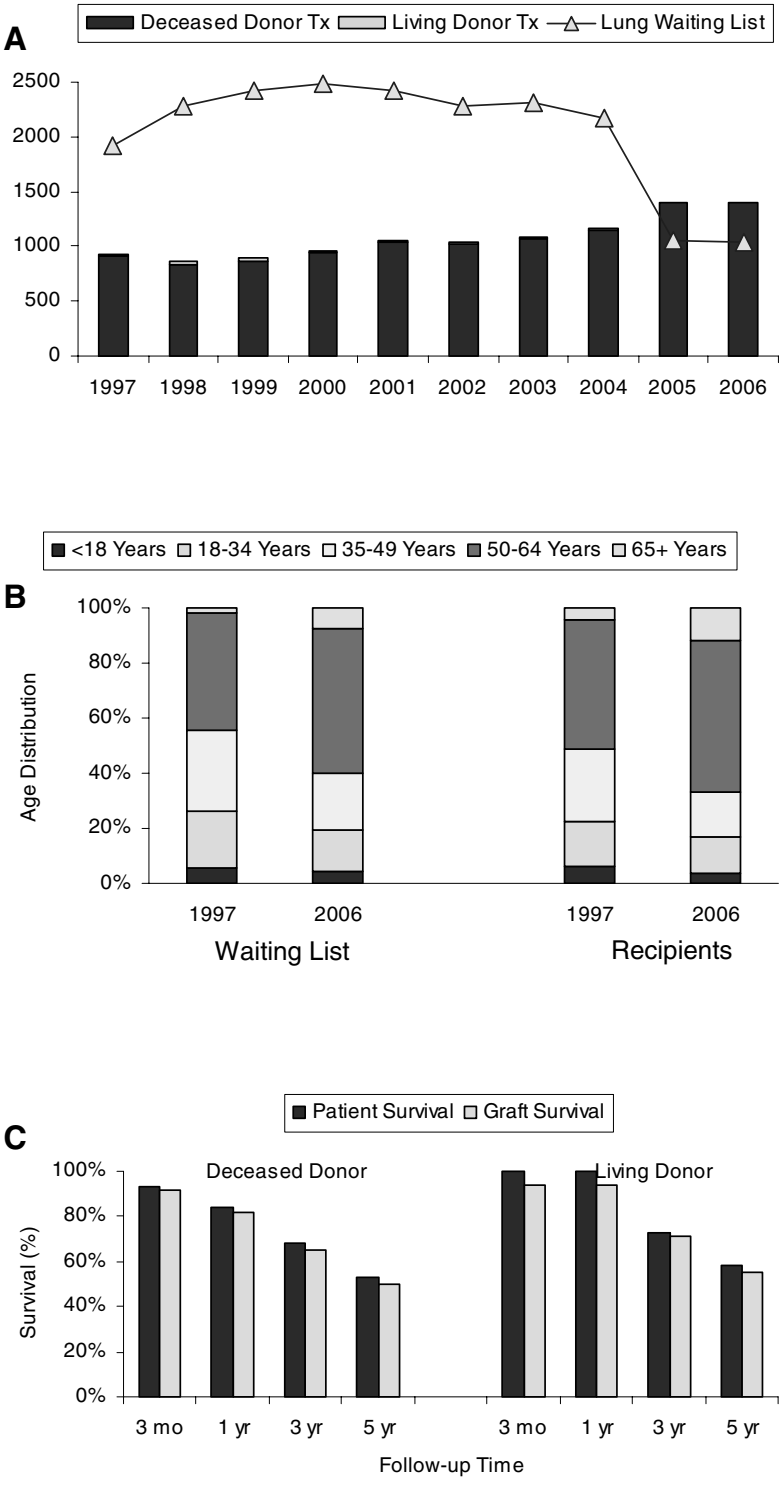

Figure 8: Lung transplantation at a glance.
(A) Number of transplants and size of active waiting list: The number of lung transplants increased steeply in the last two years. The number of patients awaiting a transplant dropped steeply in 2005 after a stable pattern during the prior 7 years. This sharp reduction is largely attributable to changes in allocation policy, which now considers urgency and benefit rather than time spent waiting. Source: *2007 OPTN/SRTR Annual Report*, Tables 1.7 and 12.1a.
(B) 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 of candidates 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 similarly a strong increase for ages above 50 years but a decrease in percentages for younger ages, including pediatric ages. Recipients included transplants from both living and deceased donors. Source: *2007 OPTN/SRTR Annual Report*, Tables 12.1a, 12.4a and 12.4b.
(C) Unadjusted patient and graft survival: Patient survival has been improving in recent years for both deceased and living donor lung transplant recipients. At one year following deceased donor and living donor lung transplantation, 84% and 100% of patients, respectively, were alive. With the recent good results at one year, it is hoped that longer term patient survival will improve. Graft survival was very similar because very few patients may live after graft failure through a second lung transplant. Source: *2007 OPTN/SRTR Annual Report*, Tables 12.10a, 12.10b, 12.14a, 12.14b.

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Note on sources: The articles in this report are based on the reference tables in the *2007 OPTN/SRTR Annual Report*, which are not included in this publication. Many relevant data appear in the figures and tables included here; other tables from the *Annual Report* that serve as the basis for this article include the following: Tables 1.1–1.4, 1.7, 1.13, 1.14, 5.1a, 5.4a–c,

5.10a–c, 5.14a–c, 6.1a, 6.4, 6.10, 6.14, 7.1a, 7.4, 7.10, 7.14, 8.1a, 8.4, 8.10, 8.14, 9.1a–b, 9.4a–b, 9.10a–b, 9.14a–b, 10.1a, 10.4, 10.10, 10.14, 11.1a, 11.4, 11.10, 11.14, 12.1a, 12.4a–b, 12.10a–b and 12.14a–b. All of these tables may be found online at www.ustransplant.org.

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