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폐이식 환자에서 심장 리모델링이 원발성 이식편 장애에 미치는 영향: 정상 대조군과의 비교

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지도교수 구현정

이 논문을 의학석사학위 논문으로 제출함

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울산대학교 대학원
의학과
최재연

최재연의 의학석사학위 논문을 인준함

심사위원 양 동 현 인
심사위원 구 현 정 인
심사위원 박 지 은 인

울산대학교 대학원
2024 년 2 월

영문요약

Cardiac remodeling and its effect on primary graft dysfunction in lung transplantation patients: Comparison with healthy subjects

Author: Jaeyeon Choi, MD. Department of Radiology and the Research Institute of Radiology, University of Ulsan College of Medicine, Asan Medical Center.

Background: This study aimed to investigate preoperative cardiac functions in lung transplant patients, compare them to healthy individuals, and evaluate differences in cardiac function between patients with and without primary graft dysfunction (PGD).

Methods: Thirty-three patients who received lung transplantation between August 2019 and April 2023 and underwent preoperative multiphase cardiac CT were retrospectively included. Forty-nine healthy individuals, matched by age, sex, and body surface area, who had undergone cardiac CT screening were also included. PGD was assessed with postoperative chest x-rays and the PaO2/FiO2 ratio. CT-derived cardiac function and strain between patients and healthy controls were compared. Patients were divided into those with and without grade 3 PGD, and cardiac function and strain were compared between these two subgroups. Changes in cardiac function and strain were evaluated in patients with both preoperative and postoperative cardiac CT.

Results: Patients awaiting lung transplantation showed larger right ventricular (RV) volume and reduced RV global longitudinal strain and free wall strain (-19.12 vs. -15.00, $P<0.001$, -24.10 vs. -18.03, $P<0.001$) compared to healthy controls. Those with grade 3 PGD had a

preoperative reduction in the RV free wall strain (-19.51 vs. -15.76, P=0.024) and a significant decrease in left atrial (LA) reservoir strain (27.83 vs. 19.88, P=0.033), compared to those without grade 3 PGD. Decreases in left ventricle (LV), LA, and RV volume were noted after lung transplantation.

Conclusions: Preoperative ventricular function and strain were reduced in lung transplant patients. Preoperative RV and LA strain were reduced in patients who developed grade 3 PGD.

Keywords: Cardiac remodeling; Lung transplantation; Primary graft dysfunction; Cardiac strain; Computed tomography

목차

표 및 그림 차례

서론

Since the heart and lungs are interconnected, patients undergoing lung transplantation due to lung disease may experience changes in heart function, even when no underlying heart disease is present. Chronic lung disease may be accompanied by pulmonary hypertension which, if severe, should lead to consideration of a heart-lung transplantation (1). Therefore, it is advisable to perform lung transplantation before cardiac changes become apparent. Even before the onset of pulmonary hypertension, gradual changes in cardiac function are inevitable. These progressive changes in cardiac function may impact the patients' prognosis, even after a successful lung transplantation, especially in cases of primary graft dysfunction (PGD) occurring within 72 hours post lung transplantation (2-6).

We aim to assess how changes in cardiac function before lung transplantation in patients with normal echocardiography results differ from those in healthy individuals matched by age, sex, and body surface area. Additionally, we intend to evaluate the differences in cardiac function, using CT strain, between patients who develop PGD and those who do not develop PGD after lung transplantation.

연구대상 및 연구방법

Patients and Clinical setting

This retrospective study was conducted with the approval of the Asan Medical Center's Institutional Review Board (approval number: 2022-1549). The need for patients' informed consent was waived due to the retrospective nature of the study. Between August 2019 and April 2023, a total of 72 patients received lung transplantation at a tertiary referral medical center. Cardiac CT imaging was not feasible in patients with critical conditions or those who had undergone emergency surgery, and they were excluded from the study. Patients who had undergone a living donor lobar transplantation, heart-lung transplantation, or liver-lung transplantation were also excluded. Those with a history of cardiovascular disorders that resulted in an enlarged heart, and those with other structural cardiac abnormalities were not included. Out of these, cardiac CT scans were performed on 33 patients before lung transplantation, and their cardiac functions and CT-strain were analyzed (Figure 1). Among them, 13 patients had post-transplant cardiac CT scans within three months from the date of transplantation, allowing for a comparison of CT strain values before and after transplantation. Grade 3 primary graft dysfunctions within 72 h after lung transplantation were recorded, defined by the presence of radiographic infiltrates indicating pulmonary edema and a PaO2/FiO2 ratio of <200 (7-9).

To compare lung transplant patients with healthy individuals, we retrospectively collected multiphasic cardiac CT data from the healthy subjects. From March 2014 to August 2014, 49 healthy individuals, matched by age, sex, and body surface area (matching 1:1.5), who had visited the health screening center of a tertiary hospital and had undergone a multiphase cardiac CT were found to have no coronary artery stenosis and were included in the study.

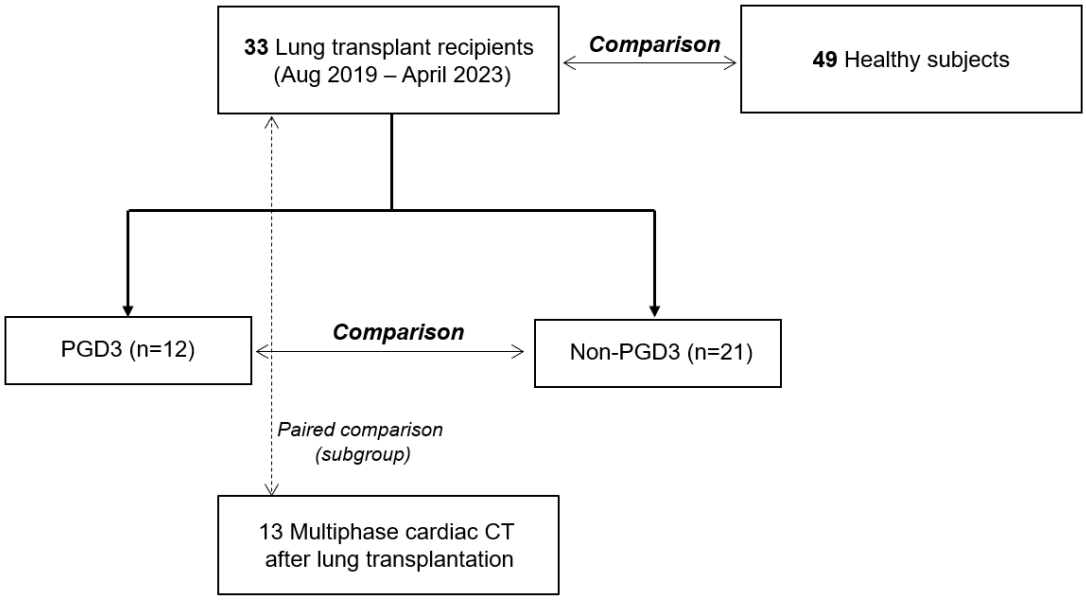


Figure 1. Patient flowchart

Cardiac CT acquisition

Retrospective electrocardiography (ECG)-gated cardiac CT scans were carried out with a second-generation dual-source CT scanner (Somatom Definition Flash, Siemens, Erlangen, Germany). An oral dose of 2.5 mg bisoprolol (Concor, Merck, Darmstadt, Germany) was administered one hour before the CT scan if a patient's heart rate exceeded 75 beats/min, and beta blockers were not contraindicated. Two puffs of oral isosorbide dinitrate (2.5 mg, Isoket Spray; UCB Pharma, Monheim, Germany) were administered to achive optimal coronary artery dilatation. ECG-based tube current modulation was applied during the scan. A bolus of 60–70 mL contrast media was injected at a rate of 4.0 mL/s, followed by a saline flush. The imaging parameters included a beam collimation of 128 × 0.6 mm^2; a gantry rotation time of 280s; tube voltage ranging from 80 to 120 kV; and a tube current–exposure time product of 185–380 mA, with automated dose modulation (CARE dose 4D; Siemens). Image reconstruction was performed using a standard cardiac filter with a smooth convolution kernel (B26f) and slices of 3 mm thickness without interslice gaps. The image sets were reconstructed at every 10% interval throughout the R-R interval, and the multiphase cardiac CT data were transferred to commercial software (Medis) for post-processing.

Measurement of CT-derived Cardiac Strain

To assess the LV strain, reconstruction images in 4-, 2-chamber long-axis, and short-axis views were generated from multiphase data using post-processing with Medis 3D view software. The Qmass package (version 8.1) was employed to automatically outline the endocardial and epicardial contours, which were manually adjusted from the mitral annulus to the cardiac apex during both end-diastolic (when the LV cavity is largest) and end-systolic (when the LV was the minimum size of the LV cavity) phases. Papillary muscles and trabeculations were excluded from the myocardium. Subsequently, LV myocardial borders were automatically tracked throughout the entire cardiac cycle, and LV strain values were computed using the QStrain package (version 4.1). The following LV strain parameters were obtained: global longitudinal (GLS), circumferential strain (GCS), and radial strain (GRS), segmental values (based on the 17-segment model of the American Heart Association) of the

longitudinal and transverse strains of the endocardium derived from the long-axis images, and segmental values for radial and circumferential strains derived from the short-axis images.

For RV measurement, the endocardial contour was manually delineated from the tricuspid annulus to the apex in a 4-chamber long-axis image. RV GLS, free wall strain, and fractional area change (FAC) were obtained. To evaluate the LA strain, the LA endocardial wall was manually outlined during both the end-diastolic and end-systolic phases in a 2-chamber long-axis image excluding the LA appendage and pulmonary veins from the selection of the LA endocardial border. The LA reservoir strain as the average peak longitudinal strain on a 2-chamber view, LA pump strain as the second peak point on the cardiac cycle-strain curve, and LA conduit strain as the difference between LA reservoir strain and LA pump strain were obtained. LA volume, LA FAC and ejection faction (EF) were also computed. Finally, for the RA strain, the RA endocardial wall was drawn, excluding the RA appendage. RA GLS was measured during the RA reservoir phase. RA volume, RA FAC and EF were also obtained. A trained radiology technician performed initial adjustments to confirm the accuracy of endocardial and epicardial margins.

Additionally, two board-certificated radiologists, each with 5 and 11 years of experience in cardiovascular radiology, independently reviewed the margins before performing the strain analysis and made manual corrections if necessary

Statistical analysis

Continuous data were noted as the medians and interquartile ranges, and categorical values were reported as numbers and percentages. The evaluation of PGD on postoperative serial chest radiographs was independently conducted by two expert radiologists, and the Kappa interobserver agreement was calculated. In cases of discordant assessment between the two radiologists, a consensus was reached to determine the final decision. Cardiac function and strain values obtained from both healthy individuals and patients with impending lung transplantation were compared using a Student t-test. In the lung transplant patient group, the patients were divided into two subgroups: those with grade 3 PGD (n=12) and those without (n=21). Differences in cardiac function and strain values

before lung transplantation were analyzed using the Mann-Whitney U test between these two subgroups. Additionally, for 13 patients who underwent lung transplantation, cardiac CT was performed before and after the surgery, and changes in cardiac function and strain were analyzed using the Wilcoxon signed-rank test for the paired data.

연구결과

Patients facing lung transplantation vs. Healthy subjects

In a cohort of 33 patients who underwent lung transplantation, there was a male predominance (78.8%, n=26). The underlying disease leading to lung transplantation, along with clinical findings, are presented in Table 1. The interobserver agreement for PGD evaluation using serial radiographs after lung transplantation showed a good agreement with kappa = 0.719 (P<0.001). Grade 3 PGD was observed in 12 (36.3%) patients. The interval between lung transplantation and preoperative cardiac CT was a median of 112 (30 – 224) days. Among the 13 patients who underwent postoperative cardiac CT, the median interval between surgery and cardiac CT was 19 (15 – 22) days.

When compared to healthy subjects (n=49), patients awaiting lung transplantation exhibited a larger RV volume and reduced RV GLS (-19.12 vs. -15.00, P<0.001) and free wall strain (-24.10 vs. -18.03, P<0.001) (Table 2, Figure 2). There were no significant differences between the two groups in terms of RA EF (39.33% vs. 42.58%, P=0.061), as well as RA volume and GLS (P>0.05). LA parameters also showed no significant differences (P>0.05). In contrast, LV volume was reduced in patients requiring lung transplantation (LV EDV, 130.33 ml vs. 121.10 ml, P=0.044; LV ESV, 58.95 ml vs. 47.01 ml, P<0.001), and LVEF was within the normal range but slightly increased (54.27 ml vs. 59.9 ml, P<0.001). LV GLS was found to be slightly decreased in the lung transplant patient group but was noted to be within the normal range (-19.21 vs. -18.15, P=0.001).

Table 1. Patient characteristics

Characteristics	Patients (n=33)
Age, year	60.00 (51.00 – 63.00)
Male : Female	26 (78.8) : 7 (21.2)
Body surface area, kg/m^2	1.70 (1.59 – 1.84)
Diabetes mellitus, n (%)	8 (24.24)
Hypertension, n (%)	8 (24.24)
Tuberculosis, n (%)	5 (15.16)
Alcohol, n (%)	16 (48.48)
Smoking, n (%)	

Nonsmoker	12 (36.36)
Ex-smoker	20 (60.61)
Current smoker	1 (3.03)
Pack year	10.00 (0.00 – 30.00)
Blood urea nitrogen, mg/dL	14.00 (13.00 –18.00)
Creatinine, mg/dL	0.56 (0.45 – 0.90)
Pre-existing lung disease, n (%)	COPD 5 (15.2)
	ILD 25 (75.8)
	Pneumoconiosis 1 (3.0)
	Diffuse panbronchiolitis 1 (3.0)
Pump time, min	294.00 (271.50 – 305.50)
Red blood cell transfusion, ml	1500 (1000 – 2250)
ICU stay, day	18.00 (12.50 – 22.00)
Ventilator use, day	7.00 (4.00 – 17.50)
Grade 3 PGD	12 (36.3)

ICU, intensive care unit; PGD, primary graft dysfunction

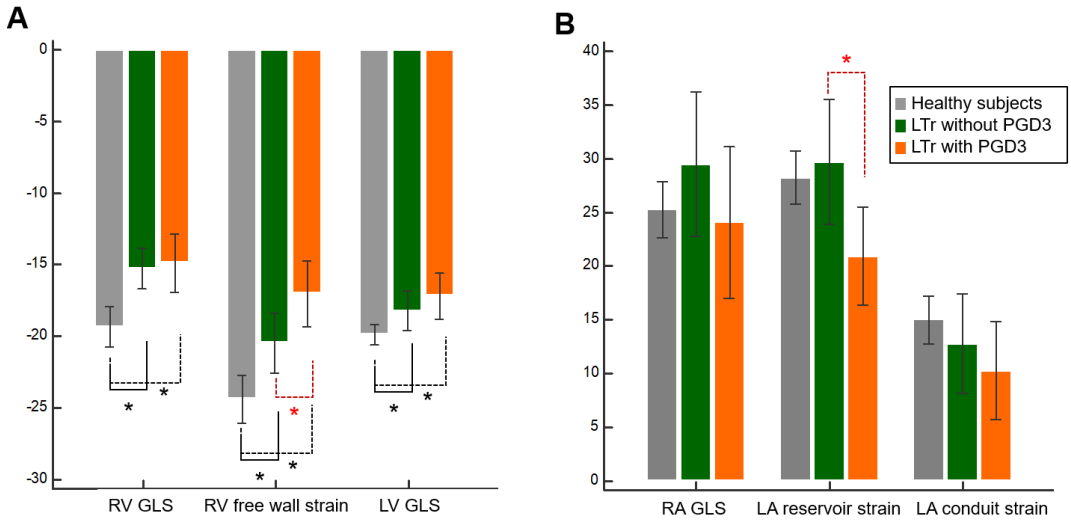
Table 2. Comparison of CT-derived cardiac function and strain values obtained from patients facing lung transplantation and from healthy individuals.

Parameter	Healthy subjects (n=49)	Preoperative lung transplantation (n=33)	*P-value*
Age, year	53.51 ± 7.39	55.45 ± 11.27	0.387
Male, n (%)	35 (71.4)	26 (78.8)	0.607
BSA, kg/m^2	1.76 ± 0.21	1.68 ± 0.20	0.097
RV EDA, cm^2	25.84 (22.11 – 30.88)	33.50 (30.32 – 36.04)	<0.001
RV ESA, cm^2	17.25 (14.45 – 20.21)	24.67 (22.05 – 28.94)	<0.001
RV FAC, %	33.76 (28.26 – 36.64)	23.24 (18.89 – 29.15)	<0.001
RV GLS, %	-19.12 (-22.70 – -15.94)	-15.00 (-17.18 – -13.07)	<0.001
RV free wall strain, %	-24.10 (-29.15 – -19.40)	-18.03 (-23.10 – -15.76)	<0.001
RA EDV, ml	36.99 (28.92 – 47.34)	35.27 (23.59 – 53.31)	0.282
RA ESV, ml	61.69 (51.18 – 73.30)	68.98 (49.08 – 91.54)	0.181
RA EF, %	39.33 (30.16 – 44.94)	42.58 (37.81 – 51.03)	0.061
RA GLS, %	26.29 (18.93 – 28.38)	28.04 (17.55 – 35.48)	0.374

LA EDV, ml	37.24 (28.69 – 43.99)	34.47 (26.27 – 43.25)	0.916
LA ESV, ml	72.05 (57.69 – 84.56)	61.68 (53.03 – 76.26)	0.504
LA EF,%	47.80 (42.66 – 53.32)	46.65 (39.54 – 54.69)	0.540
LA reservoir strain, %	26.24 (23.84 – 32.14)	22.45 (19.35 – 35.14)	0.471
LA conduit strain, %	14.10 (9.96 – 18.09)	11.08 (5.32 – 14.64)	0.098
LV EDV, ml	130.33 (115.81 – 148.20)	121.10 (102.56 – 138.12)	0.044
LV ESV, ml	58.95 (47.98 – 68.98)	47.01 (39.32 – 56.81)	<0.001
LV EF, %	54.27 (51.00 – 58.24)	59.90 (54.67 – 66.66)	<0.001
LV GLS, %	-19.21 (-21.51 – -18.45)	-18.15 (-19.87 – 15.39)	0.001

Note. – Data are mean ± standard deviation or median and interquartile range in parentheses, if otherwise not specified. BSA, body surface area; EDA, end-diastolic area; EDV, end-diastolic volume; EF, ejection fraction; ESA, end-systolic area; ESV, end-systolic volume; GLS, global longitudinal strain; LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle.

Figure 2. Comparison of cardiac strains in healthy subjects, and preoperative strains in lung transplant recipients with or without grade 3 PGD



Primary graft dysfunction and cardiac strain

There were no significant differences in most clinical parameters including BSA, ICU stay, ventilator care, pump time, RBC usage, smoking, or alcohol history between patients with grade 3 PGD within 72 hours of lung transplantation and patients without grade 3 PGD. Hypertension was more frequent in patients who developed grade 3 PGD (2 (9.5%) vs 6 (50%), p=0.015). (Table 3).

Patients who underwent lung transplantation and developed grade 3 PGD had a preoperative reduction in the RV free wall strain (-19.51 vs. -15.76, P=0.024) and a significant decrease in LA reservoir strain (27.83 vs. 19.88, P=0.033) compared to those who did not experience this complication (Figure 2). There were no significant differences between the two groups in terms of RV volume, RA volume, LA volume, or LV volume (P>0.05).

Table 3. Comparison of clinical characteristics and preoperative CT-derived cardiac function and strain between patients with and without grade 3 primary graft dysfunction (PGD) after lung transplantation.

Parameter	Non-PGD (n=21)	Grade 3 PGD (n=12)	*p*
Age, year	60.00 (44.00 – 61.50)	60.50 (55.75 – 66.50)	0.175
Male, n (%)	15 (71.4)	11 (91.7)	0.223
BSA, kg/m^2	1.65 (1.53 – 1.78)	1.73 (1.67 – 1.88)	0.187
Pack year	0.01 (0.00 – 30.00)	25.00 (0.50 – 47.50)	0.175
Creatinine, mg/dL	0.55 (0.45 – 0.84)	0.69 (0.43 – 0.99)	0.494
Pump time, min	293.00 (271.50 – 299.50)	296.50 (266.00 – 333.00)	0.427
RBC, ml	1500.00 (1000 – 2250)	1650.00 (1500 – 2375)	0.345
ICU stay, day	19.00 (14.50 – 21.50)	16.00 (9.00 – 26.00)	0.645
Ventilator care, day	6.00 (3.50 – 17.50)	7.50 (4.25 – 20.25)	0.427
Hypertension, n (%)	2 (9.5)	6 (50)	0.015
Diabetes mellitus, n (%)	4 (19)	4 (33.3)	0.420
Tuberculosis, n (%)	4 (19)	1 (8.3)	0.630
Alcohol, n (%)	10 (47.6)	6 (50)	0.895
Smoking, n (%)	12 (57.1)	9 (75)	0.305
Isosorbide dinitrate use, n (%)	3 (14.3)	3 (25.0)	0.643
6-month mortality	1	2	NA
CT parameters			
RV EDA, cm^2	32.85 (28.24 – 37.84)	34.18 (30.77 – 35.51)	0.782

RV ESA, cm^2	24.02 (20.95 – 29.69)	24.96 (22.50 – 27.05)	0.956
RV FAC, %	21.74 (18.36 – 27.67)	25.31 (20.73 – 29.70)	0.471
RV GLS, %	-15.72 (-16.85 – -13.18)	-14.23 (-17.94 – -12.59)	0.604
RV free wall strain, %	-19.51 (-23.57 – -16.80)	-15.76 (-18.94 – -14.34)	0.024
RA EDV, ml	33.24 (21.49 – 46.94)	41.41 (31.58 – 56.84)	0.141
RA ESV, ml	62.11 (43.76 – 89.05)	71.69 (52.60 – 92.56)	0.405
RA EF, %	44.19 (38.79 – 52.66)	38.99 (29.36 – 49.58)	0.200
RA GLS, %	28.04 (19.91 – 40.45)	26.32 (17.24 – 33.34)	0.449
LA EDV, ml	34.47 (26.16 – 41.01)	35.35 (27.06 – 46.37)	0.671
LA ESV, ml	61.36 (54.14 – 74.60)	65.37 (51.52 – 84.19)	0.927
LA EF, %	46.65 (40.04 – 54.78)	45.51 (38.84 – 55.60)	0.839
LA reservoir strain, %	27.83 (20.44 – 39.64)	19.88 (16.96 – 24.75)	0.033
LA conduit strain, %	12.88 (5.32 – 18.06)	10.59 (4.04 – 12.90)	0.494
LV EDV, ml	121.10 (98.21 – 138.12)	120.67 (102.84 – 137.69)	0.927
LV ESV, ml	50.62 (39.11 – 58.01)	43.67 (39.52 – 55.51)	0.839
LV EF, %	59.90 (54.31 – 66.05)	60.41 (54.88 – 66.67)	0.699
LV GLS, %	-18.51 (-20.62 – -15.42)	-17.29 (-19.58 – -15.37)	0.326

Note. – Data are median and interquartile range in parentheses, if otherwise not specified. BSA, body surface area; EDA, end-diastolic area; EDV, end-diastolic volume; EF, ejection fraction; ESA, end-systolic area; ESV, end-systolic volume; GLS, global longitudinal strain; ICU, intensive care unit; LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle.

Cardiac function and strain before and after lung transplantation

The paired comparative analysis of 13 patients who underwent cardiac CT before and after lung transplantation revealed a decrease in LV volume (LV EDV 127.62 vs. 93.11 ml, P=0.001; LV ESV 43.21 vs. 27.88 ml, P=0.001) and an increase in LVEF (62.11% vs. 69.32%, P=0.023) after surgery (Supplemental Table 1, Supplemental Figure 1). LA and RV volumes were also reduced (P<0.05), with both RV EDV and ESV decreasing, and RV FAC increasing significantly (28.27 vs. 38.39, P=0.001). There were no significant changes in RA volume, but RA FAC decreased significantly (39.26 vs. 29.38, P=0.039). RA EF also exhibited a pattern of decrease (44.19% vs. 34.26%, P=0.033), contrasting with the RV.

고찰

In this study, patients undergoing lung transplantation showed differences in ventricular function and cardiac strain values compared to healthy subjects, despite the absence of heart disease, attributed to lung abnormalities. Furthermore, in patients who experienced a grade 3 PGD (36.4%), preoperative RV free wall strain and LA reservoir strain were reduced compared to the non-PGD group. When comparing pre- and postoperative cardiac CT in a subgroup, there was an improvement in LV, LA, and RV function. However, RA EF exhibited a decrease, suggesting that post-lung transplantation cardiac remodeling is subdued in the RA compared to other chambers.

While cardiac dysfunction may not have been detected through echocardiography, this study was able to identify differences in cardiac function in patients awaiting lung transplantation in comparison to healthy subjects. It is crucial to assess cardiac remodeling due to lung disease, as it is likely related to the occurrence of PGD, depending on how well the heart adapts to the blood flow in the newly transplanted lungs. Circulatory insufficiency due to lung disease is likely to manifest as a progressive deterioration in cardiac function and may progress to the point of necessitating heart-lung transplantation, potentially leading to conditions such as pulmonary arterial hypertension. Atrial volume and strain did not exhibit significant differences between the healthy subjects and patients awaiting lung transplantation. Therefore, this study showed that changes in cardiac function may start from the ventricles rather than the atria.

There are reports suggesting that preoperative pulmonary artery pressure obtained through right heart catheterization is associated with patient outcomes after lung transplantation (10). However, since it can be challenging to perform such invasive tests in patients facing lung transplantation, it is considered meaningful to explore alternative radiological risk factors. PGD has an impact on mortality, hospital stay length, and the duration of ventilator use after lung transplantation (3). Hence, determining factors associated with PGD can be beneficial for predicting patient outcomes. Pulmonary vascular resistance due to lung disease may gradually lead to cardiac dysfunction as the pulmonary artery flow encounters resistance. Following lung transplantation, the removal of this resistance amplifies blood flow from the heart to the lungs, potentially leading to issues in

the compensation between the heart and lungs, thus contributing to the occurrence of PGD. Therefore, the development of PGD is believed to be associated with cardiac function before surgery.

However, it can be challenging to confirm PGD solely based on numerical parameters such as volume or EF when predicting preoperative cardiac function. The role of more sensitive factors like strain may be of interest. A prior study with 41 pediatric lung transplant patients suggested worse preoperative RV function was associated with PGD grade 3 (11). In contrast, better RV function was a risk factor for PGD grade 3 in a prospective study with 70 lung transplant adults (12). However, conventional 2D echocardiography could not provide accurate measurements because of the crescent-shape of the RV, and poor visualization of the cardiac apex (13). In the previous study, patients for whom RV assessment was challenging due to a poor-quality acquisition were excluded (12). Moreover, since the patients' conditions had reached a state where lung transplantation was necessary, there was a gradual onset of cardiac problems such as pulmonary hypertension, associated with the risk of PGD (14). In another study using strain from echocardiography, including patients with decreased cardiac function, the impaired LV diastolic function was associated with the deterioration of LVEF after lung transplantation (15). However, it is challenging to determine which functional parameters are associated with the occurrence of PGD when there is no obvious cardiac dysfunction. Although the sample size in our study is limited, the roles of factors such as RV free wall strain and LA reservoir strain, as observed, are promising for further investigation in lung transplant patient populations in the future.

Compared to healthy subjects, cardiac strain is impaired in patients awaiting lung transplants, especially those with PGD (Figure 2). These characteristics suggest that as the timing of lung transplantation is delayed, there may be changes in cardiac function and an increased likelihood of PGD development. This may be related to the gradual onset of pulmonary hypertension as a result of lung disease, which appears to be a risk factor for PGD. The impairment of RV strain and the failure of pulmonary artery pressure to normalize after lung transplantation are associated with postoperative mortality (16). This implies the need for consideration of the timing of lung transplantation.

This study has several limitations. Firstly, the small patient number in this study was not sufficiently large to clearly demonstrate changes in cardiac strain associated with the occurrence of grade 3 PGD. Therefore, a larger cohort study is needed to provide more conclusive evidence. Second, there may be a selection bias, as only patients with relatively stable conditions before lung transplantation that allowed for cardiac CT imaging were included. Furthermore, the decision to perform cardiac CT imaging after lung transplantation was based on the individual patient's post-transplant condition, resulting in the inability to obtain cardiac CT scans for all patients included in the study. The post-transplant cardiac CT scans may have been performed only on those patients whose condition allowed for it. However, it is believed that the role of this study lies in initiating the exploration of how cardiac function and strain are influenced by lung transplantation and the potential relevance of this to PGD.

결론

In conclusion, the ventricular function and strain values in patients awaiting lung transplantation were reduced compared to those of the healthy subjects, even in the absence of cardiac disease. In patients who developed grade 3 PGD after lung transplantation, preoperative RV free wall strain and LA reservoir strain were lower than those in the non-PGD group. Post-transplantation, improvements in LA, LV, and RV function were observed, while RA exhibited no improvement and a decrease in FAC. This suggests a slower recovery in the RA compared to the other chambers following surgery. Cardiac strain can aid in evaluating cardiac function before and after lung transplantation and help understand the changes that occur.

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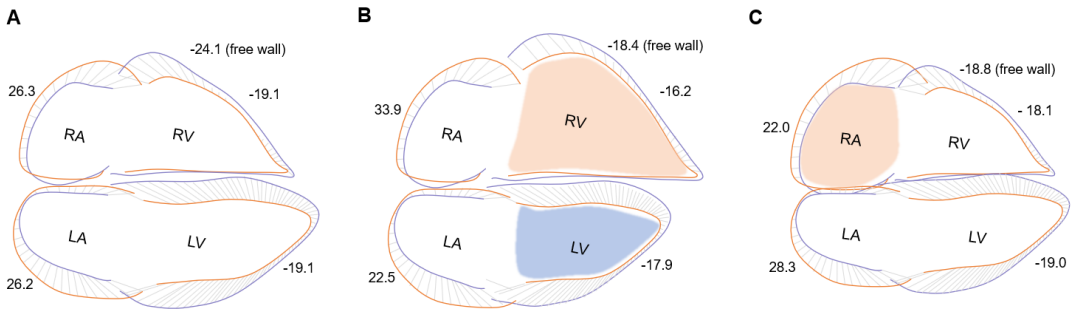
부록

Supplemental Table 1. Changes of cardiac function and strains after lung transplantation. (n=13).

	Pre	Post	p^*
LV EDV, ml	127.62 (98.47–134.92)	93.11 (76.34 – 100.37)	.001
LV ESV, ml	43.21 (34.20–54.21)	27.88 (25.20 – 28.60)	.001
LV EF, %	62.11 (57.88–69.05)	69.32 (65.50 – 70.76)	.023
LA EDV, ml	33.57 (19.87–42.36)	24.72 (19.44 – 34.18)	.028
LA ESV, ml	55.10 (51.66–73.77)	52.68 (41.14 – 64.86)	.046
LA EF, %	47.05 (39.36–61.55)	54.27 (44.10 – 58.23)	.249
RV EDV, ml	34.39 (31.03–35.57)	23.79 (22.19 – 25.82)	.001
RV ESV, ml	23.73 (21.41–27.58)	15.88 (13.41 – 16.24)	.001
RA EDV, ml	35.25 (28.66–38.93)	37.23 (25.49 – 46.05)	.972
RA ESV, ml	62.11 (56.79–71.69)	51.31 (36.50 – 69.74)	.055
RA EF, %	44.19 (38.13–53.94)	34.26 (24.36 – 39.80)	.033
LV GLS, %	-17.94 (-20.19 – -15.24)	-19.00 (-21.20 – -14.86)	.650
LA reservoir strain, %	22.45 (19.99–30.34)	28.30 (20.62 – 37.47)	.173
FAC, %	30.31 (27.57–40.71)	40.24 (32.87 – 43.64)	.173
LA conduit strain, %	9.93 (1.96–13.64)	9.46 (4.89 – 15.23)	.347
RV GLS, %	-16.22 (-18.32 – -13.52)	-18.11 (-21.10 – -16.28)	.678
RV FAC, %	28.27 (19.82–30.77)	38.39 (33.45 – 43.33)	.001
RV free wall strain, %	-18.37 (-22.09 – -16.33)	-18.76 (-24.90 – -17.30)	.701
RA GLS, %	33.86 (18.83–40.45)	22.00 (16.78 – 29.65)	.133
RA FAC, %	39.26 (28.86–42.24)	29.38 (23.09 – 33.56)	.039

Note. – Data are median and interquartile range in parentheses. *Paired comparison using Wilcoxon signed rank test was performed in patients who had both pre- and post-lung transplantation cardiac CT scans. EDA, end-diastolic area; EDV, end-diastolic volume; EF, ejection fraction; ESA, end-systolic area; ESV, end-systolic volume; GLS, global longitudinal strain; ICU, intensive care unit; LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle.

Supplemental Figure 1. Illustrations for demonstrating the mean strain values and volume changes obtained from (A) healthy subjects (n=49), (B) pre-operative, and (C) post-transplant patients (n=13).



국문요약

연구제목: 폐이식 환자에서 심장 리모델링이 원발성 이식편 장애에 미치는 영향: 정상 대조군과의 비교

연구배경: 폐 이식 환자군에서의 폐 이식 전 심장 기능을 측정하여 정상 대조군과 비교하고, 원발성 이식편 장애 (Primary graft dysfunction, PGD)가 발생하는 환자들과 그렇지 않은 환자들 사이의 심장 기능의 차이를 평가하고자 한다.

연구방법: 2019년 8월부터 2023년 4월까지 폐 이식을 받고 수술 전 다상 심장 CT (multiphase cardiac CT)를 시행 받은 33명의 환자가 후향적으로 포함되었다. 건강검진으로 심장 CT를 시행 받은 49명의 정상 대조군을 나이, 성별 및 체표면적으로 매칭하여 포함하였다. PGD는 수술 후 흉부 X선 및 PaO2/FiO2 비율로 평가하였다. 심장 CT를 이용하여 이들의 심장 기능 및 변형 (strain)을 측정하였다. 폐 이식 환자와 정상 대조군 간의 CT 심장 기능 및 변형을 비교하였고, 폐 이식 환자는 grade 3 PGD가 있는 그룹과 없는 그룹으로 나누어서 이 두 하위 그룹 간에도 심장 기능 및 변형을 비교하였다. 수술 전과 수술 후 심장 CT를 모두 시행한 환자들에서는 수술 전, 후의 심장 기능과 변형의 변화를 평가하였다.

연구결과: 폐 이식을 기다리는 환자들은 정상 대조군에 비해 우심실 부피가 더 컸고, 우심실 global longitudinal strain과 free wall strain이 감소해 있었다 (-19.12 vs. -15.00, P<0.001, -24.10 vs. -18.03, P<0.001). Grade 3 PGD가 있는 환자들은 없는 환자들에 비해서 수술 전 우심실 free wall strain (-19.51 vs. -15.76, P=0.024) 및 좌심방 reservoir strain(27.83 vs. 19.88, P=0.033) 의 유의미한 감소를 보였다. 폐 이식 후 좌심실, 좌심방, 그리고 우심실 부피의 감소가 확인되었다.

연구결론: 폐 이식 환자군에서 수술 전 심실 기능과 strain이 감소되어 있으며, grade 3 PGD가 발생하는 환자들에서는 수술 전 우심실 및 좌심방 strain이 감소되어 있었다.