

ORIGINAL CLINICAL SCIENCE

Impact of the lung allocation score on resource utilization after lung transplantation in the United States

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BACKGROUND: The United States lung allocation score (LAS) allows rapid organ allocation to higher acuity patients. Although, wait-list time and wait-list mortality have improved, the costs of lung transplantation (LTx) in these higher acuity patients are largely unknown. We hypothesize that LTx in high LAS recipients is associated with increased charges and resource utilization.

METHODS: Clinical and financial data for LTx patients at our institution in the post-LAS era (May 2005 to 2009) were reviewed with follow-up through December 2009. Patients were stratified by LAS quartiles (Q). Total hospital charges for index admission and all admissions within 1 year of LTx were compared between Q4 vs Q1–3 using rank-sum and Kruskal–Wallis tests, as charge data were not normally distributed.

RESULTS: Eighty-four LTxs were performed during the study period. Sixty-three (75%) patients survived 1 year; 10 (11.9%) died during the index admission. Median LAS was 37.5 (interquartile range [IQR] 34.3 to 44.8). LAS quartiles were: Q1, 30.1 to 34.3, $n = 21$; Q2, 34.4 to 37.5, $n = 21$; Q3, 37.6 to 44.8, $n = 21$; and Q4, 44.9 to 94.3, $n = 21$. Charges for index admission were: Q4, \$276,668 (IQR 191,301 to 300,156) vs Q1–3, \$153,995 (IQR 129,796 to 176,849) ($p < 0.001$). Index admission median length of stay was greater in Q4 (Q4: 35-day IQR 23 to 46 vs Q1–3: 15-day IQR 11 to 22, $p = 0.003$). For 1-year charges: Q4, \$292,247 (IQR 229,192 to 421,597) vs Q1–3, \$188,342 (IQR 153,455 to 252,045) ($p = 0.002$). Index admission and 1-year charges in Q4 were higher than for other quartiles when examined individually.

CONCLUSIONS: This is the first study to show increased charges in high LAS patients. Charges for the index admission and hospital care in the year post-LTx were higher in the highest LAS quartile compared with patients in the lowest 75% of LAS.

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The lung allocation score (LAS) has shifted the demographics of United States (US) lung transplantation (LTx), with increased numbers of critically ill patients receiving LTx. Several studies have examined the impact of high LAS on post-LTx survival, although the system was not initially

designed for this purpose. High LAS is known to negatively impact short-term mortality in IPF patients, and predicts decreased 1-year survival and increased post-operative complications in all LTx patients.^{1–3} LTx is a resource-intensive surgical therapy requiring careful follow-up.^{4–6} However, the effects of high LAS on actual resource utilization are unknown. Therefore, we used an institutional cohort of patients to test the hypothesis that high LAS is associated with increased hospital charges and resource utilization.

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Methods

Patients

This study is a retrospective review of the prospectively maintained LTx database at The Johns Hopkins Hospital. LTx patients in the post-LAS era (May 2005) were included. Patients with prior LTx and children (<18 years) were excluded. Patients undergoing retransplantation were excluded because prior national cohort studies examining the impact of LAS on survival have only used primary LTx recipients.^{1,3} Upon receiving institutional review board approval, relevant clinical information was extracted from the LTx database. Demographic variables included age, gender, race, cardiovascular comorbidities, pulmonary function testing, wait-list time and transplant diagnosis. Donor and operative information (ischemic time, cardiopulmonary bypass [CPB] and induction therapy) were included. LAS was calculated as detailed by Egan et al,⁷ and recorded for each patient. For patients with multiple LAS values, the one immediately prior to transplantation was used.

Outcomes

Post-operative data included: length of stay (LOS); in-hospital infections; rejection episodes during index hospitalization; mechanical ventilation duration; re-intubation; tracheostomy; renal replacement therapy (RRT); extracorporeal mechanical oxygenation (ECMO); and in-hospital mortality. The Social Security Death Index was queried for survival status.

Peri-operative care

LTx was performed using standardized techniques. CPB was used only for patients with pulmonary hypertension or patients intolerant of single-lung ventilation. Induction therapy was utilized at the transplant surgeon's discretion, as was triple immunosuppression based on tacrolimus, mycophenolate mofetil and steroids. A standardized care pathway for the initial post-operative period was utilized in all patients and provided by a multidisciplinary team in the ICU and hospital wards. Inhaled nitric oxide is routinely initiated intra-operatively and weaned on the first day post-operatively. Follow-up and outpatient care are standardized. When necessary, patients are re-admitted to The Johns Hopkins Hospital.

Charges data

Hospital charges are obtained through the billing department as reported to the authorities in the State of Maryland, and represent all hospital charges for the index admission only, including charges incurred during the operation. Charges data are categorized as follows: routine charges; operating room facility use; operating room supply use; pharmacy charges; laboratory charges; radiology charges; and physical therapy charges. An organ acquisition fee is unique to this patient population, and represents charges related to the organ recovery process and is included with index admission charges for all patients. This fee is determined at the beginning of each calendar year, and incurred evenly by all LTx patients in the same calendar year. For any patient hospitalized pre-LTx, index admission charges begin with the date of transplant. For patients with 1 year of follow-up, charges accumulated during all inpatient re-admissions in the first post-LTx year were compared among LAS quartiles. Financial information was

adjusted for inflation in US dollars for 2009 according to the United States Department of Labor Consumer Price Index.

Statistical analysis

Patients were stratified into quartiles (Q) by LAS. Differences between Q1–3 and Q4 patients were compared using 2-tailed Student's *t*-test for normally distributed continuous variables. For non-parametric continuous data, Wilcoxon's rank-sum test was used. Chi-square analysis was used for categorical variables. Continuous variables are presented with the mean \pm standard deviation (SD). Categorical variables are shown in whole numbers and percentages. All charges data are presented as medians with interquartile range (IQR), as these data were not normally distributed. To confirm a non-parametric distribution, the data were visually inspected in graphical form and checked for skewness. Wilcoxon's rank-sum test compared index admission and 1-year charges data between Q1–3 and Q4. To determine differences between individual quartiles, the Kruskal–Wallis non-parametric analysis of variance was used. Post hoc testing analyzed individual differences among the quartiles. To test for an LAS threshold predictive of increased charges, receiver operating characteristic (ROC) curves were used. The outcome measure for high charges was defined as the upper 25% of index admission charges. An area under the curve (AUC) of >0.7 was considered significant.

After logarithmic transformation of charges data, linear regression tested for a correlation between LAS and index admission charges. A multivariate linear regression model was constructed to determine the relative contributions of individual variables toward index admission charges. In addition to variables associated with charges on exploratory univariate analysis ($p < 0.1$), those with biologic plausibility were incorporated in a forward and backward stepwise fashion into the model. The likelihood ratio test and Akaike's information criterion were used in a nested model approach to identify which covariates increased the explanatory power of the model. Coefficients are presented with 95% confidence intervals (CIs). The final model incorporated LAS, pre-LTx intensive care unit (ICU) and ventilation time, tracheostomy, RRT, in-hospital infection and in-hospital mortality.

Post-operative complications were compared between Q1–3 and Q4. One-year survival was estimated using the Kaplan–Meier method, and the log-rank test compared survival by LAS quartiles. $p \leq 0.05$ was considered significant. Analysis was performed using STATA, version 9.2 (StataCorp, College Station, TX).

Results

Cohort statistics

Between May 2005 and June 2009, 84 patients underwent LTx at our institution. The mean age was 49 ± 13 years, with 47% being females ($n = 40$). Recipient race distribution was: 81% Caucasian ($n = 68$); 17% African American ($n = 14$); and 2% Hispanic ($n = 2$). Patients' diagnoses consisted of: chronic obstructive pulmonary disease (COPD) in 25 (29.7%); idiopathic pulmonary fibrosis (IPF) in 18 (21.4%); cystic fibrosis (CF) in 16 (19.0%); primary pulmonary hypertension in 4 (4.7%); bronchiolitis obliterans syndrome in 6 (7.1%); sarcoidosis in 5 (6.0%); and other in 10 (11.9%). Seventy-three (87%) patients underwent bilateral LTx (BLTx). Nineteen (23%) pa-

tients' required ICU care pre-LTx. The majority of patients (67%) received induction immunotherapy with daclizumab (Zenapax; Hoffmann-La Roche, Inc., Nutley, NJ). Median wait-list time was 70 (IQR 19 to 527) days. During the study, the number of adult LTxs remained constant, ranging from 14 to 21 annually.

LAS results

Mean LAS for the entire cohort was 42.5 (± 14.4). LAS quartiles were: Q1, 30.1 to 34.3, $n = 21$; Q2, 34.4 to 37.5, $n = 21$; Q3, 37.6 to 44.8, $n = 21$; and Q4, 44.9 to 94.3, $n = 21$. Baseline demographic information was compared between Q1–3 and Q4 (Table 1). Patients in Q4 had shorter wait-list times and were more likely to require pre-LTx ICU care and have diabetes mellitus, and they also had higher oxygen requirements. Predicted forced expiratory volume in 1 second (FEV₁) was lower in Q1–3. Ischemia time was similar in both groups, as were all examined donor characteristics.

Outcomes and survival

Mean follow-up was 19 ± 14 months. Re-admission rates between Q4 and Q1–3 were similar. Q4 patients had longer median hospital and ICU LOS; patients in Q4 also had longer duration of mechanical ventilation, more re-intuba-

tions and a greater need for tracheostomy. No difference was seen for RRT, in-hospital infections or in-hospital mortality (Table 2).

During the study, 27 (32.1%) patients died and 17 (20.2%) did not survive to 1 year. When the cohort was analyzed without stratification, overall 1-year survival was 76.2%. After stratification by Q1–3 vs Q4 there was no difference in 30-day, 90-day or 1-year Kaplan–Meier survival. However, there was a trend toward improved survival in Q1–3 (Figure 1). Further division into individual LAS quartiles revealed no significant survival differences; however, a trend toward improved 1-year survival was evident for Q1 patients (90.2% vs 71.4% for Q4; Figure 2).

Hospital charges

Median index admission charges were higher in LAS Q4 patients: \$276,668 (IQR 191,301 to 300,156) for Q4 compared with \$153,995 (IQR 129,796 to 176,849) for Q1–3 ($p < 0.001$) (Figure 3). Median index admission charges for individual quartiles are listed in Table 3. Total median 1-year hospital charges were greater in Q4 patients: \$316,213 (IQR 245,794 to 469,006) for Q4 vs \$190,261 (IQR 153,455 to 240,364) for Q1–3 ($p = 0.002$). After excluding index admission charges, there was no difference in median 1-year hospital charges between the two groups: \$44,657 (IQR 9,041 to 123,369) for Q4 vs \$27,875 (IQR

Table 1 Baseline Demographics According to LAS Quartile

Variables	Q1-3 ($N = 63$)	Q4 ($N = 21$)	p -value
Demographic information			
Mean age, years (SD)	44.8 (14.1)	50.6 (12.9)	0.08
Male gender, n (%)	30 (47)	14 (67)	0.1
Diabetes mellitus, n (%)	8 (13)	7 (33)	0.04
Coronary artery disease, n (%)	1 (1.6)	0 (0)	0.6
BMI, kg/cm ² (SD)	23.7 (4.6)	24.8 (5.2)	0.4
Hypertension, n (%)	17 (27)	4 (20)	0.5
Creatinine, mg/mol (SD)	0.8 (0.2)	0.9 (0.3)	0.1
O ₂ requirement, liters/min	2.9 (1.6)	8.0 (6.4)	<0.001
FEV ₁ , % predicted (SD)	30.4 (24.7)	43.8 (23.2)	0.04
FVC, % predicted (SD)	44.7 (14.2)	50.2 (22.0)	0.2
ICU prior to LTx, n (%)	5 (8)	14 (67)	<0.001
Primary diagnosis			
COPD	25 (40%)	0 (0)	0.01
Idiopathic pulmonary fibrosis	12 (19%)	6 (29%)	0.4
Cystic fibrosis	10 (16%)	6 (29%)	0.2
Sarcoidosis	2 (3%)	3 (14%)	0.1
Primary pulmonary hypertension	2 (3%)	2 (10%)	0.2
Other	12 (19%)	4 (19%)	0.9
Transplant /donor variables			
Donor age, years (SD)	42.1 (15.3)	42.1 (14.3)	0.9
Donor smoking history, n (%)	27 (43.5)	12 (57.1)	0.5
Left lung ischemic time, minutes (SD)	235 (88)	275 (98)	0.08
Right lung ischemic time, minutes (SD)	194 (81)	231 (72)	0.08
Bilateral LTx, n (%)	55 (87)	18 (86)	0.9
Median wait-list time, days (IQR)	133 (30-677)	24 (7-149)	0.006

BMI, body mass index; COPD, chronic obstructive pulmonary disease; FEV₁, forced expiratory volume in 1 second; FVC, forced vital capacity; ICU, intensive care unit; IQR, interquartile interval; LTx, lung transplantation; Q, quartile; SD, standard deviation.

Table 2 Post-operative Outcomes According to LAS Group

Variables	Q1-3 (<i>N</i> = 63)	Q4 (<i>N</i> = 21)	<i>p</i> -value ^a
Median hospital LOS, days (IQR)	15 (11-22)	35 (23-46)	0.003
Median ICU LOS, days (IQR)	3 (2-4)	6 (3-15)	0.01
Re-admissions, <i>n</i> (\pm SD)	3.4 (\pm 2.9)	3.3 (\pm 2.2)	0.9
In-hospital-treated rejection, <i>n</i> (\pm SD)	1 (\pm 1.6)	0 (\pm 0)	0.6
In-hospital infection, <i>n</i> (%)	38 (60%)	16 (76%)	0.1
Median time of mechanical ventilation, hours (IQR)	31 (21-41)	43 (29-121)	0.05
Re-intubation, <i>n</i> (%)	8 (12%)	7 (35%)	0.02
Tracheostomy, <i>n</i> (%)	9 (14%)	7 (33%)	0.03
Renal replacement therapy, <i>n</i> (%)	10 (16%)	4 (19%)	0.7
In-hospital mortality, <i>n</i> (%)	8 (12%)	2 (10%)	0.7

ICU, intensive care unit; IQR, interquartile interval; LAS, lung allocation score; LOS, length of stay; SD, standard deviation.

^a*p*-value based on results of either 1-way Student's *t*-test (continuous variables) or chi-square test (categorical variables).

13,831 to 7,160) for Q1–3 ($p = 0.3$). Among patients who died within 1 year, there was no difference in total charges when comparing Q4 with Q1–3. When examining individual LAS quartiles, Q4 patients had significantly higher index admission charges compared with all other quartiles. There were no differences among Q1, Q2 or Q3 when analyzing index admission charges.

For LAS Q4 and Q1–3, the relative contributions of each charge category to total index hospitalization charges are depicted in Figures 4 and 5. Hospital charges according to category were compared between LAS Q4 and Q1–3. When analyzing index admission charges only, the following categories were higher for LAS Q4: operating room (OR) supplies charges; OR facilities charges; routine ward and ICU care; pharmacy charges; and laboratory services. There was no difference for radiology or physical therapy services.

Area under the receiver operating characteristic (ROC) curve was 0.76 (95% CI: 0.64 to 0.89) (Figure 6). An LAS of 43.314 had the best discriminatory power for predicting the upper 25% of index admission charges, with a sensitivity of 67% and specificity of 84%. Adjusting the LAS threshold to 45.2 achieved a specificity of 88%, but decreased sensitivity to 54%.

Linear regression analysis

Linear regression of charges data after logarithmic transformation revealed a positive correlation between LAS and index admission charges (coefficient: 0.009, 95% CI: 0.001 to 0.017, $p = 0.03$), with Spearman's r -value = 0.28 (Figure 7). Similarly, there was a positive correlation between LAS and 1-year charges, including index admission (coefficient: 0.010, 95% CI: 0.001 to 0.020, $p = 0.04$), with a Spearman's r -value = 0.23. After adjustment with multivariate linear regression, ICU pre-LTx (coefficient: 0.22, 95% CI: 0.001 to 0.44, $p = 0.05$), duration of mechanical ventilation post-operatively (coefficient: 0.004, 95% CI: 0.002 to 0.005, $p < 0.001$), RRT (coefficient: 0.41, 95% CI: 0.11 to 0.69, $p < 0.006$) and tracheostomy (coefficient: 0.61, 95% CI: 0.36 to 0.84, $p < 0.001$) were significantly associated with index admission charges (Table 4).

Discussion

This is the first study to evaluate the impact of high LAS on hospital charges and resource utilization. The analysis included

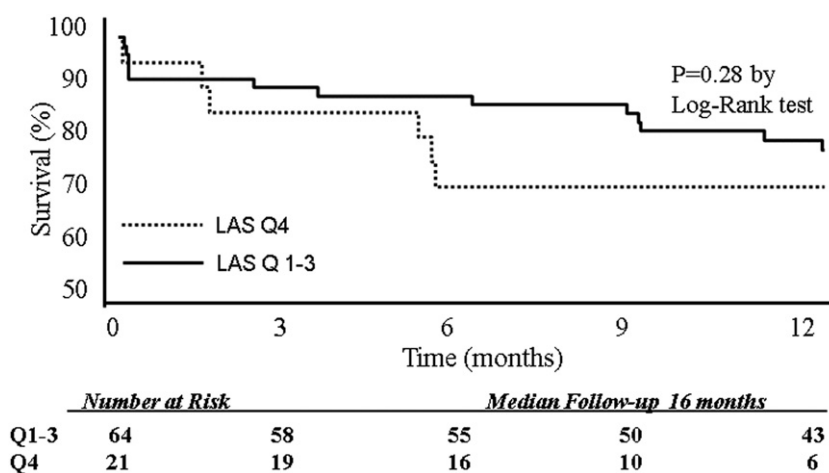


Figure 1 Kaplan–Meier estimates of 1-year survival stratified by LAS Q1–3 vs LAS Q4. By log-rank analysis, survival was similar between the two groups.

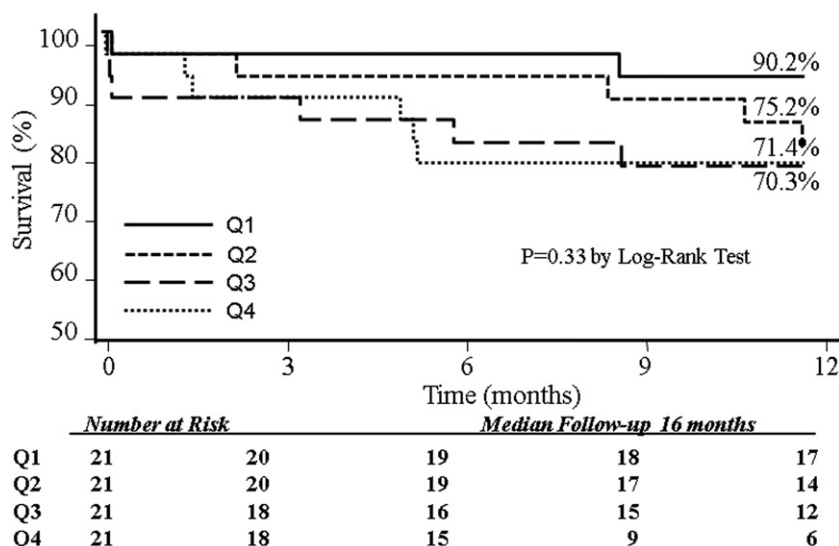


Figure 2 Kaplan-Meier estimates of 1-year survival stratified by individual quartiles. By log-rank analysis, survival was improved in Q1 patients (90% 1-year survival) compared with the remaining three quartiles ($p < 0.05$).

84 consecutive LTx recipients at our institution since inception of the LAS in 2005. Because high LAS patients are known to have worse 1-year survival and more complications,^{1,3} we hypothesized that these patients would also incur greater hospital charges. Indeed, index admission charges were significantly greater in the highest quartile LAS patients. However, only a weak linear relationship between LAS and index admission charges was detected, and thus the LAS is an imperfect tool for predicting increased charges.

As would be predicted, patients in Q4 differ in clinical characteristics from Q1–3. Consistent with other reports, Q4 patients were more likely to have diabetes mellitus and require pre-LTx ICU care, and had higher pre-LTx oxygen requirements.^{1,8} Consistent with one of the aims of the LAS, wait-list times were inversely correlated with LAS, as Q4 patients had shorter wait-list times by 109 days than Q1–3 patients.

Q4 patients had twice the median duration of hospitalization and ICU stays, as well as longer durations of

mechanical ventilation post-LTx, higher re-intubation rates and greater need for tracheostomy. In contrast to large national cohort studies, no significant differences were found in 1-year survival.^{1,3} Although a trend toward improved survival in Q1 patients was present, this study was underpowered to detect significant survival differences.

Charges analysis

Although Q4 patients had significantly higher index admission and total 1-year charges, there was no difference in 1-year charges when index admission charges were excluded. Re-admission rates were similar among the groups. Together these findings suggest greater resource utilization in the peri-operative period for Q4 patients, although long-term utilization appears to be equivalent among all LTx recipients.

Because the focus of this study was to evaluate charges associated with LTx, all pre-operative charges for patients hospitalized prior to LTx were omitted. We surmise that high LAS patients also incur higher hospital charges pre-LTx, but this was not examined in our study. For many critically ill patients in the upper quartile of LAS, transplantation represents the only viable option for improved survival and quality of life. The charges associated with caring for high LAS patients who never receive LTx are unknown, but are likely to be high, as these patients frequently require repeat hospitalizations with assisted ventilation and ICU care.

A detailed breakdown of hospital charges according to category yielded noteworthy results. Higher pharmacy and laboratory charges for Q4 patients are likely a function of their greater LOS. Increased OR charges for Q4 patients likely reflects longer intra-operative times and increased use of cardiopulmonary bypass in these patients. We would have expected Q4 patients to have poorer pre-operative conditioning and therefore incur higher physical therapy charges post-operatively. However, this was not the case,

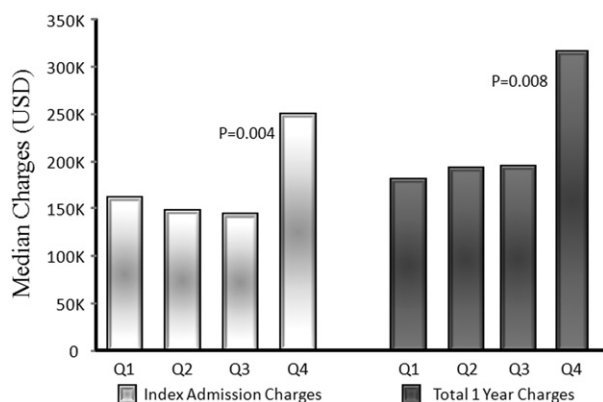


Figure 3 Breakdown of median charges according to LAS quartile. Rank-sum comparison shows index admission and total 1-year charges were higher for LAS Q4 patients compared with LAS Q1–3 patients ($p = 0.004$ for index admission and $p = 0.008$ for total 1-year charges).

Table 3 Median Charges Values According to LAS Quartile

Charges information	Quartile 1 (N = 21)	Quartile 2 (N = 21)	Quartile 3 (N = 21)	Quartile 4 (N = 21)	p-value ^a
Index admission, USD (IQR)	\$160,170 (\$141,480-169,378)	\$147,756 (\$121,846-181,851)	\$153,995 (\$129,796-172,597)	\$276,668 ^b (\$191,301-300,156)	0.003
1-year without index admission, USD (IQR)	\$33,661 (\$20,760-93,179)	\$14,351 (\$6,491-48,942)	\$43,686 (\$19,618-71,650)	\$44,657 (\$9,041-123,369)	0.3
Total 1-year, USD (IQR)	\$190,876 (\$164,613-264,606)	\$181,408 (\$141,174-252,045)	\$192,215 (\$163,935-240,364)	\$292,247 ^b (\$229,192-421,597)	0.02

P-value <0.05 indicates significance. IQR, interquartile interval; LAS, lung allocation score; USD, United States dollars.

^ap-value based on results of Kruskal-Wallis non-parametric analysis of variance (ANOVA).

^bIndividual pairwise post hoc comparison by rank-sum after non-parametric Kruskal-Wallis ANOVA, $p < 0.05$ (reference = Quartile 1).

probably because all LTx patients undergo vigorous post-operative physical therapy regimens and are liberally admitted to a dedicated rehabilitation ward.

Regression analysis

Univariate linear regression showed LAS to have a positive correlation with index admission charges, albeit with a small coefficient. The low r -value suggests that LAS has only a weak linear relationship with hospital charges. On multivariate analysis, pre-LTx ICU care was the only pre-operative variable associated with increased charges. This finding was expected as patients requiring pre-operative ICU care were 8 times more likely to be in Q4. None of the charges associated with pre-LTx ICU care were included, suggesting that pre-LTx ICU is a strong marker of acuity, which portends high post-LTx charges.

Not surprisingly, the need for post-LTx RRT was correlated with increased charges. For all patients needing renal replacement in this series, continuous RRT was used due to hemodynamic instability, which has been previously reported to have increased charges compared with intermittent RRT.⁹ Duration of mechanical ventilation and tracheostomy were other predictors of increased charges in the multivar-

iate model. The association between LAS and increased charges on univariate analysis was no longer evident in the multivariate model. However, as Q4 patients had longer duration of mechanical ventilation, we suspect the added charges associated with mechanical ventilation likely masked any detectable independent effect of LAS on hospital charges in the multivariate model.

An LAS threshold of approximately 45 was most predictive of increased index admission charges; previous reports using UNOS data have cited an LAS >46 as being associated with decreased 1-year survival.¹ This suggests a potential threshold for worse outcomes and increased resource utilization at an LAS of 45 or 46. However, patients with low LASs occasionally have high charges, as 9 (14%) patients in Q1–3 incurred index admission charges above the 75th percentile. Examining these 9 patients by diagnosis revealed 3 cases of COPD, 3 IPF, 1 primary pulmonary hypertension and 2 bronchiolitis obliterans syndrome.

Previous work

Few studies have examined resource utilization in LTx, but no formal study has been published since the inception of the LAS. The first US study was performed in 1995 by Ramsey et

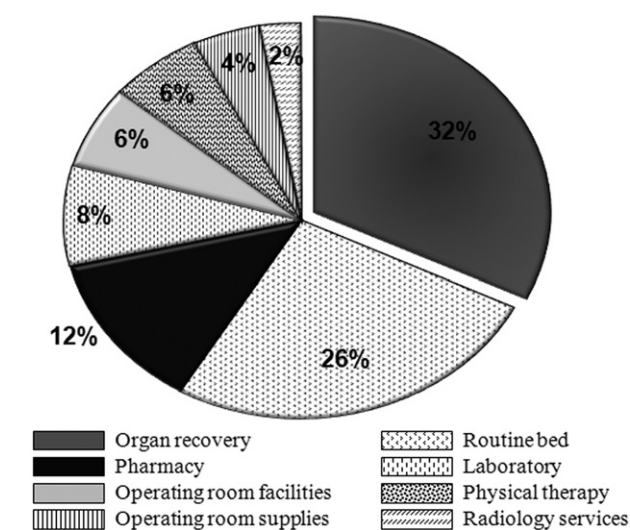


Figure 4 Pie chart depicting charges by category for LAS Q1–3.

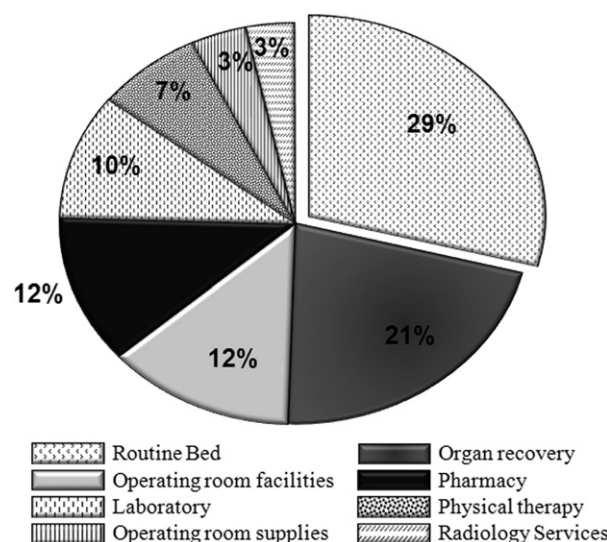


Figure 5 Pie chart depicting charges by category for LAS Q4.

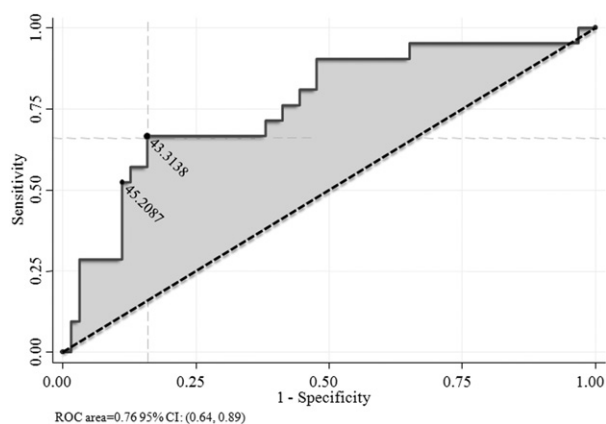


Figure 6 ROC curve for increased index admission charges (upper 25% of index admission charges). Area under the curve was 0.76 (95% CI: 0.64 to 0.89). An LAS of 45.2 had 88% specificity and 54% sensitivity for predicting outcome of interest.

al, who reported average charges of nearly \$165,000 in their first 25 LTx recipients.⁵ Life expectancy was similar between wait-list patients and LTx recipients; however, quality-adjusted life years (QALYs) were improved in LTx recipients. This led to the conclusion that LTx patients highly value the improved quality of life that results from undergoing transplantation.

In 1997, Gartner et al performed a single institutional review of 20 LTx recipients, describing average charges of \$154,000, and determining the survival gain from surgery must be 2.7 years to justify LTx from a societal perspective.⁴ After adjusting for interval inflation differences, average charges found by Ramsey and Gartner were \$216,000 and \$232,000, respectively, which are greater than our findings for Q1–3, but less than for Q4. Thus, although the LAS era has improved wait-list mortality, patients who receive preferential allocation of organs with high LAS have greater hospital charges.

Obtaining data from 7 LTx centers in the UK, Anyanwu et al undertook the largest multi-institutional study to examine cost–utility post-LTx.¹⁰ Their study revealed the mean cost for a single LTx was \$177,000, with additional costs of \$48,000 per QALY. They determined the cost-

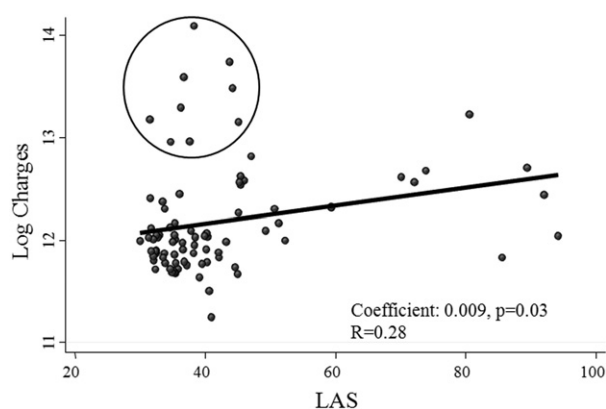


Figure 7 Scatterplot of log linear index admission charges according to LAS. There was a significant positive correlation (0.009, $p = 0.03$), but a weak goodness of fit for the linear model, with Spearman's R -value = 0.28.

Table 4 Results of Linear Regression Analysis

Variable	Coefficient	95% CI	<i>p</i> -value
Univariate ^a			
LAS	0.009 ^b	0.001-0.017	0.03
Multivariate ^b			
LAS	−0.002	−0.009-0.004	0.4
ICU before LTx	0.23	0.00-0.46	0.05
Duration of mechanical ventilation, hours	0.001	0.001-0.003	0.006
Tracheostomy	0.61	0.36-0.84	<0.001
Renal replacement therapy	0.41	0.11-0.69	<0.006
In-hospital infection	0.11	−0.04-0.26	0.2
In-hospital mortality	−0.19	−0.48-0.09	0.2

^a*p*-value <0.05 indicates significance. CI, confidence interval; ICU, intensive care unit; LAS, lung allocation score; LTx, lung transplantation.

^b*p*-value based on univariate Cox proportional hazards analysis.

^c*p*-value based on multivariate Cox proportional hazards regression.

The final model incorporated the following covariates: LAS, ICU before LTx, duration of mechanical ventilation, tracheostomy, renal replacement therapy, in-hospital infection and in-hospital mortality.

effectiveness of LTx could be improved with reduced rejection drug costs and improved quality of life post-LTx. A Canadian study by Vasiliadis et al reached similar findings, with LTx patients realizing greater QALYs.⁶ Our study builds on the few previous studies by detailing charges according to category and by examining the impact of high LAS on resource utilization.

Limitations

A limitation of this study is the use of hospital charges as a surrogate index for cost. However, the unique structure for medical reimbursement in the State of Maryland neutralizes this issue. A multi-institutional study across many states cannot be easily performed because of variable payment rates. To contain costs, the Maryland Health Services Cost Review Commission (HSCRC) determines payment rates for insurers—both private and public—including Medicare and Medicaid within Maryland hospitals. Thus, the common practice of “cost shifting” by overcharging privately insured patients is absent. The authors’ institution HSCRC rate for charge payment has been *cost + 1% to 3%* over the study interval. Accordingly, we believe this study represents the most accurate assessment of charges associated with LTx to date.

This is the first study to rigorously review the impact of LAS on hospital charges and resource utilization after LTx. Patients in the highest LAS quartile had significantly increased index admission and total 1-year hospital charges, as well as greater lengths of stay, when compared with patients in the lower 75% of LAS. However, the increased expenses appear to be confined to the index admission only. These results illumi-

nate the increased charges and resource utilization associated with the transplantation of high LAS patients.

Disclosure statement

These findings were presented at the plenary session of the 30th annual meeting of the International Society for Heart and Lung Transplantation, April 2010, Chicago, Illinois.

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The authors have no conflicts of interest to disclose.

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