DOI: 10.1002/pul2.12427

RESEARCH ARTICLE

Pulmonary Circulation Open Access | PVRI | WILEY

Pretransplant NT-proBNP levels are associated with mortality among lung transplant recipients

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Funding information
None

Abstract

The prognostic significance of pretransplant N-terminal pro-brain (B)-type natriuretic peptide (NT-proBNP) level has not been investigated in lung transplant recipients. The electronic files of 173 patients with chronic lung disease who underwent lung transplantation in 2018–2022 at a tertiary medical center were retrospectively reviewed. Right heart catheterization (RHC) and NT-proBNP determination were performed preoperatively in all cases. Pretransplant demographic, clinical, and laboratory data were compared between posttransplant survivors and nonsurvivors. Correlations of NT-proBNP values with lung function and RHC parameters and all-cause mortality were analyzed. NT-proBNP level correlated positively with mean pulmonary artery pressure ($R = 0.51$, $p < 0.001$) and pulmonary vascular resistance (PVR) ($R = 0.45$, $p = 0.0013$), and negatively with diffusing lung capacity for carbon monoxide ($R = -0.25$, $p = 0.0017$), cardiac index ($R = -0.26$, $p = 0.001$), and cardiac output ($R = -0.23$, $p = 0.004$). Over a median follow-up time of 23.22 months, 74 patients died. On univariate analysis, mortality was significantly associated with higher log-NT-proBNP (hazard ratio [HR] = 0.54, 95% confidence interval [CI] 1.15–2.05, $p = 0.016$), older age at transplant registration (HR = 1.033, 95% CI 1.009–1.058, $p = 0.0068$), higher PVR (HR 1.15, 95% CI 1.07–1.23, $p = 0.015$), and lower cardiac output (HR = 0.62, 95% CI 0.42–0.92, $p = 0.045$). On multivariate analysis adjusted for age, sex, and body mass index, mortality significance was maintained only for higher log-NT-proBNP (HR = 1.54, 95% CI 1.12–2.11, $p = 0.007$). Among lung transplant recipients, pretransplant NT-proBNP levels correlated well with RHC parameters and were strongly associated with posttransplantation mortality. Assessment of NT-proBNP may improve risk stratification of lung transplant candidates.

KEYWORDS
lung transplantation, mortality, N-terminal pro-B-type, prognosis, survival

INTRODUCTION

Brain (B-type) natriuretic peptide (BNP) is a pivotal component of the natriuretic peptide system.[1–3] Primarily synthesized in myocytes, BNP plays a crucial role in maintaining cardiovascular homeostasis by exerting diuretic, natriuretic, and vasodilatory effects.[1–3] Its release is triggered by myocardial stretch resulting from pressure overload or volume expansion.[1–3] Elevated BNP levels are observed in conditions such as myocardial dysfunction, pulmonary arterial hypertension, and hypoxemia, reflecting its responsiveness to these cardiovascular stressors.[2–6]

N-terminal pro-BNP (NT-proBNP) is the circulating fragment representing biologically active BNP within the bloodstream.[1–3] The assessment of plasma NT-proBNP has emerged as a valuable tool for risk stratification and disease management, particularly in patients with World Health Organization (WHO) group I pulmonary hypertension (PH)[5,6] and WHO group II PH (attributable to left heart disease).[4,5] Furthermore, a limited number of studies also revealed associations of elevated NT-proBNP levels with the presence of PH within the context of chronic lung diseases (WHO group III)[7–11] as well as with an increased risk of death.[8–10,12] Our previous study showed that the assessment of NT-proBNP level may improve risk stratification of lung transplant candidates.[13] However, its prognostic role in lung transplant recipients has not been investigated.

The aims of the present study were to evaluate correlations between pretransplant NT-proBNP levels and parameters of pulmonary function tests (PFTs) and right heart catheterization (RHC) in lung transplant recipients as well as associations of NT-proBNP levels with all-cause mortality.

PATIENTS AND METHODS

Subjects

An observational study was conducted at a tertiary university medical center, which has served as the national center for lung transplantation since 1997. The electronic medical records were reviewed for all patients who underwent lung transplantation from January 2018 to December 2022 due to chronic lung disease. Only those evaluated preoperatively for both RHC and NT-proBNP determination were included. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Ethics Committee.

Methods

Pretransplantation evaluation

The study participants were routinely placed on the lung transplantation waiting list in accordance with the guidelines of the International Society for Heart and Lung Transplantation.[14] RHC and plasma NT-proBNP testing were conducted before placement on the list. Plasma NT-proBNP levels were analyzed within 8 h after venous blood sampling using a commercially validated high-sensitivity immunoassay (Elecsys® proBNP Cobas e602 analyzer, Roche Diagnostics).[15] The lower limit of NT-proBNP detection by this assay is 5 pg/mL, with an intra-assay coefficient of variation of <10%.[14] NT-proBNP reference values are 5–450 pg/mL. The transplant candidates were followed in the ambulatory clinic every 3–4 months on average. At each visit, a detailed medical interview, physical examination, and PFTs were performed. Computed tomography (CT) of the chest and echocardiography were routinely performed every 12 months.

Posttransplantation evaluation

Lung transplant recipients underwent routine evaluations at the hospital's ambulatory clinic at 2 and 4 weeks following transplantation and every 2–3 months on average thereafter. More frequent visits were scheduled as needed. Follow-up assessments included a detailed medical interview, physical examination, PFTs, and chest X-ray. Chest CT was routinely performed 6 and 12 months following transplantation and annually thereafter. The follow-up period concluded on August 30, 2023.

Data collection

Data were collected for each patient during the prelisting period for lung transplantation. The parameters collected included age, sex, reasons for lung transplantation, body mass index (BMI), plasma NT-proBNP level, 6-min walk test distance (6MWD), and findings on PFTs and RHC. The recorded PFT parameters included forced expiratory volume in 1 s (FEV1), forced vital capacity (FVC), FEV1/FVC ratio, total lung capacity, residual volume, and diffusing lung capacity for carbon monoxide (DLCO). RHC parameters included mean pulmonary artery pressure (MPAP), pulmonary capillary wedge pressure, cardiac index (CI), cardiac output (CO), and pulmonary vascular resistance (PVR). Vital status was documented through the hospital's electronic medical records and the Ministry of Internal Affairs registry. The primary outcome of the study was all-cause mortality following lung transplantation.

Statistical analysis

The results were summarized as mean and standard deviation for quantitative data and number and percent for qualitative data. Categorical variables were compared using χ^2 test, and continuous variables, using Student's *t*-test. Log transformation was applied to compare variables that did not follow a Gaussian distribution (log-NT-proBNP). The Spearman correlation coefficient (R) was calculated to assess the correlation of NT-proBNP levels with PFT and RHC parameters and 6MWD. Univariate analysis was performed to assess associations of recorded variables with mortality. $p \leq 0.05$ were considered significant. Demographic and clinical parameters were categorized according to NT-proBNP reference values. However, given that NT-proBNP levels vary by sex, BMI, and age, we adjusted for these factors in our multivariate analysis. Statistical analyses were performed using SAS software, version 9.4 (SAS Institute Inc.).

RESULTS

Patient characteristics

During the study period, 174 patients underwent lung transplantation, of whom one lacked NT-proBNP data and was excluded from the analysis. The mean age was 58.6 ± 11.7 years; 130 patients (75.1%) were male. The most common reasons for lung transplantation were idiopathic pulmonary fibrosis and chronic obstructive pulmonary disease (Table 1).

NT-proBNP level was ≤450 pg/mL in 148 patients and >450 pg/mL in 23. Patients with levels of >450 pg/mL were more likely to have higher pre-transplant values of FEV1% ($p = 0.04$) and FVC% ($p < 0.001$) and lower levels of DLCO ($p = 0.004$), higher values of MPAP ($p < 0.001$), and lower levels of CI ($p = 0.01$) (Table 1).

On Spearman's correlation analysis (Table 2), NT-proBNP levels correlated positively with MPAP ($R = 0.51$, $p < 0.001$) and PVR ($R = 0.45$, $p = 0.001$), and negatively with DLCO ($R = -0.25$, $p = 0.001$), CI ($R = -0.26$, $p = 0.001$), and CO ($R = -0.23$, $p = 0.004$).

Survival analysis

Short-term survival

During a 3-month follow-up, 22 patients died after lung transplantation. On univariate analysis, log-NT-proBNP was significantly associated with mortality (hazard ratio [HR] 1.57, 95% confidence interval [CI] 1.08–2.28, $p = 0.016$). On multivariate analysis adjusted for potential confounders of age, sex, and BMI, a higher log-NT-proBNP level (HR 1.71, 95% CI 1.09–2.67, $p = 0.01$) was the sole variable most significantly associated with mortality.

The main causes of death within 3 months post-transplantation were primary graft dysfunction ($n = 6$), pneumonia ($n = 5$), multiorgan failure ($n = 3$), unknown causes ($n = 3$), colon perforation ($n = 3$), gall bladder perforation ($n = 1$), and major bleeding ($n = 1$).

Long-term survival

During a median follow-up of 23.22 months (interquartile range: 9–38), extending up to 64 months, 74 lung transplant recipients (42%) died. The following variables were significantly associated with mortality: log-NT-proBNP (HR 1.54, 95% CI 1.15–2.05, $p = 0.016$), older age at lung transplant registration (HR 1.033, 95% CI 1.009–1.058, $p = 0.0068$), higher PVR (HR 1.15, 95% CI 1.07–1.23, $p = 0.015$), and lower CO (HR 0.62, 95% CI 0.42–0.92, $p = 0.045$). On multivariate analysis adjusted for potential confounders of age, sex, and BMI, a higher log-NT-proBNP level (HR 1.54, 95% CI 1.12–2.11, $p = 0.007$) was the sole variable most significantly associated with mortality.

The main causes of death from 3 months post-transplantation until the end of follow-up were primary CLAD ($n = 19$), pneumonia ($n = 8$), COVID-19 infection ($n = 8$), chronic renal failure ($n = 4$), malignancy ($n = 3$), unknown causes ($n = 3$), acute lung rejection ($n = 2$), colon perforation ($n = 1$), liver failure ($n = 1$), urinary tract infection ($n = 1$), skin infection ($n = 1$), and brain abscess ($n = 1$).

DISCUSSION

To the best of our knowledge, the prognostic significance of pretransplant NT-proBNP testing has not been studied in lung transplant recipients. The main novelty of the present study is the association shown between pre-transplant NT-proBNP levels and all-cause post-transplant mortality. An association of elevated BNP values with increased mortality was previously reported in a general population of patients with chronic lung diseases[9] and in patients with specific pulmonary disorders such as interstitial lung disease[8,10] and chronic obstructive pulmonary disease.[12]

The pathophysiologic mechanisms responsible for BNP elevation in chronic lung diseases are not completely understood. Right ventricular overload has

TABLE 1 Baseline characteristics of lung transplant recipients according to NT-proBNP level.

Characteristic	Entire group ($n = 173$)	NT-proBNP >450 ($n = 23$)	NT-proBNP ≤ 450 ($n = 148$)	p Value[a]
Age (years)	58.67 ± 11.79	60.45 ± 12.59	58.40 ± 11.68	0.35
Male sex	130 (75.14%)	20 (86.96%)	110 (74.32%)	0.29
Body mass index (kg/m^2)	26.31 ± 5.06	26.67 ± 4.55	26.26 ± 5.15	0.72
Reason for transplantation				
Pulmonary fibrosis	91 (52.60%)	11 (47.83%)	79 (53.38%)	0.13
COPD	39 (22.54%)	6 (26.09%)	33 (22.3%)	
Primary pulmonary hypertension	2 (1.16%)	2 (8.7%)	0 (0%)	
Bronchiectasis	8 (4.62%)	1 (4.35%)	7 (4.73%)	
Scleroderma	7 (4.05%)	1 (4.35%)	6 (4.05%)	
Silicosis	7 (4.05%)	0 (%)	7 (4.73%)	
Other	19 (10.98%)	2 (8.7%)	16 (10.81%)	
6-min walk test distance (m)	289.29 ± 131.43	237.94 ± 156.69	296.0 ± 126.9	0.13
Lung function tests				
FEV1 (% of predicted value)	44.01 ± 20.31	53.59 ± 24.09	42.56 ± 19.37	**0.04**
FVC (% of predicted value)	50.32 ± 18.34	62.32 ± 19.65	48.51 ± 17.50	**<0.001**
FEV1/FVC ratio	0.72 ± 0.23	0.68 ± 0.20	0.72 ± 0.23	0.22
TLC (% of predicted value)	73.96 ± 35.15	80.43 ± 28.31	72.99 ± 36.05	0.12
RV (% of predicted value)	123.57 ± 95.7	125.29 ± 81.02	123.31 ± 98	0.58
DLCO (% of predicted value)	34.47 ± 14	28.76 ± 18.51	35.38 ± 12.99	**0.004**
Right heart catheterization				
MPAP (mmHg)	25.57 ± 10.69	37.11 ± 15.54	23.97 ± 8.79	**<0.001**
PCWP (mmHg)	10.25 ± 6.75	11.83 ± 8.08	10.03 ± 6.55	0.42
CI (1/min/m^2)	2.41 ± 0.57	2.06 ± 0.45	2.46 ± 0.57	**0.01**
CO (1/min)	4.48 ± 1.26	3.72 ± 0.93	4.59 ± 1.27	**0.007**
PVR (WU)	4.0 ± 3.77	7.07 ± 5.69	3.54 ± 3.18	**0.007**

Note: Data are presented as means ± standard deviations or numbers (percentages) of presented cases.

Abbreviations: CI, cardiac index; CO, cardiac output; DLCO, diffusing lung capacity for carbon monoxide; FEV1, forced expiratory volume in one second; FVC, forced vital capacity; MPAP, mean pulmonary artery pressure; NT-proBNP, N-terminal pro-brain-type natriuretic peptide; PCWP, pulmonary capillary wedge pressure; PVR, pulmonary vascular resistance; RV, residual volume; TLC, total lung capacity; WU, Wood units.

[a]Bold entries in the table indicate $p \leq 0.05$.

been suggested, attributable to PH from the underlying pulmonary disease.[7,9,11,12] PH in chronic lung diseases may result from hypoxia, inflammation, and thromboembolism.[12] Another potential mechanism is left ventricular dysfunction stemming from comorbidities such as hypertension, coronary artery disease, and cardiac arrhythmias.[12] None of our patients exhibited left heart failure. Thus, in our patient population, the elevated NT-proBNP levels were most likely a consequence of right ventricular dysfunction and PH secondary to severe chronic lung disease. Indeed, we observed a strong correlation of pretransplant NT-proBNP values with RHC parameters, indicating PH and right heart failure.

The correlation of BNP with RHC indices has been well-established for WHO PH groups I and II,[4–6] but information is limited for patients with PH in the context of chronic lung diseases (WHO group III), which affected the present cohort.[7,9–11] Our findings support previous reports of a positive correlation of BNP levels with MPAP[7,9–11] and PVR,[7] and negative correlations with CI and CO.[7]

TABLE 2 Correlations of NT-proBNP levels with other baseline parameters in lung transplant recipients.

Parameter	*R*	*p* Value[a]
6-min walk test distance (m)	−0.09	0.2
Data on lung function test		
FEV1 (% of predicted value)	0.12	0.1
FVC (% of predicted value)	0.22	**0.002**
TLC (% of predicted value)	0.05	0.46
DLCO (% of predicted value)	−0.25	**0.001**
Data of right heart catheterization		
MPAP (mmHg)	0.51	**<0.001**
PCWP (mmHg)	0.036	0.65
CI (1/min/m^2)	−0.20	**0.02**
CO (1/min)	−0.26	**0.001**
PVR (WU)	0.45	**<0.001**

Abbreviations: CI, cardiac index; CO, cardiac output; DLCO, diffusing lung capacity for carbon monoxide; FEV1, forced expiratory volume in 1 s; FVC, forced vital capacity; MPAP, mean pulmonary artery pressure; NT-proBNP, N-terminal pro-brain-type natriuretic peptide; PCWP, pulmonary capillary wedge pressure; PVR, pulmonary vascular resistance; TLC, total lung capacity; WU, Wood units.

[a]Bold entries in the table indicate $p \leq 0.05$.

Also unclear are the pathophysiologic mechanisms responsible for the strong association of higher pretransplant NT-proBNP levels with mortality in lung transplant recipients. The magnitude of the elevation in NT-proBNP may reflect the baseline severity of the PH and right ventricular dysfunction, posing an increased risk of death after transplantation.

Since 2023, lung allocation for transplantation in the United States has primarily relied on a composite allocation score (CAS),[16] calculated from estimates of survival probability during the wait for transplantation and its aftermath. Factors used to predict posttransplant survival include recipient age, values of pulmonary artery systolic pressure and CI, 6MWD, serum creatinine level, functional status, and underlying diagnosis.[16] NT-proBNP is not currently included in the CAS, and the prognostic value of pretransplant NT-proBNP has not been investigated in lung transplant recipients. The present study shows, for the first time, that pretransplant assessment of NT-proBNP may be a useful tool for risk stratification of lung transplant recipients. Further investigation is warranted to determine whether incorporation of NT-proBNP in the CAS could enhance decision-making regarding lung transplant allocation.

The use of this biomarker has advantages and pitfalls. The advantages of NT-proBNP testing include easy assessment through fully automatic analysis in addition to faster availability and lower costs compared to other modalities such as echocardiography and RHC. The disadvantages include a tendency for NT-proBNP values to increase with age, to be higher in women than men, and to be lower in patients with obesity.[15,17,18] To address these issues, we conducted a multivariate analysis incorporating age, sex, and BMI. The results showed that NT-proBNP remained a powerful biomarker for increased mortality.

The present investigation has several limitations. First, the retrospective design limits our ability to establish a definitive causal relationship between NT-proBNP levels and mortality. Second, the relatively small sample size and reliance on a single pretransplant NT-proBNP measurement may have influenced the results. To fully support our hypothesis and strengthen our conclusions, larger studies are needed. Specifically, separating variables between different end-stage lung disease groups, including PH, could provide more detailed and refined insights. Third, the study was conducted at a single medical center, which may affect the generalizability of the findings.

The main strength of our study is the inclusion of patients with a variety of end-stage lung diseases, reflecting worldwide indications for lung transplantation; thus, these findings may be generalizable to other medical centers. Another strength is the completeness of the collected data for RHC, which was performed in all patients.

In conclusion, among lung transplant recipients, higher pretransplant NT-proBNP levels correlate well with RHC parameters and are strongly associated with an increased risk of all-cause mortality following lung transplantation. We suggest that pretransplant NT-proBNP level could serve as a novel prognostic biomarker for lung transplant recipients. Its assessment may improve risk stratification for waitlisted lung transplant candidates before and after transplantation.

AUTHOR CONTRIBUTIONS

Conceptualization and methodology: Shimon Izhakian and Mordechai R. Kramer. *Data curation*: Shimon Izhakian, Osnat Shtraichman, Alon Gorenshtein, Dror Rosengarten, and Assaf Frajman. *Validation*: Shimon Izhakian, Ariel D. Hayat, Alon Gorenshtein, Lev Freidkin, and Mordechai R. Kramer. *Formal analysis*: Shimon Izhakian, Osnat Shtraichman, Lev Freidkin, Ariel D. Hayat, Dror Rosengarten, Assaf Frajman, and Mordechai R. Kramer. *Writing—original draft preparation*: Shimon Izhakian, Ariel D. Hayat, Alon Gorenshtein, Lev Freidkin, and Mordechai R. Kramer.

ACKNOWLEDGMENTS

Shimon Izhakian and Mordechai R. Kramer are the guarantors of this work and, as such, had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. The authors have no funding to report.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

ETHICS STATEMENT

This material is the authors' own original work, which has not been previously published elsewhere. The paper is not currently being considered for publication elsewhere. The paper reflects the authors' own research and analysis in a truthful and complete manner. The paper properly credits the meaningful contributions of co-authors and co-researchers.

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How to cite this article: Izhakian S, Frajman A, Hayat AD, Gorenshtein A, Shtraichman O, Freidkin L, Rosengarten D, Kramer MR. Pretransplant NT-proBNP levels are associated with mortality among lung transplant recipients. Pulm Circ. 2024;14:e12427. https://doi.org/10.1002/pul2.12427