**SOCIOECONOMIC STATUS AND LUNG TRANSPLANTATION IN THE US**

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**ABSTRACT**

Improvements in operative techniques and postoperative management have greatly evolved across the board in the surgical field regarding to survival outcomes. Lung transplantation (LTx) is no different. Despite these improvements for the past three decades, however, the 5-year survival of patients undergoing LTx remains in the range of 55%. Some medical professionals may argue that our improvements have plateaued in 2005 due to administrative changes. Nevertheless, our goal should be to identify methods in which we can improve medical care given to these patients to push the field forward and improve outcomes. As end end-stage pulmonary disease affects more individuals and the demand increases, we need to continue to analyze the state of lung transplantation. One potential area of improvement is the looking at the association between access as well as outcomes following lung transplantation and socioeconomic status. Compared to other surgical fields, the current literature on SES in lung transplantation leaves much to be desired. We need to definitively quantify and character the public health relevance of SES in lung transplantation. This will provide us with the ability to identify techniques to minimize the health disparities caused by SES.

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# 1.0 INTRODUCTION

Dating to the early 1990s, over 51,000 lung transplantations have been performed around the world [1]. Like with many medical modalities, it has been monitored and continues to improve since the very first attempt in the 1960s by Dr. James Hardy [2]. Though this first attempt was not labeled as a success due to early mortality, through trial and error, our ability to provide this treatment to those in need has improved greatly [3, 4]. Lung transplantation has since become the modality of choice with patients with end-stage pulmonary disease.

 Currently, one and five year survival follow lung transplantation has improved to roughly 85% and 55% respectively in the US [3]. This is a drastic improvement from Dr. Hardy’s attempt of 18 days [2]. Improvement has been steadily achieved through the decades and can be attributed to various improvement in patient selection, operative techniques and postoperative management. This improvement halted in 2005 despite considerable efforts from both the cardiothoracic surgeons and pulmonary internists. Some attribute this plateau in progress to changes in organ distribution as the Lung Allocation Score was implemented in 2005 [5]. This complicated algorithm was designed to prioritize the sickest potential waitlisted candidates and includes various patient characteristics that have been extensively studied in the literature [6, 7].

A survival rate of 55% following lung transplantation should not be the end goal when survival following other solid organs is well into the 80s and 90s [8, 9]. One area that can be used to further improve this percentage is how socioeconomic status interacts with patients requiring lung transplantation. Compared to other surgical fields, the current literature on SES in lung transplantation leaves much to be desired. We need to definitively quantify and character the public health relevance of SES in lung transplantation. This will provide us with the ability to identify techniques to minimize the health disparities caused by SES.

# 2.0 THE DEFINITION OF SOCIOECONOMIC STATUS

It is of upmost importance to define socioeconomic status prior to analyzing its effects on various populations. According to the U.S. Department and the Institute of Education Sciences, SES is “defined broadly as one’s access to financial, social, culture, and human capital” [10]. However, many other factors play a role in the total SES status of an individual. Traditionally, one’s SES includes components such as parental educational attainment, parental occupational status, and household/family income after adjusting for household composition. Income, educational attainment, and occupational status has traditionally been known as the primary components of SES. Due to the dynamic nature of SES, expanded measure included in the analysis may also include household, neighborhood, and school resources. As we get more intricate in defining SES, it is important to note that all of these variables are interdependent and have shown to all represent SES in various patient populations [10].

## 2.1 Income

According to the National Assessment of Educational Progress, income is highly correlated to access to possessions such as books, encyclopedias, magazines, and technology in the home [11]. Moreover, household income is used to obtain services that help augment health such as health insurance, medications, and other home services that may be needed by an individual. Some indirect measure of family income include housing tenure, moves per year, immigration status, school resources, and the level of support from the home, school, or neighborhood [11].

## 2.2 Educational Attainment

Educational attainment is often defined by the highest level of schooling that one has completed. Educational attainment and health outcomes such as mortality are highly correlated in many populations [12]. One of first studies identifying this relationship was the Wisconsin model. Sewell and colleagues observed a positive correlation between educational attainment through a model looking at personal aspirations, the influence of peers, educational achievement, and cognitive ability among other variables and social mobility in American males. However, educational attainment and health interactions may not be completely uniform throughout the social hierarchy and care must be used whenever analyzing this relationship [13].

## 2.3 Occupational Status

SES is partly determined by an individual’s occupation. Occupational status is defined as the current level or type of employment of an individual [14]. It often reflects their educational level, provides income, and can be used to identify one’s social standing. Occupational status has been hypothesized to be related to both population and individual health for several reasons. An individual’s occupation positions him/her within the social structure, which defines the access to resources and constraints they are exposed to [15, 16]. Moreover, every type of job exposes individuals to a different set of demands and rewards which can impact health negatively or positively such as physically hazardous or psychologically stressful environments [17, 18].

## 2.4 The Effects of SES

Within a particular population, SES can exhibit its impact in various stages that are all important. Much of the literature focuses on the effects of SES in specific populations on outcomes following certain types of treatments. This is true regarding patients undergoing surgery for various diseases as well as for medical patients receiving medications. Many of these studies have been pivotal in identify health disparities among patients of varying SES. However, what is lacking in this type of analysis is the fact that many patients are indeed left out of these analyses because SES also can affect the access to these treatments. Because these patients are left out even before any studies are performed, certain effects of SES may be misrepresented or masked because of the selection that already has occurred. Since this selection bias is something that can greatly affect results, care is needed to ensure it is addressed prior to drawing any conclusions.

# 3.0 SES AND THE SURGICAL PATIENT

When studying the impact of SES in a particular cohort of patients, it may be informative to see how it has impacted other similar populations. This is particularly useful in the setting of lung transplant patients because the impact of SES on the lung transplant population has not been as extensively investigated like others. Lowered SES has been shown to be associated with worse outcomes [19-22]. Demonstrating the differences between these relationships within SES in various populations rests upon how to identify the particular patients with lower SES who are at risk for worse outcomes. Two comparison groups to provide better insight into how SES affects the lung transplant population are the following: 1). patients undergoing lung resection surgery, 2). patients undergoing transplantation.

## 3.1 The Cardiothoracic Patient

Patients undergoing lung resection surgery can provide great insight into the lung transplant population in terms of how they are affected by SES. The first reason is the fact that the same organs are being operated on by surgeons with a similar skillset. This highly specialized skillset is often only provided in high volume centers that provide this specialty. Moreover, because the same organ is being manipulated , patients often require the same support staff taking care of them as well as similar hospital resources such as breathing machines, nearly identical operating rooms, and similar pharmaceutical therapy.

Indeed patient access to cardiothoracic services for lung resection surgery vary a great deal within the US population. The Board of Directors of the American Thoracic Society (ATS) acknowledge that their patient population was not immune to the effects of SES. They performed a systematic review looking at insurance status to identify any health disparities regarding practices and outcomes for patients with lung cancer in the US [23]. Following the Meta-analysis of Observational Studies in Epidemiology (MOOSE) guidelines, they identified 23 out of 3,739 studies that were deemed eligible. Their analysis showed the patients with Medicaid insurance (indirect indicator of lower SES) were more likely to be diagnosed in more advanced stages both in the adult and elderly population. Analysis of mortality in many of the studies included showed a decrease 3 year survival between various reputable cancer registries throughout the US [24-27].

The same relationship was found between delivery of care and SES in patients diagnosed with lung cancer. Patients with private insurance (indirect marker of higher SES) were more likely to receive surgery as well as radiation, both of which have shown to increase overall and cancer free survival greatly. This correlation was seen in populations with varying disease and age utilizing databases such as the California Cancer Registry [28]. Because of these findings, patients with Medicaid insurance had poorer outcomes and survival even after adjusting for stage of diagnosis. One may argue that these results do not apply to the lung transplant community because the lung cancer cohort is clinically and demographically different. However, this analysis can be looked as a prequel to the analysis of the effect of SES in the lung transplant population because of the similarities between the services and requirements that both patient populations require during the preoperative workup, surgical intervention, and postoperative management.

## 3.2 Solid Organ Recipient Population

The effects of SES in other non-pulmonary solid organ recipient populations also provides guidance. All of these patients are inflicted with end organ failure and require solid organ transplant as definitive treatment. These patients all undergo very similar if not equivalent testing to ensure that they are suitable as a transplant recipient. Many of these patients also present to surgery on multiple medications to treat many co-morbidities . Lastly, postoperative management is very similar among patients undergoing different solid organ transplant. These patients have to take similar regimens of anti-rejection medications that all have similar side effect profiles and complications.

### 3.2.1 Liver Transplant Recipients

As in the general medical population, lower SES has been shown to be associated with lower survival and increased morbidity following liver transplantation. Through neighborhood income identified by zip-code had no effect on graft or patient survival, those with only an educational attainment level of high school or below experienced a decrease in survival when compared to those with achieved higher education (70.8% vs. 77.6%, P < 0.01) [29]. When stratifying individuals by insurance type, patients with private insurance showed both a higher 5 year patient survival and 5 year graft survival (76.6% p < 0.01 and 67.8% p < 0.01 respectively) compared to those with other methods of insurance ( HMO/PPO, Medicare, Medicaid) [29].

 Access to liver transplant was also heavily correlated to SES. In a studying utilizing the Scientific Registry of Transplant Recipients (SRTR), Quillin and colleagues separated patients into SES quintiles utilizing geographic measure of wealth, income, education, and occupational status. They found that patients in the lowest SES quintile (Q1) were more than likely to be transplanted in low volume centers, which had been shown to have decreased long term survival. Moreover, these patients experienced lower 2 year survival independent of recipient, donor, center, or location variables [30]. Though studies may show various relationships between SES and health disparities in the liver transplant population, we cannot ignore that effects are still prevalent and concerning. Especially since passing the Affordable Care Act 2008, we need to continue to identify these health disparities and eliminate them.

###  3.2.2 Renal Transplant Recipients

The renal transplant population is perhaps the most well studied and recorded transplant community in the US. This is in part due to the databases set forth such as the US Renal Data System which actively records not only patients that undergo kidney transplant but also those with chronic kidney disease (CKD) and end-stage renal disease (ESRD) as well as the UNOS dataset. This plethora of data has led to a number of surprising findings. Despite near universal insurance coverage by Medicare, disparities in access to kidney transplantation as well as outcomes do exist in our health care system. Patients identified in the highest SES quartile had increased access to transplant as well as 14% decreased incidence of death while on waitlist. Higher SES patients were more prone to receiving renal transplants from live donors as well (29.4% vs 13.5%). They experienced lower mortality after receiving either living (77% vs 63% P < 0.0001) or deceased (69% vs 53% P < 0.0001) donor transplant [31].

 These findings regarding effects of SES on outcomes following renal transplant are heavily supported in the literature. Both patients in the US with college (HR=0.93, P < 0.005) and post college education (HR=0.85, P < 0.005) levels had improved graft survival [32]. In addition, patients who had private health insurance showed a significant benefit in graft survival compared to the Medicare reference group (HR=0.87, P < 0.001). These findings are not seen in other health care systems such as in Ireland [33]. This raises a red flag when comparing to the US Healthcare System because though we now have universal healthcare and medication coverage as well, healthcare disparities still plague our system in the same populations.

### 3.2.3 Cardiac Transplant Recipients

The cardiac transplant population can be argued to be the closest transplant population when comparing to its lung counterpart because of the similar preoperative, perioperative, and postoperative management they require. Just like the liver and kidney transplant community, lower SES position who survived transplant hospitalization were more likely to experience graft failure (HR=1.8) [34]. Moreover, rejection episodes were more frequent in this same low SES group. Similar findings are also present in the pediatric cardiac transplant patient in terms of graft failure (HR=2.4) and late rejection (HR=1.8) [35]. In addition to these outcomes, pediatric cardiac transplant patients with low SES was associated with worse outcomes both on the waitlist as well as following surgery. Waitlist mortality was significantly higher in the lower SES group. Patients in the lower SES group also had a higher incidence of medication-treated rejection (p=0.02) as well as non-compliance with immunosuppressive medications ( p < 0.0001) [36]. Though not fully understood in the lung transplant population, we can use these other transplant populations, which show us that indeed effects of SES are present in the US Healthcare System.

# 4.0 LUNG TRANSPLANTATION POPULATION

Looking at the effects of SES in both cardiothoracic surgery and transplant patients gives us the basis for performing this analysis on the lung transplant community. Though these populations have differences, they overlap regarding the workup and management required to treat these patients. Like in other fields, health disparities associated with SES are present in all of these populations. However, even when comparing the SES effects on these populations, there is variation. Because of the variation seen within the literature, identifying the exact effects of SES on the lung transplant community is important to accurately characterize this relationship. Though the literature leaves much to be desired, several pivotal studies have been done to indirectly investigate these findings. Several of these studies many variables that would that do not directly characterize the effects of SES on lung transplant patients but can provide heavy insight. These variables include the LAS score, geographic distribution, insurance status, and medical regimen adherence. In addition to these variables, SES in specific populations, especially those that are inflicted by cystic fibrosis, have been studied more extensively.

## 4.1 The Lung Allocation Score

The Lung Allocation Score (LAS) was implemented by the Organ Procurement and Transplantation Network (OPTN) in May 2005 [37]. Since then it has become the primary method of determining allocation of lungs to individuals > 12 years in the US [38]. The objective for the LAS is the use of an algorithm to rank waitlisted patients in accordance with medical urgency and expected benefit following transplantation. Some argue that improvements in survival following lung transplantation have plateaued in 2005 due to the implementation of the LAS system. Indeed this new method of organ allocation has brought benefits to the field. Since its application, there have been reported to have no difference in survival between whites and non-whites in the historic era (1987-April 2005) and modern era (May 2005-2009) [6]. However, black patients ≥ 18 were less likely to undergo transplantation in the pre-LAS era (56.3% vs 69.2%; OR =0.54; p =< 0.001). After controlling for various variables, this health disparity was not present after 2005 (86.0% vs 86.7%; OR = 1.07; p=0.74). A surprising finding from this analysis was that women were more likely than men to die or become too sick for transplantation within 3 years of listing in the LAS era (16.1% vs 11.3%; OR=1.58; p < 0.001) [7]. From these findings, it is clear that though the LAS score has decreased racial disparities, it may still be associated with other types of health disparities. This variation in effects should be properly characterized so we can better understand exactly what is occurring. It is only after this information is revealed that we can formulate proper solutions to the issues at hand.

## 4.2 Geographic Distribution

Because the bases of the LAS algorithm was expected outcome and medical urgency, it has also improved with disparities associated with some geographic differences. However, it has not fully solved this issue. One lingering issue is the disparity between utilization and access of lung transplantation caused by geographic distribution [39]. Time from waitlist to transplantation as well as survival after transplant were both not associated with distance to the closest center. However, distance of primary residence to nearest transplant center had an inverse relationship with the hazard of being listed both before (HR for 100 miles = 0.870) and after (HR=0.81) LAS implementation [39].

These results may be attributed to the selection bias that naturally occurs at the time of referral to lung transplantation and waitlist evaluation. Patients who have decreased access due to lower SES have already been eliminated prior to any analysis [39]. Those that lived further away had exhibited decreased access to this health service. Though they were unable to attribute this to disparities in SES status, we can speculate this relationship. One sound theory is the fact that lower SES entails having fewer resources such as modes of transportation or funding to access referral services. Because of the additive financial deterrent of further distance, these may all result in decreased access and utilization of lung transplantation services. In a healthcare system that is described as universal, these differences in access should not exist. These disparities must understood more so we can properly address them make available the necessary resources to those that require them.

## 4.3 Insurance Status

Insurance status is been used to link SES and lung transplant recipients [40]. Utilizing the UNOS database, an overwhelming majority (62.4%) of patients utilized private/self-pay insurance compared to Medicare (26.1%) and Medicaid (7.2%) [40]. When looking at the effects of insurance status on mortality, Medicare and Medicaid patients had a 7.0% and 8.1% lower 10 year survival compared to those with private/self-pay insurance. Multivariable analyses identified Medicare (HR=1.10) and Medicaid (HR=1.29) as predictors of increased risk of death. These survival differences persisted even when deaths within the first year of surgery were excluded from the analyses.

Private/self-pay insurance is an indicator of higher SES because of financial resources necessary to purchase such a services. These results indicate that patients with higher SES status have better outcomes following lung transplantation. Moreover, the discrepancy between the number of patients who have private/self-pay insurance compared to Medicare/Medicaid may be an indication that access to lung transplantation may not be equal. These types of discrepancies should not be present in our healthcare system especially after the implementation of the ACA in 2008. The fact that these inequalities are still plaguing our system shows that this needs to be investigated more to find more effective solutions.

## 4.4 Medical Regimen Adherence

One factor that makes any transplant patient unique is the requirement of strict adherence to a whole regimen of medications and clinical follow-up. Because of this, medical regimen adherence has studied as a consequence of lower SES in many medical populations with chronic disease states. Specifically, when compared to lung transplant recipients had a significantly higher nonadherence to not only to completing blood work (28% vs 17%), monitoring blood pressure (70% vs 59%), and spirometry nonadherence (62%) [41]. Moreover, having public insurance such as Medicaid increased patient’s risk of nonadherence in all areas studied. Nonadherence specifically to the necessary and required medications was also more of an issue in the lung transplant population compared to heart transplant recipients [42].

Characterizing SES is very difficult when data is limited so sometimes we may need to find indirect measure of it. Because these are indirect, they may not be able to fully characterize how SES effects access and outcomes following lung transplantation. Adherence to medical regimen and medication is one of the ways we can achieve this. Following up with blood work, testing, and costs of medications not only takes resources but also a financial and personal support system. These things unfortunately become limiting factors for people of lower SES status. However, instead of looking at these factors as limiting, a lower SES may be an identifying factor to find those patients who may require extra assistance or attention in order for them to experience similar results to their higher SES counterparts.

## 4.5 Cystic Fibrosis Population

Cystic fibrosis (CF) is a specific indication of lung transplantation surgery. Many of these individuals are followed through specialized databases. there is an abundance of data available regarding the effects of SES and access and outcomes [43]. Patients from zip codes of residence where the median income was < $20,000 had a 44% increased risk of death compared to patients living in areas with a median income of ≥ $50,000 [43].

 The Epidemiologic Study of Cystic Fibrosis (ESCF) cohort and found that disease severity was inversely correlated with median income of zip code of residence, maternal educational attainment, and eligibility for Medicaid [44]. However, they were unable to find any association between SES and usage of health services or prescription of chronic therapy. Regarding disparities in access to lung transplantation in the CF community, Medicaid recipients had a 1.56 fold increased odds of not being accepted for lung transplantation when compared to patients without Medicaid [45]. This was independent of other SES indicators such as race, educational attainment, zip-code median household income, and distance from transplant center. Moreover, multivariate analysis showed that patients who did not complete high school (OR = 2.37) and those living in zip-codes with the lowest median household income (OR = 1.39) had higher odds of not being accepted for lung transplantation as well [45].

In the same patient cohort, reasons fueling these disparities were found to be Medicaid insurance (OR = 2.27), older age, (OR = 2.48), and lack of high school graduate education (OR = 2.27) were among SES variables identified in a multivariate model to be associated with non-referral patters in the CT population [46]. Because these findings are specific to patients with CF as an indication, these results cannot be directly applied to the general lung transplant population.

## 4.6 Current Analysis

Several of the studies mentioned in sections 4.1-4.5 have merit and provide good insight into how SES effects access and outcomes following lung transplantation. They provide a good basis and rational for further studying the effects of SES in the lung transplant population. Many of these authors agree with the limitations of their studies. Allen et al stated that the ideal analysis would involve income, occupation, and education to directly measure SES rather than using insurance status. Results linking SES to access to and outcomes following lung transplantation in the CF population also cannot be directly applied to the entire general lung transplant population because CF rather one of the more minor indications for lung transplantation when compared to others such as COPD and fibrotic disease.

### 4.6.1 Methods

#### 4.6.1.1 Current Methods of SES Analysis: Design

We performed an ecological study utilizing areal measures to assess SES and access to medical care in the US and their association with outcomes following lung transplantation. This design was chosen because only population-based areal measures of SES, access to care, and diagnosis based mortality and hospitalization discharge were available. The data sources identified for this study included information on the zip code level defined by the U.S. Census Bureau. Data at the zip code level was used due to the incidence of lung transplantation and clinical diagnoses treated by this surgery. IRB approval was obtained prior to the manipulation of the data and the performing of the analysis.

#### 4.6.1.2 Current Methods of SES Analysis: Data Sources

Data was drawn from two sources: the United Network for Organ Sharing (UNOS) Database and the 2010 U.S. Census.

We analyzed data from the United Network for Organ Sharing (UNOS) database to identify recipients who had undergone lung transplantation between May 2005 and December 2014. Patients included in the analysis were those between the ages of 14 and 84 and had received a single, double or re-lung transplant within the study period. Both patient-level data and transplantation center data were provided in a de-identified format. Patients who had undergone a heart-lung transplantation were excluded from the analysis. Primary outcomes include all-cause mortality, 1 and 5 year survival, LOS, as well as SES and access to lung transplantation.

#### 4.6.1.3 Current Methods of SES Analysis: SES Calculation

We acquired data from the 2010 U.S. Census to compute an area based measure of SES based on the six characteristics including: median household income, median value of housing units, percentage of households receiving interest, dividends, or net rental income, percentage of adults 25 years old who had completed high school, percentage of 25 years old who had completed college, and percentage of employed persons 16 years old in executive, managerial, or professional specialty occupations [47]. These area based SES characteristics were used to compute the Diez Roux SES Indicator Score for a geographic location based on the procedure outlined by Diez Roux and colleagues [47]. A z score for each geographic group was estimated by subtracting the overall mean and dividing by the standard deviation. These z scores were all summed up for each variable.

This score is based on the idea of combining multiple area based variables and providing a summary score that can accurately describe the SES of an individual from that given geographic location [48]. In attempt to validate this scoring system, it was observed that area and individual based data had a correlation coefficient of up to 0.8. However, though heterogeneity is still present in the population, when putting several variables together, in this case six, this raises the accuracy of the score. Moreover, this SES scoring system was chosen for our analysis because of its ability to incorporate indicators of SES from all three major categories (income, occupation, and educational attainment.)

**Table 1:** Variables included in the Diez Roux SES score calculation

|  |
| --- |
| Diez Roux Variables |
| * + median household income
	+ median value of housing units
	+ percentage of households receiving interest, dividends, or net rental income
	+ percentage of adults 25 years old who had completed high school
	+ percentage 25 years old who had completed college
	+ percentage of employed persons 16 years old in executive, managerial, or professional specialty occupations
 |

**Table 1** lists all of the variables included in calculating the Diez Roux score. This score was chosen because it not only is very well established in the literature but also includes all SES variables (education, occupation, income, resources) [47]. This SES score was utilized as it has been proven to provide complementary information with individual level SES indicators [48].

### 4.6.2 Results

**Figure 1** depicts the distribution of Diez Roux scores for all zip codes across the US. For the general population, the Diez Roux score computed for all zip codes in the US showed a normal distribution of scores all centered at 0. This is the expected result because of the utilization of a z score calculation in the Diez Roux score calculation. However, when we calculated the Diez Roux score for the lung transplant population, the entire distribution shifts to the right and is no longer centered around 0 (**Figure 2**). The center of distribution of the zip codes of lung transplant recipients is approximately 4.



**Figure 1:** Diez Roux SES score distribution across all US zip codes



**Figure 2:** Diez Roux SES score distribution in the US lung transplant population

### 4.6.3 Discussion

Utilizing the general population of the US, we see that the Diez Roux score indeed was calculated correctly according to the procedure outlined in the literature (**Figure 1**).However, when this score is calculated for the US lung transplant population, the entire distribution is dramatically is no longer centered at zero. This shift to the right indicates that lung transplant recipients in the US are indeed coming from zip codes that are of higher SES status (**Figure 2**). Though we cannot tell exactly which SES variable is causing this shift, it is clear through these results that patients of higher SES are utilizing lung transplant services in the US more frequently.

These results complement those that are in the literature currently. Patients from higher SES areas are more likely to be able to afford private health insurance, which was a major component of lung transplant patients in the US [40]. This should not be the case. These services should be available to those in need of them. The LAS scoring system does a great job identifying that need in those who are referred for the surgery. However, these results along with others in the literature indicate that certain individuals may not even receive a referral or be evaluated with an LAS score because of their lower SES status.

# 5.0 SOLUTIONS

Our analysis as well as the limited findings in the literature support the notion that differences in SES leads to disparities in access and outcomes in the lung transplant community. Though it is necessary to better characterize this relationship, we must being the process of finding solutions to these issues. This process has already been acknowledged, most recently by the American Colleges of Surgeons and the National Institutes of Health- National Institute of Minority Health and Disparities. In May 2015, leading expects from various disciplines categorized these disparities into 5 themes: (1) clinician, (2) patient, (3) systemic/access, (4) clinical quality, and (5) postoperative care and rehabilitation-related factors. Based on the current literature regarding SES and lung transplantation, we can utilize several of these themes to introduce improvements into our current system [49].

## 5.1 Clinician Factors

Clinician re-education may be a route that can prove fruitful in minimizing health disparities caused by SES in lung transplant patients. Major transplant societies such as the International Society for Heart and Lung Transplantation (ISHLT) have set forth guidelines for indications for both heart and lung transplantation. However, in the CT patient population, currently studies have shown a difference in referral pattern in accordance to patients SES. Additions to these guidelines addressing this issue may promote more equal referral patterns and minimize the impact of SES.

 There may be several reasons causing these referral disparities. Knowledge and proper training may be a viable solution to these referral issues. Physicians may not be aware of services in medical centers around them. Moreover, they may not understand or know of protocols that would allow them to refer their patients to alternate hospitals not in their immediate area. Outreach programs from major centers that offer lung transplantation services geared towards recruiting referring clinicians can also decrease the effects of SES on referral and access. These types of outreach programs can promote referral from clinicians who treat lower SES neighborhoods. It will encourage clinicians to offer transplant services to their patient population despite disparities in SES or geographic distance.

## 5.2 Patient Factors

Currently, patient SES variables such as income, educational attainment, and occupation are not a part of the standard battery of information that is collected. Moreover, some patients are not even making it to this step of the whole procedure. Identification of patients of lower SES status who require lung transplantation as treatment for their end-stage pulmonary disease may be the first step in minimizing these health disparities. This step is intertwined with the varying referral patterns that are a part of our healthcare system today. One method of ensuring everyone who needs this surgery is evaluated properly is to create registries all individuals with the correct indications. These types of registries already exist in certain states as well as nationally for specific indications such as CF [43-46]. Expanding these registries and linking statewide databases can help gather information on all of these potentially transplantable patients. This would also encourage primary care physicians to refer patients regardless of SES standing because they are now part of a larger network that can be monitored for quality.

## 5.3 Systematic/Access Factors

The guideline revisions, outreach programs, and nationwide registries mentioned in the previous sections are geared towards relieving any access or systemic factors that may be contributing to health disparities in the lung transplant population fueled by SES differences. However, reinventing the delivery of this service across the country is also a feasible solution. As of June 2015, there are 74 centers in the US performing lung transplantation. A long term solution can be to make more lung transplant fellowships across the country. We will then be able to train more cardiothoracic surgeons with lung transplant surgical skills to open more transplant centers. This may relieve the issue of geographic hindrances that may cause physician referral patterns to decrease. Changes in guidelines may also be needed to favor patients of lower SES status. Because they are more prone to increased morbidity, mortality, and non-referral, guidelines highlighting these patients may help equalize these outcomes by making physicians and medical staff more aware of these patients.

 Restructuring reimbursement criteria for patients with lung transplant indications may also help for those with lower SES. Currently, renal transplantation is fully covered under Medicare for those with end-stage renal disease, those over 65, or disabled individuals. However, this is not the case for end-stage pulmonary disease. The criteria is much more stringent which is why the insurance patterns are as reported with over 60% of lung transplant recipients paying with private/self-pay insurance [40]. This restructuring can mirror what is already in place for other types of transplant patients such as renal.

## 5.4 Postoperative Care and Rehabilitation-Related Factors

With the several suggestions mentioned previously, we believe we can take a step forward in eliminating SES effects on outcomes following lung transplantation. As previously state, any organ transplant population requires extra follow-up, postoperative care, and rehabilitation support. Because of the regimen of anti-rejection medications and steroids necessary post-transplant, these patients are even more susceptible to complications. Protocols education patients on their medical regimen which includes clinic visits, laboratory and imaging testing, and medication, may help patients understand the importance of adhering to it. As mentioned previously, identifying those patients who are at risk of medical regimen nonadherence may very well help improve outcomes in the lung transplant field [41]. Applications either on the phone or tablet have been studied in the literature to help with continued monitoring in surgical patients. Implementations of these applications specifically for these patients identified as at risk of nonadherence may help promote consistence and eliminate health disparities in the lung transplant population. Lastly, others suspected several reasons including the financial stress and burden that accompanies the rehabilitation and management of lung transplant recipients after surgery [41]. Restructuring of reimbursement for patients without private/self-pay insurance can help patients at risk of nonadherence.

# 6.0 CONCLUSION

The acknowledgement that the effects of SES influence medical populations is a starting point. Since the implementation of the ACA in 2008, measures should have been put in place to eliminate these disparities within our healthcare system. We are fortunate that a handful of individuals have already started to unfold the complicated association between the effects of SES on access and outcomes following lung transplantation. Nonetheless, there are so many more things we need to learn before we can implement plans to solve these issues.

Insurance status and geographic location are very good indirect SES indicators that can be studied efficiently. A more in-depth analysis of SES on access and outcomes in CF patients can provide us with limited insight into the lung transplantation. However, from the literature regarding other transplant populations, we see that every SES component effects are completely different from one another. Therefore these results can only provide us with inferences and suggestions regarding the general lung transplant population. From our limited analysis, we see a shift in the general lung transplant population favoring higher SES status. The next step will be to see what is fueling this shift and how it is affecting outcomes in the patients. Only after uncovering these factors can we propyl implement administrative changes and clinical pathways to not only better the care for future patients but make these services more widely available to the public despite any kind of SES and demographic difference.

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