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Enhanced [^{18}F]fluorodeoxyglucose accumulation in the right ventricular free wall predicts long-term prognosis of patients with pulmonary hypertension: a preliminary observational study

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Aims We have previously demonstrated that [^{18}F]fluorodeoxyglucose (FDG) accumulation is increased in the right ventricular (RV) free wall of patients with pulmonary hypertension (PH), and that this accumulation is ameliorated after the treatment with epoprostenol associated with improvement of haemodynamic overload. The aim of this study was to examine whether enhanced RV FDG accumulation by gated positron emission tomography (PET) has a prognostic impact in patients with PH.

Methods and results We examined the prognostic impact of the RV standardized uptake value (SUV) of FDG-PET corrected for the partial volume effect (cRV-SUV) in 27 patients with PH who underwent gated FDG-PET from March 2001 to June 2004. During the follow-up period of 69 $\pm$ 49 (mean $\pm$ SD) months, among the 27 patients, 15 showed clinical worsening (CW) and 11 died. FDG-PET examination showed that cRV-SUV was significantly higher in the CW group compared with the non-CW group (10.1 vs. 7.6, $P = 0.02$). Univariate Cox hazard analysis showed that cRV-SUV was significantly correlated with the time to CW (hazard ratio 1.25, 95% confidence interval 1.04–1.51, $P = 0.02$), which remained significant even after adjustment of World Health Organization functional class. Kaplan–Meier analysis showed that the patients with cRV-SUV $\geq$8.3 had poor prognosis compared with those with cRV-SUV $<$8.3 (log-rank $P = 0.005$ for time to CW and $P = 0.07$ for mortality).

Conclusion These results indicate that enhanced FDG accumulation in the RV free wall may be a novel prognostic factor in patients with PH.

Keywords Positron emission tomography • Fluorodeoxyglucose • Pulmonary hypertension • Myocardial energy substrate metabolism • Prognosis

Introduction

Pulmonary arterial hypertension (PAH) and chronic thromboembolic pulmonary hypertension (CTEPH) are the disorders of abnormal pulmonary circulation characterized by a progressive increase in pulmonary arterial pressure and pulmonary vascular resistance with the different underlying aetiologies.[1,2] They are the two main subgroups of pulmonary hypertension (PH) with poor prognosis,[3] despite the recent advance in medical therapy.[4,5]

A number of prognostic factors for PAH have been previously identified,[6] including World Health Organization (WHO) functional class, 6-minute walk distance (6MWD), brain natriuretic peptide

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(BNP), and haemodynamic variables by right heart catheterization,[7] many of which are related to the right ventricular (RV) function. Indeed, RV failure is the most common cause of death in PH. Although precise evaluation of RV function in PH is a key to estimate the prognosis of patients with PH, it is difficult to predict the prognosis accurately, possibly because the most parameters to assess RV function are based on functional class, exercise capacity, haemodynamic data, or mechanical function. Thus, it is required to develop new modalities to evaluate RV function or new biomarkers to predict the prognosis of PH patients.

We have previously demonstrated with nuclear imaging that myocardial metabolic function can be changed in various ventricular conditions in both animal and human studies.[8–11] We observed the significant correlation between increased RV free wall [^{18}F]fluorodeoxyglucose (FDG) uptake evaluated by positron emission tomography (PET) and pulmonary haemodynamic parameters in PH patients, and this accumulation was ameliorated after epoprostenol therapy.[11]

In the present study, we thus examined whether enhanced RV free wall standardized uptake value (SUV) of FDG accumulation evaluated by electrocardiogram-gated PET (FDG-PET) has a prognostic impact in patients with PAH or CTEPH.

Methods

The present study was approved by the Committee for the Ethics and the Administration of Radioactive Substances of the Tohoku University School of Medicine, in accordance to the ethical guidelines of Declaration of Helsinki. Written informed consent was obtained from all patients.

Study population

We enrolled 27 patients who were diagnosed as pre-capillary PH and underwent FDG-PET from March 2001 to April 2004 in our Tohoku University Hospital. No patients had diabetes mellitus or glucose intolerance. The diagnosis of pre-capillary PH was defined as mean pulmonary arterial pressure (mPAP) $\geq$25 mmHg and mean pulmonary capillary wedge pressure (mPCWP) $<$15 mmHg by right heart catheterization.[7] The classification of pre-capillary PH was made according to the Dana Point criteria of PH.[12] Baseline clinical characteristics of the 27 patients are summarized in *Table 1*, including 18 patients with PAH and 9 with CTEPH. Only one CTEPH patient was operable. Seventeen (63%) patients were classified as having advanced WHO functional class ($\geq$III). At baseline, 2 patients were treated with intravenous prostacyclin (epoprostenol), 15 with oral prostacyclin, and 5 with a calcium channel blocker. These pulmonary vasodilators and conventional therapy, including digitalis, diuretics, and oxygen supplementation, were initiated or intensified in various combinations in each patient according to the severity of PH.[13] During the patient recruitment period, endothelin receptor antagonists and phosphodiesterase-5 inhibitors were not available in Japan.

Data collections

Baseline demographic information was collected from the medical records, including age, sex, body mass index, aetiology of PH, WHO functional class, distance of 6-minute walk test, plasma BNP level, cardiothoracic ratio, and medications.

FDG-PET scanning and data analysis

PET images were acquired on a SET-2400W PET scanner (Shimadzu Co. Ltd, Kyoto, Japan). The detailed protocol for PET scanning and data quantification was described previously.[11] Briefly, following at least 8-h long-fasting condition, each patient underwent the FDG-PET study, using the standard oral glucose loading protocol. The scanning was performed with ECG-gated two-dimensional acquisition after the FDG injection (185 MBq). Blood glucose, insulin, and free fatty acid were measured just before FDG injection and after the transmission scan. We calculated a SUV in the RV free wall, the interventricular septum, and the left ventricular (LV) free wall using the mean count in regions of interest placed on of the end-diastolic transaxial image. The correction of SUV for partial volume effect was made by the recovery coefficient curve obtained from a board phantom experiment.[11]

Haemodynamic study

All patients underwent bilateral heart catheterization under the stable condition within 2 weeks from the PET study. The following haemodynamic variables were measured; mPAP, mean right atrial pressure (mRAP), mPCWP, and mean aortic pressure (mAoP). Fick principle was used to calculate cardiac output and pulmonary and systemic vascular resistance.

Cardiac magnetic resonance and electron beam computed tomography

We performed electron beam computed tomography (EBCT) or cardiac magnetic resonance (CMR) in all patients within 2 weeks from the PET study. The decision of the employment was based on their availability. Eleven patients underwent EBCT and 16 CMR. The method that we used for EBCT or CMR was previously described in detail.[11] Briefly, the transaxial images of EBCT or CMR morphologically corresponding to the PET images were selected to measure the wall thickness of RV and LV free wall and interventricular septum. Ventricular end-diastolic volume, ejection fraction, and ventricular diastolic mass in both ventricles were also calculated using the cine mode images.

Endpoint and follow-up

To examine the relationship between baseline data and outcome, primary endpoint was defined as a composite endpoint of the time to clinical worsening (CW), including all-cause mortality, lung transplantation, hospitalization for the progression of PH, and deterioration of WHO functional class and/or $>$15% reduction in 6MWD from baseline during the follow-up period.[14] The secondary endpoint was defined as all-cause mortality. Follow-up was performed regularly by 1- to 6-month intervals. CW-free and overall survival times were calculated from the date of FDG-PET examination to the date of disease progression or the date of last clinical visit or contact by telephone or death, respectively. No patients were lost to follow-up.

Statistical analysis

Results are expressed as the mean $\pm$ standard deviation (SD) or percentages. Comparisons between the two groups were performed by unpaired Student's *t*-test for continuous variables or χ^2 test for categorical variables. To assess the association of baseline variables with prognosis, univariate and multivariate Cox proportional hazards regression analyzes were used. For multivariate analysis, stepwise backward elimination using variables with $P < 0.05$ in the univariate model was selected to identify independent variables associated with CW. Results of these analyses are shown as hazard ratios with 95% confidence intervals. Survival-free curves of each endpoint were estimated by the Kaplan–Meier method and compared by the log-rank test. A value of $P < 0.05$ was considered to be statistically significant. All analyses were performed with JMP Pro 10.0.2 (SAS Institute, Inc., Cary, NC, USA).

Table 1 Baseline variables in the patients with PH according to the presence or absence of CW

	CW group (n = 15)	No-CW group (n = 12)	P-value
Age (years)	43 ± 18	49 ± 19	0.365
Sex (female/male)	11/4	9/3	1.000
Body mass index (kg/m^2)	22.2 ± 3.6	21.9 ± 3.3	0.829
Aetiology of PH			
Idiopathic PAH	11 (73)	4 (27)	0.042
Portal hypertension	2 (67)	1 (33)	
CTEPH	2 (22)	7 (78)	
WHO functional class ≥III	13 (76)	4 (24)	0.007
6MWD (m)	409 ± 84	346 ± 153	0.292
BNP (pg/mL)	283 ± 221	110 ± 193	0.044
Cardio-thoracic ratio (%)	55 ± 4	54 ± 4	0.613
Medication			
Intravenous prostacyclin	0 (0)	2 (7)	0.188
Oral prostacyclin	10 (67)	5 (42)	0.258
Calcium antagonist	4 (27)	1 (8)	0.342
Haemodynamic variables			
mPCWP (mmHg)	8 ± 4	7 ± 2	0.419
mPAP (mmHg)	57 ± 12	45 ± 12	0.013
mRAP (mmHg)	7 ± 3	5 ± 3	0.039
mAoP (mmHg)	86 ± 10	86 ± 8	0.924
SVO_2 (%)	66 ± 11	69 ± 7	0.396
Cardiac index (L/min/m^2)	2.2 ± 0.5	2.5 ± 0.7	0.269
Heart rate (bpm)	80 ± 15	74 ± 9	0.261
PVR (WU)	15 ± 4	12 ± 7	0.119
SVR (WU)	24 ± 7	24 ± 8	0.778
CMR or EBCT			
RV end-diastolic volume index (mL/m^2)	106 ± 30	90 ± 11	0.266
LV end-diastolic volume index (mL/m^2)	53 ± 9	67 ± 22	0.041
Diastolic RV mass index (g/m^2)	76 ± 25	49 ± 18	0.005
Diastolic LV mass index (g/m^2)	65 ± 8	63 ± 4	0.624
RV ejection fraction (%)	33 ± 11	43 ± 15	0.071
LV ejection fraction (%)	63 ± 7	65 ± 12	0.753
RV wall thickness (mm)	6 ± 2	5 ± 3	0.538
LV wall thickness (mm)	8 ± 2	6 ± 4	0.242
Corrected SUV of FDG-PET			
RV free wall	10.1 ± 2.7	7.6 ± 2.2	0.018
Interventricular septum	7.7 ± 3.8	7.3 ± 3.1	0.748
LV free wall	6.7 ± 3.8	6.3 ± 2.3	0.756

Results are expressed as the mean ± SD or the number (%).
BNP, brain natriuretic peptide; CMR, cardiac magnetic resonance; CTEPH, chronic thromboembolic pulmonary hypertension; CW, clinical worsening; EBCT, electron beam computed tomography; FDG, [^{18}F]fluorodeoxyglucose; LV, left ventricular; mAoP, mean aortic pressure; mPAP, mean pulmonary arterial pressure; mPCWP, mean pulmonary capillary wedge pressure; PAH, pulmonary arterial hypertension; PET, positron emission tomography; PVR, pulmonary vascular resistance; RAP, right atrial pressure; RV, right ventricular; 6MWD, 6-minute walk distance; SUV, standard uptake value; SVO_2, mixed venous oxygen saturation; SVR, systemic vascular resistance; WHO, World Health Organization.

Results

Comparison with the CW and non-CW groups at baseline

The prevalence of PAH and advanced WHO functional class were significantly higher in the CW group compared with the non-CW group (*Table 1*). Plasma levels of BNP were also significantly increased in the CW group compared with the non-CW group. There was no significant difference in the use of medications at baseline between the two groups. In haemodynamic parameters, the CW group had significantly higher mPAP and mRAP compared with the non-CW group (*Table 1*). In contrast, mixed venous oxygen saturation, cardiac index, heart rate, and pulmonary vascular resistance were

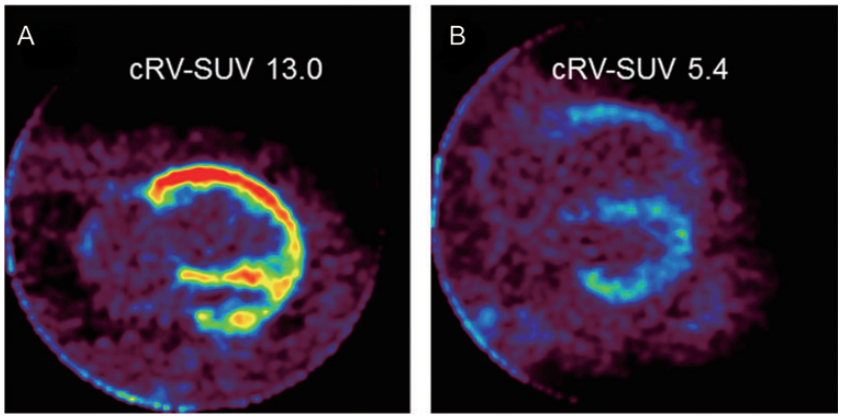

Figure 1 Evaluation of RV metabolism by FDG-PET in PH patients. A representative FDG-PET image is shown in a patient with CW (*A*) and that without it (*B*). cRV, corrected right ventricular; SUV, standardized uptake value.

Table 2 The primary and secondary endpoints in the study population

	All (n = 27)
Primary endpoint (CW)	
Mean follow-up period (months)	69 ± 49
Total number	15 (56)
All-cause mortality	4 (15)
Lung transplantation	1 (4)
Hospitalization for PH progression	9 (33)
Deterioration of WHO functional class and/or >15% reduction in 6MWD from baseline during the follow-up period	1 (4)
Secondary endpoint	
Mean follow-up period (months)	97 ± 42
All-cause mortality	11 (41)

Results are expressed as the mean ± SD or the number (%).
PH, pulmonary hypertension; 6MWD, 6-minute walk distance; WHO, World Health Organization.

comparable between the two groups. In CMR or EBCT measurements, LV end-diastolic volume index was significantly smaller in the CW group compared with the non-CW group (*Table 1*). Diastolic RV mass index was significantly higher and RV ejection fraction tended to be lower in the CW group compared with the non-CW group. Importantly, FDG-PET showed that cRV-SUV was significantly higher in the CW group compared with the non-CW group (*Figure 1* and *Table 1*). None of other SUV parameters was significantly different between the two groups.

Prognosis of patients with PH

During the mean follow-up period of 69 ± 49 months (interquartile range 17–115 months), among the 27 patients, 15 (60%) reached CW, including all-cause mortality in 4, lung transplantation in 1, hospitalization due to PH progression in 9, and deterioration of WHO functional class and/or >15% reduction in 6MWD from baseline in 1 (*Table 2*). Finally, 11 (41%) died (secondary endpoint, cardiopulmonary causes in 9) (*Table 2*). In Kaplan–Meier survival analysis, the time to CW was significantly higher in patients with cRV-SUV ≥8.3 compared with those with cRV-SUV <8.3 (log-rank, $P = 0.005$) (*Figure 2A*). The median cRV-SUV of FDG values were used as arbitrary the cut-off values. Similarly, the patients with the cRV-SUV of ≥8.3 tended to have a higher all-cause mortality rate compared with those with the cRV-SUV of <8.3 (log-rank, $P = 0.07$) (*Figure 2B*). Univariate Cox proportional hazard analysis showed that the aetiology of PAH and advanced WHO functional class was significantly associated with time to CW (*Table 3*). In haemodynamic measurement, higher mPAP and mRAP were also associated with the poor outcome (*Table 3*). Other reported haemodynamic variables for the prognosis of PH patients, such as mixed venous oxygen saturation, cardiac index, heart rate, and pulmonary vascular resistance, were not identified as prognostic values. In imaging modalities, diastolic RV mass index and corrected RV free wall SUV were significantly associated with time to CW (*Table 3*). Mutivariate Cox analysis demonstrated that the best model predicting time to CW consisted of the cRV-SUV of ≥8.3 and advanced WHO functional class (*Table 4*). cRV-SUV ≥8.3 remained an independent predictor of time to CW even after adjustment of 6MWD or diastolic RV mass index of ≥63 g/m^2 (the value obtained from the median value RV mass index).

Discussion

The novel findings of the present study are that (i) enhanced RV free wall SUV of FDG is a useful predictor of long-term prognosis of PH patients and (ii) the cut-off point of cRV-SUV ≥8.3 might be useful for the prediction of long term. To our knowledge, this is the first study that demonstrates the association between impaired RV substrate metabolism and long-term prognosis of PH patients.

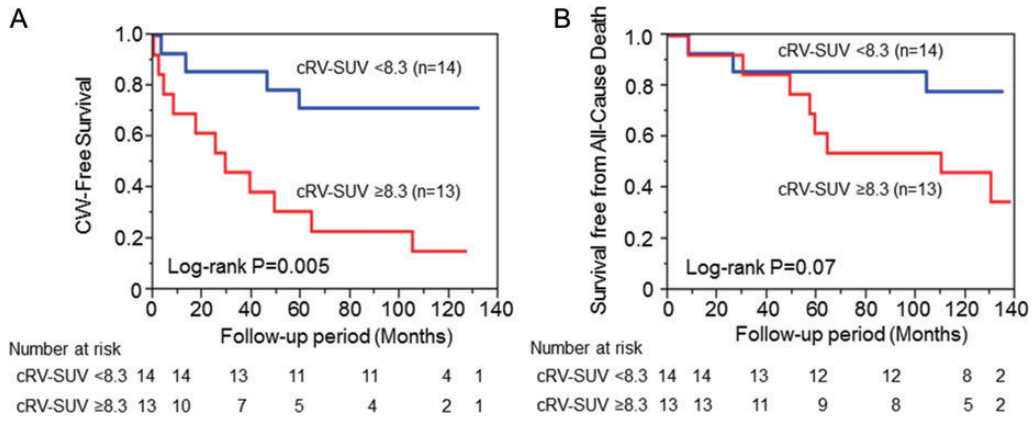

Figure 2 Prognostic importance of enhanced right ventricular free wall FDG uptake in PH patients. Kaplan–Meier curves shows that the cut-off level of the cRV-SUV of 8.3 is useful to predict the long-term survival free from CW (*A*) and the long-term survival free from all-cause mortality (*B*) in PH patients. See *Figure 1* for abbreviations.

Prognostic significance of enhanced RV free wall FDG uptake in PH

Since PH is a fatal disease, accurate evaluation of the disease severity and prognosis is essential for the management. A number of prognostic factors have been reported, most of which were derived from the studies for idiopathic PAH,[15,16] and current treatment guideline recommends to use some important predictors in PH.[7] Since RV failure is the main cause of death in patients with PH,[3,17] RV function is the most important determinant of the outcome.[18] Recently, there have been an increasing number of reports on RV parameters by echocardiography and CMR[19,20] in relation to the long-term prognosis of PH patients. Furthermore, several parameters on RV function have been reported to have a prognostic impact, including functional class, exercise capacity, and haemodynamics or structural ventricular remodelling.[7] However, accurate prediction of the long-term prognosis of PH patients still remains to be improved.

Metabolic and neurohormonal activations are the earliest changes in response to various overloads to the heart, preceding mechanical dysfunction and structural remodelling with resultant development of heart failure.[21,22] Thus, the impairment of myocardial energetics has been implicated in the pathogenesis of LV failure[23] and as prognostic biomarkers for patients with idiopathic cardiomyopathy.[21,22] This notion could also be the case for RV failure.[24] Indeed, we have previously demonstrated that improvement of RV glucose metabolism precedes that of RV structure in response to epoprostenol therapy.[11] Nagaya *et al.*[25] have shown that the impaired fatty acid uptake in the RV was significantly associated with increased mortality of PH patients. In the present study, we were able to demonstrate that enhanced FDG accumulation in the RV free wall may be a novel prognostic factor in patients with PH. These results indicate that FDG uptake in the RV free wall, as semi-quantitatively expressed by cRV-SUV, might be a significant prognostic impact in the management of PH.

Mechanisms of increased glucose uptake in the RV in patients with PH

Alterations in cardiac energy and substrate metabolism, including high-energy phosphate levels, mitochondrial function, and increased glucose utilization, play an important role in the pathogenesis of hypertrophied and failing heart.[26] Regarding substrate metabolism, a number of animal studies, including our previous study using autoradiography, have previously demonstrated the shift in cardiac substrate utilization from fatty acids to glucose in pressure-overloaded rats,[8,27,28] although there were conflicting data human studies.[29,30] However, the enhanced glucose uptake in hypertrophied and failing heart was also noted in the pressure-overloaded RV in both animals and humans.[9,11] We also have previously demonstrated that myocardial glucose uptake (MGU) was increased in the pressure-overloaded RV free wall in rats with constricted pulmonary artery.[9] Furthermore, we demonstrated that FDG uptake in the RV free wall was significantly increased in accordance with the severity of RV pressure overload in patients with PH,[11] and this notion was subsequently confirmed in patients with PAH and those with PAH due to left heart disease by other groups.[31,32]

Recently, an increased RV-to-LV ratio of MGU using Patlak analysis has been reported in patients with both PH[33] and idiopathic PAH[34] in accordance with increased RV afterload. This study indicated that time to CW was significantly associated with cRV free wall SUV but not with the ratio of RV-to-LV SUV, which might be explained by the methodological difference between SUV and MGU. Bokhari *et al.*[34] have also demonstrated that MGU of RV free wall was significantly correlated with mPAP, which was consistent with our previous findings.[11] Thus, the alteration in RV substrate metabolism assessed by the SUV of FDG-PET can estimate the severity of RV pressure-overload, which may be a novel biomarker of prognosis in PH patients.

Table 3 Univariate Cox proportional hazard analysis for the time to CW

	HR (95% CI)	*P*-value
Age (years)	0.99 (0.96–1.02)	0.454
Sex (female)	0.78 (0.26–2.82)	0.676
Body mass index (kg/m^2)	1.04 (0.89–1.20)	0.637
PAH as an aetiology of PH	3.96 (1.08–25.41)	0.036
WHO functional class ≥III	5.96 (1.63–38.37)	0.005
6MWD (m)	1.00 (1.00–1.01)	0.182
BNP (pg/mL)	3.73 (0.82–15.2)	0.085
Cardio-thoracic ratio (%)	1.07 (0.92–1.24)	0.384
Oral prostacyclin	1.98 (0.70–6.38)	0.199
Calcium antagonist	2.51 (0.68–7.63)	0.153
Haemodynamic variables		
mPCWP (mmHg)	1.05 (0.90–1.18)	0.515
mPAP* (mmHg)	1.24 (1.02–1.52)	0.033
mRAP (mmHg)	1.21 (1.02–1.43)	0.022
mAoP** (mmHg)	1.06 (0.60–1.92)	0.850
SVO_2* (%)	0.71 (0.51–1.00)	0.051
Cardiac index (L/min/m^2)	0.51 (0.21–1.19)	0.120
Heart rate** (bpm)	0.82 (0.56–1.24)	0.516
PVR (WU)	1.05 (0.98–1.12)	0.157
SVR (WU)	1.02 (0.96–1.09)	0.476
CMR or EBCT		
RV end-diastolic volume index** (mL/m^2)	1.06 (0.93–1.15)	0.322
LV end-diastolic volume index** (mL/m^2)	0.71 (0.47–1.01)	0.056
Diastolic RV mass index** (g/m^2)	1.38 (1.11–1.73)	0.004
Diastolic LV mass index** (g/m^2)	1.12 (0.68–1.70)	0.633
RV ejection fraction** (%)	0.72 (0.49–1.04)	0.078
LV ejection fraction** (%)	0.92 (0.57–1.67)	0.759
RV wall thickness (mm)	1.09 (0.88–1.36)	0.418
LV wall thickness (mm)	1.27 (0.90–2.20)	0.211
Corrected SUV of FDG-PET		
RV free wall	1.25 (1.04–1.51)	0.017
Interventricular septum	1.05 (0.86–1.27)	0.606
LV free wall	1.06 (0.90–1.23)	0.445
RV-to-LV ratio	1.54 (0.84–2.61)	0.152

HR, hazard ratio; CI, confidence intervals; *, per 5 units increment; **, per 10 units increment; BNP, brain natriuretic peptide; CMR, cardiac magnetic resonance; CW, clinical worsening; EBCT, electron beam computed tomography; FDG, [^{18}F]fluorodeoxyglucose; LV, left ventricular; mAoP, mean aortic pressure; mPAP, mean pulmonary arterial pressure; mPCWP, mean pulmonary capillary wedge pressure; PAH, pulmonary arterial hypertension; PET, positron emission tomography; PVR, pulmonary vascular resistance; mRAP, mean right atrial pressure; RV, right ventricular; 6MWD, 6-minute walk distance; SUV, standard uptake value; SVO_2, mixed venous oxygen saturation; SVR, systemic vascular resistance; WHO, World Health Organization.

Clinical implications

In this study, we demonstrate that an enhanced RV free wall SUV of FDG predicts a long-term prognosis of PH patients. This parameter could become an early biomarker of RV metabolic dysfunction and make it possible to identify PH patients at a risk of poor prognosis.

Table 4 Multivariate Cox proportional hazard analysis for time to CW

	HR (95% CI)	*P*-value
Symptom		0.003
WHO functional class ≥III	4.05 (1.05–26.84)	0.042
cRV-SUV of FDG ≥8.3	3.15 (1.03–11.82)	0.043
Exercise capacity		0.008
6MWD (m)	1.00 (1.00–1.01)	0.314
cRV-SUV of FDG ≥8.3	7.91 (1.85–54.06)	0.004
CMR parameter		0.001
Diastolic RV mass index ≥63 (g/m^2)	1.68 (0.59–5.15)	0.059
cRV-SUV of FDG ≥8.3	4.66 (1.56–17.06)	0.025

HR, hazard ratio; CI, confidence intervals; CMR, cardiac magnetic resonance; CW, clinical worsening; FDG, [^{18}F]fluorodeoxyglucose; RV, right ventricular; SUV, standard uptake value; 6MWD, 6-minute walk distance; WHO, World Health Organization.

Furthermore, the change of cRV-SUV was correlated with that of pulmonary haemodynamics after epoprostenol therapy;[11] it may also become a post-treatment biomarker, which could be more predictive than baseline.

Study limitations

Several limitations should be mentioned for the present study. First, the present study enrolled a small number of patients with either PAH or CTEPH. In addition, we were unable to fully adjust co-variables in the multivariate model. Thus, the present findings should be confirmed in future studies with a larger number of PH patients. Secondly, we were unable to evaluate myocardial perfusion or fatty acid metabolism with an imaging device in the present study. Since impairment of fatty acid uptake in the pressure-overloaded RV has been reported,[25,35] future studies are need to clarify this important issue. Thirdly, we used EBCT and CMR for the measurement of cardiac volumes and structures, which may cause a potential difference between the two modalities. Finally, in the present study, possible changes in medical therapy during the follow-up period (e.g. endothelin receptor antagonists, phosphodiesterase-5 inhibitors, pulmonary balloon angioplasty for CTEPH[36]) were not included in the Cox model. However, the results of this study would still hold, even in patients who receive current treatments including endothelin receptor antagonists and phosphodiesterase-5 inhibitors.

Conclusions

In the present study, we were able to demonstrate that enhanced FDG accumulation in the RV free wall may be a novel prognostic factor in patients with PH.

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Conflict of interest: None declared.

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