Atrial FDG uptake and atrial fibrillation: A systematic review and meta-analysis

Ahmad Kassar, MD,[1] Nadia Chamoun, MD,[1] Romanos Haykal, MD,[1] Yaacoub Chahine, MD,[1,2] Miles Babb, MD,[2] Hala Al Yasiri, MD,[1] Tori Hensley, BSc,[1] Efstathia Andrikopoulou, MD,[1] Nazem Akoum, MD, MS[1,3]

From the [1]Division of Cardiology, University of Washington, Seattle, WA Washington, [2]Department of Medicine, University of Washington, Seattle, Washington, and [3]Department of Bioengineering, University of Washington, Seattle, Washington.

BACKGROUND Atrial inflammatory and metabolic derangements have been reported in patients with atrial fibrillation (AF).

OBJECTIVE We sought to evaluate the association of ^{18}F-fluorodeoxyglucose (FDG) uptake on positron emission tomography (PET) in the left and right atria and AF.

METHODS We conducted a systematic review and meta-analysis, using the PRISMA Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, of studies involving patients undergoing FDG-PET scans with reported atrial or ventricular uptake and outcomes of AF. Data were pooled and analyzed, and FDG uptake in AF and non-AF patients was compared using odds ratios (ORs).

RESULTS Six studies (4 retrospective, 1 prospective, and 1 case-control) were included in the meta-analysis of studies on patients not meeting diagnostic criteria for cardiac sarcoidosis (CS): 832 patients with a mean age of 67 years, 62% male, and 53% with hypertension. AF patients demonstrated higher odds of FDG uptake in the left atrium (pooled OR 14.50, 95% confidence interval 6.78–31.02; $P < .0001$, $I^2 = 0$) and right atrium (pooled OR 51.98, 95% confidence interval 22.77–118.63, $P < .0001$, $I^2 = 0$). Two studies on patients met diagnostic criteria for CS: one did not report atrial uptake and the other did not demonstrate a statistically significant association between right or left atrial uptake in AF patients.

CONCLUSION In patients undergoing FDG-PET without meeting CS diagnostic criteria, FDG uptake in the atria was strongly associated with AF, suggesting altered metabolism or inflammation in AF pathophysiology and risk assessment.

KEYWORDS Atrial fibrillation; FDG uptake; PET imaging; Left atrium; Right atrium

(Heart Rhythm O^2 2025;6:417–423)

Introduction

Atrial fibrillation (AF) is associated with structural,[1] electrical,[2] mechanical,[3] metabolic, and inflammatory[4] derangements affecting the atrial myocardium. Atrial cardiomyopathy has been proposed as an entity incorporating this wide spectrum of abnormalities. Previous observations have reported the presence of inflammatory infiltrates on left atrial (LA) tissue biopsy.[5] Systemic inflammation has also been implicated with the persistence of AF, in which C-reactive protein levels were found to be associated with prevalent AF and the development of incident AF.[6]

Positron emission tomography (PET) imaging is currently used to evaluate for glucose avid myocardium, indicated by ^{18}F-fluorodeoxyglucose (FDG) uptake. FDG-PET is commonly used for the evaluation of ventricular glucose uptake, which can be seen in inflammatory, such as sarcoid, as well as other cardiomyopathies, such as genetic.[7] Several studies have also reported FDG-PET uptake, indicating increased metabolic activity in the atria of patients with sarcoidosis, AF, or both.[8,9] One study reported that persistent AF patients exhibited higher FDG uptake in the LA and LA appendage compared with those in sinus rhythm, with significant reductions in uptake following successful rhythm control interventions.[8] FDG uptake is not limited to the LA, and is also observed in the right atrium (RA), where it has been reportedly associated with an increased risk of stroke.[10]

Therefore, FDG-PET imaging can offer a unique window into the metabolic shifts occurring within the heart associated with AF and an understanding of the metabolic demands of the atrial tissue in different rhythms.

The available data on the association of atrial FDG uptake with AF suggest a possible link. For these reasons, we conducted a meta-analysis to synthesize the current evidence and assess the consistency and strength of this relationship across various studies.

Address reprint requests and correspondence: Dr Nazem Akoum, 1959 NE Pacific Street, Seattle, Washington 98195. E-mail address: nakoum@cardiology.washington.edu.

2666-5018/

https://doi.org/10.1016/j.hroo.2025.01.002

KEY FINDINGS

- The role of atrial changes in metabolism and their association with atrial fibrillation is under investigated.
- In a systematic evidence review and meta-analysis, right and left atrial uptake on ^{18}F-fluorodeoxyglucose positron emission tomography imaging were strongly associated with atrial fibrillation in patients not meeting diagnostic criteria for cardiac sarcoidosis.
- No statistically significant association was found between left or right atrial ^{18}F-fluorodeoxyglucose uptake and atrial fibrillation in patients meeting cardiac sarcoidosis criteria, but the number of studies is very small.

Methods

This systematic review and meta-analysis were conducted according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement.[11]

Information sources and research strategy

A systematic search of PubMed/Medline, Embase, and Scopus was performed in March 2024 by an experienced medical librarian. The search was performed using the following key terms along with their MeSH (Medical Subject Headings) when applicable: "atrial fibrillation," "FDG uptake," "nuclear PET/CT scans," "atria," and "ventricles." The references of the pertinent articles were also reviewed to identify any additional missed articles. Details of individualized search strategies were submitted as Supplemental Material. A PRISMA chart was used to describe the flow of the screening process (Figure 1).

Selection process

Two independent reviewers (A.K., N.C.) screened the titles and abstracts of the previously identified articles by utilizing EndNote (Clarivate). The same two reviewers screened the remaining articles' full texts based on the inclusion criteria further described subsequently. In case any discrepancies between the two reviewers were noted, a third reviewer (M.B.) would further screen the full text of the article. All reviewers were blinded to each other's decisions.

Eligibility criteria

The following inclusion criteria were used to retrieve the articles: (1) study design, observational (cross-sectional, prospective cohorts, and retrospective cohorts) or case-control studies; (2) full text retrievable in English; (3) studies that included patients with known AF and a control group with no AF; (4) patients who underwent inflammatory protocol studies for suspected cardiac sarcoidosis (CS); and (5) studies that reported visual FDG uptake in the RA or LA.

The following exclusion criteria were applied: (1) secondary studies (review papers, meta-analyses), letters, editorials, case reports, case series, and abstracts; (2) articles not available in English; (3) visual uptake not reported in the article; and (4) no control group (AF-free group).

Data extraction

Data extraction was performed by one reviewer (A.K.) using a predesigned standardized spreadsheet. The pertinent data included the following: study characteristics (country, year of publication), participant demographics (age, sex), number of AF patients, number of non-AF patients, number of patients with LA uptake, and number of patients with RA uptake. Uptake was defined as a binary outcome (presence or absence of LA or RA uptake at the time of the study).

Risk-of-bias assessment

Two independent reviewers (A.K., N.C.) assessed the quality of the studies using the MINORS (Methodological Index for Non-Randomized Studies) score.[12] The MINORS score is a validated tool used to assess the methodological quality of nonrandomized surgical studies. It consists of 12 items, each rated from 0 to 2, with the total score ranging from 0 to 24 for comparative studies and 0 to 16 for noncomparative studies. The items evaluate aspects such as the clarity of the study's aim, the inclusion of consecutive patients, prospective data collection, endpoint appropriateness, unbiased assessment, follow-up adequacy, and statistical analysis. A higher MINORS score indicates better methodological quality, aiding in the evaluation and comparison of nonrandomized research (Supplemental Material).

Synthesis methods

The total number of patients, including those with AF and those without (non-AF), was recorded. Measurements of LA and RA FDG uptake were extracted for each group. The LA uptake was compared between AF and non-AF patients, and a separate comparison was conducted for RA uptake between these two groups.

Statistical analysis

Data from the individual studies were combined and compared. Statistical analysis was conducted using R software (version 4.2.3; R Foundation for Statistical Computing). The meta package was specifically utilized to conduct the meta-analysis. LAFDG uptake in AF patients and non-AF patients was pooled and compared using odds ratios (ORs).

Confidence intervals (CIs) were set at 95% and statistical significance was attained for a P value $<.05$. Heterogeneity was assessed using the I^2 test,[13] with levels $< 25\%$ considered as low heterogeneity, levels 25% to 50% as moderate heterogeneity, and levels $>50\%$ as high heterogeneity.[14] A P value $<.05$ was considered statistically significant.

A fixed-effects model was used for reported outcomes.[15] In the even that a certain group had zero patients with FDG uptake, we used the continuity equation to proceed with the analysis.[16]

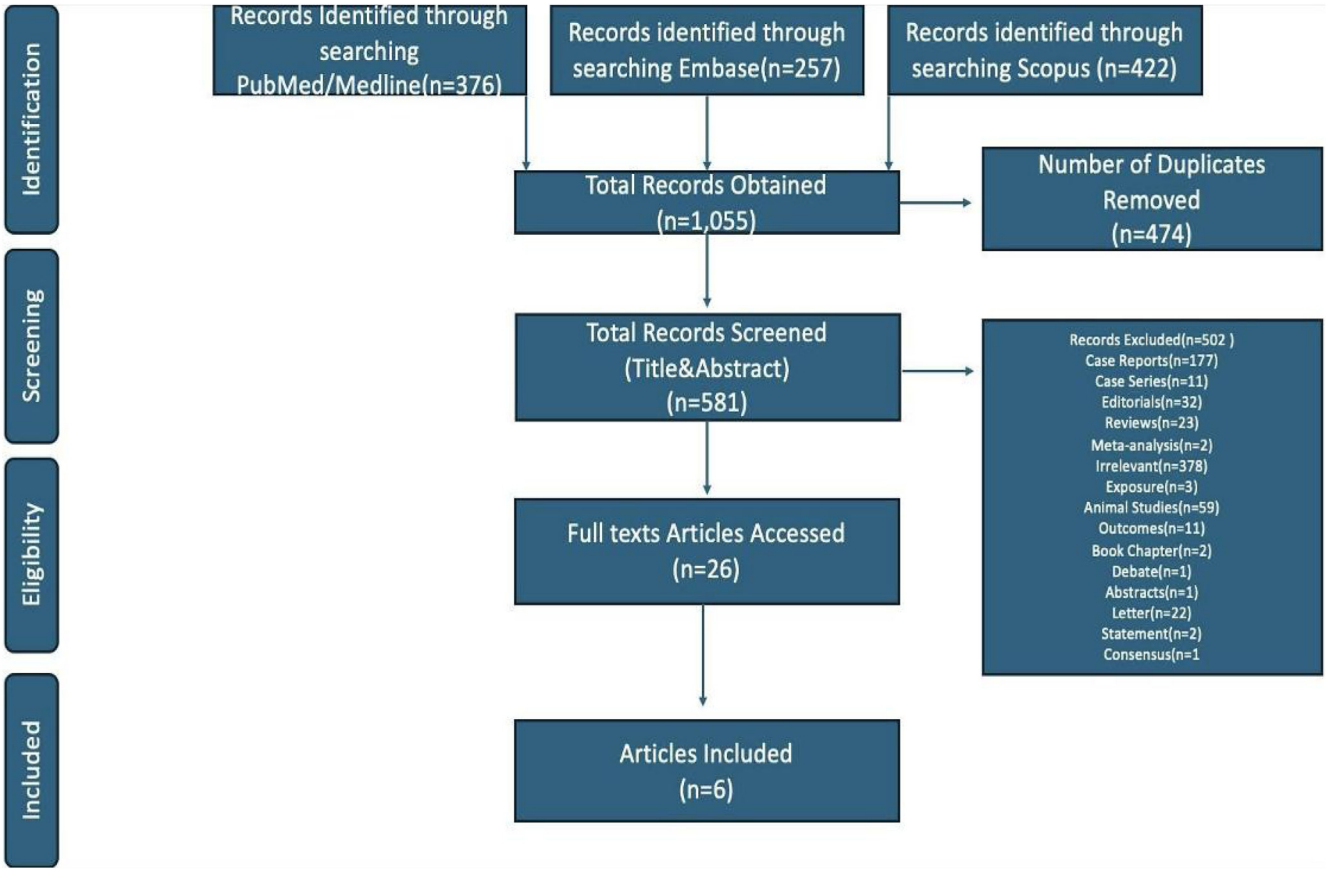

Figure 1 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow chart showing the screening and selection process of the articles included.

Results

Article selection

A total of 1055 articles were obtained from the initial search. After removing duplicates, 581 articles were screened through title and abstract screening, which resulted in 26 articles for full-text screening. Two independent reviewers (A.K., N.C.) then excluded 20 articles based on the previously mentioned exclusion criteria. The final selection included 6 studies of patients not meeting CS diagnostic criteria. We also reported on atrial FDG uptake in 2 studies that did not exclude CS patients (one of which was included in the meta-analysis because patients who developed AF were CS negative). The entire process is depicted in Figure 1 using the PRISMA flow diagram.

Atrial FDG uptake and AF in patients not meeting diagnostic criteria for CS

Demographics

A total of 832 patients from 6 observational studies of patients without CS were included. The included studies were published from Germany (n = 1), France (n = 1), China (n = 3), and Japan (n = 1). The mean age was 67 years, 518 (62%) patients were male, and 439 (53%) of the patients had a history of hypertension. Other reported demographic and echocardiographic parameters are summarized in Table 1.

LA FDG uptake and AF

Compared with patients without AF, patients with AF demonstrated a significant propensity for LA FDG uptake on their FDG PET scans with a pooled OR of 14.50 (95% CI 6.78–31.02, $P < .0001$, $I^2 = 0$) (Figure 2, top panel). The study by Sinigaglia and colleagues[18] demonstrated the highest OR among the included studies, with an OR of 20.78 (95% CI 1.18–366.73).

RA FDG uptake and AF

Compared with patients without AF, patients with AF demonstrated RA FDG uptake on their FDG PET studies, with a pooled OR of 51.98 (95% CI 22.77–118.63, $P < .0001$, $I^2 = 0$ (Figure 2, bottom panel). Wang and colleagues[10] had the highest statistically significant OR among the included studies, with an OR of 117.33 (95% CI 23.91–1315.38).

Left and right ventricular FDG uptake and AF

Of the 6 studies of patients not meeting diagnostic criteria for CS included in our analysis, 5 did not report on left or right ventricular FDG uptake in patients with AF. The study by Wang and colleagues[10] reported LV uptake in 58 of 115 patients in the AF group vs 47 of 115 in the non-AF group

Table 1 Summary of patient demographics and baseline characteristics from included studies of patients not meeting cardiac sarcoidosis diagnostic criteria

	Kupusovic et al, 2023[17]			Sinigaglia et al, 2019[18]			Wan et al, 2023[19]		
	Total (n = 50)	AF (n = 25)	No AF (n = 25)	Total (n = 128)	AF (n = 64)	No AF (n = 64)	Total (n = 105)	AF (n = 70)	No AF (n = 35)
Age, y	65.8 ± 9.5	68.4 ± 9.5	63.2 ± 9.5	70.1 ±14	70.2 ± 14	69.9 ± 14.6	64.9 ± 9.8	65.2 ± 9.9	64.3 ± 9.8
Male	36 (72)	17 (68)	19 (76)	70 (55)	36 (56)	34 (53)	63 (60)	42 (60)	21 (60)
CAD	16 (32)	10 (40)	6 (24)	21 (16)	14 (22)	7 (11)	N/A	N/A	N/A
DM	12 (24)	6 (24)	6 (24)	42 (33)	24 (37)	18 (28)	12 (11.4)	7 (10)	5 (14)
CHF	21 (42)	15 (60)	6 (24)	N/A	N/A	N/A	N/A	N/A	N/A
HTN	35 (70)	17 (68)	18 (72)	64 (50)	38 (59)	26 (41)	61 (58)	43 (62)	18 (51)
Valvular disease	N/A	N/A	N/A	42 (33)	24 (37)	18 (28)	N/A	N/A	N/A
Dyslipidemia	N/A	N/A	N/A	35 (27)	17 (27)	18 (28)	40 (38)	25 (36)	15 (44)
Smoker	N/A	N/A	N/A	13 (10)	9 (14)	4 (6)	34 (32)	23 (33)	11 (31)
Drinking	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Obesity	N/A	N/A	N/A	16 (12)	7 (11)	9 (14)	N/A	N/A	N/A
BMI, kg/m^2	27.1 ± 1.16	27.6 ± 1.3	26.7 ± 1	N/A	N/A	N/A	25.11 ± 3.07	25.2 ± 3.29	24.92 ± 2.58
TIA/stroke	N/A	N/A	N/A	19 (15)	17 (26)	2 (3)	N/A	N/A	N/A
LVEF, %	46.55 ± 12.65	43.6 ± 12.5	49.5 ± 12.8	N/A	N/A	N/A	61.87 ± 4.22	61 ± 4.9	63.6 ± 2.3
LAVI, mL/m^2	38.65 ± 10.03	47.3 ± 12.9	30 ± 5.9	N/A	N/A	N/A	N/A	N/A	N/A
LAD, mm	N/A	N/A	N/A	N/A	N/A	N/A	39.9 ± 5.7	42.4 ± 6.4	34.9 ± 3.95
RA area, cm^2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
LA area, cm^2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
CRP, mg/L	N/A	N/A	N/A	45.58 ± 48.98	37.69 ± 45.49	58.08 ± 52.59	3.5 (3.1–4.68)	3.5 (3.1-4.2)	3.8 (3-4.68)
LA enlargement	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RA enlargement	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Values are mean ± SD, median (interquartile range), or n (%). AF = atrial fibrillation; BMI = body mass index; CAD = coronary artery disease; CHF = congestive heart failure; CRP = C-reactive protein; DM = diabetes mellitus; HTN = hypertension; LA = left atrial; LAD = left atrial diameter; LAVI = left atrial volume index; LVEF = left ventricular ejection fraction; N/A = not available; RA = right atrial; TIA = transient ischemic attack.

(P = .186). Right ventricular uptake was reported in 3 of 115 patients with AF compared with 5 of 115 patients without AF (P = .719).

Atrial FDG uptake and AF in patients meeting diagnostic criteria for CS

There were 2 studies identified that specifically evaluated atrial uptake in patients meeting diagnostic criteria for CS. Sinigaglia and colleagues[18] reported atrial uptake in patients who were referred for suspected sarcoidosis, endocarditis, or infection of a cardiac implantable electronic device. There were only 4 patients diagnosed with CS; however, none of these patients had atrial uptake. Weng and colleagues[22] reported on atrial FDG uptake in patients with atrial arrhythmias (AAs) vs no AAs from a pool of patients diagnosed with CS, in which LA uptake was reported in 3 of 11 of patients with AA vs 1 of 22 in patients without AA (P = .059). As for RA uptake, no patients had RA uptake in the AA group, while 3 of 22 patients in the no AA group had RA uptake.

Discussion

We conducted a systematic evidence review and meta-analysis of studies reporting on atrial FDG uptake and AF. In patients who did not meet the diagnostic criteria for CS, we show a strong association between LA and RA FDG uptake and AF, with RA FDG uptake associated with a higher risk. LA FDG uptake was also found to be associated with AF in one study of patients meeting the criteria for CS.

FDG uptake refers to the uptake of FDG, a glucose analog used in PET imaging to detect a metabolic shift from the typical fatty acid to a glucose myocardial oxidation pathway. This can be seen in inflammatory and neoplastic conditions, as well as genetic cardiomyopathies, in which metabolic activity may be altered due to the genetic mutations.[23] FDG uptake helps identify regions of inflammation or abnormal metabolic activity within the heart.[24] Ventricular FDG uptake is frequently reported, reflecting pathological processes within these chambers.[25] PET imaging can also detect atrial FDG uptake, which may indicate isolated or additional atrial involvement, which is of great interest in relation to AF, as it provides a new perspective and deepens our understanding of the alterations in atrial metabolism or inflammation that might occur in patients with AF.

There are two scenarios where atrial FDG uptake can be encountered. In the first, atrial FDG uptake, without ventricular uptake, has been demonstrated in patients with persistent AF, imaged prior to catheter ablation.[26] Following ablation, repeat imaging revealed a decrease in atrial FDG uptake with maintenance of sinus rhythm.[26] This suggested that persistent AF was associated with abnormal atrial metabolism and decreased myocardial efficiency or a shift to glucose metabolism in the setting of AF.[26] In the second scenario, the presence of systemic inflammatory disease, such as sarcoidosis, with additional or isolated atrial cardiac involvement, may contribute to the development of AF by providing both substrates and triggers for the arrhythmia through the inflammatory process. Our findings in patients without CS likely fall in the second scenario, as the patients included in the studies selected for the meta-analysis underwent FDG-PET for the evaluation of CS, in which these patients ultimately did not meet the diagnostic criteria, but in whom FDG uptake in both RA and LA were associated with significant odds of AF. There are various criteria put forward by different societies for a clinical diagnosis of CS.[27–29]

Table 1 *Continued.*

Wang et al, 2022[10]			Watanabe et al, 2019[20]			Xie et al, 2022[21]		
Total (n = 230)	AF (n = 115)	No AF (n = 115)	Total (n = 199)	AF (n = 137)	No AF (n = 62)	Total (n = 120)	AF (n = 100)	No AF (n = 20)
68 ± 8	69 ± 9	67 ± 7	73 (68-80)	73 (68–80)	73 (68 –76)	65.7 (56–75)	65.7 (56-75)	66 (61-68)
153 (66.5)	78 (67.8)	75 (65.2)	120 (60)	88 (64)	32 (52)	76 (63)	63 (63)	13 (65)
N/A	N/A	N/A	N/A	N/A	N/A	30 (25)	30 (30)	0 (0)
37 (16)	17 (14)	20 (17)	N/A	N/A	N/A	39 (33)	35 (35)	4 (20)
20 (8.7)	16 (13.9)	4 (3.4)	N/A	N/A	N/A	N/A	N/A	N/A
115 (50)	59 (51.3)	56 (49)	98 (49)	72 (54)	26 (42)	66 (55)	61 (61)	5 (25)
N/A	N/A	N/A	30 (15)	28 (21)	2 (4)	N/A	N/A	N/A
46 (20)	23 (20)	23 (20)	69 (35)	44 (32)	25 (40)	N/A	N/A	N/A
79 (34)	38 (33)	41 (36)	101 (51)	75 (60)	26 (50)	N/A	N/A	N/A
40 (20)	23 (20)	24 (21)	49 (25)	35 (29)	14 (34)	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
22.8 ± 2.91	22.92 ± 3.24	22.84 ± 2.56	22.5 (20.5–25.4)	22.8 (20.6–25.4)	22.2 (20.5–24.4)	25.99 (22.4–28.7)	25.99 (23.6–28.7)	24.1 (22.4–26.6)
N/A	N/A	N/A	N/A	N/A	N/A	26 (22)	25 (25)	1 (5)
63 (60-65)	61 (58-63)	64 (62-66)	63 (52-69)	63 (54-68)	62 (52–69)	N/A	64.88 (6)	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
39.29 ± 7.17	43.71 ± 6.82	34.87 ± 4.15	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	21.8 (6.6–34.8)	21.8 (14.6–34.8)	9 (6.6–9.6)	N/A	N/A	N/A
N/A	N/A	N/A	30.7 (11.4–65)	30.7 (20.6–65)	12.9 (11.4–14)	N/A	N/A	N/A
4.3 (3.5-5.5)	4 (3.5-5)	4.6 (3.5-5.9)	0.2 (0.05–0.89)	0.2 (0.06–0.89)	0.11 (0.05–0.34)	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	15 (15)	N/A
N/A	N/A	N/A	N/A	N/A	N/A	N/A	79 (79)	N/A

Evaluation of FDG uptake typically focuses on ventricular uptake. Isolated atrial uptake in the setting of CS is certainly plausible, even though it is currently not used in the diagnostic criteria of CS. Our systemic evidence review revealed one study of patients meeting diagnostic criteria for CS, in which the investigators demonstrated diverging associations of RA and LA FDG uptake and AF.

The LA is recognized to play a pivotal role in the initiation and maintenance of AF, with many studies reporting on the electrical and structural remodeling.[30] LA FDG uptake reflects abnormal metabolic activity that may be associated with inflammation, metabolic changes, and atrial myopathy.[17] Inflammatory markers and cytokines may be elevated in patients with AF, supporting the role of inflammation in its pathogenesis.[31] Alteration in LA metabolism toward higher FDG uptake may reflect myopathic changes, including altered cellular metabolism and energy utilization. These changes contribute to the development and maintenance of AF by promoting abnormal electrical activity, as well as structural change, such as LA fibrosis commonly seen in AF.[32]

The RA also demonstrated increased FDG uptake in patients with AF, underscoring its role in this arrhythmia. The RA, traditionally under emphasized in AF studies, can also undergo significant structural and electrical remodeling.[28] The increased FDG uptake in the RA suggests that metabolic alterations are not confined to the LA but are a more generalized, biatrial disease process in AF patients. Recognizing the deranged metabolic activity in the RA makes a strong case to include both atria in the pathophysiological and therapeutic approaches in AF. Our findings showed that there was a stronger association between RA uptake and AF, which is consistent with previous findings.[19,33] This could be attributed to the fact that the LA typically exhibits more extensive fibrosis compared with the RA, often accompanied by apoptosis and cell loss, which can reduce glucose uptake and explain the lower FDG PET signal.[19,20,28,34] While diffuse atrial remodeling affects both atria, the relatively less fibrotic RA may retain higher metabolic activity, contributing to its increased FDG uptake compared with the LA.

Limitations

We relied on observational studies to extract prevalence data, after which we computed the OR between atrial FDG uptake and AF. The studies included in the analysis have small cohorts, which is reflected in the wide CIs. The methods used to define atrial visual or qualitative FDG uptake, the outcome of interest in our study, are not uniformly defined and may have contributed to some variability among studies. However, the heterogeneity tests showed low variability in the results among the various studies. Another limitation in the studies reported is that the time from the onset of AF to the scan was not well elucidated.

Furthermore, the studies included in the meta-analysis were from centers in Europe and Asia, where diagnostic criteria for CS vary based on societal recommendations. The utilization of FDG-PET scans for detecting atrial uptake presents certain limitations, primarily due to the thinness of the atrial wall. However, our primary focus is to highlight the potential of these scans in future research to enhance the understanding of the atrial involvement in CS or the pathophysiology of AF. Furthermore, a limitation of the FDG-PET modality, as with other imaging techniques such as late gadolinium enhancement magnetic resonance imaging, is its susceptibility to variations in image acquisition quality and the methodologies used for result quantification. Finally, the terms avidity and uptake have been used interchangeably across the various pooled manuscripts. While

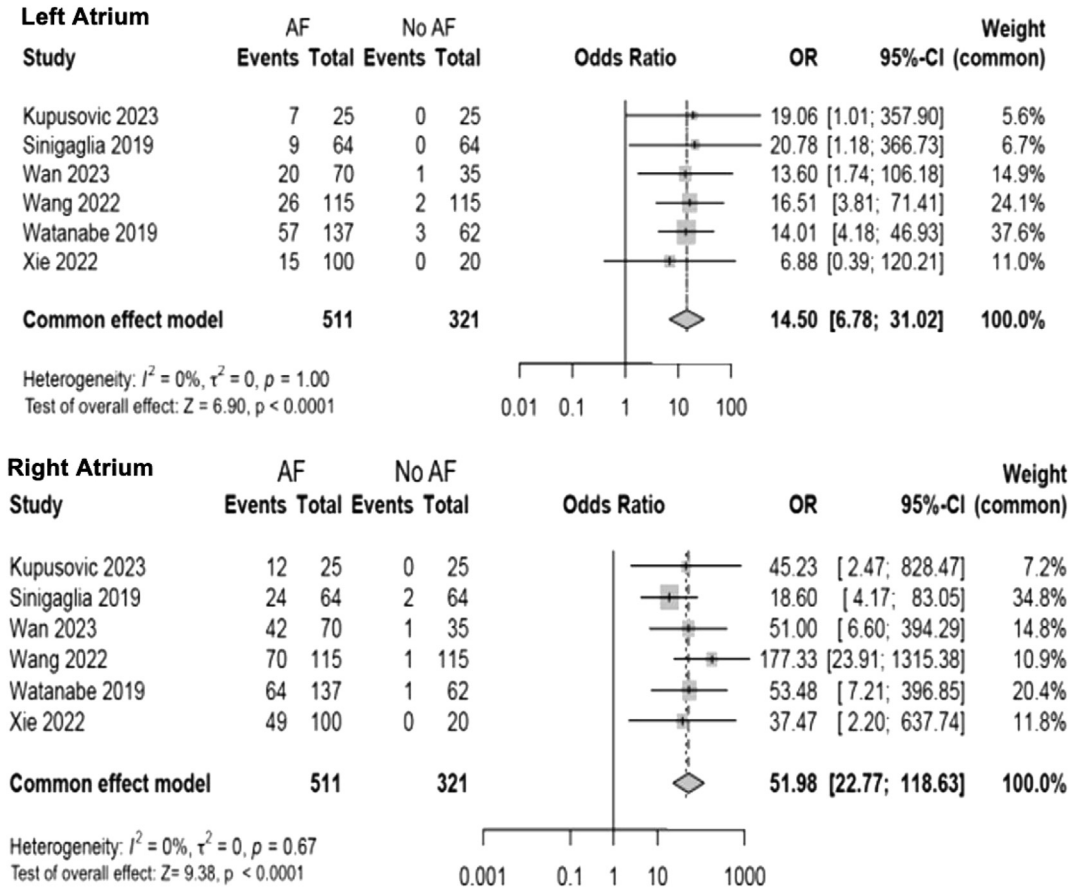

Figure 2 Funnel plots showing pooled odds ratios of atrial ^{18}F-fluorodeoxyglucose (FDG) uptake in the left atrium (top) and right atrium (bottom) in patients with vs without atrial fibrillation (AF), not meeting diagnostic criteria for cardiac sarcoidosis. CI = confidence interval; OR = odds ratio.

the two terms differ conceptually, we used *uptake* to refer to the visual or qualitative presence of FDG across the atrial myocardium.

Implications for future research

Future longitudinal studies could elucidate changes in myocardial (atrial and ventricular) FDG uptake and its association with clinical AF disease over time. Studies of a potentially targeted anti-inflammatory or metabolic approach to AF, and the role of FDG-PET in risk stratification and monitoring of treatment efficacy, may offer a new perspective on managing the arrhythmia in a more personalized and tailored approach for individual patients.

Conclusion

In patients undergoing FDG-PET without meeting CS diagnostic criteria, increased FDG uptake in the atria demonstrated a strong association with AF. While these results offer compelling preliminary insights, they should be interpreted cautiously as hypothesis-generating. They serve to prepare the ground for future studies systematic investigations to determine whether FDG-PET can be reliably employed as a clinical tool for risk stratification and the tailored management of AF.

Funding Sources: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Disclosures: The authors have no conflicts to disclose.

Authorship: All authors attest they meet the current ICMJE criteria for authorship.

Ethics Statement: This systematic review and meta-analysis were conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement.

Disclaimer: Given his role as Associate Editor, Nazem Akoum had no involvement in the peer review of this article and has no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to Guest Editor E. Kevin Heist.

References

1. Iwasaki Y-K, Nishida K, Kato T, Nattel S. Atrial fibrillation pathophysiology. Circulation 2011;124:2264–2274.
2. Pozios I, Vouliotis AI, Dilaveris P, Tsioufis C. Electro-mechanical alterations in atrial fibrillation: structural, electrical, and functional correlates. J Cardiovasc Dev Dis 2023;10:149.
3. Gan GCH, Ferkh A, Boyd A, Thomas L. Left atrial function: evaluation by strain analysis. Cardiovasc Diagn Ther 2018;8:29–46.
4. Packer M. Characterization, pathogenesis, and clinical implications of inflammation-related atrial myopathy as an important cause of atrial fibrillation. J Am Heart Assoc 2020;9:e015343.
5. Frustaci A, Chimenti C, Bellocci F, Morgante E, Russo MA, Maseri A. Histological substrate of atrial biopsies in patients with lone atrial fibrillation. Circulation 1997;96:1180–1184.

6. Aviles RJ, Martin DO, Apperson-Hansen C, et al. Inflammation as a risk factor for atrial fibrillation. Circulation 2003;108:3006–3010.
7. Lal M, Chen C, Newsome B, Masha L, Camacho SA, Masri A, Nazer B. Genetic cardiomyopathy masquerading as cardiac sarcoidosis. J Am Coll Cardiol 2023; 81:100–102.
8. Nakamura O, Goetz C, Meyer PT, Arentz T, Jadidi A. Increased 18F-fluorodeoxyglucose uptake in the cardiac atria: an evidence for increased atrial inflammation in patients with atrial fibrillation? Europace 2022;24:euac053.599.
9. Kupusovic J, Weber M, Kessler L, et al. Increased FDG uptake in AF individuals suggesting atrial inflammation visualized by FDG PET/CT with glucose uptake suppression protocols. Eur Heart J 2021;42:ehab724.0324.
10. Wang B, Xu Y, Wan P, et al. Right atrial fluorodeoxyglucose uptake is a risk factor for stroke and improves prediction of stroke above the CHA(2)DS(2)-VASc score in patients with atrial fibrillation. Front Cardiovasc Med 2022;9:862000.
11. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. J Clin Epidemiol 2009;62:e1–e34.
12. Slim K, Nini E, Forestier D, Kwiatkowski F, Panis Y, Chipponi J. Methodological index for non-randomized studies (minors): development and validation of a new instrument. ANZ J Surg 2003;73:712–716.
13. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. BMJ 2003;327:557–560.
14. West S, Gartlehner G, Mansfield AJ, et al. Comparative effectiveness review methods: clinical heterogeneity. Agency for Healthcare Research and Quality; 2010.
15. Barili F, Parolari A, Kappetein PA, Freemantle N. Statistical Primer: heterogeneity, random- or fixed-effects model analyses? Interact Cardiovasc Thorac Surg 2018; 27:317–321.
16. Haviland MG. Yates's correction for continuity and the analysis of 2 x 2 contingency tables. Stat Med 1990;9:363–367. discussion: 369–383.
17. Kupusovic J, Weber M, Bruns F, et al. PET/CT- identified atrial hypermetabolism is an index of atrial inflammation in patients with atrial fibrillation. J Nucl Cardiol 2023;30:1761–1772.
18. Sinigaglia M, Mahida B, Piekarski E, et al. FDG atrial uptake is associated with an increased prevalence of stroke in patients with atrial fibrillation. Eur J Nucl Med Mol Imaging 2019;46:1268–1275.
19. Wan P, Wang B, Yu W, et al. Right atrial wall inflammation detected by 18F-FDG PET/CT may be significantly associated with persistent atrial fibrillation: a prospective case-control study. BMC Cardiovasc Disord 2023;23:587.
20. Watanabe E, Miyagawa M, Uetani T, et al. Positron emission tomography/computed tomography detection of increased (18)F- fluorodeoxyglucose uptake in the cardiac atria of patients with atrial fibrillation. Int J Cardiol 2019;283:171–177.
21. Xie B, Chen BX, Nanna M, et al. 18F-fluorodeoxyglucose positron emission tomography/computed tomography imaging in atrial fibrillation: a pilot prospective study. Eur Heart J Cardiovasc Imaging 2022;23:102–112.
22. Weng W, Wiefels C, Chakrabarti S, et al. Atrial arrhythmias in clinically manifest cardiac sarcoidosis: Incidence, burden, predictors, and outcomes. J Am Heart Assoc 2020;9:e017086.
23. Yamamoto H, Kitagawa T, Susawa H, et al. Occasionally increased 18F-fluorodeoxyglucose uptake in apical hypertrophic cardiomyopathy with midventricular obstruction. J Cardiol Cases 2017;16:44–47.
24. Martineau P, Grégoire J, Harel F, Pelletier-Galarneau M. Assessing cardiovascular infection and inflammation with FDG-PET. Am J Nucl Med Mol Imaging 2021;11:46–58.
25. Minamimoto R. Series of myocardial FDG uptake requiring considerations of myocardial abnormalities in FDG-PET/CT. Jpn J Radiol 2021;39:540–557.
26. Marchandise S, Roelants V, Raoult T, et al. Left atrial glucose metabolism evaluation by 18F-FDG-PET in persistent atrial fibrillation and in sinus rhythm. JACC Basic Transl Sci 2024;9:459–471.
27. Korantzopoulos P, Letsas KP, Tse G, Fragakis N, Goudis CA, Liu T. Inflammation and atrial fibrillation: A comprehensive review. J Arrhythm 2018; 34:394–401.
28. Gunturiz-Beltrán C, Nuñez-Garcia M, Althoff TF, et al. Progressive and simultaneous right and left atrial remodeling uncovered by a comprehensive magnetic resonance assessment in atrial fibrillation. J Am Heart Assoc 2022;11:e026028.
29. Cheng RK, Kittleson MM, Beavers CJ, et al. Diagnosis and management of cardiac sarcoidosis: a scientific statement from the American Heart Association. Circulation 2024;149:e1197–e1216.
30. Zhou X, Dudley SC. Evidence for inflammation as a driver of atrial fibrillation. Front Cardiovasc Med 2020;7:62.
31. Rafaqat S, Afzal S, Khurshid H, Safdar S, Rafaqat S, Rafaqat S. The role of major inflammatory biomarkers in the pathogenesis of atrial fibrillation. J Innov Card Rhythm Manag 2022;13:5265–5277.
32. Nattel S, Burstein B, Dobrev D. Atrial remodeling and atrial fibrillation. Circ Arrhythm Electrophysiol 2008;1:62–73.
33. Santi ND, Wu KY, Redpath CJ, et al. Metabolic activity of the left and right atria are differentially altered in patients with atrial fibrillation and LV dysfunction. J Nucl Cardiol 2022;29:2824–2836.
34. Akoum N, McGann C, Vergara G, et al. Atrial fibrosis quantified using late gadolinium enhancement MRI is associated with sinus node dysfunction requiring pacemaker implant. J Cardiovasc Electrophysiol 2012; 23:44–50.