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Cardiac Positron Emission Tomography Enhances Prognostic Assessments of Patients With Suspected Cardiac Sarcoidosis

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Objectives This study sought to relate imaging findings on positron emission tomography (PET) to adverse cardiac events in patients referred for evaluation of known or suspected cardiac sarcoidosis.

Background Although cardiac PET is commonly used to evaluate patients with suspected cardiac sarcoidosis, the relationship between PET findings and clinical outcomes has not been reported.

Methods We studied 118 consecutive patients with no history of coronary artery disease, who were referred for PET, using [^{18}F]fluorodeoxyglucose (FDG) to assess for inflammation and rubidium-82 to evaluate for perfusion defects (PD), following a high-fat/low-carbohydrate diet to suppress normal myocardial glucose uptake. Blind readings of PET data categorized cardiac findings as normal, positive PD or FDG, positive PD and FDG. Images were also used to identify whether findings of extra-cardiac sarcoidosis were present. Adverse events (AE)—death or sustained ventricular tachycardia (VT)—were ascertained by electronic medical records, defibrillator interrogation, patient questionnaires, and telephone interviews.

Results Among the 118 patients (age 52 ± 11 years; 57% males; mean ejection fraction: 47 ± 16%), 47 (40%) had normal and 71 (60%) had abnormal cardiac PET findings. Over a median follow-up of 1.5 years, there were 31 (26%) adverse events (27 VT and 8 deaths). Cardiac PET findings were predictive of AE, and the presence of both a PD and abnormal FDG (29% of patients) was associated with hazard ratio of 3.9 ($p < 0.01$) and remained significant after adjusting for left ventricular ejection fraction (LVEF) and clinical criteria. Extra-cardiac FDG uptake (26% of patients) was not associated with AE.

Conclusions The presence of focal PD and FDG uptake on cardiac PET identifies patients at higher risk of death or VT. These findings offer prognostic value beyond Japanese Ministry of Health and Welfare clinical criteria, the presence of extra-cardiac sarcoidosis and LVEF. (J Am Coll Cardiol 2014;63:329–36) © 2014 by the American College of Cardiology Foundation

Cardiac sarcoidosis can be difficult to detect, in part because of the focal nature of the disease (1). As a result, endomyocardial biopsy has a sensitivity of only ~20% to 30% because it often misses areas of cardiac involvement (2). The clinical guidelines published by the Japanese Ministry of Health and Welfare (JMHW) have not been clinically validated and have an imperfect diagnostic accuracy (3,4). Therefore, the diagnosis of cardiac sarcoidosis is challenging and often relies on integrating both clinical and imaging findings.

Despite the potential of cardiac positron emission tomography (PET) to aid in the diagnosis and treatment of patients with cardiac sarcoidosis (5), it is unknown whether such testing can be used to identify patients who are at a higher risk of adverse events. Improved methods of risk assessment are of particular interest because autopsy studies have suggested that only a small subset of patients with cardiac sarcoidosis are at increased risk of sudden death (1), and therapies such as

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Abbreviations and Acronyms

CMR = cardiac magnetic resonance imaging
CT = computed tomography
EMBx = endomyocardial biopsy
FDG = fluorodeoxyglucose
ICD = implantable cardiac defibrillator
JMHW = Japanese Ministry of Health and Welfare
LVEF = left ventricular ejection fraction
PET = positron emission tomography
RV = right ventricular
VT = ventricular tachycardia

corticosteroids and implantable cardiac defibrillators (ICD) have considerable side effects. Our objective was to identify how findings on cardiac PET imaging related to adverse cardiac events in patients referred for evaluation of known or suspected cardiac sarcoidosis.

Methods

Study population. We studied consecutive patients without coronary artery disease referred for an initial cardiac PET examination at Brigham and Women's Hospital (Boston, Massachusetts) for the evaluation of known or suspected cardiac sarcoidosis between May 2006 and January 2011. The study was approved by the Partners Healthcare Institutional Review Board and conducted in accordance with institutional guidelines.

PET imaging procedure and analysis. Patients underwent resting myocardial perfusion and metabolic imaging using rubidium-82 and ^{18}F-labeled fluorodeoxyglucose (FDG) and a whole-body PET-CT scanner. Images were independently interpreted by 2 experienced cardiologists and were divided into one of the following patterns: normal perfusion and metabolism, abnormal perfusion or metabolism, or abnormal perfusion and metabolism (Fig. 1). Normal metabolism was defined as either complete suppression of FDG from the myocardium or diffuse FDG uptake without any areas of focal uptake. In addition, for each patient, the presence or absence of focal right ventricular (RV) FDG uptake was recorded (Fig. 2). Whole-body FDG images were interpreted by readers who were blinded

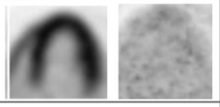
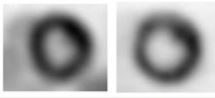
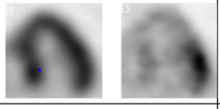
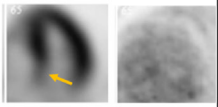
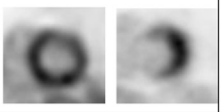
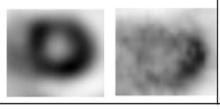
Rest Perfusion	FDG	Frequency	Example		Interpretation / Comment
			Perfusion	FDG	
Normal perfusion and metabolism					
Normal	Normal (negative)	32 (27%)			Normal
Normal	Diffuse (non-specific)	15 (12%)			Diffuse FDG most likely due to failure to suppress FDG from normal myocardium
Abnormal perfusion or metabolism					
Normal	Focal	20 (17%)			Nonspecific pattern; focal increase in FDG may represent early disease vs. normal variant
Positive	Negative	17 (14%)			Rest perfusion defect may represent scar from cardiac sarcoidosis or other etiologies
Abnormal perfusion and metabolism					
Positive	Focal increase ("mismatch pattern")	23 (19%)			Presence of active inflammation ± scar in the same location
Positive	Focal on diffuse	6 (5%)			Similar to above but also areas of inability to suppress FDG from normal myocardium vs. diffuse inflammation
Positive	Focal increase (different area)	5 (4%)			Presence of both scar and inflammation but in different segments

Figure 1 Classification of Cardiac PET/CT Perfusion and Metabolism Imaging

Normal perfusion and metabolism (Category 1), abnormal perfusion or metabolism (Category 2), abnormal perfusion and metabolism (Category 3). FDG = fluorodeoxyglucose.

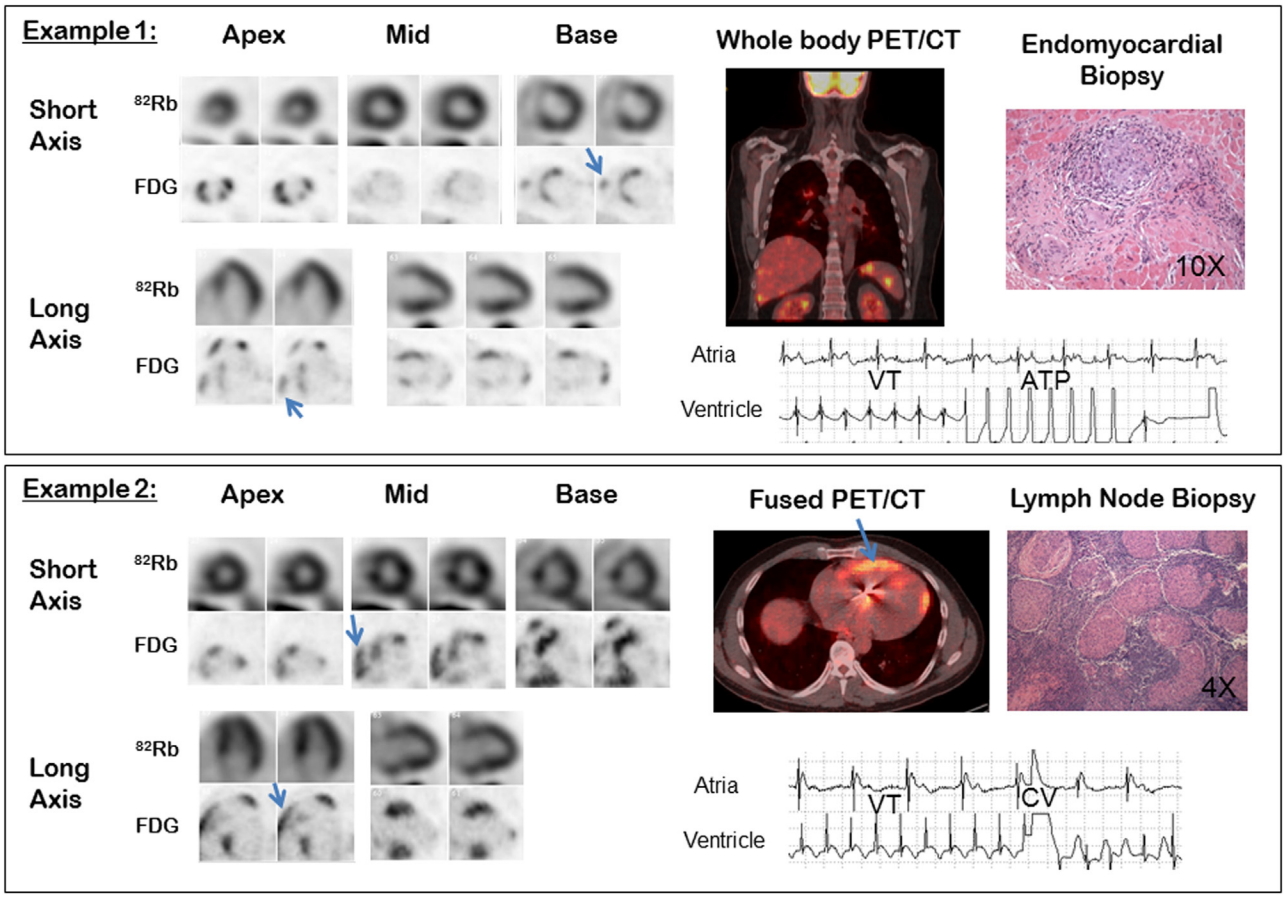


Figure 2 **Examples of Focal Inflammation Involving Right Ventricle**

Example 1: 50-year-old female who had pacemaker implantation for heart block after presenting with episodes of lightheadedness. PET/CT obtained for suspected cardiac sarcoidosis identified a medium sized perfusion defect throughout the basal septum with increased FDG uptake ("mismatch pattern"). There was also FDG uptake involving the apex and RV free wall **(arrow)**. Whole-body images show FDG uptake in the liver and spleen and in paratracheal lymph nodes. EMBx identified the presence of granulomas consistent with the diagnosis of sarcoidosis. Interrogation of her ICD 3 months later identified the presence of rapid VT at a rate of 200 beats/min, which required antitachycardia pacing therapy. Example 2: 48-year-old male with pulmonary sarcoidosis who was referred for PET/CT for suspected cardiac involvement. He was found to have a perfusion defect associated with focal FDG uptake along the basal anterior and inferior septum as well as multiple focal areas of FDG uptake throughout the right ventricle **(arrows)**. Lymph node biopsy results confirmed the presence of sarcoidosis. Less than 1 month after ICD implantation, he had an episode of VT (see rhythm strip). CT = computed tomography; PET = positron emission tomography; other abbreviations as in Figure 1.

to the cardiac PET results to assess for any active extracardiac disease (Online Fig. 1, Online Table).

Ascertainment of clinical data. Medical history, including risk factors and medication use, was ascertained at the time of the study by patient interviews as well as by reviews of electronic medical records. We used the revised guidelines for the diagnosis of cardiac sarcoidosis from the JMHW (6) in order to classify patients as JMHW-positive (+) or JMHW-negative (−) (Online Fig. 2).

Ascertainment of outcomes. The primary outcome was death from any cause or documented sustained VT. Patients' vital status was ascertained from the Social Security Death Index (SSDI). For patients with ICDs, device interrogation records were used to identify any ventricular arrhythmias requiring cardioversion or antitachycardia pacing. Outcomes were also ascertained by comprehensive review of electronic medical records, mailed patient questionnaires, and scripted phone interviews. All significant patient self-reported events were verified using medical records. Follow-up was available for 121 of the 125 (97%) patients. Of the 4 patients who were lost to follow-up, 2 refused to participate, 2 could not be contacted, and all were alive per SSDI data. As a secondary outcome, we also assessed the endpoint of cardiac death or sustained VT. Cardiac death included any death attributed to heart failure and/or cardiac arrhythmias.

Results

Baseline patient characteristics are listed in Table 1.

Patient outcomes. Over a median follow-up of 1.5 years, 31 patients (26%) experienced death or VT. There were 27 (23%) VT events requiring device related therapies (n = 25)

Table 1 Baseline Characteristics Stratified by Presence or Absence of Subsequent Adverse Events

Characteristic	All Patients (N = 118)	Patients With Adverse Events (n = 31)	Patients Without Adverse Events (n = 87)	p Value
Age (yrs)	51.5 ± 11.2	50.3 ± 9.5	51.9 ± 11.7	0.52
Males	67 (57%)	22 (71%)	45 (52%)	0.06
Race				
White	91 (77%)	23 (74%)	68 (78%)	0.07
Black	19 (16%)	8 (26%)	11 (13%)	
Other/unknown	8 (7%)	0 (0%)	8 (9%)	
Reason for testing				
Known cardiac sarcoidosis (prior to PET)	9 (8%)	3 (10%)	6 (7%)	0.36
Known extracardiac sarcoidosis with no known cardiac involvement (prior to PET)	21 (18%)	4 (13%)	17 (20%)	0.38
Evaluation of cardiac signs and symptoms				
Syncope	20 (17%)	4 (13%)	16 (18%)	0.48
Heart failure	17 (14%)	3 (10%)	14 (16%)	0.38
Palpitations	7 (6%)	1 (3%)	6 (7%)	0.45
Ventricular tachycardia	24 (21%)	9 (31%)	15 (18%)	0.13
Electrocardiographic data (available for 120 patients)				
Right bundle branch block	21 (19%)	4 (14%)	17 (20%)	0.44
Left bundle branch block	7 (6%)	1 (3%)	6 (7%)	0.48
Left axis deviation	22 (19%)	6 (21%)	16 (19%)	0.85
AV block	44 (39%)	13 (45%)	31 (37%)	0.45
Premature ventricular contractions	12 (11%)	4 (14%)	8 (10%)	0.52
Ventricular function (by gated PET)				
Ejection fraction (%)	47 ± 16	40 ± 15	49 ± 16	0.007
End-diastolic volume (ml)	154 ± 90	173 ± 112	147 ± 80	0.15
End-systolic volume (ml)	91 ± 79	115 ± 100	82 ± 69	0.05
Baseline medications and devices				
Steroid treatment at baseline	31 (26%)	11 (35%)	20 (23%)	0.18
ICD (at baseline or upon follow-up)	64 (54%)	28 (90%)	36 (41%)	<0.001
Implanted prior to PET	48	24	24	
Implanted after PET	16	4	12	
JMHW criteria (of 112)				0.03
Negative	80 (66%)	15 (50%)	59 (72%)	
Positive	38 (34%)	15 (50%)	23 (28%)	
Histological diagnosis: (+) EM biopsy results	13	9	4	0.001
Clinical diagnosis: all with tissue or clinical diagnosis of extra cardiac disease, ECG abnormality AND 1 or more of the following:	25	6	19	0.50
Abnormal wall motion	17	5	12	
Abnormal wall thinning/thickening	16	4	12	
Abnormal left ventricular dilatation	15	4	11	
Abnormal intra-cardiac pressure	1	0	1	

Continued on the next page

or emergency room admission (n = 2). There were 8 (7%) deaths, including 4 patients who also had a VT event. Compared to patients without events, those with events were more likely to have a lower left ventricular ejection fraction (LVEF) and to meet JMHW criteria (Table 1).

PET findings. Forty-seven patients (40%) had normal cardiac PET findings (32 had complete suppression of FDG, 15 had diffuse uptake with no areas of focal increase), 37 (31%) had myocardial perfusion defects or focal FDG uptake, and 34 (29%) had abnormal myocardial perfusion and FDG imaging. The corresponding annualized event rate for these three groups were 7.3%, 18.4%, and 31.9%, respectively ($p < 0.01$).

Six of the 47 patients (13%) with normal cardiac PET results experienced an adverse event (4 VT events and 3 deaths, 1 in a patient who also had VT). Of note, all 6 of these patients had cardiomyopathy, 5 had LV systolic dysfunction and 1 had severe RV systolic dysfunction from pulmonary hypertension. None of these 6 patients had extracardiac FDG uptake (see the Online Table). Patients with complete suppression of myocardial FDG uptake tended to

Table 1 Continued

Characteristic	All Patients (N = 118)	Patients With Adverse Events (n = 31)	Patients Without Adverse Events (n = 87)	p Value
Positive biopsy results at any time (may be >1 site)	28 (24%)	5 (16%)	23 (26%)	0.25
Lung	6	0	6	
Lymph node	17	5	12	
Skin	3	0	3	
Eye	1	0	1	
Bone	1	0	1	
Cardiac MRI results (available for 39 patients)				0.30
No late enhancement	13	2	11	
(+) LGE of myocardium	26	8	18	
Cardiac PET results				
Abnormal perfusion OR metabolism	37 (31%)	11 (35%)	26 (30%)	0.56
Abnormal perfusion AND metabolism	34 (28%)	14 (45%)	20 (23%)	0.019
Right ventricular uptake of FDG	11 (9%)	8 (26%)	3 (3%)	<0.001
Lateral wall uptake of FDG only	5 (4%)	0 (0%)	5 (6%)	0.17

Values are mean ± SD or n (%).

AV = atrioventricular; ECG = electrocardiogram; EM = endomyocardial; FDG = fluorodeoxyglucose; ICD = implantable cardiac defibrillator; JMHW = Japanese Ministry of Health and Welfare; LGE = late gadolinium enhancement; MRI = magnetic resonance imaging; PET = positron emission tomography.

have a lower event rate than those with diffuse FDG uptake (6.2% vs. 26.7%, respectively; p = 0.07).

Among the 71 patients with abnormal cardiac PET results, 11 (15%) had focal RV FDG uptake, of whom 8 (73%) experienced an adverse event, corresponding to an annualized event rate of 55.2%. All patients who had focal RV FDG uptake also had abnormal FDG uptake involving the LV. Six patients with focal RV FDG uptake underwent endomyocardial biopsy (EMBx), 5 of which had positive results for sarcoidosis.

Table 2 Predictors of Death or Ventricular Tachycardia

Predictor	Hazard Ratio (95% CI)	p Value
Univariate analysis		
Ejection fraction (Δ10%)	0.77 (0.62–0.95)	0.016
Age (Δ10 yrs)	0.87 (0.62–1.20)	0.39
Males	1.73 (0.80–3.78)	0.17
History of ventricular tachycardia	1.74 (0.80–3.78)	0.17
Japanese Ministry of Health and Welfare criteria (+)	2.33 (1.14–4.78)	0.020
Abnormal perfusion OR metabolism	2.55 (0.94–6.92)	0.065
Abnormal perfusion AND metabolism	3.94 (1.50–10.31)	0.005
Presence of extra-cardiac FDG uptake	0.93 (0.42–2.09)	0.87
Right ventricular uptake of FDG	4.22 (1.87–9.50)	0.001
Multivariable model		
Ejection fraction (Δ10%)	0.78 (0.63–0.98)	0.04
Japanese Ministry of Health and Welfare criteria (+)	1.76 (0.83–3.72)	0.14
Abnormal perfusion OR metabolism	2.44 (0.90–6.66)	0.08
Abnormal perfusion AND metabolism	2.87 (1.05–7.85)	0.039
Right ventricular uptake of FDG*	2.82 (1.03–7.60)	0.042

*Added to the model, including left ventricular ejection fraction and diagnosis of cardiac sarcoidosis, by the Japanese Ministry of Health and Welfare criteria, but not including abnormal perfusion and/or metabolism (see the Methods).

CI = confidence interval; FDG = fluorodeoxyglucose.

Whole-body FDG PET/CT images demonstrated abnormal FDG uptake in 31 (26%) patients. There was no significant association between the absence or presence of extra-cardiac FDG uptake and the cardiac PET examination results (see Table 3, lower part).

Predictors of death or VT. In univariate analysis, lower LVEF, positive JMHW criteria, abnormalities in myocardial perfusion and metabolism, and presence of abnormal FDG uptake in the RV were all associated with adverse events (Table 2). The presence of extra-cardiac FDG uptake had no significant association with adverse events.

In multivariable modeling including LVEF, JMHW criteria, and pattern of abnormality on PET scanning, the presence of both perfusion and metabolic abnormality on PET had the strongest association with death or VT (Table 2, Fig. 3). Similarly, in a multivariable model where the presence of focal RV FDG uptake was added to LVEF and JMHW criteria, focal RV uptake remained associated with subsequent death or VT (Fig. 4). Similar results were observed when the endpoint of cardiac death or sustained VT was used (Online Fig. 1).

Discrepancies between cardiac PET findings and JMHW criteria. When cardiac PET results were compared with JMHW criteria (Table 3), modest discordance was observed: 41 individuals with JMHW(−) criteria had abnormal PET findings, of whom 15 had abnormal perfusion and metabolism (Table 3). Similarly, 11 individuals who were categorized as having cardiac sarcoidosis by JMHW criteria had negative PET results. Among the 41 patients who had abnormal PET but were JMHW(−), 11 (27%) had adverse events, whereas among the 11 patients who were JMHW positive but had negative PET findings, there were 2 (18%) adverse events.

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Table 3 Comparison of Findings on Cardiac PET Examination Versus Clinical Criteria and Extra-Cardiac Findings

Cardiac PET Versus JMHW Criteria			
		Cardiac PET (Any Abnormality)	
		Positive	**Negative**
JMHW criteria	Positive	27	11
	Negative	41	33
Kappa = 0.13			
		Cardiac PET (Abnormal Perfusion and Metabolism)	
		Positive	**Negative**
JMHW criteria	Positive	16	22
	Negative	15	59
Kappa = 0.23			
Cardiac PET Versus Extra-Cardiac FDG			
		Cardiac PET (Any Abnormality)	
		Positive	**Negative**
Extra-cardiac FDG	Positive	19	12
	Negative	52	35
		Cardiac PET (Abnormal Perfusion and Metabolism)	
		Positive	**Negative**
Extra-cardiac FDG	Positive	12	19
	Negative	22	65

Values are n.

FDG = fluorodeoxyglucose; JMHW = Japanese Ministry of Health and Welfare; PET = positron emission tomography.

Comparison of cardiac PET findings versus endomyocardial biopsy. Forty-eight patients underwent RV EMBx as part of their clinical care; 13 (27%) had results that were positive for sarcoidosis. When examining EMBx results by PET examination findings, we found that 11 patients had negative PET examination and EMBx results while 1 patient had negative PET and positive EMBx results. This patient did not experience adverse events during a 3-year follow-up. Conversely, among the 20 patients with abnormal perfusion and FDG uptake undergoing EMBx, 9 (45%) were positive and 11 (55%) were negative. The remaining 3 patients in our cohort with positive EMBx results had focal FDG uptake without perfusion defects; all experienced adverse events (2 VT, 1 death) during follow-up.

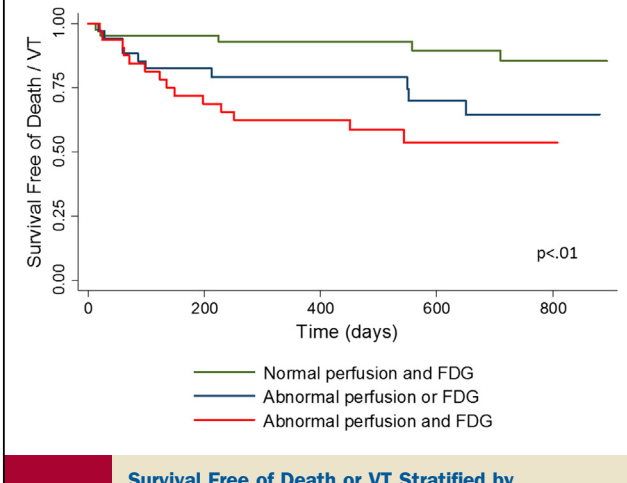

Figure 3 Survival Free of Death or VT Stratified by Cardiac PET Examination Results

Survival free of death or VT stratified by cardiac PET examination results. VT = ventricular tachycardia; other abbreviations as in Figures 1 and 2.

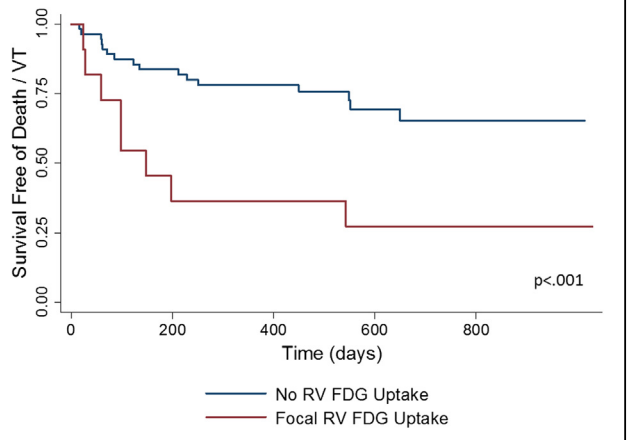

Figure 4 Survival Free of Death or VT Stratified by Focal RV Inflammation

Survival free of death or VT stratified by the presence or absence of focal right ventricular FDG uptake among individuals with abnormal cardiac PET examination findings. RV = right ventricular; other abbreviations as in Figure 1 to 3.

Discussion

Cardiac sarcoidosis is increasingly recognized as a cause of heart failure and arrhythmias. Both PET and cardiac magnetic resonance imaging (CMR) imaging have been proposed as potentially useful tests in the diagnosis of cardiac sarcoidosis and have been shown to improve diagnosis compared to standard diagnostic criteria (3,4,7). However, there is limited information about the prognostic implications of imaging findings, arguably a better measure of clinical performance. We found that patients who had abnormalities in both myocardial perfusion and metabolism (reflecting active inflammation) had the highest event rate, particularly if there was also evidence of RV involvement. Indeed, patients with either a PET mismatch or RV involvement had a 3-fold increase in the rate of adverse events. In our cohort, age, JMHW criteria, and presence of extra-cardiac sarcoidosis were not associated with adverse events. Our study represents the largest study to date of patients referred for known or suspected cardiac sarcoidosis by cardiac PET and is the first study to report the prognostic value of PET findings. These findings are potentially

important as patients with adverse prognosis may be more likely to benefit from ICD implantation as well as systemic anti-inflammatory therapies.

A novel insight from our study is that among patients with abnormal cardiac PET examination findings, those with focal RV inflammation had a 5-fold higher event rate than those with normal perfusion and metabolism. Because all these patients also had PET abnormalities involving the LV, it is conceivable that the presence of focal RV inflammation may be a marker for greater extent and/or severity of disease. In addition, it is also possible that RV involvement signifies active disease involving a more arrhythmogenic substrate. Involvement of the RV by sarcoidosis is likely under-recognized, and it is noteworthy that such a finding has been described as mimicking arrhythmogenic RV dysplasia (8).

Although not the primary focus of our study, we found a poor correlation between JMHW criteria and cardiac PET results. Because JMHW criteria require histological or clinical diagnosis of extra-cardiac sarcoidosis, studies in populations which are known to have disease may have a higher correlation as more patients who meet some of the JMHW criteria will be categorized as JMHW(+). The apparently low specificity of PET examination (versus JMHW criteria) has also been reported by others (9) and may in part be related to the limited sensitivity of the JMHW criteria (3).

Our study suggests that inflammation-targeted cardiac PET imaging has a potentially important role in evaluating patients with known or suspected cardiac sarcoidosis. In comparison to CMR, PET has the advantage of being able to image patients with implanted pacemakers or defibrillators and those with impaired renal function. Furthermore, the metabolic signal can be used as a marker of disease activity and to guide the need for and response to immunosuppressive therapies (10). In addition, PET may identify FDG-avid disease outside the heart, which may be more accessible to biopsy than the myocardium.

Study limitations. While our study represents a single-center experience, it is the largest cohort of individuals with suspected cardiac sarcoidosis undergoing PET reported to date. As is also true of most previous studies in this field, a limitation of our study is that we were unable to identify the true diagnostic accuracy of PET, as short of autopsy findings, there is no reliable reference standard for cardiac sarcoidosis. Hence, we used clinical outcomes to define the value of imaging findings. Nonetheless, the outcomes of death or sustained VT are not unique to cardiac sarcoidosis, and it is conceivable that patients with both positive and negative imaging findings may have had events related to other cardiomyopathies (e.g., myocarditis). Nevertheless, such uncertainty is not uncommon in clinical practice, and it could be argued that regardless of their underlying pathology, patients at higher risk of arrhythmias or death should be considered for ICD therapy.

Results of the cardiac PET examinations were available to clinicians and thus were used to influence patient care. Because the initiation of anti-inflammatory therapy may lower event rates, we expect that if results were not available, differences among patient subgroups could potentially be larger.

While all patients in our study underwent PET imaging, other tests which might have provided useful diagnostic and prognostic value, such as Holter monitoring, were not routinely performed in all patients. The yield of cardiac biopsy results was low in our study, and image-guided biopsy, while potentially leading to biopsy results of higher-risk sites, may result in a higher sensitivity.

The relatively higher event rate observed in our study might have been the result of referral bias, as our center is a quaternary care center with frequent referrals of patients with advanced heart failure and arrhythmias. However, a similar event rate has been found in other studies. For instance, Patel et al. (3) found that 8 out of 21 (29%) of patients with abnormal MRI had death or VT, which is comparable to our finding that 25 out of 71 (35%) patients with abnormal cardiac PET had such events, particularly when considering that patients referred for PET are more likely to have higher risk (e.g. patients with existing pacemaker or defibrillator devices would not be excluded). Supporting the higher event rate observed in patients treated with ICD, Schuller et al. (11) reported that appropriate ICD therapies occurred in 36 (32%) of 112 patients with CS who underwent ICD implantation and were followed for a mean of 29 months while Betensky et al. (12) reported ICD therapies in 17 (38%) of 45 patients with CS followed over a median of 2 years. However, it should be noted that appropriate ICD shocks occur more frequently than sudden cardiac death (13) and that the high event rate noted in our study and others (11,12) should not be used as a surrogate for expected mortality. Nevertheless, despite the high event rate observed in our population and the finding that even among patients with normal myocardial perfusion and metabolism by PET the annual event rate was 7%, we observed a 4-fold increase in the annual event rate among 30% of patients who had abnormal perfusion and inflammation. Thus, while our findings cannot be used to identify a true "low risk" group, these results suggest that cardiac PET can be used to identify individuals who have the highest risk of adverse events.

Conclusions

The presence of focal perfusion defects and FDG uptake on cardiac PET identifies patients at higher risk of death or ventricular tachycardia. These findings offer prognostic value beyond Japanese clinical criteria, presence of extra cardiac sarcoidosis, and LVEF.

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Key Words: FDG ■ PET ■ prognosis ■ sarcoidosis ■ VT.

APPENDIX

For supplemental background, methods, and results sections, as well as a table and figures, please see the online version of this article.