OPTN/SRTR 2012 Annual Data Report: lung

ABSTRACT Lung transplants are increasingly used as treatment for end-stage lung diseases not amenable to other medical and surgical therapies. Lungs are allocated to adult and adolescent transplant candidates on the basis of age, geography, blood type compatibility, and the Lung Allocation Score, which reflects risk of wait-list mortality and probability of posttransplant survival. The overall median waiting time in 2012 was 4 months, and 65.3% of candidates underwent transplant within 1 year of listing; however, this proportion varied greatly by donation service area. Unadjusted median survival of lung transplant recipients was 5.3 years in 2012, and median survival conditional on living for 1 year posttransplant was 6.7 years. Among pediatric lung candidates in 2012, 32.1% were wait-listed for less than 1 year, 17.9% for 1 to less than 2 years, 16.7% for 2 to less than 4 years, and 33.3% for 4 or more years. Both graft and patient survival have continued to improve; survival rates for recipients aged 6-11 years are better than for younger recipients. Compared with recipients of other solid organ transplants, lung transplant recipients experienced the highest rates of rehospitalization for transplant complications: 43.7 per 100 patients in year 1 and 36.0 in year 2.

KEY WORDS End-stage lung diseases, Lung Allocation Score, lung transplant, organ allocation, transplant outcomes.

I still catch myself on the street, or at a cafe, or wherever, and I'll think about how wonderful it feels to breathe – and I'll start welling up... I've had beautiful (donated) lungs for over 13 years now. I still think about them every single day, and about my donor.

Steve, lung/kidney recipient

Introduction

Lung transplants are increasingly used as treatment for end-stage lung diseases that are no longer amenable to other medical and surgical therapies. As of June 30, 2012, more than 10,000 recipients were alive with a lung transplant (Figure 5.5). Lungs are allocated to US transplant candidates primarily on the basis of age, geography, blood type (ABO) compatibility, and the Lung Allocation Score (LAS). Implemented in 2005, the LAS calculation is a score that reflects risk of wait-list mortality while avoiding transplants that have a very poor likelihood of survival.

The LAS applies to adolescent (aged 12 to 17 years) and adult (aged 18 years or older) candidates. Therefore, the adult section below includes data for candidates and recipients aged 12 years or older; the pediatric section reports data for candidates and recipients who are less than 12 years old.

As part of the development of the LAS system, pulmonary diagnoses of candidates (aged 12 years or older) were categorized into four main groups based on survival probability and pathophysiology of the underlying disease. The four groups are: Group A, obstructive lung disease (e.g., chronic obstructive lung disease/emphysema); Group B, pulmonary vascular disease (e.g., idiopathic pulmonary arterial hypertension); Group C, cystic fibrosis and immunodeficiency disorders; and Group D, restrictive lung disease (e.g., idiopathic pulmonary fibrosis). The first comprehensive revision of the LAS calculation was approved by the OPTN Board of Directors in November 2012 and will be implemented pending programming. This revision includes modifications to the variables included in the LAS calculation and the relative weight of the variables used to predict risk of death without a transplant and after transplant. The revised LAS will further improve the survival predictability for all diagnostic groups; these effects will be most notable for candidates in Group B.

Adult lung transplant

WAITING LIST

After an initial decline immediately following implementation of the LAS system in May 2005, the number of new patients added to the waiting list grew steadily until 2010; however, this trend appears to have reached a plateau (Figure 1.1). The number of inactive candidates has continued to decline every year since implementation of the LAS and was at an all-time low of 317 on December 31, 2012 (Figure 1.1). This steady decrease in inactive candidacy may indicate that candidates are being more appropriately chosen for the waiting list and those at risk of being designated as inactive because of becoming too sick for transplant are undergoing transplant more efficiently.

The LAS system changed the character of the waiting list. Since its implementation, candidates on the waiting list are increasingly older, are more likely to be from diagnosis Group D, and are sicker (Figure 1.2). Candidates aged 65 years or older continue to compose an increasing proportion of the waiting list. In 2012, 25.9% of the waiting list was aged 65 years or older compared with 5.8% in 2004 (the last full year before implementation of the LAS). In contrast, the proportion of candidates aged 18 to 34 years decreased from 15.2% of the waiting list in 2004 to 11.8% in 2012, the group aged 35 to 49 years decreased from 23.5% to just 13.5%, and the group aged 50 to 64 years decreased from 52.9% to 47.9% of the waiting list. The proportion of Group D candidates continues to increase every year and was at an all-time high of 49.5% of the waiting list in 2012. All other diagnostic groups represent a smaller proportion of the waiting list now than they did in 2004. The LAS distribution on the waiting list is also trending to higher scores; for example, 12.7% of the candidates had an LAS of 50 to 100 in 2006 (the first full year after implementation of the LAS) in contrast to 22.5% in 2012. The use of retransplant as an option has remained relatively stable despite the potential for a high LAS and increased access to transplant for this population. On December 31, 2012, 3.0% of those on the waiting list had been listed for retransplant (Figure 1.3). Candidates who need a lung transplant are rarely listed for multi-organ transplant; the most common combinations are heart-lung transplant (2.0%) and liver-lung transplant (0.5%) (Figure 1.3).

Since implementation of the LAS, transplant rates have increased for all candidates awaiting a lung transplant; however, that increase is most dramatically illustrated in candidates aged 65 years or older and those in diagnosis Group D (Figure

1.4). Overall median waiting time for candidates listed for lung transplant in 2012 was 4.0 months, varying from 3.1 months for Group D patients to a median that was not observed in Group B patients. Median months to transplant for Group B patients listed in 2011 was 9.7 months (Figure 1.8). While 65.3% of lung transplant candidates underwent transplant within 1 year of listing, the proportion of candidates undergoing lung transplant varied greatly by donation service area (DSA) ranging from 37.5 to 93.5% for those with at least 10 listings (Figure 1.9).

Wait-list mortality rates by candidate demographics have changed dramatically since implementation of the LAS. The LAS was originally implemented to minimize wait-list mortality while considering the probability of posttransplant survival. This methodology also de-emphasized time on the waiting list, effectively removing any incentive for early listing. As a result of the changing priorities in the new allocation model, candidates being listed for transplant have more advanced lung disease at listing than in previous years. After the initial decline in mortality rates, wait-list mortality rates are on the rise again and were at 15.4 per 100 wait-list years in 2010-2012, trending toward the high mortality rates preceding the LAS (Figure 1.10). Candidates aged 12 to 17 years had the highest wait-list mortality, at 19.7 deaths per 100 wait-list years, followed by those aged 18 to 34 years. Those in diagnosis Group D not only compose the largest proportion of the waiting list but also had the highest wait-list morality rates. In 2010-2012, those in Groups B and C had the next highest mortality rates; however, Group C has had a higher mortality than Group B at all other time points from the pre-LAS era to the post-LAS era. Minority candidates (Asian, Hispanic, and black) have higher mortality rates than whites – a trend that is not easily explained and will need further analysis. Candidates with an LAS of 50 or higher have a mortality risk that is nearly 10 times greater than that for candidates whose LAS is less than 50. Those with a score of less than 40 have nearly the same mortality rate, ranging from 4.5 to 8.6 deaths per 100 wait-list years.

DONATION

Deceased donors are the primary source of lungs for transplant, accounting for 99.9% of all transplants. Deceased lung donation rates have steadily increased over the past decade. While overall donation rates have increased, increases have been larger for certain demographic groups than for others. Specifically, from 2000 to 2011, rates among donors aged 15 to 34 years increased from 5.8 to 12.2 donations per 1000 deaths; compared with other age groups, this age group continues to have the highest donation rates of lungs for transplant (Figure 2.1). Lungs from donors aged 55 years or older were rarely used, with donation rates in 2011 of 0.5 and 0.04 for donors aged 55 to 64 years and those aged 65 to 74 years, respectively (Figure 2.1). Donation rates vary by race as well. In the last 10 years, donation rates for Hispanics are almost twice the rate for whites and are the highest rates of all racial groups. Geographically, donation rates continue to vary by state. Alaska, District of Columbia, Delaware, Maryland, and Kansas had the highest deceased donor lung donation rates in the US in 2009-2011 (Figure 2.2).

The number of lungs recovered and transplanted per deceased donor has been steadily increasing, from 0.25 lungs recovered per donor in 2000 to 0.39 lungs recovered per donor in 2012 (Figure 2.1, Deceased Organ Donation chapter). Similarly, the rate of lungs transplanted per donor has increased, from 0.25 in 2000 to 0.37 in 2012 (Figure 3.1, Deceased Organ Donation chapter). Discard rates appear to be increasing particularly in the past 10 years, going from 5.5% to 7.3% of lungs recovered (Figure 2.3). However, this is in the setting of more aggressive recovery of organs; in 2002 a total of 1138 lungs were recovered compared with 1939 in 2012. With utilization of new lung repair technologies currently under investigation in the US, such as ex vivo lung perfusion, perhaps the number of lungs recovered and ultimately transplanted will increase if these techniques are found to be effective and can be widely used by US transplant programs.

TRANSPLANT

In 2012, 1783 lung transplants were performed, a decline as compared with 1849 and 1811 in 2011 and 2010, respectively (Figure 3.1). This trend was not due to increased relative percentage of bilateral transplants, as they too decreased from 70% of transplants in 2010 and 2011 to 68% in 2012. However,

the overall utilization of bilateral lung transplants has grown from a total of 49.9% of all lung transplants in 2002 to 67.3% in 2012 (Figure 3.7), a trend that precedes implementation of the LAS. Retransplant rates have also increased, compared with the pre-LAS era; however, they have remained stable since implementation of LAS and still account for a small percentage of all transplants in 2012 at 5.5% (Figure 3.5).

Since implementation of the LAS, candidates aged 65 years or older, men, and those in diagnosis Group D have composed a larger proportion of patients undergoing transplant each year (Figure 3.2). In 2004, only 6.8% of the transplants in the US were performed in recipients aged 65 years or older. By 2012, recipients aged 65 years or older composed 26.3% of US lung recipients. During that same period, all recipients less than 65 years old received a smaller proportion of lung transplants compared with the pre-LAS era. Part of this shift reflects the aging of the US population. Also, LAS policy priorities, such as increased transplant access for patients who are at increased risk of mortality, (e.g., those in Group D, who tend to be older), may be reinforcing this shift to older recipient age. The proportion of female lung transplant recipients has also markedly decreased since implementation of the LAS. In 2004, female candidates received 50.1% of all lung transplants, but by 2012 women represented only 42.0% of lung transplant recipients. The trend appears stable in the post-LAS era. This trend cannot be explained by the decline in female lung transplant candidates, as they continue to represent nearly 60% of the waiting list (Figure 1.3). However, it is possible that the higher prevalence of men with pulmonary fibrosis—the predominant diagnosis in Group D patients, who have preferential access to transplant as a result of their high LAS scores—can explain this trend. Minority recipients (Asian, Hispanic, and black) are receiving a smaller number of transplants, but they represent a small proportion of the waiting list (Figures 3.2 and 1.2). During 2010-2012, these candidates experienced slightly higher mortality rates compared with whites: 20.8 for Asian, 18.7 for Hispanic, and 17.2 for black versus 14.8 deaths per 100 wait-list years for white candidates (Figure 1.10).

Lung transplant recipients are undergoing transplant with higher LAS scores (Figures 3.2 and 3.4). When the LAS system was implemented, the median LAS at transplant was 36.6; it increased to the median value of 40.7 in 2010 and has remained stable since then (Figure 3.4). The distribution of the LAS has also shifted, with an increase in the 75th percentile scores indicating that more candidates are being transplanted with higher LAS. The combined observed trends of increasing LAS on the waiting list (Figure 1.2), increasing LAS at transplant (Figure 3.4), and increasing wait-list mortality (Figure 1.10) very likely support the notion that sicker patients are being listed for lung transplant in the post-LAS era.

IMMUNOSUPPRESSION

The growing interest in antibody-mediated rejection has not yet resulted in significant changes in choice of initial immunosuppression in lung transplant recipients. The triple-drug regimen of a calcineurin inhibitor, an anti-metabolite, and a steroid is still the norm. Since 1998, use of tacrolimus as the primary calcineurin inhibitor has steadily increased; today, it is used in more than 90% of lung transplant recipients (Figure 3.8). Mycophenolate remains the predominant anti-metabolite used in lung transplant recipients, and its use continues to grow annually. Steroid use is also virtually universal and extends from the immediate posttransplant period through at least 1 year after transplant. Mammalian target of rapamycin (mTOR) inhibitors are used rarely, if at all, immediately after transplant; however, it is reported to be used in a small percentage of patients (less than 10%) in the first year after transplant. No induction was used after lung transplant in most lung transplant recipients from 1998 to 2005; however, that trend changed starting in 2006. In 2012, 55% of patients received some form of induction compared with 23% of patients in 1998. For patients who did receive an induction agent, interleukin-2 receptor antagonists were the primary agents chosen, with a minority of patients receiving a T-cell depleting agent (Figure 3.8).

DONOR/RECIPIENT HLA MATCHING

The significance of antibody-mediated rejection is well recognized in other solid organ transplants, but its role in graft dysfunction after lung transplant is not well understood and

is a subject of increasing interest in the scientific community. While there is no strong consensus regarding its diagnostic characteristics, it is accepted that closer immunologic or HLA match between a donor and a recipient will minimize risk of antibody-mediated and cellular rejection. However, the past decade has seen an apparent trend toward more liberally performing transplants with higher PRA (Figure 3.2) and HLA (at A, B, and DR loci) mismatches (Figure 4.1), particularly since implementation of the LAS. It is unclear whether this noted trend is the result of recent changes in methods that make the detection of circulating anti-HLA antibodies more sensitive, or whether it reflects an intentional practice trend at transplant centers.

DONOR/RECIPIENT SEROLOGIC MATCHING

In approximately 70% of lung transplants performed from 2008 to 2012, donor cytomegalovirus (CMV) status and recipient CMV status were either matched or CMV-positive candidates received CMV-negative lungs (Figure 4.2). This practice decreases the risk of a CMV-negative recipient seroconverting to CMV and suffering its potential known consequences, such as CMV viremia, pneumonia, or increased risk of developing bronchiolitis obliterans syndrome. However, 24.5% of lung transplants were from a CMV-positive donor to a CMV-negative recipient. Similarly, donors and recipients are often matched on the basis of Epstein-Barr virus (EBV) status; only 10.3% of lung transplants were from an EBV-positive donor to an EBV-negative recipient (Figure 4.3). This contrast between EBV and CMV trends is explained by 76.8% of transplant candidates being positive for EBV but only 54.0% of candidates being positive for CMV.

OUTCOMES

Since 2007, median survival for lung transplant recipients, including survival conditional on living 1 year after transplant, has remained stable (Figure 5.4). Unadjusted median survival for all lung transplant recipients is now 5.3 years, while 1-year conditional median survival is 6.7 years. Short-term survival (30-day and 1-year) has in fact improved; however, 3-year survival has plateaued and 5-year survival has decreased when comparing post-LAS with pre-LAS survival outcomes (Figure 5.2). However, given the relatively short follow-up period since implementation of the LAS, it may be that 3- and 5-year survival data do not represent stable trends. Survival is lowest among recipients aged 65 years or older (Figure 5.1), those with LAS greater than 50, and possibly for those in diagnosis Group B (Figure 5.3). It is notable that patients with higher LAS are increasingly undergoing transplant (Figure 3.4) and that patients aged 65 years or older are undergoing transplant at increasingly higher rates than those in other age categories (Figure 1.4). If these transplant trends continue, it is reasonable to expect a continued decline in overall survival or at least in long-term survival of lung transplant recipients.

Procedure choice appears to affect survival as well, with patients receiving a left single lung transplant having the worst survival compared with those receiving single right and bilateral lung transplants (log-rank $P < 0.0001$). However, it is important to keep in mind that these registry data regarding single and bilateral lung transplant have not been adjusted for age, LAS, and diagnoses—variables that may mediate the observed survival differences. Patients undergoing transplant for diagnoses that do not require a bilateral transplant (e.g., alpha-1 antitrypsin deficiency, chronic obstructive pulmonary disease, and idiopathic pulmonary fibrosis), and who therefore receive both types of transplant with some frequency, also have improved survival when they receive a bilateral lung transplant compared with a single lung transplant (log-rank $P < 0.0001$).

Five years after transplant, the vast majority of surviving recipients require no assistance in their activities of daily living (Figure 5.7). However, several complications can adversely affect the health of transplant recipients and likely contribute to mortality. Five years after transplant, of recipients in 2005-2007, 66.7% were reported to have drug-treated hypertension; 53.8% reported drug-treated hyperlipidemia; 49.8 reported some degree of renal dysfunction; 42.5% reported diabetes, and 18.3% were diagnosed with a malignancy (Figure 5.7). These complications are presumed to stem in large part from the long-term use of immunosuppressive medications. Despite the rather aggressive immunosuppression of lung transplant patients, bronchiolitis obliterans or chronic rejection was reported in the

first year in 7.9% of recipients. By 5 years, 43% of patients were reported to have bronchiolitis obliterans. However, graft failure is not the primary cause of death in lung transplant recipients; rather, it is infection (Figure 5.9). Graft failure, other respiratory causes (e.g., respiratory failure, acute respiratory distress, pulmonary embolism), cardiovascular/cerebrovascular disease, and malignancy are the other frequently reported causes of death in this population.

Pediatric Lung Transplant

WAITING LIST

Since 1998, the number of new child candidates (aged 0 to 11 years) added each year to the lung transplant waiting list has consistently decreased, with 25 total additions in 2012 (Figure 6.1). Among prevalent lung transplant candidates, those listed as inactive continue to outnumber those listed as active. The age distribution of child candidates on the lung transplant waiting list has changed over time due to changes in the diagnoses for which lung transplant is indicated and also due to earlier detection and more aggressive testing for diseases such as surfactant deficiencies. The proportion of candidates less than 1 year old has steadily increased, from 7.4% in 2002 to 15.4% in 2012 (Figure 6.2). In 2012, 28.2% of candidates were aged 1 to 5 years and 56.4% were aged 6 to 11 years. As seen in all pediatric transplantation, the ethnic distribution of candidates on the waiting list has changed, with increasing representation of Hispanic patients, who accounted for 17.9% of candidates in 2012. Among pediatric lung candidates in 2012, 32.1% were on the waiting list for less than 1 year, 17.9% for 1 to less than 2 years, 16.7% for 2 to less than 4 years, and 33.3% for 4 or more years (Figure 6.2).

Of patients removed from the waiting list in 2012, 47.1% were removed from the waiting list because they received a transplant, 32.4% because of death, and 17.6% because of improved condition (Figure 6.3). Looking at 3-year outcomes for pediatric lung transplant candidates listed in 2009, 60% received a transplant, 15% died, 15% were still waiting, and 10% were removed from the list for reasons other than transplant or death (Figure 6.4). The overall lung transplant rate was 78 per 100 wait-list years in 2012, 77 in candidates aged less than 6 years old, and 94 in candidates aged 6 to 11 years (Figure 6.5). Pretransplant mortality in 2012 was 17.7 per 100 wait-list years; the rates were 2-fold higher in patients less than 6 years old compared with patients aged 6 to 11 years: 29.4 versus 13.3 per 100 wait-list years, respectively (Figure 6.6).

TRANSPLANT

In 2012, the total number of lung transplants in candidates aged 0 to 11 years was 12: 4 in recipients less than 1 year old, 4 in recipients aged 1 to 5 years, and 4 in recipients aged 6 to 11 years (Figure 6.7). Five percent of recipients had a history of a prior transplant (Figure 6.8). Lung transplants were part of a multi-organ transplant in 8.8% of cases in 2012, with heart being the most common other organ at 5.9% (Figure 6.9). Looking at the past decade of lung transplantation in child recipients, there has been a shift toward younger recipients; in 2010-2012, nearly 60% of recipients were less than 6 years old, compared with 39% in 2000-2002 (Figure 6.10). The etiology of lung disease among child lung transplant recipients has changed over time, with a decrease in the proportion of recipients with cystic fibrosis and pulmonary hypertension and an increase in pulmonary fibrosis and "other diagnoses," such as surfactant protein B deficiency and bronchopulmonary dysplasia, which now account for 36.8%. Among child lung transplant recipients in 2010-2012, 57.9% waited less than 3 months for transplant compared with 37.3% in 2000-2002. Among the 2010-2012 recipients, 33.3% were in the intensive care unit immediately before transplant, 38.6% were on the ventilator, and 3.5% were receiving extracorporeal membrane oxygenation. The procedure of choice was bilateral sequential transplant, which was performed in 87.7% of patients. Medicaid coverage for pediatric lung transplant has increased, with a corresponding decrease in private insurance coverage (Figure 6.10).

Posttransplant lymphoproliferative disorder (PTLD) is a marked concern in pediatric transplantation. Among child lung transplant recipients in 2008-2012, 60% were EBV-negative and 39% were EBV-positive (Figure 6.11). The highest risk for EBV infection and PTLD occurs in EBV-negative recipients of EBV-positive donor organs; this occurred in 33% of recipients

in 2008-2012 (Figure 6.11). The incidence of PTLD among EBV-negative recipients was 14.4% at 5 years after transplant, compared with 2.8% among EBV-positive recipients (Figure 6.13).

Among child lung transplant recipients in 2008-2012, 63.1% were CMV-negative and 35.7% were CMV-positive (Figure 6.12). The combination of a CMV-positive donor and CMV-negative recipient occurred in 35.7% of recipients.

IMMUNOSUPPRESSION

The trends in immunosuppression for lung transplant recipients less than 12 years old are similar to those in recipients aged 12 years or older (Figure 6.15). In 2012, tacrolimus was used in 85.7% of child lung transplant recipients, with no cyclosporine use reported; similarly, mycophenolate was used in 85.7% and no azathioprine use was reported. Steroids were used at the time of transplant in 92.9% of recipients and in almost all at 1 year after transplant. The past decade has seen a shift from no induction therapy to an increasing use of interleukin-2 (IL-2) receptor antagonist therapy (Figure 6.15). In 2012, 50% of recipients received IL-2 receptor antagonist therapy for induction, 28.6% received T cell depleting agents, and 21.4% reported no induction therapy.

OUTCOMES

Both graft and patient survival have continued to improve over the past decade. For transplants performed in 2007-2008, patient survival was 96.3% at 30 days, 87.0% at 1 year, 60.1% at 3 years, and 49.0% at 5 years (Figure 6.16).

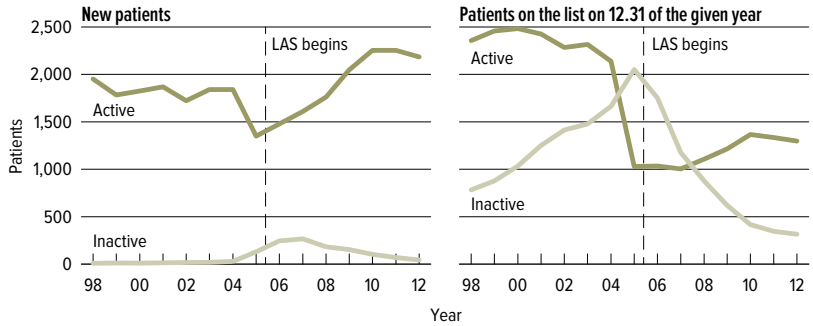
In 2008-2011, rehospitalization occurred in just over half of pediatric lung transplant recipients at 1 year (Figure 6.14). Post-transplant complications for child lung transplant recipients are similar to adult recipients and include hypertension, renal dysfunction, diabetes, bronchiolitis obliterans syndrome, and malignancy. Most child lung transplant recipients are reported as "fully active" at 1 year after transplant.

Among child lung recipients who underwent transplant in 2006-2011, the incidence of acute rejection was 17% within 1 year and 21% within 2 years after transplant (Figure 6.17). Figure 6.18 shows the variations in 5-year recipient survival by age, sex, race, and primary diagnosis. Recipients aged 6 to 11 years have higher survival rates compared with younger recipients. The diagnosis of pulmonary hypertension is associated with higher survival rates than cystic fibrosis or the "other" category, which includes diagnoses such as pulmonary fibrosis, bronchiolitis obliterans, and bronchopulmonary dysplasia.

ECONOMICS

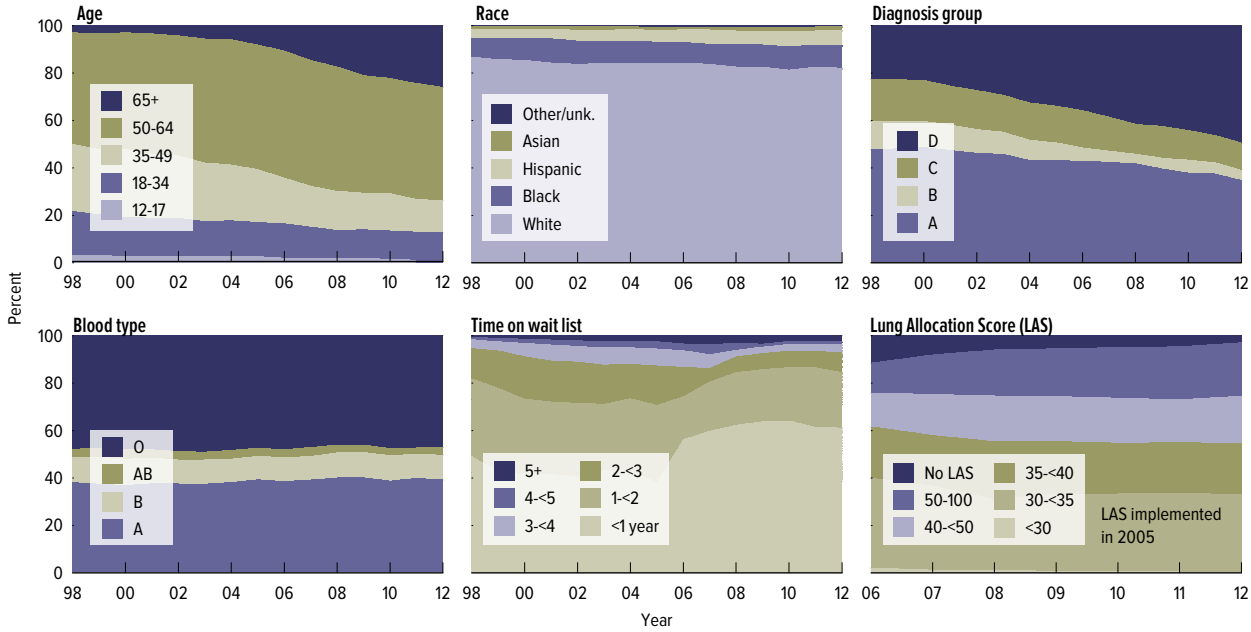
Medicare paid for some or all of the care for more than 50% of lung transplants in 2010 (Figure 7.1). For lung recipients with primary Medicare coverage, average reimbursement from transplant through 1 year after transplant was $207,013 for Part A and $28,862 for Part B (Figure 7.5), totaling $235,875; this is approximately three times the Medicare Parts A and B expenditure for a kidney transplant recipient (Figure 8.5, Kidney chapter) and is the least expensive of heart, lung, and intestine transplant (Figure 7.5, Heart chapter; Figure 5.5, Intestine chapter). Rehospitalization is common after lung transplant with relatively high rates of rehospitalization in the first year after transplant (Figure 7.2), dropping by half in the second year (Figure 7.3). Primary causes for rehospitalization during the first and second years after transplant are for transplant complications and infections (Figure 7.4). Compared with kidney, pancreas, liver, intestine, and heart recipients, lung transplant recipients experienced the highest rates of rehospitalization for transplant complications with 43.7 per 100 patients in year 1 and 36.0 per 100 patients in year 2 (Figure 7.4; compare with: Figure 8.4, Kidney chapter; Figure 6.4, Pancreas chapter; Figure 8.4, Liver chapter; Figure 5.4, Intestine chapter; Figure 7.4, Heart chapter). Annual costs after the first year are smaller for Medicare Parts A and B, averaging $38,253 and $13,425, respectively, during year 2 (Figure 7.6), totaling $51,678. Additional costs not accounted for here include reimbursement to hospitals for the transplant portion of the Medicare Cost Report and Medicare Part D. Including estimates for these brings average Medicare cost to approximately $300,000 in the first year after transplant and approximately $60,000 in subsequent years. Lung transplant recipients account for 6% of all Medicare Parts A and B expenditures after solid organ transplant; in 2010 this totaled $233 million, or $41,429 per patient (Figure 7.7).

wait list



LU 1.1 Adult patients waiting for a lung transplant

Patients waiting for a transplant. A "new patient" is one who first joins the list during the given year, without having listed in a previous year. However, if a patient has previously been on the list, has been removed for a transplant, and has relisted since that transplant, the patient is considered a "new patient." Patients concurrently listed at multiple centers are counted only once. Those with concurrent listings and active at any program are considered active; those inactive at all programs at which they are listed are considered inactive.



LU 1.2 Distribution of adult patients (active) waiting for a lung transplant

Patients waiting for a transplant any time in the given year. Age determined on the earliest of listing date or December 31 of the given year. Concurrently listed patients are counted once. Patients first listed prior to LAS implementation may remain score-less after 2005 due to missing data among elements required to compute LAS. LAS is the first known in the given year.

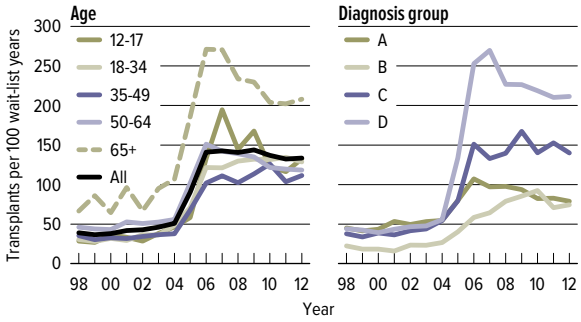
wait list

	Level	2002 N	2002 %	2007 N	2007 %	2012 N	2012 %
Age	12-17	94	2.5	40	1.8	23	1.4
	18-34	608	16.5	314	14.4	167	10.3
	35-49	1,113	30.2	523	24.0	235	14.5
	50-64	1,733	47.0	1,118	51.3	857	53.0
	65+	143	3.9	186	8.5	334	20.7
Sex	Female	2,142	58.0	1,317	60.4	945	58.5
	Male	1,549	42.0	864	39.6	671	41.5
Race	White	3,041	82.4	1,778	81.5	1,314	81.3
	Black	397	10.8	210	9.6	168	10.4
	Hispanic	171	4.6	138	6.3	96	5.9
	Asian	67	1.8	41	1.9	26	1.6
	Other/unk.	15	0.4	14	0.6	12	0.7
Diagnosis group	A	1,578	42.8	930	42.6	724	44.8
	B	544	14.7	235	10.8	104	6.4
	C	527	14.3	301	13.8	175	10.8
	D	840	22.8	588	27.0	581	36.0
	Other/unk.	202	5.5	127	5.8	32	2.0
Most recent lung allocation score	<30	0	0.0	154	7.1	38	2.4
	30-<35	0	0.0	1,007	46.2	818	50.6
	35-<40	0	0.0	282	12.9	350	21.7
	40-<50	0	0.0	145	6.6	258	16.0
	50-100	0	0.0	62	2.8	109	6.7
	No LAS*	3,691	100.0	531	24.3	43	2.7
Blood type	A	1,343	36.4	861	39.5	639	39.5
	B	390	10.6	210	9.6	152	9.4
	AB	138	3.7	72	3.3	44	2.7
	O	1,820	49.3	1,038	47.6	781	48.3
Time on waiting list	<1 month	91	2.5	104	4.8	133	8.2
	1-<3 months	280	7.6	201	9.2	219	13.6
	3-<6 months	350	9.5	217	9.9	228	14.1
	6-<12 months	523	14.2	231	10.6	252	15.6
	1-<2 years	855	23.2	267	12.2	297	18.4
	2-<3 years	536	14.5	186	8.5	183	11.3
	3+ years	1,056	28.6	975	44.7	304	18.8
Status	Inactive	1,354	36.7	1,129	51.8	299	18.5
	Active	2,337	63.3	1,052	48.2	1,317	81.5
Transplant history	Listed for first tx	3,597	97.5	2,119	97.2	1,567	97.0
	Listed for subseq. tx	94	2.5	62	2.8	49	3.0
Multi-organ Listing	Lung-Heart	145	3.9	80	3.7	32	2.0
	Lung-Kidney	3	0.1	0	0.0	3	0.2
	Lung-Pancreas	0	0.0	2	0.1	1	0.1
	Lung-Liver	6	0.2	8	0.4	8	0.5
	Lung-Liver-Kidney	0	0.0	0	0.0	1	0.1
	Lung alone	3,537	95.8	2,091	95.9	1,571	97.2
Total		3,691	100.0	2,181	100.0	1,616	100.0

In 2007, all but 5 patients with missing LAS were listed before May 4, 2005.
In 2012, all patients with missing LAS were listed before May 4, 2005.

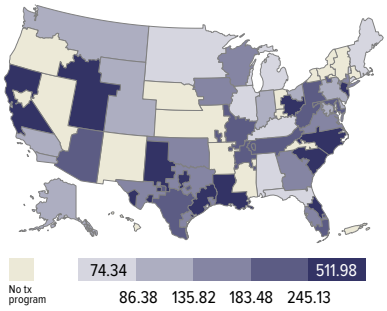
LU 1.3 Characteristics of adult patients on the lung transplant waiting list on December 31 of 2002, 2007, & 2012

Patients waiting for a transplant on December 31 , 2002 and December 31, 2012, regardless of first listing date; active/inactive status is on this date, and multiple listings are not counted. Patients missing LAS in 2012 are all inactive.



LU 1.4 Lung transplant rates among active adult waiting list candidates, by age

Transplant rates are computed as the number of deceased donor transplants per 100 patient-years of active waiting time in a given year. Age is calculated on the first active listing date in a given year.



LU 1.5 Deceased donor lung transplant rates per 100 patient years on the waiting list among active adult candidates, by DSA, 2011–2012

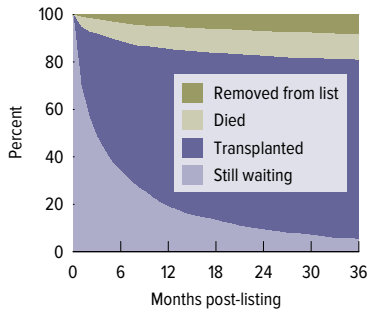
Transplant rates by DSA of the listing center, limited to those with active time on the waiting list in 2011 and 2012; deceased donor transplants only. Maximum time per listing is two years. Patients with concurrent listings in a single DSA are counted once in that DSA, and those listed in multiple DSAs are counted separately per DSA.

wait list

	2010	2011	2012
Patients at start of year	1,836	1,780	1,679
Patients added during year	2,359	2,323	2,231
Patients removed during year	2,409	2,420	2,294
Patients at end of year	1,786	1,683	1,616
Removal reason			
Deceased donor transplant	1,776	1,818	1,754
Living donor transplant	0	1	1
Patient died	338	348	303
Patient refused transplant	6	11	8
Improved, tx not needed	158	69	41
Too sick to transplant	45	81	110
Other	86	92	77

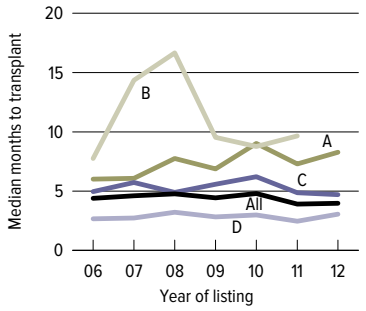
LU 1.6 Lung transplant waiting list activity among adult patients

Patients with concurrent listings at more than one center are counted once, from the time of earliest listing to the time of latest removal. Patients listed, transplanted, and re-listed are counted more than once. Patients are not considered "on the list" on the day they are removed. Thus, patient counts on January 1 may be different from patient counts on December 31 of the prior year. Patients listed for multi-organ transplants are included. Known deaths following removal for being too ill are counted as deaths.



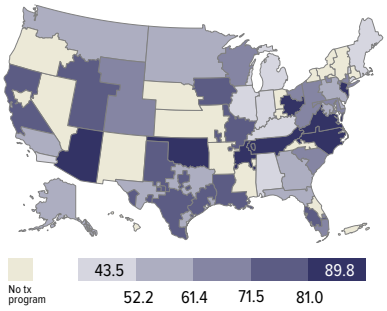
LU 1.7 Three-year outcomes for adult patients waiting for a lung transplant among new listings in 2009

Adult patients waiting for any lung transplant and first listed in 2009. Patients with concurrent listings at more than one center are counted once, from the time of the earliest listing to the time of latest removal.



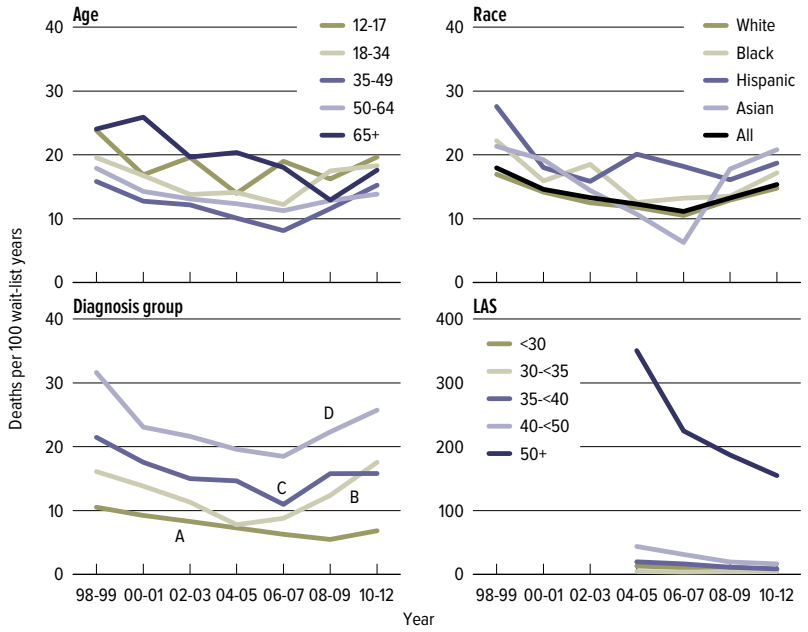
LU 1.8 Median months to lung transplant for wait-listed adult patients, by diagnosis group

Patients waiting for a transplant, with observations censored at December 31, 2012; Kaplan-Meier methods used to estimate time to transplant. If an estimate is not plotted, 50% of the cohort listed in that year had not been transplanted at the censoring date. Only the first transplant is counted.



LU 1.9 Percent of adult wait-listed patients, 2011, who received a deceased donor lung transplant within one year, by DSA

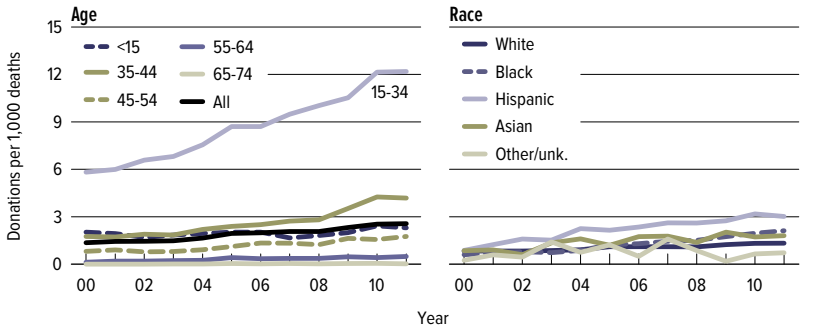
Patients with concurrent listings in a single DSA are counted once in that DSA, and those listed in multiple DSAs are counted separately per DSA.



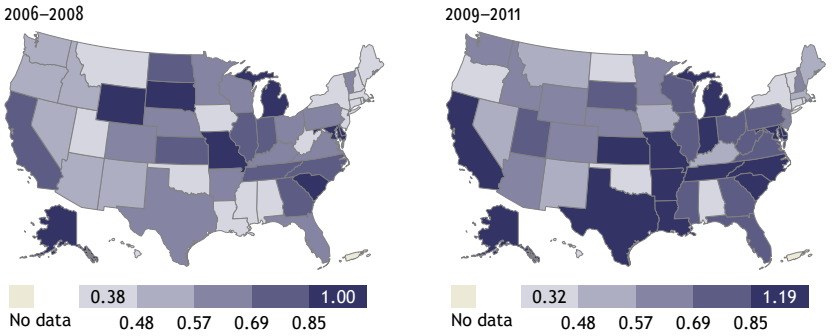
LU 1.10 Pre-transplant mortality rates among adult patients wait-listed for a lung transplant

Patients waiting for a transplant. Mortality rates are computed as the number of deaths per 100 patient-years of waiting time in the given interval. For rates shown by different characteristics, waiting time is calculated as the total waiting time in the interval for patients in that group. Only deaths that occur prior to removal from the waiting list are counted. Age is calculated on the latest of listing date or January 1 of the given interval. Other patient characteristics come from the OPTN Transplant Candidate Registration form.

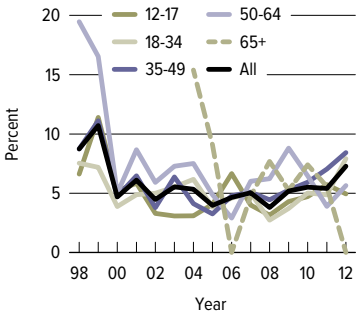
deceased donation



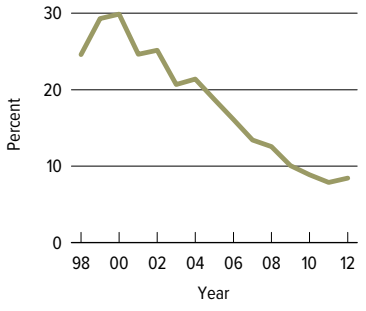
LU 2.1 Deceased donor lung donation rates
Numerator: Deceased donors age less than 75 with at least one lung recovered for transplant. Denominator: US deaths per year, age less than 75. (Death data available at http://www.cdc.gov/nchs/products/nvsr.htm.) Death data were available only through 2011.



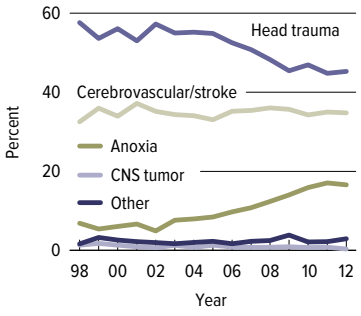
LU 2.2 Deceased donor lung donation rates (per 1,000 deaths), by state
Numerator: Deceased donors residing in the 50 states whose lung(s) was/were recovered for transplant in the given year range. Denominator: US deaths by state during the given year range. (Death data available at http://www.cdc.gov/nchs/products/nvsr.htm.) Rates are calculated within ranges of years for more stable estimates. Donors who donated two lungs are counted twice.



LU 2.3 Discard rates for lungs recovered for transplant
Percent of lungs discarded out of all lungs recovered for transplant. Lungs recovered as a block are counted as one organ. Lungs recovered separately are counted as two organs.

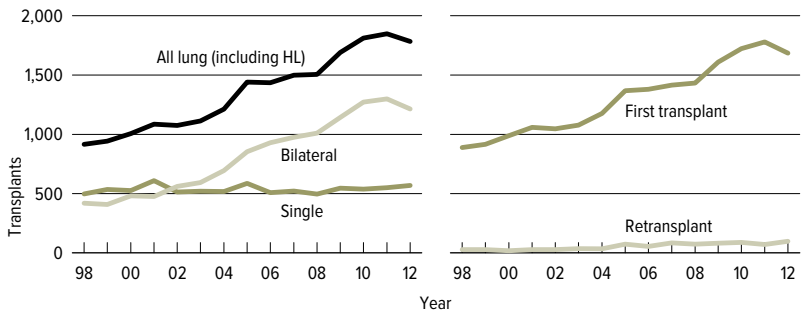


LU 2.4 Lung donors with a smoking history of 20 pack-years or more
All deceased donors whose lung(s) were transplanted in the given year. Smoking history as reported to the OPTN.

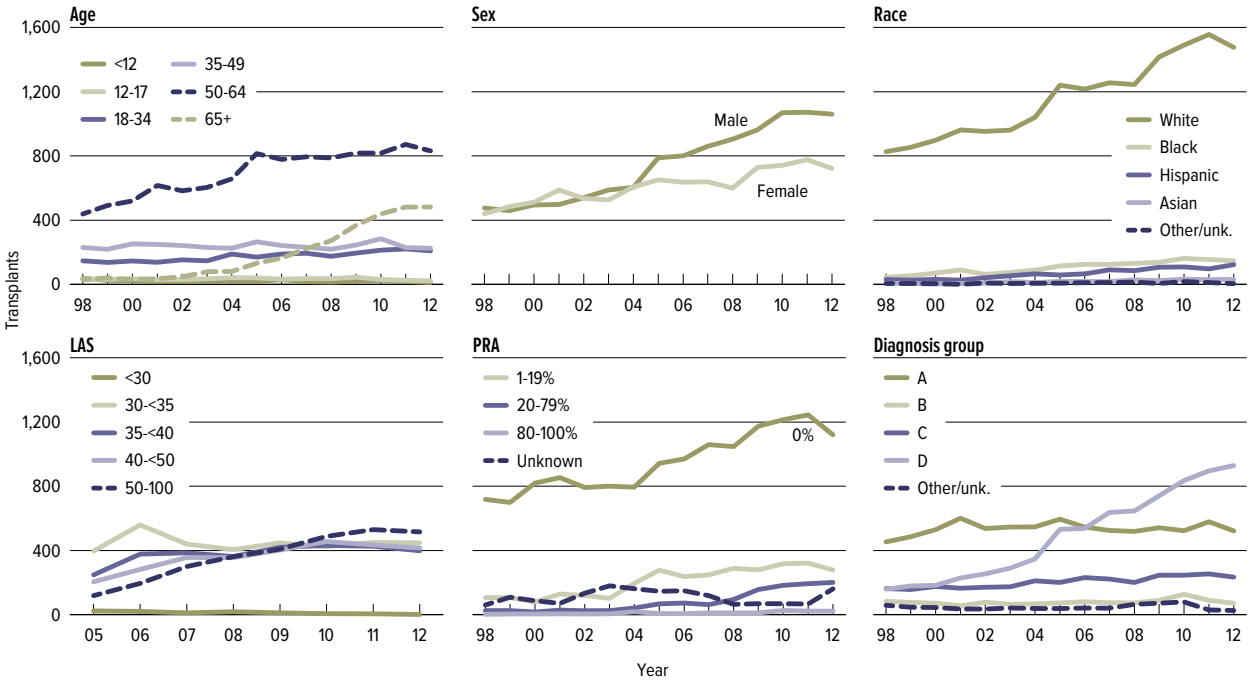


LU 2.5 Cause of death among deceased lung donors
Deceased donors whose lungs were transplanted. Donors who contributed more than one lung were counted once. CNS = central nervous system.

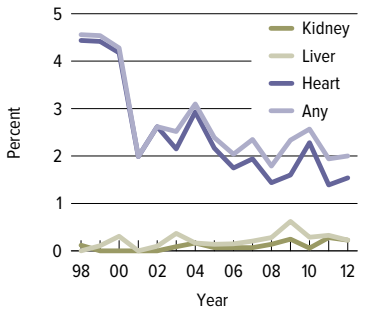
transplant



LU 3.1 Total lung transplants
Patients receiving a transplant, including multi-organ transplants and pediatric patients. Retransplants are counted.

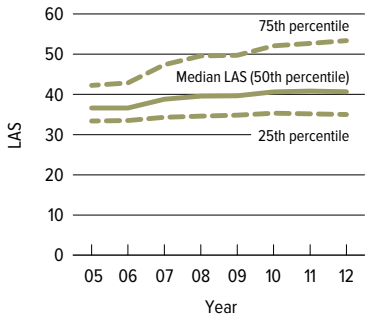


LU 3.2 Lung transplants
Patients receiving a transplant, including multi-organ transplants and pediatric patients. Retransplants are counted.



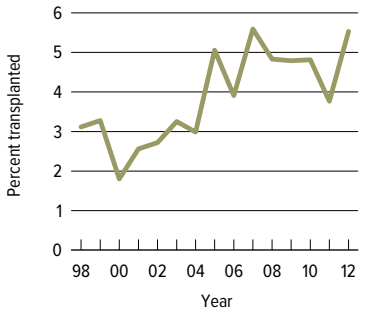
LU 3.3 Lung transplants that were part of a multi-organ transplant

All adult patients receiving a deceased donor lung transplant with at least one additional organ. A multi-organ transplant may include more than two different organs in total; if so, each non-lung organ will be considered separately. Kidney transplants include living donor transplants.



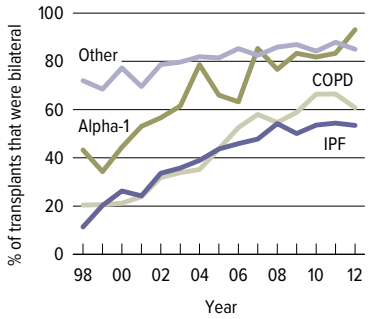
LU 3.4 Median LAS at transplant

Patients aged 12 years and older with all data required to compute LAS non-missing; last LAS prior to transplant.



LU 3.5 Retransplants among adult lung transplant recipients

Patients receiving a lung retransplant in the given year.



LU 3.6 Utilization of bilateral transplants for adult lung recipients

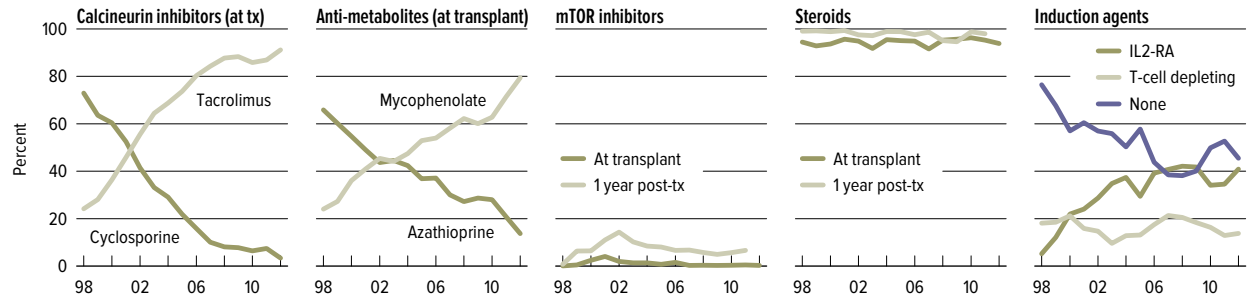
Percentage of adult lung transplants that were bilateral. Heart-lung transplants are excluded.

transplant

		2002		2007		2012	
		N	%	N	%	N	%
Age	12-17	30	2.8	37	2.5	22	1.2
	18-34	153	14.5	194	13.1	209	11.8
	35-49	242	22.9	232	15.7	226	12.8
	50-64	583	55.3	795	53.7	832	47.0
	65+	47	4.5	223	15.1	482	27.2
Sex	Female	528	50.0	627	42.3	714	40.3
	Male	527	50.0	854	57.7	1,057	59.7
Race	White	939	89.0	1,242	83.9	1,470	83.0
	Black	62	5.9	123	8.3	145	8.2
	Hispanic	40	3.8	89	6.0	121	6.8
	Asian	7	0.7	16	1.1	31	1.8
	Other/unknown	7	0.7	11	0.7	4	0.2
Diagnosis group	A	537	50.9	525	35.4	522	29.5
	B	77	7.3	75	5.1	71	4.0
	C	171	16.2	222	15.0	234	13.2
	D	254	24.1	637	43.0	929	52.5
	Other/unknown	16	2	22	1.5	15	0.8
Lung allocation score (LAS)	<30	0	0	11	0.7	2	0.1
	30-<35	0	0	432	29.2	445	25.1
	35-<40	0	0	382	25.8	398	22.5
	40-<50	0	0	355	24.0	413	23.3
	50-100	0	0.0	299	20.2	513	29.0
Blood type	A	462	43.8	580	39.2	688	38.8
	B	107	10.1	163	11.0	213	12.0
	AB	41	3.9	72	4.9	69	3.9
	O	445	42.2	666	45.0	801	45.2
Time on waiting list	<1 month	83	7.9	459	31.0	649	36.6
	1 -<3 months	121	11.5	372	25.1	386	21.8
	3 -<6 months	169	16.0	231	15.6	291	16.4
	6 -<12 months	196	18.6	170	11.5	212	12.0
	1-<2 years	249	23.6	109	7.4	150	8.5
	2-<3 years	155	14.7	48	3.2	47	2.7
	3+ years	77	7.3	91	6.1	36	2.0
	Unknown	5	0.5	1	0.1	0	0.0

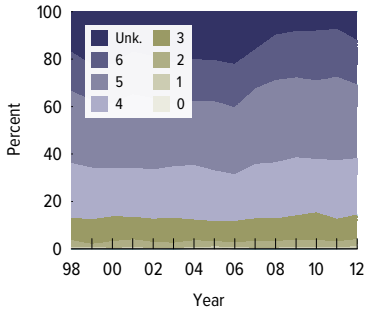
		2002		2007		2012	
		N	%	N	%	N	%
Pretransplant medical cond.	Hospitalized: ICU	44	4.2	131	8.8	174	9.8
	Hosp.: not ICU	51	4.8	127	8.6	171	9.7
	Not hospitalized	960	91.0	1,223	82.6	1,389	78.4
	Unknown	0	0.0	0	0.0	37	2.1
On ventilator /ECMO at tx	Vent + ECMO	3	0.3	7	0.5	35	2.0
	Vent only	22	2.1	63	4.3	80	4.5
	ECMO	0	0.0	3	0.2	21	1.2
	Neither	1,030	97.6	1,408	95.1	1,635	92.3
Procedure type	Lobar	12	1.2	3	0.2	1	0.1
	Single	501	49.0	520	35.8	569	32.7
	Bilateral	510	49.9	930	64.0	1,172	67.3
Donor type	Deceased	1,043	98.9	1,478	99.8	1,770	99.9
	Donation after brain death	1,042	98.8	1,469	99.2	1,749	98.8
	Donation after cardiac death	1	0.1	9	0.6	21	1.2
	Living	12	1.1	3	0.2	1	0.1
Prior solid organ tx		28	2.7	86	5.8	100	5.6
Primary payer	Private	702	66.5	885	59.8	912	51.5
	Medicare	234	22.2	429	29.0	686	38.7
	Other government	109	10.3	153	10.3	139	7.8
	Other	10	0.9	14	0.9	34	1.9
HL vs. LU	HL	32	3.0	28	1.9	29	1.6
	LU	1,023	97.0	1,453	98.1	1,742	98.4
DCD	DCD	1	0.1	9	0.6	21	1.2
	Non-DCD	1,041	98.7	1,469	99.2	1,749	98.8
	Unknown	13.0	1.2	3.0	0.2	1.0	0.1
Total	All patients	1055	100.0	1481	100.0	1771	100.0

LU 3.7 Characteristics of adult lung transplant recipients, 2002, 2007, & 2012
Patients receiving a transplant. Retransplants are counted. Transplants of left and right lobes for a patient on the same day are counted as one.



LU 3.8 Immunosuppression use in adult lung transplant recipients
One-year post-transplant data limited to patients alive with graft function one year post-transplant. Mycophenolate group includes mycophenolate mofetil and mycophenolate sodium.

donor-recipient matching



LU 4.1 Total HLA mismatches among adult lung transplant recipients

Donor and recipient antigen matching is based on the OPTN's antigen values and split equivalences policy as of 2012.

	DONOR			
RECIPIENT	Negative	Positive	Unknown	Total
Negative	15.8	24.5	0.1	40.4
Positive	18.8	35.2	0.1	54.0
Unknown	2.4	3.2	0.0	5.5
Total	36.9	62.8	0.2	100

LU 4.2 Adult lung donor-recipient cytomegalovirus (CMV) serology matching, 2008–2012

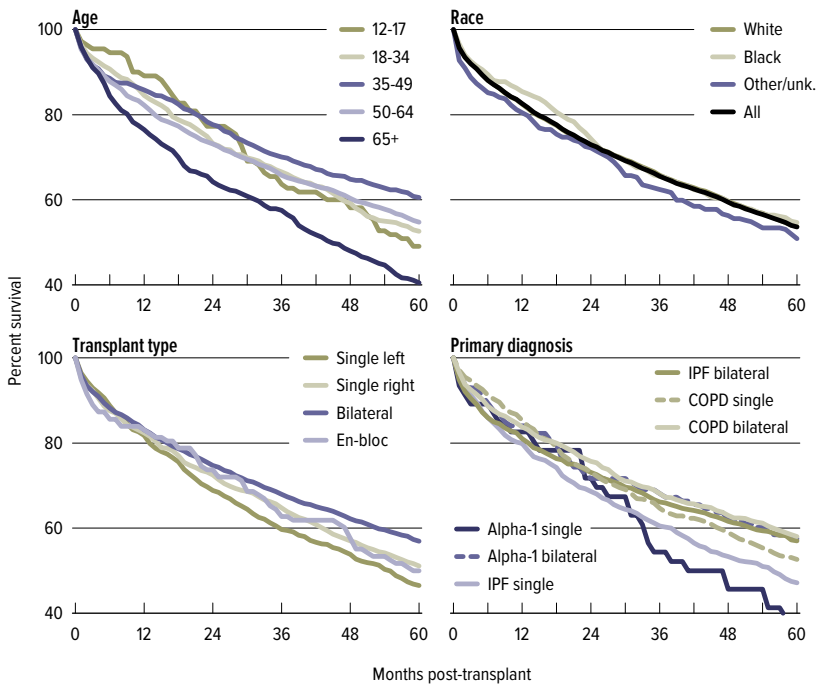
Adult transplant cohort from 2008–2012. Donor serology is reported on the OPTN donor registration forms; recipient serology is reported on the OPTN recipient registration forms. Any evidence for a positive serology is taken to indicate that the person is positive for the given serology; if all fields are unknown, not done, or pending, the person is considered to be "unknown" for that serology; otherwise, serology is assumed negative.

	DONOR			
RECIPIENT	Negative	Positive	Unknown	Total
Negative	0.6	10.3	0.0	10.9
Positive	4.4	72.2	0.2	76.8
Unknown	0.7	11.5	0.0	12.3
Total	5.8	94.0	0.2	100

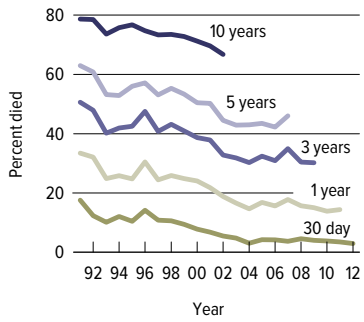
LU 4.3 Adult lung donor-recipient Epstein-Barr virus (EBV) serology matching, 2008–2012

Adult transplant cohort from 2008–2012. Donor serology is reported on the OPTN donor registration forms; recipient serology is reported on the OPTN recipient registration forms. Any evidence for a positive serology is taken to indicate that the person is positive for the given serology; if all fields are unknown, not done, or pending, the person is considered to be "unknown" for that serology; otherwise, serology is assumed negative.

outcomes

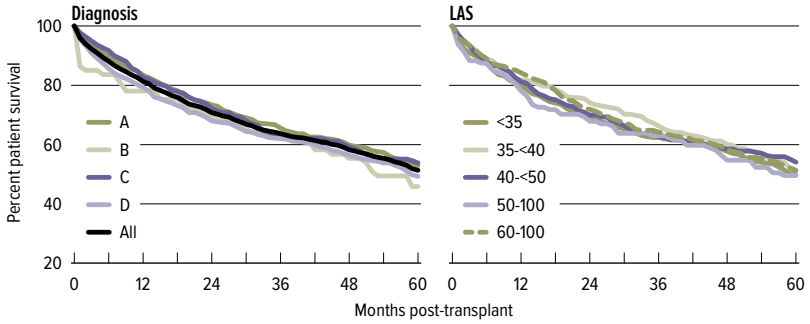


LU 5.1 Patient survival among adult lung transplant recipients, 2005–2007
Percent patient survival using unadjusted Kaplan-Meier methods. For patients with more than one transplant during the period, only their first transplant is considered.

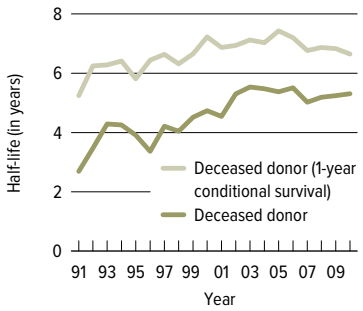


LU 5.2 Patient death among adult lung transplant recipients
Cox proportional hazards models reporting probability, adjusting for age, sex, and race.

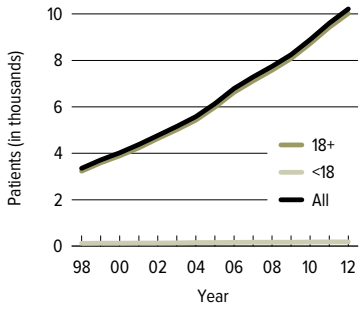
outcomes



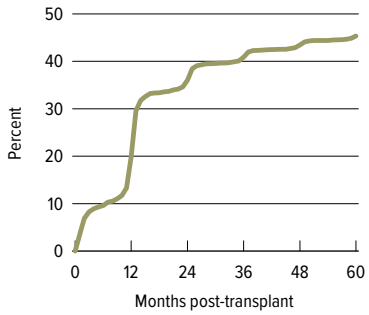
LU 5.3 Patient survival among adult lung transplant recipients transplanted in 2007
Recipient survival estimated using unadjusted Kaplan-Meier methods.



LU 5.4 Half-lives for adult lung transplant recipients
The half-life for a transplant cohort (e.g. 2009 lung transplants) is the time point in follow-up at which 50% of the transplanted grafts have failed. A conditional half-life for a transplant cohort is the same calculation but limited to those who survive with function at least 1 year post-transplant.



LU 5.5 Recipients alive & with a functioning lung transplant on June 30 of the year
Txs before June 30 of the year that are still functioning. Pts are assumed alive with function unless a death or graft failure is recorded. A recipient can experience a graft failure and drop from the cohort, then be retransplanted and re-enter the cohort. Age cut is based on age at tx.



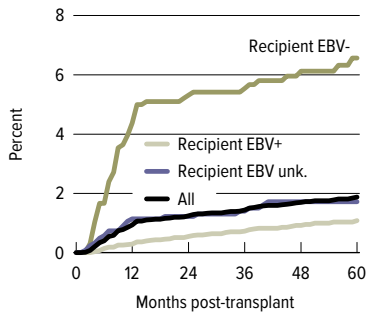
LU 5.6 Incidence of first acute rejection among adult patients receiving a lung transplant in 2006–2010
Acute rejection defined as a record of acute or hyperacute rejection, or a record of an anti-rejection drug being administered on either the Transplant Recipient Registration form or the Transplant Recipient Follow-up form. Only the first rejection event is counted. Cumulative incidence, defined as the probability of acute rejection at any time prior to the given time, is estimated using Kaplan-Meier competing risk methods.

outcomes

	Level	One-year events, 2009–11 tx N	One-year events, 2009–11 tx %	Five-year events, 2005–07 tx N	Five-year events, 2005–07 tx %
Bronchiolitis Obliterans syndrome (BOS)	Grade 3	36	0.8	133	6.2
	Grade 2	33	0.8	110	5.1
	Grade 1	81	1.9	229	10.6
	Grade OP	97	2.2	236	10.9
	Grade unk.	97	2.2	219	10.2
	No	3,886	88.8	1,225	56.8
	Unk.	148	3.4	4	0.2
Renal dysfunction	Yes	754	17.2	1,074	49.8
	No	3,614	82.5	1,082	50.2
	Unk.	10	0.2	0	0.0
Creatinine > 2.5 mg/dl	Yes	183	4.2	287	13.3
	No	569	13.0	782	36.3
	Unk.	3,626	82.8	1,087	50.4
Chronic Dialysis	Yes	46	1.1	52	2.4
	No	707	16.1	1,021	47.4
	Unk.	3,625	82.8	1,083	50.2
Renal tx after thoracic tx	Yes	3	0.1	13	0.6
	No	751	17.2	1,061	49.2
	Unk.	3,624	82.8	1,082	50.2
Hypertension, drug-treated	Yes	1,647	37.6	1,438	66.7
	No	1,687	38.5	463	21.5
	Unk.	1,044	23.8	255	11.8
Diabetes	Yes	744	17.0	917	42.5
	No	3,621	82.7	1,239	57.5
	Unk.	13	0.3	0	0.0
Malignancy	Yes	140	3.2	395	18.3
	No	4,212	96.2	1,761	81.7
	Unk.	26	0.6	0	0.0
Drug-treated hyperlipidemia	Yes	1,002	22.9	1,161	53.8
	No	2,298	52.5	834	38.7
	Unk.	1,078	24.6	161	7.5
Re-hospitalization	Yes	2,244	51.3	1,763	81.8
	No	2,053	46.9	371	17.2
	Unk.	81	1.9	22	1.0
Functional status	No assistance needed	3,679	84.0	1,864	86.5
	Some assistance needed	436	10.0	151	7.0
	Total assistance needed	78	1.8	30	1.4
	Unknown	185	4.2	111	5.1
All		4,378	100.0	2,156	100.0

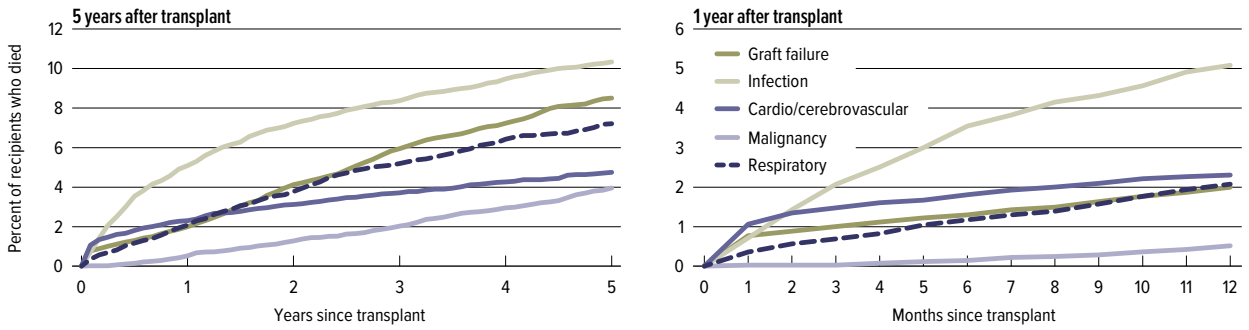
LU 5.7 Post-transplant events among adult lung transplant recipients

Post-transplant morbidities are recorded on the Transplant Recipient Follow-up forms and are included in the table if they are reported anytime on or before the 1-year and 5-year follow-ups. One-year events are reported for survivors transplanted 2009–2011; five-year events are reported for survivors transplanted 2005-2007. Patients with more than one transplant are counted separately per transplant. For BOS, the most severe complication recorded for each transplant is counted.



LU 5.8 Incidence of PTLD among adult patients receiving a lung transplant in 2006–2010, by recipient Epstein-Barr virus (EBV) status at transplant

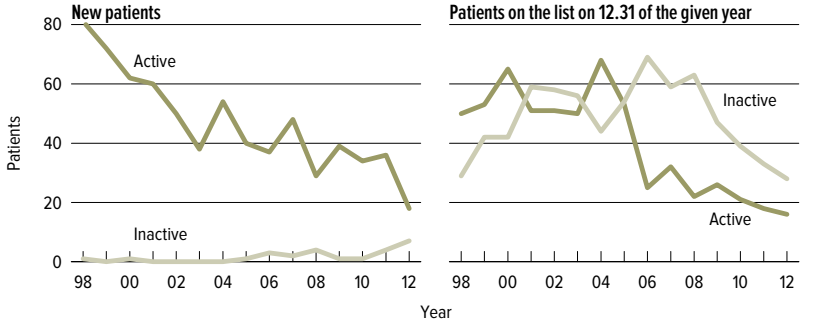
The cumulative incidence is estimated using Kaplan-Meier competing risks methods. PTLD is identified as either a reported complication or cause of death on the Transplant Recipient Follow-up form or on the Post-transplant Malignancy form as polymorphic PTLD, monomorphic PTLD, or Hodgkin's Disease. Only the earliest date of PTLD diagnosis is considered.



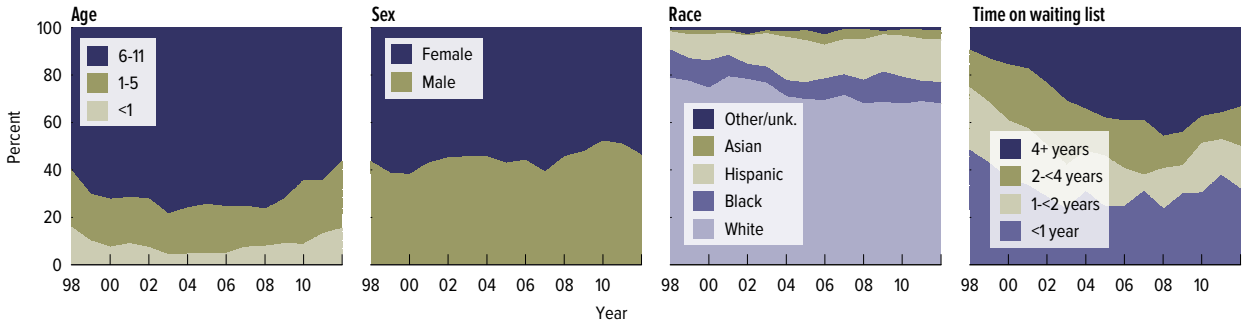
LU 5.9 Cumulative incidence of death by cause among adult lung recipients transplanted 2006–2010

Primary cause of death is as reported to the OPTN from the Transplant Follow-up form. Other causes of death include hemorrhage, trauma, non-compliance, unspecified other, unknown, etc. Cumulative incidence is estimated using Kaplan-Meier competing risk methods.

pediatric transplant



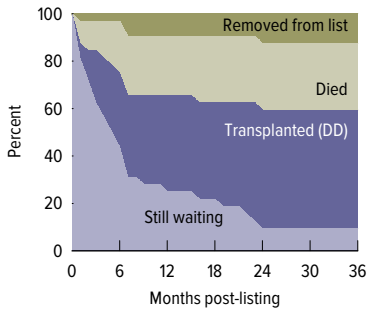
LU 6.1 Pediatric patients waiting for a lung transplant
Patients waiting for a transplant. A "new patient" is one who first joins the list during the given year, without having listed in a previous year. However, if a patient has previously been on the list, has been removed for a transplant, and has relisted since that transplant, the patient is considered a "new patient." Patients concurrently listed at multiple centers are counted only once. Those with concurrent listings and active at any program are considered active; those inactive at all programs at which they are listed are considered inactive.



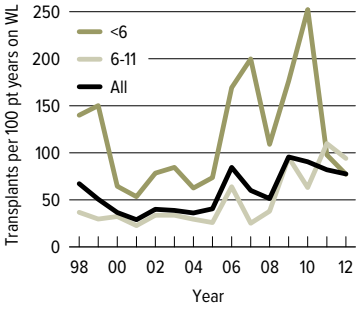
LU 6.2 Distribution of pediatric patients waiting for a lung transplant
Patients waiting for a transplant any time in the given year. Age determined on the lastest of listing date or January 1 of the given year. Concurrently listed patients are counted once.

	2010	2011	2012
Patients at start of year	80	66	53
Patients added during year	35	40	25
Patients removed during year	49	53	34
Patients at end of year	66	53	44
Removal reason			
Received a transplant	26	20	16
Patient died	12	13	11
improved, tx not needed	10	7	6
Too sick to transplant	0	4	0
Other	1	9	1

LU 6.3 Lung transplant waiting list activity among pediatric patients
Patients with concurrent listings at more than one center are counted once, from the time of earliest listing to the time of latest removal. Patients listed, transplanted, and re-listed are counted more than once. Patients are not considered "on the list" on the day they are removed. Thus, patient counts on January 1 may be different from patient counts on December 31 of the prior year. Patients listed for multi-organ transplants are included.

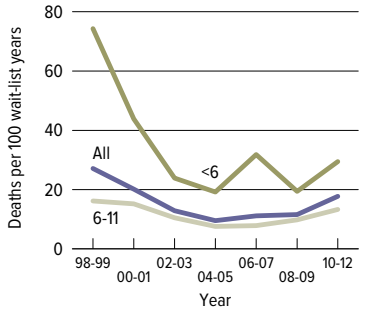


LU 6.4 Three-year outcomes for pediatric patients waiting for a lung transplant among new listings in 2009
Patients waiting for a transplant and first listed in 2009. Patients with concurrent listings at more than one center are counted once, from the time of the earliest listing to the time of latest removal.



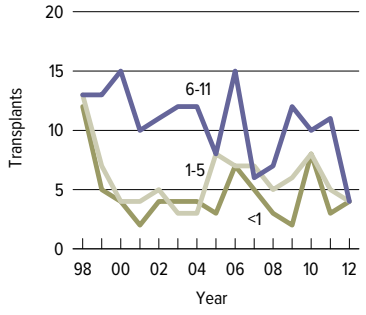
LU 6.5 Lung transplant rates among active pediatric waiting list candidates, by age
Transplant rates are computed as the number of deceased donor transplants per 100 patient-years of active waiting time in the given year. Age is calculated on the first active listing date in a given year.

pediatric transplant



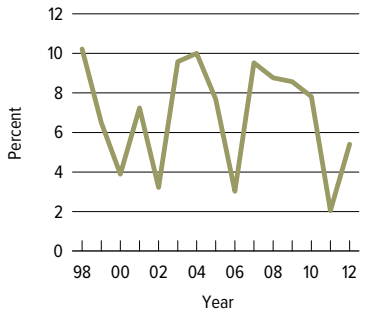
LU 6.6 Pre-transplant mortality rates among pediatric patients wait-listed for a lung transplant, by age

Patients waiting for a transplant. Mortality rates are computed as the number of deaths per 100 patient-years of waiting time in the given interval. Waiting time is calculated as the total waiting time per age group in the interval. Only deaths that occur prior to removal from the waiting list are counted. Age is calculated on the latest of listing date or January 1 of the given period.



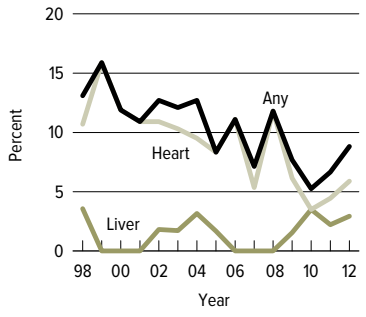
LU 6.7 Pediatric lung transplants, by age

Patients receiving a lung or heart-lung transplant.



LU 6.8 Retransplants among pediatric lung transplant recipients

Includes patients transplanted after age 17, but listed at age 17 or younger. Retransplanted patients include only those with a prior transplant of the same type. Includes patients transplanted after age 12, but listed at age 12 or younger. Retransplanted patients include only those with a prior transplant of the same type.



LU 6.9 Pediatric lung transplants that were part of a multi-organ transplant

Patients receiving a deceased donor lung transplant with at least one additional organ. A multi-organ transplant may include more than two different organs in total; if so, each non-lung organ will be considered separately.

		2000–02		2010–12	
	Level	N	%	N	%
Age	<1	10	16.9	15	26.3
	1-5	13	22.0	17	29.8
	6-11	36	61.0	25	43.9
Sex	Female	37	62.7	30	52.6
	Male	22	37.3	27	47.4
Race	White	42	71.2	36	63.2
	Black	6	10.2	7	12.3
	Hispanic	6	10.2	12	21.1
	Asian	3	5.1	2	3.5
	Other/unk.	2	3.4	0	0.0
Primary diagnosis	Cystic fib.	18	30.5	11	19.3
	Pulm. HTN	14	23.7	9	15.8
	Pulm. fibrosis	4	6.8	12	21.1
	Other vasc.	2	3.4	4	7.0
	All others	21	35.6	21	36.8
Transplant number	First	57	96.6	54	94.7
	Retx	2	3.4	3	5.3
Blood type	A	19	32.2	23	40.4
	B	8	13.6	9	15.8
	AB	2	3.4	4	7.0
	O	30	50.8	21	36.8
Time on waiting list	<1 mo.	11	18.6	12	21.1
	1 -<3 mo.	11	18.6	21	36.8
	3-<6 mo.	6	10.2	11	19.3
	6-<12 mo.	13	22.0	7	12.3
	1-<2 yrs	12	20.3	4	7.0
	2+ yrs	4	6.8	2	3.5
	Unknown	2	3.4	0	0.0
Pretx medical condition	Hosp: ICU	17	28.8	19	33.3
	Hosp: not ICU	6	10.2	8	14.0
	Not hosp.	36	61.0	30	52.6
Pt on vent. imm.ly pre-tx	No	48	81.4	35	61.4
	Yes	11	18.6	22	38.6
Procedure type	Bilat. seq.	41	69.5	50	87.7
	Bilat. en-bloc	7	11.9	5	8.8
	Lobe	3	5.1	0	0.0
	Heart-lung	8	13.6	2	3.5
Donor type	Deceased	56	94.9	57	100.0
	Living	3	5.1	0	0.0
Primary payer	Private	37	62.7	22	38.6
	Medicaid	18	30.5	27	47.4
	Other public	3	5.1	3	5.3
	Unknown	1	1.7	5	8.8
HL vs. LU	LU	51	86.4	55	96.5
	HL	8	13.6	2	3.5
ECMO	not ECMO	56	94.9	55	96.5
	ECMO	3	5.1	2.0	3.5
All patients		59	100.0	57	100.0

LU 6.10 Characteristics of pediatric lung transplant recipients, 2000–2002 & 2010–2012

Patients receiving a transplant. Retransplants are counted.

pediatric transplant

RECIPIENT	DONOR Negative	Positive	Unknown	Total
Negative	25.0	33.3	1.2	59.5
Positive	13.1	26.2	0.0	39.3
Unknown	1.2	0.0	0.0	1.2
Total	39.3	59.5	1.2	100

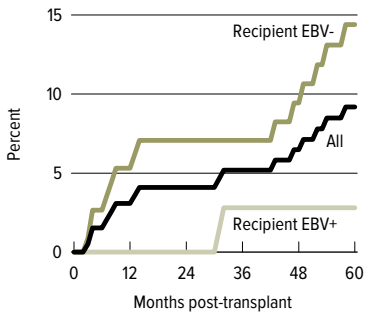
LU 6.11 Lung donor-recipient Epstein-Barr virus (EBV) serology matching for pediatric transplant recipients, 2008–2012

Pediatric transplant cohort from 2008–2012. Donor EBV serology is reported on the OPTN donor registration forms; recipient EBV serology is reported on the OPTN recipient registration forms. Any evidence for a positive serology is taken to indicate that the person is positive for EBV; if all fields are unknown, not done, or pending, the person is considered to be "unknown" for that serology; otherwise, serology is assumed negative.

RECIPIENT	DONOR Negative	Positive	Unknown	Total
Negative	27.4	35.7	0.0	63.1
Positive	9.5	23.8	2.4	35.7
Unknown	0.0	1.2	0.0	1.2
Total	36.9	60.7	2.4	100

LU 6.12 Lung donor-recipient cytomegalovirus (CMV) serology matching for pediatric transplant recipients, 2008–2012

Pediatric transplant cohort from 2008–2012. Donor CMV serology is reported on the OPTN donor registration forms; recipient CMV serology is reported on the OPTN recipient registration forms. Any evidence for a positive serology is taken to indicate that the person is positive for CMV; if all fields are unknown, not done, or pending, the person is considered to be "unknown" for that serology; otherwise, serology is assumed negative.



LU 6.13 Incidence of PTLD among pediatric patients receiving a lung transplant, 2000–2010, by recipient Epstein-Barr virus (EBV) status at transplant

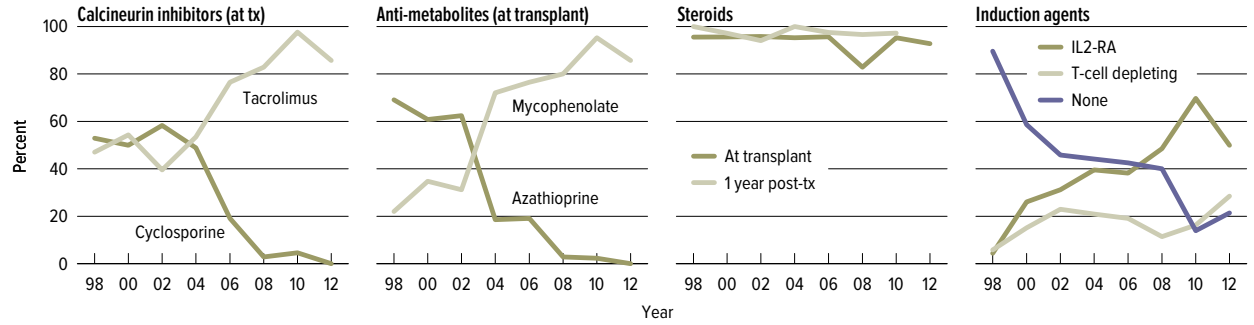
The cumulative incidence, is estimated using Kaplan-Meier competing risks methods. PTLD is identified as either a reported complication or cause of death on the Transplant Recipient Follow-up form or on the Post-transplant Malignancy form as polymorphic PTLD, monomorphic PTLD, or Hodgkin's Disease. Only the earliest date of PTLD diagnosis is considered.

	Level	One-year events, 2008–11 tx N	%	Five-year events, 2004–07 tx N	%
Bronchiolitis Obliterans syndrome (BOS)	Grade 3	1	1.6	0	0.0
	Grade 2	0	0.0	1	2.2
	Grade 1	0	0.0	1	2.2
	Grade OP	0	0.0	1	2.2
	Grade unk.	1	1.6	5	11.1
	No	57	90.5	37	82.2
	Unk.	4	6.3	0	0.0
Renal dysfunction	Yes	1	1.6	8	17.8
	No	62	98.4	37	82.2
	Unk.	0	0.0	0	0.0
Hypertension, drug-treated	Yes	16	25.4	26	57.8
	No	44	69.8	17	37.8
	Unk.	3	4.8	2	4.4
Diabetes	Yes	1	1.6	5	11.1
	No	62	98.4	40	88.9
	Unk.	0	0.0	0	0.0
Malignancy	Yes	0	0.0	2	4.4
	No	63	100.0	43	95.6
	Unk.	0	0.0	0	0.0
Drug-treated hyperlipidemia	Yes	2	3.2	9	20.0
	No	58	92.1	35	77.8
	Unk.	3	4.8	1	2.2
Re-hosp.	Yes	33	52.4	39	86.7
	No	30	47.6	6	13.3
	Unk.	0	0.0	0	0.0
Functional status	Fully active	56	88.9	40	88.9
	Min. active	4	6.3	3	6.7
	Bedbound	1	1.6	0	0.0
	Unknown	2	3.2	2	4.4
Total		63	100.0	45	100.0

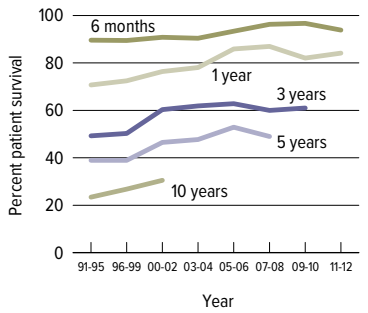
LU 6.14 Post-transplant events among pediatric lung transplant recipients

One-year events are reported for patients transplanted 2008–2011; five-year events are reported for those transplanted 2004–2007. Patients with more than one transplant are counted separately per transplant. Patients who did not survive the transplant hospitalization are excluded. For BOS, the most severe complication recorded for each transplant is counted.

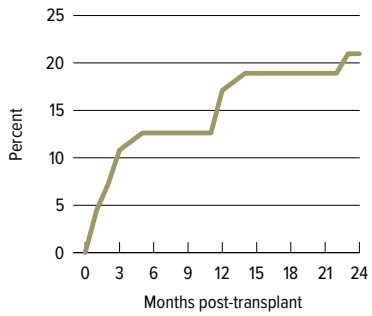
pediatric transplant



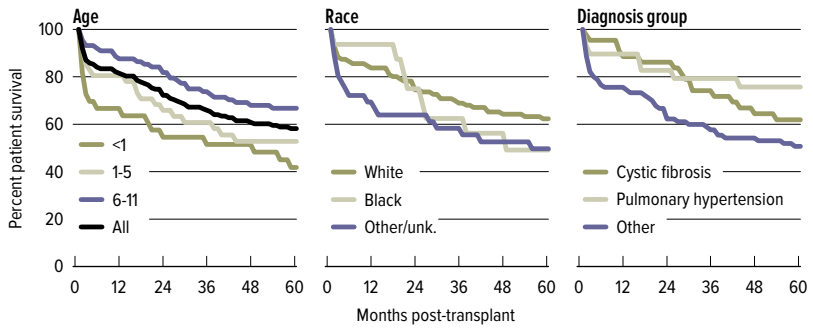
LU 6.15 Immunosuppression use in pediatric lung transplant recipients
One-year post-transplant data limited to patients alive with graft function one year post-transplant. Mycophenolate group includes mycophenolate mofetil and mycophenolate sodium.



LU 6.16 Patient survival among pediatric lung transplant recipients
Estimates computed with Cox proportional hazards model, adjusted for age, sex, and race.

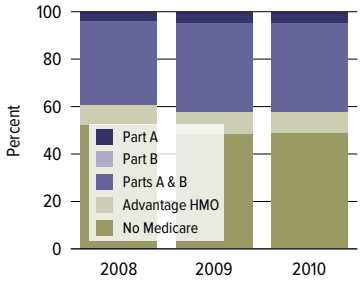


LU 6.17 Incidence of first acute rejection among pediatric patients receiving a lung transplant in 2006–2011
Acute rejection defined as a record of acute or hyperacute rejection, or a record of an anti-rejection drug being administered on either the Transplant Recipient Registration form or the Transplant Recipient Follow-up form. Only the first rejection event is counted. Cumulative incidence, defined as the probability of acute rejection at any time prior to the given time, is estimated using Kaplan-Meier competing risk methods.



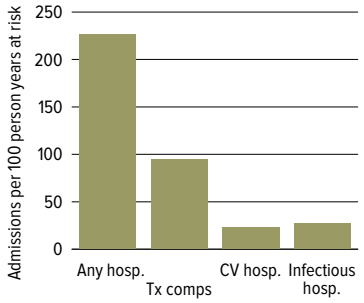
LU 6.18 Survival among pediatric lung transplant recipients transplanted in 2000–2007
Recipient survival estimated using unadjusted Kaplan-Meier methods.

Medicare data



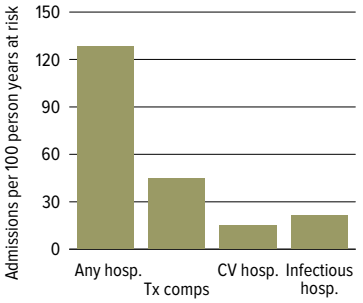
LU 7.1 Medicare coverage among lung transplant recipients

Coverage at the time of transplant as identified by the Medicre Beneficiary Annual Summary supplied by CMS.



LU 7.2 Rehospitalization rates among lung transplant recipients in the first post-transplant year

Transplant recipients, 2008, with Medicare as the primary payer at transplant. Rehospitalizations and reasons for rehospitalization determined from Medicare claims. First year rates are based on rehospitalizations occuring from initial discharge to one year later.



LU 7.3 Rehospitalization rates among lung transplant recipients in the second post-transplant year

Transplant recipients, 2008, with Medicare as the primary payer at transplant. Rehospitalizations and reasons for rehospitalization determined from Medicare claims. Second year rates are based on hospitalizations occuring from initial discharge+1 year to initial discharge+2 years.

Year 1 Cause of hospitalization	Percent of hospitalizations	Year 2 Cause of hospitalization	Percent of hospitalizations
Transplant complication	43.7	Transplant complication	36.0
Gastro-intestinal	10.4	Other	8.6
Other	6.0	Respiratory infection	7.5
Respiratory	5.2	Other infection	6.5
Other infection	5.0	Gastro-intestinal	6.3
Respiratory infection	4.2	Genito-urinary and breast	4.1
Genito-urinary and breast	4.2	Circulatory system	4.1
Conduction disorders & dysrhythmias	3.4	Respiratory	3.7
Immune and hematologic	2.6	Bacteremia, viremia & septicemia	2.6
CHF, fluid overload and cardiomyopathy	1.9	metabolic, endocrine, nutritional	2.6

LU 7.4 Top ten causes of rehospitalization among lung recipients transplanted in 2008 with Medicare primary coverage

Transplant recipients, 2008, with Medicare as the primary payer at transplant. Reasons for rehospitalization determined from Medicare claims, denominator for percentages includes only those re-hospitalized.

Medicare data

		# patients	Total costs Part A	Total costs Part B	PPPY costs Part A	PPPY costs Part B
	All patients	885	162,982,412	22,723,606	207,013	28,862
Age	18-34	73	15,242,024	2,123,656	230,681	32,141
	35-49	99	19,809,798	2,815,768	235,018	33,406
	50-64	345	61,346,851	8,475,409	197,793	27,326
	65+	368	66,583,738	9,308,774	203,753	28,486
Sex	Male	536	94,170,722	13,254,563	199,624	28,097
	Female	349	68,811,690	9,469,043	218,057	30,006
Race	White	753	136,868,978	19,297,569	202,295	28,522
	Black	78	14,784,870	2,098,958	230,382	32,707
	Hispanic	40	8,107,618	978,864	241,062	29,104
	Asian/Pac. Isl.	*	*	*	*	*
	Other/unk.	*	*	*	*	*
Primary diagnosis	A: obstructive/COPD	380	66,349,558	9,257,207	194,297	27,109
	B: pulm vasc/iPAH	41	8,327,867	1,280,021	261,028	40,121
	C: cystic fibrosis	86	16,816,251	2,612,529	212,437	33,004
	D: restrictive/IPF	352	67,334,802	8,994,053	216,455	28,912
	E: other/unk. (HL)	26	4,153,934	579,795	175,424	24,485

LU 7.5 Total and per-person per-year (PPPY) Medicare costs ($) among lung transplant recipients in the first post-transplant year

Costs among recipients transplanted in 2008 and 2009 who had Medicare as the primary payer at the time of transplant. First year costs include the transplant hospitalization. Costs incurred after a transplant failure are excluded. Values for cells with 9 or fewer patients are suppressed.

		# patients	Total costs Part A	Total costs Part B	PPPY costs Part A	PPPY costs Part B
	All patients	324	11,407,184	4,003,364	38,253	13,425
Age	18-34	30	1,489,390	467,791	55,040	17,287
	35-49	31	1,057,578	386,592	38,952	14,239
	50-64	135	4,607,606	1,590,841	36,068	12,453
	65+	128	4,252,610	1,558,139	36,584	13,404
Sex	Male	200	6,060,637	2,346,428	32,902	12,738
	Female	124	5,346,547	1,656,936	46,898	14,534
Race	White	275	10,168,438	3,459,637	40,494	13,777
	Black	29	759,355	314,181	28,087	11,621
	Hispanic	13	413,574	180,127	31,726	13,818
	Asian/Pac. Isl.	*	*	*	*	*
	Other/unk.	*	*	*	*	*
Primary diagnosis	A: obstructive/COPD	152	5,526,159	1,737,600	39,306	12,359
	B: pulm vasc/iPAH	13	378,278	164,539	31,069	13,514
	C: cystic fibrosis	31	1,586,942	495,456	57,124	17,834
	D: restrictive/IPF	117	3,830,954	1,518,090	35,929	14,238
	E: other/unk. (HL)	11	84,851	87,679	7,693	7,949

LU 7.6 Total and per-person per-year (PPPY) Medicare costs ($) among lung transplant recipients in the second post-transplant year

Costs among recipients transplanted in 2008 who had Medicare as the primary payer at the time of transplant. The second post-transplant year runs from 366 to 730 days after transplant. Costs incurred after a transplant failure are excluded. Values for cells with 9 or fewer patients are suppressed.

Medicare data

Total costs

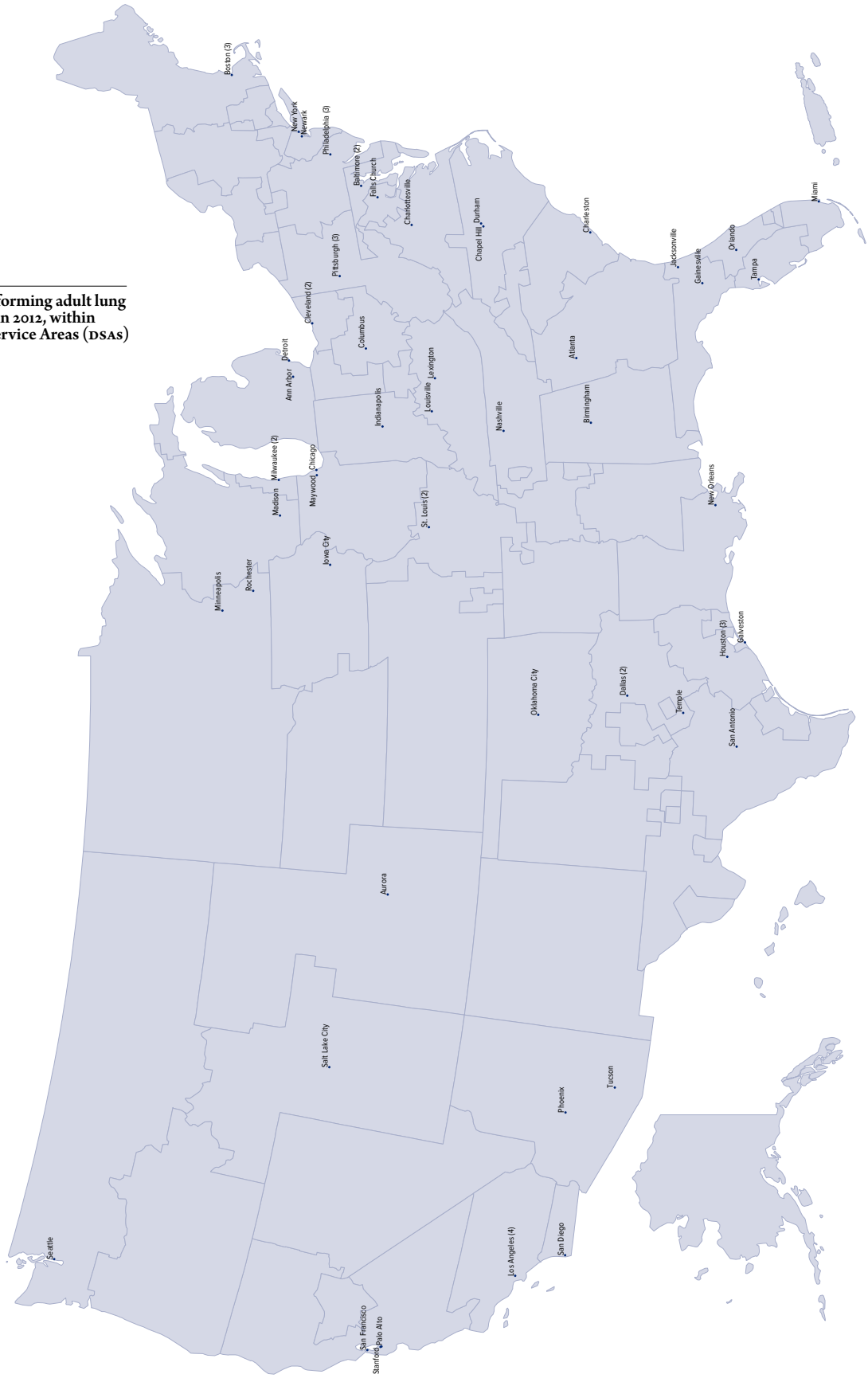
		2008 total costs			2009 total costs			2010 total costs		
		# patients	Part A	Part B	# patients	Part A	Part B	# patients	Part A	Part B
	All patients	4,693	145,171,793	33,458,212	5,197	174,454,896	43,047,009	5,617	186,471,645	46,234,769
Age	0-11	*	*	*	11	160,342	59,002	*	*	*
	12-17	10	360,876	96,504	16	758,434	83,698	17	133,818	59,964
	18-34	449	14,998,736	3,150,111	479	17,585,257	4,484,646	508	16,607,033	4,068,712
	35-49	965	23,949,182	6,247,577	997	28,010,650	7,522,287	1,027	28,343,631	7,601,674
	50-64	2,622	70,008,960	17,252,230	2,865	79,030,205	21,344,853	2,980	82,473,712	22,235,390
	65+	639	35,690,123	6,666,645	829	48,910,007	9,552,522	1,076	58,804,909	12,221,164
Sex	Male	2,529	84,513,219	18,736,353	2,858	97,959,723	24,101,142	3,120	105,175,762	26,257,101
	Female	2,164	60,658,575	14,721,859	2,339	76,495,174	18,945,867	2,497	81,295,883	19,977,668
Race	White	4,124	124,219,330	29,088,764	4,539	149,059,229	37,548,064	4,894	158,579,766	40,297,524
	Black	367	13,989,953	2,836,839	413	15,840,390	3,256,190	435	15,970,472	3,344,090
	Hispanic	141	4,725,583	1,074,693	181	7,006,529	1,642,190	209	8,921,331	1,940,496
	Asian/Pacific Islander	38	1,608,477	297,079	40	1,845,714	321,772	49	1,687,516	358,942
	Other/unk.	23	628,450	160,837	24	703,035	278,795	30	1,312,560	293,717
Primary diagnosis	A: obstructive/COPD	2,436	70,934,523	17,406,676	2,544	77,653,967	20,785,395	2,579	78,104,935	21,302,431
	B: pulm vasc/iPAH	274	7,369,342	1,799,178	295	9,839,667	2,440,269	331	13,272,912	2,951,984
	C: cystic fibrosis	492	15,284,124	3,501,858	533	18,516,242	4,937,632	590	18,458,000	5,085,290
	D: restrictive/IPF	1,401	48,961,935	10,196,576	1,702	64,675,281	13,989,699	1,974	73,123,442	15,914,706
	E: other/unk.	90	2,621,869	553,923	123	3,769,740	894,014	143	3,512,356	980,359

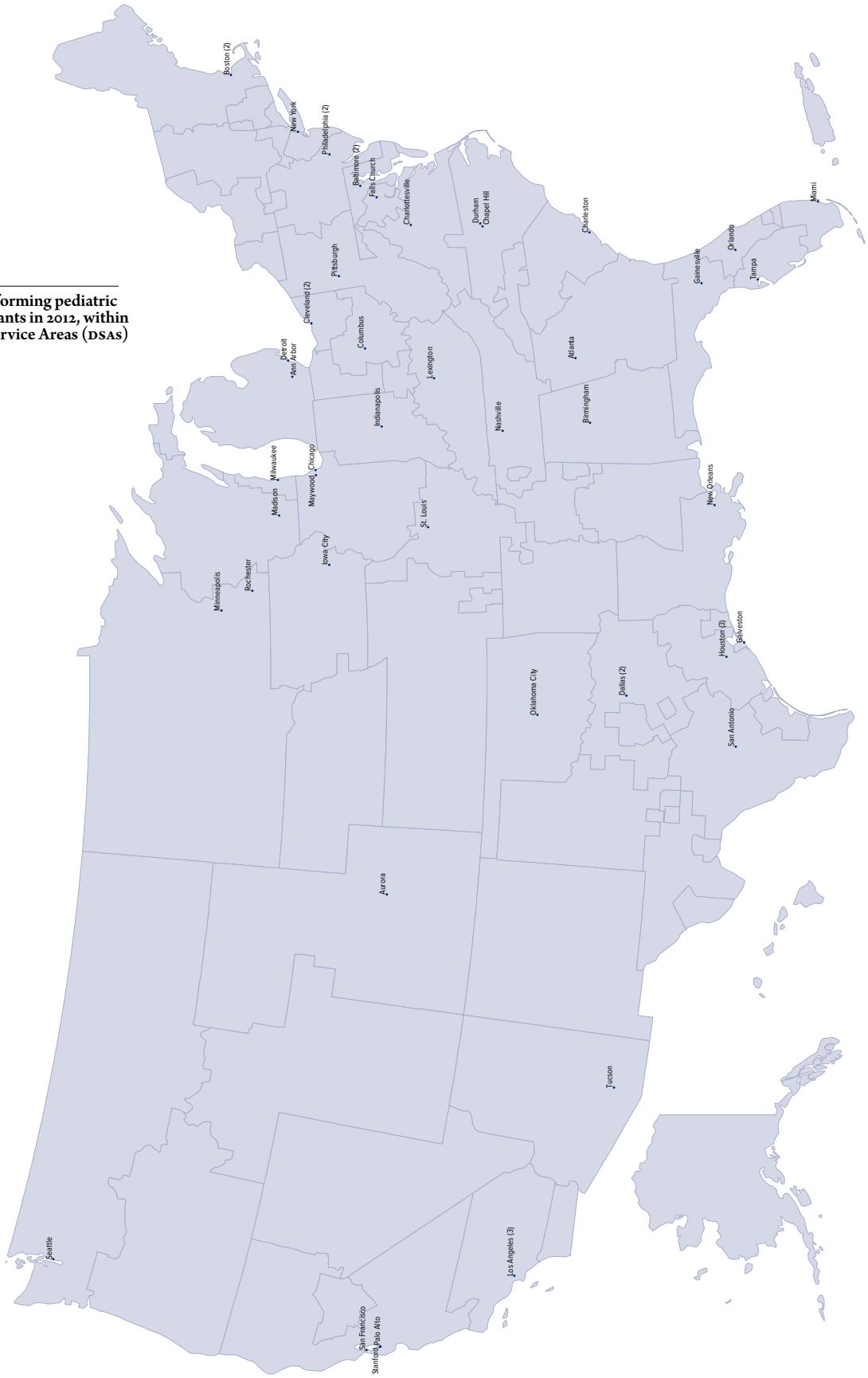
Per person per year costs

		2008 PPPY costs			2009 PPPY costs			2010 PPPY costs		
		# patients	Part A	Part B	# patients	Part A	Part B	# patients	Part A	Part B
	All patients	4,693	35,382	8,155	5,197	38,855	9,588	5,617	38,313	9,500
Age	0-11	*	*	*	11	16,375	6,026	*	*	*
	12-17	10	36,088	9,650	16	47,532	5,246	17	9,585	4,295
	18-34	449	37,269	7,827	479	41,022	10,462	508	37,474	9,181
	35-49	965	27,413	7,151	997	31,483	8,455	1,027	30,224	8,106
	50-64	2,622	30,020	7,398	2,865	31,205	8,428	2,980	31,216	8,416
	65+	639	74,820	13,976	829	79,771	15,580	1,076	71,619	14,884
Sex	Male	2,529	38,507	8,537	2,858	40,095	9,865	3,120	39,481	9,857
	Female	2,164	31,788	7,715	2,339	37,375	9,257	2,497	36,901	9,068
Race	White	4,124	34,377	8,050	4,539	38,003	9,573	4,894	37,327	9,485
	Black	367	44,525	9,029	413	43,943	9,033	435	42,632	8,927
	Hispanic	141	38,310	8,712	181	46,418	10,879	209	50,181	10,915
	Asian/Pacific Islander	38	48,953	9,041	40	54,255	9,459	49	41,275	8,779
	Other/unk.	23	32,901	8,420	24	31,774	12,600	30	51,888	11,611
Primary diagnosis	A: obstructive/COPD	2,436	33,418	8,201	2,544	35,119	9,400	2,579	34,464	9,400
	B: pulm vasc/iPAH	274	29,700	7,251	295	37,740	9,360	331	47,595	10,585
	C: cystic fibrosis	492	34,471	7,898	533	39,056	10,415	590	35,819	9,868
	D: restrictive/IPF	1,401	40,497	8,434	1,702	44,981	9,730	1,974	43,563	9,481
	E: other/unk.	90	32,841	6,938	123	35,544	8,430	143	27,443	7,660

LU 7.7 Total calendar-year and per-person per-year (PPPY) Medicare costs ($) spent on lung transplant recipients, 2008, 2009, & 2010
Costs paid by Medicare in each calendar year among recipients alive with graft function in the given year, regardless of Medicare eligibility at the time of transplant. Costs incurred after transplant failure are excluded. Values for cells with 9 or fewer patients are suppressed.

LU 8.1 Centers performing adult lung transplants in 2012, within Donation Service Areas (DSAs)





LU 8.2 Centers performing pediatric lung transplants in 2012, within Donation Service Areas (DSAs)