Liver and Intestine Transplantation in the United States, 1995–2004

M. L. Shiffman[a,*]**, S. Saab**[b]**, S. Feng**[c]**,
M. I. Abecassis**[d]**, A. G. Tzakis**[e]**, N. P. Goodrich**[f]
and D. E. Schaubel[g]

[a] *Hepatology Section and Liver Transplant Program, Virginia Commonwealth University Medical Center, Richmond, VA, USA*
[b] *Department of Medicine and Surgery, University of California at Los Angeles, Los Angeles, CA, USA*
[c] *Department of Surgery, University of California San Francisco, San Francisco, CA, USA*
[d] *Department of Surgery, Northwestern Memorial Hospital, Chicago, IL, USA*
[e] *Department of Surgery, University of Miami School of Medicine, Miami, FL, USA*
[f] *Scientific Registry of Transplant Recipients, University Renal Research and Education Association, Ann Arbor, MI, USA*
[g] *Department of Biostatistics, University of Michigan, Ann Arbor, MI, USA*
Corresponding Author: Mitchell Shiffman, email mshiffma@hsc.vcu.edu

Three years of survival data are now available and the impact of the model for end-stage liver disease (MELD) allocation system is becoming clear. After a decline in new registrants to the waiting list in 2002, the number increased to 10 856 new patients in 2004. Since the implementation of MELD, the percentage of patients who have been on the list for 1–2 years has declined from 24% to 19%. There has been a shift upward in the percentage of patients with higher MELD scores on the waiting list.

An increasing percentage of adult living donor liver recipients are over the age of 50 years; from 1% in 1997 to 51% in 2004. Parents donating to children (93% of living donors in 1995), represented only 14% in 2004. Long-term adjusted patient survival declined with increasing recipient age in adults following either DDLT or LDLT.

Cirrhosis caused by chronic hepatitis C virus (HCV) is the leading indication for liver transplantation and is associated with reduced long-term survival in recipients with HCV compared to those without HCV, 68% at 5 years compared to 76%.

Although the intestine waiting list has more than doubled over the last decade, an increasing number of centers now perform intestinal transplantation with greater success.

Key words: Deceased donors, graft survival, intestine transplantation, liver transplantation, liver-intestine transplantation, living donors, MELD, organ donation, patient survival, PELD, SRTR, waiting list, HCV

Introduction

The field of liver transplantation remains in constant evolution. This is essential for a specialty in which the number of patients in need far exceeds the availability of organ resources. Periodic changes in organ allocation policy and innovative methods for expansion of the donor pool have been utilized over the past decade to increase the supply of livers available for the many patients in need. However, the impact of these changes on liver transplant candidates and recipients must be constantly assessed.

The most significant change in organ allocation policy within the past decade has been the adoption of the model for end-stage liver disease (MELD) and a companion system for children, the pediatric end-stage liver disease (PELD) score, as the method by which livers from deceased donors are allocated to patients on the Organ Procurement and Transplantation network (OPTN) waiting list. Last year's *Report on the State of Transplantation* was the first one where the impact of the MELD/PELD system could be evaluated (1). A marked decline in new registrations to the (OPTN) waiting list was observed. However, an insufficient amount of time had passed for the impact of this policy change on waiting list and posttransplant mortality to be fully evaluated. Three years of survival data are now available and the impact of MELD on both waiting list and posttransplant survival is becoming clear.

In an effort to expand the donor pool and reduce waiting list mortality, livers from older donors have been increasingly utilized over the past decade. However, several single center studies have recently reported that the use of livers from older donors may reduce survival following liver

transplantation (2,3). Some reports have suggested that older donors reduce survival only in patients with chronic hepatitis C virus (HCV) (4,5). The impact of donor age on posttransplant liver survival has been carefully evaluated in the present report.

Cirrhosis caused by chronic HCV is the leading indication for liver transplantation and as the HCV epidemic continues to mature this trend is certain to increase (6). This is of major concern, since the survival of HCV patients after liver transplantation appears to be reduced compared to patients without HCV (7). Several studies have attempted to identify various pre- and posttransplant factors associated with reduced survival in these patients. Unfortunately, many of these studies provide only limited information because they contain too few patients or were conducted at single centers, with limited variables. In addition to the tables in the *Annual Report (AR)*, we have analyzed data contained within the SRTR database to evaluate the impact of maintenance immunosuppression and coexistent hepatocellular carcinoma (HCC) on posttransplant survival in patients with chronic HCV.

The field of intestinal transplantation also continues to evolve. Both graft and patient survival were reported as increasing in the 2004 *AR* (1). An increasing number of centers now perform intestinal transplantation. The current report summarizes the continuing improvements in graft and patient survival experienced by recipients of an intestine transplant.

The basic structure of this article, which includes the preceding highlights, starts with a discussion on the liver transplant waiting list characteristics. It moves on to liver recipient characteristics, liver patient survival, liver graft survival and posttransplant death rates. The liver section wraps up with a discussion on chronic HCV. The chapter then discusses the state of intestine transplantation, in a similar order as the liver section.

Unless otherwise noted, the statistics in this article are drawn from the reference tables in the *2005 OPTN/SRTR Annual Report*. A companion article in this report, 'Analytical Methods and Database Design: Implications for Transplant Researchers, 2005', explains the methods of data collection, organization and analysis that serve as the basis for this article (8). Additional detail on the methods of analysis employed herein may be found in the reference tables themselves or in the technical notes of the *OPTN/SRTR Annual Report*, both available online at http://www.ustransplant.org.

Liver

Liver transplant waiting list characteristics
Patients on the active and inactive waiting list: The number of new patients added to the liver transplant waiting list had been increasing steadily every year until peak-
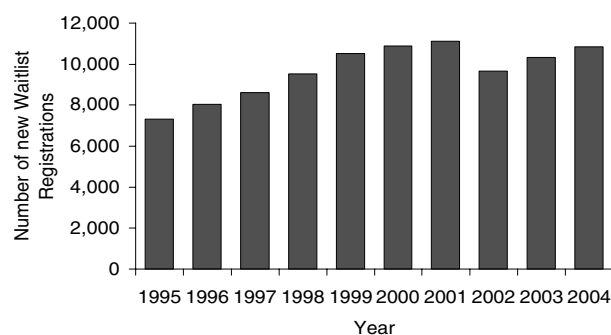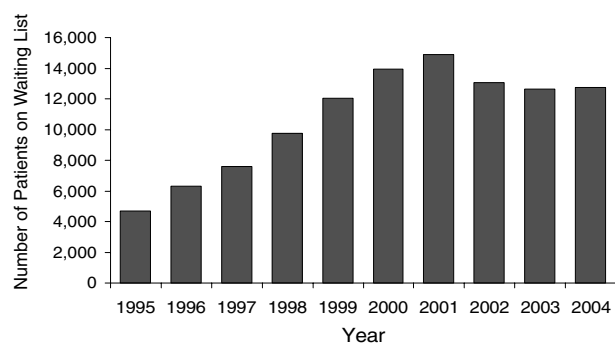

Source: *2005 OPTN/SRTR Annual Report*, Table 1.5.

**Figure 1: New liver waiting list registrations, 1995–2004.**

ing in 2001. In 2002, the number of new registrants declined for the first time in over a decade, but then increased in 2003 and 2004. In 2004, 10 856 new patients were registered, a value still less than the peak value in 2001 (Figure 1). It is possible that this 1-year decline in new registrants to the liver transplant waiting list was secondary to the anticipated change in liver allocation policy implemented in early 2002; from a system which favored the length of time a patient had been listed to the MELD or PELD model where waiting time played only a minor role. This removed the incentive to place patients on the liver transplant waiting list before they actually required liver transplantation.

Patients on the liver waiting list can either be active or inactive. The number of active patients increased steadily between 1995 and 2001 (Figure 2). In 2002, the number of patients active on the list declined for the first time in over a decade and has remained relatively stable since then, numbering 12 744 at the end of 2004. Between the years 2000–2004, 79% of listed patients were active on the waiting list. In 2004, 74% of listed patients were in the active

Source: *2005 OPTN/SRTR Annual Report*, Table 9.1a.

Figure 2: Number of patients on the liver waiting list active at year-end, 1995–2004.
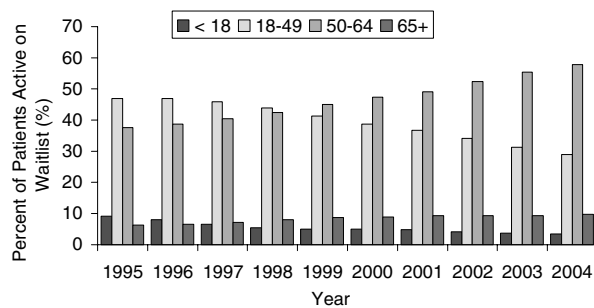
Source: *2005 OPTN/SRTR Annual Report*, Table 9.1a.

Figure 3: Percentage of patients on the liver waiting list, active at year-end, by age, 1995–2004.

category. The percentage of patients on the inactive list increases with the length of time the patient has been listed. In 2004, 13% of all inactive patients had been on the waiting list for 1–2 years, while 74% had been on the waiting list for 2 or more years.

Age: Pediatric patients continue to make up a smaller proportion of the entire active liver waiting list (Figure 3). Although the number of pediatric patients listed for liver transplantation remained relatively stable between 1995 and 2004, the proportion of patients who were children (defined as age <18 years) declined from 9% to 3% during this time. This reflects the increased number of adults added to the active waiting list. The age of patients on the active list shifted upward between 1995 and 2004. In 1995, 44% of patients were at least 50 years of age. In 2004, patients in this age range accounted for 68% of patients on the active liver waiting list.

Race and ethnicity: The racial and ethnic distribution of patients on the liver waiting list has remained steady over the past decade, except for a slight increase in the proportion of Hispanic/Latinos. In 2004, most patients on the active liver waiting list were white (72%), followed by Hispanics/Latinos (16%), African Americans (7%) and Asians (5%). The peak year for nonresident aliens on the waiting list was 1999, when this group accounted for 2% of patients. The percentage of nonresident aliens on the active liver waiting list has since steadily declined. In 2004, the waiting list comprised only 0.5% nonresident aliens.

Gender: There continues to be more males than females waiting for liver transplantation and this gap has increased slowly over the last decade. This is because more males have been added to the waiting list than females. In 1995, 55% of the patients on the active waiting list were males. In 2004, this increased to 60%.

ABO type: Approximately half of all patients on the liver transplant waiting list have blood type O. Blood type A ac-

counts for just over one-third of patients, blood type B for about 10%–11% and type AB 2%–2.5%. The distribution of blood types for patients on the liver waiting list has remained relatively stable over the past decade and is similar to that observed for the general population.

Prior transplantation: Although the absolute number of patients on the active waiting list who had a prior transplant of any kind increased from 264 patients in 1995 to 382 in 2004, the percentage of listed patients with a prior transplant declined from 6% to 3%, respectively. Similarly, the percentage of patients on the active waiting list who received a previous liver transplant declined from 5.3% in 1995 to 2.6% in 2004. Thus, the vast majority of patients on the current liver waiting list who received a prior transplant, had a prior liver transplant. However, this percentage has declined over the past decade, from 95% in 1995 to 87% in 2004. This suggests that either recipients of other organ transplants are increasingly being listed for liver transplants or that retransplantation for liver graft failure is being performed less frequently.

Diagnosis: Cirrhosis caused by a noncholestatic chronic liver disease has been the primary indication for placing individuals on the active liver transplant waiting list during the past decade and the proportion of active patients on the waiting list with this diagnosis has been increasing. In 1995, 65% of patients waiting for liver transplantation had cirrhosis secondary to a noncholestatic liver disease. In 2004, this had increased to 72%. This represented a 204% increase in the absolute number of patients on the waiting list with this diagnosis. This was primarily driven by patients with chronic HCV that now accounts for just under 40% of listed patients. During this time period, the overall number of patients active on the waiting list increased by 172%. In comparison, the number of patients with a cholestatic liver disease who were active on the waiting list grew by only 87% during this time. In 2004, cholestatic liver disease, acute hepatic necrosis, biliary atresia and metabolic liver disorders accounted for 11%, 45%, 1.7% and 1.5% of patients on the active liver transplant waiting list, respectively.

Time on waiting list: Time spent on the liver waiting list over the past decade is illustrated in Figure 4. The range of <90 days is important since the MELD/PELD score is based upon a 3-month mortality risk. Overall, the percentage of patients active on the waiting list that have been waiting for long periods of time has increased steadily between 1995 and 2004. In 1995, 28.0% of patients had been on the list 90 days or less and 29.7% had been on the list for more than 1 year. In 2001, the percentage of patients who had been on the list less than 90 days declined to 12% and the percentage on the list for more than 1 year had ballooned to 60%. Since the implementation of the MELD/PELD system in 2002, the percentage of patients who had been on the list for 1–2 years has declined from 24% to 19%. The percentage of patients now waiting for
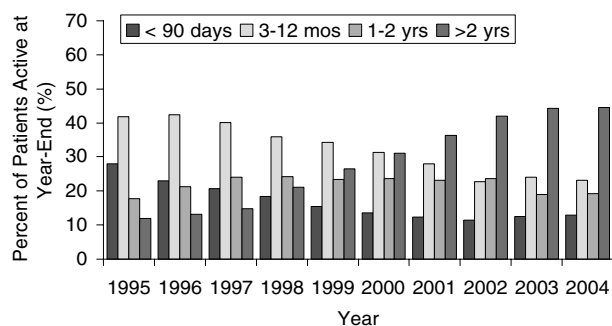
Source: *2005 OPTN/SRTR Annual Report*, Table 9.1a.

Figure 4: Percentage of patients on the liver waiting list, active at year-end, by waiting time, 1995–2004.

Source: *2005 OPTN/SRTR Annual Report*, Table 9.2b.

Figure 5: Events at 30, 60 and 90 days after snapshot of liver waiting list by MELD score, as of January 1, 2004.

2 years or more appears to be reaching a steady state (45% in 2004).

Status 1: During 2003 and 2004, 47% of patients listed as Status 1 received a liver transplant within 7 days. During this time, 14% of patients remained listed as Status 1, 3% were downgraded to a MELD/PELD score, 10% were inactivated, 10% died, 5% were considered too sick for transplantation and 9% had recovered. Fifteen days after the initial listing as Status 1, the percentage of patients transplanted had increased to 52% and only 5% remained listed as Status 1. Another 5% were downgraded to a MELD/PELD score, 9% were inactivated, 12% had died, 5% were now considered too sick for transplantation and 11% had recovered.

MELD/PELD system: The MELD/PELD system was introduced in early 2002 as a better way to prioritize patients on the active liver waiting list. Since then there has been a shift upward in the percentage of patients with higher MELD scores. At the end of 2002, 44% of patients had a MELD score of 6–10, this declined to 40% by 2004. During this same time, the percentage of patients with MELD scores of 11–20 increased while the percentage of patients with MELD scores over 20 remained stable. In contrast, the distribution of PELD scores has remained very similar since this system was implemented. In 2002, 66%, 12%, 3% and 0.4% of pediatric patients on the active waiting list had PELD scores of less than 11, 11–20, 21–30 and greater than 30, respectively. In 2004, these values were 64%, 13%, 2% and 0.5%, respectively.

The positive impact of MELD was recently demonstrated (9). In this study patients with MELD scores above 18 had an improved survival 1 year following liver transplantation as opposed to remaining on the waiting list; and the survival advantage of liver transplantation increased with increasing MELD score. In contrast, patients with MELD scores less than 18 had a reduced survival 1 year following liver transplantation as opposed to remaining on
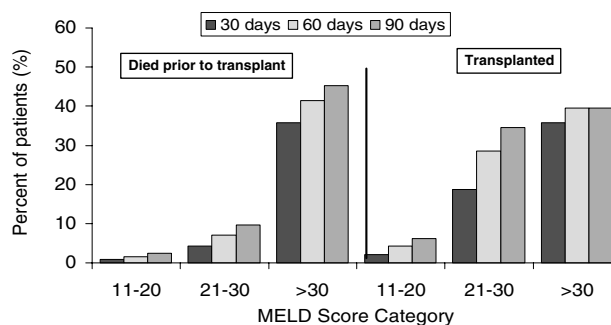
the waiting list. Another way to evaluate the impact of MELD is to review what happens to patients listed at various MELD scores after various waiting time intervals (i.e. 30, 60 and 90 days) from an arbitrary index date or 'snapshot'. The date utilized for this snapshot analysis was January 1, 2004. The results of this analysis are illustrated in Figure 5.

For patients with a MELD score of less than 11 within 30 days of the snapshot, 94% remained within this MELD range and 4% had an increase in their MELD score. Transplantation and death, within 30 days of the snapshot, were uncommon in patients with these very low MELD scores. They occurred in only 0.6% and 0.3% of patients. After 60 days, 7% of patients had developed an increase in their MELD scores, 1% had undergone liver transplantation and 0.6% had died. After 90 days, these values had increased to 9%, 1.6% and 0.8%, respectively. Thus, over time, a small but increasing percentage of patients with a MELD score of less than 11 underwent liver transplantation or died.

For patients with MELD scores of 11–20 at the snapshot, 90% remained within this MELD range after 30 days, 3% had a lower MELD score, and 2% had a higher MELD score. During this 30-day period, 2.1% of patients received a liver transplant and 0.8% died. After 60 days, 6% had a lower MELD score and 3% had a higher MELD score. The percentage of patients who received a liver transplant had increased to 4% and 2% of patients had died. After 90 days, 8% had a lower MELD score, 3% had a higher score, 6% of patients had received a transplant and 2% died.

For patients with a MELD score of 21–30 at the snapshot, 52% remained within this same MELD range after 30 days, 15% had a decline in MELD scores and 3% had an increase in MELD values to greater than 30. During these 30 days, 19% underwent liver transplantation and 4% died. After 60 days, 16% had a lower MELD score, 2% had a

higher MELD score, 29% had received a transplant and 7% died. After 90 days, 29% of patients continued to have a stable MELD score, 15% had a lower score, 2% had a higher score and the percentage that had undergone liver transplantation or died increased to 35% and 10%, respectively.

For patients with the highest MELD scores (greater than 30) at the snapshot, 11% were still alive and waiting for transplants with this high MELD score 30 days later, 9% had a decline in MELD scores, 36% had received a liver transplant and 36% had died. After 60 days, only 13% of patients remained on the waiting list at any MELD score, 40% had received a transplant and 42% died. After 90 days, only 10% of patients who had a MELD score greater than 31 remained on the waiting list, 40% of patients had received a transplant and 45% had died. Thus, nearly all patients who achieved a MELD score greater than 30 either received a liver transplant within the first 30 days of this event or did not survive.

Hepatocellular carcinoma and other MELD exceptions:
A similar snapshot analysis was performed for patients with HCC (Figure 6). For patients with HCC stage T1, 28% received a liver transplant within 30 days of the snapshot date; 43% and 50% had a transplant within 60 and 90 days, respectively. During these same time intervals, 3%, 5% and 5% of patients died while waiting for a liver transplant 30, 60 and 90 days after the snapshot. For patients with HCC stage T2, 31% of patients received a liver transplant within 30 days of the snapshot date; 42% and 53% of patients had undergone transplantation by 60 and 90 days, respectively. During these same time intervals, 0.8% of patients had died within 30 days, while 0.8% and 2.4% of patients had died within 60 and 90 days, respectively. For patients listed with an exception other than HCC, 1% died and 47% received a liver transplant within 90 days of the snapshot date.
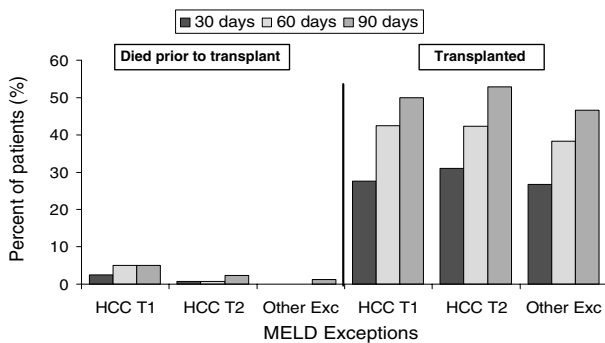
Source: *2005 OPTN/SRTR Annual Report*, Table 9.2b.

Figure 6: Events after snapshot of waiting list for liver candidates with exceptions from the MELD system, as of January 1, 2004.
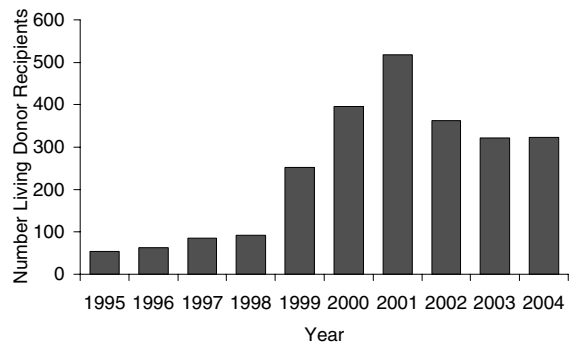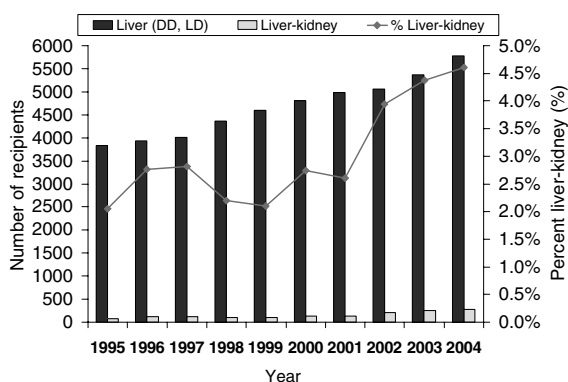

Source: *2005 OPTN/SRTR Annual Report*, Table 9.4b.

Figure 7: Number of living donor liver recipients, 1995–2004.

Liver transplant recipient characteristics
Number of transplants: The number of liver transplants in the U.S. has risen incrementally over the past decade. Part of this can be attributed to the increased use of marginal donors and expanded criteria donors, including donation after cardiac death. Another reason is the increased utilization of living donors. The number of living donor liver transplants (LDLT) increased steadily between 1995 and 2001, declined, and then stabilized in 2003–2004 (Figure 7). The decline in the number of recipients of LDLT since 2002 likely reflects: the change in the allocation policy to the MELD system, which provides high priority for patients with HCC; the results from a National Institute of Health Conference on living donor liver transplantation, which pointed out the limitations and complications associated with LDLT (10); and the highly publicized deaths of at least two donors in this country.

The MELD/PELD system was implemented in 2002 as a way to better prioritize patients for liver transplantation. In this system, worsening renal dysfunction is associated with a marked increase in MELD/PELD score and significantly increased priority for liver transplantation. As a result, many patients who have received liver transplants since 2002 have some degree of renal insufficiency. Renal dysfunction in liver transplant candidates can be secondary to either type-I or type-II hepatorenal syndrome or intrinsic renal dysfunction, which is most commonly secondary to hypertension and/or diabetes mellitus. The increased incidence of renal dysfunction in liver transplant recipients has led to an increase in the number of patients undergoing combined liver and renal transplantation. In 2001, prior to the implementation of MELD/PELD, only 3% of liver transplant recipients had a simultaneous renal transplant. In 2004, combined liver and renal transplantation had increased to 5% of all liver transplant recipients (Figure 8). Although it is believed that a combined liver-kidney transplant in this setting may improve survival, hard data demonstrating this are lacking. Recipient survival in patients undergoing combined renal and liver transplantation should be evaluated in future studies.
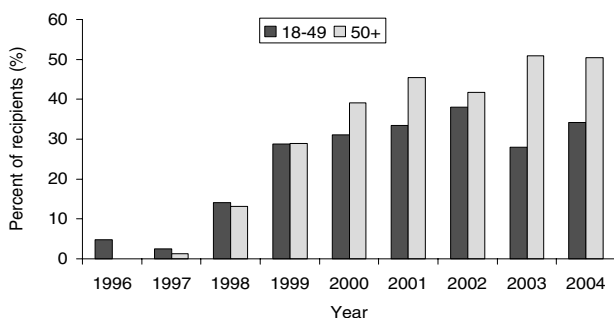
Source: *2005 OPTN/SRTR Annual Report*, Tables 1.7 and 1.8.

Figure 8: Recipients of liver transplants and simultaneous liver-kidney transplants by year, 1995–2004.

Age: The increase in the number of deceased donor liver transplant (DDLT) recipients over the past decade has been predominantly in the adult population. As a result, despite a 17% increase in the absolute number of pediatric (age <18 years) liver transplants performed, the proportion of pediatric liver transplant recipients relative to the total number of liver transplant recipients has declined over the past decade from 12% in 1995 to 9% in 2004.

There has been a significant increase in the number of LDLT recipients during the past decade. However, as was observed for DDLT, the majority of this increase has been in the adult population. The number of pediatric LDLT recipients has remained very stable during this decade. In 1995, all of the 54 LDLT recipients were in the pediatric population. In 2004, virtually the same number of LDLT recipients were children, which accounted for only 16% of all LDLT recipients. Since the initiation of LDLT in adults, an increasing percentage of adult living donor liver recipients have been over the age of 50 years; from 1% in 1997 to 51% in 2004 (Figure 9).

Year
No recipients for 1995; no recipients age 50+ in 1996

Source: *2005 OPTN/SRTR Annual Report*, Table 9.4 b.

Figure 9: Age of living donor liver transplant recipients, 1995–2004.

Gender, race, ethnicity and blood type: The percentage of males receiving a DDLT has slowly and gradually increased over the past decade from 57% in 1995 to 66% in 2004. This likely reflects the increasing prevalence of chronic HCV, which is twice as common in males as in females, as the major indication for undergoing liver transplantation (11). The proportion of DDLT recipients that are white has slowly and gradually declined from 76% in 1995 to 72% in 2004. During this time there have been compensatory increases in the percentage of African American recipients (from 8% in 1995 to 10% in 2004) and Asian recipients (from 3.4% in 1995 to 4.8% in 2004). There have been no obvious trends in the blood types of liver transplant recipients during the past decade. Approximately 42% have type O, 40% type A, 13% type B and about 5% blood type AB.

Prior transplantation: The percentage of DDLT recipients who received a previous transplant of any kind declined from 11% in 1995 to 9% in 2004. The most common type of previous transplant received by liver transplant recipients is a previous liver transplant, accounting for over 90% of previous transplants in 2004. In 1995, 10% of liver transplant recipients had received a prior liver transplant. In 2004, this had declined to 8%.

Payor type: Private insurance carriers continue to fund over half of all DDLTs performed in this country. However, the percentage of liver transplant recipients with private insurance has declined from 63% in 1995 to 60% in 2004. The percentage of patients whose transplant was funded through Medicaid has declined slightly during the past decade; from 17.3% to 16.1%. These changes have been offset by an increase in the number of liver transplants funded though the federal Medicare system. This increased from 12% in 1995 to 18% in 2004. This gradual shift from private and state funding to the federal funding of liver transplantation likely reflects a higher percentage of patients undergoing liver transplantation with more advanced liver disease and who, therefore, must seek disability through the federal social security system prior to transplantation.

Most of the LDLTs performed in the US over the past decade were funded by private insurance carriers. In 2004, 73% of LDLT recipients had private insurance, 11% had Medicaid and 10% of recipients were funded through the Medicare system.

Nearly all DDLT recipients are U.S. residents and this has increased to an even higher percentage during the past decade, from 97% in 1995 to 99% in 2004. A similar trend was observed for recipients of a LDLT.

Diagnosis: During the past decade there has been an incremental and gradual rise in the percentage of recipients who received a DDLT for malignant neoplasms, from 2% in 1995 to 7% in 2004. This rise has been particularly evident

since 2002, and consistent with the implementation of the MELD system, which provides higher priority for patients with T1 or T2 HCC. In contrast, the proportion of recipients with cholestatic liver disease has declined over the past decade from 15% to 9%, respectively. Over 60% of liver transplant recipients had cirrhosis secondary to non-cholestatic liver disease as the primary indication for transplantation. In 2004, 41% of these patients had cirrhosis secondary to chronic HCV (SRTR Analysis, May 2005). The major indication for transplantation in recipients of a living donor was also cirrhosis secondary to a non-cholestatic liver disease. In 2004, this accounted for over half of all living donor recipients. The percentage of living liver donor recipients whose primary indication for transplantation was a malignant neoplasm has fluctuated between 2% and 9% between 1999 and 2004.

Hospitalization status: Over the past decade, the percentage of DDLT recipients who were hospitalized at the time of their transplant declined from 26% in 1995 to only 16% in 2004. The percentage of recipients who were in an intensive care unit increased from 21% in 1995 until peaking at 27% in 2001. This coincided with the last year of the previous allocation system when patients in the intensive care unit received higher priority on the liver waiting list. With the implementation of the MELD/PELD system in 2002, the percentage of recipients in intensive care units declined (Figure 10). The percentage of recipients who received a liver transplant while on life support has declined, as well, from 14% in 1995 to only 7% in 2004.

For recipients of a LDLT, the percentage of patients hospitalized at the time of transplant has also declined during the past decade. In 1995, all LDLT recipients were in the pediatric age range and 26% were hospitalized. This declined to 12% in 2004 and only 16% of recipients were in the pediatric age range. The percentage of LDLT recipients in intensive care units and on life support has also declined during this time, from 17% and 15% in 1995 to 7% and 2% in 2004, respectively.
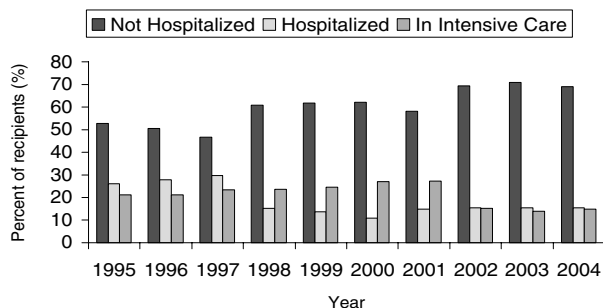
Source: *2005 OPTN/SRTR Annual Report*, Table 9.4a.

Figure 10: Hospitalization status at transplant for deceased donor liver transplant recipients, by year, 1995–2004.
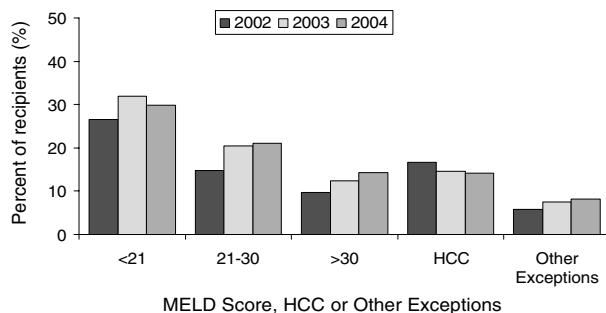
Source: *2005 OPTN/SRTR Annual Report*, Table 9.4a.

Figure 11: Distribution of deceased donor liver recipients by MELD score, 2002–2004.

MELD score: There are now 3 years of data available to assess the effects of the MELD/PELD system. In 2002, 27% of DDLT recipients had a MELD score of less than 21 and 10% had a MELD score of greater than 30. In 2004, the percentage of DDLT recipients with a MELD score of less than 21 remained fairly stable while the percentage of recipients with a MELD score greater than 30 increased to 14% (Figure 11). One of the primary features of the MELD system is that it provides a higher MELD score for patients with HCC than they otherwise would have had, based upon their liver and renal function alone. The percentage of DDLT recipients with HCC remained relatively stable between 2002 and 2004, ranging between 14% and 17%. Another feature of MELD is that it allows exceptions to be assigned and provides an elevated MELD for patients with unique circumstances. Such exception proposals are submitted to the respective regional review boards for a vote before being applied. Recipients of a DDLT with an exception increased slightly since implementation of the MELD system, from 6% in 2002 to 8% in 2004.

In contrast to what has been observed with DDLT recipients, the MELD scores for LDLT recipients have declined since 2002. The percentage of LDLT recipients with a MELD of less than 21 increased from 55% in 2002 to 70% in 2004. The percentage of LDLT recipients with HCC has remained stable, ranging from 2.8% to 3.4% for 2002 to 2004.

Characteristics of living donors: The vast majority of living donors are related to their recipients. However, as the number of adult LDLT recipients has increased, so has the percentage of unrelated donors. In 1995, when all living donor recipients were in the pediatric age group, only 2% of donors were unrelated to their recipients. The percentage of unrelated donors has increased every year since 1995, to 22% in 2004. Of the donors related to their recipients, the majority are now donating to their adult parents or siblings. This accounted for 14% and 19% of all donors in 2004, respectively. Parents donating to their

children, which accounted for 93% of living donors in 1995, represented only 14% in 2004. This again represents the increased utilization of living donors for adult recipients and that parents of adult recipients are in many cases too old to be considered viable living donors.

Immunosuppression: *Induction immunosuppression.* The use of induction immunotherapy in liver transplantation is low when compared to that utilized for other organs. In 1995, 15% of patients received induction with a monoclonal antibody, either OKT3 or anti-thymocyte globulin (ATG). In 2004, the use of these monoclonal antibodies for induction had declined to only 0.6%. The use of thymoglobulin has emerged in its place, along with interleukin receptor antagonists (Zenepax and Simulect), in roughly equal proportions.

Maintenance immunosuppression. The most common agent utilized for maintenance immunosuppression during the past decade has been tacrolimus. The percentage of recipients discharged, following transplantation while on this agent, has steadily increased from 48% in 1995 to 89% in 2004. The use of cyclosporin and its various forms, including generic formulations of this calcineurin inhibitor, has declined during the past decade from 47% in 1995 to only 8% in 2004.

The use of an antimetabolite as a second maintenance immunosuppressive agent has increased from 42% to 58% of liver transplant recipients. During this time mycophenolate mofetil (MMF) has become the primary antimetabolite utilized in liver transplant recipients, largely replacing azathioprine. In 1995, only 6% of liver transplant recipients were discharged with MMF. This increased to 56% in 2004. Sirolimus was utilized as a maintenance immunosuppressive agent in 9%–10% of patients in 2000–2001, shortly after this agent became available. However, the percentage of patients discharged on Sirolimus following liver transplantation has declined to only 4%–5% between 2003 and 2004. The decline in Sirolimus usage after liver transplantation may be related to recent studies, which have suggested that this agent may be associated with a higher incidence of portal vein thrombosis and poor wound healing (12). The use of corticosteroids at the time of discharge in liver transplant recipients has declined from 88% in 1995 to 81% in 2004, reflecting a trend by some centers to either rapidly taper off steroids or to perform liver transplantation in a steroid-free environment.

Treatment of rejection. The incidence of antirejection treatment within the first year following liver transplantation has declined from 43% to 18% over the past decade (Figure 12). Steroids have been utilized for treatment of acute rejection within the first year of transplantation in approximately 90% of liver transplant recipients and this has not changed over the past decade. The use of various antibody preparations for treatment of acute rejection during the first year after liver transplantation has declined from
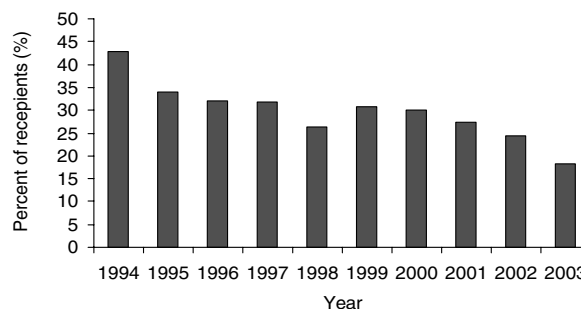
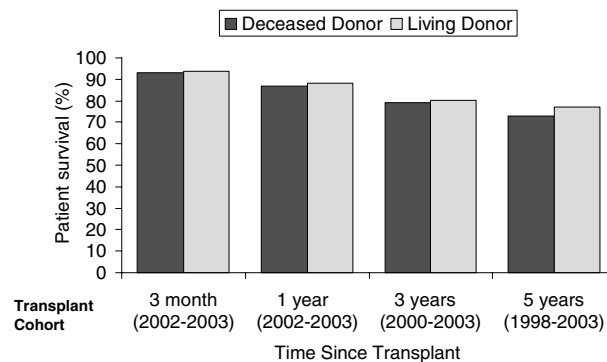Source: *2005 OPTN/SRTR Annual Report*, Tables 9.6i.

Figure 12: Incidence of acute antirejection treatment during the first year following liver transplant, 1994–2003.

30% in 1995 to only 18% in 2004. OKT3 had been the antibody preparation of choice in 1995. By 2004, thymoglobulin and OKT3 were being utilized in a similar percentage of patients for treatment of acute rejection.

Liver transplant patient survival
Deceased and living donor transplants: Patient survival, adjusted for recipient age, gender, race and diagnosis at the time of deceased donor transplantation, was 93% at 3 months, 87% at 1 year, 79% at 3 years and 73% at 5 years. For recipients of a LDLT, survival was 94%, 88%, 80% and 77%, respectively (Figure 13). Thus, patients who had a LDLT appeared to have somewhat improved survival after 5 years compared to patients who received a DDLT. However, it is important to note that the vast majority of patients who received a LDLT who had enough data available to calculate 5-year survival were in the pediatric population.

During the past decade there has been a small, gradual increase in unadjusted patient survival 3 months following deceased donor transplantation, from 90% in 1995 to 93%
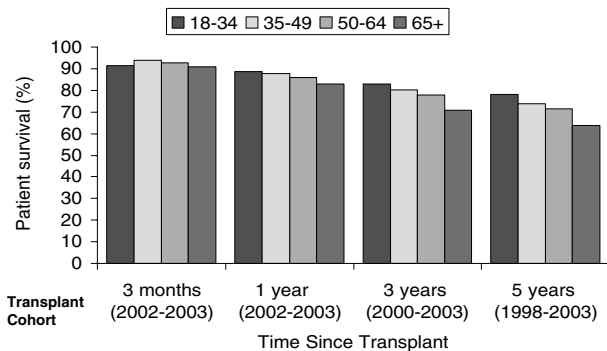

Source: *2005 OPTN/SRTR Annual Report*, Tables 9.11a and 9.11b.

Figure 13: Adjusted patient survival of deceased and living donor liver recipients.

in 2004. A similar upward trend in unadjusted patient survival was observed in patients who received a LDLT, from 87% in 1995 to 96% in 2004. At 1 year, patient survival was slightly lower in recipients of a DDLT compared to LDLT, at 87% versus 88%, respectively. Unadjusted patient survival remained higher for recipients of a LDLT compared to the recipients of a DDLT after 3 (80.2% vs. 79.1%) and 5 years (77% vs. 73%).

Recipient demographics: Long-term, but not short-term, adjusted patient survival declined with increasing recipient age in adults following either a DDLT or LDLT (Figures 14 and 15). Adjusted patient survival was similar in recipients regardless of age 3 months after either a DDLT or LDLT. However, by 1 year a small but consistent step-wise decline in adjusted patient survival was observed with increasing age in adults and this decline widened at 3 and 5 years. Adjusted patient survival 5 years following a DDLT in recipients aged 18–34 years was 78% compared to 64% for those 65 years or older. This decline in survival with increasing age was even greater in the adult recipients of

Source: *2005 OPTN/SRTR Annual Report*, Table 9.11a.

Figure 14: Adjusted patient survival of deceased donor liver recipients at various time intervals, by age.
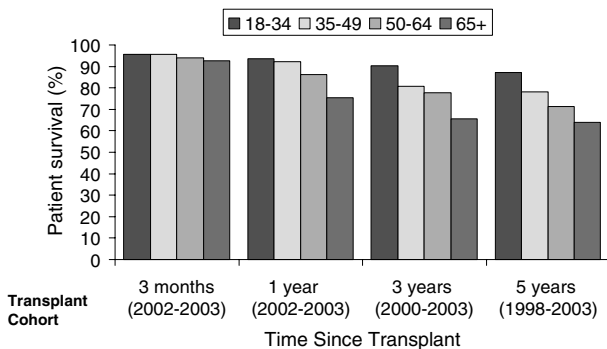
Source: *2005 OPTN/SRTR Annual Report*, Table 9.11b.

Figure 15: Adjusted patient survival of living donor liver recipients at various time intervals, by age.

a LDLT. Adjusted patient survival 1 year after a LDLT was 94% in patients aged 18–34 years and 75% in patients 65 years or older. At 5 years, adjusted survival in the recipients of a LDLT aged 18–34 years was 87% compared to 64% in those 65 years or older. No consistent relationship between survival and age was observed in pediatric liver transplant recipients who received either a LDLT or DDLT.

Adjusted patient survival at various time points was essentially identical for males and females with a DDLT. After 5 years, survival was 73% for both. Survival was similar in males and females who received a LDLT through 1 year. Thereafter, the survival of female LDLT recipients tended to be greater; 82% at 3 years and 79% at 5 years, compared to 79% and 76% in males for the same lengths of time.

Asians had the best survival following a DDLT at all time points. After 5 years this was 77% compared to 73% for whites, 74% for Hispanics and 65% in African Americans. The survival of African Americans was consistently lower than other racial/ethnic groups at all time points following a DDLT. African Americans also had the lowest survival following a LDLT. After 5 years, LDLT survival was 71% compared to 81% in Asians, 77% in whites and 80% in Hispanics.

Recipient disease: Adjusted patient survival at 3 months was similar regardless of the etiology for liver transplantation in both DDLT and LDLT (>90%). The only exceptions were those patients who received a DDLT for acute hepatic necrosis (87%) and a LDLT for either a metabolic liver disease (81%) or acute hepatic necrosis (81%). After 1 year, adjusted patient survival was similar for DDLT with regard to diagnosis (>85%). At 5 years, the highest survival rates were observed in recipients who received a DDLT for biliary atresia (83%) and metabolic diseases (81%). The lowest survival rates were observed in patients with acute hepatic necrosis (70%) and malignant neoplasia (60%). Similar trends exist for patients who received a LDLT. After 5 years, the survival of patients who received a LDLT for biliary atresia was 84%; survival was 87% for patients with a cholestatic liver disease. The lowest survivals after LDLTs were observed in patients with acute hepatic necrosis and malignant neoplasia at 71% and 58%, respectively (Figure 16).

Effect of disease severity: Unadjusted patient survival declined with worsening disease acuity, which was assessed by the intensity of medical services provided at the time of transplantation. In patients who received a DDLT, the 3-month survival was 95% for patients not hospitalized, 91% when hospitalized, 86% when in an ICU and 80% when on life support. In patients who had a LDLT, a similar relationship was observed. Survival at 3 months following a LDLT was 95% in patients not hospitalized, 91% in those hospitalized, 81% in patients in an ICU and 82% for patients when on life support.
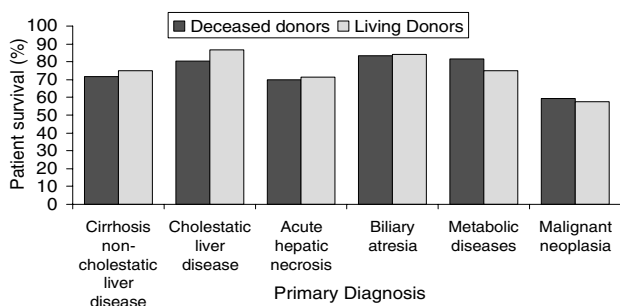
Figure 16: Adjusted patient survival of deceased and living donor liver recipients at 5 years after transplant, by primary diagnosis.
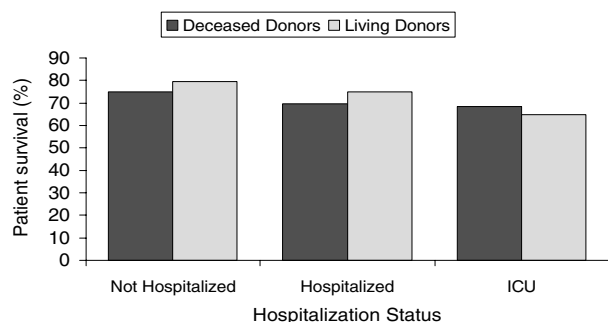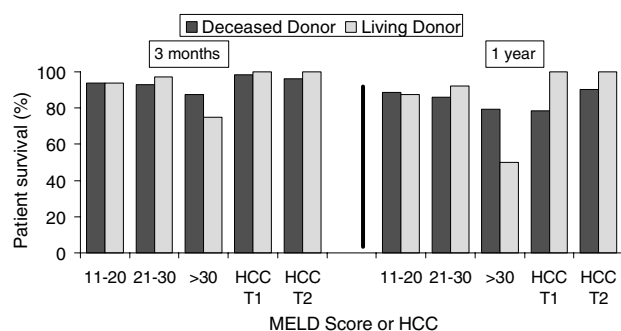
Figure 17: Unadjusted patient survival of deceased and living donor liver recipients at 5 years after transplant, by hospitalization status at transplant.

The decline in survival with increasing disease acuity at the time of either DDLT or LDLT was maintained after 1, 3 and 5 years. Survival at 5 years following a DDLT was 75%, 70%, 68% and 62%, respectively. Similar results were observed for patients who received a LDLT (Figure 17).

The recipients of DDLTs listed as Status 1 had a 3-month survival of 86% compared to 81% for patients who received a LDLT. This difference declined with time. Five years later, survival for Status 1 patients following a DDLT and LDLT was at 74% and 72%, respectively.

Because the MELD/PELD system was initiated in 2002, only short-term survival data on a limited number of adults are available at this time. Insufficient data exist to examine the effect of PELD on recipient survival. Overall patient survival at 3 months was above 92% for recipients of a DDLT or a LDLT in MELD groups except for those with a MELD score above 30, where it was 88% for DDLT recipients. There were not enough LDLT recipients with a MELD
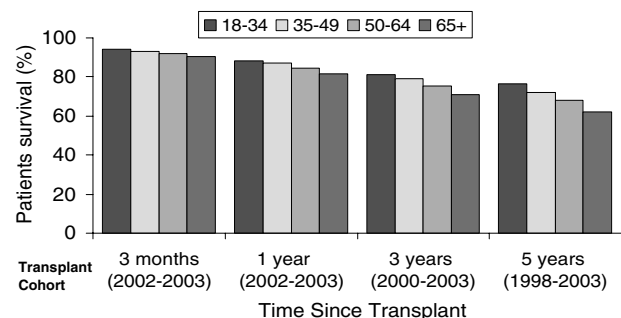
Figure 18: Unadjusted patient survival of deceased and living donor liver recipients at 3 months and 1 year, by MELD score, 2002–2004.

score above 30 to get precise survival estimates. After 1 year, patient survival was over 84% for all MELD groups, excepting those patients with a MELD score greater than 30. In these patients, 1-year DDLT survival had declined to 79%. Patients who underwent either a DDLT or LDLT for HCC had a 1-year survival of over 89%. DDLT recipients with an exception had similar 3-month and 1-year survival (94% and 89%) as observed for other patients (Figure 18).

Donor age: Increasing donor age did not appear to affect short-term survival but had a profoundly negative impact on long-term survival following a DDLT (Figure 19). After 3 months, unadjusted patient survival was greater than 90% for recipients of livers obtained from all donor age groups. In contrast, by 1-year survival had declined in those recipients who received a liver from a donor over 50 years of age (85% for donors aged 50–64 years and 82% for donors over 65 years of age) compared to those patients who received a liver from a younger donor (87%–92%). The survival of recipients who received older donor livers continued to decline with time and after 5 years this

Figure 19: Unadjusted patient survival of deceased donor liver recipients at various time intervals, by donor age.
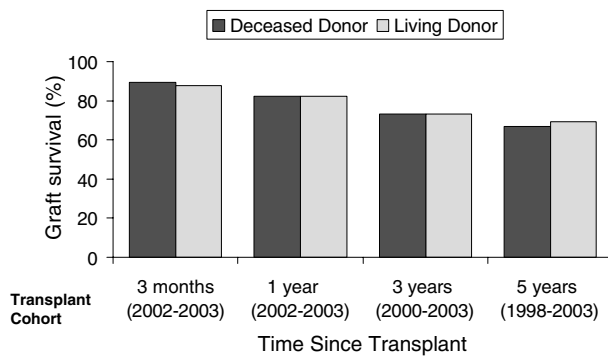
Source: *2005 OPTN/SRTR Annual Report*, Tables 9.8a and 9.8b.

Figure 20: Adjusted graft survival of deceased and living donor liver recipients at various time intervals following transplant.

difference became evident for donors down to 35 years of age. After 5 years, the survival of DDLT patients with donors less than 35 years of age was above 76%. In contrast, the 5-year survival for a 35–49-year-old donor was 72%, for donors aged 50–64 years survival was 68% and for donors over 65 years of age survival was only 62%. The effect of increased donor age on recipients of a LDLT is unknown, primarily because very few individuals over 50 years of age become living donors (only 75 donors out of 664 living donations; 11% in 2002–2003).

Transplant factors: In 2004, the majority of livers from deceased donors (74%) had a cold ischemia time of 10 h or less. Of the remaining livers, cold ischemia times were 11–15 h for 10%, and over 16 h for 1% of donor livers. Increasing cold ischemia time was not associated with a decline in patient survival following a DDLT.

The vast majority of DDLTs (82%) and LDLTs (86%) performed in 2002–2003 were done at transplant centers performing at least 35 DDLTs and/or LDLTs yearly. No consistent relationship was observed between transplant center volume and either short-term or long-term survival following liver transplantation. However, a recent report from the National Institutes of Health sponsored Adult-to-adult living donor liver transplant cohort study (A2ALL) has clearly demonstrated that morbidity and graft mortality is significantly greater in the first 20 patients who undergo LDLT when such a program is first initiated (13).

Liver transplant graft survival
Deceased and living donor transplants: Graft survival adjusted for recipient age, gender, race and diagnosis at the time of a DDLT was 89% at 3 months, 82% at 1 year, 73% at 3 years and 67% at 5 years. For recipients of a LDLT, graft survival was similar; 88%, 82%, 73% and 69%, respectively (Figure 20).

During the past decade there has been a gradual increase in unadjusted graft survival 3 months after a DDLT, from 84% in 1995 to 90% in 2004. A similar upward trend in unadjusted graft survival was observed in LDLT recipients, from 81% in 1995 to 88% in 2004. Graft survival was similar in recipients of a DDLT (82%, 73%, and 67%) as compared to a LDLT (82%, 73%, and 70%) after 1, 3 and 5 years, respectively.

Recipient demographics: Short-term graft survival adjusted for population characteristics at the time of deceased donor liver transplantation was similar across all age groups (greater than 84% survival) except for patients less than 1 year of age where graft survival at 3 months was 82%. Graft survival declined in all age groups over time but this was greatest in those patients 65 years of age and over. For all other age groups, adjusted graft survival following a DDLT was always greater than 72% at 3 years and greater than 67% at 5 years. In patients over 65 years of age, graft survival was 68% and 60% at 3 and 5 years, respectively. For recipients of a LDLT, adjusted graft survival was similar throughout all age groups without any apparent relationship to patient age. Graft survival declined in all age groups over time. However, as was observed for recipients of a deceased donor graft, graft survival following a LDLT declined to a greater extent in patients 65 years and older. After 5 years, graft survival in patients 65 years and older was 61% compared to greater than 66% for all other age groups.

Adjusted graft survival was similar in both males and females following a DDLT. In contrast, long-term graft survival after 5 years was lower in males who received a LDLT at 67% compared to 72% for females. With respect to race, graft survival in African Americans was consistently lower compared to that of other races for all time periods following either a DDLT or LDLT. Short-term adjusted graft survival following a DDLT at 3 months was 87.8% in African Americans compared to greater than 89.3% for all other racial and ethnic groups. After 5 years, graft survival in African Americans was 59% compared to greater than 67% for all other racial and ethnic groups. In LDLT recipients, adjusted graft survival was 81% and 57% in African Americans compared to greater than 87% and greater than 69% for all other racial and ethnic groups at 3 months and 5 years, respectively.

Recipient disease: Adjusted graft survival at 3 months was similar regardless of the etiology for liver transplantation in both DDLT and LDLT recipients (greater than 83%). The only exceptions were in those patients who received a DDLT for acute hepatic necrosis (82%) and LDLT for either a malignant neoplasia (79%) or acute hepatic necrosis (78%). After 1 year, adjusted graft survival was similar with regard to diagnosis following DDLT (greater than 78%) except in those patients who received a DDLT for acute hepatic necrosis (74%). At 5 years, the highest graft survival rates were observed in recipients of DDLTs for metabolic

diseases (75%). The lowest survival rates were observed in patients with acute hepatic necrosis (63%), cirrhosis secondary to a noncholestatic disease (66%) and malignant neoplasia (54%). After 5 years, graft survival was highest for LDLT recipients with a diagnosis of either biliary atresia (73%) or cholestatic liver disease (73%). The lowest graft survival after LDLT were observed in patients with metabolic diseases and malignant neoplasia, at 62% and 52%, respectively.

Unadjusted graft survival at all time points was markedly reduced in patients who underwent retransplantation compared to patients with just an initial transplant. This was true for the recipients of either a DDLT or LDLT. At 3 months, graft survival of patients who underwent retransplantation with either a deceased or living donor graft was 77% and 73%, respectively, compared to 90% and 88% for recipients of their initial graft. At 5 years, graft survival following retransplantation was 50% and 54% for recipients of deceased and living donor grafts, compared to 69% and 70% for patients undergoing their initial liver transplant, respectively.

Effect of disease severity: Unadjusted graft survival declined with the intensity of medical care provided at the time of transplantation. In patients who received a DDLT, 3-month graft survival was 92% for patients not hospitalized, 88% when hospitalized, 79% when in an ICU and 73% when on life support. In patients who received a LDLT, a similar relationship was observed. Survival 3 months after a LDLT was 89% in patients not hospitalized, 89% in those hospitalized, 71% for patients in an ICU and 68% for patients when on life support. The decline in survival associated with the intensity of medical care at the time of either DDLTs or LDLTs was observed after 1, 3 and 5 years. Graft survival 5 years after a DDLT was 70%, 63%, 60% and 52% for each level of medical care provided, respectively. Similar results were observed for patients who received a LDLT.

Three-month graft survival in DDLT recipients, while listed as Status 1, was 79% compared to 70% for patients who received a LDLT. This difference declined with time. Five years later, graft survival for Status 1 patients following a DDLT or LDLT was 60% and 62%, respectively.

Since the MELD/PELD system was initiated in 2002, only short-term graft survival data are available at this time. Graft survival 3 months after a DDLT was greater than 88% in all groups except for those with a MELD/PELD score over 30 (85% and 71%, respectively). After 1 year, graft survival was greater than 79% for all MELD/PELD groups, again except those patients with a MELD/PELD score higher than 30 at the time of transplantation (76% and 64%, respectively). Although a similar relationship was observed in LDLT recipients, very few patients with a MELD/PELD score greater than 30 underwent this procedure, so reliable graft survival data for this group is not available. Patients

who received either a DDLT or LDLT for either stage T1 or T2 HCC had a 1-year graft survival greater than 85%. Patients who underwent a DDLT with an exception had similar 3-month and 1-year graft survival (greater than 89% and greater than 83%) as was observed for other patients.

Donor age: A parabolic relationship appears to exist with respect to donor age and unadjusted short-term graft survival following a DDLT (Figure 21). At 3 months, graft survival was greater than 92% for recipients of livers obtained from donors 11 to 34 years of age. Graft survival declined stepwise with donor ages less than 11 years of age to only 79% for donors under 1 year of age. Graft survival at 3 months also declined with increasing donor age above 34 years to 84% for donors over 65 years of age. The decline in graft survival with donors under 6 years old likely reflects an increased risk of technical complications in smaller donor livers (14). With an increase in time following liver transplantation, graft survival in patients who received a younger donor graft became similar to that observed for the 11–34-year-old group. In contrast, graft survival in older donors continued to decline with time. By 1 year, graft survival had declined to 79% in those recipients who received a liver from a donor 50 to 64 years of age and to 75% in recipients of donors over 65 years of age. Graft survival continued to decline with time in those that received an older donor graft; this difference was evident for donors down to 35 years of age. After 5 years, graft survival following a DDLT with donors less than 35 years of age was greater than 69%. In contrast, 5-year graft survival for donors aged 35–49 years was 66%, for donors aged 50–64 years survival was 61% and for donors over 65 years of age graft survival was only 54%.

Cold ischemia time: Unadjusted graft survival appeared to decline with increasing duration of cold ischemia time. When the deceased donor liver graft had less than 6 h of cold ischemia time, graft survival 3 months after the transplant was at 92%. Survival declined to 90% when cold ischemia time was between 6 and 10 h, 87% with
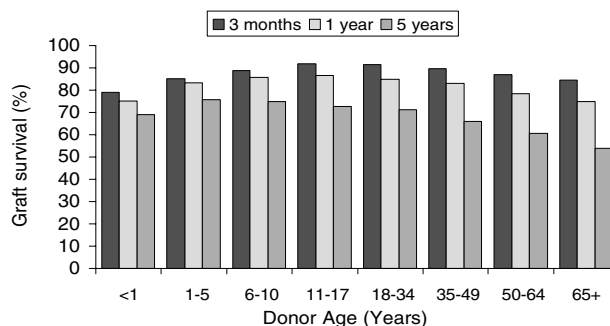
Source: *2005 OPTN/SRTR Annual Report*, Table 9.9a.

Figure 21: Unadjusted graft survival of deceased donor liver recipients at various time intervals, by donor age.

11–15 h of cold ischemia time and 82% with 16–20 h of cold ischemia time. Less than 1% of grafts had greater than 21 h of ischemia time so graft survival data is likely to be unreliable for this group. This trend of declining survival with increased duration of cold ischemia time was observed at 1, 3 and 5 years following transplantation.

Pretransplant death rates
Crude death rates for patients on the liver transplant waiting list have decreased consistently and considerably over the past decade. For all patients on the waiting list, there were 200 deaths per 1000 patient-years at risk (TPYAR) in 1995 and this declined to 126 deaths per TPYAR in 2004 (Figure 22).

Age: The highest age-specific waiting list death rates were observed at the extremes of the age distribution. Candidates less than 1 year of age consistently experienced the highest death rates during the past 10 years. However, by 2004 there had been a 43% reduction in the death rate of this age group, from 1044 to 591 deaths per TPYAR. The second highest death rate was observed in patients above 65 years of age. However, the death rate in this age group also declined by 41% between 1995 and 2004 from 296 to 174 deaths per TPYAR.

Demographic features: During the past decade, African Americans have consistently had the highest death rate for any of the racial and ethnic groups on the liver transplant waiting list. In 2004, the death rate observed in African Americans was 144 per TPYAR compared to 130 for Hispanics, 125 for whites and 90 for Asians. Asians have generally had the lowest waiting list death rates over the past decade. Between 1995 and 2004, males have consistently had a higher death rate while on the liver waiting list compared to females. In 2004, the death rate for males was 131 deaths per TPYAR compared to 119 per TPYAR for females. No consistent relationship between blood type and death rates has been observed during the past decade. In 2004, the lowest death rates, at 114 deaths per TPYAR,
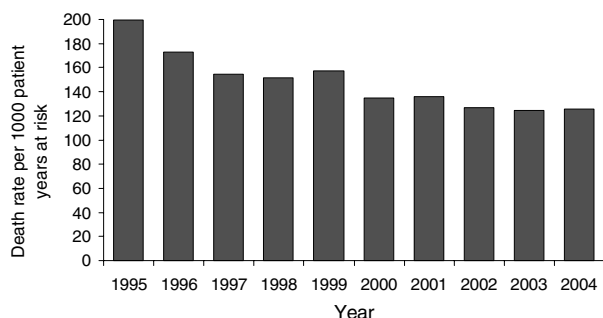
Source: *2005 OPTN/SRTR Annual Report*, Table 9.3.

Figure 22: Unadjusted death rates per 1000 patient-years at risk for patients on the liver waiting list, 1995–2004.
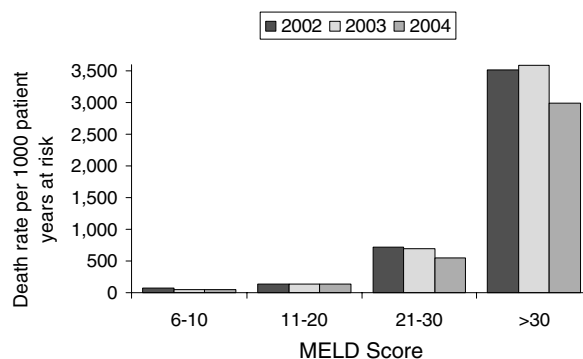
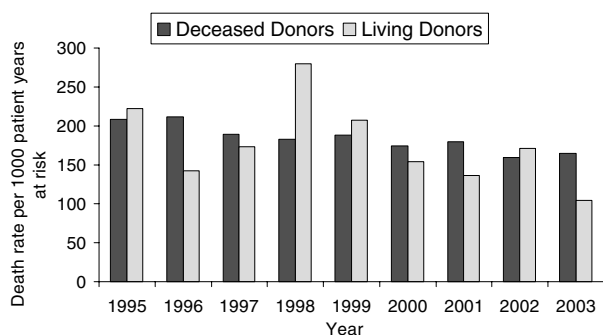Source: *2005 OPTN/SRTR Annual Report*, Table 9.3.

Figure 23: Unadjusted death rates per 1000 patient-years at risk for patients on the liver waiting list, by MELD Score 2002–2004.

were observed in patients with blood type B. The highest death rates, at 130 per TPYAR, occurred in patients with blood type O.

Medical urgency: As expected, waiting list death rates increased with increasing MELD/PELD scores at the time of listing. However, death rates within each MELD grouping have consistently declined between 2002, when the MELD/PELD system was first adopted, and 2004. During 2004, the death rate ranged from 45 deaths per TPYAR, among patients with a MELD score between 6 and 10, to 2993 deaths per TPYAR in patients listed with a MELD score greater than 30 (Figure 23). Death rates also tended to increase with increasing PELD scores; although, due to small numbers, the PELD-specific death rates are much more variable than their MELD counterparts. The death rate for patients initially listed at Status 1 has also declined stepwise over the past 10 years. In 1995, the death rate for a Status 1 patient was 984 per TPYAR compared to 545 per TPYAR in 2004.

Posttransplant death rates
Recipient death rates during the first year following liver transplantation have also decreased over the past 10 years (Figure 24). This is similar to the trend observed in waiting list death rates. The 1-year death rate following DDLTs in 1995 was 208 per TPYAR compared to 165 per TPYAR in 2003, the last year from which data is available to calculate 1-year survival. Similarly, the 1-year posttransplant death rate also declined over the past decade in LDLT recipients. In 1995, the 1-year posttransplant death rate for patients who underwent a LDLT was 222 per TPYAR and this declined to 136 per TPYAR in 2001. The death rate increased to 171 per TPYAR in 2002 before declining again to 104 deaths per TPYAR in 2003. The reason behind the increase in the 1-year posttransplant death rate during 2002 in patients who underwent LDLT is unclear at this time. Because of limited data, it is not possible to evaluate for specific risk

Source: *2005 OPTN/SRTR Annual Report*, Table 9.7a and 9.7b.

Figure 24: Unadjusted death rates per 1000 patient-years at risk for deceased and living donor liver recipients, in the first year after transplant, 1995–2003.

categories for 1-year posttransplant death rates in patients who underwent a LDLT.

Age: The highest 1-year posttransplant death rates have consistently been observed in patients who are 65 years of age or older and in recipients less than 1 year old. No consistent relationship was apparent between death rates and recipient age in patients under 65 years at the time of liver transplantation.

Race and ethnicity: With rare exceptions, African Americans have consistently had the highest 1-year posttransplant death rate of any racial or ethnic group. In 2003, the death rate observed in African Americans following a DDLT was 222 per TPYAR compared to 164 in whites, 146 in Hispanics and 135 in Asians. It is interesting that African Americans appear to have a higher death rate both while waiting for a liver transplant and after receiving a liver transplant. This observation requires further evaluation.

Previous transplantation: Patients with a previous organ transplant of any type have a markedly higher death rate compared to patients who have only received one liver transplant. This has been a consistent observation since 1995. In 2003, the 1-year posttransplant death rate among DDLT recipients who had received a previous organ transplant was 400 per TPYAR compared to 146 per TPYAR for those without a previous transplant.

Primary diagnosis: During the past decade, patients who received a DDLT for acute hepatic necrosis have almost always had the highest death rates compared to any other disease category. In 2003, the 1-year posttransplant death rate observed in patients with acute hepatic necrosis was 229 per TPYAR compared to 167 per TPYAR for patients with cirrhosis secondary to non-cholestatic liver disease, 151 for patients with malignant neoplasia, 135 for patients with cholestatic liver disease, 112 for patients with

metabolic liver disease and 87 deaths per TPYAR for patients with biliary atresia.

Disease severity: The 1-year posttransplant death rate for patients hospitalized at the time of their DDLT has been consistently greater over the past decade than that observed for nonhospitalized patients. Patients on life support at the time of their transplant have had the lowest posttransplant survival during the past decade. In 2003, the death rate for patients who received their liver transplant while not hospitalized was 135 per TPYAR compared to 203 for hospitalized patients, 300 for patients in an intensive care unit and 368 deaths per TPYAR for patients on life support at the time they underwent liver transplantation.

Patients listed as Status 1 at the time of their DDLT had the highest death rate in 2003, at 257 deaths per TPYAR compared to patients in any MELD score grouping. In general, the 1-year posttransplant death rate increased with increasing MELD score. The death rate in patients with a MELD score of 11–20 was 133 per TPYAR compared to 179 in those patients with a MELD score of 21 to 30 and 242 deaths per TPYAR in patients with a MELD score greater than 30. A similar trend was observed for PELD scores in the pediatric population. However, since the number of transplants performed in the pediatric population with PELD values above 30 is limited, death rates for this group could not be calculated.

Chronic hepatitis C virus infection

Chronic HCV is the single most common indication for liver transplantation in this country and has been steadily increasing over the past decade (Figure 25). In 1995, cirrhosis secondary to chronic HCV either alone or in combination with another cause accounted for 35% of patients undergoing liver transplantation. By 2004 this had increased to 43%. The incidence of HCC has increased over the past decade and this appears to be primarily related to the increased prevalence of chronic HCV (15). As a result, the
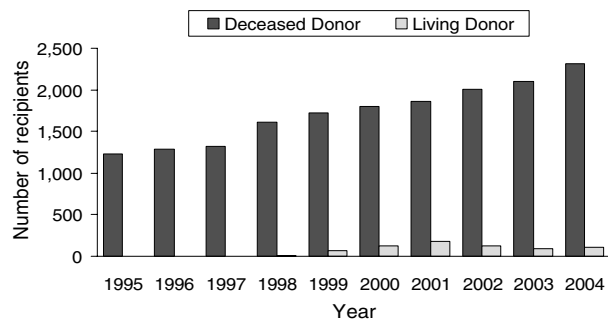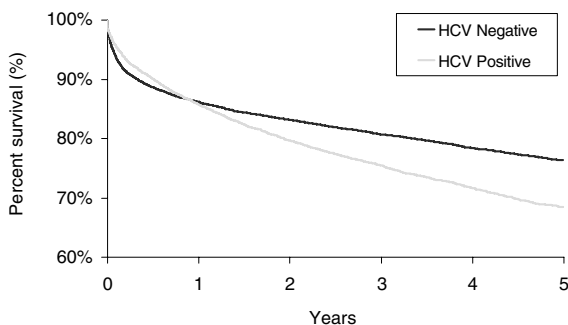

Source: SRTR analysis, July 2005.

Figure 25: Living and deceased donor transplant recipients with chronic HCV, 1995–2004.

majority of patients who underwent liver transplantation for HCC had coexistent HCV infection. In 2004, 60% of patients with HCC who received a DDLT and 46% who received a LDLT had chronic HCV.

Patient survival: Nearly all patients with chronic HCV develop recurrent disease (16). Recurrent HCV progresses to cirrhosis at a faster rate in liver transplant recipients compared to their nontransplant counterparts and survival in these recipients also appears to be significantly reduced (17). It is therefore not surprising that long-term survival is reduced in liver transplant recipients with HCV compared to those without HCV, 68% at 5 years compared to 76%, respectively (Figure 26).
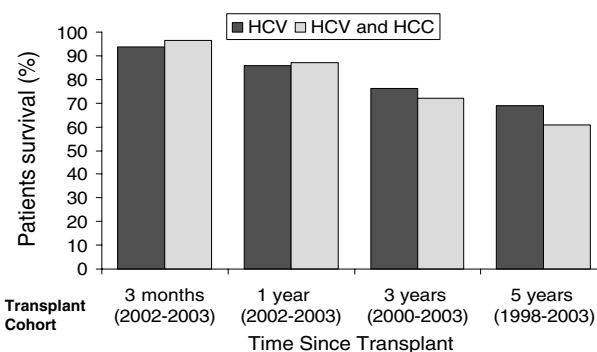
Chronic HCV and HCC: Approximately 10% of liver transplant recipients with chronic HCV between 1995 and 2004 had coexistent HCC. Since patients who undergo liver transplantation for malignant neoplasia have the lowest long-term survival of any group, this may contribute to the reduced survival observed in HCV liver transplant recipients. After 3 months and 1 year, the survival of HCV recipients with and without HCC was similar (Figure 27). However, by 3 and 5 years, survival in patients with coexistent HCV and HCC declined to a greater extent than observed in recipients with HCV alone. After 5 years, survival of patients with HCV but without HCC was 69% compared to 61% for recipients with HCV and HCC.

Chronic HCV and immunosuppression: Previous studies have suggested that certain immunosupressive agents may contribute to more severe recurrent HCV and more rapid progression to cirrhosis than other agents (18). Significant controversy exists regarding these observations. In the SRTR database, no consistent reduction in either short-term or long-term survival was observed with respect to the maintenance immunosupressive regimen utilized (Figure 28).
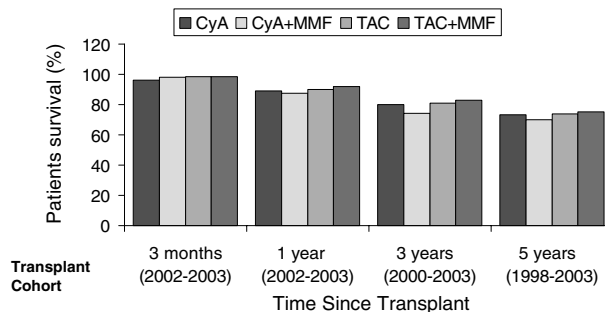

Source: SRTR analysis, July 2005.

Figure 27: Unadjusted patient survival of HCV positive liver recipients at various time intervals, by HCC status.
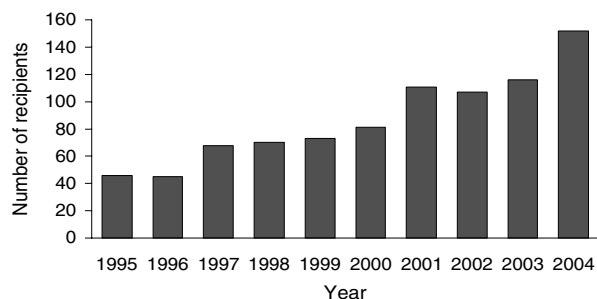
Intestine

Transplantation of the intestine, isolated or in combination with other abdominal organs, is an uncommon procedure, but is being performed with increasing frequency and success. The number of patients who received a small intestinal transplant has gradually increased over the past 10 years from 46 in 1995 to 152 in 2004 (Figure 29). The incidence of intestinal transplantation per 1 million population has increased from 0.18 in 1995 to 0.52 in 2004. The prevalence of people living with a functioning intestinal graft has also increased. In 1995, only 65 people were alive with a functioning intestinal graft. This value has increased stepwise every year since; in 2004, 443 patients were alive with a functioning intestinal graft. This increase is consistent across all demographic and other patient-specific subgroups.

Waiting list characteristics: The number of patients active on the waiting list at the end of the year for an intestinal transplant has more than doubled over the previous

Source: SRTR analysis, July 2005.

Figure 26: Unadjusted patient survival curves for deceased and living donor liver recipients, by HCV status.

Source: SRTR analysis, July 2005.

Figure 28: Unadjusted survival of HCV positive liver recipients at various time intervals, by discharge immunosuppressive regimen.

Source: *2005 OPTN/SRTR Annual Report*, Table 10.4.

Figure 29: Recipients of intestine transplants, 1995–2004.

10 years, from 69 patients in 1995 to 143 in 2004. At the end of 2004, approximately 70% of these patients were in the pediatric group (<18 years of age) and 14% were less than 1 year of age. The majority of intestinal transplant candidates (62% in 2004) suffer from short gut syndrome. Approximately 8% of candidates active at the end of 2004 had received a previous intestinal transplant.

Time to transplant and waiting list mortality: The median time to transplant among patients on the waiting list has decreased over time, from 497 days in 1995 to 238 days in 2004. The waiting time is longer for children and patients with blood type O. Although the median waiting time declined during the past 10 years, the annual death rate per TPYAR for patients on the intestinal transplant waiting list has remained fairly constant since 1995. In 1995, the death rate for patients on the waiting list was 279 per TPYAR compared to 306 in 2004. The waiting list death rate appears to be highest in the youngest children and the older adult candidates. The annual death rates in 2004 for patients under 1 year of age and between 50 and 64 years of age were 700 and 421 per TPYAR, respectively. The lowest death rates were observed in those patients between the ages of 6 and 17 years.

Recipient characteristics: There have been no systematic changes in the percentage of patients transplanted over the past 10 years by demographic characteristics (race, ethnicity, gender, blood type, etc.). The percentage of patients who were hospitalized at the time of transplantation has decreased from 30% in 1995 to 22% in 2004. There has been no discernible trend in the percentage of patients who were in the intensive care unit at the time of transplant, ranging from 11% to 27% over the past decade. Similarly, there was no trend in the number of recipients on life support at the time of transplant, ranging from 3% to 16% during the past 10 years.

Immunosuppression: Tacrolimus is the maintenance immunosuppressive agent of choice and utilized in practically all patients who receive an intestine transplantation. This is combined with steroids in the majority of patients. Approximately 12% of patients also receive Sirolimus. Induction, mainly with Thymoglobulin, Campath or Zenapax, is being used with increasing frequency. Induction was only used in 7% of recipients in 1995. This increased to 50% in 2004.

Rejection is common following intestine transplantation. During the past decade, about half of all patients were treated for rejection in the first year after transplantation. Corticosteroids are utilized for treatment of rejection in over 90% of patients. Monoclonal and polyclonal antibody preparations have been utilized in over one-third of patients with rejection. During 2003, the most common of these agents were OKT3 and Campath.

Annual death rates after transplantation: The annual death rate per 1000 patient-years at risk for recipients in the first year after intestinal transplantation decreased by nearly 50% between 1995 and 2003, from 417 to 208 deaths per TPYAR. There appears to be no consistent difference in the annual 1-year posttransplant death rate across demographic characteristics, with the possible exception of a higher death rate in children less than 1 year of age. In 2003, among age groups that contained enough recipients to calculate the death rate during the first posttransplant year, children under 1 year of age had the highest death rate at 331 deaths per TPYAR, followed by recipients 18–34 years with 313 deaths per TPYAR. The lowest posttransplant death rate was observed in recipients aged 11–17 years with 99 deaths per TPYAR. Death rates for intestine transplant recipients in 2003 were greatest for patients in an intensive care unit at the time of the transplant, at 628 per TPYAR compared to 218 per TPYAR for hospitalized patients and 158 per TPYAR for patients who were not hospitalized at the time they underwent an intestinal transplant.

Graft survival: Unadjusted graft survival following intestinal transplantation was 87% at 3 months, 73% at 1 year, 52% at 3 years and 43% after 5 years (Figure 30). However,
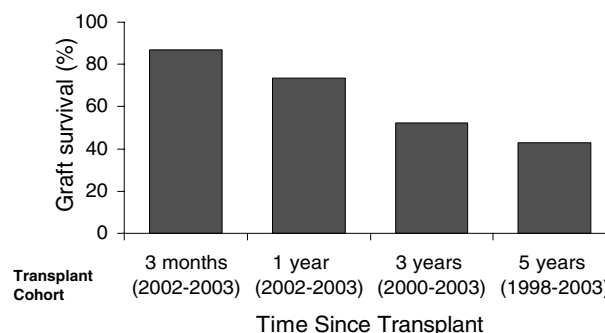
Source: *2005 OPTN/SRTR Annual Report*, Table 10.8.

Figure 30: Unadjusted graft survival of intestine recipients at various time intervals following transplant.
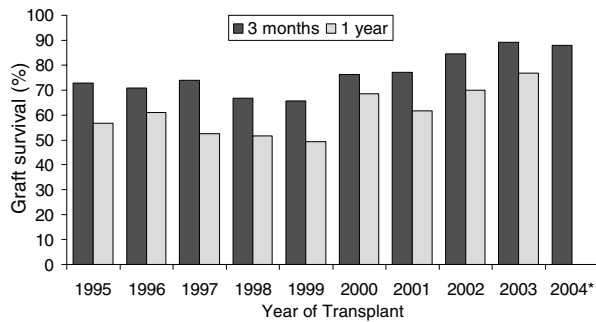
*1-Year survival not determined due to insufficient follow-up

Source: *2005 OPTN/SRTR Annual Report*, Table 10.10.

Figure 31: Unadjusted graft survival of intestine recipients at 3 months and 1 year by year of transplant, 1995–2004.

Source: *2005 OPTN/SRTR Annual Report*, Table 10.11.

Figure 32: Adjusted patient survival at various time intervals following intestine transplant.

graft survival at 3 months and 1 year has improved step-wise since 1995 (Figure 31). Most of this improvement has occurred since 1999. From 1995 to 1999, 3-month graft survival ranged between 66% and 74% and 1-year survival between 49% and 61%. Since 2000, 3-month survival increased to 88% in 2004 and 1-year survival to 77% in 2003 (the last year for which 1-year survival is available). Survival rates were calculated based on isolated intestinal transplants, along with those performed in combination with a liver and/or pancreas transplant as part of a multivisceral graft. No consistent relationship was observed between graft survival and age, gender, race/ethnicity, recipient blood type, primary diagnosis, donor age or cold ischemia time. In contrast, graft survival was reduced in recipients of a previous intestinal transplant and in those hospitalized or in an intensive care unit at the time of transplantation. Unadjusted graft survival at 1, 3 and 5 years for the recipients of a primary intestinal transplant was 76%, 55% and 44%, compared to 52%, 26% and 32% in recipients with a previous intestinal transplant, respectively. Graft survival in patients who were not hospitalized at the time of their transplant at 1, 3 and 5 years was 77%, 57% and 48%, respectively. In comparison, graft survival in patients hospitalized at the time of their transplant was 70%, 47% and 40%, and patients in an intensive care unit had a graft survival of 62%, 39% and 27%, respectively.

Patient survival: Adjusted patient survival for the recipients of an intestine transplant was 90% at 3 months, 80% at 1 year, 61% at 3 years and 52% after 5 years (Figure 32). As was observed for graft survival, unadjusted patient survival at 3 months and 1 year remained relatively stable between 1995 and 1999 and then increased stepwise through 2004. Between 1995 and 1999, 3-month survival ranged between 77% and 81% (Figure 33). This increased to 90% in 2004. Between 1995 and 1999, patient survival at 1 year ranged between 57% and 68%. This increased to 81% in 2003 (the last year for which 1-year survival data is available). As with graft survival, patient survival rates were calculated from isolated intestine transplants
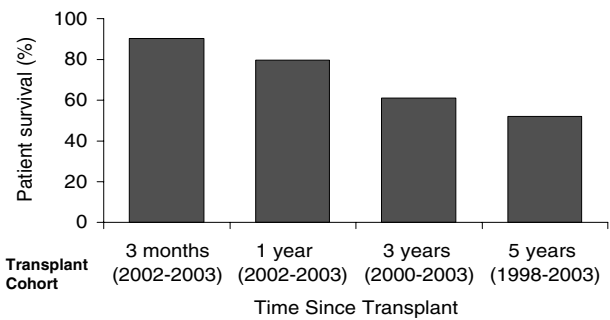
and those performed in combination with a liver and/or pancreas transplant as part of a multivisceral graft. No notable difference in survival following intestinal transplant was observed with respect to recipient age, gender, race/ethnicity, recipient blood type, primary diagnosis, donor age or cold ischemia time.

As was observed with graft survival, the intensity of medical therapy, assessed by the need for hospitalization or an intensive care unit, had a negative impact on patient survival. Unadjusted patient survival at 1, 3 and 5 years for patients not hospitalized at the time of transplant was 82%, 67% and 58%, respectively. For hospitalized patients, patient survival was 76%, 50% and 46% and for those in an intensive care unit survival had declined to 68%, 42% and 33%, respectively.

Intestinal transplants by transplant center: Between 1995 and 1998 only three centers had performed five or more intestinal transplants each year. In contrast, during 2004 the number of centers that performed five or more intestinal transplants had increased to nine. Thus, although
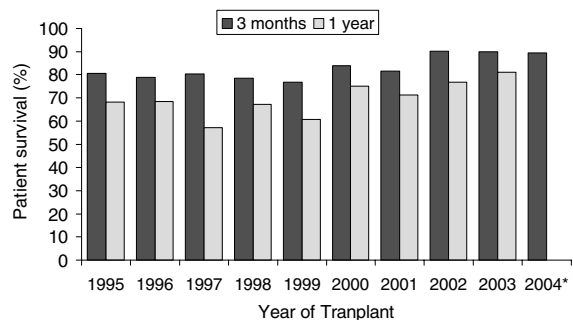
*1-Year survival not determined due to insufficient follow-up

Source: *2005 OPTN/SRTR Annual Report*, Table 10.13.

Figure 33: Unadjusted patient survival of intestine recipients at various time intervals, by year of transplant, 1995–2004.

the total number of centers performing intestinal transplantation in the United States is relatively small, a growing number of centers are gaining experience and developing expertise in this procedure.

Summary

The overall success of liver transplantation continues to improve. The increased utilization of deceased donor livers and a resurgence in living donor transplants has enabled the number of liver transplants performed yearly to surpass 5500. This represents a 51% increase in the number of liver transplants performed yearly since 1995. Although waiting time for all patients on the waiting list has not declined, pretransplant death rates have. Three years after implementation of the MELD/PELD system, the percentage of patients undergoing liver transplantation with higher MELD/PELD scores has increased and the percentage of recipients with HCC or exceptions for reasons other than HCC has remained relatively stable. Posttransplant death rates have also declined during the past decade.

There is now mounting evidence that donor age impacts posttransplant graft and patient survival. Specifically, utilizing livers from donors over 50 years of age is associated with a significant decline in long-term survival. Why short-term survival appears to be only marginally affected by the older donor remains to be explained.

Chronic HCV remains the single most common indication for liver transplantation and has become even more prevalent during the past decade. In 2004, 43% of all liver transplants were in patients with chronic HCV. Long-term survival following liver transplantation does appear to be reduced in patients with chronic HCV. Patients with HCV and coexistent HCC have even lower survival compared to patients with HCV alone. Neither of the standard maintenance immunosuppression regimens, cyclosporin or tacrolimus with or without MMF, appears to affect long-term graft or patient survival.

Intestinal transplantation is being performed at more centers, with increasing frequency and success. Posttransplant graft survival has increased stepwise since 2000 and patient survival at 1 year now exceeds 80% for the first time.

Acknowledgment

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