American Journal of Transplantation 2009; 9 (Part 2): 869–878
Wiley Periodicals Inc.

doi: 10.1111/j.1600-6143.2009.02564.x

Trends in Organ Donation and Transplantation in the United States, 1998–2007

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The articles in this report are based on the reference tables in the 2008 OPTN/SRTR Annual Report. Table numbers are noted in brackets and may be found online at: http://www.ustransplant.org.

Key words: Allocation, graft survival, OPTN, organ donation, patient survival, SRTR, transplantation, waiting list

Introduction

This article presents an overview of solid organ transplantation in the United States and is produced as part of the 2008 *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 reviews 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 eight articles focused on specific topics in solid organ transplantation. Each article was written by experts in the field of transplantation and provides a comprehensive look at the current state of transplantation and trends over the past 10 years. The text and figures in these articles are drawn from recent SRTR analyses and the extensive reference tables of the 2008 *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 eight articles and the 2008 *Annual Report* 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

At the close of 2006 there were 173 339 persons recorded in available OPTN data, who were living with a functioning organ transplant *[Table 1.14]*. This number reflects an increase of 1.6% over 2005 and a 60% increase since 1998.

The total number of organs transplanted decreased from 28 291 in 2006 to 27 578 in 2007; this was an overall decrease of 713 organs transplanted (2.5%) and a decrease of 423 (6.3%) in living donor transplants (Table 1). Deceased donor kidney transplants decreased by 1.3%, and living donor kidney transplants dropped by 6.1%. A decrease of 3.8% was observed in deceased donor liver transplants in 2007.

The number of lung transplants increased 4.3% while heart, deceased donor intestine, pancreas and heart–lung transplantation changed little. The 27 578 organs transplanted in 2007 came from 14 399 organ donors, 357 fewer donors than there were in 2006 (2.4% decrease) *[Table 1.1]*.

The total number of transplants in the United States increased on average by 872 transplants per year between 1998 and 2006 *[Table 1.7]*. Thus, the decrease of 713 transplants in 2007 represents a substantial divergence from the longstanding trend. This drop was largely due to decreases in donation, particularly by living donors. There were 423 (6.3%) fewer living donors in 2007 than in 2006. Living donation has been decreasing since 2004 *[Table 1.1]*.

The number of organs recovered for transplant from deceased donors has similarly departed from the recent trend. In 2007, there were 28 409 organs recovered compared with 28 322 in 2006 (Table 2). This increase of 87 organs is the smallest in 10 years. An average increase of 930 organs per year was seen between 1998 and 2006 *[Table 1.2]*.

More multiorgan transplants (97) were performed in 2007 than in 2006, the biggest increase in the number of multiorgan transplants in 10 years. Those 97 transplants involved 229 total organs *[Table 1.8]*.

The percentage of kidneys recovered but not used for transplant was the highest in 10 years. In 2007, there were

Table 1: Change in number of transplanted organs, 2006–2007

Transplanted organs	2006	2007	Percent change
Total	28 291	27 578	−2.5
Deceased donor	21 562	21 272	−1.3
Living donor	6729	6306	−6.3
Kidney	16 644	16 119	−3.2
Deceased donor	10 212	10 082	−1.3
Living donor	6432	6037	−6.1
Pancreas	1368	1304	−4.7
PTA	98	110	12.2
PAK	292	259	−11.3
Kidney–pancreas	914	848	−7.2
Liver	6136	5890	−4.0
Deceased donor	5849	5625	−3.8
Living donor	287	265	−7.7
Intestine	60	57	−5.0
Deceased donor	57	57	0.0
Living donor	3	—	n/a
Heart	2148	2141	−0.3
Deceased donor	2147	2141	−0.3
Living donor	1	—	n/a
Lung	1401	1461	4.3
Deceased donor	1397	1458	4.4
Living donor	4	3	−25.0
Heart–lung	31	29	−6.5

Source: 2008 *OPTN/SRTR Annual Report*, Table 1.7.

Table 2: Growth in number of recovered organs, 2006–2007

Recovered organs	2006	2007	Percent change
Total	28 322	28 409	0.31
Kidney	14 284	14 384	0.70
Pancreas–all	2032	1927	−5.17
Liver	7084	7029	−0.78
Intestine	185	205	10.81
Heart	2276	2289	0.57
Lung	2461	2575	4.63

Source: 2008 *OPTN/SRTR Annual Report*, Table 1.2.

Table 3: Patients on waiting lists, 2006–2007

	End of year		
Organs	2006	2007	Percent change
Total	92 845	97 248	4.7
Kidney	66 352	71 862	8.3
PTA	598	585	−2.2
PAK	988	918	−7.1
Kidney–pancreas	2326	2242	−3.6
Liver	16 623	16 438	−1.1
Intestine	234	222	−5.1
Heart	2769	2659	−4.0
Lung	2822	2217	−21.4
Heart–lung	133	105	−21.1

Source: 2008 *OPTN/SRTR Annual Report*, Table 1.3. PTA = pancreas transplant alone; PAK = pancreas after kidney.

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

Organ transplanted	One-year survival (%)	Five-year survival (%)
Kidney		
Deceased donor	95.0	81.0
Living donor	98.2	90.6
Pancreas alone	97.9	88.7
Pancreas after kidney	97.3	83.9
Kidney–pancreas	95.1	86.6
Liver		
Deceased donor	87.1	73.3
Living donor	89.9	77.3
Intestine	81.4	56.2
Heart	87.6	73.9
Lung	83.6	53.4
Heart–lung	73.8	46.5

Source: 2008 *OPTN/SRTR Annual Report*, Table 1.13.

2389 kidneys (16.6% of kidneys recovered that year) that were discarded compared with the 2129 (14.9%) kidneys discarded in 2006 *[Table 3.1]*.

At the end of 2007, there were 97 248 people registered on organ waiting lists (65 411 active, 31 821 inactive and 16 of unknown status); this reflects a 4.7% increase over the number of people waiting for an organ at the end of 2006 *[Table 1.4]*. The percentage of patients who were inactive on the kidney waiting list at the end of each year has increased from 15% to 32% from 2003 to 2007, with 23 089 patients listed as inactive status in 2007 *[Tables 5.1a and b]*. This increase is presumably due to policy implemented in 2003 that allows accrual of waiting time during inactive status.

Table 3 shows the 1-year change in the number of patients on the waiting list for each organ and includes patients listed at both active and inactive status. The kidney waiting list grew by 8.3% while the list for kidney–pancreas

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

Organ transplanted	One-year survival (%)	Five-year survival (%)
Kidney		
Deceased donor	90.4	68.2
Living donor	95.6	80.7
Pancreas alone	81.2	51.3
Pancreas after kidney	77.2	53.6
Kidney–pancreas (kidney)	92.8	78.5
Kidney–pancreas (pancreas)	86.0	72.6
Liver		
Deceased donor	82.4	67.6
Living donor	84.8	70.9
Intestine	68.3	36.3
Heart	87.2	72.8
Lung	82.2	50.5
Heart–lung	73.7	45.2

Source: 2008 *OPTN/SRTR Annual Report*, Table 1.13.

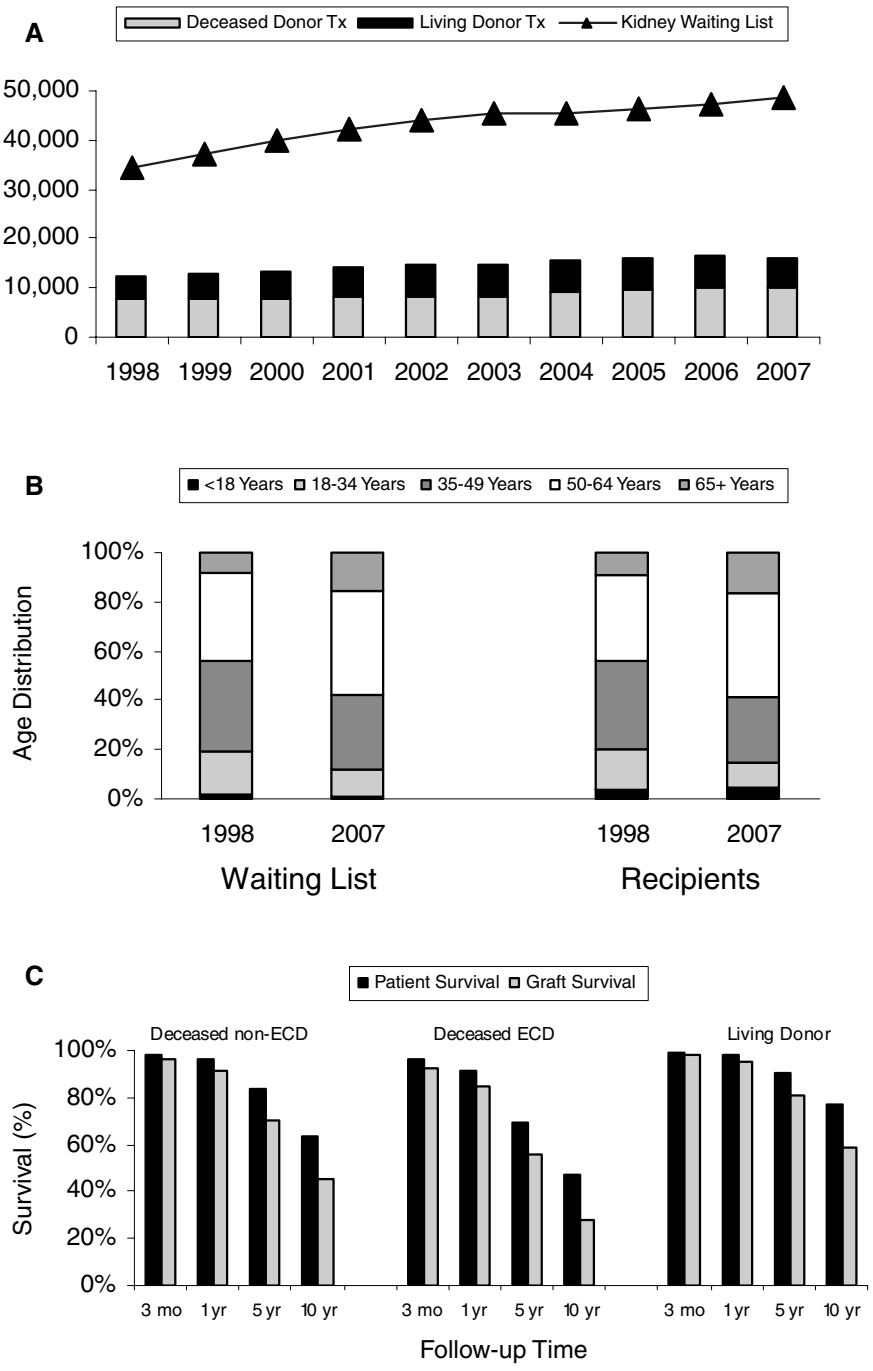

Figure 1: Kidney transplantation at a glance. (A) Number of transplants and size of active waiting list: There was a very large gap between the number of patients waiting for a transplant and the number receiving a transplant. This gap widened over the decade, meaning that the waiting times from listing to transplant continued to increase. The number of living donor transplants grew until 2004, while the number of deceased donor transplants continued to rise gradually. Source: *2008 OPTN/SRTR Annual Report*, Tables 1.7, 5.1a. (B) Age distribution of recipients and active waiting list: In 2007, 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 patients (age < 35 years) showed a greater representation among recipients than on the waiting list. Source: *2008 OPTN/SRTR Annual Report*, Tables 5.1a, 5.4a, 5.4b, 5.4c. (C) Unadjusted patient and graft survival: Five-year patient survival percentages (based on transplants during 2001–2006) and 10-year patient survival (based on transplants during 1996–2006) 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: *2008 OPTN/SRTR Annual Report*, Tables 5.10a, 5.10b, 5.10d, 5.14a, 5.14b, 5.14d.

shrank by 3.6%. Other modest declines were seen on the liver and heart lists; the largest decline (21.4%) was seen on the lung waiting list. Dramatic changes regarding the lung waiting list in 2005 and 2006 might be largely caused by changes in the deceased donor lung allocation policy that were implemented in May 2005. 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.

Patient survival after transplant 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 2005–2006, while the cohort for 5-year survival is based on recipients transplanted in 2001–2006. These are the most recent cohorts for which adequate follow-up data have been collected. Kidney recipients and pancreas

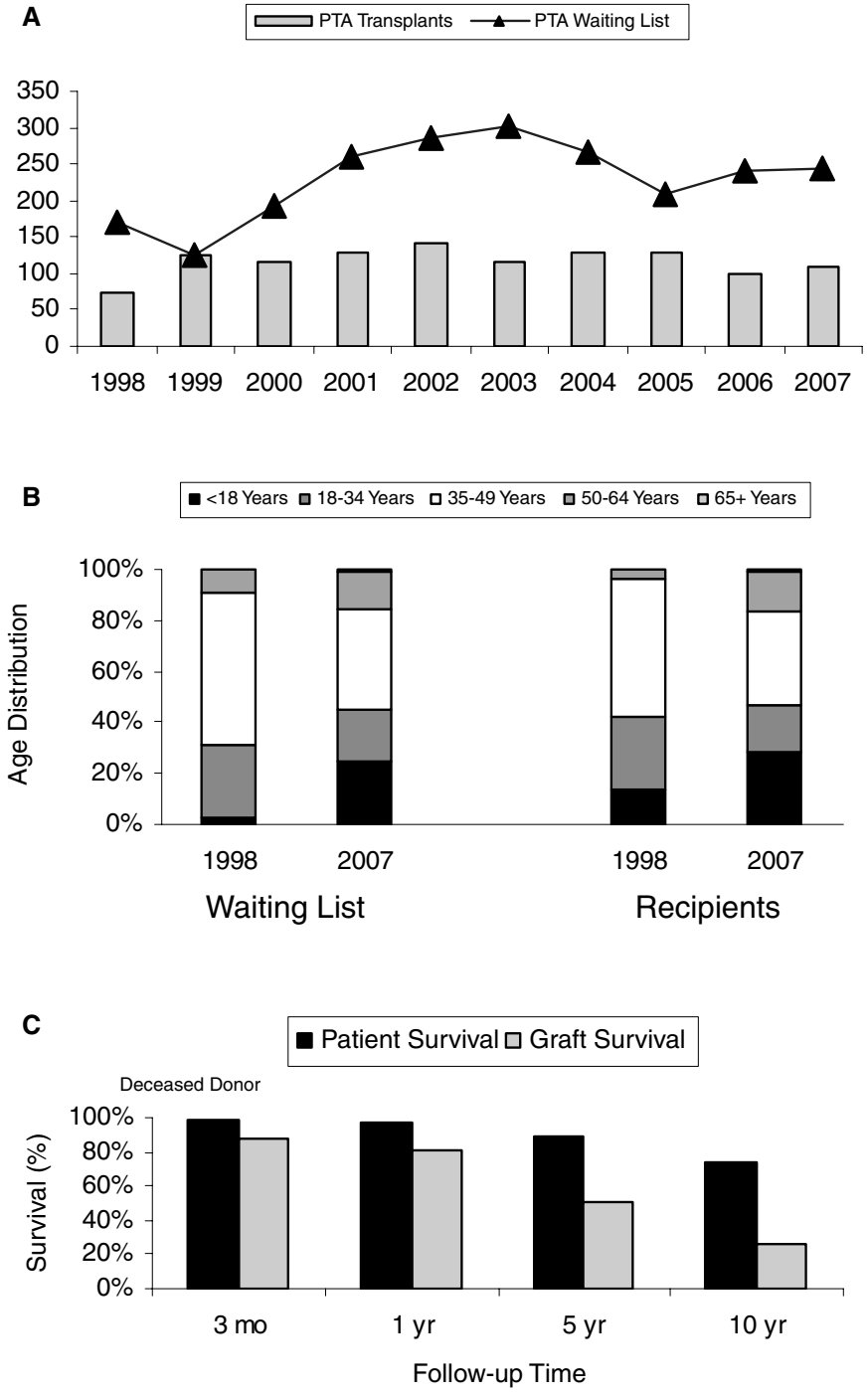

Figure 2: Pancreas transplantation alone (PTA) at a glance. (A) Number of transplants and size of active waiting list: The number of patients on the waiting list for a pancreas transplant alone had been decreasing since 2003, but it rose slightly in 2006 and 2007. The number of PTA transplants per year was relatively stable. Source: *2008 OPTN/SRTR Annual Report*, Tables 1.7, 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 2007 than in 1998, 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: *2008 OPTN/SRTR Annual Report*, Tables 6.1a, 6.4. (C) Unadjusted patient and graft survival: For PTA transplants, patient survival has been excellent. The 5-year patient survival rate was 89%. Graft survival was considerably lower, especially at 5 and 10 years post-transplant. Source: *2008 OPTN/SRTR Annual Report*, Tables 6.10, 6.14.

recipients had the highest 1-year patient survival rates, ranging from about 95% to 98%. One-year survival for liver, intestine, lung and heart recipients was approximately 81–90%. Survival was lowest for the small number of heart–lung recipients: approximately 74% survived 1 year.

Table 5 shows graft survival by organ, that is, the percentage of transplanted organs that were still functioning 1 and 5 years after transplantation. Graft survival was calculated using the same cohorts as patient survival (Table 4); these groups represent the most recent cohorts available with adequate follow-up data. 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 organ failure by receiving

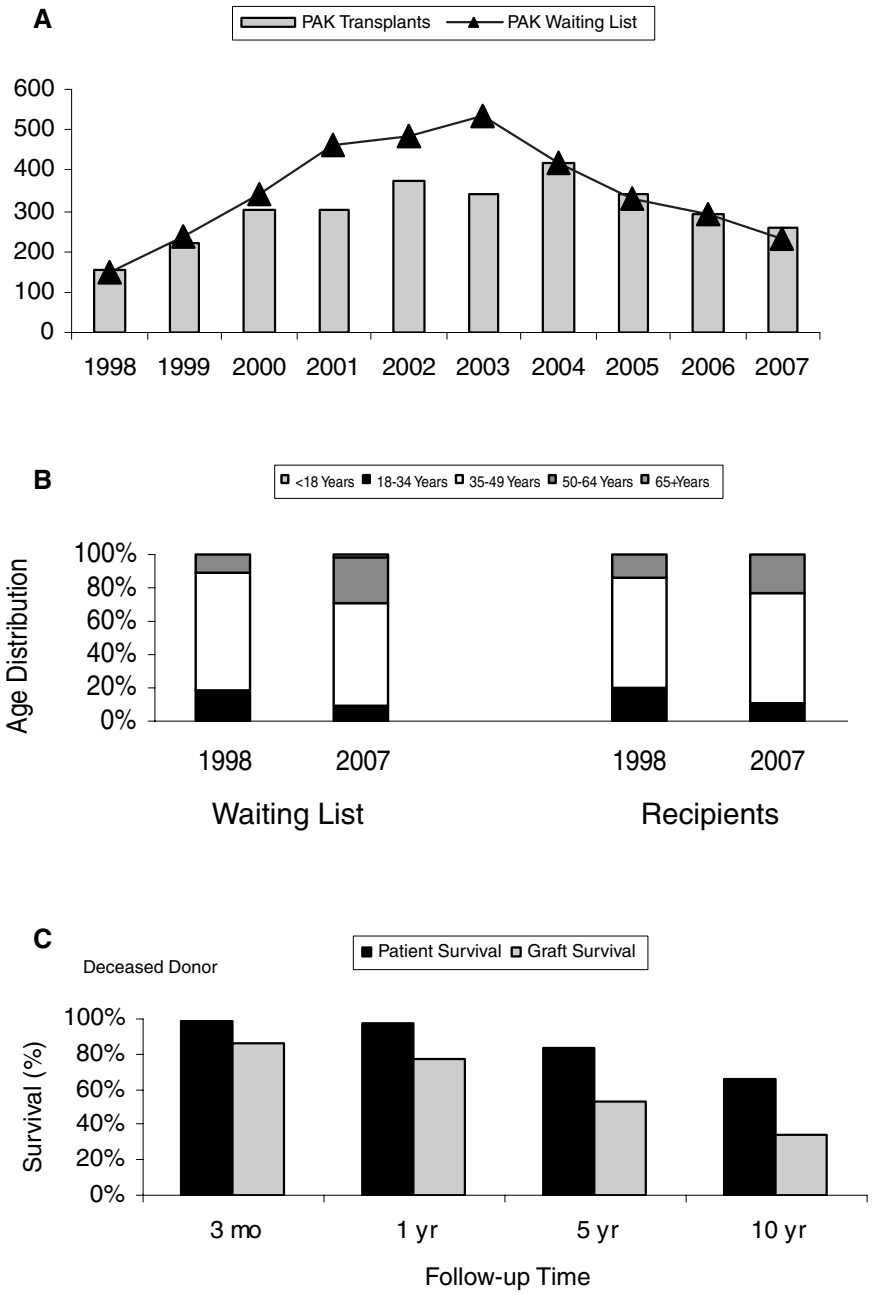

Figure 3: Pancreas after kidney (PAK) transplantation at a glance. (A) Number of transplants and size of active waiting list: As with PTA, the number of patients on the waiting list for a PAK transplant has decreased since 2003. The number who received a transplant has matched the number of candidates each year since 2004. The number of PAK transplants has decreased from its highest level of the decade in 2004. Source: *2008 OPTN/SRTR Annual Report*, Tables 1.7, 7.1a. (B) 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 2007 than in 1998. 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: *2008 OPTN/SRTR Annual Report*, Tables 7.1a, 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%. Pancreas graft survival after PAK was considerably lower. Source: *2008 OPTN/SRTR Annual Report*, Tables 7.10, 7.14.

a subsequent transplant or alternative therapy such as dialysis or insulin therapy.

Transplantation at a Glance

The figure sets accompanying this article (Figures 1–8) provide overviews of the state of transplantation for different organs. These summary graphics are included for six organs: kidney, pancreas (as PTA or PAK transplant, liver, intestine, heart and lung), as well as the most common multiorgan procedure, simultaneous pancreas–kidney transplantation. Other multiorgan procedures are excluded from the counts presented here (e.g. heart–lung transplants) because of the small numbers 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 compare, for each of the past 10 years, the size of the active waiting list and the number of transplants

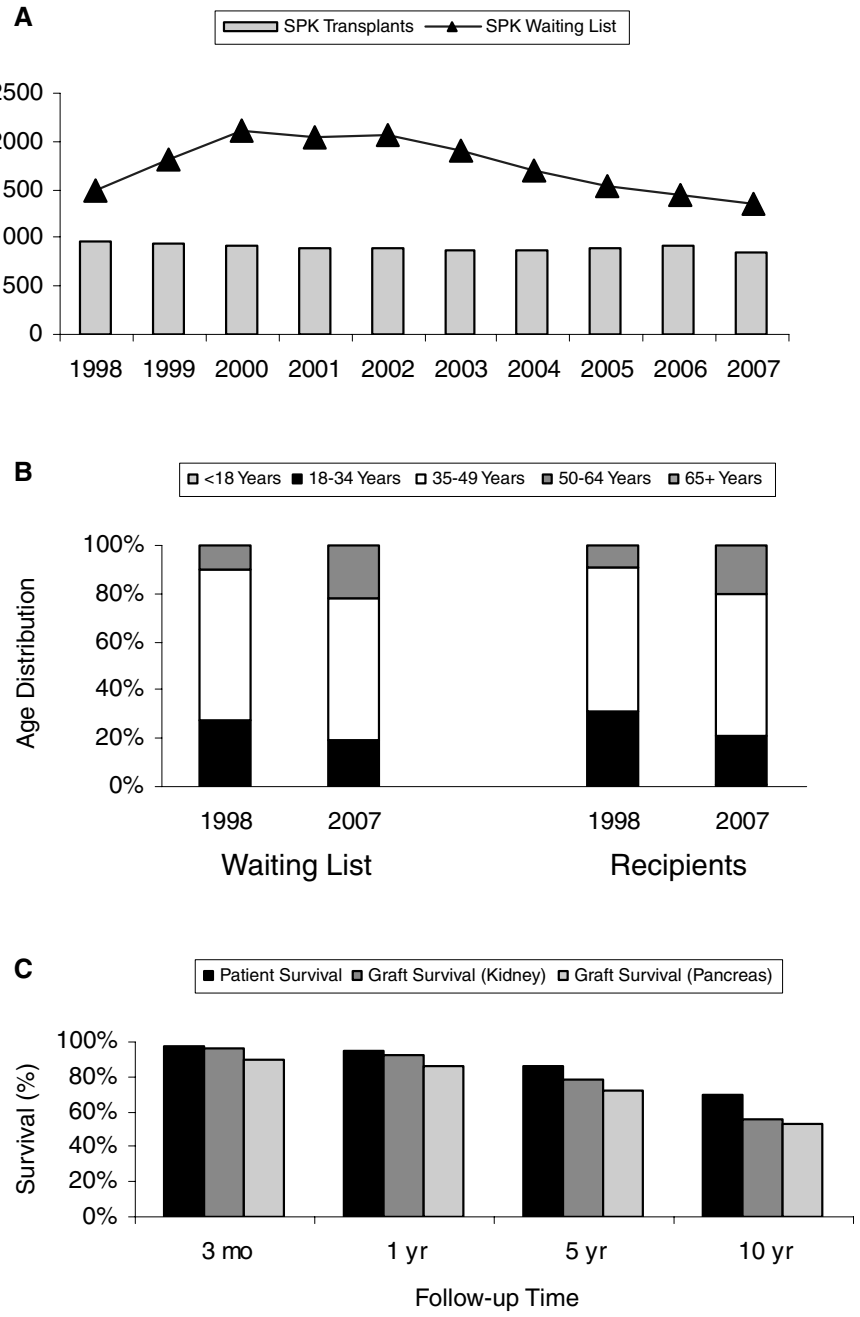

Figure 4: Simultaneous pancreas–kidney (SPK) transplantation at a glance. (A) Number of transplants and size of active waiting list: SPK accounts for the majority of all pancreas transplants. Numbers of this procedure were stable over the decade. The gap between the number of patients waiting for a transplant and the number receiving a transplant has dropped substantially since 2000. Source: *2008 OPTN/SRTR Annual Report*, Tables 1.7, 8.1a. (B) 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: *2008 OPTN/SRTR Annual Report*, Tables 8.1a, 8.4. (C) Unadjusted patient and graft survival: Patient survival has improved for SPK recipients in recent years. Five- and 10-year patient survival was 87% and 70%, respectively. Graft survival is shown separately for the pancreas graft and the kidney graft of each SPK transplant. Source: *2008 OPTN/SRTR Annual Report*, Tables 8.10, 8.14.

performed. The size of the waiting list is a snapshot of the number of candidates active on the waiting list on December 31 of each year, and does not count patients who were transplanted, listed or removed during the preceding 12 months. 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. In other cases, changes in allocation policy and wait-listing practices help explain the narrowing gap between waiting list size and number of transplants.

Unadjusted patient and graft survival

These summary figures show survival of transplant recipients (patient survival) and continued function of the transplanted organ (graft survival) at 3 months, 1, 5 and 10 years following transplantation. The results for each follow-up

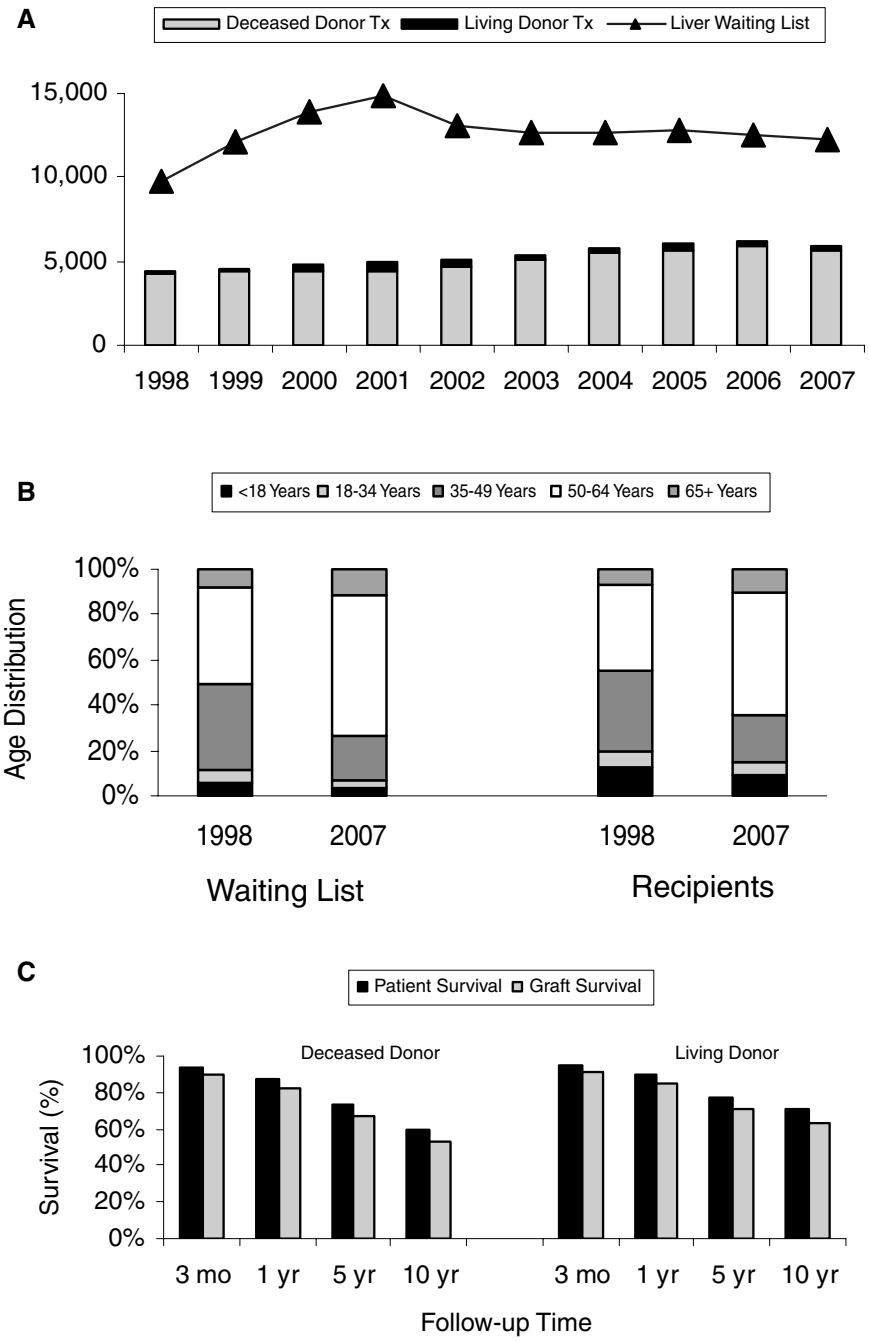

Figure 5: Liver transplantation at a glance. (A) Number of transplants and size of active waiting list: The number of patients awaiting a liver transplant at year-end peaked in 2001; this is clearly related to the introduction of the MELD/PELD allocation system in 2002. The number who received a deceased 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: *2008 OPTN/SRTR Annual Report*, Tables 1.7, 9.1a, 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: *2008 OPTN/SRTR Annual Report*, Tables 9.1a, 9.4a, 9.4b. (C) Unadjusted patient and graft survival: Patient survival in recent years has been improving for both deceased donors and living donors, with 73% and 77% 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: *2008 OPTN/SRTR Annual Report*, Tables 9.10a, 9.10b, 9.14a, and 9.14b.

time are based on information about the most recent cohorts that allow sufficient follow-up time for data collection and ascertainment of events.

The Articles in the 2008 Report on the State of Transplantation

The articles in this report begin with a review of trends in organ donation and utilization (1). Following are four organ-specific articles covering kidney and pancreas (2), liver and intestine (3), heart (4) and lung transplantation (5); these 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, clinical practice and other areas relevant to the transplantation of different organ types.

This year's report concludes with two special-focus articles that look closely at issues of recent interest to

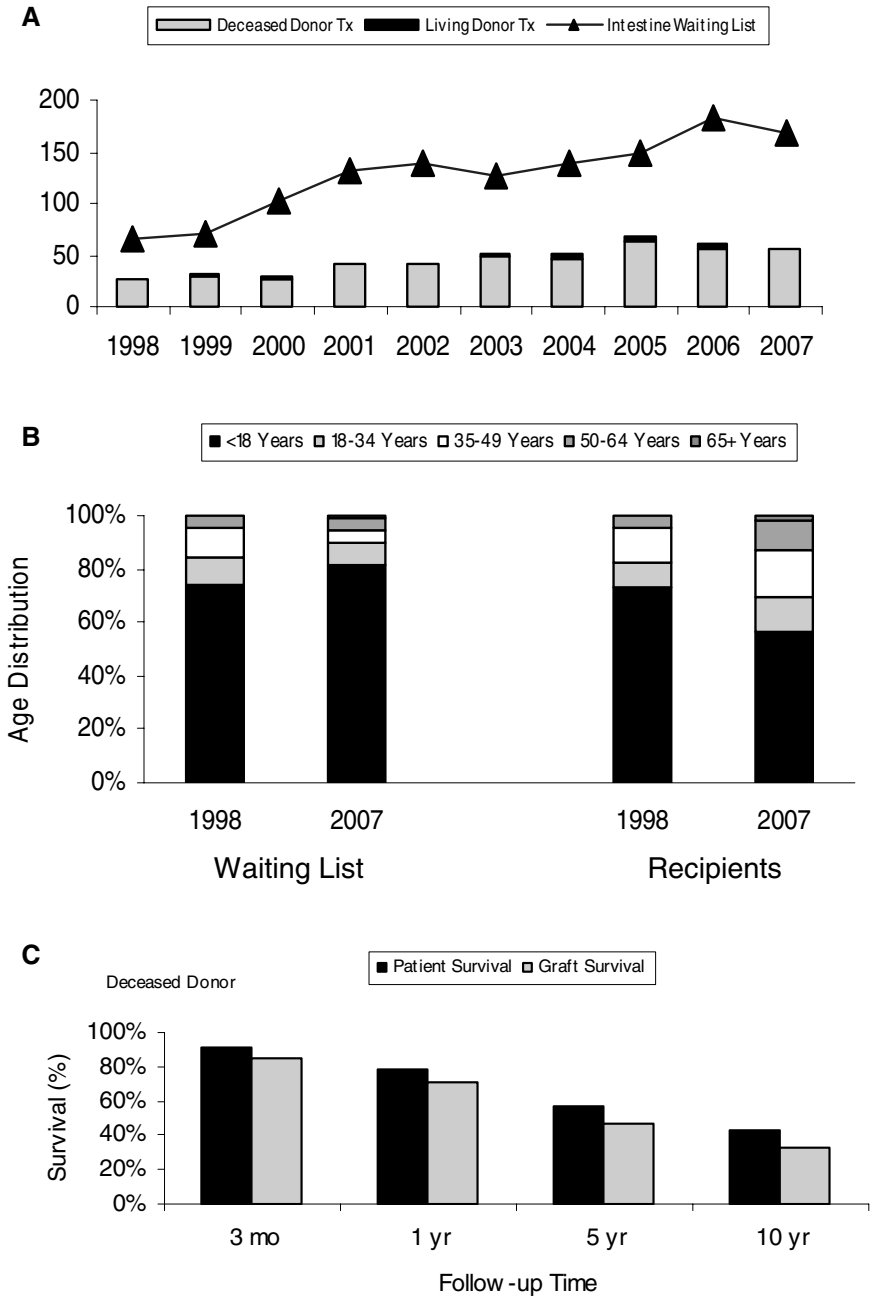

Figure 6: Intestine transplantation at a glance. (A) Number of transplants and size of active waiting list: The numbers of patients on the intestine waiting list and the number receiving a transplant both more than doubled between 1998 and 2007. The difference between the number of candidates and transplant recipients increased through the second half of the decade. Source: *2008 OPTN/SRTR Annual Report*, Tables 1.7, 10.1a. (B) Age distribution of recipients and active waiting list: About 74% of intestine candidates were in the pediatric age group in 1998 compared with 81% in 2007. The small group of candidates and recipients in the age group > 50 years doubled during the decade. Adults made up a greater portion of recipients than candidates. Source: *2008 OPTN/SRTR Annual Report*, Tables 10.1a, 10.4. (C) Unadjusted patient and graft survival: One-year patient survival was 79% in 2007. Survival at 5 years was 57%. Graft survival was lower, since recipients may receive parenteral alimentation or retransplantation after graft failure. Source: *2008 OPTN/SRTR Annual Report*, Tables 10.10, 10.14.

the transplant community. 'Innovation in Outcomes Assessment Follow Transplantation' (6) details the methodology used in recent SRTR work that focuses on providing better quality assessment and improvement tools for transplant programs. 'Survival Benefit-Based Deceased Donor Liver Allocation' (7) discusses ongoing methodological approaches developed by the SRTR to calculate the incremental years of life attributable to liver transplantation. This concept is central to a revision of deceased donor liver allocation policy currently under consideration. These articles all include special analyses conducted by the SRTR and touch on topics that are both timely and pertinent because of their implications for policy and clinical practice.

Acknowledgments

The SRTR is funded by contract number 234-2005-37009C from the HRSA, U.S. Department of Health and Human Services. The views expressed

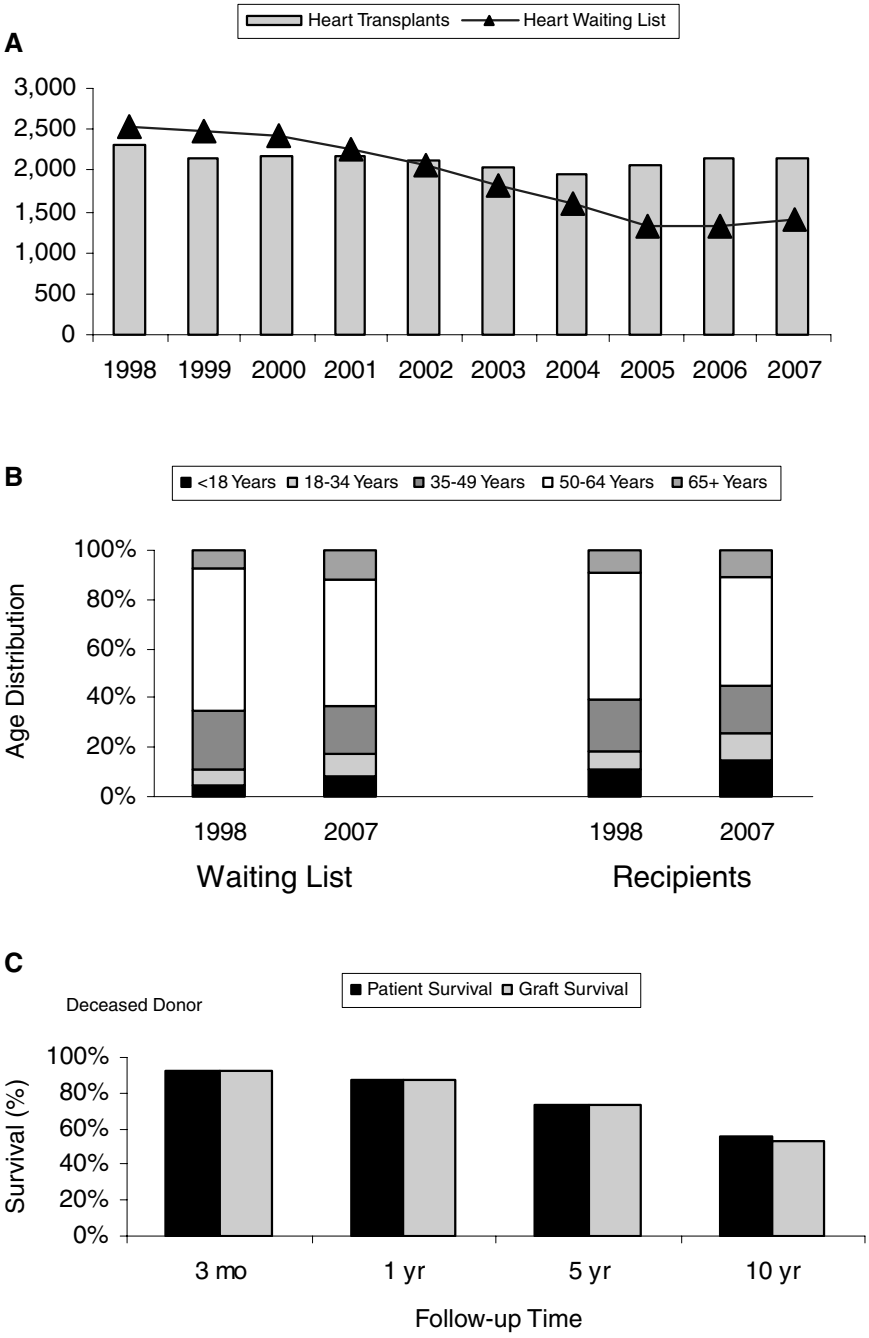

Figure 7: Heart transplantation at a glance. (A) Number of transplants and size of active waiting list: The number of heart transplants has increased since 2005 following several years of gradual reduction. The number of patients awaiting a heart decreased steeply from 2000 to 2005, likely reflecting improvements in medical and surgical therapy for end-stage heart failure. Source: *2008 OPTN/SRTR Annual Report*, Tables 1.7, 11.1a. (B) 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 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: *2008 OPTN/SRTR Annual Report*, Tables 11.1a, 11.4. (C) Unadjusted patient and graft survival: Patient survival improved in recent years for heart recipients. At 1, 5, and 10 years following heart transplantation, 88%, 74%, and 55% of patients, respectively, were alive. Graft survival was very similar to patient survival because very few patients receive a second heart transplant. Source: *2008 OPTN/SRTR Annual Report*, Tables 11.10, 11.14.

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This study was approved by HRSA's SRTR project officer. HRSA has determined that this study satisfies the criteria for the IRB exemption described in the 'Public Benefit and Service Program' provisions of 45 CFR 46.101(b)(5) and HRSA Circular 03.

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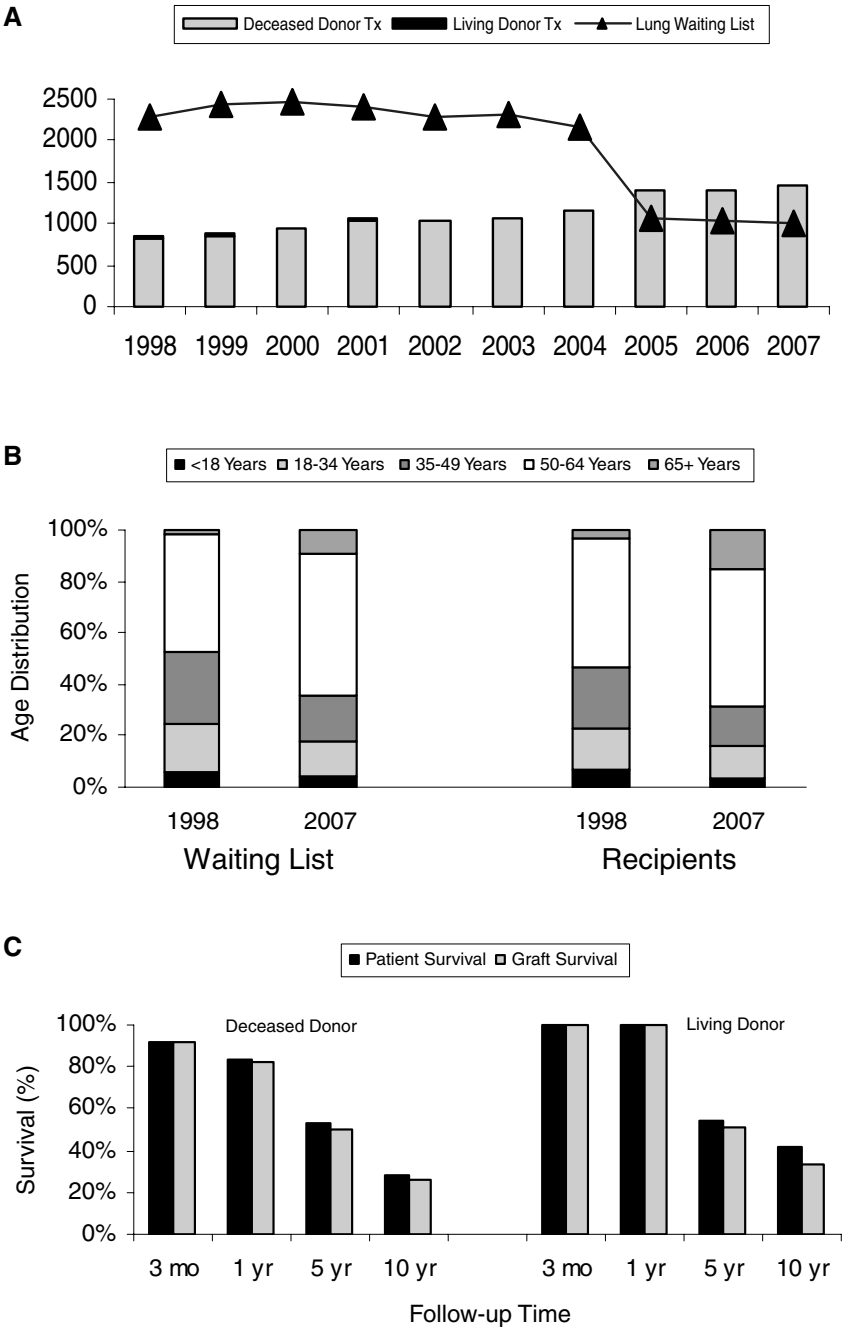

Figure 8: Lung transplantation at a glance. (A) Number of transplants and size of active waiting list: The number of lung transplants has increased in the last two years. The number of patients awaiting a transplant dropped steeply in 2005 after a stable pattern during the prior 7 years. This sharp reduction is largely attributable to a major changes in allocation policy, which is now based on medical urgency and calculated transplant benefit rather than waiting time. Source: *2008 OPTN/SRTR Annual Report*, Tables 1.7, 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 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 similarly strong increase for ages 50 years and above, but a decrease in percentages for younger ages, including children. Source: *2008 OPTN/SRTR Annual Report*, Tables 12.1a, 12.4a, 12.4b. (C) Unadjusted patient and graft survival: Patient survival has been improving in recent years for recipients of deceased and (very small numbers of) living donor lung transplants. At 1 year following deceased donor and living donor lung transplantation, 84% and 100% of patients, respectively, were alive. Graft survival was very similar to patient survival because very few lung re-transplants are performed. Source: *2008 OPTN/SRTR Annual Report*, Tables 12.10a, 12.10b, 12.14a, 12.14b.

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