A Guide to Calculating the Lung Allocation Score

U.S. lung allocation policy prioritizes lung transplant candidates for lung offers by assigning them a lung allocation score.

What is the Lung Allocation Score?

The lung allocation score (LAS) is used to prioritize waiting list candidates 12 years and older based on a combination of waitlist urgency and post-transplant survival. In this context, *waitlist urgency* is defined as what is expected to happen to a candidate, given his or her characteristics, in the next year if he or she doesn't receive a transplant. *Post-transplant survival* is defined as what is expected to happen to a candidate, given his or her characteristics, in the first year after a transplant if he or she does receive the transplant.

What is involved in the LAS calculation?

The LAS involves the following steps:

1. *Calculate the waiting list survival probability during the next year*
2. *Calculate the waitlist urgency measure*
3. *Calculate the post-transplant survival probability during the first post-transplant year*
4. *Calculate the post-transplant survival measure*
5. *Calculate the raw allocation score*
6. *Normalize the raw allocation score to obtain the LAS.*

A detailed explanation for each of the steps follows.

How is the LAS actually calculated?

We've computed the LAS for a hypothetical candidate to help you understand the process.

The following description of the calculation of the LAS in this document assumes that all characteristics are known. With the exception of a few characteristics (e.g., age and diagnosis), the LAS can also be computed when characteristics are missing. If a characteristic is missing, such as creatinine level or BMI, a default value is used. For some characteristics the default value is a normal value for that characteristic; for other characteristics the default is the least beneficial value for that characteristic. A normal value is a value that a person healthy for the given characteristic would exhibit. The least beneficial value is the value for that characteristic that will yield the lowest LAS. In general the least beneficial value is either the minimum or maximum possible value for the characteristic.

CAUTIONARY NOTES:

- *We rounded the parameter estimates and survival rates to 6 places after the decimal. These rounded values are used for <u>explanatory purposes only</u>. The parameter estimates and survival rates used in the actual calculation of the LAS will contain up to 16 positions after the decimal. The estimated LAS computed using the method in this document will be close to, but not identical to, that using the actual allocation algorithm. For candidates currently on the lung or heart-lung waiting list, please contact your transplant center to obtain your precise LAS.*
- *The parameter estimates and baseline survival rates shown in this document are current as of September 30, 2021. Though the characteristics or estimates used in the computation may be modified in the future, the basic method for computing the LAS will not change.*

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Calculating the LAS Step by Step

Step 1. **Calculate the expected waiting list survival probability during the next year:**

$$S_{WL,i}(t) = S_{WL,0}(t)^{e^{\beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_p X_{pi}}}$$

where

$S_{WL,i}(t)$ is the expected waiting list survival probability at time t for candidate i

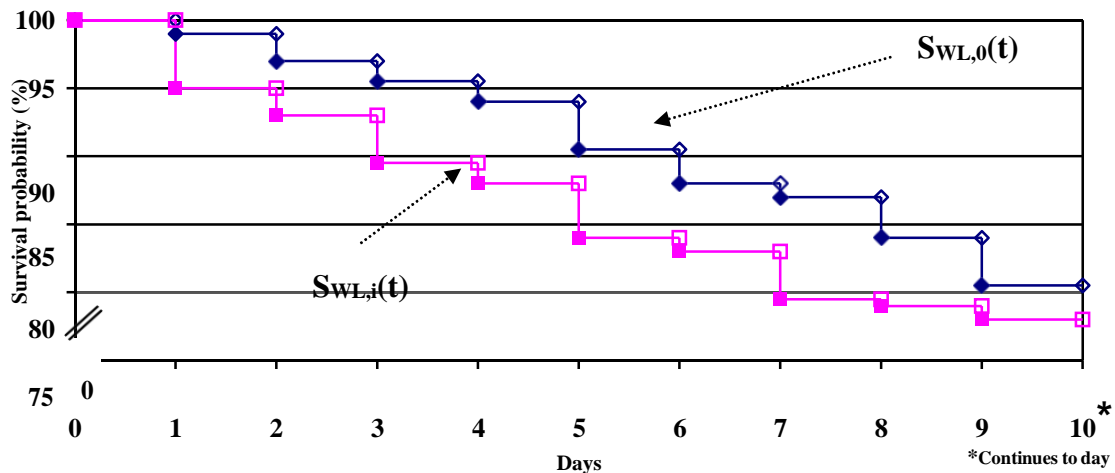$S_{WL,0}(t)$ is the baseline waiting list survival probability at time t
   i.e., the survival probability for a candidate with all characteristics at
   baseline values (OPTN Policy Table 10-11: Baseline Waiting List
   Survival ($S_{WL}(t)$) Probability Where t=Time in Days)

$\beta_1, \beta_2, \ldots \beta_p$ are the parameter estimates from the waiting list model (Table 1)

X_{ji} is the value of characteristic j for candidate i (j = 1, 2, …, p)

i = 1, 2, …, N is the candidate identifier

This step adjusts the baseline survival at each time point ($S_{WL,0}(t)$) by the candidate's characteristics to yield the expected waiting list survival probability for the candidate, $S_{WL,i}(t)$. The resulting survival may be either higher or lower than the baseline survival. A hypothetical example, in which the expected survival for candidate i is lower than the baseline survival, follows:

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Computing a candidate's expected waiting list survival probability during the next year involves three calculations:

(i) Sum the product of parameter estimates and characteristic values for candidate i: $\beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_p X_{pi}$ (For β values see Table 1.)

(ii) Exponentiate this sum: $e^{\beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_p X_{pi}}$

(iii) Apply the exponent to the baseline survival at all time points during the next year:
$S_{WL,0}(t)^{e^{\beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_p X_{pi}}}$ (For baseline survival values see OPTN Policy Table 10-11: Baseline Waiting List Survival ($S_{WL}(t)$) Probability Where t=Time in Days.)

Table 1. Parameter estimates for waiting list model

CHARACTERISTIC (X)		B
Age at offer (years)		0.0281444188123287 * age
Bilirubin (mg/dL)	Bilirubin more than 1.0 mg/dL	0.15572123729572 *(bilirubin − 1)
	Bilirubin 1.0 mg/dL or less	0
Body mass index (BMI) (kg/m^2)	BMI less than 20 kg/m2	0.10744133677215 *(20 − BMI)
	BMI at least 20 kg/m2	0
Creatinine (serum) (mg/dL)	Candidate is at least 18 years old	0.0996197163645* creatinine
	Candidate is less than 18 years old	0
Ventilation status if candidate is hospitalized	continuous mechanical ventilation needed	1.57618530736936
	no continuous mechanical ventilation needed	0
Functional Status	No assistance needed with activities of daily living	-0.59790409246653
	Some or total assistance needed with activities of daily living	0
PA systolic for Diagnosis Groups B, C, and D (mm Hg)		0.1230478043299*PA systolic/10

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PA systolic for Diagnosis Group A (mm Hg) if PA systolic pressure is greater than 40 mm Hg		$0.55767046368853*(\text{PA systolic} - 40)/10$
PA systolic for Diagnosis Group A (mm Hg) if PA systolic pressure is 40 mm Hg or less		0
O_2 requirement at rest for Diagnosis Groups A, C and D (L/min)		$0.08232292818591*O_2$
O_2 requirement at rest for Diagnosis Group B (L/min)		$0.0340531822566417*O_2$
Six-minute walk distance		$-0.09937981549564*\text{Six-minute-walk distance}/100$
PCO_2 [*] (obtained from arterial or capillary) PCO_2 is at least 40 mm Hg		$0.12639905519026*PCO_2/10$
PCO_2 threshold change	Increase in PCO2 of 15% or greater within a 6-month period	0.15556911866376
	No change or change of less than 15%	0
Diagnosis group[**]	Group A	0
	Group B	1.26319338239175
	Group C	1.78024171092307
	Group D	1.51440083414275
Diagnosis detailed	Bronchiectasis (Diagnosis Group A only)	0.40107198445555
	Pulmonary fibrosis, not idiopathic (Diagnosis Group D only)	0.2088684500011
	Sarcoidosis with PA mean pressure > 30 mm Hg (Diagnosis Group D only)	-0.64590852776042
	Sarcoidosis with PA mean pressure of ≤ 30 mm Hg (Diagnosis Group A only)	1.39885489102977

[*] If PCO2 was obtained from venous blood, subtract 6 to estimate an arterial value.

[**] Diagnosis groups are defined as:
    Group A = Obstructive lung disease (e.g., emphysema)
    Group B = Pulmonary vascular disease (e.g., primary pulmonary hypertension)
    Group C = Cystic fibrosis or immunodeficiency disorder
   Group D = Restrictive lung disease (e.g., idiopathic pulmonary fibrosis)

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Calculate the waitlist urgency measure:

The *waitlist urgency measure* (WL_i) is defined as the area under the waiting list survival probability curve during the next year on the waiting list. This can be interpreted as the number of days a candidate with a specified set of characteristics is expected to live during the next year on the waiting list.

Since the baseline survival, $S_{WL,0}(t)$, is based on information collected on a per-day basis (e.g., patients alive or having died per day) rather than an hourly basis, the survival probability stays the same during an entire day. This results in a "curve" that is actually a large set of stair-steps. Similarly the candidate's waiting list survival curve, $S_{WL,i}(t)$, is also a stair-step function but with different heights for the steps (as shown in the previous figure.)

In this example, the area under the baseline survival curve, $S_{WL,0}(t)$, can be computed as the sum of the areas of the rectangles, where the width is 1 day and the height is the survival rate on that day:
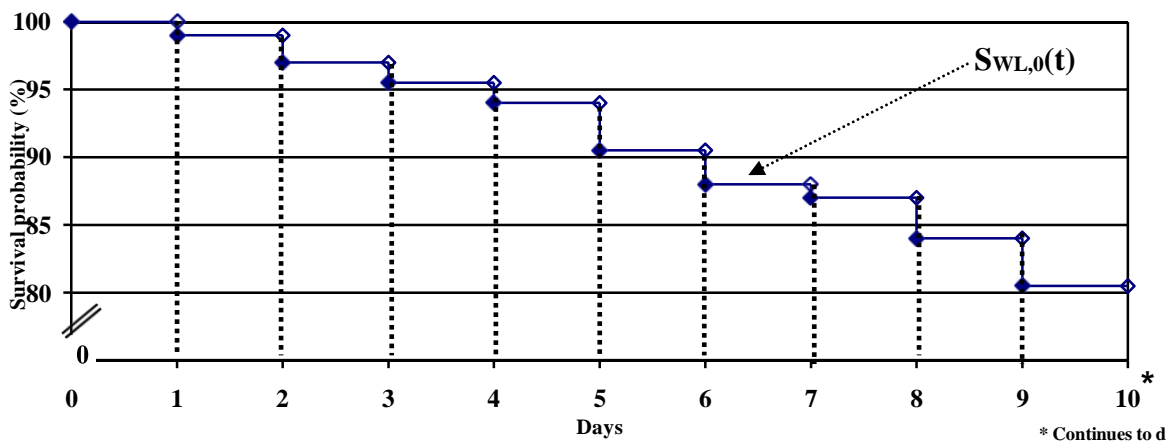
Each candidate's set of characteristics will adjust the height of each rectangle: $S_{WL,0}(t)$ is adjusted by the candidate's characteristics to $S_{WL,i}(t)$. The height of the rectangle for candidate i from 0 to 1 day is $S_{WL,i}(0)$, from 1 to 2 days the rectangle's height is $S_{WL,i}(1)$, and so on. The width of the rectangles remains the same for all candidates: 1 day.

The waiting list urgency measure (WL_i), the area under the waiting list survival probability curve during the next 1 year, can be written mathematically as:

$$WL_i = \sum_{k=1}^{365} Height_k * Width_k = \sum_{k=1}^{365} S_{WL,i}(k-1) * 1\, day, \text{ for candidate i}$$

Theoretically WL_i can range from approximately 0 days (if the expected survival is 0 at day 1) to 365 days (if the expected survival is 100% during the entire next year on the waiting list). But these are the most extreme cases; most candidates will have a WL_i value greater than 0 but less than 365 days.

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Step 2. Calculate the expected post-transplant survival probability during the first post-transplant year:

$$S_{TX,i}(t) = S_{TX,0}(t)^{e^{\alpha_1 Y_{1i} + \alpha_2 Y_{2i} + ... + \alpha_q Y_{qi}}}$$

where

$S_{TX,i}(t)$ is the expected post-transplant survival probability at time t for candidate i

$S_{TX,0}(t)$ is the baseline post-transplant survival probability at time t,
i.e., the survival probability for a candidate with all characteristics at the baseline value (OPTN Policy Table 10-12: Baseline Post-Transplant Survival ($S_{TX}(t)$) Probability Where t=Time in Days)

$\alpha_1, \alpha_2, ... \alpha_q$ are the parameter estimates from the post-transplant model (Table 2)

Y_{ji} is the value of characteristic j for candidate i (j = 1, 2, …, q)

i = 1, 2, …, N is the candidate identifier

This is the same calculation as was performed in Step 1, but now the characteristics, parameter estimates and baseline survival are for the post-transplant period rather than for the waiting period.

Table 2. Parameter estimates for post-transplant model

CHARACTERISTIC (Y)		A
Age at transplant (years)	Candidate greater than 45 (years)	0.0208895939056676 *(age–45)
	Candidate is 45 or younger (years)	0
Creatinine at transplant (mg/dl)	Candidate at least 18 years old	0.25451764981323 *creatinine
	Candidate is less than 18 years old	0
Cardiac index (L/min/m2) at rest, prior to any exercise	Cardiac index less than 2 L/min/m^2	0.1448727551614
	Cardiac index at least 2 L/min/m^2	0
Ventilation status if candidate is hospitalized	Continuous mechanical ventilation needed	0.33161555489537
	No continuous mechanical ventilation needed	0
Diagnosis group*	Group A	0
	Group B	0.51341349576197
	Group C	0.23187885123342
	Group D	0.12527366545917
Diagnosis detailed	Bronchiectasis (Diagnosis Group A only)	0.12048575705296
	Obliterative bronchiolitis (non-retransplant, Diagnosis Group D only)	-0.33402539276216
	Constrictive bronchiolitis (Diagnosis Group D only)	-0.33402539276216
	Sarcoidosis with PA mean pressure > 30 mm Hg (Diagnosis Group D only)	0.43537371336129

	Sarcoidosis with PA mean pressure of ≤ 30 mm Hg (Diagnosis Group A only)	0.98051166673574
	Sarcoidosis with PA mean pressure missing (Diagnosis Group A only)	0.98051166673574
O_2 requirement at rest for Diagnosis Group A (L/min)		$0.0100383613234584 * O_2$
O_2 requirement at rest for Diagnosis Groups B, C and D (L/min)		$0.0093694370076423 * O_2$
Six-minute-walk-distance (feet)	Six-minute-distance-walked is less than 1,200 feet	$0.0001943695814883 * (1200 - \text{Six-minute walk distance})$
	Six-minute-distance-walked is at least 1,200 feet	0

* Diagnosis groups are defined as:
  Group A = Obstructive lung disease (e.g., emphysema)
  Group B = Pulmonary vascular disease (e.g., primary pulmonary hypertension)
  Group C = Cystic fibrosis or immunodeficiency disorder
  Group D = Restrictive lung disease (e.g., idiopathic pulmonary fibrosis)

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As with the waiting list survival probability computation in Step 1, the expected post-transplant survival probability computation requires 3 separate calculations:

(i)   Sum the product of parameter estimates and characteristic values for candidate i:

$\alpha_1 Y_{1i} + \alpha_2 Y_{2i} + \ldots + \alpha_q Y_{qi}$ (For α values see Table 2.)

(ii)   Exponentiate this sum: $e^{\alpha_1 y_{1i} + \alpha_2 y_{2i} + \ldots + \alpha_q y_{qi}}$

(iii)   Apply the exponent to the baseline survival at all time points during the first post-transplant year: $S_{TX,0}(t)^{e^{\alpha_1 Y_{1i} + \alpha_2 Y_{2i} + \ldots + \alpha_q Y_{qi}}}$ (For baseline survival values see OPTN Policy Table 10-12: Baseline Post-Transplant Survival ($S_{TX}(t)$) Probability Where t=Time in Days.)

Step 3. Calculate the post-transplant survival measure:

The logic for this computation is identical to the waiting list side. The ***post-transplant survival measure*** for candidate i (PT_i) is the area under the post-transplant curve during the first year. It can be calculated by summing the area of rectangles with height of $S_{TX,i}(t)$ and width of 1 day.

$$PT_i = \sum_{k=1}^{365} Height_k * Width_k = \sum_{k=1}^{365} S_{TX,i}(k-1)*1\,day, \text{ for candidate i}$$

As with WL_i, the theoretical range of PT_i is 0 days to 365 days, though most candidates will fall somewhere in between.

Step 4. Calculate the raw allocation score:

The ***transplant benefit measure*** for candidate i ($Benefit_i$) is:

$Benefit_i$ = $PT_i - WL_i$
           =   expected days lived during 1st year post-transplant – expected days lived during additional year on waiting list
           =   additional days of life lived with a transplant than without a transplant

The ***raw allocation score*** for candidate i (Raw score$_i$) is:

Raw score$_i$ = $Benefit_i - WL_i$
             = $PT_i - 2*WL_i$

Since WL_i and PT_i both range from 0 to 365 the range of the raw score is -730 to 365.

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Step 5. Normalize the raw allocation score to obtain the LAS:
To obtain a final score that ranges from 0 to 100, the raw score must be normalized.

After normalization, the raw score of -730 should correspond to an LAS of 0; and a raw score of 365 will correspond to an LAS of 100.

Therefore the normalization is:

$$\text{LAS}_i = \frac{100 * [\text{Raw score}_i - minimum]}{range}$$

$$= \frac{100 * [\text{Raw score}_i - (-730)]}{1095}$$

$$= \frac{100 * [\text{Raw score}_i + 730]}{1095}$$

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EXAMPLE

Assume that Candidate Z has the following set of characteristics:

Characteristic	Value for Candidate Z
Diagnosis	Emphysema (Group A)
Age	51 years
Height	5 ft. 8 in. (1.727 m)
Weight	165 lbs (74.84 kg)
Cardiac index (L/min/m^2) at rest, prior to any exercise	1 L/min/m^2
Bilirubin	1 mg/dL
Functional status	Requires no assistance to perform activities of daily living (ADL)
PA systolic pressure	40 mm Hg
O$_2$ required at rest	2 L/min
Six-minute walk distance	800 ft
Continuous mechanical ventilation	Not on continuous mechanical ventilation
PCO$_2$	52 mm Hg
Increase in PCO$_2$ (%)	30%
Creatinine	1.0 mg/dl

$$BMI = \text{weight (kg)} / \text{height (m)}^2 = .84 \text{ kg}/(1.727 \text{ m})^2$$

$$= 25.092799 \text{ kg/m}^2$$

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Step 1. Calculate the waiting list survival probability:

$$S_{WL,Z}(t) = S_{WL,0}(t)^{e^{\beta_1 X_{1z} + \beta_2 X_{2z} + \ldots + \beta_p X_{pz}}}$$

a) **First, calculate the exponent: $\beta_1 X_{1z} + \beta_2 X_{2z} + \ldots + \beta_p X_{pz}$**

Characteristic		Value for Candidate Z ($X_{pz}{}^\dagger$)	β_p	$\beta_p * X_{pz}$
Age at offer		51	0.0281444188123287	1.441703
Bilirubin (mg/dL)		1	0.15572123729572 *(bilirubin − 1)	0
BMI (kg/m²)		25.0928	0	0
Creatinine (serum) (mg/dL)		1	0.0996197163645	0.099620
Functional status	No assistance needed with activities of daily living	1	-0.59790409246653	-0.597904
	Some or total assistance needed with activities of daily living	0	0	0
PA systolic for Diagnosis Groups B, C, and D (mm Hg)		0	0.1230478043299	0
PA systolic for Diagnosis Group A (mm Hg) if PA systolic pressure is greater than 40 mm Hg		0	0.55767046368853	0
PA systolic for Diagnosis Group A (mm Hg) if PA systolic pressure is 40 mm Hg or less		1	0	0
O₂ requirement at rest for Diagnosis Groups A, C and D (L/min)		2	0.08232292818591	0.164646
O₂ requirement at rest for Diagnosis Group B (L/min)		0	0.0340531822566417	0
Six-minute walk distance		0	-0.09937981549564	-0.795039
Continuous mechanical ventilation		0	1.57618530736936	0
PCO₂ * (obtained from arterial or capillary) PCO₂ is at least 40 mm Hg		52	0.12639905519026	0.657275
Increase in PCO2 of 15% or greater within a 6-month period		1	0.15556911866376	0.155570
Diagnosis Group	Group A	1	0	0
	Group B	0	1.26319338239175	0
	Group C	0	1.78024171092307	0
	Group D	0	1.51440083414275	0

Diagnosis detailed	Bronchiectasis (Diagnosis Group A only)	0	0.40107198445555	0
	Pulmonary fibrosis, not idiopathic (Diagnosis Group D only)	0	0.2088684500011	0
	Sarcoidosis with PA mean pressure greater than 30 mm Hg (Diagnosis Group D only)	0	-0.64590852776042	0
	Sarcoidosis with PA mean pressure of 30 mm Hg or less (Diagnosis Group A only)	0	1.39885489102977	0
TOTAL			$\beta_1X_{1z} + \beta_2X_{2z} +...+ \beta_pX_{pz} = 1.125870$	

Note: If the characteristic is dichotomous (e.g., Yes/No) and the candidate does not have the characteristic, the value of X is 0. If the candidate does have the characteristic X = 1.

b) **Exponentiate the exponent:** $e^{\beta_1X_{1i}+\beta_2X_{2i}+...+\beta_pX_{pi}} = e^{1.125870} = 3.082899$

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c) Compute the waiting list survival probabilities at each time point for Candidate Z.

(Baseline waiting list survival excerpted from OPTN Policy Table 10-11: Baseline Waiting List Survival ($S_{WL}(t)$) Probability Where t=Time in Days)

Time (days) = t	Baseline waiting list survival = $S_{WL,O}(t)$	$SW_{L,Z}(t) = S_{WL,O}(t)^{3.082899}$
0	1.000000	1.000000
1	0.999998	0.999992
2	0.999983	0.999947
3	0.999956	0.999865
4	0.999928	0.999777
5	0.999902	0.999697
6	0.999878	0.999623
7	0.999856	0.999557
8	0.999814	0.999428
9	0.999786	0.999342
10	0.999770	0.999290
…	…	….
364	0.994390	0.982805
$\sum S_{WL}$ = WL	363.927888 days	361.707480 days

Step 2. Calculate the waitlist urgency measure:

$$WL_z = \sum_{k=1}^{365} S_{WL,Z}(k-1)*1\,day = 361.707480\,days$$

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Step 3. Calculate the post-transplant survival probability during the first post-transplant year:

$$S_{TX,Z}(t) = S_{TX,0}(t)^{e^{\alpha_1 Y_{1z} + \alpha_2 Y_{2z} + \dots + \alpha_q Y_{qz}}}$$

a) **First, calculate the exponent:** $\alpha_1 Y_{1z} + \alpha_2 Y_{2z} + \dots + \alpha_q Y_{qz}$

CHARACTERISTIC (Y)		Value for Candidate Z (Y_{qz}†)	$\alpha\, q$	$\alpha\, q * Y_{qz}$
Age at transplant if candidate greater than 45 (years)		51	0.0208895939056676	0.130042
Creatinine at transplant (mg/dl) if candidate at least 18 years old		1	0.25451764981323	0.254518
Cardiac index (L/min/m2) at rest, prior to any exercise		1	0.1448727551614	0.144873
Ventilation status if candidate is hospitalized		0	0.33161555489537	0
Diagnosis Group	Group A	1	0	0
	Group B	0	0.51341349576197	0
	Group C	0	0.23187885123342	0
	Group D	0	0.12527366545917	0
Diagnosis detailed	Bronchiectasis	0	0.12048575705296	0
	Obliterative bronchiolitis (non-retransplant)	0	-0.33402539276216	0
	Constrictive bronchiolitis	0	-0.33402539276216	0
	Sarcoidosis and PA mean > 30 mm Hg	0	0.43537371336129	0
	Sarcoidosis and PA mean ≤ 30 mm Hg	0	0.98051166673574	0
	Sarcoidosis with PA mean pressure missing	0	0.98051166673574	0
O₂ requirement at rest for Diagnosis Group A (L/min)		2	0.0100383613234584	0.020077
O₂ requirement at rest for Diagnosis Groups B, C and D (L/min)		0	0.0093694370076423	0
Six-minute walk distance		800	0.0001943695814883	0.077748
TOTAL			$\beta_1 X_{1z} + \beta_2 X_{2z} + \dots + \beta_p X_{pz}$ = 0.627257	

†**Note**: If the characteristic is dichotomous (e.g., Yes/No) and the candidate does not have the characteristic, the value of Y is 0. If the candidate does have the characteristic Y = 1.

b) **Exponentiate the exponent:** $e^{\alpha_1 Y_{1i} + \alpha_2 Y_{2i} + \dots + \alpha_q Y_{qi}} = e^{0.627257} = 1.872467$

c) **Compute the post-transplant survival probabilities at each time point for Candidate Z.**

(Baseline post-transplant survival excerpted from OPTN Policy
Table 10-12: Baseline Post-Transplant Survival ($S_{TX}(t)$) Probability Where t=Time
in Days.)

Time (days) = t	Baseline post-transplant survival = $S_{TX,O}(t)$	$S_{TX,Z}(t) = S_{TX,O}(t)^{1.872467}$
0	1.000000	1.000000
1	0.998917	0.997973
2	0.998435	0.997071
3	0.997771	0.995831
4	0.997348	0.995041
5	0.997046	0.994476
6	0.996563	0.993573
7	0.996199	0.992895
8	0.995897	0.992330
9	0.995472	0.991539
10	0.995109	0.990861
…	…	…
364	0.953508	0.914714
$\sum S_{TX} = PT$	355.017648 days	346.570477 days

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Step 4. Calculate the post-transplant survival measure:

$$PT_i = \sum_{k=1}^{365} S_{TX,i}(k-1)*1\,day = 346.570477 \text{ days}$$

Step 5. Calculate the raw allocation score:

Raw score$_i$ = $PT_i - 2*WL_i$
= $346.570477 - 2*361.7074800$

= -376.844483

Step 6. Normalize the raw allocation score to obtain the LAS:

LAS = $\dfrac{100*[\text{Raw score}_i + 730]}{1095}$

= $\dfrac{100*[-376.844483 + 730]}{1095}$

= 32.251645