The limited performance of echocardiography in specific infectious processes involving the heart led to the search for additional diagnostic tools. Fluorodeoxyglucose positron emission tomography computed tomography (FDG PET/CT) has been proposed for its diagnostic abilities in several infectious diseases including cardiac infections. A literature review of studies evaluating FDG PET/CT in native valve infective endocarditis (IE), prosthetic valve IE, cardiac implantable electrical device (CIED) infection, and left ventricular assist device (LVAD) infection is presented, focusing on studies published in recent years. Overall, in prosthetic valve endocarditis (PVE), FDG PET/CT demonstrate high sensitivity (73–93%) and specificity (80–95%), while in native valve endocarditis (NVE) the sensitivity is very low (22–68%), with high specificity (97–100%) similar to PVE. For CIED, LVAD infection, and transcatheter aortic valve implantation associated endocarditis, data come from small studies and show good diagnostic performance of FDG PET/CT. International guidelines are increasingly recommending FDG PET/CT for the diagnosis of specific conditions of cardiac infections. Beyond the diagnostic performance ability, few studies have evaluated the added benefit of FDG PET/CT in terms of clinical outcomes of patients with suspected cardiac infection. This should be the focus in future studies.

**Keywords:** Fluorodeoxyglucose positron emission tomography computed tomography; FDG PET/CT; Infective endocarditis; Cardiac implantable electrical device; Left ventricular assist device
Key Summary Points

Fluorodeoxyglucose positron emission tomography computed tomography (FDG PET/CT) has high sensitivity and specificity in the diagnosis of prosthetic valve endocarditis.

FDG PET/CT has low sensitivity but high specificity for the diagnosis of native valve endocarditis.

FDG PET/CT has a promising role in the diagnosis of cardiac implantable electrical device and left ventricular assist device infections and in transcatheter aortic valve associated endocarditis.

Further studies are needed to evaluate the clinical impact of FDG PET/CT in cardiac infection.

INTRODUCTION

For many years, echocardiography was the exclusive imaging tool for evaluating impaired structural conditions of the heart, including infectious processes. Besides its clear advantages, echocardiography has limitations. The poor imaging quality due to echoic prosthetic devices, difficulties in demonstrating small processes, and inability to differentiate between infectious and non-infectious masses are major limitations. In addition, transesophageal echocardiography (TEE) is an invasive procedure, often withheld for elderly patients, who represent a growing population of patients with cardiac infections [1]. Fluorodeoxyglucose positron emission tomography computed tomography (FDG PET/CT) has the advantage of providing anatomic and functional information of such processes. In recent years, growing data have been published dealing with different aspects of FDG PET/CT in native and prosthetic valve infective endocarditis, cardiac implantable electrical device (CIED), and left ventricular assist device (LVAD) infections.

In this review, we discuss the available data evaluating FDG PET/CT in cardiac infections from recent years. We review the accumulating data of accuracy of FDG PET/CT in diagnosis of infective endocarditis (IE) as well as the added clinical value of this imaging tool and its impact on patient outcomes. We also review the utility of FDG PET/CT in growing groups of patients with specific conditions of cardiac infections such as transcatheter aortic valve implantation-IE (TAVI-IE), CIED, and LVAD infections. Also, we summarize the recommendations for myocardium preparation in cardiac infection imaging by FDG PET/CT and the current status of the utility of FDG PET/CT in cardiac infections according to guidelines from international professional societies.

A search was conducted in PubMed, google scholar, and articles’ references. The search term combined the terms fluorodeoxyglucose positron emission tomography, computed tomography, or FDG PET/CT with the terms infection, infectious disease, native and prosthetic infective endocarditis, cardiac implantable electrical device infection, or left ventricular assist device. We searched studies published in English and reviewed clinical studies other than case reports. The focus was on studies published since 2015. This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by the author.

DIAGNOSTIC ACCURACY OF FDG PET/CT IN IE

First publications on FDG PET/CT in cardiac infections were case reports and small case series suggesting the potential role of FDG PET/CT in the diagnosis of IE [2]. Thereafter, it was followed by studies focusing on the yield of the FDG PET/CT in the diagnosis of extracardiac septic emboli [3, 4]. With the improvement in techniques of imaging of the heart and overcoming the physiological myocardial glucose uptake, more attention was given to the diagnosis of infectious processes involving the heart, including native valve IE (NVE) and
prosthetic valve IE (PVE), CIED infection, and more recently, LVAD infection.

Most studies evaluating FDG PET/CT in cardiac infections were conducted in single centers leading to relatively small cohorts. The cohorts are heterogeneous as some included together all types of cardiac infections (NVE, PVE, CIED infection) [5–7], while others focused on a specific group of patients, mainly PVE [8–10]. Despite the differences in studies’ design, prescan protocol, and interpreting criteria used, accumulating data show relatively high sensitivity of FDG PET/CT in PVE (73–93%) compared with a low sensitivity in NVE (22–68%) [5–7, 11–15]. On the other hand, specificity is high in almost all studies for both NVE (97–100%) [7, 11, 14] and PVE (80–95%) [7–10].

**IMPROVING THE DIAGNOSTIC PERFORMANCE OF FDG PET/CT**

There are several factors that affect the diagnostic yield of FDG PET/CT in cardiac imaging. The majority of these factors are technical challenges related to physical and physiological issues such as the cardiac-pulmonary motions, sub-optimal spatial resolution, and long data acquisition times as well as the physiological myocardial glucose uptake. Technical improvements have overcome some of these factors in recent years. A recent meta-analysis that included 26 studies with 1358 patients evaluating the performance of FDG PET/CT in IE showed that in studies published after 2015, sensitivity was higher for all subtypes of IE compared with studies published before 2015 [12]. The increasing sensitivity over time seems to be highly related to technical improvement in FDG PET/CT machines, acquisition protocols, and pre-scan preparation for myocardial suppression techniques. In a prospective study that included 92 patients with suspected PVE with or without CIED infection, a higher sensitivity was observed when combining CT angiography (CTA) with FDG PET compared with non-enhanced CT with FDG PET, reaching a sensitivity of 91% [9]. In another study that evaluated FDG PET/CT in suspected PVE, a standardized semi-quantitative measure of FDG uptake with a specific value improved the sensitivity to 100% without reducing the specificity [10]. In addition, excluding patients with low C-reactive protein or with a history of use of surgical adhesives for prosthetic valve implantation increased sensitivity and specificity. Other studies suggested different technical approaches for improving the accuracy of FDG PET/CT. For example, in a small study that included 41 patients with suspected PVE, improved specificity was achieved when FDG uptake was observed in both attenuation correction and non-attenuation correction PET images [16]. The authors emphasized the importance of the patient preparation and image interpretation methods on the FDG PET/CT yield. It is widely accepted that focal rather than diffuse, and heterogeneous rather than homogenous uptake are the main findings suggestive of true infection [17, 18]. Conversely, recent surgery and prolonged antibiotic duration before PET CT performance, commonly assumed to affect isotope imaging results, were rejected by several studies. One study that included 80 patients with suspected NVE, PVE, or CIED infection showed that there were no significant differences in the length of antibiotic therapy before FDG PET/CT performance between false negative and true positive results [5]. Similarly, in a previously mentioned study, recent valve surgery was not significantly associated with increased false positives [10].

Important factors that determine the performance of FDG PET/CT are the gold standard used for making the final diagnosis and the length of follow-up used for making the diagnosis. Some studies used the modified Duke criteria as the gold standard for diagnosis [7, 14], while others used a consensus by a multidisciplinary endocarditis team [5, 9, 10]. Alongside the advantage of the standardized definition of the Duke criteria, the low sensitivity of these criteria is a limitation [19]. On the other hand, consensus by a multidisciplinary team is a non-standardized and difficult to compare reference method. As the results of FDG PET/CT were known in real time, it was inevitably incorporated in the final diagnosis given by the endocarditis teams [5]. Length of follow-up for final diagnosis ranged from...
diagnosis on discharge of the index admission [7, 14] to 3 months [8], 4 months [16], 6 months [6], and up to 12 months [20].

**CLINICAL IMPACT OF FDG PET/CT ON IE**

Beyond the diagnostic value, it is of interest whether FDG PET/CT findings lead to changes in management and improved patients’ outcomes. This may be related to the detection of either cardiac or extracardiac findings by FDG PET/CT. In a recent large study that included 303 patients with both NVE and PVE/ascending aortic prosthesis infection (AAPI) who underwent FDG PET/CT, 76% (47/62) of PVE/AAPI cases who were initially classified as possible IE according to modified Duke criteria were reclassified as definite IE when adding FDG PET/CT results [7]. In this study, extracardiac infectious foci were identified in 47/129 (28%) patients. In a previous small study that focused on identification of extracardiac embolic events by FDG PET/CT in IE, treatment modification was reported in 14 (35%) of 40 cases with definite IE they included. The main modifications regarded antibiotic treatment prolongation, referral to surgical procedures, and even prevention of unnecessary device extraction. In another small cohort, FDG PET/CT led to treatment modification, due to diagnostic reclassification or extracardiac findings necessitating treatment, in five out of 20 patients with IE [21]. In another single-center retrospective study that reviewed data of 72 patients with suspected IE who underwent FDG PET/CT focusing on extracardiac findings, new findings detected first time by FDG PET/CT were reported in 17 (23.6%) out of 72 patients with IE, of which in 11 patients the findings were considered of clinical importance as they led to treatment adjustment [22]. The calculated number needed to perform FDG PET/CT to have a clinically significant finding in this setting with obvious selection bias was seven, the true number in non-selected cases of IE may be much higher. The overall detection rate of extracardiac metastatic foci of infection in IE in a meta-analysis that included 13 studies was 17% (34/198) [23]. The variability in detection of extracardiac infectious foci is related to type of IE, specific pathogen, and timing of performance of FDG PET/CT.

FDG PET/CT was evaluated for its prognostic value. In a prospective study that included 179 patients with suspected NVE and PVE who underwent FDG PET/CT, a significant association between positive FDG PET CT and adverse clinical outcome (death, unplanned heart surgery, and embolic events) was observed among patients with PVE [20]. Furthermore, the intensity of FDG valvular uptake was associated with new embolic events in both PVE and NVE [20].

**FDG PET/CT IN TAVI-IE**

One of the specific conditions that poses a challenge on the sensitivity of the modified Duke criteria in general and on echocardiography specifically is TAVI-IE. The decreased sensitivity of echocardiography is a attributed to the location of vegetation and the acoustic shadow of the valve stent [24–26]. Recently, a few reports have suggested that FDG PET/CT in this setting can contribute to improved diagnosis [27, 28]. In a small cohort of 16 cases with suspected TAVI-IE, echocardiography showed findings compatible with endocarditis according to the modified Duke criteria in only five out of 10 definite IE cases, while FDG PET/CT was positive for IE in nine cases [27]. In another retrospective multicenter study that evaluated the change in diagnosis with adding FDG PET/CT and/or cardiac CTA in 30 patients with suspected TAVI-IE, the diagnosis had been changed (for both rejection and confirmation) in one-third of the patients [28]. Whether TAVI by itself may result in “normal” FDG uptake due to a non-infectious inflammatory reaction following the implantation procedure is a question that was targeted by a recent small study that compared the FDG uptake within 1 month following TAVI in 31 patients (control group) with 14 cases with suspected TAVI-IE [29]. FDG uptake was observed in 7 (22%) patients from the control group and in all seven cases with definite IE as well as in one case with rejected IE.
Yet, the uptake representing true infection was focal and involved less than 25% of the valve circumference compared with wide uptake involving more than 50% of valve circumference in the control group and the rejected case of IE [29]. These findings and other open questions such as the duration of “physiological” uptake following TAVI and the prognostic value of FDG PET/CT in this setting need further investigation in larger studies.

FDG PET/CT IN CIED INFECTION

The accuracy of FDG PET/CT for diagnosis of cardiac implantable electrical device (CIED) infections is variable and limited in comparison with IE. In general, studies included small cohorts. In a recent meta-analysis that included 14 studies with 492 patients overall, the pooled sensitivity and specificity were 83% and 89%, respectively. The results showed better diagnostic accuracy for pocket infection than lead infection [30]. In a more recent study that included 63 patients with suspected CIED infection, a very high specificity was reported. For lead infection, sensitivity and specificity of PET/CT for CIED-IE were 38.5% and 98.0%, respectively [31]. A large French multicenter study is planned, aiming to evaluate the accuracy of FDG PET/CT in the diagnosis of CIED infection (ENDOTEP), but its status is currently unknown [32, 33]. The true impact of using FDG PET/CT in cases with suspected CIED infection should be evaluated in order to identify the conditions where FDG PET/CT can make a difference in patient outcome.

FDG PET/CT IN LVAD INFECTION

The use of FDG PET/CT in the diagnosis of left ventricular assist device (LVAD) infection has been evaluated in small cohorts. In a recent meta-analysis that included four studies with 119 FDG PET/CT scans performed in suspected LVAD infection, the pooled sensitivity and specificity were 92% and 83%, respectively [34]. These results mandate further validation in larger studies. In addition to its diagnostic yield, FDG PET/CT was associated with clinical outcome in a small retrospective study that included 35 patients with LVAD who underwent FDG PET/CT [35]. In 28 patients, the FDG PET/CT was performed for suspected infection. The extent of infection on the device as detected by PET/CT was associated with prognosis. Similar association was observed in another cohort of 57 patients, who underwent 85 FDG PET/CT scans, with a trend toward lower survival when FDG PET/CT showed involvement of all components of LVAD and thoracic lymph nodes [36]. If further validated in larger studies, prognostic stratification using FDG PET/CT should be included in the criteria for heart transplantation, where patients with widespread infection according to FDG PET/CT should be prioritized.

MYOCARDIUM PREPARATION PROTOCOLS

Quality of imaging of FDG PET/CT in cardiac infection depends on achieving optimal suppression of the physiological myocardial glucose uptake. FDG, as a glucose analogue, is normally taken up by the myocardial cells owing to their high metabolic activity. In order to restrict the FDG uptake in the heart to pathological processes as in inflammatory cells and bacteria, there is a need to reduce the normal glucose uptake. The latter can be achieved by diverting the myocardial metabolism to free fatty acid instead of glucose. Studies investigating FDG PET/CT in cardiac infections had applied different patient preparation protocols [12, 15, 23]. Recently, standardized recommendations by the European Association of Nuclear Medicine (EANM) and the European Association of Cardiovascular Imaging (EACVI) were established [17]. The main recommendations are a high-fat-enriched diet lacking carbohydrates for 12–24 h followed by a prolonged fasting period of 12–18 h, with or without the use of intravenously administered heparin of 50 IU/kg approximately 15 min prior to FDG injection [17].
FDG PET/CT IN GUIDELINES OF CARDIAC INFECTIONS

International guidelines increasingly recommend FDG PET/CT in cardiac infections in recent years. The European Society of Cardiology (ESC) in 2015 suggested FDG PET/CT as an optional diagnostic test for possible or even rejected cases of PVE when a high clinical suspicion for IE exists [37]. The American Heart Association guidelines for infective endocarditis, endorsed by the Infectious Diseases Society of America (IDSA), published in 2015 as well, did not include FDG PET/CT among the recommended diagnostic imaging tests, awaiting further evidence [38]. The Heart Rhythm Society (HRS) guidelines from 2017 (endorsed by IDSA) recommend the use of FDG PET/CT when the diagnosis of CIED pocket or lead infection is doubtful (a weak recommendation based on limited data) [39]. The European Heart Rhythm Association (EHRA) guidelines from 2020, endorsed among others by the European Society of Clinical Microbiology and Infectious Diseases (ESCMID), recommend FDG PET/CT more strongly and include it as a major criterion for the diagnosis of CIED/IE. It is recommended strongly in suspected CIED-related IE with positive blood cultures and negative echocardiography; in all Staphylococcus aureus bacteremia among patients carrying a CIED; and for identification of unexpected embolic localizations and metastatic infections.

With the accumulating data, it seems that in the near future more infectious diseases societies will adopt FDG PET/CT as a diagnostic imaging modality in the diagnosis of cardiac infections. Differences may exist in the specific conditions and indications.

To summarize, FDG PET/CT is a good diagnostic tool for cardiac infections and may have added value in the following situations: (1) suspected PVE (including TAVI) that lack imaging proof (i.e., without typical findings in echocardiography). Negative TEE and FDG PET/CT highly exclude PVE. (2) In native valve with difficult to define echocardiographic findings when IE is in the differential diagnosis (due to the high specificity). Negative FDG PET/CT should not be used to exclude NVE. (3) Suspi- cion of clinically significant extracardiac septic foci in both NVE and PVE. (4) Suspcion of CIED infection with non-conclusive findings in echocardiography. (5) Susicion of LVAD infection for confirming, localizing, and determining the extension of infection. Special attention should be given to maximize the patient pre-scan preparation for myocardial suppression of physiological FDG uptake. Focal and heterogeneous rather than diffuse and homogenous uptake are the main findings suggestive of true infection.

Additional research is still needed. Large multicenter prospective studies are crucial for validation of the current evidence of many of the issues discussed above. Beyond the diagnostic accuracy performance of FDG PE/CT in different IE/CIED infection, the question should be whether this modality usage can improve patient outcome. Therefore, studies should focus on the clinical impact of adding FDG PET/CT in the management of patients with suspected cardiac infection and the optimal timing for its performance. In addition, further evaluation of factors that affect the physiological myocardial suppression of FDG uptake and the cardiac-pulmonary motion-related disturbances in order to improve the current protocols is needed. Finally, could FDG PET/CT have a role in the follow-up of patients diagnosed with cardiac infection and potentially lead to individualized treatment decision-making?

ACKNOWLEDGEMENTS

Funding. No funding or sponsorship was received for publication of this article.

Author Contributions. Nesrin Ghanem-Zoubi contributed for the review conception and design, literature searching, reviewing and data analysis, interpretation and summarizing and manuscript preparation.

Disclosures. Nesrin Ghanem-Zoubi has nothing to disclose.
Compliance with Ethics Guidelines. This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by the author.

Open Access. This article is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License, which permits any non-commercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by-nc/4.0/.

REFERENCES

1. Leibovici-Weissman Y, Tau N, Yahav D. Bloodstream infections in the elderly: what is the real goal? Aging Clin Exp Res. 2021;33(4):1101–12. doi:10.1007/S40520-019-01337-W.

2. Bertagna F, Bisleri G, Motta F, et al. Possible role of F18-FDG-PET/CT in the diagnosis of endocarditis: preliminary evidence from a review of the literature. Int J Cardiovasc Imaging. 2012;28(6):1417–25. doi:10.1007/s10554-011-9984-1/FIGURES/1.

3. Van Riet J, Hill EE, Gheysens O, et al. 18F-FDG PET/CT for early detection of embolism and metastatic infection in patients with infective endocarditis. Eur J Nucl Med Mol Imaging. 2010;37(6):1189–97. doi:10.1007/s00259-010-1380-x/FIGURES/3.

4. Orvin K, Goldberg E, Bernstine H, et al. The role of FDG-PET/CT imaging in early detection of extra-cardiac complications of infectious endocarditis. Clin Microbiol Infect. 2015;21(1):69–76. doi:10.1016/j.cmi.2014.08.012.

5. Granados U, Fuster D, Pericas JM, et al. Diagnostic accuracy of 18F-FDG PET/CT in infective endocarditis and implantable cardiac electronic device infection: a cross-sectional study. J Nucl Med. 2016;57(11):1726–32. doi:10.2967/jnumed.116.173690.

6. Gazzilli M, Albano D, Lucchini S, et al. New criteria for the diagnosis of infective endocarditis using 18F-FDG PET/CT imaging. J Nucl Cardiol. 2021. doi:10.1007/S12350-021-02663-1.

7. De Camargo RA, Sommer Bitencourt M, Meneghetti JC, et al. The role of 18F-fluorodeoxyglucose positron emission tomography/computed tomography in the diagnosis of left-sided endocarditis: native vs prosthetic valves endocarditis. Clin Infect Dis. 2020;70(4):838–94. doi:10.1093/CID/CIZ267.

8. Saby L, Laas O, Habib G, et al. Positron emission tomography/computed tomography for diagnosis of prosthetic valve endocarditis: increased valvular 18F-fluorodeoxyglucose uptake as a novel major criterion. J Am Coll Cardiol. 2013;61(23):2374–82. doi:10.1016/J.JACC.2013.01.092.

9. Pizzi MN, Roque A, Fernández-Hidalgo N, et al. Improving the diagnosis of infective endocarditis in prosthetic valves and intracardiac devices with 18F-fluorodeoxyglucose positron emission tomography/computed tomography angiography: initial results at an infective endocarditis referral center. Circulation. 2015;132(12):1113–26. doi:10.1161/CIRCULATIONAHA.115.015316.

10. Swart LE, Gomes A, Scholtens AM, et al. Improving the diagnostic performance of 18 F-fluorodeoxyglucose positron-emission tomography/computed tomography in prosthetic heart valve endocarditis. Circulation. 2018;138(14):1412–27. doi:10.1161/CIRCULATIONAHA.118.035032.

11. Kouijzer IJE, Berrevoets MAH, Aarnetzen EHJG, et al. 18F-fluorodeoxyglucose positron-emission tomography combined with computed tomography as a diagnostic tool in native valve endocarditis. Nucl Med Commun. 2018;39(8):747–52. doi:10.1097/MNM.0000000000000864.

12. Wang TKM, Sánchez-Nadales A, Igbinomwanhia E, Cremer P, Griffin B, Xu B. Diagnosis of infective endocarditis by subtype using 18 F-fluorodeoxyglucose positron emission tomography/computed tomography: a contemporary meta-analysis. Circ Cardiovasc Imaging. 2020;13(6). doi:10.1161/CIRCIMAGING.120.010600.
13. Gomes A, van Geel PP, Santing M, et al. Imaging infective endocarditis: adherence to a diagnostic flowchart and direct comparison of imaging techniques. J Nucl Cardiol. 2020;27(2):592–608. https://doi.org/10.1007/S12350-018-1383-8/FIGURES/4.

14. Abikhzer G, Martineau P, Grégoire J, Finnerty V, Harel F, Pelletier-Galarneau M. [18F]FDG-PET CT for the evaluation of native valve endocarditis. J Nucl Cardiol. 2020;27(2):592–608. https://doi.org/10.1007/S12350-018-1383-8/FIGURES/4.

15. Kamani CH, Allenbach G, Jreige M, et al. Diagnostic performance of 18F-FDG PET/CT in native valve endocarditis: systematic review and bivariate meta-analysis. Diagnostics (Basel, Switzerland). 2020;10(10). https://doi.org/10.3390/DIAGNOSTICS10100754.

16. Jiménez-Ballvé A, Pérez-Castejón MJ, Delgado-Bolton RC, et al. Assessment of the diagnostic accuracy of 18F-FDG PET/CT in prosthetic infective endocarditis and cardiac implantable electronic device infection: comparison of different interpretation criteria. Eur J Nucl Med Mol Imaging. 2016;43(13):2401–12. https://doi.org/10.1007/s00259-016-3463-9.

17. Slart RHJA, Glaudemans AWJM, Gheyens O, et al. Procedural recommendations of cardiac PET/CT imaging: standardization in inflammatory-, infective-, infiltrative-, and innervation (4Is)-related cardiovascular diseases: a joint collaboration of the EACVI and the EANM. Eur J Nucl Med Mol Imaging. 2021;48(4):1016. https://doi.org/10.1007/S00259-020-05066-5.

18. ten Hove D, Slart RHJA, Sinha B, Glaudemans AWJM, Budde RPJ. 18 F-FDG PET/CT in infective endocarditis: indications and approaches for standardization. Curr Cardiol Rep. 2021;23(9). https://doi.org/10.1007/S11886-021-01542-Y.

19. Gomes A, Glaudemans AWJM, Touw DJ, et al. Diagnostic value of imaging in infective endocarditis: a systematic review. Lancet Infect Dis. 2017;17(1):e1–14. https://doi.org/10.1016/S1473-3099(16)30141-4.

20. San S, Ravis E, Tessonier L, et al. Prognostic value of 18F-fluorodeoxyglucose positron emission tomography/computed tomography in infective endocarditis. J Am Coll Cardiol. 2019;74(8):1031–40. https://doi.org/10.1016/j.jacc.2019.06.050.

21. Hohmann C, Michels G, Schmidt M, et al. Diagnostic challenges in infective endocarditis: is PET/CT the solution? Infection. 2019;47(4):579–87. https://doi.org/10.1007/S15010-019-01278-6.

22. Asmar A, Özcan C, Diederichsen ACP, Thomassen A, Gill S. Clinical impact of 18F-FDG-PET/CT in the extra cardiac work-up of patients with infective endocarditis. Eur Hear J Cardiovasc Imaging. 2014;15(9):1013–9. https://doi.org/10.1093/EHJCI/JEU054.

23. Mahmood M, Kendi AT, Ajmal S, et al. Meta-analysis of 18F-FDG PET/CT in the diagnosis of infective endocarditis. J Nucl Cardiol. 2019;26(3):922–35. https://doi.org/10.1007/S12350-017-1092-8.

24. Amat-Santos JJ, Messika-Zeitoun D, Eltchaninoff H, et al. Infective endocarditis after transcatheter aortic valve implantation results from a large multicenter registry. Circulation. 2015;131(18):1566–74. https://doi.org/10.1161/CIRCULATIONAHA.114.014089.

25. Alexis SI, Malik AH, George I, et al. Infective endocarditis after surgical and transcatheter aortic valve replacement: a state of the art review. J Am Heart Assoc. 2020;9(16). https://doi.org/10.1161/JAHA.120.017347.

26. Lnu K, Ansari S, Mahto S, et al. Transcatheter aortic valve replacement associated infective endocarditis case series: broadening the criteria for diagnosis is the need of the hour. BMC Cardiovasc Disord. 2021;21(1). https://doi.org/10.1186/S12872-021-02364-0.

27. Salaun E, Sportouch L, Barral PA, et al. Diagnosis of infective endocarditis after TAVR: value of a multimodality imaging approach. JACC Cardiovasc Imaging. 2018;11(1):143–6. https://doi.org/10.1016/j.jcmg.2017.05.016.

28. Wahadat AR, Tanis W, Swart LE, et al. Added value of 18F-FDG-PET/CT and cardiac CTA in suspected transcatheter aortic valve endocarditis. J Nucl Cardiol. 2021;28(5):2072–82. https://doi.org/10.1007/s12350-019-01963-x.

29. San S, Iti I, Lim P. Characterization of 18-fluorodeoxyglucose uptake pattern in infective endocarditis after transcatheter aortic valve implantation. Eur Hear J Cardiovasc Imaging. 2021;22(Supplement_1). https://doi.org/10.1093/EHJCI/JEAA356.349.

30. Mahmood M, Kendi AT, Farid S, et al. Role of 18 F-FDG PET/CT in the diagnosis of cardiovascular implantable electronic device infections: a meta-analysis. J Nucl Cardiol. 2019;26(3):958–70. https://doi.org/10.1007/S12350-017-1063-0.

31. Jerónimo A, Olmos C, Vilacosta I, et al. Accuracy of 18 F-FDG-PET/CT in patients with the suspicion of cardiac implantable electronic device infections. J Nucl Cardiol. 2020. https://doi.org/10.1007/S12350-020-02285-Z.
32. Amraoui S, Tili G, Hindié E, et al. Accuracy of positron emission tomography as a diagnostic tool for lead endocarditis: design of the prospective multicentre ENDOTEP study. Eur Cardiol. 2016;11(1). https://doi.org/10.15420/ECR.2016:6:2.

33. ClinicalTrials.gov. Diagnostic accuracy of 18FDG-PET-CT for pacing or defibrillation lead infection. https://clinicaltrials.gov/ct2/show/NCT02251262?term=ENDOTEP&draw=2&rank=1. Accessed Dec 23, 2021.

34. Tam MC, Patel VN, Weinberg RL, et al. Diagnostic accuracy of FDG PET/CT in suspected LVAD infections: a case series, systematic review, and meta-analysis. JACC Cardiovasc Imaging. 2020;13(5):1191–202. https://doi.org/10.1016/J.JCMG.2019.04.024.

35. Kim J, Feller ED, Chen W, Liang Y, Dilsizian V. FDG PET/CT for early detection and localization of left ventricular assist device infection: impact on patient management and outcome. JACC Cardiovasc Imaging. 2019;12(4):722–9. https://doi.org/10.1016/j.jcmg.2018.01.024.

36. Sommerlath Sohns JM, Kröhn H, Schöde A, et al. 18 F-FDG PET/CT in left-ventricular assist device infection: initial results supporting the usefulness of image-guided therapy. J Nucl Med. 2020;61(7):971–6. https://doi.org/10.2967/JNUMED.119.237628.

37. Habib G, Lancellotti P, Antunes MJ, et al. 2015 ESC Guidelines for the management of infective endocarditis: The Task Force for the Management of Infective Endocarditis of the European Society of Cardiology (ESC). Endorsed by: European Association for Cardio-Thoracic Surgery (EACTS), the European. Eur Heart J. 2015;36(44):3075–3123. https://doi.org/10.1093/EURHEARTJ/EHV319.

38. Baddour LM, Wilson WR, Bayer AS, et al. Infective endocarditis in adults: diagnosis, antimicrobial therapy, and management of complications. A scientific statement for healthcare professionals from the American Heart Association. Circulation. 2015;132(15):1435–86. https://doi.org/10.1161/CIR.0000000000000296.

39. Kusumoto FM, Schoenfeld MH, Wilkoff BL, et al. 2017 HRS expert consensus statement on cardiovascular implantable electronic device lead management and extraction. Hear Rhythm. 2017;14(12):e503–51. https://doi.org/10.1016/J.HRTHM.2017.09.001.

Publisher’s Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.